

# FOUNDATION INVESTIGATION AND DESIGN REPORT

**REYNOLDS MUNICIPAL DRAIN CROSSING HIGHWAY 23  
MUNICIPALITY OF WEST PERTH, ONTARIO  
LATITUDE AND LONGITUDE: 43.409671, -81.247653**

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REPORT

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## **PART A – FOUNDATION INVESTIGATION REPORT**

**REYNOLDS MUNICIPAL DRAIN CROSSING HIGHWAY 23  
MUNICIPALITY OF WEST PERTH, ONTARIO**

## **1. INTRODUCTION**

ASF Associates Inc. (ASF) has been retained by Dietrich Engineering Limited (DEL), to conduct a foundation investigation for the planned trenchless crossing of a new Reynolds Municipal Drain crossing of Highway 23 north of Perth Line 24 in the Municipality of West Perth, Ontario.

The purpose of the foundation investigation was to identify the subsurface conditions expected to influence the selection of trenchless method, design and construction of the proposed municipal drain.

## **2. SITE DESCRIPTION**

The site of the proposed trenchless crossing is located on Highway 23 about 600 m north of Perth Line 24 in the Municipality of West Perth, Ontario. The key plan on the Borehole Locations and Soil Strata Drawing, (Drawing 1) provides an overview of the site location.

The proposed drain will comprise a 36 m long 500 mm diameter smooth wall steel casing pipe with invert approximately 3.9 m at the centre line of Highway 23. The pipe crossing is to allow drainage from nearby farm fields under Highway 23.

The lands on either side of the highway are currently agricultural cropland. The topography of the area is generally flat. The Highway 23 right of way at the proposed drainage crossing is approximately 36 m in width. Highway 23 accommodates two 3.5± m wide lanes of vehicular traffic at the crossing location, with 3 m wide gravel shoulders on both sides.

## **3. INVESTIGATION PROCEDURE**

The field work for this project was carried out on December 21, 2023. Two boreholes numbered 1-23 and 2-23 were drilled within the shoulders of Highway 23 and sampled to depths of 6.7 m below ground surface. In addition, two pionjar's numbered HA1-23 and HA2-23 were advanced to depths of 1.3 m and 1.9 m, respectively, below ground surface. The approximate locations of the boreholes and pionjar's (boreholes) are shown on Drawing 1.

ASF's staff located and marked the boreholes in the field offset from the proposed casing centreline. DEL marked the centreline of the casing in the field, with paint and stakes along the alignment.

The boreholes were also surveyed for coordinates and geodetic elevation with a Trimble GEO 7X Real-Time Accuracy connected to the Global Navigation Satellite System. The borehole survey data is considered accurate to 0.1 m for coordinates and elevations. This data is summarized in the following table.

Borehole No.	MTM NAD 83 Coordinates (MTM Zone ON11)		Ground Surface Elevation (m)	Borehole Depth (m)
	Northing (m)	Easting (m)		
1-23	4 808 514.0	406 226.8	345.7	6.7
2-23	4 808 506.5	406 234.1	345.8	6.7
HA1-23	4 808 516.6	406 218.8	343.8	1.3
HA2-23	4 808 504.5	406 243.3	343.9	1.9

Prior to initiating the field work, ASF contacted public utility companies to locate the existing underground services and clear the borehole locations.

The boreholes were drilled with a Diedrich D50 truck mounted drill rig equipped with continuous flight hollow stem augers, and automatic hammer. Boreholes HA1-23 and HA2-23 were advanced using a pionjar. The drilling equipment was owned and operated by London Soil Test Ltd. of London, Ontario, who is a specialist drilling contractor working under subcontract to ASF. ASF's senior geotechnical staff observed and recorded the drilling, sampling and in situ testing operations and logged the boreholes.

Samples of the overburden soils were generally obtained at regular intervals of 0.75 m to the borehole termination depth using a 50 mm outer diameter (O.D.) split-spoon sampler in conjunction with the Standard Penetration Testing (SPT) procedures as specified in ASTM Method D 1586.

The groundwater conditions at the borehole locations were assessed during drilling by visual examination of the soil, the sampler and drill rods as samples were retrieved. To permit longer term groundwater level monitoring, a piezometer consisting of a 50 mm diameter PVC pipe with a slotted screen enclosed in sand was installed in borehole 1-23. The drilling, installation of piezometer and decommissioning of the boreholes were carried out in accordance with O.Reg. 903.

#### **4. LABORATORY TESTING**

All samples were visually examined by a Geotechnical Engineer. Selected soil samples were submitted for moisture content, grain size distribution analysis and Atterberg Limits testing. Soil samples were also submitted to SGS Canada Inc. (SGS) for chemical testing.

The geotechnical laboratory testing program for the borehole samples is summarized in the table below.

Test Description	Number of Tests
Moisture Content	21
Hydrometer & Sieve Analyses (Grain Size Distribution)	6
Atterberg Limits	5
Chemical Testing	2

The chemical testing noted in the table above consisted of two samples shipped to SGS in Mississauga, Ontario for corrosivity chemical testing, including determination of sulphate, sulphide, and chloride contents, pH and resistivity.

The results of the grain size distribution analyses are provided in Figures GS-1 and GS-2 and the Atterberg Limit test results are presented in Figures PC-1 and PC-2, in Appendix B. All test results are provided in the record of borehole sheets.

#### **5. SITE GEOLOGY AND SUBSURFACE CONDITIONS**

##### **5.1 Regional Geology**

This project lies within the physiographic region of southwestern Ontario known as the Stratford Till Plain<sup>1</sup>. The soils generally consist of silty clay with variable silt and clay contents.

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<sup>1</sup> L.J. Chapman and D.F. Putnam: The Physiography of Southern Ontario, Third Edition. Ontario Geological Survey, Special Volume 2, 1984.

Based on the Ontario Geological Survey Preliminary Map No. P.956 titled “Quaternary Geology, St. Marys Area, (Western Half), Southern Ontario”, surficial deposits within the project section of Highway 23 generally consists of Lacustrine silt and clay.

## **5.2 Subsurface Conditions**

Reference is made to the Record of Borehole Sheets in Appendix A. Details of the encountered soil stratigraphy are presented in this appendix and on the “Borehole Locations and Soil Strata” drawing. An overall description of the stratigraphy is given in the following paragraphs.

The stratigraphic boundaries shown on the Record of Borehole Sheets and on the interpreted stratigraphic section are inferred from non continuous soil sampling and therefore represent transitions between soil types rather than exact planes of geological change. The subsurface conditions will vary between and beyond the borehole locations.

In general, the subsurface soil conditions encountered at the borehole locations consist of topsoil, pavement structures and / or fill materials overlying a major native silty clay till deposit.

### **5.2.1 Pavement Structure**

Boreholes 1-23 and 2-23 were drilled through the existing gravel pavement shoulders of Highway 23. These boreholes encountered a granular pavement structure comprising gravelly sand fill. The locations, thicknesses and base elevations of the pavement granular fill are summarized in the following table.

<b>Borehole No.</b>	<b>Thickness (m)</b>	<b>Base Elevation (m)</b>
1-23	1.3	344.4
2-23	0.3	345.5

A Standard Penetration Test (SPT) N-value of 23 blows per 0.3 m penetration of the split spoon sampler was measured within the gravelly sand fill, indicating a compact relative density. The natural water content of samples of the gravelly sand fill range from 4% to 11% by weight.



#### 5.2.2 Topsoil

Boreholes HA1-23 and HA2-23 were drilled within the ditch area of Highway 23 and encountered 600 mm and 100 mm of topsoil, respectively. A 600 mm thick layer of topsoil was also encountered buried below the shoulder of Highway 23 in Borehole 1-23. Topsoil thickness may vary between and beyond the boreholes.

#### 5.2.3 Fill – Sandy Silt and Silt

Sandy silt and silt fill materials were encountered beneath the granular shoulders. The locations, thicknesses, depths and base elevations of the sandy silt and silt fill are summarized in the following table.

Borehole No.	Thickness (m)	Depth (m)	Base Elevation (m)
1-23	0.5	1.8	344.0
2-23	1.2	1.5	344.3

SPT N-values within the fill measured 6 and 15 blows for 0.3 m of penetration, indicating a loose to compact relative density. The natural water content of a sample of the silt fill is 5% by weight.

#### 5.2.4 Fill – Silty Clay

Silty clay fill was encountered in Boreholes 1-23 and 2-23. The locations, thicknesses, depths and base elevations of the silty clay fill are summarized in the following table.

Borehole No.	Thickness (m)	Depth (m)	Base Elevation (m)
1-23	0.4	2.2	343.5
2-23	1.5	3.0	342.8

SPT N-values within the silty clay fill range from 4 to 11 blows for 0.3 m of penetration, indicating a firm to stiff consistency. The natural water content of samples of the silty clay fill range from 14% to 20% by weight.

A grain size distribution test was carried out on a sample of the silty clay fill and the grain size distribution curve is illustrated in Figure GS-1 in Appendix B. The results show a grain size distribution consisting of 15% gravel, 17% sand, 49% silt, and 19% clay size particles.

One sample of the silty clay fill was also subjected to Atterberg Limits test and the results are presented in Figure PC-1 in Appendix B. The results indicate that the silty clay fill is of low plasticity (CL) soil.

The Atterberg limits test result is provided below:

Liquid Limit:	25%
Plastic Limit:	12%
Plasticity Index:	13%
Natural Moisture Content:	16%

#### 5.2.5 Silty Clay (Till)

A major native silty clay till deposit was encountered underlying the pavement structure, topsoil and fill layers. A discontinuous, 295 mm thick sand and gravel layer was encountered within the till deposit in borehole 1-23 below elevation 342.7 m. Based on infrequent auger resistance during drilling, it is inferred that occasional cobbles exist within the till. The till deposits of southern Ontario are known to contain cobbles and boulders and these materials should be anticipated to be present throughout the till deposit at this site. The locations, thicknesses, depths, and base elevations of the silty clay till are summarized in the following table.

Borehole No.	Thickness (m)	Depth (m)	Base Elevation (m)
1-23	4.0	6.7*	339.0
2-23	3.7	6.7*	339.1
HA 1-23	0.7	1.3*	342.5
HA 2-23	1.8	1.9*	342.0

\* Borehole termination depth.

SPT N-values within the silty clay till range from 9 to 35 blows for 0.3 m of penetration, indicating a stiff to hard consistency. The natural water content of samples of the silty clay till range from 9% to 21% by weight.

Grain size distribution tests were carried out on five samples of the silty clay till deposit and the grain size distribution curves are illustrated in Figure GS-2 in Appendix B. These results show a grain size distribution consisting of 4% to 13% gravel, 12% to 20% sand, 45% to 53% silt, and 18% to 36% clay size particles.

Four samples of the silty clay till deposit were also subjected to Atterberg Limits tests and the results are presented on Figure PC-2 in Appendix B. These results indicate that the silty clay deposits are low plasticity (CL) soils.

The results from the Atterberg limits tests are summarized below:

Liquid Limit:	25% to 31%
Plastic Limit:	12% to 14%
Plasticity Index:	12% to 17%
Natural Moisture Content:	9% to 20%

### 5.3 Groundwater Conditions

The groundwater conditions were observed in the boreholes during and upon completion of drilling. No free water was encountered within the boreholes at the time of drilling. A standpipe piezometer was installed in BH 1-23 to allow measurement of the long term stabilized groundwater at the site. The stabilized groundwater level measured in the installed piezometer is summarized in the following table:

Piezometer Location	Date	Water Level Readings	
		Depth (m)	Elevation (m)
1-23	December 21, 2023	Dry	-
	February 02, 2024	2.2	343.5

It should be noted that the groundwater levels and gradient at the site may be influenced by the road structure, topography, underlying geology, and the water level in surrounding agricultural lands, and may fluctuate because of seasonal changes, periods of precipitation, and temperature.

#### 5.4 Chemical Test Results

Two samples of the silty clay till were submitted for corrosivity testing with results summarized in the following table. Details of the chemical test results are presented on the certificate of analysis presented in Appendix B.

Borehole No.	Samples	Elevation (m)	Sulphide (%)	Sulphate (µg/g)	Chloride (µg/g)	pH	Resistivity (Ohm-cm)
1-23	5 and 6	341.3 – 342.7	<0.01	22	630	8.80	879
2-23	5 and 6	341.4 – 342.8	<0.04	180	160	8.12	1380

## 6. CLOSURE

This report was prepared by Mr. Jun Le Li, EIT. and Mr. Romin Agahzadeh, P.Eng., a Senior Geotechnical Engineer, and Principal Consultant with ASF. Mr. Amin Farsoodeh, P.Eng., carried out an independent quality control review.

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## **PART B – FOUNDATION DESIGN REPORT**

**REYNOLDS MUNICIPAL DRAIN CROSSING HIGHWAY 23  
MUNICIPALITY OF WEST PERTH, ONTARIO**

## **7. DISCUSSION AND ENGINEERING RECOMMENDATIONS**

### **7.1 General**

This report presents interpretation of the geotechnical data in the factual report and presents geotechnical design recommendations to assist Dietrich Engineering Limited (DEL) to carry out design and construction of the Reynolds Drain Crossing of Highway 23. The discussion and recommendations presented in this report are based on our understanding of the project and our interpretation of the factual data obtained from the subsurface investigations.

Where comments are made on construction, they are provided to highlight those aspects that could affect the design of the project. Contractors must make their own interpretation of the factual data provided in the foundation investigation report (Part A), as it may affect equipment selection, proposed construction methods and scheduling.

The project involves the planned trenchless installation of a new Reynolds Municipal Drain crossing of Highway 23 north of Perth Line 24 in the Municipality of West Perth, Ontario. The proposed drain will comprise a 36 m long 500 mm diameter smooth wall steel casing pipe. The elevations at key locations along the proposed alignment are provided in the table below. The minimum depth of cover below the ditch lines is greater than 1 m and below the highway travelled lanes, greater than 3 m.

<b>Location Along Drain Alignment</b>	<b>Approximate Surface Elevation (m)</b>	<b>Depth of Cover (m)</b>
Northbound Ditch Line	343.7	1.3
Northbound Shoulder	345.8	3.2
Centreline of Highway	345.9	3.4
Southbound Shoulder	345.7	3.2
Southbound Ditch Line	343.9	1.2
Invert of Steel Casing	341.9 to 342.1	-

The profile and detail drawings provided by DEL and utility locates carried out prior to the field work identified underground telecommunications (Bell) utility located within the proposed alignment crossing. The crossing will be located about 9 m to 10 m south of an existing 900 mm diameter Corrugated Steel Pipe (CSP) culvert crossing the highway. The storm water runoff in this area appears to be carried by the drainage ditches located on both sides of the highway. Existing underground service(s) may impose potential conflict with the proposed alignment of the drain and precautionary measures to prevent damage must be arranged with the respective utility owner(s).

The entry and exit pits for the trenchless installation will be located outside of the MTO highway right of way within the adjacent farm fields.

A copy of the plan and profile drawing provided by DEL, outlining the proposed crossing, is included in Appendix C, for reference.

## **7.2 MTO Requirements and Policy for Encroachments and Utilities**

As the project involves the crossing of Highway 23, the investigation must comply with the Ministry of Transportation (MTO) *"Guidelines for Foundation Engineering - Tunnelling Specialty for Corridor Encroachment Permit Application"* dated February 2021, a copy of which has been provided in Appendix D. This crossing falls under the Low Complexity rating for tunnelling specialty. This foundation design report has been prepared as per the project requirements and the above noted MTO guidelines.

MTO does not permit open cut or trenching for installation of utility pipe or casing across the highway corridor, except where in the opinion of the Ministry other methods are not possible because of the size of the pipe or the nature of the subsoil conditions.

## **7.3 Subsoil and Groundwater Conditions**

In general, the subsurface stratigraphy encountered at the tunnel crossing comprises the highway pavement structure / fill embankment over a major stiff to very stiff (locally hard) silty clay till deposit. Buried topsoil was encountered below the embankment shoulder at borehole 1-23. The measured groundwater level at the site lies at elevation 343.5 m. The tunnel interface will generally be within the very stiff to hard silty clay till and / or stiff silty clay fill. Occasional cobbles and an interbedded discontinuous non-cohesive sand and gravel layer are also anticipated within the tunnel interface.



## **8. INSTALLATION USING TRENCHLESS TECHNOLOGY**

### **8.1 Selection of Installation Method**

Consideration was given to a range of tunnelling methodologies, and it was concluded that trenchless methods such as Jack and Bore, Pipe Ramming, and Microtunnelling, may be employed to install the casing. The diameter, length and anticipated subsurface conditions limit the range of installation techniques that are practical and economically viable. It should also be noted that with a tunnelling operation there is always a possibility that excavations may be required to retrieve tunnelling equipment or, equipment may have to be abandoned if adverse subsurface conditions are encountered.

Ground behaviour will be, in part, dependent on the installation method adopted and this report provides guidance on the influence of ground behaviour on installation methods. It should not be construed that the Contractor is restricted to the methods considered herein, and in the event of alternative methods, the Contractor must make his own interpretation of the anticipated ground behaviour, based on the factual information provided in this report under Part A, Foundation Investigation Report. Alternative methods, if employed, should meet the requirements of the MTO policy for encroachment.

The discussions and recommendations below are limited only to these three trenchless methods that are considered feasible and practical at this site. A comparison of the technical advantages and disadvantages of the trenchless technologies are presented under Section 8.2 titled “Assessment of Tunnelling Methods”.

Further, the recommendations presented are based on the boreholes drilled along the currently proposed alignment. Additional subsurface investigation will be required if the alignment of the crossing 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 plan of action, should difficulties occur during the tunnelling operations. The plan should also be reviewed by the project design team prior to construction. ASF can assist in reviewing the plan to check that the assumptions regarding soil and groundwater conditions are appropriate.

#### 8.1.1 Jack and Bore

Jack and Bore typically involves the simultaneous advancement of a continuous flight auger and steel casing pipe. The auger flight system generally comprises the auger flight and a cutter or auger head designed for the ground condition. The auger system is an open face system generally used to excavate soil a short distance as a fraction of the bore diameter in advance of the casing and the auger flutes transport cuttings back to the receiving pit where they are removed. Rotary power to the auger and jacking force is provided by a drill rig located within a jacking pit. This method is applicable for all types of crossings to install sewer or utility pipes to a maximum length of 150 m, which is longer than the length of the proposed casing of 30 m. The diameter of the proposed casing (500 mm) is also larger than the minimum diameter required to employ this method. The pipe for employing this method should resist abrasion caused by the rotation of augers and steel is the typical material used, although concrete pipe may also be used in a corrosive environment. Jack and Bore is a common method of trenchless installation and in appropriate site and soil conditions is expected to be preferable from a cost perspective.

Jack and Bore method is feasible for the stiff to very stiff / hard silty clay till / fill soils and discontinuous sand and gravel layer encountered along the tunnel alignment. It is imperative when carrying out a Jack and Bore operation that the augers be located behind the cutting edge of the casing. This arrangement is necessary to create a soil plug that mitigates the risk associated with uncontrolled soil loss immediately in front of and above the casing. Groundwater control is not expected to be a concern within the impermeable silty clay soils. In the more permeable sand and gravel seam(s) groundwater inflow is expected to be higher if perched water is encountered. However, this perched water inflow is expected to subside over a short period of time and can be controlled by conventional sump pumps installed in the entry and exit pits.

In general, Jack and Bore methods are well suited for installations where more precise vertical grade control of the bore is required. However, the presence of cobbles and / or boulders in till soils may increase the risk for alignment deviations to occur.

### 8.1.2 Pipe Ramming

Pipe Ramming uses a pneumatic or hydraulic hammer attached to an open-ended casing, which is driven through the ground horizontally. During the advance, most of the soil being penetrated fills the casing rather than being excavated. The rammed casing is terminated in a receiving pit at which point the soil spoils contained in the pipe is removed using water pressure (jetting), air pressure, augering, or pipe shovels. Pipe Ramming can be applied to a wide variety of soil types but some soils are better suited for this method than others. The most suitable soil conditions are soft to very soft clays, organic deposits and loose to compact sands and silts. Pipe ramming is more difficult in very dense or hard soils and soils containing obstructions such as cobbles and boulders. Very stiff to hard glacial till soils will be encountered within the tunnel alignment making it challenging and difficult for Pipe Ramming. Therefore, this tunnelling method was not considered feasible for this project.

### 8.1.3 Microtunnelling

Microtunneling involves the advancement of a tunnel boring machine from the jacking pit to the receiving pit. The microtunnel boring machine (MTBM) is remotely controlled and offers good grade control. 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 may be designed with, cutter head and hydraulic controlled flood doors, and also 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 to a settling tank. Given the machines' design 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 launching and receiving pits may still be required to provide a dry working platform.

Cognizant of the tunnel size, grade requirements and subsurface conditions, Microtunnelling may be considered for the proposed crossing. However, cost effectiveness will depend on availability of a previously used tunnel boring machine of the required size, setting up a bentonite-slurry delivery system at site, and contractor availability. The substantial cost associated with Microtunnelling may be prohibitive considering the relative costs of other tunneling methods that can be used for the proposed tunnel at this site.

## 8.2 Assessment of Tunnelling Methods

The following table summarizes the advantages and disadvantages of the tunnelling methods described.

Tunnelling Method	Advantages	Disadvantages
Jack and Bore	<ul style="list-style-type: none"> <li>▪ Larger pool of contractors than other trenchless technologies</li> <li>▪ Contractor availability</li> <li>▪ Better alignment control compared to Pipe Ramming</li> <li>▪ Typically least costly method</li> <li>▪ Can accommodate variable soils (including discontinuous sand and gravel layers' in the onsite till) without major tooling adjustments</li> <li>▪ Small staging areas required</li> <li>▪ Well suited for shorter tunnel lengths</li> </ul>	<ul style="list-style-type: none"> <li>▪ Elevated potential for ground subsidence if adequate groundwater control is not achieved</li> <li>▪ Subsurface obstructions can cause deflections from the intended alignment and can impede a jack and bore operation</li> <li>▪ Once operation is started it should continue without major stoppage until completion to mitigate potential for sloughing of face and void formation</li> </ul>
Pipe Ramming	<ul style="list-style-type: none"> <li>▪ Low risk for loss of ground compared to Jack and Bore</li> <li>▪ Relatively faster installation than Jack and Bore</li> </ul>	<ul style="list-style-type: none"> <li>▪ High ramming resistance required for liner penetration in stiff to hard silty clay till overburden</li> <li>▪ Thicker steel needed to sustain ramming stresses</li> <li>▪ Poor grade control compared to Jack and Bore and Microtunneling</li> <li>▪ More costly than Jack and Bore</li> <li>▪ May require encroachment into right of way to maintain grade control</li> <li>▪ Grades cannot be corrected once installation has started</li> </ul>

Tunnelling Method	Advantages	Disadvantages
Microtunnelling	<ul style="list-style-type: none"> <li>▪ Machine can be designed to be able to counter- balance earth and water pressures in a controlled manner, thereby reducing the risk of ground losses during tunnelling</li> <li>▪ Good grade control</li> </ul>	<ul style="list-style-type: none"> <li>▪ Cost effectiveness depends on sourcing an appropriate MTBM</li> <li>▪ Groundwater control is required for launching pits</li> <li>▪ More costly than Jack and Bore, or Pipe Ramming</li> <li>▪ Challenging if cobbles / boulders larger than 1/3 of the tunnel diameter are present</li> </ul>

Based on the geotechnical assessment, the most favourable tunnelling method is Jack and Bore. There are inherent risks and consequences involved with Jack and Bore that could include obstructions such as cobbles and boulders within the tunnel reach. The till deposits of southern Ontario are known to contain cobbles and boulders and these materials should be anticipated to be present throughout the till deposit at this site.

Based on the design alignment of the municipal drain crossing, the soils within the alignment have been classified in accordance with the Tunnelman's Ground Classification System (Terzaghi, 1950). This system is commonly used to describe the potential behaviour of an unsupported tunnel face during excavation and it uses qualitative "stand-up time" criteria to classify the ground at and above the tunnel face into the following principal categories: firm, slow ravelling, fast ravelling, squeezing, cohesive running, running, flowing and swelling. Reference is made to the Tunnelman's Ground Classification for Soils table provided in Appendix E. Efforts to predict soil behaviour must also be tempered by experience and engineering judgement. The soil conditions within the tunnel alignment are typically stiff to hard silty clays with discontinuous sand and gravel seam(s). The soil conditions generally range from "firm" to "slow to fast ravelling".

From a geotechnical perspective, we recommend installing the drain crossing by Jack and Bore. Jack and Bore tunnelling shall be carried out in accordance with the Non-Standard Special Provision "*Pipe Installation By Trenchless Method*" a copy of which is included in Appendix F.

### 8.3 Settlement

The zone of influence of soils disturbed by the tunnelling operations will be about two tunnel diameters and Jack and Bore tunnelling will result in ground movements that will produce a settlement trough above and ahead of the tunnel face.

After a tunnel is constructed, the transverse settlement trough that develops can be described by a Gaussian distribution curve as:

$$S = S_{\max} \exp \left( \frac{-x^2}{2i^2} \right)$$

Where     $S$      = settlement observed at a distance  $x$  from the tunnel axis;  
             $S_{\max}$  = maximum settlement above the tunnel axis;  
             $x$        = horizontal distance from the tunnel axis; and  
             $i$        = horizontal distance from the tunnel axis to the inflexion point on the settlement trough.

The settlement trough induced by tunnelling can be characterized by means of two parameters namely the volume of settlement per unit length of tunnel ( $V_s$ ) and the horizontal distance from the tunnel axis to the inflexion point ( $i$ ).

The volume of the settlement trough ( $V_s$ ) is difficult to evaluate as this parameter is dependent on construction methods and workmanship. This parameter ( $V_s$ ), is usually compared to the volume of ground loss produced at the tunnel level and is expressed as a percentage of the theoretical volume of excavated soils ( $V_t$ ).

Correlations by Mair and Taylor (1997)<sup>2</sup> concluded that the parameter  $i$ , can be reasonably estimated using the following expression:

$$i = K Z$$

Where     $K$      = is the trough width parameter and its value is a function of ground type; and  
             $Z$      = depth to the tunnel centre line.

---

<sup>2</sup> Mair, R. J. and Taylor, R. N. (1997). Bored tunnelling in the urban environment, Theme Lecture, Plenary Session 4, 14<sup>th</sup> International Conference on Soil Mechanics and Foundation Engineering, Hamburg, 6-12 September.

The equations outlined above were used to estimate settlement due to tunnelling below the highway pavements. Trough width parameters of 0.25 and 0.6 were selected for tunnels in non-cohesive and cohesive soils, respectively. The estimated maximum settlement below the Highway 23 pavements, assuming a 4% volume of ground loss, is not expected to exceed  $5\pm$  mm. This estimate assumes that the wall thickness of the casing pipe will be designed to resist deformation from the surcharge loads above the tunnel and that the work will be carried out by experienced tunnellers with great care and good workmanship.

#### **8.4 Entry and Receiving Pits**

It is anticipated that open cut excavations will be used for staging areas and tie points to the tunnelling segment. These excavations are understood to be located just beyond the Highway 23 right of way.

Excavations for access pits and tie-in locations will extend to a maximum 2.5 m depth and generally extend into stiff to very stiff silty clay till soils with occasional non-cohesive soil layers.

##### **8.4.1 Backfilling and Compaction Requirements**

It is anticipated that the bulk of the excavated material from the staging pits will comprise of native silty clay till. The excavated silty clay soils are considered suitable for reuse however, it should be noted that the in-situ silty clay materials will tend to retain a voided structure when placed as backfill. All lumps / clods within the till matrix shall be pulverised as appropriate prior to placement and compaction to achieve a non voided condition. Backfill should comprise of approved material placed in uniform 200 mm thick lifts within 3% of optimum moisture content and be compacted to at least 95% standard Proctor maximum dry density (SPMDD).

Surficial topsoil may be reused for landscaping purposes only.

Reference is given to OPSS 501 for further Construction Specification for Compacting, as well as OPSS 401, Construction Specifications for Trench Backfilling, and Compacting.

#### 8.4.2 Temporary Protection Systems

Decisions regarding shoring methods and sequencing are the responsibility of the Contractor. Temporary protection systems should be designed in accordance with OPSS.PROV 539 and the design should limit the lateral movement of the temporary shoring system to meet Performance Level 2. The designs should be carried out by a licensed Professional Engineer experienced in shoring design. Support systems for shallower excavations should be installed in accordance with OPSS.PROV. 404. All temporary protection systems installed within the MTO right of way shall be removed after construction is complete.

The shape of the soil pressure distribution diagram behind a temporary protection system depends upon the type of soil to be encountered and the amount of movement that can be permitted. The sequence of work will also alter the shape of the shoring pressure diagram during the various construction phases.

Earth pressure computations must also consider the groundwater level. Above the groundwater level, earth pressure is computed using the bulk unit weight of the retained soil. Below the groundwater level, the earth pressures are computed using the submerged unit weight of the soil. A hydrostatic pressure is also applied if the retained soil is not fully drained.

The appropriate lateral earth pressure parameters for use in the design of temporary protection systems are provided in the following table. The lateral earth pressure coefficients are based on the assumption that the ground surface behind the temporary protection system is horizontal. Where the retained ground is sloping, the lateral earth pressure coefficients must be adjusted to account for the slope. The values tabulated below are guideline values and the responsibility for selecting the appropriate design values is the responsibility of the shoring designer.

Soil Type	Unit Weight (kN/m <sup>3</sup> )	Angle of Internal Friction ( $\phi$ )	Coefficient of Active Earth Pressure ( $K_a$ )	Coefficient of At-Rest Earth Pressure ( $K_o$ )	Coefficient of Passive Earth Pressure ( $K_p$ )
Fill Soils	19	28	0.36	0.53	2.77
Silty Clay Till	21	28	0.36	0.53	2.77



#### 8.4.3 OHSA Soil Classification

All excavations must be carried out in accordance with the guidelines outlined in the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. Provided adequate groundwater control is achieved, the onsite soils are classified as Type 3 material as defined in the OHSA. Excavations within Type 3 soils that are to be entered by workers, may not be steeper than one horizontal to one vertical (1H:1V) from the base. Workers should not enter an unprotected excavation if there is evidence of ongoing groundwater seepage.

#### 8.5 Groundwater Control

Surface water and groundwater control will be required to maintain sufficiently dry conditions during tunnelling operations. Extensive dewatering techniques will not be required where open cut excavations are made through and into relatively impermeable silty clay soils. In the more permeable sand and gravel layer groundwater inflow is expected to be higher if perched water is encountered. However, the groundwater inflow into excavations from perched water is expected to subside over a short period of time. Therefore, surface settlement due to dewatering is not a concern.

For these conditions any surface water run-off into excavations as well as minor subsurface seepage from any wet seams within the overburden can be controlled by employing a system of gravity drainage and pumping from strategically placed filtered sumps.

The design, installation, operation and maintenance of the dewatering system is the Contractor's responsibility.

The Ontario Ministry of Environment and Climate Change (MOECC) requires a Permit to Take Water (PTTW) for any groundwater and storm water takings in excess of 400,000 L/day. If the groundwater and storm water taking is between 50,000 L/day and 400,000 L/day, then the activity must be registered on the Environmental Activity and Sector Registry (EASR). A PTTW is not considered necessary.

## **8.6 Frost Penetration Depth**

In accordance with OPSD 3090.101 - Foundation Frost Penetration Depths for Southern Ontario, the frost penetration depth for design purposes in the area where the site is located is 1.4 m.

## **8.7 Soil Corrosivity**

Two representative soil samples of the silty clay recovered within the proposed depth of drain casing were tested to determine the potential for soil corrosivity, and potential exposure of concrete to sulphate attack. A summary of the chemical test results is provided in Section 5.4 in Part A of this report. The Certificates of Analysis are included in Appendix B.

Based on results of 22 µg/g and 180 µg/g (0.018% to 0.0022%) for soluble sulphate (SO<sub>4</sub>) and pH of 8.12 and 8.80, buried concrete pipe, if considered, will be subject to a negligible degree of exposure to sulphate attack. Reference should be made to CSA A23.1 for further comments regarding cement requirements for sulphate resistance.

The tested parameters were also used for assessing the corrosivity potential of soil to ductile iron pipe in accordance with the 10-point soil evaluation procedure described in ANSI/AWWA C105/A21.5 Standard. Based on this soil corrosivity scale, a total of 10 points or more indicates that the soil is corrosive to as-manufactured ductile iron pipe (DIP), and additional corrosion protection measures are recommended. The Corrosivity Indices of the two tested samples are 10 and 13.

## **9. CONSTRUCTION CONSIDERATIONS**

Reference is given to Non-Standard Special Provision “*Pipe Installation By Trenchless Method*” a copy of which is included in Appendix F.

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.

## **9.1 Instrumentation and 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 23 would be a major inconvenience to highway users and possibly a safety issue.

Distress at the ground surface is generally prevented or minimized by good construction practices and proper planning. In this regard, a settlement monitoring and instrumentation programme is recommended.

The active roadway surface and embankments shall be monitored before, during and after construction. A precondition survey shall be carried out prior to construction, to document the existing conditions of the pavement and embankments; for the purpose of determining any restoration that may be required due to construction impacts. In addition, a pre and post condition survey of the pavement and embankments above the existing CSP culvert crossing, north of the tunnel path, will also be required.

An instrumentation and monitoring program has been developed for this project consistent with the *“Guidelines for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application”* (February 2021), included in Appendix D, and modified as appropriate. The instrumentation includes arrays of in-ground and surface monitoring points and also reflective targets aligned perpendicular to the tunnel alignment. These monitoring points are considered sufficient in providing an advance indicator of subsurface disturbance and the potential for settlement/heave at the ground surface due to the tunnelling operation.

The instrumentation and monitoring program is required to:

- Document the effects of the installation on the overlaying roadway and embankments;
- Obtain prior warning of ground movements that could occur due to construction methods and equipment or, unforeseen ground conditions;
- Verify the Contractor’s compliance with the settlement limits imposed in the Contract; and,
- Allow adjustments to be made to the tunnelling methodology such that the established settlement limits are not exceeded.

The Settlement Monitoring Plan presented in Appendix G illustrate the approximate locations of the monitoring instruments and provide typical instrument details.

Monitoring points should be installed under the supervision of a geotechnical engineer at least fourteen days prior to any tunnelling operation. Before the start of tunnelling, all monitoring points should be surveyed for elevation with at least two sets of readings on two separate days being used to establish a pre-construction baseline. During construction, a minimum of three sets of readings shall be taken daily. Daily readings and monitoring of movements is also required during work stoppages, such as during non-operation periods (off-shifts) or weekends. After tunnelling has been completed, the monitoring points shall be surveyed once per day for ten days or until the data indicates that all movements have essentially ceased.

An experienced firm in monitoring should be retained to setup and carry out the monitoring during construction. The equipment and procedures must be capable of surveying the instruments laterally and vertically to within  $\pm 2$  mm. The survey data shall be provided to and reviewed by ASF and MTO shall be kept informed on a weekly basis.

Below the Highway 23 lanes and shoulders, a Review Level of 10 mm and an Alert Level of 15 mm is considered appropriate for horizontal and vertical displacements. The following procedure should be followed if displacements reach the Review and Alert Levels.

- If the Review Level (10 mm) is reached the Contractor shall provide a formal plan that clearly states what measures will be taken to ensure that the Alert Level is not reached; and,
- If the Alert Level (15 mm) is reached, the Contractor shall stop all work and ASF, the Owner, and MTO shall have the authority to order the Contractor to alter the construction methodology to maintain integrity of existing conditions. MTO shall also have the authority to order the Contractor to make the mined excavation stable and suspend all tunnelling until an approved mitigation solution is developed. The Contractor must have an emergency plan in place to ensure public safety.

## 10. CLOSURE

This report was prepared by Mr. Jun Le Li, EIT. and Mr. Romin Agahzadeh, P.Eng., a Senior Geotechnical Engineer, and Principal Consultant with ASF. Mr. Amin Farsoodeh, P.Eng., carried out an independent quality control review.

ASF Associates Inc.



Jun Le Li, M.Eng., EIT.  
Project Manager



Romin Agahzadeh, P.Eng.  
Manager, Geotechnical Services  
Principal Consultant



Mr. Amin Farsoodeh, M.Sc., P.Eng.  
Manager, MTO Services



## **APPENDIX A**

### **Record of Borehole Sheets**

## **LIST OF SYMBOLS AND ABBREVIATIONS**

The abbreviations commonly used on the Record of Boreholes, on figures and in the text of the report are as follows:

### **PENETRATION RESISTANCE**

#### **Standard Penetration Resistance (SPT), N:**

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

#### **Dynamic Cone Penetration Resistance; Nd:**

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

### **SOIL DESCRIPTION**

#### **Compactness of Cohesionless Soils**

Density Index (Relative Density)	SPT N-Value (Blows/300 mm)
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	Over 50

#### **Consistency of Cohesive Soils**

Consistency	Undrained Shear Strength ( $C_u, S_u$ )		Corresponding Approximate SPT N-Value
	kPa	psf	
Very soft	0 to 12	0 to 250	0 to 2
Soft	12 to 25	250 to 500	2 to 4
Firm	25 to 50	500 to 1000	4 to 8
Stiff	50 to 100	1000 to 2000	8 to 15
Very stiff	100 to 200	2000 to 4000	15 to 30
Hard	Over 200	Over 4000	Over 30

### **COMPOSITION**

Trace sand	Less than 10% by weight
Some sand	10 to 20% by weight
Sandy	20 to 35% by weight
Sand and Silt	greater than 35% by weight

### **FIELD SAMPLING**

SS: Split spoon sample  
AS: Auger sample  
GS: Grab sample  
RC: Rock core  
SC: Soil core  
ST: Slotted tube  
TW: Thin-walled, open  
TP: Thin-walled, piston

### **SYMBOLS**

MC (w): Moisture Content  
LL (w<sub>l</sub>): Liquid Limit  
PL (w<sub>p</sub>): Plastic Limit  
PI (I<sub>p</sub>): Plasticity Index  
 $\gamma$ : Unit weight of soil  
 $C_u, S_u$ : Undrained shear strength

### **SOIL MOISTURE CONDITION**

DRY: No observable pore water  
MOIST: Inferred pore water, not observable  
WET: Visible pore water



**METRIC**

W.P.	LOCATION			Coords: 4 808 514.0 N; 406 226.8 E (MTM ON11)		ORIGINATED BY	R.A.
DIST	Perth County	HWY	23	BOREHOLE TYPE	Continuous Flight Hollow Stem Augers	COMPILED BY	R.A.
DATUM	Geodetic			DATE	December 21, 2023	CHECKED BY	R.A.

[illegible]

# RECORD OF BOREHOLE No 2-23

1 of 1

**METRIC**

W.P.		LOCATION		Coords: 4 808 506.5 N; 406 234.1 E (MTM ON11)		ORIGINATED BY		R.A.			
DIST		Perth County HWY 23		BOREHOLE TYPE		Continuous Flight Hollow Stem Augers		COMPILED BY		R.A.	
DATUM		Geodetic		DATE		December 21, 2023		CHECKED BY		R.A.	

[illegible]

RECORD OF BOREHOLE No HA1-23

1 of 1

METRIC

W.P. \_\_\_\_\_ LOCATION \_\_\_\_\_ Coords: 4 808 516.6 N; 406 218.8 E (MTM ON11) \_\_\_\_\_ ORIGINATED BY \_\_\_\_\_ R.A. \_\_\_\_\_  
DIST \_\_\_\_\_ Perth County HWY 23 \_\_\_\_\_ BOREHOLE TYPE \_\_\_\_\_ Pionjar \_\_\_\_\_ COMPILED BY \_\_\_\_\_ R.A. \_\_\_\_\_  
DATUM \_\_\_\_\_ Geodetic \_\_\_\_\_ DATE \_\_\_\_\_ December 21, 2023 \_\_\_\_\_ CHECKED BY \_\_\_\_\_ R.A. \_\_\_\_\_

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT							PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa														
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE														
343.8 0.0	Topsoil		1	GS																		
343.2 0.6	Silty clay, some sand mottled, moist to wet (TILL)		2	GS																		
342.5 1.3	End of Borehole NO FURTHER PROGRESS DUE TO AUGER REFUSAL ON POSSIBLE COBBLE																					

RECORD OF BOREHOLE No HA2-23

1 of 1

METRIC

W.P. \_\_\_\_\_ LOCATION \_\_\_\_\_ Coords: 4 808 504.5 N; 406 243.3 E (MTM ON11) \_\_\_\_\_ ORIGINATED BY \_\_\_\_\_ R.A. \_\_\_\_\_  
DIST \_\_\_\_\_ Perth County HWY 23 \_\_\_\_\_ BOREHOLE TYPE \_\_\_\_\_ Pionjar \_\_\_\_\_ COMPILED BY \_\_\_\_\_ R.A. \_\_\_\_\_  
DATUM \_\_\_\_\_ Geodetic \_\_\_\_\_ DATE \_\_\_\_\_ December 21, 2023 \_\_\_\_\_ CHECKED BY \_\_\_\_\_ R.A. \_\_\_\_\_

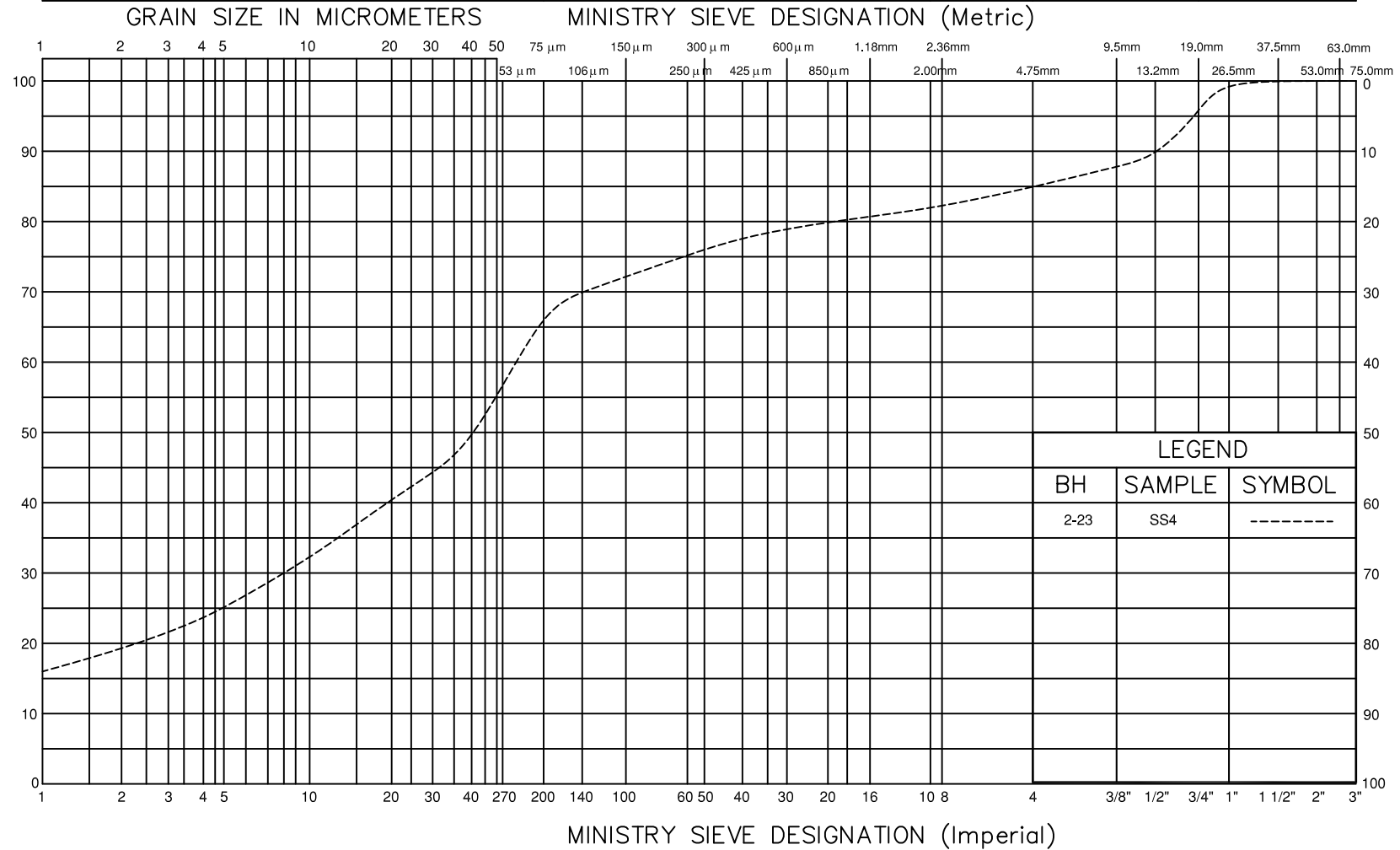
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT							PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa														
								○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE														
343.9								20	40	60	80	100										
0.0	Topsoil	○	1	GS																		
	Silty clay, some sand mottled, moist to wet (TILL)	○	2	GS			343															
342.0		○																				
1.9	End of Borehole	○																				

## **APPENDIX B**

### **Laboratory Test Results**

# UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY & SILT	SAND			GRAVEL	
	FINE	MEDIUM	COARSE	FINE	COARSE



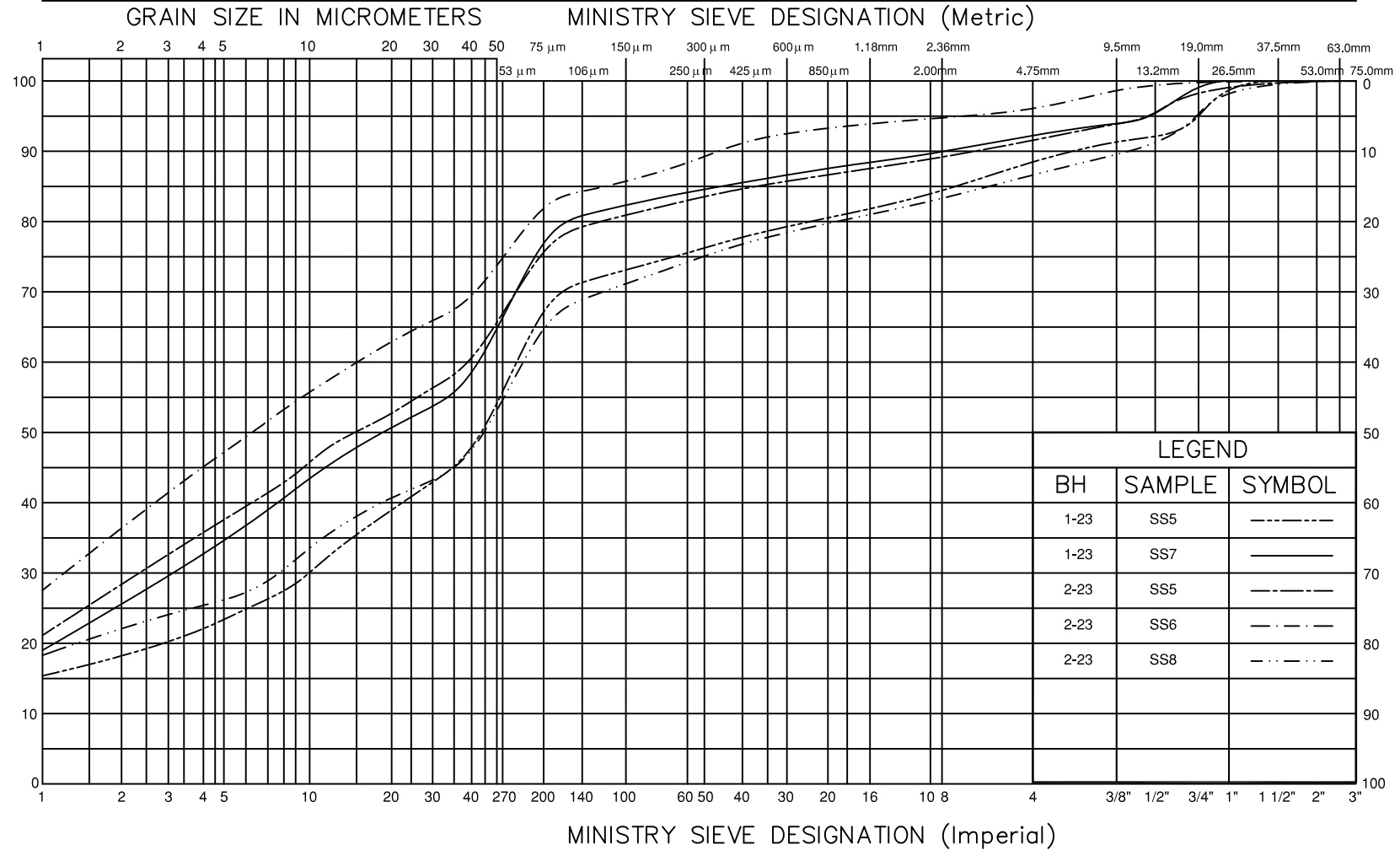
GRAIN SIZE DISTRIBUTION  
SILTY CLAY, some sand (FILL)

HWY 23  
W.P  
FIG. No GS-1



# UNIFIED SOIL CLASSIFICATION SYSTEM

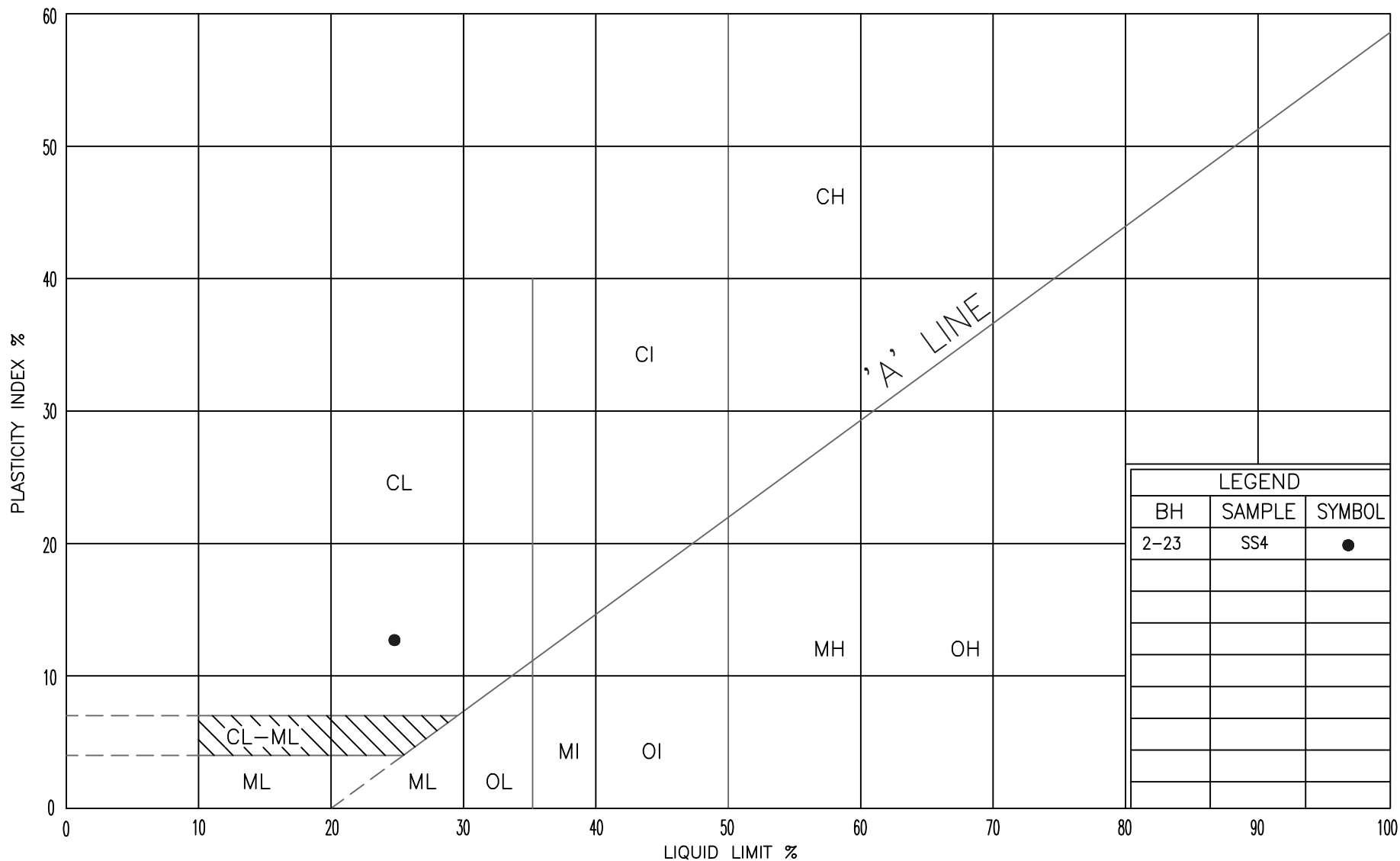
CLAY & SILT	SAND			GRAVEL	
	FINE	MEDIUM	COARSE	FINE	COARSE



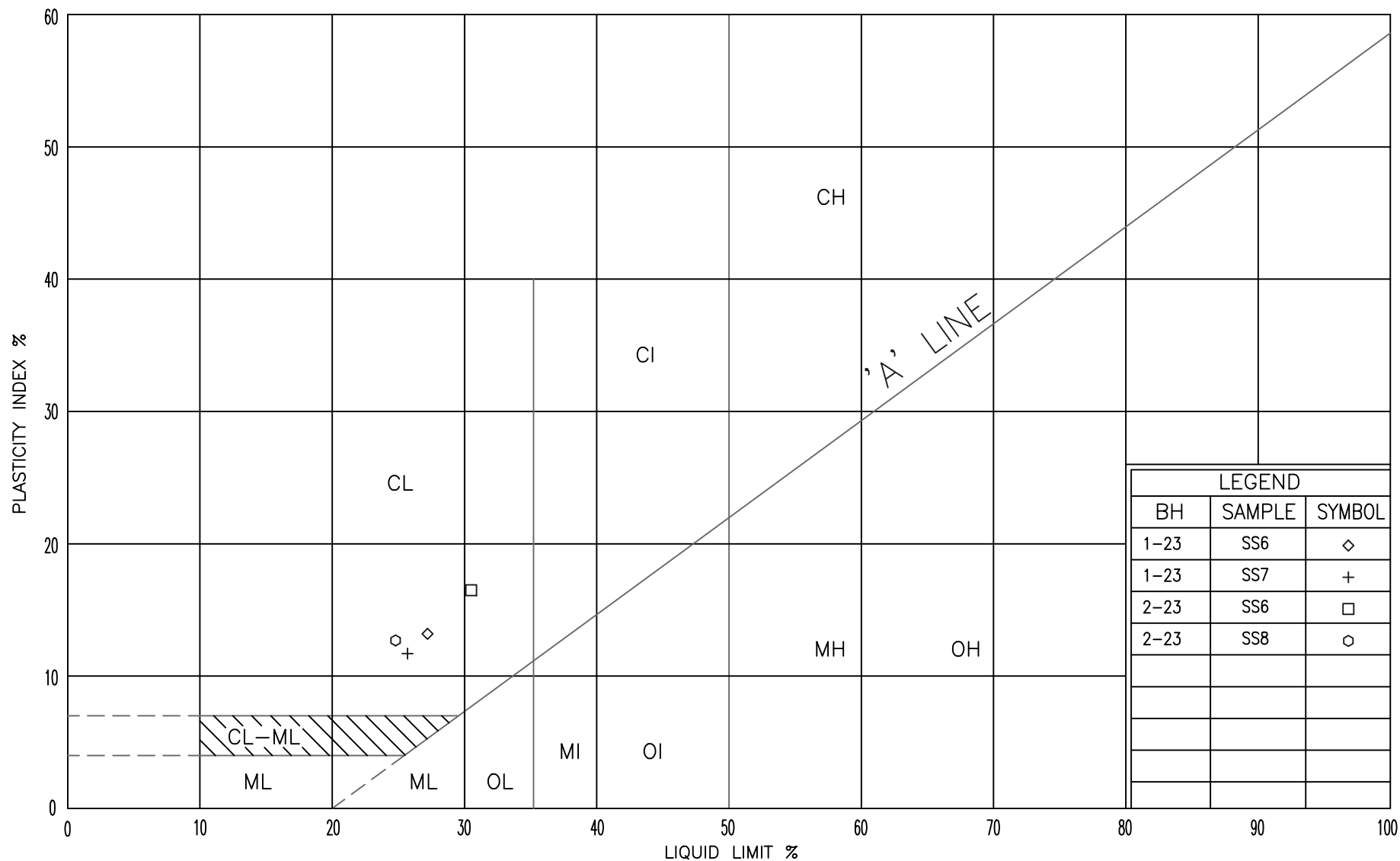
GRAIN SIZE DISTRIBUTION  
SILTY CLAY, some sand (TILL)

HWY 23  
W.P  
FIG. No GS-2









Industries Environment - Lakeland: 185 Concession St., Lakeland, ON K0L 2H0 Phone: 705-652-2000 Fax: 705-652-6365 Web: www.sgs.com/environment  
- London: 657 Consortium Court, London, ON, N6E 2S8 Phone: 519-672-4500 Toll Free: 877-848-8060 Fax: 519-672-0361

Received By: Muhammad Khan Received By (signature): Muhammad Khan Type: SE LAB LIMS #: CA40131-FEB24  
Received Date: FEB 16 2024 (mm/dd/yy)  
Received Time: 12:00 (hr:min)

**REPORT INFORMATION**  
Company: ASF ASSOCIATES INC  
Contact: ROMIN AGAHZADEH  
Address: 250 THOMPSON DR.  
Phone: 519-589-1570  
Fax: UN171  
Email: ROMIN@ASFASSOCIATES.CA

**INVOICE INFORMATION**  
☒ (same as Report Information)  
Company: \_\_\_\_\_  
Contact: \_\_\_\_\_  
Address: \_\_\_\_\_  
Phone: \_\_\_\_\_

**Received Information**  
Received By (signature): \_\_\_\_\_  
Cooling Agent Present: Yes ☐ No ☐  
Custody Seal Intact: Yes ☐ No ☐  
Custody Seal Present: Yes ☐ No ☐  
Temperature Upon Receipt (°C): SE

**Quotation #:** G23-08-015 **P.O. #:** \_\_\_\_\_  
**Project #:** HWY 23 **Site Location/ID:** HWY 23

**TURNAROUND TIME (TAT) REQUIRED**  
☒ Regular TAT (5-7days)  
TAT's are quoted in business days (exclude statutory holidays & weekends).  
Samples received after 6pm or on weekends: TAT begins next business day

**RUSH TAT (Additional Charges May Apply):** ☐ 1 Day ☐ 2 Days ☐ 3 Days ☐ 4 Days  
**PLEASE CONFIRM RUSH FEASIBILITY WITH SGS REPRESENTATIVE PRIOR TO SUBMISSION**

**Specify Due Date:** \_\_\_\_\_ **\*NOTE: DRINKING (POTABLE) WATER SAMPLES FOR HUMAN CONSUMPTION MUST BE SUBMITTED WITH SGS DRINKING WATER CHAIN OF CUSTODY**

ANALYSIS REQUESTED										COMMENTS:	
REGULATIONS											
RECORD OF SITE CONDITION (RSC)											
Other Regulations:											
Sewer By-Law:											
DATE SAMPLED											
TIME SAMPLED											
# OF BOTTLES											
MATRIX											
SAMPLE IDENTIFICATION											
1	BH1 SSS & SSB										
2	BH2 SSS & SSB										
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											

**Observations/Comments/Special Instructions**

**Sampled By (NAME):** Romin Agahzadeh **Signature:** [Signature] **Date:** \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_ (mm/dd/yy)

**Relinquished by (NAME):** \_\_\_\_\_ **Signature:** \_\_\_\_\_ **Date:** \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_ (mm/dd/yy)

**Yellow & White Copy - SGS**

**Note:** Submission of samples to SGS is acknowledged that you have been provided direction on sample collection/handling and transportation of samples. (2) Submission of samples to SGS is considered authorization for completion of work. Signatures may appear on this form or be retained on file in the contract, or in an alternative format (e.g. shipping documents). (3) Results may be sent by email to an unlimited number of addresses for no additional cost. Fax is available upon request. This document is issued by the Company under its General Conditions of Service accessible at [http://www.sgs.com/terms\\_and\\_conditions.htm](http://www.sgs.com/terms_and_conditions.htm). (Printed copies are available upon request.) Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein.

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
 Lakefield - Ontario - KOL 2H0  
 Phone: 705-652-2000 FAX: 705-652-6365

**Project :** G23-08-015, HWY 23

23-February-2024

**ASF Associates Inc.****Attn :** Romin Agahzadem

250 Thompson Dr.  
 Unit 1  
 Phone: 519-589-1570  
 Email:romin@asfassociates.ca

**Date Rec. :** 16 February 2024  
**LR Report:** CA40131-FEB24  
**Reference:** G23-08-015 Romin Agahzadem

**Copy:** #1

# CERTIFICATE OF ANALYSIS

## Final Report

Analysis	1: Analysis Start Date	2: Analysis Start Time	3: Analysis Completed Date	4: Analysis Completed Time	5: BH1 SS5 & SS6
Sample Date & Time					
Corrosivity Index [none]	23-Feb-24	08:16	23-Feb-24	08:17	13
Redox Potential Soil [mV]	20-Feb-24	14:48	21-Feb-24	09:33	321
Sulphide1 [%]	22-Feb-24	15:14	22-Feb-24	16:53	< 0.01
Moisture Content [%]	20-Feb-24	13:57	21-Feb-24	09:19	< 0.1
pH [pH Units]	21-Feb-24	13:19	22-Feb-24	10:15	8.80
Cl [µg/g]	20-Feb-24	09:17	23-Feb-24	15:00	630
SO4 [µg/g]	20-Feb-24	09:17	23-Feb-24	15:00	22
Conductivity [uS/cm]	21-Feb-24	13:19	22-Feb-24	10:15	1140
Resistivity (calc) [ohms.cm]	21-Feb-24	13:19	22-Feb-24	10:15	879

Analysis	6: BH2 SS5 & SS6
Sample Date & Time	
Corrosivity Index [none]	14
Redox Potential Soil [mV]	286
Sulphide1 [%]	0.04
Moisture Content [%]	0.1
pH [pH Units]	8.12
Cl [µg/g]	160
SO4 [µg/g]	180
Conductivity [uS/cm]	726
Resistivity (calc) [ohms.cm]	1380

Temperature of Sample upon Receipt: 6 degrees C  
 Cooling Agent Present: Yes  
 Custody Seal Present: Yes



**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
Lakefield - Ontario - K0L 2H0  
Phone: 705-652-2000 FAX: 705-652-6365

**Project :** G23-08-015, HWY 23

**LR Report :** CA40131-FEB24

Chain of Custody Number: 035584

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

*Maarit Wolfe, Hon.B.Sc*  
*Project Specialist,*  
*Environment, Health & Safety*



**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.  
Lakefield - Ontario - K0L 2H0  
Phone: 705-652-2000 FAX: 705-652-6365

**Project :** G23-08-015, HWY 23

**LR Report :** CA40131-FEB24

## Quality Control Report

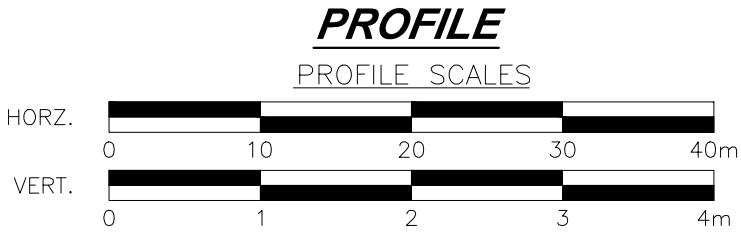
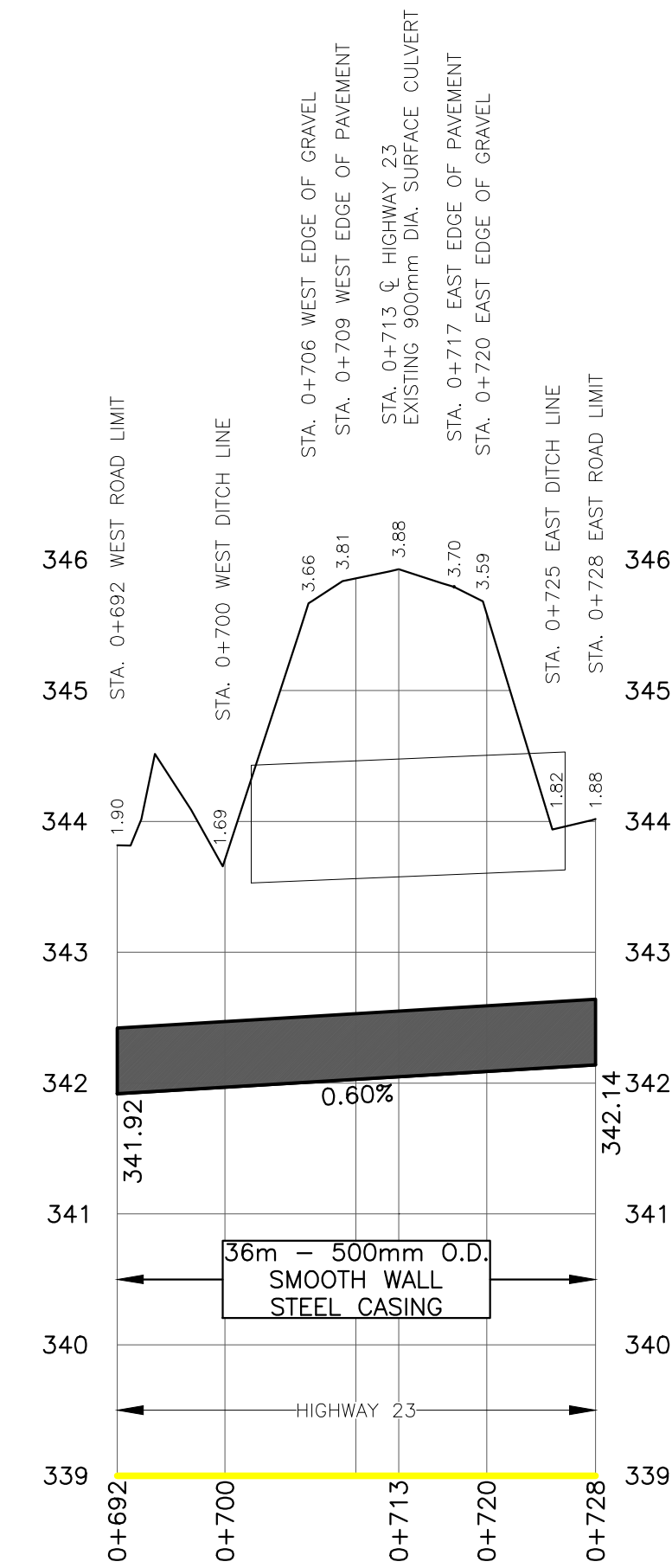
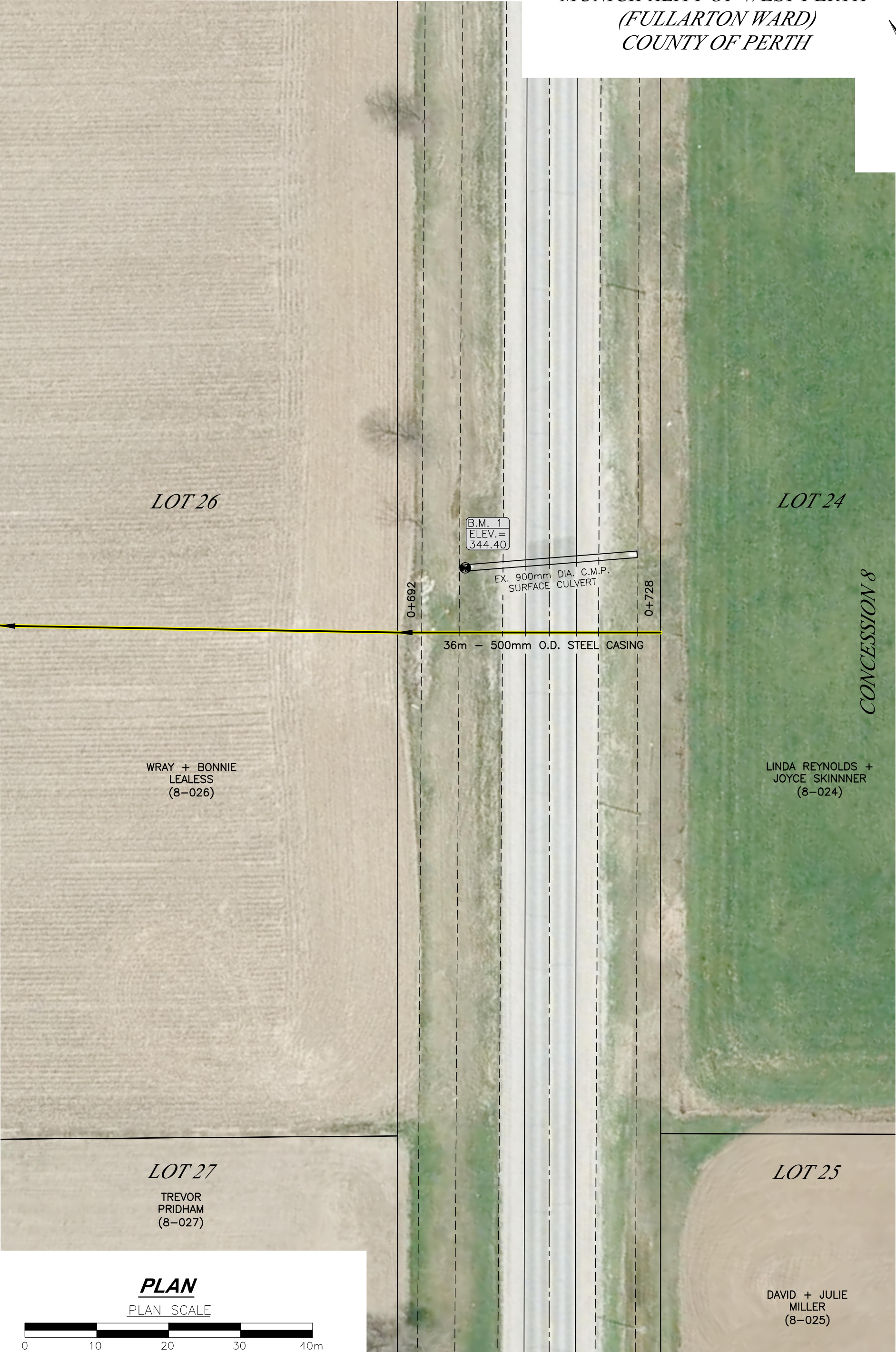
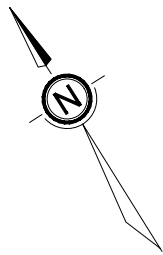
Inorganic Analysis													
Parameter	Reporting Limit	Unit	Method Blank	Duplicate				LCS / Spike Blank			Matrix Spike / Reference Material		
				Result 1	Result 2	RPD	Acceptance Criteria	Spike Recovery (%)	Recovery Limits (%)		Spike Recovery (%)	Recovery Limits (%)	
							%		Low	High		Low	High
Anions by IC - QCBatchID: DIO0430-FEB24													
Chloride	0.4	µg/g	<0.4			1	35	101	80	120	100	75	125
Sulphate	0.4	µg/g	<0.4			0	35	101	80	120	97	75	125
Carbon/Sulphur - QCBatchID: ECS0072-FEB24													
Sulphide (Na2CO3)	0.01	%	< 0.01										
Conductivity - QCBatchID: EWL0349-FEB24													
Conductivity	2	uS/cm	< 2			0	20	100	90	110	NA		
pH - QCBatchID: EWL0349-FEB24													
pH	0.05	pH Units	NA			0		100			NA		

## **APPENDIX C**

**Copy of Plan and Profile Drawing by Dietrich Engineering Limited**



MUNICIPALITY OF WEST PERTH  
(FULLARTON WARD)  
COUNTY OF PERTH



- NOTES:
1. ALL SOLID HIGH DENSITY POLYETHYLENE PIPE SHALL BE BELL & SPIGOT CSA B182.8 UNLESS OTHERWISE NOTED.
  2. ALL PERFORATED HIGH DENSITY POLYETHYLENE PIPE SHALL BE EXTERNAL SPLIT COUPLER JOINING SYSTEMS UNLESS OTHERWISE NOTED.

BENCHMARK No. 1 ELEV.=344.40  
TOP OF 900mm DIA. SURFACE CULVERT 6 METRES NORTH OF STA. 0+700 (REYNOLDS DRAIN).

LEGEND:

— DRAIN NAME —	EXISTING MUNICIPAL DRAIN
— — — — —	INTERIOR/EXTERIOR WATERSHED BOUNDARY
— — — — —	PROPERTY BOUNDARY
— — — — —	LOT OR CONCESSION BOUNDARY
— DRAIN NAME —	MUNICIPAL DRAIN (AREA OF WORK)
— — — — —	WATERSHED BOUNDARY
BENCHMARK LOCATION	B.M. 1 ELEV.=344.40
	BENCHMARK No.
	BENCHMARK ELEVATION

4.	ISSUED FOR TENDER	2023-04-11	DEL
3.	REPORT SUBMISSION	2023-03-06	DEL
2.	INFORMATION MEETING	2023-02-27	DEL
1.	ON-SITE MEETING	2022-12-07	DEL
No.	ISSUES AND REVISIONS	DATE	BY

PROJECT: REYNOLDS MUNICIPAL DRAIN 2023

DRAWING: ROAD CROSSING

**DIETRICH ENGINEERING LIMITED**  
CONSULTING ENGINEERS

10 Alpine Court, Kitchener, ON, N2E 2M7

PROJ. MGR:	W.J.D.	DESIGNED BY:	W.J.D.	DRAWN BY:	K.M.	CHECKED BY:	K.M.
DRAWING SCALE:	AS NOTED	DATE:	August 29, 2023	PROJECT No.	2235	DRAWING No.	1 of 1



## **APPENDIX D**

### **Copy of Ministry of Transportation's “Guidelines for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application”**



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

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

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### **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)	$\leq 300 \text{ mm}$		$1 \text{ m} \geq \text{Ø} > 300 \text{ mm}$		$2 \text{ m} \geq \text{Ø} > 1 \text{ m}$		$\text{Ø} > 2 \text{ m}$
Design Cover* (m)	$\geq 1.5 \text{ m}$	$< 1.5 \text{ m}$	$\geq 3 \text{ Ø}$ and $> 1.5 \text{ m}$	$< 3 \text{ Ø}$ or $< 1.5 \text{ m}$	$\geq 3 \text{ Ø}$	$< 3 \text{ Ø}$	N/A
King's Highway	<b>Low</b>	<b>Medium</b>	<b>Low</b>	<b>Medium</b>	<b>Medium</b>	<b>High</b>	<b>High</b>
400 Series Freeway	<b>Low</b>	<b>High</b>	<b>Medium</b>	<b>High</b>	<b>High</b>	<b>High</b>	<b>High</b>

\* 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**

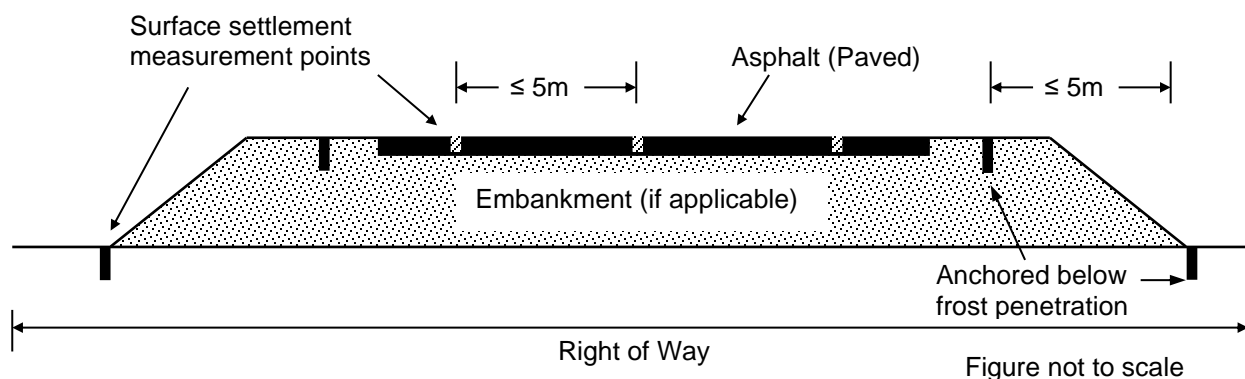
All measurement points shall be installed and surveyed before the start of excavation to establish benchmarks/baseline.

#### **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.

## **APPENDIX E**

### **Copy of Tunnelman's Ground Classification for Soils**

**TUNNELMAN'S GROUND CLASSIFICATION FOR SOILS<sup>1</sup>**

CLASSIFICATION		BEHAVIOUR	TYPICAL SOIL TYPES
Firm		Heading can be advanced without initial support, and final lining can be constructed before ground starts to move.	Loess above water table; hard clay, marl, cemented sand and gravel when not highly overstressed.
Raveling	Slow raveling ----- Fast raveling	Chunks or flakes of material begin to drop out of the arch or walls sometime after the ground has been exposed, due to loosening or to overstress and "brittle" fracture (ground separates or breaks along distinct surfaces, opposed to squeezing ground). In fast raveling ground, the process starts within a few minutes, otherwise the ground is slow raveling.	Residual soils or sand with small amounts of binder may be fast raveling below the water table, slow raveling above. Stiff fissured clays may be slow or fast raveling depending upon degree of overstress.
Squeezing		Ground squeezes or extrudes plastically into tunnel, without visible fracturing or loss of continuity, and without perceptible increase in water content. Ductile, plastic yield and flow due to overstress.	Ground with low frictional strength. Rate of squeeze depends on degree of overstress. Occurs at shallow to medium depth in clay of very soft to medium consistency. Stiff to hard clay under high cover may move in combination of raveling at excavation surface and squeezing at depth behind surface
Running	Cohesive running ----- Running	Granular materials without cohesion are unstable at a slope greater than their angle of repose (approximately 30° – 35°). When exposed at steeper slopes they run like granulated sugar or dune sand until the slope flattens to the angle of repose.	Clean, dry granular materials. Apparent cohesion in moist sand, or weak cementation in any granular soil, may allow the material to stand for a brief period of raveling before it breaks down and runs. Such behavior is cohesive-running.
Flowing		A mixture of soil and water flows into the tunnel like a viscous fluid. The material can enter the tunnel from the invert as well as from the face, crown, and walls, and can flow for great distances, completely filling the tunnel in some cases.	Below the water table in silt, sand, or gravel without enough clay content to give significant cohesion and plasticity. May also occur in highly sensitive clay when such material is disturbed.
Swelling		Ground absorbs water, increases in volume, and expands slowly into the tunnel.	Highly preconsolidated clay with plasticity index in excess of about 30, generally containing significant percentages of montmorillonite.

<sup>1</sup> Modified by Heuer (1974) from Terzaghi (1950)

## **APPENDIX F**

### **Copy of Non-Standard Special Provision “Pipe Installation By Trenchless Method”**

## **PIPE INSTALLATION BY TRENCHLESS METHOD – Item No.**

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Special Provision

July 2020

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### **CONSTRUCTION SPECIFICATION FOR THE INSTALLATION OF PIPES BY TRENCHLESS METHODS**

#### **TABLE OF CONTENTS**

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<b>2.0</b>	<b>REFERENCES</b>
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<b>4.0</b>	<b>DESIGN AND SUBMISSION REQUIREMENTS</b>
<b>5.0</b>	<b>MATERIALS</b>
<b>6.0</b>	<b>EQUIPMENT</b>
<b>7.0</b>	<b>CONSTRUCTION</b>
<b>8.0</b>	<b>QUALITY ASSURANCE- Not Used</b>
<b>9.0</b>	<b>MEASUREMENT FOR PAYMENT</b>
<b>10.0</b>	<b>BASIS OF PAYMENT</b>
<b>1.0</b>	<b>SCOPE</b>

This specification covers the requirements for the installation of pipe by a selected trenchless method.

#### **2.0 REFERENCES**

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

##### **Ontario Provincial Standard Specifications, General**

OPSS 180      Management of Disposal of Excess Material

##### **Ontario Provincial Standard Specifications, Construction**

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	Support Systems
OPSS 409	Closed-Circuit Television (CCTV) Inspection of Pipelines

OPSS 491	Preservation, Protection, and Reconstruction of Existing Facilities
OPSS 492	Site Restoration Following Installation of Pipelines, Utilities and Associated Structures
OPSS 517	Dewatering
OPSS 539	Temporary Protection Systems

### **Ontario Provincial Standard Specifications, Material**

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

### **CSA Standards**

B182.6	Profile polyethylene (PE) sewer pipe and fittings for leak-proof sewer applications
A3000	Cementitious Materials Compendium
W59	Welded Steel Construction (Metal Arc Welding)

### **American Society for Testing and Materials (ASTM) International Standards**

A 252	Standard Specification for Welded and Seamless Steel Pipe Piles
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 specification, the following definitions apply:

**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.

**Design Engineer** means the Engineer retained by the Contractor who produces the design and working drawings and other engineering documents required of the Contractor.

**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.

**Horizontal Directional Drilling (HDD)** means horizontal directional boring or guided boring.

**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.

**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 microtunnel boring



machine (MTBM) or hand mining using a shield to support the opening.

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

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

**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.

**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 m<sup>3</sup> 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 TBM or MTBM through which spoil can pass only by manner of controlled-pressure and controlled flow slurry pumping 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.

**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.

**TBM** means a tunnel boring machine.

**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 microtunnel 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 Working Drawings**

Three (3) sets of Working Drawings for each trenchless installation method selected, and a Request to Proceed shall be submitted to the Contract Administrator two (2) weeks prior to the commencement of the trenchless installation operation work.

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 check Engineer. A copy of the Working Drawings shall be kept at the site during construction.

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

##### **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 safety plan including the company safety manual and emergency procedures.
- v. The work area layout.
- vi. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.

- vii. 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.
- viii. 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.
- ix. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
- x. Excavated materials disposal plan.
- xi. Locations of protection systems.

b) Designs

- i. Primary liner design (e.g., steel liner plates, steel ribs and wood lagging, steel casing pipe, 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.

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, Slurry Pressure Balance
- 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 EPB TBM and 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;

- the 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 tunnelling fluids or EPB spoil; and method of disposal of the slurry, drilling fluids and associated spoil

d) Upstream/Downstream Portal Installation Procedure:

- i. Access shaft or entry/exit pit details, as applicable.
- ii. Face support and other temporary support details, if applicable.

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

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

f) Excavation and Dewatering:

- i. Equipment and methods for control, handling, treatment, and disposal of groundwater and water or fluids introduced by the Contractor.
- ii. Equipment and methods for maintaining control of ground inflow at the excavation face during excavation.
- iii. Equipment and methods for removal of cobbles and boulders.
- iv. 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, SPB and EPB pressures;
- v. 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;
- vi. 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;
- vii. 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.);
- 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 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 HDPE 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 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 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 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. 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.
- ii. 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.
- iii. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
- iv. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
- v. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
- vi. 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.
- vii. 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.
- viii. 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 - Provide an 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 Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
- ii. 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 percent 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. CONSTRUCTION**

#### **7.01 General**

The Contractor shall notify the Contract Administrator at least 48 hours in advance of starting work. The proposed method of pipe installation to be used by the Contractor shall be 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 work 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 OPSS539. Where the stability, safety, or function of an existing roadway, watercourse, other works, proposed works or ESA's may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

#### **7.01.04 Settlement or Heave**

Any disturbance to the ground surface (settlement or heave) as a result of the pipe installation shall be immediately corrected by the 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 handling and storage recommendations shall be followed.

#### **7.01.08      Trenching, Backfilling and Compacting**

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

#### **7.01.09      Support Systems**

Support systems shall be according to OPSS 404.

If any open excavation will encroach into the highway embankment the protection system shall satisfy the requirements for Performance Level 2 as specified in OPSS 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 should be anticipated in the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles shall be expected to be routine and will not be considered cause for obstruction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

\*\* The native till deposits along the proposed pipe crossing alignment may contain cobbles and boulders. The Contractor must be equipped to handle those conditions. Boulder Volume Ratio (BVR) and Boulder Number Ratio (BNR) were not accessed for this project and shall not be considered as a baseline for payment.

#### **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 water tight, expandable and stable grout.

### **7.03 Pipe Ramming Installation**

For pipe ramming installation the following requirements apply:

Only smooth walled steel pipe shall be used. Butt welding of pipe joints shall conform to CAS 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 water tight, 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, 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**

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 work areas.

#### **7.04.03 Pilot Bore**

The pilot bore shall be drilled along the bore path in accordance with the grade, alignment, and tolerances as indicated on the Contractor’s submitted drilling plan to ensure that the product is installed to the line and grade shown on the Contract Drawings. The Contractor’s methods shall take into consideration the conditions at each crossing within the pipe alignment and shall be suitable to advance through such obstructions such as cobbles

and boulders and address the potential for deflection off these obstruction and/or soil conditions.

In the event the pilot bore deviates from the submitted path, the Contract Administrator shall be notified. The Contract Administrator may require the Contractor to pullback, 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**

##### **7.04.06.0 General**

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

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

The minimum allowable bending radius for the product shall not be 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 manufacturer’s 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 insure that, once started, all reaming and back pulling operations are completed without stopping and within the permitted work hours.

The space between the pipe and the 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 OSHA 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.

### **7.05.01 Tunnelling Method**

The tunnelling method shall be suitable to provide face support in changing ground conditions that may be



encountered during the progress of the work. The selection of the tunnelling method should consider the soil conditions at each pipe crossing and the presence of obstructions, such as cobbles and boulders, with respect to the tunnel alignment.

#### **7.05.02 Primary Liner (Support System)**

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

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

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

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

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

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

All voids between the primary lining and the 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.

#### **7.05.03 Secondary Liner**

##### **7.05.03.01 Placing of Grout**

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

Grout shall not be placed until the lining has achieved 85% of its specified strength or 30 MPa. Grouting shall be limited to such sequences and programs as are necessary to avoid damaging any part of the works or any other structure or property. 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)  $\pm 2$  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 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 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 CA and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.
- 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 the public and maintain traffic. No construction related to trenchless operation 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.
  - iii.        Any approved corrective and/or preventive measure deemed necessary by the Contractor is implemented.
  - iv.         The CA's written approval.

#### **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 and 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. QUALITY ASSURANCE - NA**

## **9. MEASUREMENT FOR PAYMENT**

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

## **10. BASIS OF PAYMENT**

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

Payment for the pipe installed inside the pipe liner shall be paid separately under the appropriate tender items.

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

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

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

Payment for removal of boulders exceeding Boulder Volume Ratios (BVR) and Boulder Number Ration (BNR) shall be by Time and Material.

### **NOTES TO DESIGNER:**

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

\*\* Insert the following fill-in: Subsurface Condition Baseline Reporting that includes Boulder Volume Ration (BVR), Boulder Number Ration (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.

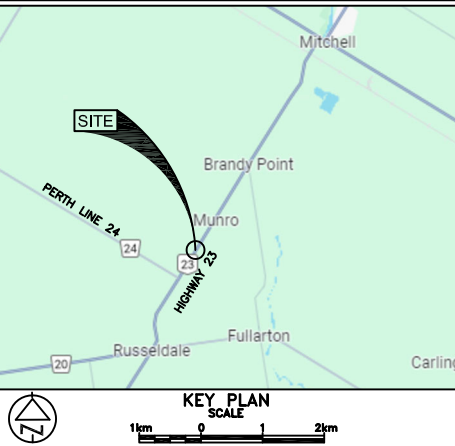
\*\*\*\* Insert the following fill-in: The Instrumentation and Monitoring program shall be project specific.  
The work specified in this Section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability.

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

WARRANT: Always with this specification

## **APPENDIX G**

### **Settlement Monitoring Programme**



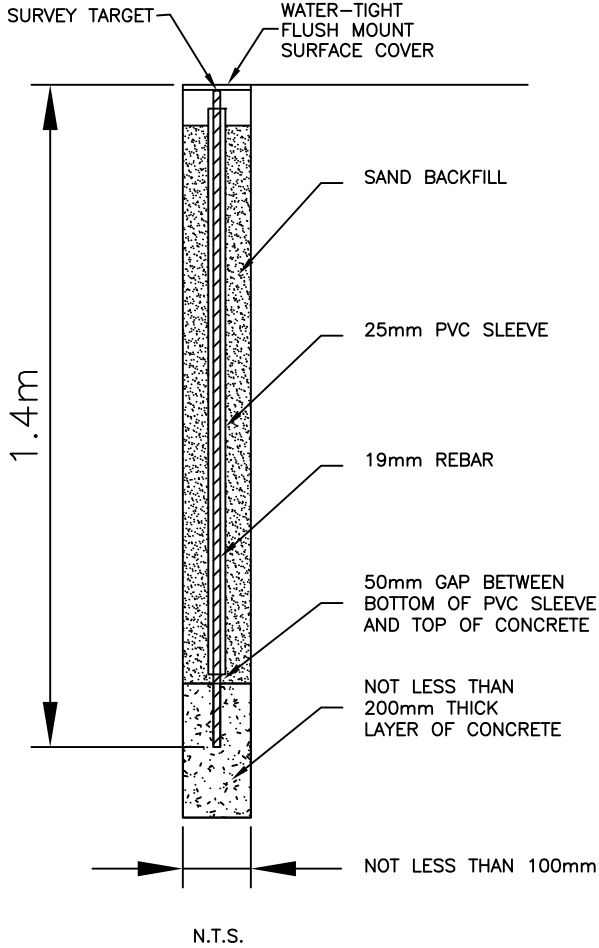
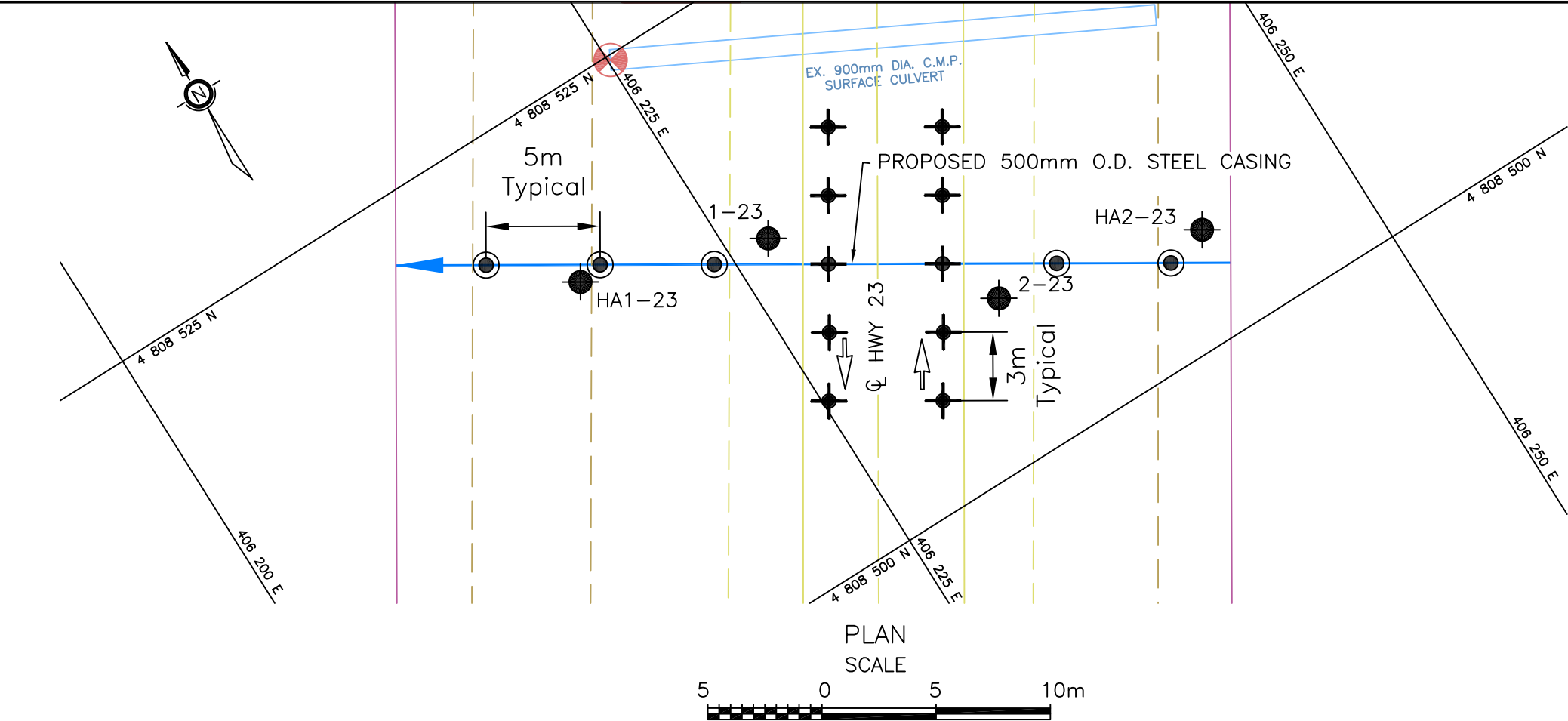
- LEGEND
- Borehole
  - Surface Monitoring Point
  - Deep In-ground Monitoring Point

BH No	ELEVATION	COORDINATES	
		NORTHINGS	EASTINGS
1-23	345.7	4 808 514.0	406 226.8
2-23	345.8	4 808 506.5	406 234.1
HA1-23	343.8	4 808 516.6	406 218.8
HA2-23	343.9	4 808 504.5	406 243.3

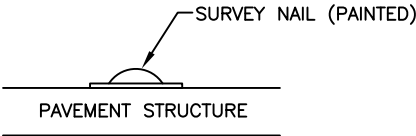
REVISIONS	DATE	BY	DESCRIPTION

Geocres No. 40P06-028

HWY No 23	SUBM'D RA	CHECKED AF	DATE April 25, 2024	DIST PERTH CTY.
DRAWN RA	CHECKED AF	APPROVED RA	SITE ---	DWG 2



IN-GROUND SETTLEMENT POINT INSTALLATION DETAIL



SURFACE MONITORING DETAIL

- NOTES:
- THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH ASF ASSOCIATES INC. REPORT TITLED: FOUNDATION INVESTIGATION AND DESIGN REPORT – REYNOLDS MUNICIPAL DRAIN CROSSING HIGHWAY 23; ASF PROJECT NO. G23-08-015 DATED March 14, 2024.
  - ALL MONITORING LOCATIONS SHOULD BE CONSIDERED APPROXIMATE AND MUST BE CONFIRMED BY THE GEOTECHNICAL ENGINEER PRIOR TO INSTALLATION / CONSTRUCTION AND MAY HAVE TO BE ADJUSTED IN THE FIELD.
  - A QUALIFIED ENGINEERING FIRM OR REGISTERED ONTARIO LAND SURVEYOR SHALL BE RETAINED TO ESTABLISH AND SURVEY THE MONITORING POINTS FOR THE DURATION OF CONSTRUCTION
  - ALL MONITORING POINTS SHALL BE INSTALLED AT LEAST 14 DAYS PRIOR TO ANY EXCAVATION OR TUNNELLING TAKING PLACE TO ESTABLISH BASELINE READINGS
  - IN-GROUND MONITORING POINTS SHALL BE AS PER THE IN-GROUND SETTLEMENT POINT INSTALLATION DETAIL ON THIS SHEET
  - SURFACE MONITORING POINTS SHALL BE A STANDARD NAIL / WASHER SYSTEM PAINTED OR ADEQUATELY MARKED WITH A SURVEYING PRISM ATTACHED TO IT
  - TEMPORARY BENCHMARKS SHALL BE ESTABLISHED OUTSIDE THE AREA OF CONSTRUCTION AND APPROVED BY MTO
  - PRIOR TO CONSTRUCTION ALL MONITORING POINTS SHALL BE SURVEYED FOR ELEVATION AND LOCATION TO A TOLERANCE OF NOT MORE THAN 2mm IN THE VERTICAL AND HORIZONTAL DIRECTION
  - THE SPECIFIED SETTLEMENT REVIEW LEVEL BELOW HIGHWAY 23 IS 10mm AND THE SPECIFIED SETTLEMENT ALERT LEVEL IS 15mm RELATIVE TO THE BASELINE READING. THE REQUIRED ACTIONS TO BE TAKEN IF THE REVIEW AND ALERT LEVELS ARE REACHED OR EXCEEDED ARE SPECIFIED IN ASF'S REPORT.
  - THE FREQUENCY AND DURATION FOR THE SURVEY OF THE MONITORING POINTS ARE SPECIFIED IN ASF'S REPORT
  - WITHIN 24 HOURS OF COMPLETION OF ANY MEASUREMENT A COPY OF THE RESULTS SHALL BE MADE AVAILABLE TO THE GEOTECHNICAL ENGINEER AND MTO
  - ALL MONITORING POINTS SHALL BE REMOVED FOLLOWING COMPLETION OF THE SURVEY, SUBJECT TO APPROVAL OF THE GEOTECHNICAL ENGINEER AND MTO