



FOUNDATION INVESTIGATION AND DESIGN REPORT

for

**PROPOSED SANITARY FORCEMAIN CROSSING
AT HIGHWAY 26 AT FINLAY MILL ROAD/SNOW VALLEY ROAD
PROPOSED EXTERNAL SERVICING FOR MIDHURST HEIGHTS
RESIDENTIAL SUBDIVISION
MIDHURST, TOWNSHIP OF SPRINGWATER, ONTARIO
LATITUDE AND LONGITUDE: 44.438169, -79.732789**

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distribution to MTO
Electronic Copy: The Rose Corporation
Electronic Copy: PML Toronto

PML Ref.: 20BF042A
Geocres No.: 31D-825
August 24, 2023



PART A – FOUNDATION INVESTIGATION REPORT

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Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page TOC 1 of 1



TABLE OF CONTENTS

PART A – FOUNDATION INVESTIGATION REPORT

1. INTRODUCTION	1
2. SITE DESCRIPTION	2
3. CURRENT FIELD INVESTIGATION PROCEDURES	2
4. LABORATORY TEST PROCEDURES.....	4
5. SITE GEOLOGY AND SUBSURFACE CONDITIONS	4
5.1 Site Geology	4
5.2 Subsurface Conditions	5
5.2.1 Pavement Structure	5
5.2.2 Fill	6
5.2.3 Gravelly Sand.....	6
5.2.4 Sand and Gravel	6
5.2.5 Sand.....	7
5.2.6 Groundwater	7
6. CLOSURE	8

ATTACHMENTS

Appendix A – Borehole Locations Plan DWG No. 1
Explanation of Terms Used in Report
Record of Borehole Sheets 27, 28, and 29
Results of Grain Size Distribution Analyses - Figures GS-1 and GS-2

PART A – FOUNDATION INVESTIGATION REPORT

For

Proposed Sanitary Forcemain Crossing at Highway 26 at
Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario

1. INTRODUCTION

Peto MacCallum Ltd. (PML) is pleased to submit the geotechnical investigation factual data and recommendations to support the design and proposed external servicing for the Midhurst Heights Residential Subdivision project, located in Midhurst, Ontario. Authorization to proceed with this assignment was provided by Mr. Kurt Vendrig, P.Eng. of C.F. Crozier & Associates Inc. (C.F. Crozier), on behalf of the Client, Midhurst Landowners Group Inc., via email dated May 26, 2022. Our Services were provided in accordance with our proposal (PML Reference Sales Quote 20BF042A, dated 1ST PG April 21, 2022).

C.F. Crozier has retained PML to provide geotechnical engineering services, including a geotechnical investigation and report, and geotechnical engineering design recommendations to accommodate the external servicing for the Midhurst Heights Residential Subdivision project, comprised of the following:

- A sanitary forcemain is planned with alignment along Gill Road, Doran Road, Finlay Mill Road, and Snow Valley Road to the Wastewater Treatment Plant on Snow Valley Road.
 - Open-cut or Trenchless methods are planned along Doran Road and Finlay Mill Road
 - Trenchless methods are planned along Gill Road and Snow Valley Road
 - Pavement Rehabilitation may be required in some areas
 - Finlay Mill Road may need to be widened from Wattie Road to Highway 26

This report only summarizes the results of the foundation investigation of three boreholes carried out for the proposed sanitary forcemains using trenchless methods planned along Snow Valley Road/Finlay Mill Road crossing Highway 26.

The elevations (EL.) in this report are expressed in meters, unless otherwise noted.

Part A - Foundation Investigation Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 2

**2. SITE DESCRIPTION**

The site is a generally flat area, located within the Township of Springwater, as part of Simcoe County, and crosses Highway 26 at Finlay Mill Road/Snow Valley Road. The surrounding area is predominantly residential east of Highway 26, and mainly used for agricultural purposes west of Highway 26.

3. CURRENT FIELD INVESTIGATION PROCEDURES

The current fieldwork for the foundation investigation was carried out on August 3, 2022. The locations of the boreholes were selected based on drawings provided by C.F. Crozier via email dated February 21, 2021. A total of three (3) boreholes were investigated for this site. A summary of the coordinates (northing/easting, latitude/longitude), ground surface elevations, and depths of the boreholes with respect to the proposed service pipes and structure is provided in Table 1. The locations of the boreholes are presented on drawings DWG. No. 1.

Table 1: Summary of Boreholes

LOCATION	BH ID	GROUND SURFACE ELEVATION (m)	BH DEPTH (m)	COORDINATES			
				(UTM ZONE 17)		DECIMAL DEGREE	
				NORTHING	EASTING	LATITUDE	LONGITUDE
Hwy 26 Crossing	27	239.2	6.7	4 921 323.0	600 876.0	44.438173	-79.732425
	28	239.8	6.7	4 921 322.0	600 847.0	44.438169	-79.732789
	29	239.3	6.7	4 921 292.0	600 834.0	44.437900	-79.732958

The borehole locations were selected based on the provided preliminary proposed external servicing plan. The locations of these boreholes were reviewed and approved by Midhurst Landowners Group Inc. and C.F. Crozier & Associates Inc. prior to commencement of field work.

PML staff used a portable GPS device to establish the borehole locations in the field. Subsequently, PML carried out the survey of the borehole locations as drilled and elevations using a Sokkia SHC5000 Differential GPS system, equipped with a GCX3 (Network RTK rover) GNSS

Part A - Foundation Investigation Report

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Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 3



Receiver. The vertical and horizontal accuracy of this equipment are within 0.1 m and 0.5 m, respectively. The survey information provided in this report are referred to in UTM NAD 83 Northing and Easting (UTM Zone – 17T) Geodetic datum and expressed in meters.

PML engineering staff arranged for the clearance of underground services and appropriate permit applications. The respective utility companies cleared the underground services at the borehole locations. Public and private utility authorities were informed, and all of the utility clearance documents were obtained prior to commencement of drilling work.

The equipment used for drilling was owned and operated by TCI Field Services (TCI), of Pickering, Ontario. TCI are specialist drilling contractors and worked under the full-time supervision of a PML field supervisor. The boreholes were advanced using a CME 75 truck-mounted drilling rig equipped with 150mm/200 mm diameter solid/hollow stem augers.

Traffic control services were provided during field investigation by PML, in accordance with Ontario Traffic Manual Book 7-Temporary Conditions (January 2014).

Representative soil samples were recovered from the boreholes at 0.75 m 0.75 m intervals to a depth of 3.0 m, and at 1.5 m to the depth of termination using a conventional 51 mm OD split spoon sampler in accordance with the SPT procedure. SPTs were conducted simultaneously with the sampling operation to assess the strength characteristics of the substrata. The granular base and subbase material were recovered by manual method (i.e. grab samples). The recovered soil samples were returned to the PML laboratory for detailed visual examination, and testing.

The groundwater conditions at the borehole locations were observed during the drilling by visual examination of the soil samples, sampler, and drill rods as the samples were retrieved. In addition, water level measurements were taken using a Solinst flat tape water level reader in the open boreholes upon completion of drilling. Monitoring wells, consisting of 50 mm diameter PVC pipe, were installed in two (2) selected boreholes. Refer to the Record of Borehole Sheets in Appendix A for details of the monitoring well installation.

Part A - Foundation Investigation Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 4



Upon completion of drilling, one borehole was decommissioned in accordance with R.R.O. 1990, Reg. 903: Wells under Ontario Water Resources Act, as amended. It is anticipated that the monitoring wells will be decommissioned at the time of the construction by the contractor.

4. LABORATORY TEST PROCEDURES

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

- Natural moisture content determinations (24)
- Grain size distribution analyses (7)
- Hydrometer tests (1)

The results of the grain size distribution analyses are presented on Figures GS-1 and GS-2. All test results are summarized on the attached Record of Borehole sheets and provided in Appendix A.

5. SITE GEOLOGY AND SUBSURFACE CONDITIONS

5.1 Site Geology

In general, the project area is located within the Sand Plains and Till Plains (Drumlinized) of the Simcoe Uplands physiographic region, which is floored with sand, silt, and clay deposits, as outlined in The Physiography of Southern Ontario (Chapman and Putnam, 1984).

The Quaternary Geology map published by the Ontario Ministry of Northern Development and Mines (MNDM), indicates that the surface conditions in the area of the site consist of Glaciolacustrine deposits at the west side of the project limits; predominantly sand, gravelly sand, and gravel, nearshore and beach deposits; and Glaciofluvial Ice deposits can be expected on the east side of the project limits; consisting of gravel and sand, and minor till deposits.

Part A - Foundation Investigation Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 5



Based on the Bedrock Geology map (MRD126-REV1, 2011) published by the MNM, the bedrock underlying the project area mainly consists of Middle Ordovician limestone, dolostone, shale, arkose, and sandstone from the Ottawa Group formations. Bedrock was not encountered during the current field investigation.

5.2 Subsurface Conditions

The subsurface conditions encountered during the current investigation along with the field and laboratory test results are shown on the attached Record of Borehole Sheets. The boundaries between soil strata have been established at the borehole locations only. The boundaries of soil strata between and beyond the boreholes are assumed and may vary from location to location.

Boreholes 27 to 29 were drilled in the area of proposed service along Finlay Mill Road/Snow Valley Road crossing Highway 26. The approximate locations of the boreholes are shown on Drawing DWG. No. 1. The subsurface conditions encountered at this location can be categorized into five (5) distinct zones as follows;

- a) Pavement Structure
- b) Fill
- c) Sand and Gravel
- d) Gravelly Sand
- e) Sand

5.2.1 Pavement Structure

A pavement structure consisting of 160 mm to 270 mm thick asphalt, over 230 mm to 270 mm of granular material was encountered immediately below the existing ground surface in Boreholes 27 to 29.

Part A - Foundation Investigation Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 6



5.2.2 Fill

Fill comprised of sand/silty sand was encountered below the pavement structure in Boreholes 27 and 28, which extended to 2.1 m and 1.4 m below existing ground surface, respectively. The SPT N values recorded in this layer ranged from as low as 1 blow to 11 blows for 30 cm penetration, indicating very loose to compact state of compactness. The moisture content of samples tested from this layer varied approximately from 2.0% to 5.0%, with an average value of 3.3%.

5.2.3 Gravelly Sand

The gravelly sand layer was encountered below fill in Borehole 28 at 1.4 m, extending to 3.8 m below ground surface. The SPT N values recorded in this layer varied from 22 blows to 32 blows, indicating compact to dense state of compactness.

The moisture content of samples tested from this layer varied approximately from 3.0% to 4.0%, with an average value of 3.3%. The results of the sieve and hydrometer analysis tests performed on two (2) representative samples from this layer are provided on Figure GS-1. The test results indicate that samples consist of 27% and 28% gravel, 66% and 68% sand, and 5% and 8% silt and clay sized particles.

5.2.4 Sand and Gravel

This sand and gravel layer was encountered below the fill layer in Borehole 27 at 2.1 m, extending to 5.2 m below ground surface, and in Borehole 29 this layer was encountered below the pavement structure at 0.4 m, extending to 4.7 m below ground surface. In Borehole 28, this layer was encountered approximately at 3.8 m below gravelly sand, extending to 6.0 m below ground surface. The thickness of this layer ranged from 2.1 m to 4.3 m.

The SPT N values recorded in this layer ranged from 11 blows to 87 blows for 295 mm penetration, indicating compact to very dense state of compactness.

Part A - Foundation Investigation Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 7



The moisture content of samples tested from this layer varied approximately from 2.0% to 6.0%, with an average value of 3.3%. The results of the sieve and hydrometer analysis tests performed on five (5) representative samples from this layer are provided on Figure GS-2. The test results indicate that samples consist of 35% to 50% gravel, 41% to 59% sand, and 5% to 9% silt and clay sized particles.

5.2.5 Sand

Below the sand and gravel/gravelly sand, a layer of dense to very dense sand layer was encountered, extending to the termination depth of 6.7 m below ground surface in all three boreholes.

The SPT N values recorded in this layer ranged from 24 blows to 57 blows. The moisture content of samples tested from this layer varied approximately from 3.0% to 9.9%, with an average value of 5.8%.

5.2.6 Groundwater

Groundwater was not encountered during or upon completion of drilling in Boreholes 27 to 29.

A groundwater monitoring well consisting of 50 mm diameter PVC pipe was installed in both Boreholes 27 and 29. Groundwater was not encountered in the monitoring wells on September 8, 2022 and on July 28, 2023.

Groundwater levels may fluctuate due to the influence of precipitation and seasonal change.

Groundwater measurement was carried out prior to backfilling the borehole (Borehole 28). It is anticipated that the monitoring wells at Boreholes 27 and 29 will be decommissioned at the time of the construction by the contractor.

Part A - Foundation Investigation Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
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Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 8



6. CLOSURE

Mr. Niklas Gardlund carried out the supervision of drilling under the direction of Mr. Nazibur Rahman, P.Eng. This Report was prepared by Ms. Natasha Leong-Sem, EIT and reviewed by Mr. Nazibur Rahman, P.Eng. Mr. Robert Ng, P.Eng., MTO Designated Principal Contact, conducted an independent review of the report.

Yours very truly,

Peto MacCallum Ltd.


Natasha Leong-Sem, EIT
Geotechnical Services



Nazibur Rahman, P.Eng.
Senior Engineer, Geotechnical Services



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

NLS/NR/RN:nls-nr

Part A - Foundation Investigation Report

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Proposed External Servicing for Midhurst Heights Residential Subdivision

Midhurst, Township of Springwater, Ontario

PML Ref.: 20BF042A, August 24, 2023



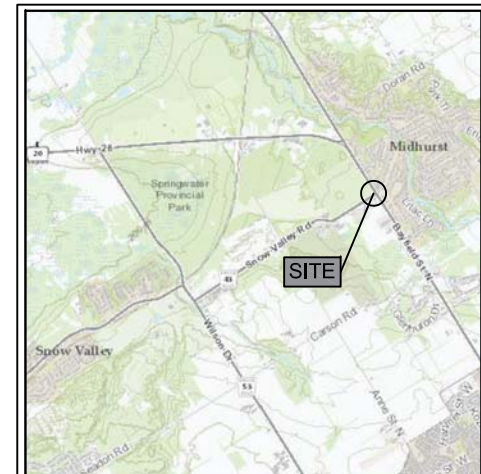
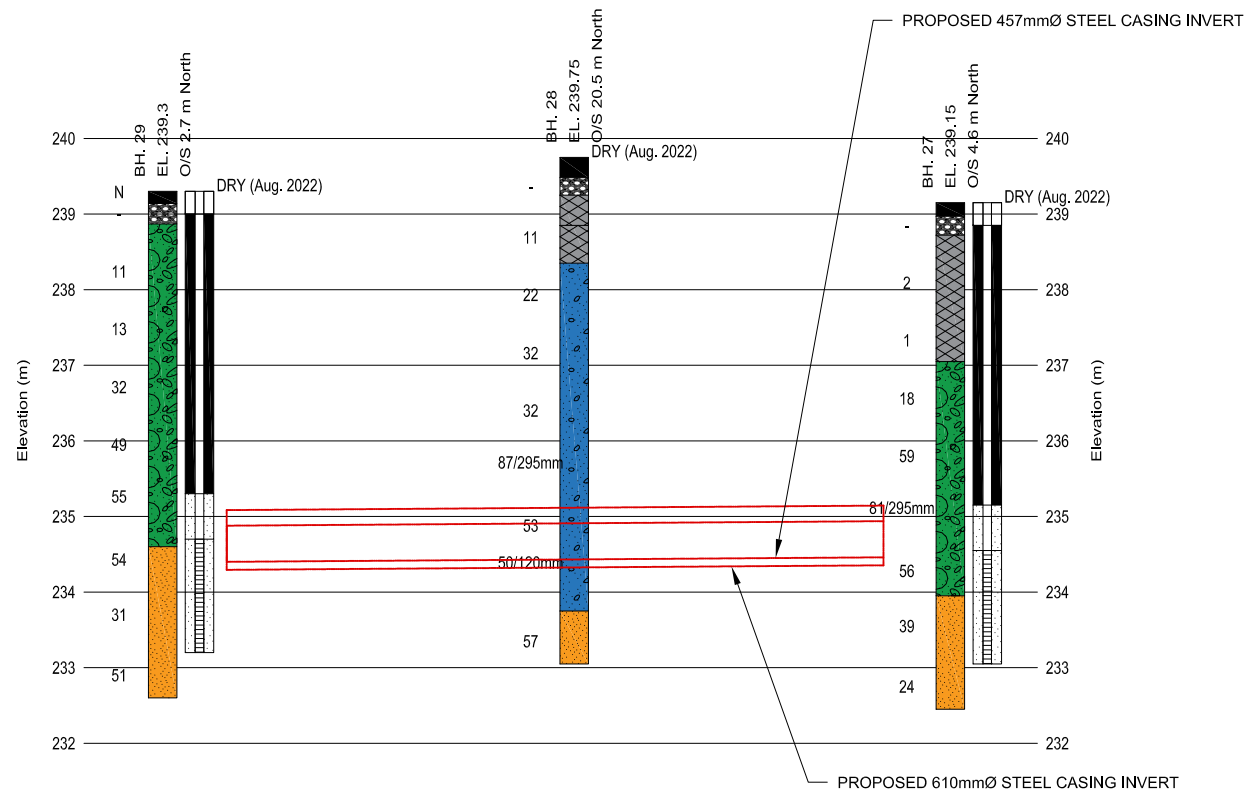
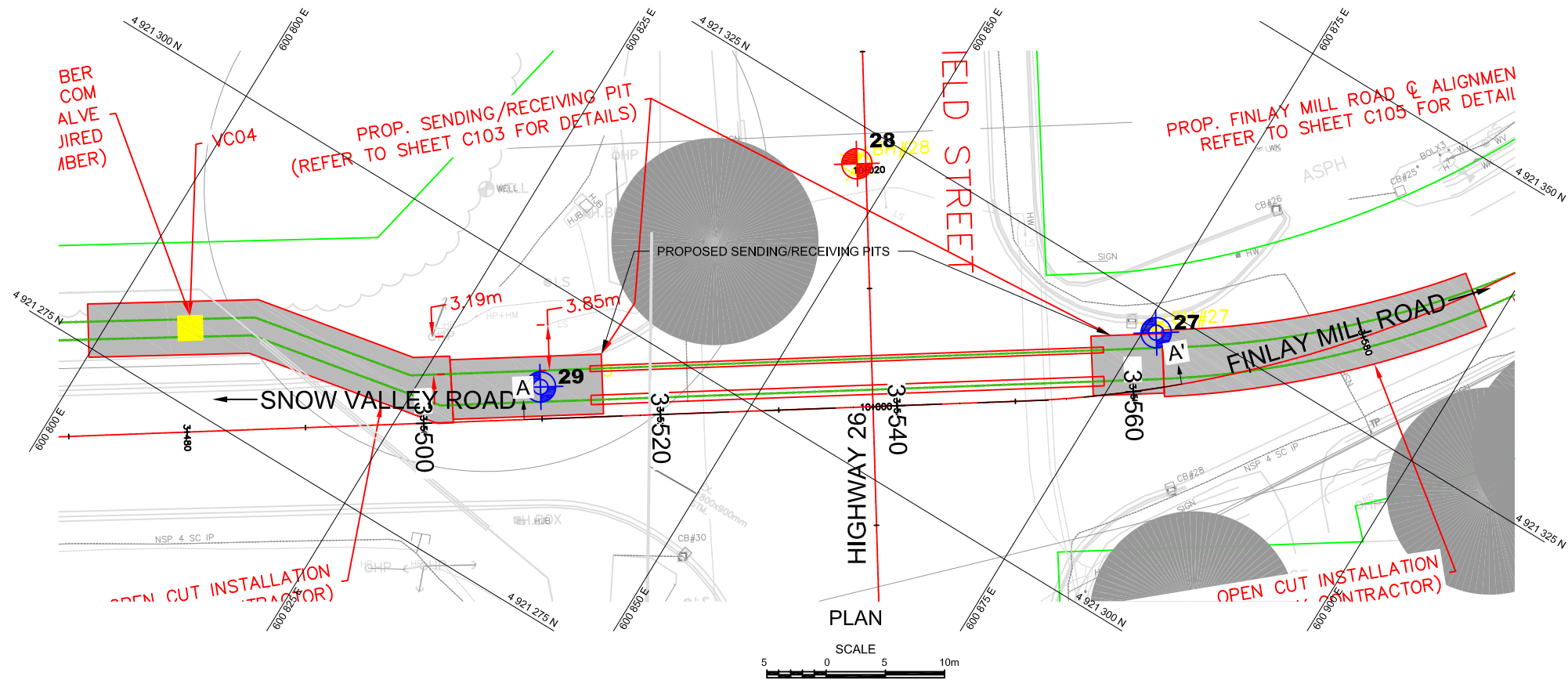
APPENDIX A

Borehole Locations Plan Drawings DWG No. 1

Explanation of Terms Used in Report

Record of Borehole Sheets 27, 28, and 29

Results of Grain Size Distribution Analyses – Figures GS-1 and GS-2



KEY PLAN
N.T.S.

LEGEND

- 27** BOREHOLE WITH 50mm dia, MONITORING WELL
- 29** BOREHOLE
- Surface Monitoring Point (SMP) Location
- N Blows/0.3m (Std. Pen Test, 475 J/blow)
- DRY Groundwater Not Established During or Upon Completion of Drilling
- Groundwater Level Measured in Monitoring Well
- Asphalt
- Granular Base/Subbase
- Fill
- Sand and Gravel
- Gravelly Sand
- Sand
- Stick-Up Monument
- Bentonite
- Filter Sand
- Screen

BH No	ELEVATION	COORDINATES (UTM17)	
		NORTHINGS	EASTINGS
27	239.2	4 921 323.0	600 876.0
28	239.8	4 912 322.0	600 847.0
29	239.3	4 921 292.0	600 834.0

NOTE

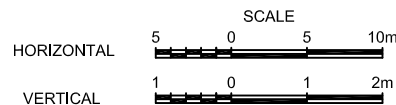
The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.

REVISIONS					
	DATE	BY	DESCRIPTION		
Geocres No. Not Assigned					
HWY No		26		DIST	
SUBMD	NL	CHECKED	NR	DATE AUGUST 2023	SITE
DRAWN	NL	CHECKED	RN	APPROVED RN	DWG 1

NOTES:

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

PROFILE ALONG A-A'



EXPLANATION OF TERMS USED IN REPORT

SPT N VALUE: THE STANDARD PENETRATOIN TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT-BARREL SAMPLER TO PENETRATE 0.3 m, AFTER AN INITIAL PENETRATIO OF 150 mm, INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5 kg, FALLING FREELY A DISTANCE OF 0.76 m FOR PENETRATIONS. A SPT N VALUE IS INDICATED AS THE NUMBER OF BLOWS REQUIRED TO DRIVE THE SPLIT-BARREL SAMPLER A DISTANCE OF 300 MM. AN AVERAGE SPT N VALUE IS DENOTED as \bar{N} .

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

SOILS ARE DESCRIBED BY THEIR COMPOSITION, CONSISTENCY OR COMPACTNESS.

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

PERCENTAGE BY MASS	0 - 10	10 - 20	20 -35	>35	>35 and main fraction
	'trace'	'some'	Adjective (silty, sandy, clayey etc.)	'and'	Noun (gravel, sand, silt, clay)

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

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

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

N (BLOWS/0.3 m PENETRATION)	0 - 4	4 - 10	10 -30	30 - 50	>50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

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

TOTAL CORE RECOVERY (REC): CORE RECOVERED AS A PERCENTAGE OF TOTAL CORE RUN LENGTH.

ROCK QUALITY DESIGNATION (RQD): TOTAL LENGTH OF SOUND ROCK RECEIVED IN PIECES 10 cm OR LARGER AS A PERCENTAGE OF TOTAL CORE RUN LENGTH. CLASSIFICATION OF ROCK WITH RESPECT TO RQD VALUE AS FOLLOWS:

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

UNIAXIAL COMPRESSIVE STRENGTH (UCS): MAXIMUM AXIAL COMPRESSIVE STRESS THAT A ROCK CORE SPECIMEN CAN WITHSTAND BEFORE FAILING.

POINT LOAD STRENGTH INDEX: AN INDEX TEST TO DETERMINE POINT LOAD STRENGTH INDEX OF ROCK.

CLASSIFICATION OF ROCK WITH RESPECT TO STRENGTH IS AS FOLLOWS:

GRADE*	R0	R1	R2	R3	R4	R5	R6
UCS (MPa)	0.25 - 1	1 - 5	5 - 25	25 - 50	50 - 100	100 - 250	>250
POINT LOAD INDEX (MPa)	**	**	**	1 - 2	2 - 4	4 - 10	>10
TERM	EXTREMELY WEAK	VERY WEAK	WEAK	MEDIUM STRONG	STRONG	VERY STRONG	EXTREMELY STRONG

* - GRADE ACCORDING TO THE INTERNATIONAL SOCIETY OF ROCK MECHANICS (ISRM), 1981.

** - ROCKS WITH UNIAXIAL COMPRESSIVE STRENGTH BELOW 25 MPa ARE LIKELY TO YIELD HIGHLY AMBIGUOUS RESULTS UNDER POINT LOAD TESTING.

DISCONTINUITY SPACING: DISTANCE BETWEEN A PAIR OF DISCONTINUITIES MEASURED ALONG A LINE OF SPECIFIED LOCATION AND ORIENTATION. CLASSIFICATION OF ROCK WITH RESPECT TO DISCONTINUITY SPACING IS AS FOLLOWS (ISRM, 1981):

SPACING WIDTH (m)	<0.02	0.02 - 0.06	0.06 - 0.20	0.20 - 0.6	0.6 - 2.0	2.0 - 6.0	>6.0
SPACING CLASSIFICATION	EXTREMELY CLOSE	VERY CLOSE	CLOSE	MODERATELY CLOSE	WIDE	VERY WIDE	EXTREMELY WIDE

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS - SPLIT SPOON TP - THINWALL PISTON SAMPLE
WS - WASH SAMPLE OS - OSTERBERG SAMPLE
AS - AUGER SAMPLE RC - ROCK CORE
FV - FIELD VANE BS - BLOCK SAMPLE
CS - CHUNK SAMPLE FS - FOIL SAMPLE
TW - THINWALL SHELBY TUBE SAMPLE
PH - TW ADVANCED HYDRAULICALLY
PM - TW ADVANCED MANUALLY

STRESS AND STRAIN

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

MECHANICAL PROPERTIES OF SOIL

C_c	COMPRESSION INDEX
C_{cr}	RECOMPRESSION INDEX
C_s	SWELL INDEX
c_v	COEFFICIENT OF CONSOLIDATION - VERTICAL (cm ² /s)
c_h	COEFFICIENT OF CONSOLIDATION - HORIZONTAL (cm ² /s)
C_α	COEFFICIENT OF SECONDARY CONSOLIDATION
m_v	COEFFICIENT OF VOLUME CHANGE (kPa ⁻¹)
σ'_p	PRECONSOLIDATION PRESSURE (kPa)
σ'_{vo}	EFFECTIVE OVERBURDEN PRESSURE (kPa)
H	DRAINAGE PATH (m)
U	DEGREE OF CONSOLIDATION
T_v	TIME FACTOR; VERTICAL DRAINAGE
T_h	TIME FACTOR; HORIZONTAL DRAINAGE
S_{u, c_u}	UNDRAINED SHEAR STRENGTH (kPa)
S_R	RESIDUAL SHEAR STRENGTH (kPa)
S_r	REMOULDED SHEAR STRENGTH (kPa)
σ_c	UNIAXIAL COMPRESSIVE STRENGTH (kPa)
c'	EFFECTIVE COHESION INTERCEPT (kPa)
c	APPARENT COHESION INTERCEPT (kPa)
Φ'	EFFECTIVE ANGLE OF INTERNAL FRICTION (Degrees)
S_t	SENSITIVITY (= c_u/S_c)
I_p	POINT LOAD STRENGTH INDEX

PHYSICAL PROPERTIES

W _p - PLASTIC LIMIT (%)	W _L - LIQUID LIMIT (%)	W - MOISTURE CONTENT (%)
W _s - SHRINKAGE LIMIT (%)	I _p - PLASTICITY INDEX (%)	γ_w - UNIT WEIGHT OF WATER (kg/m ³)
γ - UNIT WEIGHT OF SOIL (kg/m ³)	γ_{sat} - UNIT WEIGHT OF SATURATED SOIL (kg/m ³)	γ_d - UNIT WEIGHT OF DRY SOIL (kg/m ³)
ρ_w - DENSITY OF WATER (kN/m ³)	ρ - DENSITY OF SOIL (kN/m ³)	ρ_{sat} - DENSITY OF SATURATED SOIL (kN/m ³)
ρ_d - DENSITY OF DRY SOIL (kN/m ³)	S_r - DEGREE OF SATURATION (%)	D_r, SG - RELATIVE DENSITY (FORMERLY SPECIFIC GRAVITY)
C_u - UNIFORMITY COEFFICIENT	C_c - CURVATURE COEFFICIENT	

RECORD OF BOREHOLE No 27

1 OF 1

METRIC

G.W.P. _____ LOCATION Coordinates: 4921323.0 N, 600876.0 E (17 UTM) ORIGINATED BY NG
 DIST _____ HWY 26 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NG
 DATUM Geodetic DATE 2022.08.03 LATITUDE 44.438173 LONGITUDE -79.732425 CHECKED BY NR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION STANDARD PENETRATION TEST		PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE			
239.2	GROUND SURFACE													
239.0	PAVEMENT: 180 mm asphalt, over 250 mm of granular base and subbase, moist		1A/B	GS	-									
238.8														
0.4	SAND/SILTY SAND, trace to some gravel		2	SS	2									
	Very loose, Brown, Moist													
	(FILL)		3	SS	1									
237.1														
2.1	SAND AND GRAVEL, trace silt, trace clay, Compact to very dense, Brown, Moist		4	SS	18									
			5	SS	59									
			6	SS	81/295mm									
			7	SS	56									
234.0														
5.2	SAND, trace to some gravel, trace silt Dense to compact, Brown, Moist		8	SS	39									
232.5			9	SS	24									
6.7	End of borehole													
	NOTES: 1. No first water strike noted during drilling 2. No water or cave was noted upon completion of drilling. 3. Groundwater not encountered in the monitoring well on September 8, 2022 and on July 28, 2023.													

RECORD OF BOREHOLE No 28

1 OF 1

METRIC

G.W.P. _____ LOCATION Coordinates: 4921322.0 N, 600847.0 E (17 UTM) ORIGINATED BY NG
 DIST _____ HWY 26 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NG
 DATUM Geodetic DATE 2022.08.03 LATITUDE 44.438169 LONGITUDE -79.732789 CHECKED BY NR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION STANDARD PENETRATION TEST					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
239.8	GROUND SURFACE																
0.0 239.5 239.3	PAVEMENT: 270 mm of asphalt, over 230 mm of granular base and subbase, moist		1A/B	GS	-												
0.5 238.9	SILTY SAND, trace clay, trace gravel						239										
0.9 238.4	Compact, Dark brown to brown, Moist Becoming sand, some gravel, trace silt (FILL)		2	SS	11												
1.4 236.0	GRAVELLY SAND, trace silt Compact to dense, Brown, Moist		3	SS	22		238										28 66 (6)
			4	SS	32		237										
			5	SS	32												27 68 (5)
3.8 233.8	SAND AND GRAVEL, trace silt Very dense, Brown, Moist		6	SS	87/295mm		236										
			7	SS	53		235										41 54 (5)
			8	SS	50/120mm												
6.0 233.1	SAND, trace to some gravel, trace silt Very dense, Brown, Moist		9	SS	57		234										
6.7	End of borehole																
	NOTES: 1. No first water strike noted during drilling 2. No water observed upon completion of augering 3. Cave was measured at 3.0 m depth upon removing hollow augers																

RECORD OF BOREHOLE No 29

1 OF 1

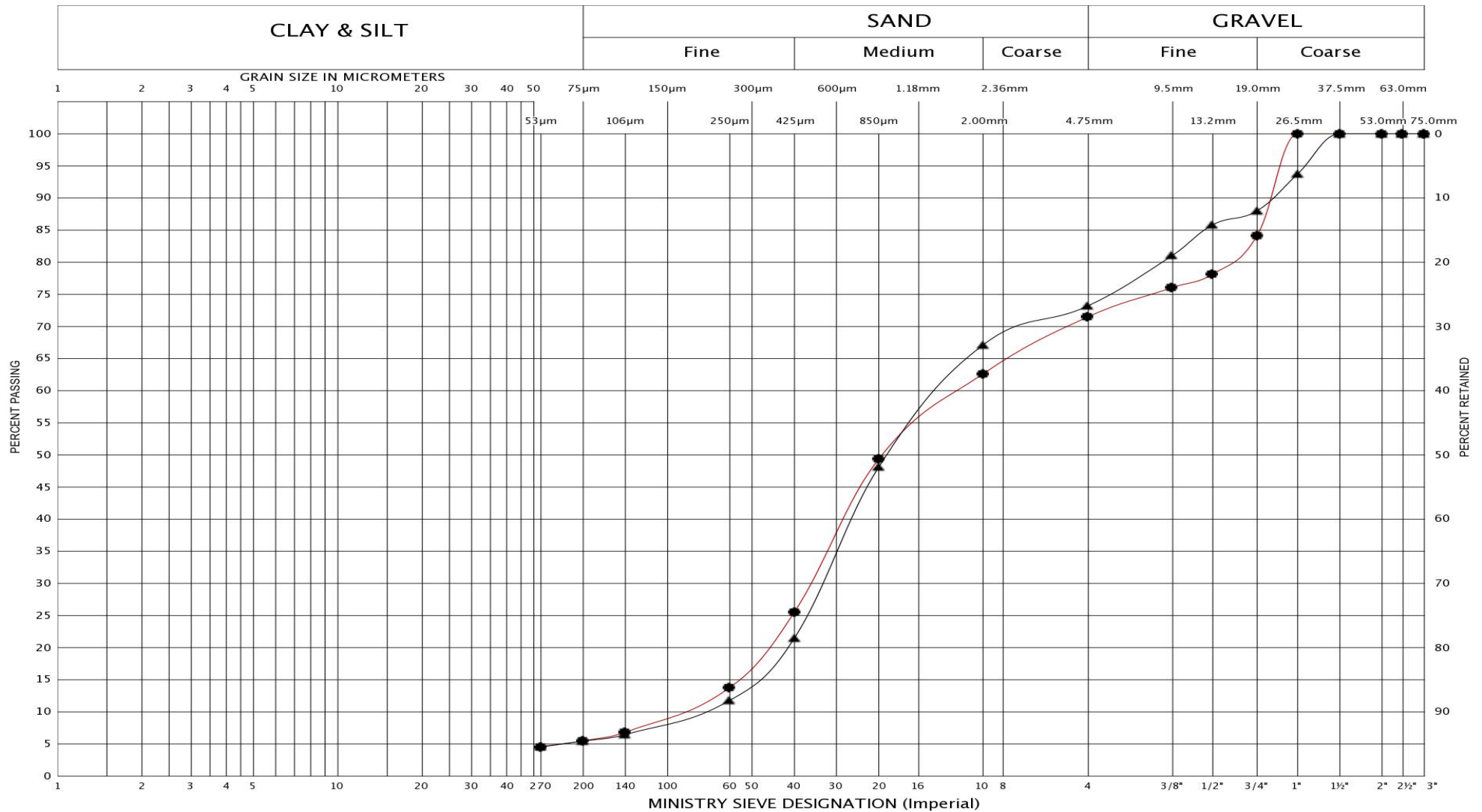
METRIC

G.W.P. _____ LOCATION Coordinates: 4921292.0 N, 600834.0 E (17 UTM) ORIGINATED BY NG
 DIST _____ HWY 26 BOREHOLE TYPE Hollow Stem Augers COMPILED BY NG
 DATUM Geodetic DATE 2022.08.03 LATITUDE 44.437900 LONGITUDE -79.732958 CHECKED BY NR

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION STANDARD PENETRATION TEST					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	WATER CONTENT (%)					
239.3	GROUND SURFACE						20	40	60	80	100		20	40	60		GR SA SI CL
239.1	PAVEMENT: 160 mm asphalt, over 270 mm of granular base and subbase, moist		1A/B	GS	-												
238.9	SAND AND GRAVEL, trace silt, trace clay																
0.4	Compact to very dense, Brown, Moist		2	SS	11								○				
			3	SS	13								○				
			4	SS	32								○				35 59 (6)
			5	SS	49								○				41 52 (7)
			6	SS	55								○				
234.6	SAND, trace gravel, trace silt		7	SS	54								○				
4.7	Very dense to compact, Brown, Moist		8	SS	31								○				
			9	SS	51								○				
232.6	End of borehole																
6.7	NOTES: 1. No first water strike noted during drilling 2. No water or cave was noted upon completion of drilling. 3. Groundwater not encountered in the monitoring well on September 8, 2022 and on July 28, 2023.																

ONTARIO MTO 20BF042 MTO BH LOGS (2022-08-25).GPJ ONTARIO MTO.GDT 8/25/22

UNIFIED SOIL CLASSIFICATION SYSTEM



LEGEND	BH	28	28
	SAMPLE	3	5
	SYMBOL	●	▲



GRAIN SIZE DISTRIBUTION

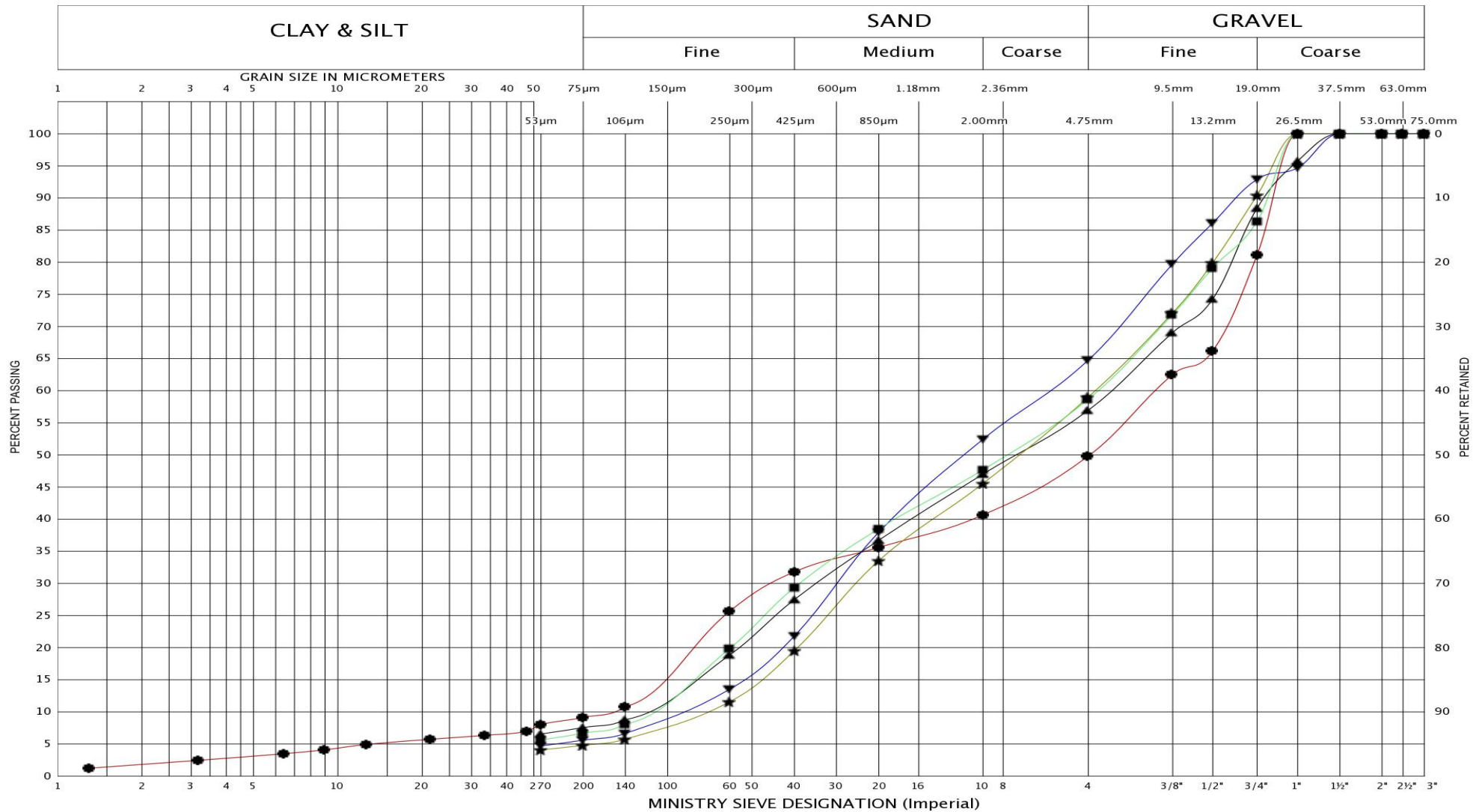
GRAVELLY SAND, Trace Silt

FIG No.: GS-1

HWY : 26

Project No.: 20BF042

UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
SAND AND GRAVEL, Trace Silt, Trace Clay

FIG No.: GS-2
HWY : 26
Project No.: 20BF042



PART B –FOUNDATION DESIGN REPORT

for

**PROPOSED SANITARY FORCEMAIN CROSSING
AT HIGHWAY 26 AT FINLAY MILL ROAD/SNOW VALLEY ROAD
PROPOSED EXTERNAL SERVICING FOR MIDHURST HEIGHTS
RESIDENTIAL SUBDIVISION
MIDHURST, TOWNSHIP OF SPRINGWATER, ONTARIO
LATITUDE AND LONGITUDE: 44.438169, -79.732789**

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PML Ref.: 20BF042A
Geocres No.: 31D-825
August 24, 2023

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page TOC 1 of 2



TABLE OF CONTENTS

PART B – FOUNDATION DESIGN REPORT

7. INTRODUCTION	9
8. PROJECT DESCRIPTION	9
8.1 General	9
9. PROPOSED SCOPE OF WORK.....	10
9.1 Proposed Installation.....	10
10. SUBSURFACE CONDITIONS.....	10
11. SUMMARY OF PROPOSED TRENCHLESS INSTALLATION	11
12. CONSTRUCTION CONSIDERATIONS	11
12.1 Frost Penetration Depth	11
12.2 Seismic Zone and Site Response	11
12.3 Existing Culvert	12
13. INSTALLATION METHODS	12
14. INSTALLATION USING TRENCHLESS TECHNOLOGY.....	12
14.1 Requirements and Policy for Encroachments and Utilities	12
14.2 Ground Classification	13
14.3 Selection of Installation Method.....	14
14.3.1 Jack and Bore.....	15
14.3.2 Microtunnelling.....	17
14.3.3 Pipe Ramming	18
14.3.4 Recommended Method.....	21
14.4 Anticipated Settlement	21
14.5 Settlement Monitoring	22
14.6 Sending and Receiving Pits	25
14.6.1 Excavation for Sending and Receiving Pits	25
14.6.2 Groundwater Control	27
14.6.3 Backfill of Sending and Receiving Pits.....	27

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road

Proposed External Servicing for Midhurst Heights Residential Subdivision

Midhurst, Township of Springwater, Ontario

PML Ref.: 20BF042A, August 24, 2023, Page TOC 2 of 2



14.7 Construction Considerations for Trenchless Method.....	28
15. CLOSURE	29

References

List of Standard Specifications Relevant to Report

ATTACHMENTS

- Appendix B – Drawing DWG A – Settlement Monitoring Plan
 - Drawing DWG B – Settlement Monitoring Instrumentation
 - C.F. Crozier Drawings at Highway 26 (Drawing Nos. C102I and C103)
- Appendix C – NSSP – Pipe Installation by Trenchless Method
 - Guideline for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 9



PART B - FOUNDATION DESIGN REPORT

For

Proposed Sanitary Forcemain Crossing at Highway 26 at
Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario

7. INTRODUCTION

This geotechnical design report including the interpretations and recommendations are intended for the use of C.F. Crozier & Associates (C.F. Crozier), for this project, and shall not be used or relied upon for any other purposes or by any other parties. Where comments related to construction are made in this report, they are provided only to highlight those aspects that could affect the design of the project. Contractors must make their own interpretation of the factual information provided in the geotechnical investigation report (Part A) of the report for construction purposes, as it may affect equipment selection, proposed construction methods and scheduling.

The scope of geotechnical investigation does not include assessing the impact on the pavement and utilities that may be in the vicinity of the alignment.

8. PROJECT DESCRIPTION

8.1 General

The purpose of this report is to provide recommendations and discussions on installation of the service pipes by trenchless method along Finlay Mills Road/Snow Valley Road at Highway 26. The recommendations are based on interpretation of the geotechnical data presented in Part A.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 10



9. PROPOSED SCOPE OF WORK

9.1 Proposed Installation

The proposed updated 95% design drawings for the sanitary sewer, storm sewer, watermain and sanitary force mains were provided by C.F. Crozier, via email dated April 18 and 21, 2023. The proposed updated 100% design drawings were provided via email dated July 31, and August 22, 2023.

Based on the drawings, a 250 mm diameter HDPE forcemain pipe and a 350 mm diameter HDPE forcemain pipe will be installed within 457 mm (external) diameter and 610 mm (external) diameter steel casings, respectively, across Highway 26. The installation length for both pipes will be approximately 43.3 m.

The elevations (EL.) in this report are expressed in meters, unless otherwise noted.

10. SUBSURFACE CONDITIONS

In summary, the subsoil conditions encountered in Boreholes 27 to 29 consisted of 430 mm to 500 mm of pavement structure immediately at the ground surface. Sand/silty sand fill was encountered below the pavement structure in Boreholes 27 and 28, which extended to 2.1 m and 1.4 m respectively. Below the fill in Boreholes 27 and 28, and below the pavement structure in Borehole 29, compact to very dense gravelly sand/sand and gravel was encountered, which extended to 4.7 m to 6.0 m below ground surface. Below the sand and gravel/gravelly sand, a layer of dense to very dense sand layer was encountered, extending to the termination depth of 6.7 m below ground surface in all three boreholes.

It should be noted that Borehole 27, adjacent to the proposed receiving pit, revealed about 1.7 m of very loose sand/silty sand fill approximately 2.0 m +/- over the proposed level of the casing obvert. In addition, soils in the area of the existing concrete culvert may comprise of backfill materials as a result of the construction of the concrete culvert.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 11



Groundwater was not encountered during and upon completion of drilling the borehole. Additional water level measurements from the monitoring wells installed in Boreholes 27 and 29 were carried out, and did not encounter the groundwater level, as indicated on the corresponding Record of Borehole sheet.

11. SUMMARY OF PROPOSED TRENCHLESS INSTALLATION

The proposed 250 mm diameter and the 350 mm diameter HDPE forcemain pipes invert levels will range approximately from EL. 234.58 to EL. 234.52 and from EL. 234.57 to EL. 234.62, respectively. The invert level of the 457 mm diameter steel casing will range from EL. 234.47 to EL. 234.41 and the invert level of the 610 mm diameter steel casing will range from EL. 234.45 to EL. 234.39. The length of the installation will be approximately 43.4 m.

12. CONSTRUCTION CONSIDERATIONS**12.1 Frost Penetration Depth**

In accordance with Ontario Provincial Standard Drawing (OPSD) 3090.101, the frost penetration depth for design purposes within the site area is 1.6 m. The average annual freezing index in the area is in the range of 750-degree days Celsius.

12.2 Seismic Zone and Site Response

Based on the type of soil, the site for seismic design purposes may be classified as Site Class D in accordance with Table 4.1.8.4B of the Ontario Building Code 2020. It should be noted that the OBC site class is determined based on the average properties of the top 30.0 m of the soil profile below founding level. The site class is provided based on average subsurface conditions encountered in the boreholes, and assumes that similar conditions will most probably be encountered to a depth of 30.0 m below the founding depth.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 12



The site specific spectral acceleration (SA) and peak ground acceleration (PGA) numbers for the project site, for the 2% in 50 year probability of exceedance, are $S_a(0.2)=0.256$, $S_a(0.5)=0.268$, $S_a(1.0)=0.165$, $S_a(2.0)=0.0795$, $S_a(4.0) = 0.0293$, and $PGA=0.14$ (Earthquakes Canada, 2020).

12.3 Existing Culvert

The Crozier Drawing C103 Plan and Profile (Road Crossing Plan Bayfield Street/Highway 26) shows an existing 1800 x 900 mm concrete box culvert crossing Snow Valley Road and the invert is about 2.4 m above the proposed obvert of the casings based on the updated drawings. The edge of the culvert is located about 2.9 m horizontally from the closest edge of the proposed sending pit wall. The location of the culvert should be surveyed prior to construction, and the condition of the existing culvert should also be checked and verified.

The impact the new construction must be assessed by the Contractor such that method of installation will not have adverse impact on the culvert. The contractor's plan must be reviewed by the project team to assure that adequate support and protection have been provided to assure that there is no impact to the existing concrete culvert and the forcemain pipes under construction. Alternatively, the alignment should be reviewed or adjusted to provide sufficient clearances.

13. INSTALLATION METHODS

It is understood that trenchless method will be utilized for the installation across Highway 26 at Finlay Mill Road/Snow Valley Road.

14. INSTALLATION USING TRENCHLESS TECHNOLOGY**14.1 Requirements and Policy for Encroachments and Utilities**

Reference is given to the Transportation Association of Canada (TAC) Guidelines for Underground Utility Installations Crossing Highway Rights-of-Way, dated March 2013.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 13



The standard depth of cover for buried utility pipes under the travelled portion of the highway should not be less than 1.2 m. In Southern Ontario, the depth of cover for buried pipes should not be less than 0.75 m below the bottom of highway ditch. However, TAC requires 1.8 m of cover below the paved area, 1.5 m of cover below the ground area, and 1.2 m of cover in the ditch area.

MTO Encroachment permit will be required for the proposed crossing across Highway 26 by tunnelling methods. The standards, policies and RAQs requirements should be followed.

14.2 Ground Classification

The trenchless operation will in general advance through dense to very dense sand and gravel/gravelly sand. It is expected that the soil deposits will exhibit different resistances across the boring diameter along the tunnel length.

The Tunnelman's Ground Classification System (Heuer, 1974, Deere et.al. 1969, Terzaghi, 1950) has been used as a basis to describe the anticipated behaviour of the ground. Considering the encountered subsurface soil and groundwater conditions, the soils may be classified as 'Running'. The 'Running' ground may change into "Flowing" ground below the water table or in the presence of water, requiring the excavation to be supported at the crown, perimeter and face.

The stand-up time for these soils is shown in the table below. The stand-up time is based on the behavioristic classification of various soils by Deere et. al. (1969).

Table 2: Stand-Up Time for Soil Type

TUNNELMAN'S SOIL TYPE	STAND-UP TIME RANGE
Running/Flowing	Up to 0.5 minute

Clean gravel and sands have practically no stand-up time.

It should be noted that unsupported vertical side walls cannot be maintained in the running/flowing soils.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 14



The tunnelling equipment and procedures shall ensure that the tunnel face, heading and tunnel bore will be supported immediately at all time during and after construction.

14.3 Selection of Installation Method

Oversize casings are generally installed so that a carrier pipe can be inserted within the casing to fine tune or correct the vertical and horizontal alignment.

Based on the provided drawings, the proposed sanitary forcemain pipes alignment crosses Highway 26 at the Finlay Mill Road/Snow Valley Road intersection. Since this section of the alignment falls within the Ministry of Transportation Ontario (MTO) right-of-way (ROW), communications/consultation with MTO and an encroachment permit will be required prior to construction.

Open cut or trenching to install the casing does not comply with the MTO policy for encroachments and utilities within the MTO ROW. It should be noted that the MTO Corridor Management Office (CMO) generally requires pressurized pipes under the highway to be encased within a casing/liner. For the Highway 26 crossing at Finlay Mill Road and Snow Valley Road, trenchless method must be used to install the service pipe, in accordance with MTO regulations.

There are a number of trenchless technologies employed in the industry, depending on the site conditions and the size of the casing to be installed. The installation of casings at this site generally requires boring through gravelly sand/sand and gravel soil deposits. Most of the trenchless methods are feasible through the subsoil conditions encountered.

Pipe Jacking method is generally unsuitable to install utility pipe of small diameter, and requires a minimum boring diameter of 1.43 m to employ this method. As a result, the pipe jacking method is not recommended for this project.

Horizontal Directional Drilling is not considered suitable either to utilize in gravelly sand/sand and gravel grounds, and the alignment will be difficult to control and will lose drilling fluids during the

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 15



tunnelling operations. Considering that the bore would be unlined during the HDD process (until the final pass is made and the casing is pulled through), there may be a potential for loss of ground and sink holes to develop at surface. The ground surface over the tunnel route may become distorted and distressed by tunnelling. The most common type of distress is settlement caused by loss of ground around the tunnel. Heave of the ground surface and/or inadvertent drilling fluid returns are also possible.

There appears to be three (3) possible trenchless methods to consider for the installation of the casings. Jack and Bore is an option, which can be used to install pipes with diameters ranging from as large as 1.8 m to as small as 203 mm and for lengths as much as 150 m. Microtunnelling is also an option to be considered. This method can be used to install the steel casings. The pipe ramming method is inexpensive and the technology is available for installation of casing with diameter as small as 305 mm.

It should be noted that the following discussion and recommendations are presented in relation to the reference drawings provided by C.F. Crozier. Further, the recommendations presented are based on the boreholes drilled along the currently proposed alignment. Additional subsurface investigation will be required if the crossing alignment is altered or shifted. Regardless of the method used, it is recommended that the contractor prepare a plan in advance of construction outlining the details of the installation to provide instructions for the construction crews and provide a contingency action plan should difficulties occur during the tunnelling operations. Since the tunnelling process should be continuous, any stoppage in the tunnel advancement under the travelled portion of Highway 26 at Finlay Mill Road/Snow Valley Road must be avoided, and a mitigation action plan prior to tunnelling should be provided. The plan should also be reviewed by the client and C.F. Crozier, the design team, prior to construction.

The presence of buried utilities must be verified, and measures should be implemented to prevent damage.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 16



14.3.1 Jack and Bore

Jack and Bore typically involves the simultaneous advancement of a continuous flight auger and conduit pipe. The auger is used to excavate soil in advance of the casing and transport cuttings back to the jacking/entry pit where they are removed. Rotary power to auger and pushing force is provided by a drill rig located within the jacking/entry pit. Jack and Bore is a common method of trenchless installation, and in appropriate site and soil conditions, may be preferable from a cost perspective.

The Jack and Bore is generally compatible with a variety of stable soil conditions, although there are geotechnical constraints when used below the groundwater table where soils may exhibit flowing behaviour. To utilize this method in this situation, dewatering of the alignment will be required.

This method is applicable for all types of crossings to install sewer or utility pipes to a maximum length of 150 m. A minimum casing diameter of 203 mm required to employ this method. The pipe for employing this method should resist abrasion caused by the rotation of augers. Steel is the typical material used, although concrete pipe may also be used in a corrosive environment for place of buried metallic pipes.

With this method, surface subsidence and heave during installation may pose major problems. Heave occurs when excessive force is applied to the face of boring and surface subsidence occurs when over excavation is permitted. Conversely, if the rate of advancement is too slow in loose or wet deposits, then the risk of over cut and loss due to ravelling at the cutting face increases. The workers are not required to enter the shaft to remove the spoil, however, adequate working space for sending (jacking) and receiving (exit) pits will be required.

The most critical part of this method is positioning the track system on the same line and grade as the bore of the casing. The jacking forces should be estimated to select the appropriate jacking system. Suitable jacking head and bracing between jacks and jacking head should be used to assure that pressure will be applied to the pipe uniformly around the ring of the pipe. The drive shaft should have a stable foundation and an adequate thrust block designed to transmit the horizontal jacking force.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 17



The Jack and Bore method has a limited steering ability, which can affect the line and accuracy of the grade. It is typically unguided once it is launched and any subsurface obstructions can cause large deflections. One percent (1%) accuracy of the length of drive may be achieved vertically with a steering head and grade monitoring system combined with good workmanship and suitable equipment. However, horizontal alignment is generally not controlled.

Utilization of an effective lubrication system may minimize potential casing friction during advancement. A suitable face pressure or soil plug should be maintained to minimize loss of ground during advancement. The conventional Jack and Bore system of auger boring is generally open face, and in certain soil conditions such as cohesionless running sand, gravels and sand/gravelly sand, the conventional system may require the inclusion of a closed face articulated steering cutter head equipped with grout injection ports and as necessary, provision of slurry pressure. Any over cutting during augering and casing advance, which may potentially create soil disturbance, space or void outside the casing, should be grouted to avoid potential ground movements.

Jack and Bore installation(s) should be conducted in accordance with MTO NSSP Pipe Installation by Trenchless Methods (refer in Appendix C).

Distress at the ground surface is generally prevented or minimized by proper planning and good construction practices. The contractor should submit a plan for review indicating the planned processes/methods.

14.3.2 Microtunnelling

Micro-tunnelling involves the advancement of a tunnel boring machine from the jacking pit to the receiving pit. The Tunnel Boring Machine (MTBM) and the tunnel segments are pushed from the jacking pit while line and grade are controlled by the tunnel boring machine as it advances. These machines typically utilize pressurized bentonite slurry to counterbalance the earth and water pressures acting at the tunnel face. The excavated soil slurry is withdrawn in a controlled manner to prevent loss of ground during tunnel advance. The slurry is circulated back through the tunnel to transport cuttings

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 18



to a settling tank. Given the machines ability to control soil and water pressures at the face, dewatering prior to advancing the tunnel would not be necessary with this tunnelling method. However, dewatering of the staging and receiving pits will still be required and reference is given to the excavation and ground water control section. The size of drive and receiving pits required may vary in length.

To minimize obstruction resulting from cobbles and boulders during tunnelling operation, the TBM can be equipped with combination heads, scraper and disc cutters, to bore through the glacial till deposit.

Microtunnelling requires a larger excavation and groundwater control for entry and exit pits. Contractor availability may be limited if microtunnelling is opted and may also pose a disadvantage from a cost perspective, largely depending on availability of a machine of the same size.

Cognizant of the tunnel size, grade requirements, and subsurface conditions, micro-tunnelling may be considered for the proposed crossing. Micro-tunnelling may pose a disadvantage from a cost perspective and will largely depend on availability of a machine of the same size. The method provides better control when encountering potential ground water seepage, and potential obstructions such as potential boulders during tunnelling. The costs and project scheduling may outweigh its benefits and poses risk to the project feasibility.

14.3.3 Pipe Ramming

Pipe ramming installation is analogous to driving an open-ended tube pile horizontally. Impact forces from a percussive hammer are used to advance a conduit pipe from an entry pit to a receiving pit. During advancement, most of the soil being penetrated fills the conduit rather than being excavated. The rammed conduit is terminated in a receiving pit at which point the soil contained in the pipe is removed. When the driving has been completed, soil within the pipe can be removed via augering or a pipe shovel. Augering is typically the preferred method. If soil within the pipe cannot be augured, the use of a pipe shovel will be necessary. A pipe shovel is essentially a special scoop made from a pipe which fits inside the liner. Excavation via pipe shovel involves advancing the shovel into the soil plug using impact hammer, then pulling the shovel and its contents out with a chain or cable. This process is repeated as required.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 19



In general, compared to Jack and Bore, less extensive ground water control measures should be needed along the installation path because the soil within the pipe is typically not removed until after the crossing has been completed. The retained soil will tend to act as a plug, reducing the potential for ground water seepage and soil flowing through the pipe. Ground water control via sump pumping will only be required at the entry and receiving pits. Pipe ramming is able to accommodate cobbles and boulders, if encountered, more easily than jack and bore, provided that the boulders are small enough to fit inside the casing. However, significantly thicker steel casing is generally required due to the intrinsic driving forces needed to advance the casing using pipe ramming.

The initial set-up is the critical factor in the success of any pipe ramming project. The drive shaft must be located on very stable ground or a concrete slab must be placed below the casing. With this method, the pipe is unguided, therefore the floor of the drive shaft must be engineered to be on the same line and grade as the pipe to provide the required accuracy.

Inadequate cover in the ditch areas may result in deflection of the casing during the installation and the pipe may drift upward. In addition, subsidence of the fill under the road may occur due to the compaction resulting from the vibratory action of the hammer. Due to the shoving effect of the casing, potential excessive ground loss, heaving and subsidence are generally more than the other ground tunnelling methods.

In general, it will be more difficult to install the proposed conduits where grades are less than about 1% because of the limited ability to adjust grades during pipe ramming. Pipe ramming does not allow for significant alignment corrections during installation.

Refer to Table 3 for a comparison of the alternative installation methods using trenchless technology discussed in this section of the report.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
 Proposed External Servicing for Midhurst Heights Residential Subdivision
 Midhurst, Township of Springwater, Ontario
 PML Ref.: 20BF042A, August 24, 2023, Page 20

**Table 3: Comparison of Alternate Trenchless Methods**

TUNNELLING METHOD	ADVANTAGES	DISADVANTAGES
Jack and Bore	<ul style="list-style-type: none"> • Contractor Availability; • Relatively cost effective compared to other methods; • Can accommodate variable soils without major tool adjustment; • Spoils are removed by auger through casing being placed; • Lubricant or drilling fluid is optional and could be applied; • Mixed face conditions may be dealt with by good workmanship for control; • Immediate ground support by casing and temporary face support by auger position/soil cutter head and soil plug. 	<ul style="list-style-type: none"> • Ground water control is required for the entry and exit pits (recommended for drier seasons); • It is typically unguided and horizontal alignment not controlled; • Subsurface obstructions such as large boulders pose problems in advancing and may require new drive path if worker cannot enter to remove; • Requires operators with relatively high skills; • Requires auger removal and additional tools to break up very large boulders, if encountered; • Subsurface obstruction and mixed face may cause deviation from tunnel path (acceptable if sufficient space is available for carried pipe adjustment). • A closed face articulated steering cutter head may likely be required
Microtunnelling	<ul style="list-style-type: none"> • Remotely controlled and positional control is accurate; • Better accuracy on-line and grade compared to other methods; • Some smaller obstructions can be overcome by reverse rotation; • Capable of balancing soil and hydrostatic face pressure, and ground water control may not be required; 	<ul style="list-style-type: none"> • Limited contractor availability; • Typical higher cost and availability of contractors for the MTBM or EPB MTBM method; • Require larger excavation for entry and exit pits; • Ground water control is required for the entry and exit pits (recommended for drier seasons);
Pipe Ramming	<ul style="list-style-type: none"> • Minimal ground water control required along the installation route; • Relatively faster installation than Jack and Bore; • Can advance through soil with cobbles and small boulders; • Low sensitivity to ground water seepage compared to Jack and Bore; • Can accommodate variable soils without major tool adjustment; • Small staging areas as compared to HDD. 	<ul style="list-style-type: none"> • Ground water control is required for the entry and exit pits (recommended for drier seasons); • Poor grade control (cannot be corrected once installation has started); • Effects of vibrations will have to be assessed/monitored for subsidence; • Require thicker steel casing to withstand driving forces; • High risk of excessive ground loss/ settlements/ ground heave during casing drive if large obstruction encountered.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 21



14.3.4 Recommended Method

Cognizant of the site conditions, grade requirements for the services and cost implications, it is recommended that Jack and Bore be used for the installation of casings. This method meets with the requirements of MTO policy for encroachments and utilities. Based on the sand and gravel/sandy gravel soils, the jack and boring method will require a face support for cohesionless sand and gravel/gravelly sand because the cohesionless material can enter into the jack and bore casing. To deal with the cohesionless soil, a closed face articulated steering cutter head would be required.

It should be noted that annular void between the steel casing and the tunnel excavation should be grouted immediately following installation of the steel casings into the ground. Once the HDPE pipes are installed within the steel casing, the annular space between the casings and the HDPE pipes should be pressure grouted after the installations.

It is generally preferred to install the two casings in separate drives, one after the other and not simultaneously.

As noted previously, the presence of nearby buried utilities must be verified, and measures should be implemented to prevent damage.

14.4 Anticipated Settlement

The empirical calculations based on the available pipe configurations and soils information, and coupled with experiences and case records of trenchless installation indicate that the settlements could be controlled to within acceptable tolerance of about 10 mm settlement over the pipes provided that the suitable and proper equipment and workmanship has been used. The Designer and Contractor should carry out their own settlement and horizontal displacement calculations based on their own purposes.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 22



Based on the drawing C103, the clearance from the obvert of the casing to the invert of the culvert has been increased from 1.3 m to approximately 2.4 m. It is anticipated that the additional lowering of the pipes by 1.1 m would provide soil arching effects to mitigate settlement effect on the culvert.

Since the pipe vertical alignment is lowered, the distance (and soil thickness cover support) below the culvert invert, and the loose soil layer at BH 27 (close to the receiving pit) to the casing obvert has increased, and the risk of settlement during tunnelling operations has been lessened. However, the Designer and the Contractor should carry out their own assessment of risk of settlement for these particular areas.

It is understood based on C.F. Crozier communications and drawings, the two casings will be set at minimum 2.0 m apart edge to edge and about 2.4 m apart measured from center and center. The clearance is required to mitigate disturbance and interaction effect of the two pipes, and hence to reduce ground displacements, and to result in a wider displacement/settlement trough.

The scope of the foundation investigation does not include assessing the impact on the pavement and utilities that may be in the vicinity of the alignment. The contractor will be responsible for any associated impact on the existing structure and underground utilities in the vicinity due to settlement and horizontal displacement along the bore length. It is understood that Level B SUE and a Level A SUE have been coordinated and undertaken to determine the vertical elevations of existing utilities by the client.

14.5 Settlement Monitoring

The ground surface over the tunnel route may become distorted and distressed by tunnelling. The most common type of distress is settlement caused by loss of ground around the tunnel. Heave of the ground surface and or inadvertent drilling fluid returns are also possible depending on the type of installation. Mitigation of the distress or distortion on the travelled lanes of Highway 26 would be a major inconvenience to highway/roadway users and possibly a safety issue.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 23



Distress at the ground surface is generally prevented or minimized by good construction practices and proper planning. In this regard, preparation of an installation plan as noted above is recommended.

The tunnelling process should be continuous, such that a stoppage in the advancement of the tunnel is not programmed when the end of the tunnel is under the travelled lanes of Highway 26. Such a stoppage would provide greater potential for loss of ground/settlement around the tunnel.

Monitoring during tunnelling will provide feedback to the engineer and contractor to adjust the construction procedures to control ground movements. Accordingly, changes to the progress and procedures can be made before the construction reaches locations where ground movements could be potentially damaging to the highway/roadways.

It is recommended that the contractor implement a monitoring program to check the condition of the ground over the tunnel before, during and upon completion of construction for all roadways and Highway 26 sections. The monitoring program for the Highway 26 crossing should be carried out by a qualified geotechnical consulting firm that is MTO RAQS approved and should conform to the MTO Settlement Monitoring Guidelines for Tunnelling, February 2021 (refer to Appendix C). Generally, the CMO requires submission of a Geotechnical Instrumentation and Monitoring Plan (GIMP) for the encroachment permit applications.

As noted in the drawing shown in Appendix B, monitoring points should be installed over the proposed tunnelling route at a maximum interval of 5 m. Monitoring period should begin prior to tunnelling, extend throughout the duration and continue at least two weeks after completion of tunnelling. Measurement of the monitoring points should be done at least three times a day everyday in the monitoring period. A Settlement Monitoring Plan (DWG A) and a Settlement Monitoring Instrumentation (DWG B) are appended in Appendix B for the tunnelling section. Table 4 summarizes the recommended monitoring periods and frequencies in reference to the CMO guidelines.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 24



Table 4: Monitoring Period and Frequency of Settlement Monitoring Points

Monitoring Period	Monitoring Frequency
Prior to Construction	Average of at least three readings to establish the initial baseline conditions
During Construction	Three (3) sets of reading daily (settlement are within anticipated limits) during construction, including non-operation period (off-shifts) or/and weekends. If settlement readings reach or exceed the review or alert levels, daily sets of reading should increase to a pre-planned interval based on the contractor's contingency plan, or as directed by the CA.
After Construction	One set of reading daily (provided settlement are within anticipated limits) following construction for at least two (2) weeks, provided that further settlement has stopped, or as directed by the CA.

At review level (10 mm relative to baseline readings), the method, rate or sequence of construction or ground stabilization measures should be reviewed or modified to mitigate further ground displacements. If alert level is reached (15 mm relative to the baseline readings), the contractor shall cease construction operations and execute pre-planned measures to secure the site, mitigate further movements and assure the safety of the public and maintain traffic. All actions to prevent, secure, or mitigate destruction or damage to the highway and associated features, inclusive of the concrete culvert, should be done in accordance with and approved by MTO.

Monitoring point should be marked and labeled using a method approved by MTO. Monitoring points should also be functional throughout the monitoring period and should not deteriorate because of highway traffic, maintenance activities, and weather conditions.

A pavement condition survey of the pavement directly above the pipe alignment should be carried out before, during and after the installation along Highway 26. Similarly, pre- and post-construction surveys of the culvert should be carried out by the contractor. Any distresses observed along the tunnel alignment on Highway 26 shall be reinstated to its original conditions or better. The contractor will be responsible for any reinstatement of the Highway 26 pavement.

If distress is observed during construction, the contractor should be informed and corrective action should be undertaken immediately. Specific corrective action will be dependent on the nature of

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 25



the distress and type of installation. Regardless, the process should be outlined in the monitoring program and be part of the contingency actions in the contractor's installation plan. It should be noted that the ground movement monitoring does not relieve the contractor's responsibility to undertake the necessary action and additional instrumentation and independent reading of the instrumentation to ensure that work is carried out in a safe and acceptable manner.

14.6 Sending and Receiving Pits

Based on the drawings provided by C.F. Crozier, the sending pit will be approximately 12.8 m in length, 5.0 m in width and 5.3 m deep (EL. 234.0), approximately from Station 3+502.6 to Station 3+515.3, and the receiving pit will be approximately 6.0 m in length, 5.0 m in width and 5.1 m deep (EL. 234.1), approximately from Station 3+556.6 to Station 3+562.

14.6.1 Excavation for Sending and Receiving Pits

Prior to excavation, the locations and depths of existing underground utilities should be verified. All underground utilities that might be exposed and become unsupported as a result of the excavation should be properly supported to avoid potential damage. In detail design, it may be necessary to consider relocation of the existing underground utilities if the conflicts cannot be resolved.

General Reference is given to OPSS 201, 490 and 801 for specifications associated with site preparation.

Due to the proximity of the two pipe alignments, it is assumed that the staging pits, on both sides, for both services, will be carried out using a common pit. Excavation will extend to an anticipated depth of about 5.1 to 5.3 m depth below existing grade at the pits, and will extend through surficial pavement and underlying fill, and into the native compact to very dense cohesionless soils.

Provided adequate ground water control is achieved, the on-site soils are classified as Type 3 material as defined in the Occupational Health and Safety Act (OHSA). Excavations within Type 3 soil that are to be entered by workers, may not be steeper than one horizontal to one vertical

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 26



(1H:1V) from the base. Workers should not enter an unprotected excavation if there is evidence of ongoing ground water seepage in the banks.

Any unsupported open excavation side slopes should be continuously examined and reviewed for evidence of instability, particularly following periods of heavy rain or thawing. Remedial action must be taken to ensure continued stability of the excavation slope, and the safety of the workers.

Based on the water levels observed in the boreholes, which were 'dry' to the base of the boreholes and monitoring wells, excavation described above will not encounter the water table; however, perched water condition at the crossing of the proposed tunnelling alignment may exist due to precipitations and seasonal fluctuations. Seepage volume is not anticipated to be large and conventional sump pumping techniques in conjunction with proper designed shoring should suffice to control ground water seepages (OPSS 517 amended by SSP 517F01). Further reference is made to Section 14.6.2.

It is envisioned that sheet piling will be employed to support the excavations, which will aid with ground water control. For design of temporary sheet piling for excavations, the following parameters may be assumed (wall friction ignored):

Table 5: Soil Parameters

PARAMETER	FILL	Compact Gravelly Sand/Sand and Gravel	Dense to Very Dense Gravelly Sand / Sand and Gravel
Angle of Internal Friction, ϕ , (degrees)	27	30	34
Shear Strength, S_u (kPa)	--	--	--
Bulk Unit Weight (kN/m ³)	18	19.5	20

The shoring system should be designed by an experienced Professional Engineer and should also include design check for basal stability, and it is recommended that the shoring system should extend at least about 2 to 2.5 m below the base of excavation into native dense to very dense materials. The contractor should ensure that the shoring is installed with care without

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 27



adverse effect on adjacent underground utilities including the concrete culvert. The temporary protection system shall be in accordance with OPSS 539, as amended. A Performance Level of 1b is recommended due to the proximity of MTO concrete culvert.

14.6.2 Groundwater Control

The actual groundwater control methods at the shaft/pits should be established at the contractor's discretion within the context of a performance specification for the project. Regardless of the method chosen, the hydraulic head and ground water inflow must be properly controlled to ensure a stable and safe excavation and to facilitate construction. The design of the groundwater control system should be carried out by specialists in the field and specified to maintain and control ground water at least 0.5 m below the base of the excavation, in order to provide a stable base throughout the construction.

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

14.6.3 Backfill of Sending and Receiving Pits

OPSS 1010 Granular 'A' or 'B Type II' should be used as backfill material and compacted in accordance with the requirements specified in the OPSS 902. The backfill material should be placed in layers not exceeding 200 mm (8 in.) in thickness before compaction.

Heavy vibratory compaction equipment near entry/exit pit drill shafts should be restricted to limit the compaction pressure. Restrictions on compaction near the drill shafts shall be as specified in OPSS 902. The type of compaction equipment and the compaction procedure that can be used for this purpose should be in accordance with OPSS 501 (Construction Specification for Compacting). Table 6 provides the recommended preliminary earth pressure coefficients for granular backfill.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 28

**Table 6: Preliminary Earth Pressure Coefficients**

PARAMETERS	OPSS GRANULAR 'A'	OPSS GRANULAR 'B' TYPE II
Internal Friction Angle, (degrees)	35	30
Unit weight, γ (kN/m ³)	22.5	21.5
Coefficient of Active Earth Pressure, K_a	0.27	0.33
Coefficient of Earth Pressure At Rest, K_o	0.43	0.5
Coefficient of Passive Earth Pressure, K_p	3.69	3

Following backfill of the pits, the pavement shall be reinstated to its original condition or better at the pit locations. The contractor will be responsible for the reinstatement of the pavement. All temporary shoring should be removed after completion of tunnelling construction.

14.7 Construction Considerations for Trenchless Method

If the contractor encounters obstructions, and boulders and cobbles such that further advance is not possible, and at the City's staff and/or the CA's direction, it is the responsibility of the contractor to abandon the drive and advance a new pipe alignment at no additional costs. The abandoned drive shall be fully grouted. Open cut on the Highway 26 shall not be permitted unless prior approval is provided by MTO.

The contractor shall be responsible to check and confirm all the underground utilities and structures, especially the existing concrete culvert, in the tunnel path and its vicinity to assure that there is no conflict with the tunnelling operations, and will not impact the existing underground utilities or structures. Any damages as a result of the pipe installations shall be restored to their original conditions or better.

It is the responsibility of the contractor to ensure that potential loss of ground is minimized and any excessive movements and settlements resulting from the jack and bore operations are to be dealt with immediately at no additional cost to the owner.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023, Page 29



15. CLOSURE

This report was prepared by Mr. Nazibur Rahman, P.Eng., Senior Engineer with the assistance of Ms. Natasha Leong-Sem, EIT. Mr. Robert Ng, P.Eng., MTO Designated Principal Contact, conducted an independent review of the report.

Yours very truly,

Peto MacCallum Ltd.

A handwritten signature in blue ink, appearing to read "Natasha Leong-Sem", is positioned above the printed name.

Natasha Leong-Sem, EIT
Geotechnical Services



Nazibur Rahman, P.Eng.
Senior Engineer, Geotechnical Services



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

NLS/NR/RN:nls-nr

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023



REFERENCES

- Deere, D.U., Peck, R.B., Monsees, J.E. and Schmidt, B. (1969). *Design of Tunnel Liners and Support Systems*. Report for U.S. Department of Transportation, OHSGT Contract 3-0152, No. PB 183 799, National Technical Information Service (NTIS), p.287.
- Earthquakes Canada. "2020 National Building Code of Canada Seismic Hazard Tool". <https://earthquakescanada.nrcan.gc.ca/hazard-alea/zoning-zonage/NBCC2020maps-en.php>, accessed March, 2023.
- Heuer, R.E. (1974). Important ground parameters in soft ground tunnelling. Proceedings of Specialty Conference on Subsurface Explorations for Underground Excavation and Heavy Construction, New York: ASCE.
- Terzaghi, K. (1950). Geologic aspects of soft ground tunneling. Chapter 11 in Applied Sedimentation, R. Task and D. Parker, eds. New York: John Wiley & Sons.

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road
Proposed External Servicing for Midhurst Heights Residential Subdivision
Midhurst, Township of Springwater, Ontario
PML Ref.: 20BF042A, August 24, 2023

**LIST OF STANDARD SPECIFICATIONS RELEVANT TO REPORT**

DOCUMENT	TITLE
OPSS.PROV/.MUNI 201	Cleaning, Close-Cut Clearing, Grubbing and Removal of Surface and Piled Boulder
OPSS.PROV/.MUNI 490	Site Preparation for Pipelines, Utilities and Associated Structures
OPSS.PROV/.MUNI 501	Construction Specification for Compacting
OPSS.PROV/.MUNI 517	Construction Specification for Dewatering
OPSS.PROV/.MUNI 539	Construction Specification for Temporary Protection Systems
OPSS.PROV/.MUNI 801	Construction Specification for Protection of Trees
OPSS.PROV/.MUNI 902	Construction Specification for Excavating and Backfilling - Structures
OPSS.PROV/.MUNI 1010	Material Specification for Aggregates, Base, Subbase, Select Subgrade and Backfill Material
SSP 105S22	Amendment to OPSS 501
SSP 517F01	Amendment to OPSS 517
SSP 105S09	Amendment to OPSS 539
SSP 110S06	Amendment to OPSS 1010
OPSD 3090.101	Foundation, Frost Penetration depths for Southern Ontario
NSSP	Pipe Installation by Trenchless Methods

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road

Proposed External Servicing for Midhurst Heights Residential Subdivision

Midhurst, Township of Springwater, Ontario

PML Ref.: 20BF042A, August 24, 2023

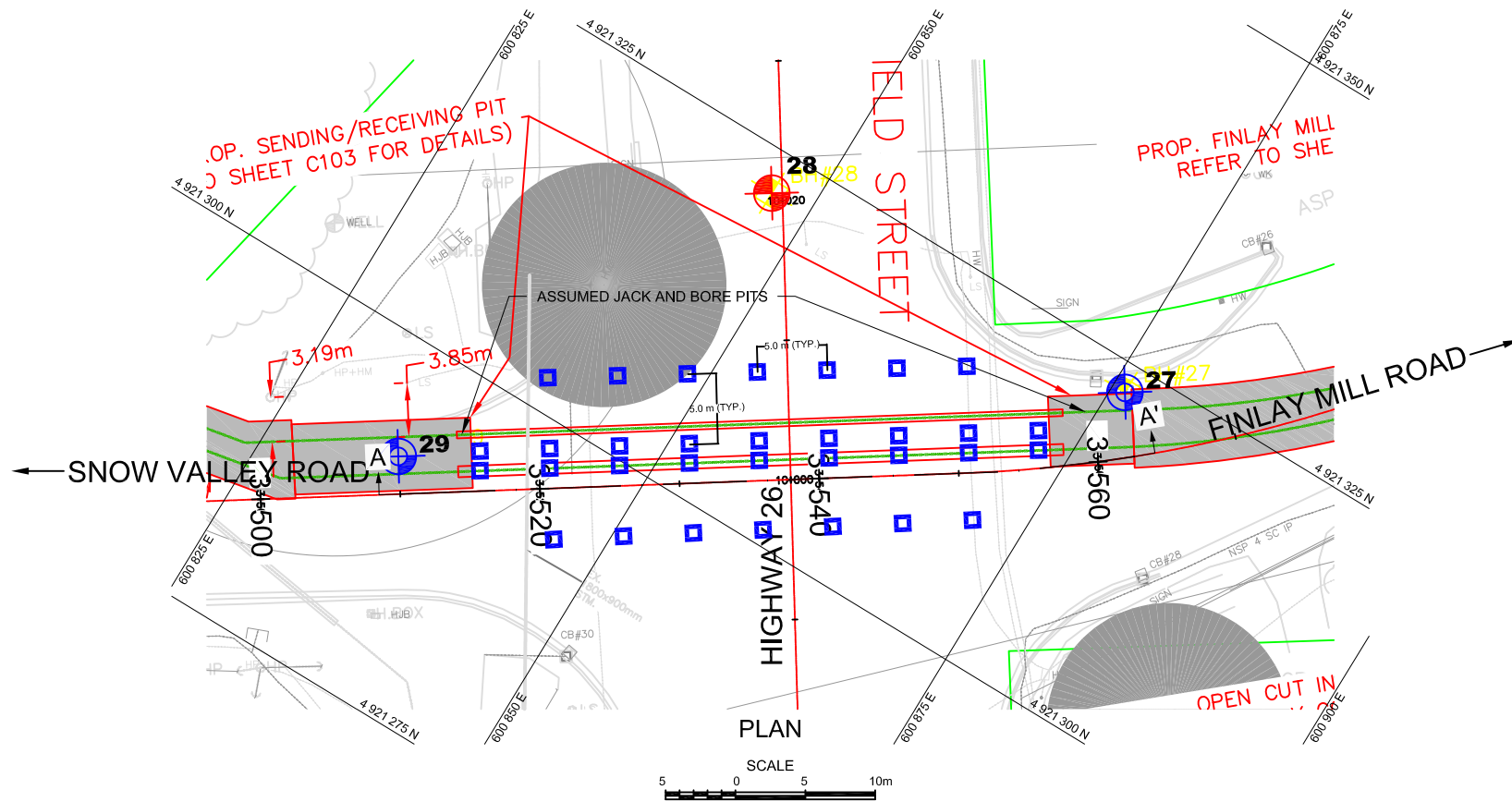


APPENDIX B

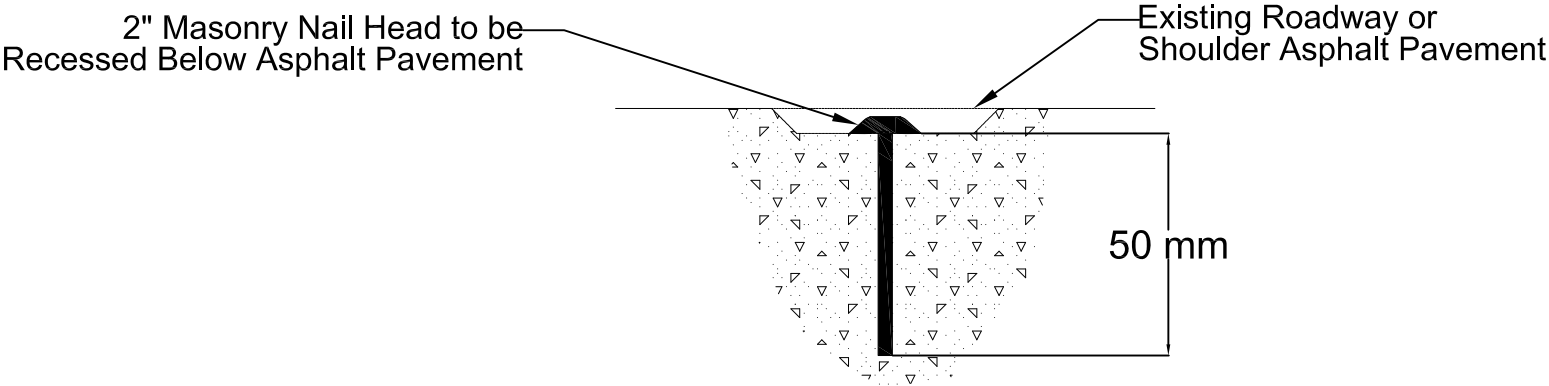
Drawing DWG A – Settlement Monitoring Plan

Drawing DWG B – Settlement Monitoring Instrumentation

C.F. Crozier Drawings at Highway 26 (Drawing No. C102I and C103)

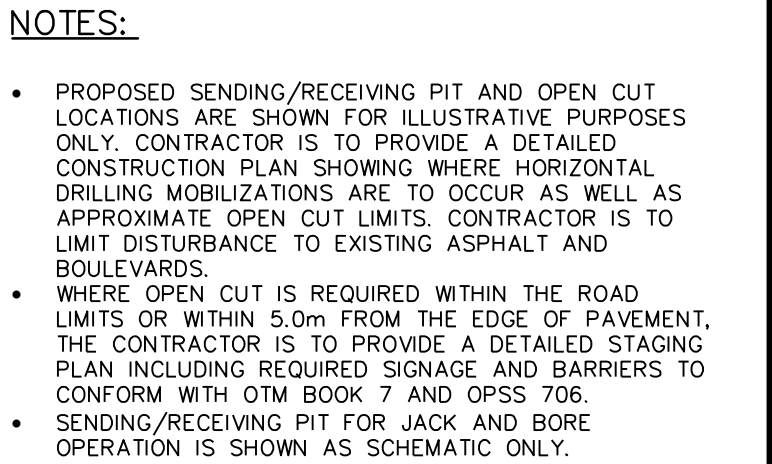
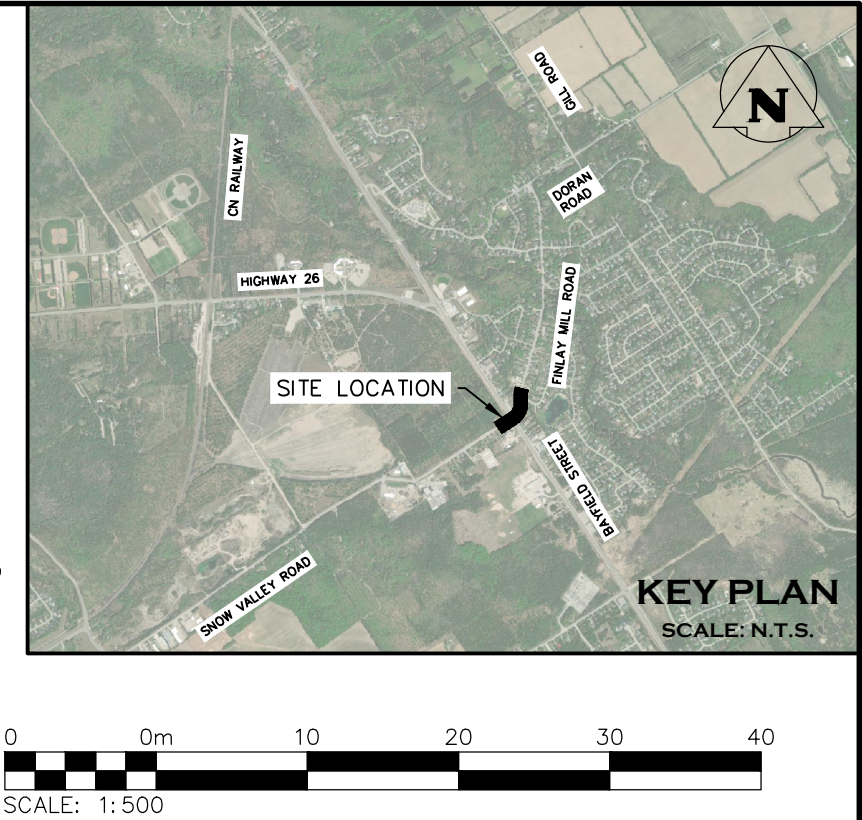



PROPOSED EXTERNAL SERVICING MIDHURST HEIGHTS HIGHWAY 26 SETTLEMENT INSTRUMENTATION	SHEET

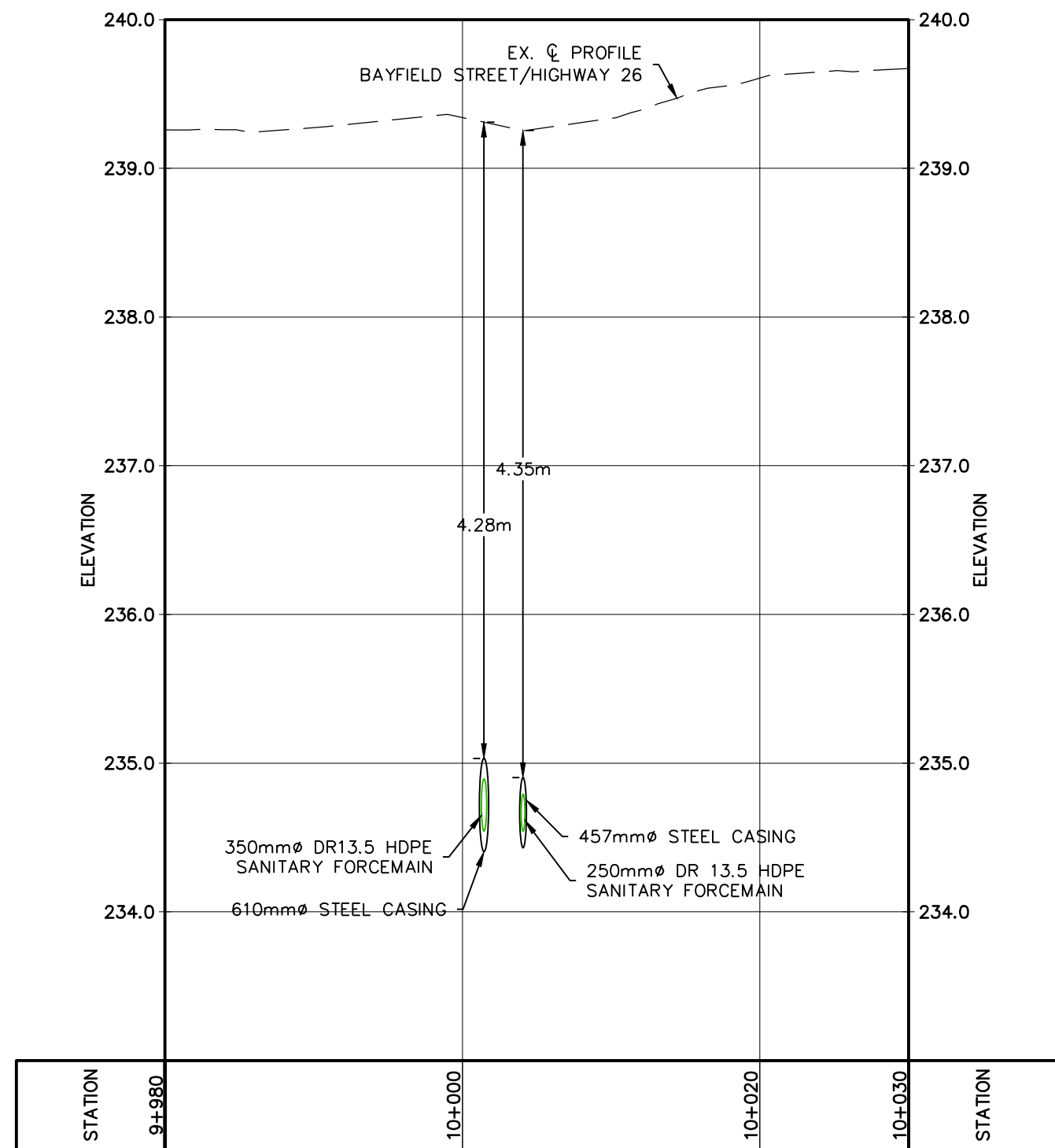


SURFACE MONITORING POINT(SMP) (TYP.)
(NTS)

REVISIONS				
	DATE	BY	DESCRIPTION	
Geocres No. Not Assigned				
HWY No	26			DIST
SUBMD	NL	CHECKED	NR	DATE AUGUST 2023 SITE
DRAWN	NL	CHECKED	RN	APPROVED RN DWG B



 <div style="display: inline-block; vertical-align: middle; margin-left: 10px;"> CROZIER CONSULTING ENGINEERS </div>					
Drawn By	DE	Design By	DE	Project	845-5201
Check By	KV	Check By		Drawing	C1021



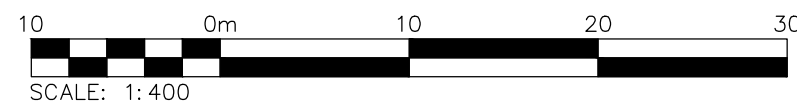
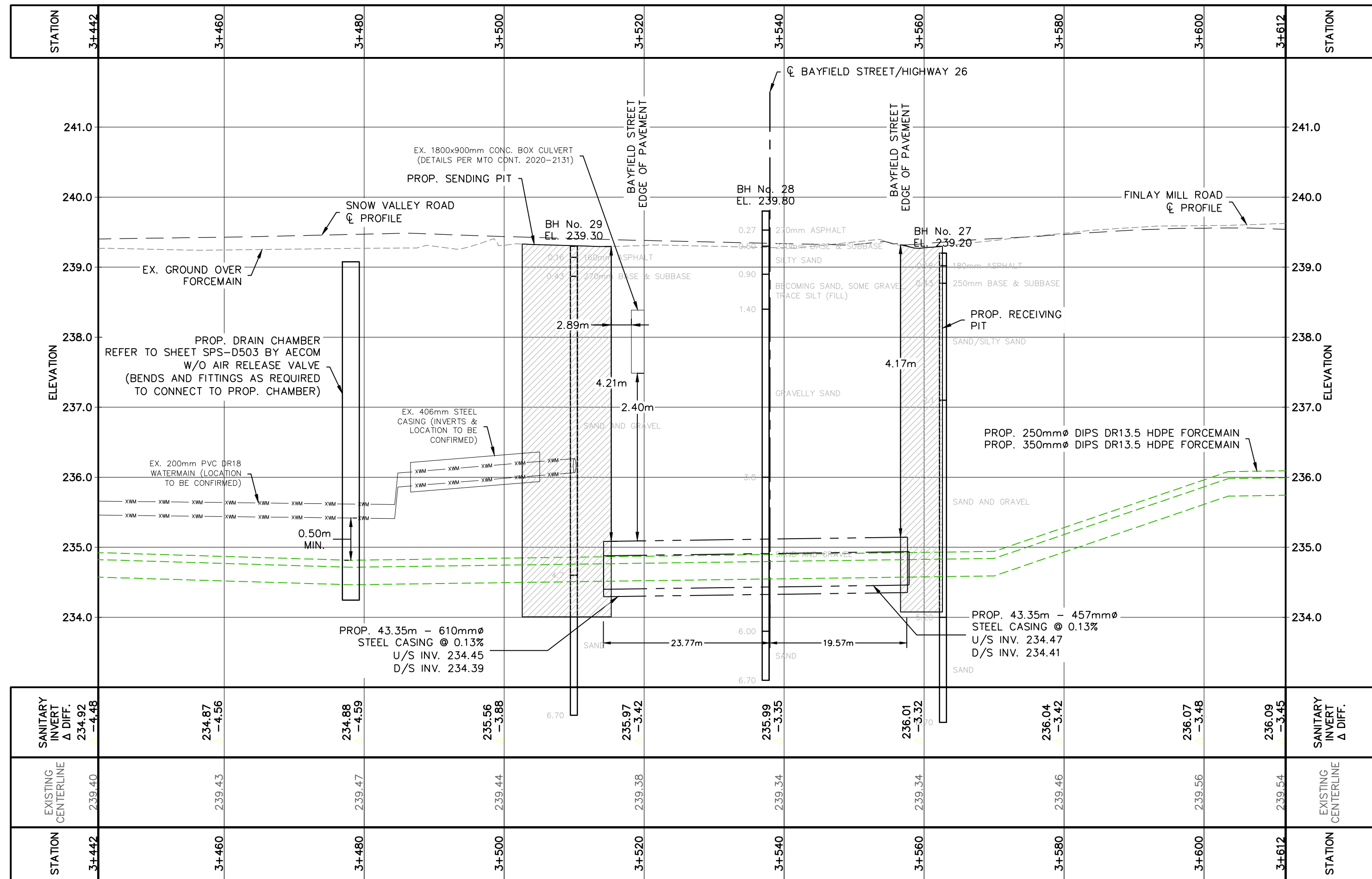
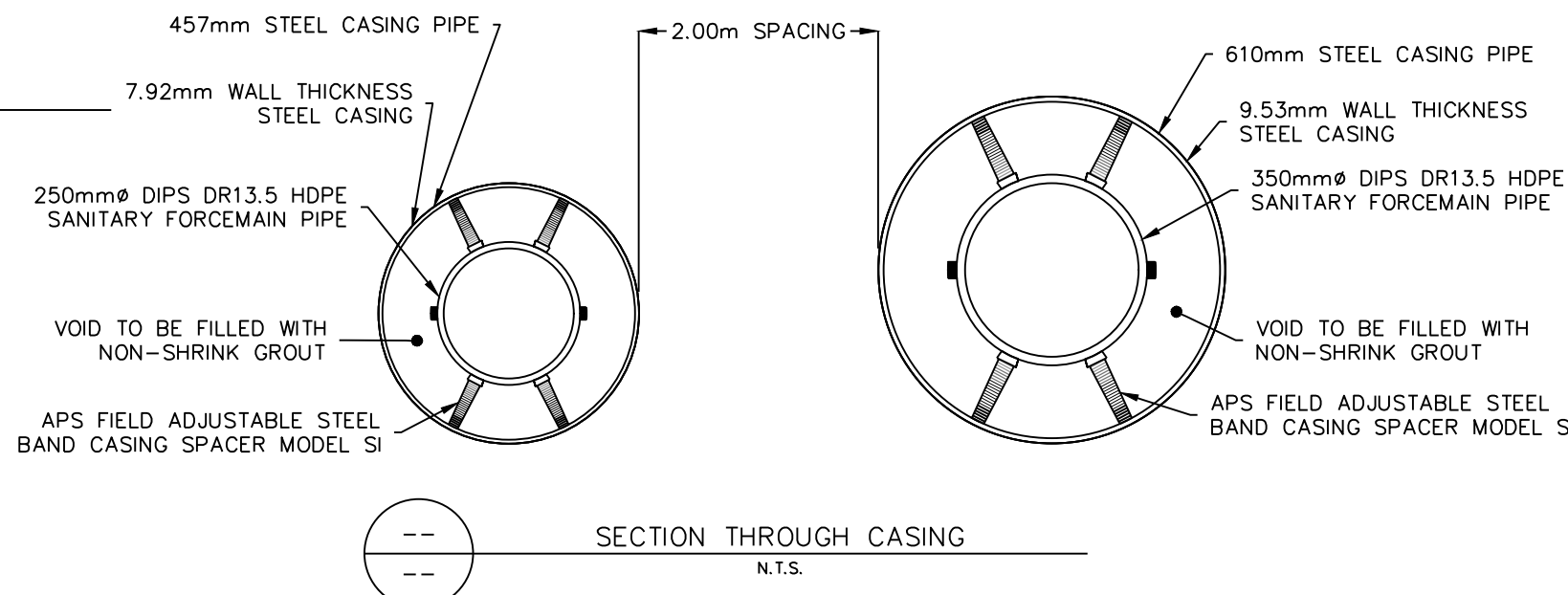
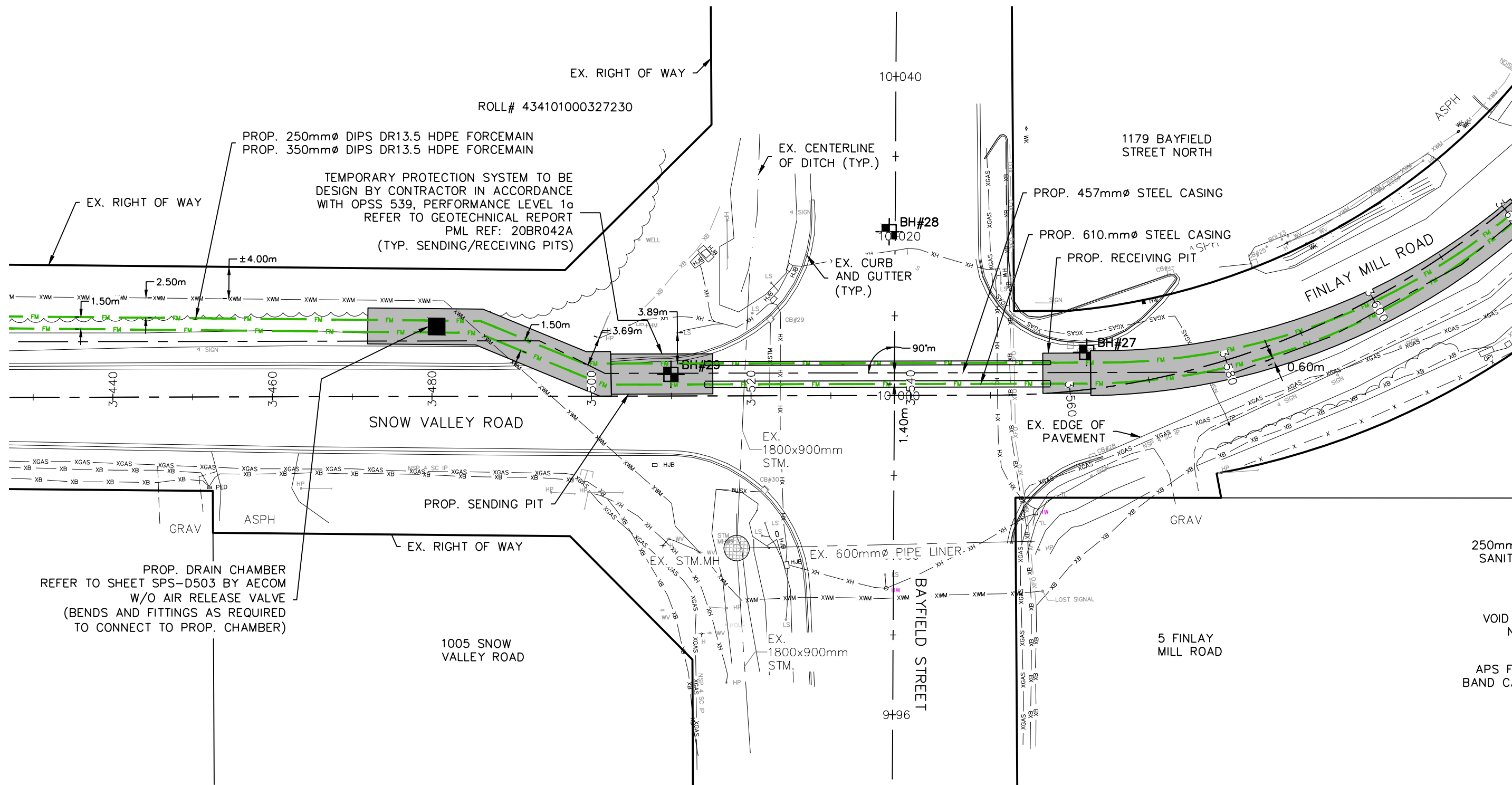
BENCH MARK (PER J.D. BARNES SURVEY DATA)
BENCHMARK No. 00819798279
ELEV. 234.68m (CGVD28:78)
NORTHING 4920678.006
EASTING 601249.404

MTD ROAD CROSSING ROAD CROSSING DETAILS

- INSTALLATION AND MAINTENANCE TO BE IN ACCORDANCE WITH STANDARD OPSS.MUNI 416 RESPECTING PIPELINE INSTALLATION BY JACKING AND BORING.
- INSTALLATION TO BE BY JACK AND BORE. SEE SCHEDULE FOR ENCASING PIPE DETAILS. ENDS OF CASING PIPE TO BE SEALED AND VOID TO BE FILLED WITH NON-SHRINK GROUT.
- BORING PIT DIMENSIONS NOT TO SCALE, SHOP DRAWINGS FROM BORING CONTRACTOR TO BE APPROVED BY ENGINEER PRIOR TO JACK AND BORE INSTALLATION.
- REFER TO GEOTECHNICAL REPORT BY PETO MACCALLUM LTD., DATED OCTOBER 21, 2022 FOR SOILS INFORMATION.

CONTENTS HANDLED:	CARRIER PIPE	CASING PIPE	CARRIER PIPE	CASING PIPE
OUTSIDE DIAMETER:	SANITARY	CARRIER	SANITARY	CARRIER
SPEC. & GRADE:	282mmØ	457mmØ	389mmØ	610mmØ
WALL THICKNESS:	DR13.5 HDPE	STEEL	DR13.5 HDPE	STEEL
MAX. OPERATING PRESSURE:	34mm	7.92mm	36mm	9.53mm
MAX. SURGE & TEST PRESSURE:	-	-	-	-
MAX. OPERATING TEMP:	-	-	-	-
MIN. OPERATING TEMP:	-	-	-	-
TYPE OF JOINT:	FUSED	WELDED	FUSED	WELDED
COATING:	-	-	-	-
METHOD OF INSTALLATION:	JACK AND BORE	JACK AND BORE	JACK AND BORE	JACK AND BORE
CATHODIC PROTECTION:	-	-	-	-

- TYPE, SIZE AND SPACING OF SUPPORTS, APS, MODEL SI, FIELD ADJUSTABLE STEEL BAND SPACERS MINIMUM 3 PER 6m LENGTH OF CARRIER PIPE, ONE MID-SPAN AND ONE 0.30-0.45m FROM EACH END.



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- THIS DRAWING IS TO BE READ AND UNDERSTOOD IN CONJUNCTION WITH ALL OTHER PLANS AND DOCUMENTS APPLICABLE TO THIS PROJECT.
- ALL EXISTING UNDERGROUND UTILITIES TO BE VERIFIED IN THE FIELD BY THE CONTRACTOR PRIOR TO CONSTRUCTION.
- DO NOT SCALE DRAWINGS.

Town

No.	ISSUE	DATE: MM/DD/YYYY
1.	ISSUED FOR 30% DESIGN SUBMISSION	06/15/2022
2.	ISSUED FOR 90% DESIGN SUBMISSION	03/03/2023
3.	ISSUED FOR 95% DESIGN SUBMISSION	03/29/2023
4.	ISSUED FOR MTO APPROVAL	04/28/2023
5.	ISSUED FOR 100% DESIGN SUBMISSION	06/09/2023
6.	ISSUED FOR TENDER	06/15/2023
7.	RE-ISSUED FOR MTO APPROVAL	07/28/2023

FOR APPROVAL
NOT TO BE USED FOR CONSTRUCTION

TOWNSHIP OF SPRINGWATER
MIDHURST HEIGHTS DEVELOPMENT
SANITARY FORCEMAIN

ROAD CROSSING PLAN
BAYFIELD STREET/HIGHWAY 26



Drawn By	DE	Design By	DE	Project	845-5201
Check By	KV	Check By	H 1:500 V 1:50	Drawing	C103

Part B - Foundation Design Report

Proposed Sanitary Forcemain Crossing at Highway 26 at Finlay Mill Road/Snow Valley Road

Proposed External Servicing for Midhurst Heights Residential Subdivision

Midhurst, Township of Springwater, Ontario

PML Ref.: 20BF042A, August 24, 2023



APPENDIX C

NSSP – Pipe Installation by Trenchless Method

Guideline for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment

Permit Application

**CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY
TRENCHLESS METHOD**

1.0 SCOPE

This Special Provision covers the requirements for the installation of pipes by a selected trenchless method.

2.0 REFERENCES

This Special Provision refers to the following standards, specifications, or publications:

Ontario Provincial Standard Specifications, General

OPSS 180 General Specification for the Management of Excess Materials

Ontario Provincial Standard Specifications, Construction

OPSS 182 Environmental Protection for Construction in Waterbodies and On Waterbody Banks
OPSS 401 Trenching, Backfilling, and Compacting
OPSS 402 Excavating, Backfilling, and Compacting for Maintenance Holes, Catch Basins, Ditch Inlets and Valve Chambers
OPSS 403 Rock Excavation for Pipelines, Utilities, and Associated Structures in Open Cut
OPSS 404 Construction Specification for Support Systems
OPSS 409 Closed-Circuit Television (CCTV) Inspection of Pipelines
OPSS 490 Site Preparation for Pipelines, Utilities, and Associated Structures
OPSS 491 Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492 Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 510 Construction Specification for Removal
OPSS 517 Construction Specification for Dewatering
OPSS 539 Construction Specification for Temporary Protection Systems

Ontario Provincial Standard Specifications, Material

OPSS 1004 Material Specification for Aggregates - Miscellaneous
OPSS 1350 Material Specification for Concrete - Materials and Production
OPSS 1440 Steel Reinforcement for Concrete
OPSS 1802 Material Specification for Smooth Walled Steel Pipe
OPSS 1820 Material Specification for Circular and Elliptical Concrete Pipe
OPSS 1840 Material Specification for Non-Pressure Polyethylene (PE) Plastic Pipe Products
OPSS 1841 Material Specification for Non-Pressure Polyvinyl Chloride (PVC) Plastic Pipe Products

CSA Standards

A3000 Cementitious Materials Compendium
B182.6 Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications

B182.8	Profile Polyethylene (PE) Storm Sewer and Drainage Pipe and Fittings
B182.13	Profile Polypropylene (PP) Sewer Pipe and Fittings for Leak-proof Sewer Applications
C22.1	Canadian Electrical Code
W59	Welded Steel Construction

American Society for Testing and Materials (ASTM) International Standards

A 252M-19	Standard Specification for Welded and Seamless Steel Pipe Piles
C-33	Standard Specification for Concrete Aggregates.
C-39	Standard Test method for Compressive Strength of Cylindrical Concrete
D 2657	Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
D6910	Standard Specification for Marsh Funnel Viscosity of Clay Construction Slurries
F 894	Standard Specification for Polyethylene Large Diameter Profile Wall Sewer and Drain Pipe

International Organization for Standardization/International Electrotechnical Commission (ISO/IEC)

17025	General Requirements for the Competence of the Testing and Calibration Laboratories
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3.0 DEFINITIONS

For the purpose of this Special Provision, the following definitions apply:

Annular Space means the space between the inside edge of the opening and the outside edge of the penetrating item or inserted pipe.

Auger Jack & Bore means a method of forming a horizontal bore in the subsurface by simultaneously or alternately jacking into the ground a casing pipe and rotating a cutter head at the lead end of an auger flight with removal of material from inside the casing by using continuous-flight augers.

Backreamer or Reamer means a cutting head suitably designed for the subsurface conditions that is attached to drilling equipment and used to enlarge the bore

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

Boulder Number Ratio (BNR) means the number of individual boulders per m³ of cumulative boulder volume.

Boulder Volume Ratio (BVR) means the ratio between the cumulative volume of boulders and the volume of the material excavated.

Design Engineer means the Engineer retained by the Contractor who produces the design and Working Drawings and other engineering documents required of the Contractor. 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.

Digger Shield/Hand Mining means a method of forming a horizontal bore in the subsurface by essentially

simultaneously jacking a casing pipe, with or without a protective shield at the lead end, into the ground while tunnelling and removal of earth and rock is completed using manually-operated tools (e.g., pneumatic spades, rams, shovels, breaker bars, etc.) or a “digger” type shield with a hydraulic excavator arm or “road-header” rock cutting machine to remove materials from inside the shield and liner pipe.

Drilling Fluids means 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 Hydraulic Fracture or “Frac Out” means a condition where the drilling fluid’s pressure in the bore is sufficient to fracture the soil and/or rock materials and allow the drilling fluids to migrate to the surface at an unplanned location.

Earth Pressure Balance (EPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of mixed earth, rock and any drilling fluids or additives (spoil) as maintained by and in a chamber behind the cutting face of a tunnel boring machine through which spoil can pass only by manner of controlled-load relieving gates or an internal screw-conveyor that is separate from subsequent spoil conveyance systems (e.g., flight augers, belt conveyor, spoil bucket rail cars, etc.). Trenchless systems that apply pressure to the excavated face of the ground only through mechanical and jacking forces on metal parts of the machinery (e.g., steel parts of cutting tools, adjustable gates or doors at cutting face, etc.) will not be considered equivalent to EPB systems.

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

Environmentally Sensitive Area (ESA) means areas specified in the Contract Documents that are prohibited from entry or use.

Fill means man-made mixture of previously placed or 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.

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

Hand Mining means a method of forming a horizontal bore in the subsurface by 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.

Horizontal Directional Drilling (HDD) means a surface-launched trenchless technology for the installation of pipes, conduits, and cables. HDD creates a pilot bore along the design pathway and reams the pilot bore in one or more passes to a diameter suitable for the product, which is pulled into the prepared bore in the final steps of the process.

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

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

Microtunnelling means an underground method of constructing a passage by using a microtunnelling boring machine (MTBM) or hand mining using a shield to support the opening.

MTBM means a microtunnelling boring machine.

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

Pipe means pipe culverts, pipe storm and sanitary sewers, watermain pipe, conduits, and ducts.

Pipe Jacking means a method for installing steel casing, concrete pipe or other acceptable material in the subsurface utilizing hydraulically operated jacks of adequate number and capacity for the smooth and uniform advancement of the casing or pipe.

Pipe Ramming means 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.

Project Superintendent means an individual representing the Contractor that oversees the trenchless or tunnelling operation qualified to provide the services specified in the Contract Documents.

Pullback means that part of the HDD method in which the drilling equipment is pulled back through the bore path to the entry point.

Reaming means a process for enlarging the bore path.

Rock means 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 volume of 0.5 m³ or greater.

Shaft means an excavation used as entry and/or exit points, alternatively called entry/exit pits, from which the trenchless method is initiated for the installation of the pipe product.

Slurry Pressure Balance (SPB) means a tunnelling system that provides support to the excavated face of the ground and resistance to groundwater inflow through the pressure of slurry as maintained by and in a chamber behind the cutting face of a tunnel boring machine (TBM) or microtunnelling boring machine (MTBM), through which spoil can pass only by manner of controlled-pressure and controlled flow slurry pumping systems.

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

Soil means all soils except those defined as rock, and excludes stone masonry, concrete, and other manufactured materials.

Spoil means mix of earth cuttings, rock cuttings, water (groundwater or added water), bentonite, polymers and/or other additives that is discharged from the trenchless construction systems.

Strike Alert means 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.

TBM means a tunnel boring machine.

Trenchless Contractor means the subcontractor retained by the Prime Contractor qualified to provide the services specified in the Contract Documents.

Trenchless Installation means an underground method of constructing a passage open at both ends that involves installing a pipe product by auger jack & boring, pipe ramming, horizontal directional drilling, or tunnelling.

Tunnelling means an underground method of constructing a passage using a tunnel boring machine (TBM) operated by personnel within the tunnel, a microtunnelling boring machine (MTBM) operated by personnel at a remote control station or excavation using a shield to support the opening and protect workers.

Zone of Influence means a zone defined by lines projected outward and upward at 45 degrees from horizontal to the ground surface from the vertical and horizontal alignment of the pipe constructed using trenchless/tunnel methods.

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

The Contractor shall determine the most appropriate method of trenchless installation for each pipe crossing for each location within the terms of this specification.

The trenchless installation method selected for each pipe crossing shall be designed for the subsurface conditions in accordance with the Contract Documents.

The detailed design of the installation method selected to carry out the Work as specified in the Contract Documents shall be completed.

* Designer Fill-in, See Notes to Designer

4.02 Submission Requirements

4.02.01 Qualifications

At least two weeks prior to construction, the names of the Project Superintendent, and Trenchless Contractor shall be submitted to the Contract Administrator.

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five (5) years experience on projects with similar scope and complexity.

During construction, the Project Superintendent shall not be changed without written permission from the Contract Administrator. A proposal to change the Project Superintendent shall be submitted at least one week prior to the actual change in Project Superintendent.

** Designer Fill-in, See Notes to Designer

4.02.01.02 Trenchless Contractor

The Trenchless Contractor shall have a minimum of five (5) years experience on projects with similar scope and complexity.

*** Designer Fill-in, See Notes to Designer

4.02.02 Working Drawings

Three (3) sets of Working Drawings for the selected trenchless installation method, and a Request to Proceed shall be submitted to the Contract Administrator two weeks (2) prior to the commencement of the Work or as per the Contract Documents.

The trenchless installation operation shall not proceed until a Notice to Proceed has been received from the Contract Administrator.

All Working Drawings shall bear the seal and signature of the Design Engineer and Design Checking Engineer.

Information and details shown on the Working Drawings shall include, but not limited to the following:

a) Plans and Details:

- i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work.
- ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the Work.
- iii. A list of personnel, including backup personnel, and their qualifications and experience.
- iv. A traffic control plan.
- v. A safety plan including the company safety manual and emergency procedures.
- vi. The Working Area layout.
- vii. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
- viii. A contingency plan with 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.
- ix. 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.
- x. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
- xi. Excavated materials disposal plan.
- xii. Locations of protection systems.
- xiii. Contingency plans for the following potential conditions:
 - Unforeseen obstructions causing stoppage.

- Deviation from required alignment and grade.
- Extended service disruption.
- Damage to the existing Utilities and methods of repair.
- Soil heaving or settlement.
- Contaminated soil or water.
- Alignment passing through buried structures.

b) Designs:

- i. Primary Liner/Secondary Liner design (e.g. steel liner plates, steel ribs and wood lagging, and steel casing etc.).
- ii. Design assumption and material data when materials other than those specified are proposed for use.
- iii. Drill path design, details of alignment and alignment control, maximum curvature and reaming stages.
- iv. Minimum depth of cover for trenchless installation appropriate for the highway type and pipe diameter, maximum excavation diameter, maximum annulus, alignment and grade tolerance etc.
- v. Detailed subsurface conditions along the proposed path or within the footprint of the trenchless technology equipment or pits/shafts.

c) Materials:

- i. 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.
- ii. Manufacturer data sheets for all drilling fluids and additives for use in Earth Pressure Balance (EPB), Slurry Pressure Balance (SPB).
- iii. Manufacturer data sheets for drilling systems.
- iv. Mix designs, target rheology criteria (e.g., viscosity, density, shear strength, gel time, pressure-filtration – fluid losses under pressure, etc.) and additive dosage rates for all slurries and Earth Pressure Balance (EPB) tunnel boring machine (TBM) and microtunnelling boring machine (MTBM) operations.
- v. The proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces.
- vi. Compressive strength of concrete pipe products.
- vii. Pipe class for all steel pipe products.
- viii. Steel for Permanent Casings:
 - One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.
 - Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 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 (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory.

ix. Slurry, drilling fluids, and tunnelling fluids:

- Type, source, and physical and chemical properties of bentonite, polymer or other additives;
- Source of water;
- Method of mixing;
- Water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;
- Details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunneling fluids or EPB spoils; and
- Method of disposal of the slurry, drilling fluids and associated spoil.

d) Upstream/Downstream Portal Installation Procedure:

- Access shaft or entry/exit pit details, as applicable.
- 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.
- Details of tunnelling equipment/methods to be used for the works.

f) Excavation and Dewatering:

- Equipment and methods for control, handling, treatment, and disposal of groundwater and water or fluids introduced by the Contractor;
- Equipment and methods for maintaining control of ground inflow at the excavation face during excavation;
- Equipment and methods for removal of cobbles and boulders;
- Manufacturer data sheets for each TBM, shield, tunnelling system or drilling system noting all intermediate and final cut dimensions, and methods and equipment for controlling and measuring drilling fluid, Slurry Pressure Balance (SPB) and Earth Pressure Balance (EPB) pressures;
- Methods for measuring excavated volumes or weights of earth and rock materials cut from ground on a per meter or per pipe basis up to a maximum of 3 m long intervals per measurement;
- Target operating pressures (minimum and maximum) and range of expected pressure variation for slurry or EPB spoil at excavated face or drilling fluids at lead end of drilling equipment and in annular gap between maximum excavated dimensions and outside dimensions of tunnelling equipment, drilling equipment and primary liner systems;
- Basis for setting target operating conditions (pressures, flow rates, advance rates) and the relationship of target operating conditions to ground conditions;

- viii. Basis for selection of excavation tools (e.g., bits, TBM face tools, MTBM face tools, excavator fittings, etc.) as related to expected ground conditions;
- ix. Jacking forces for installation of pipe, for driving of trenchless equipment forward and, in the case of Auger Jack & Bore, for advancing the lead end of the casing ahead of the lead end of the auger cutting tools.

g) Monitoring Method:

Methods, equipment, frequency and repeatability (accuracy and precision) of data collection to be employed for measuring and monitoring shall be submitted for:

- i. Maintaining the alignment of the installation;
- ii. EPB, SPB and drilling fluid pressures at the leading edge of excavation (face), flow rates and volume or weights of spoil;
- iii. Jacking forces on pipes, linings and cutting tools;
- iv. Torque, total revolutions and revolution rates on rotating equipment such as TBM or MTBM heads, auger flights, drill bits, etc.
- v. Grout injection pressures and volumes;
- vi. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill bit position, etc.); and
- vii. Ground displacements (heave and settlement); and noise and ground vibrations induced by trenchless construction.

4.02.03 As-Built Drawings

As-built drawings shall be submitted to the Contract Administrator in a reproducible format prior to the Contract completion.

The as-built drawings shall be dated and bear the seal and signature of the Design Engineer and Design Checking Engineer.

5.0 MATERIALS

5.01 Pipe

5.01.01 General

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

All joints shall be suitable for jacking operations as specified in the Working Drawings.

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

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

Steel casing pipe shall meet a straightness tolerance of 1.5 mm/m. When placed anywhere on the pipe parallel to the pipe axis, there shall not be a gap more than 1.5 mm between a 1 m long straightedge and the pipe.

5.01.03 High Density Polyethylene Pipe

High density polyethylene (HDPE) pipe according to OPSS 1840 shall be used in accordance with ASTM D3350.

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

Jointing of HDPE piping shall be completed according to the manufacturer's recommended procedures and ASTM D2657. Where conflicts exist between the manufacturer's instructions and ASTM D2657, the manufacturer's instructions are to be followed.

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

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

Concrete shall be according to OPSS 1350. The concrete strength shall be as specified on the Working Drawings.

5.03 Steel Reinforcement

Steel reinforcement for concrete work shall be according to OPSS 1440.

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the Working Drawings.

Selection of drilling fluid type shall be based on the soils encountered in the subsurface investigation.

The drilling fluids shall be mixed according to the manufacturer's recommendations.

Slurry shall be mixed according to the submitted slurry design and be appropriate for the anticipated

subsurface conditions. The viscosity of slurry used for SPB tunnelling shall be no less than 40 seconds Marsh Funnel viscosity, as defined by ASTM D6910, measured prior to introduction of groundwater and spoil and as required to ensure:

- a) development of appropriate filter cake at excavation face to provide slurry support pressures exceeding ground and groundwater pressures at excavation face;
- b) lubricate installation of primary liners as required;
- c) transport spoil through pipe systems.

5.06 Grout

Purging grout shall conform to the requirements of OPSS 1004 and be wetted with only sufficient water to make the mixture plastic.

6.0 EQUIPMENT

6.01 Auger Jack & Bore

Except in the case of dewatering to at least 1 m below the tunnel/bore invert for the full length of the pipe alignment, Auger Jack & Bore shall not be used and will not be permitted where subsurface conditions indicate that saturated gravel, sand and silt soils may be encountered at pipe level or within one pipe diameter above or below outside pipe dimensions.

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 equipment with 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.

The lead end of the auger shall be maintained at least one pipe diameter inside the lead end of the casing. The auger cutting tools shall not extend to or beyond the lead end of the casing at any time unless specific exception is provided by the Ministry prior to construction. Submittals shall identify anticipated jacking forces for advancing casing ahead of leading edge of auger cutting tools in addition to friction forces that are to be overcome by jacking systems.

6.02 Pipe Ramming

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 entry pit to the exit pit through the existing subsurface conditions at the site without removal of soil from within the casing until the lead end of the pipe is outside the zone of influence for any overlying infrastructure.

Specific details of the equipment with 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 Horizontal Directional Drilling

6.03.01 General

The Horizontal Directional Drilling (HDD) equipment shall consist of a directional drilling rig and a drilling fluid mixing and delivery system to successfully complete the product installation without exceeding the maximum tensile strength of the product being installed.

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

- a) 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.
- b) Have drill rod that is suitable for both the drill and the product pipe installation.
- c) Contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.
- d) Have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.
- e) Contain a guidance system to accurately guide boring operations.
- f) Be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation.
- g) 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

Tunnelling equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein. Specific details of the Tunnelling equipment included in the submission shall be provided for:

- a) rock or boulder breaking and removal;
- b) equipment used within shields for spilling, fore-poling, face drainage, breasting boards/plates and for otherwise maintaining support of the tunnel crown and face under all anticipated conditions;
- c) jacking systems;
- d) alignment control systems;

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 without specific application and acceptance by the Ministry prior to construction.

6.05

Microtunnelling Equipment

The Contractor shall be responsible for selecting Microtunnelling equipment which, based on past experience, has proven to be satisfactory for excavation of the soils that will be encountered.

The Contractor shall employ Microtunnelling equipment that will be capable of handling the various anticipated ground conditions.

The MTBM shall also be capable of controlling loss of soil ahead of and around the machine and shall provide continuous pressurized support of the excavated face.

- a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:
 - i. Allows for operation of the system without the need for personnel to enter the microtunnel.
 - ii. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
 - iii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by product pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
 - iv. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
 - v. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
 - vi. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
 - vii. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for

successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.

- viii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.
 - ix. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.
- b) Active Direction Control – The Contractor shall provide a MTBM that includes an active direction control system with the following features:
- i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference.
 - ii. Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
 - iii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

- a) Has the main jacks mounted in a jacking frame located in the launch shaft.
- b) Has a jacking frame that successively pushes towards a receiving shaft, a string of product pipe that follows the microtunnelling excavation equipment.
- c) Has sufficient jacking capacity to push the microtunnelling excavation equipment and the string of pipe through the ground.
- d) The main jack station may be complemented with the use of intermediate jacking stations as required.
- e) Has a capacity at least 20 % greater than the calculated maximum jacking load.
- f) Develops a uniform distribution of jacking forces on the end of the casing pipe.
- g) Provides and maintains a pipe lubrication system at all times to lower the friction developed on the surface of the pipe during jacking.
- h) Jack Thrust Blocking shall adequately support the jacking pressure developed by the main jacking system.
- i) Special care shall be taken when setting the pipe guide rails in the jacking shaft to ensure correctness of the alignment, grade, and stability.

6.05.02 Spoil Separation System

The Contractor shall determine the type of spoil separation equipment needed for each drive based on the geotechnical information available and other project constraints.

6.05.03 Electrical Equipment, Fixtures and Systems

Electrical equipment shall be suitably insulated for noise reduction. Noise produced by electrical equipment must comply with local municipal noise by-laws.

Electrical systems shall conform to requirements of the Canadian Electrical Code – CSA C22.1.

7.0 CONSTRUCTION

7.01 General

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

The Contractor's Engineer shall supervise the work at all times.

A Request to Proceed shall be submitted to the Contract Administrator upon completion of each of the following operations and prior to commencement of each subsequent operation and no less than 2 weeks prior to the commencement of the trenchless installation.

- a) Site Surveying (see Clause 4.02)
- b) Excavation for pits including dewatering of excavations
- c) Jacking / Ramming / Directional Drilling of Casing / Liner
- d) Installation of the Product
- e) Grouting Operations

Operations a) to e) shall not proceed until the Contract Administrator has issued a Notice to Proceed for each proceeding operation.

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 Working Day, and shall monitor and record the alignment and depth readings provided by the tracking system every 2 m.

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

The Contractor shall submit records of the alignment and depth of the installation to the Contract Administrator at the completion of the installation.

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 539.

Where the stability, safety, or function of an existing roadway, railway, watercourse, other works, ESA's, or proposed works 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 Contractor, 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, procedures, 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 recommendations for transporting, unloading, storing, and handling of materials 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 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 Cobbles and Boulders

The Contractor is alerted that cobbles and boulders are expected within the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles and boulders shall be expected to be routine and will not be considered obstruction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

**** Designer Fill-in, See Notes to Designer

7.01.12 Removal of Obstructions

The Contractor is alerted that obstructions such as, but not limited to wood debris, roots, and construction debris consisting of (broken asphalt, concrete etc.) are expected within the trenchless alignment as identified in the Contract Documents. Accordingly, the Contractor shall address methods for the removal of obstructions in the proposed method of construction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered and the Contractor's expected method of and schedule for removal.

***** Designer Fill-in, See Notes to Designer

7.01.13 Management of Excess Material

Management of excess material shall be according to OPSS 180.

Satisfactory re-usable excavated material required for backfill shall be separated from unsuitable excavated material.

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

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:

- a) Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- b) 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.
- c) The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- d) 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 watertight and according to OPSS 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 excavated volume (e.g., maximum cut diameter) shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

The annular space between the liner and the product shall be fully grouted with a watertight, 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. Butt welding of pipe joints shall conform to CSA W59.
- Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits 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.
- Removal of materials from within the pipe shall not be undertaken until the lead end of the pipe has

passed fully through and beyond the zone of influence of any overlying infrastructure.

- 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 watertight, expandable, and stable grout.

7.04 Horizontal 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.

For Horizontal Directional Drilling (HDD), the Contractor shall ensure that during pilot hole drilling the maximum degree of deviation or “dog-leg” shall be 2.5 degrees per 9 m 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.

7.04.02 Site Preparation

Site preparation shall be according to OPSS 490 and as specified herein.

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 HDD operations are to be made. All activities shall be confined to designated Working 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, fill and abandon the hole and re-drill from the location along the bore path before the deviation.

If a drill hole beneath highways, roads, watercourses or other infrastructure must be abandoned, the hole shall be backfilled with grout or bentonite to prevent future subsidence and subsurface water conveyance.

The Contractor shall maintain drilling fluid pressure and circulation throughout the HDD 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 Losses to Surface (“Frac-Out”)

To reduce the potential for hydraulic fracturing of the hole during horizontal directional drilling, a minimum depth of cover of 5 m shall be maintained between the top of pipe and the surface of any pavements or beds of water courses. Sections of the pipe close to the entry and exit pit with less than 5 m cover shall be cased. The Contractor shall ensure that drilling fluid pressures are properly set and controlled for the full length of the bore 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.

Once a fluid loss or frac-out event is detected, the Contractor shall halt operations immediately and conduct a detailed examination of the drill path and implement measures to collect all fluids discharged to surface, mitigate and prevent additional fluid loss.

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

7.04.06.01 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 contravened.

Product shall be allowed to recover to static conditions from thermal and installation stresses 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 pipe shall be pulled through the bore path. Once the pullback operation has commenced, it shall continue without interruption until the product pipe 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. A weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

The product pipe 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 ensure 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 walls of the excavated volume shall be filled with grout or slurry with gel

strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

7.05 Tunnelling Installation

7.05.01 General

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 provide ventilation and lighting in accordance with OHSA requirements for the entire length of the tunnel installed as tunneling progresses.

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.

If excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation and make the excavation face secure. 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.

7.05.02 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.

7.05.03 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 wall of the excavated volume shall be filled with cement grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground. If an unexpanded liner is used, the space outside the liner plates shall be filled at least daily.

7.05.04 Secondary Liner

7.05.04.01 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. Grout mix design shall be chemically and thermally compatible with all pipe systems.

7.06 Microtunnelling

7.06.01 General

Excavation of soil, rock and fill shall be done in a manner to control and prevent groundwater inflow to the tunnel.

The MTBM shall be capable of fully supporting the face and shall accommodate the removal of boulders and other obstructions from the face. Continuous ground support shall be maintained during excavation.

The tunnel is to be kept well drained 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 the event that excavation threatens to endanger personnel, the Work, adjacent property, roadways, railways, waterways, or the public in any way, the Contractor shall cease excavation. The Contractor shall then evaluate the methods of construction and revise as necessary to ensure the safe continuation of the Work.

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

7.06.02 Method of Installation

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

- 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 subsurface conditions within the tunnel alignment.
- Perform microtunnelling operations in a manner that will minimize the movement of the ground in front of and surrounding the tunnel in conformance with the limits listed in the Contract Documents.
- Prevent damage to structures and utilities above and in the vicinity of the microtunnelling operations.
- Excavated diameter should be the minimum size required to permit pipe installation by jacking.
- Whenever there is a condition encountered which could endanger the microtunnel excavation or adjacent structures if tunnelling operations cease, continue to operate without intermission including 24-hour Working Days, weekends and holidays, until the condition no longer exists.
- Maintain an envelope of lubricant around the exterior of the pipe during the jacking and excavation operation to reduce the exterior soil/pipe friction and possibility of the pipe seizing in place.
- In the event a section of pipe is damaged during the jacking operation or a joint failure occurs, as evidenced by inspection, visible ground water inflow or other observations, the Contractor shall submit for approval his methods for repair or replacement of the pipe.

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

The space between the casing and the wall of the excavation shall be kept filled with lubricant during the pipe jacking operation. Upon completion of pipe jacking, the space between the casing and the wall of the excavation shall be filled with grout that is compatible with the casing.

The casing shall act as a support system to maintain the safety of personnel, minimize ground movement into the excavation, ensure stability and maintain strength of ground surrounding the casing.

The casing shall be designed to support all subsurface conditions and hydrostatic pressures and to withstand any additional loads caused by installation and grouting.

7.07 Instrumentation and Monitoring

***** Designer Fill-in, See Notes to Designer

7.07.01 General

The Contractor shall furnish, install and monitor Surface Monitoring Points (SMP) and In-Ground Monitoring Points at the locations shown on the Contract Drawings.

The equipment and procedures used for settlement monitoring during construction must be capable of

surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

7.07.02 Surface Settlement Monitoring Points

Surface settlement monitoring points shall be installed on the traffic lanes and shoulders to monitor settlement and stability. The surface settlement monitoring points shall be installed centred on the tunnel alignment as arrays of three points at intervals of 5 m or less and off-set a lateral distance of 1.5 m on either side of the tunnel centerline.

Surface settlement monitoring points 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). Surface markers shall be recessed or otherwise designed for safe passage of vehicles at highway speeds and protected from snow removal equipment in the event that work occurs during snow removal seasons.

7.07.03 In-Ground Settlement Monitoring Points

In-ground settlement monitoring points shall be installed beyond the traffic lanes and shoulders to monitor settlement and stability of the ground surface between the surface settlement monitoring points and the entry and exit portals. In-ground settlement monitoring points shall be located at intervals of 5 m or less along the tunnel alignment.

In-ground 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 or below frost penetration depth, whichever is greater. The assembly shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.04 Installation, Replacement and Abandonment

The Contractor shall install all settlement monitoring points a minimum of two (2) weeks prior to the start of works to permit baseline surveying to be completed. The settlement monitoring points shall be clearly labelled for easy field 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. Instruments damaged by the Contractor's operations or other causes shall be replaced and surveyed at the time of installation within 24 hours at no additional cost. At the completion of the job, the Contractor shall abandon all instrumentations installed during the course of the Work and restore the surface at instrument locations.

7.07.05 Monitoring and Reporting Frequency

The Contractor shall survey and otherwise obtain elevations of all settlement monitoring points at the following time intervals:

- a) Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- b) Once per shift or once daily during tunnelling operations period whichever results in the more frequent reading intervals; and

- c) 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 Administrator 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.

7.07.06 Benchmarks

Two independent benchmarks shall be used for all settlement monitoring surveying and shall be located sufficiently outside the zone of influence such that the benchmarks are not influenced by any trenchless or other construction activity or weather conditions (e.g., frost heave). All surveying shall be reported using the geodetic datum and coordinate system as defined in the Contract Documents.

7.08 Criteria for Assessment of Roadway Subsidence/Heave

***** Designer Fill-in, See Notes to Designer

Based on the monitoring of the ground movement as specified in Subsections 4.02 and 7.07, the following represents trigger levels that define magnitude of movement and corresponding action:

- a) 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 Contract Administrator 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.
- b) 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:
 - i. The cause of the settlement has been identified.
 - ii. The Contractor submits a corrective/preventive plan complete with a Request to Proceed.
 - iii. Any approved corrective and/or preventive measure deemed necessary by the Contractor is implemented.
 - iv. Operations shall not proceed until the Contract Administrator has issued a Notice to Proceed for each corrective/preventive plan.

7.09 Certificate of Conformance

A Certificate of Conformance shall be submitted to the Contract Administrator upon completion of the installation of the pipe at each location. In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Quality Control Certificate sealed and signed by the Design Engineer and the Design Checking Engineer. The Certificate shall state that the pipe has been installed in general conformance with the Contractor's Submission and Design Requirements, sealed Working Drawings and Contract Documents.

8.0 QUALITY ASSURANCE – Not Used

9.0 MEASUREMENT FOR PAYMENT

Measurement shall be by Plan Quantity Payment as may be revised by Adjusted Plan Quantity Payment in metres, following along the centreline 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.

10.0 BASIS OF PAYMENT

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

If a pipe is installed inside the pipe liner, payment for the pipe 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.

***** Designer Fill-in, See Notes to Designer

NOTES TO DESIGNER:

* Insert the following fill-in: Any method that is not suitable shall be specified.

** Insert the following fill-in: Specify minimum requirements commensurate with complexity.

*** Insert the following fill-in: Specify minimum requirements commensurate with complexity.

**** Insert the following fill-in: Subsurface Condition Baseline Reporting that includes Boulder Volume Ratio (BVR), Boulder Number Ratio (BNR) shall be project specific and included in the Foundation Engineering TOR as selected during the scoping of the project.

***** Insert the following fill-in: Any known obstructions shall be specified.

***** Insert the following fill-in: The Instrumentation and Monitoring program shall be project specific. The work specified in this section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.

***** Insert the following fill-in: Project specific Review and Alert Levels shall be provided if required.

***** Insert the following fill-in: Payment for removal of boulders exceeding Boulder Volume Ratio (BVR) and Boulder Number Ratio (BNR) shall be by Time and Material.

WARRANT: Always with this specification.

Guidelines for Foundation Engineering – Tunnelling Specialty For Corridor Encroachment Permit Application

General

These guidelines specify MTO requirements for the Foundation Engineering – Tunnelling Specialty component of submissions from proponents of development within the Ministry of Transportation's (MTO) corridor permit control area. The Foundation Engineering – Tunnelling Specialty component of submissions is a requirement for the permit application only and does not cover all the design requirements.

All applications containing tunnelling proposals shall be forwarded to the regional Geotechnical Section for review. Applications containing Low Complexity tunnelling proposals will typically be reviewed by the regional Geotechnical Section. The Geotechnical Section will forward applications involving Medium and High Complexity tunnelling proposals to the Foundation Section of the Structures Office for review.

Foundations Engineering consultants that are registered in the MTO consultant acquisition system (RAQS) at complexity ratings identified in Table 1 are eligible to provide Foundations Engineering services for this project. Alternatively, the proponents may propose a Foundations Engineering consultant that is not registered in RAQS, in which case, the proponent must submit sufficient documentation to demonstrate that the consultant's qualifications meet or exceed the RAQS complexity requirements. The submission for RAQS exemption shall demonstrate that the proponent has successfully completed tunnelling/trenchless projects on projects of similar scope and complexity. The proponent shall submit a minimum of three (3) Foundation Investigation and Design Reports on projects of similar scope and complexity produced in the last five (5) years. The proponent shall submit any supplementary engineering and construction experience to demonstrate their qualifications.

For Engineering Materials Testing and Evaluation, the consultant shall be qualified for Soil and Rock testing of complexity level at least equal to that identified for this project.

Please refer to Table 1 on Page 2 for the Foundation Engineering Complexity of Work guideline.

Table 1: Complexity ratings for tunnelling specialty services

Excavation Diameter (Ø)	≤ 300 mm		1 m ≥ Ø > 300 mm		2 m ≥ Ø > 1 m		Ø > 2 m
Design Cover* (m)	≥ 1.5 m	< 1.5 m	≥ 3 Ø and > 1.5 m	< 3 Ø or < 1.5 m	≥ 3 Ø	< 3 Ø	N/A
King's Highway	Low	Medium	Low	Medium	Medium	High	High
400 Series Freeway	Low	High	Medium	High	High	High	High

* Design cover is the proposed vertical distance measured from the lowest ground elevation to the crown of the tunnel

Site Investigation, Field Testing and Monitoring

General

This section describes requirements for site investigation, field/laboratory testing and monitoring programs for a proposed tunnelling projects. For low complexity projects, some or all of these requirements may not be necessary. Foundation field investigation, laboratory analyses and monitoring for low complexity projects with an excavation diameter of 300 mm or less will generally only be required on an exception basis. The applicant's Foundation Engineering service can contact MTO Geotechnical staff for clarification regarding appropriate levels of investigation, testing and monitoring.

Field Testing

A minimum of one borehole is required at each end of tunnel crossing. The boreholes shall be located outside but within two metres of the tunnel's excavated footprint.

Spacing between the boreholes shall not exceed 50 m. In case of larger spacing between the boreholes, additional boreholes shall be advanced except where significant traffic disruptions might occur and where consistent conditions are evident.

Boreholes shall be advanced to 3 tunnel diameters (excavated diameters) below invert. If bedrock is encountered earlier, the borehole shall advance to at least 3 m below the invert of tunnel into the bedrock.

The investigations, if required, shall be supplemented with additional and deeper boreholes to verify consistent conditions and existence of boulders within critical foundation zones.

Sampling and testing, consisting of Standard Penetration Test, thin wall tube sample, rock cores, and MTO Field Vane Test where appropriate, shall be conducted to develop a comprehensive subsurface model. Semi-continuous sampling at 0.75m (2.5ft) intervals is required within overburden; whereas, sampling interval of 1.5m (5.0ft) is required below the tunnel invert.

Where encountered, the bedrock-soil interface shall be determined by geological definition and not by the material properties.

All aspects of implementation of means of subsurface investigations including, but not limited to, planning, licensing, construction, maintenance, abandonment, and reporting, shall be in accordance with Ministry of the Environment Regulation 903 and its amendments (the water well regulation under the OWRA).

Boreholes and piezometer tubes shall be backfilled with a suitable bentonite/cement mixture. Test pits shall be backfilled with suitable material and either re-vegetated or otherwise protected from erosion. Temporary open holes shall be adequately covered. Holes in roads shall be backfilled as required to prevent future settlement and acceptably patched where pavement surfaces have been damaged. Backfilling requirements shall be described in the Foundation Investigation and Design Report.

Where encountered, artesian groundwater conditions shall be sealed. Details of the artesian condition and the sealing operation shall be included in the Foundation Investigation Report.

Fieldwork, including any Traffic Protection Plans required, shall be carried out in accordance with the Occupational Health and Safety Act.

Traffic Control in accordance with Ontario Traffic Manual Book 7 shall be provided during the course of any field investigations. However, where significant traffic disruptions might occur, boreholes may be relocated or numbers reduced with MTO's approval.

The locations and ground surface elevations of all boreholes, test pits and soundings shall be surveyed and referred to fixed reference points and data. Locations are to be identified by co-ordinates (Northing and Easting). The vertical accuracy of survey readings shall be within 0.1m; whereas, horizontal accuracy shall be within 0.5m.

The site investigation shall be of sufficient scope to verify design assumptions and to provide the contractor with adequate subsurface information for design and construction planning.

Sufficient subsurface (factual) information is required to determine the vertical and horizontal extent of subsurface materials (including both soil and rock) and their pertinent engineering properties and groundwater conditions.

Subsurface information is usually acquired by advancing boreholes, laboratory testing of soil samples and rock core samples, performing in-situ tests such as standard penetration tests, dynamic cone tests, and piezocone tests (CPTU) and test pits.

Minimum Laboratory Testing Requirements

Laboratory testing shall consist of routine testing of 25% of samples. One routine lab test is defined as natural water content plus Atterberg Limits plus grain size distribution tests. Complex laboratory testing is defined by all other tests including compressive strength, shear strength, consolidation, permeability and triaxial testing. Laboratory testing requirements shall be supplemented with additional routine and complex tests if required to verify strata boundaries and properties and behaviour of critical subsurface zones.

A minimum of one (1) soil chemical test shall be conducted at maximum of 100 m spacing. A soil chemical test includes pH, water soluble sulphate, sulphide, chloride, resistivity and electrical conductivity analyses.

Borehole Log Preparation and Foundation Drawing

Borehole log sheets, figures and drawings shall be prepared in accordance with MTO standards. The Foundation Drawing shall consist of a plan showing the locations of all borings, test pits and soundings and various stratigraphical longitudinal profiles and stratigraphical cross-sections at each tunnel structure foundation element and groundwater levels.

Requirements for the Foundation Investigation and Design Report

A Foundation Investigation and Design Report shall consist of the factual subsurface information (including the field and laboratory test information) and the recommendations required for foundation design.

Service Provider services shall be in accordance with the most recent editions of the Canadian Highway Bridge Design Code (CHBDC), and the 'Guideline for Professional Engineers Providing Geotechnical Engineering Services' published by the Professional Engineers of Ontario.

The designated principal contact identified for Foundations Engineering services by MTO shall sign, and where required, seal, all submissions and correspondence that are submitted to MTO.

The report shall be signed and sealed by two professional engineers, registered with the Professional Engineers of Ontario, representing the consulting firm; one of them shall be the firm's designated principal contact for MTO's Foundations Engineering projects.

The Foundation Investigation component of the report shall contain:

- Site Description - including topography, vegetation, drainage, existing land use, and structures.
- Investigation Procedures - including site investigation and lab testing procedures.
- Description of Subsurface Conditions - including soil, boulders, rock and groundwater conditions.
- Miscellaneous Section - that identifies the name of the drilling company, the laboratory where testing was performed, the persons who carried out the field supervision, and those who wrote and reviewed the report.

The Foundation Design component of the report shall present discussion and recommendations for design. The Service Provider shall analyse field data and test results and make comprehensive and practical recommendations pertaining to temporary, interim and permanent conditions at the Project.

The Service Provider shall identify and evaluate all reasonable and appropriate alternatives for the proposed tunnel crossing. Alternatives may include, but not limited to, jack & bore, pipe jacking using TBM, pipe ramming, micro-tunnelling, utility tunnelling using TBM (two pass system), Horizontal Directional Drilling (HDD) and cut and cover methods.

The Service Provider shall identify and present overview assessments of the advantages, disadvantages, relative costs and risks/consequences of alternative tunnelling methods in a table. The report should conclude a preferred alternative from foundation engineering and cost effectiveness perspective.

In the development and design of the preferred alternative, the Service Provider shall, as applicable, address:

- impacts on the land use and property, traffic and transportation, and environment,
- length and diameter constraints
- control of face stability
- capability of boulder excavation
- evaluation of temporary and permanent support
- alignment control
- estimated settlements and heave and management of these deformations

- special access and egress requirements for TBM's and other similar equipment such as those used for the Jack & Bore method including recommendations for vertical shafts and jacking pits;
- shored and un-shored alternatives for open-cut excavation;
- groundwater control & dewatering;
- the long-term stability of the tunnel;
- relative costs; and
- traffic management and contractor access for each alternative.

If borehole logs available from previous projects are included to meet the requirements of field investigations then the accuracy of subsurface information from these boreholes remains the responsibility of Service Provider except in situations where MTO specify the use of previous boreholes. Borehole logs from previous studies that are appended to the report shall be reformatted to meet the MTO's requirements.

The final foundation recommendations shall detail the geometric, material and strength properties of the new tunnel crossing plus the liner, bedding and backfill requirements, and slope and embankment restoration requirements. The invert elevation should be assessed in view of the subsurface conditions and the anticipated open face stability control.

The Service Provider is responsible for developing contract documents sufficient to implement the design. This typically includes:

- Contract specifications for materials and specialized construction activities, and
- Recommendations for methods of overcoming anticipated construction problems, in particular, those relating to dewatering, boulder excavation, alignment control and the stability of excavations and embankments.

The Service Provider shall develop a detailed instrumentation and monitoring program that meets the requirements of these guidelines. (see Appendix for typical settlement monitoring guidelines).

The Service Provider is responsible for preparing Traffic Control Plans, Traffic Protection Plans and to obtain approvals and an Encroachment Permit from the Ministry, which are required for lane closures necessary to install the settlement monitoring points.

The tunnelling Service Provider shall ensure that the foundations engineering component of the project is adequately reflected in the design drawings, specifications and related contract documents.

Written confirmation is required from the Proponent and the tunnelling Service Provider that the design package submitted to MTO have been reviewed by the tunnelling Service Provider and that all recommendations have been satisfactorily incorporated in the contract package.

APPENDIX: SETTLEMENT MONITORING GUIDELINES - TUNNELING

The purpose of settlement monitoring is to prevent damage to existing utilities and highway structures along the tunnel alignment. Ground settlement include settlement due to lost ground and dewatering/drainage.

Daily visual monitoring of the road surface and shoulders shall be carried out for any evidence of movements (e.g. cracks, bulges, heaves, depressions, ponding, etc.)

Instrumentation Arrays

All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

Surface Monitoring Points

Surface monitoring points will be installed to cover the whole length of the tunnel with in the right of way under the jurisdiction of MTO (Figure 1).

Surface monitoring points will be located at not greater than 5m intervals along the tunnel alignment. The surface monitoring will be identified using paint marks on the pavement. Surface monitoring points installed on the unpaved right of way shall be founded below frost penetration depths. The interval and/or marking of the points should be changed with MTO's approval where traffic disruptions might occur.

The final instrumentation plan should be finalised when Contractor's proposed construction method is available.

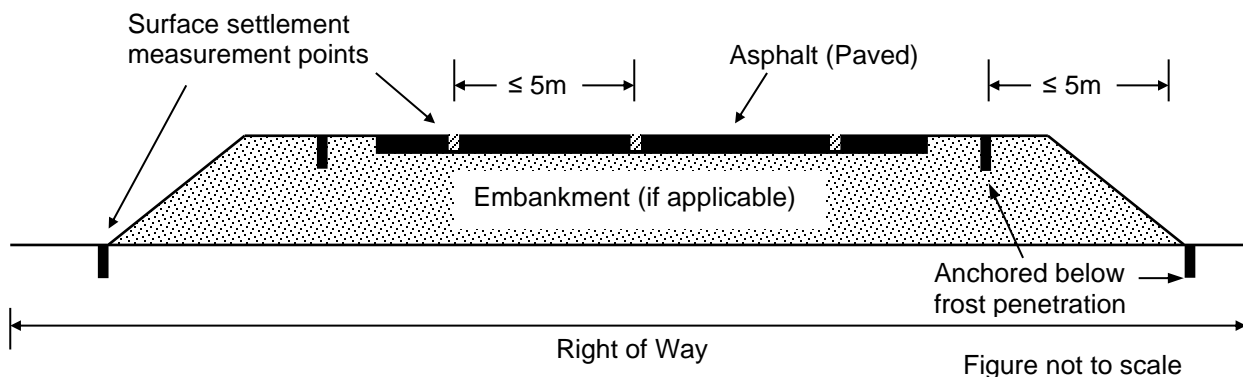


Figure 1: Typical configuration of surface settlement monitoring points along the tunnel alignment.

Condition Survey

A condition survey for the pavement will be carried out prior to commencement of construction and documented for the purpose of requirement of restoration. The condition survey shall document visible flaws such as cracks, distortions and deviations, heaves, and depressions. This surface survey will be completed during the installation of the monitors and again once the tunnel has been completed.

Reading Frequency

An average of at least two readings shall be taken to establish the initial conditions.

The reading and collection of data from the surface monitoring points shall be read and recorded by the Contractor during the construction period and after construction for period of at least 2 weeks provided that further settlement has stopped.

A minimum of three (3) sets of reading be taken daily, provided that movements are within anticipated limits. Otherwise, the frequencies should increase according to a pre-planned interval.

Monitoring of movements is required during work stoppages, such as during non-operation period (off-shifts) or weekends. A minimum of three (3) sets of readings should be taken daily.

Measurements of the monitoring points shall be reported promptly to MTO for review.

Data Collection and Data Transfer

A procedure is required to be established in consultation with MTO so that the monitoring data and the interpreted data will reach all parties as soon as necessary. The contract administrator/Service Provider and the Contractor should interpret monitoring data as needed for the purpose of on-going construction. The Foundation Engineer should be contacted for technical support to the prime Service Provider in the interpretation of ground movements and review of the Contractor's response when Review and Alert Levels are reached.

Criteria for Assessment

The acceptable surface settlement (or heave) will be according to criteria as specified below.

Baseline Reading – A baseline reading of the instrumentation shall be taken prior to commencement of the work. An average of at least two initial readings shall be recorded as baseline reading.

Review Level – A maximum value of 10 mm relative to the baseline readings is suggested for this project. If this level is reached, the method, rate or sequence of construction, or ground stabilization measures should be reviewed or modified to mitigate further ground displacements.

Alert Level – A maximum value of 15mm relative to the baseline readings is suggested for this project. If this level is reached, the Contractor shall cease construction operations and to execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic.

Review of Contractor's Proposed Method

MTO, the Proponent's prime Service Provider and Foundation Engineer should review the Contractor's proposed method of construction. The proposed method should include a description of the potential loss of ground, and calculation of the maximum settlement in relation to the Contractor's procedure and equipment, alternative/remedial measures when review level of measurement is reached; and contingency/remedial measures when alert level of measurement is reached.

Contractor's Responsibility for Restoration and Warranty Provision

In addition to the monitoring program to assess the adequacy of the construction method to control potential ground movements and groundwater, the Contractor is responsible for reinstatement (such as surface paving) should movements or other surface distress occur, and provide a reasonable warranty period acceptable to MTO. Remedial measures shall be approved by MTO; however, MTO maintains the right to perform the maintenance at the proponent's expense.

Construction Monitoring

The Proponent shall retain a RAQS qualified Geotechnical Service Provider – Medium Complexity to supervise the installation of surface settlement points on site and to provide direction, technical input and field inspection on this project.