



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 556 CULVERT REPLACEMENT AT STA 18+289
(TOWNSHIP OF DEROCHE)
REHABILITATION OF HIGHWAYS 556 & 532
DISTRICT OF ALGOMA, ONTARIO
ASSIGNMENT No.: 5020-E-0020
G.W.P. 5221-18-00**

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GEOCRES Number: 41K-123

Report

to

AECOM Canada Ltd.

Date: April 13, 2023
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PART A: FACTUAL INFORMATION

1. INTRODUCTION

This report presents the factual data obtained from a foundation investigation carried out by Thurber Engineering Ltd. (Thurber) at the site of a centreline culvert, located at STA 18+289 on Highway 556, in the Township of Deroche, District of Algoma, Ontario.

The purpose of this investigation was to explore the subsurface conditions at the culvert site and, based on the data obtained, to provide a borehole location plan, stratigraphic profile, records of boreholes, laboratory test results, and a written description of the subsurface conditions.

Thurber carried out the investigation as a subconsultant to AECOM Canada Ltd. (AECOM), under the Ministry of Transportation, Ontario (MTO) Assignment No. 5020-E-0020.

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

2. SITE DESCRIPTION

The existing culvert is located on Highway 556, approximately 6.4 km west of the intersection with Highway 532 near Searchmont, Ontario. For project orientation purposes, Highway 556 is herein described as oriented east-west and the culvert is described as oriented north-south. Details of the existing culvert are as follows:



Township and Station	Culvert Size and Type	Length of Culvert (m)	Invert Elevation at Inlet (m)	Invert Elevation at Outlet (m)
Deroche 18+289	800 mm dia. CSP	31.26 m long	285.1 (south)	282.6 (north)

The existing culvert allows flow in a south to north direction under the approximately 4.5 m high embankment. The highway pavement surface is at approximate Elev. 289.4 m. In the area of the culvert, the south-facing slope is inclined at approximately 2H:1V. The overall north-facing slope is inclined at approximately 2H:1V; however, a section of the slope is as flat as 2.7H:1V while a local section is as steep as 0.5H:1V.

Based on visual observations, no signs of slope instability of the embankment were noted near the outlet of the culvert site; however, surficial erosion was observed on the unvegetated portion of the south-facing embankment slope (Photo 5, Appendix A). A small pond of water was observed at the culvert outlet. The south and north sides of the embankment at the toe of the slope were generally surrounded by thick mixed forest, with the embankment side slopes being lightly vegetated with some visible cobbles. In addition, the bottom of the existing culvert at the outlet was observed to be partially damaged by corrosion. Site photographs can be found in Appendix A.

Highway 556 consists of two, 3.25 m wide, paved lanes and narrow partially paved shoulders. The alignment in the immediate vicinity of the culvert is relatively straight, with curves further east and west of the site. The paved shoulders are narrow and are flanked by steel cable guiderails on both sides of the highway. Overhead utility lines are present on the south side of the highway. It is understood that the projected 2023 AADT for Highway 556 is 540. Granular entrances to rural properties are located approximately 95 m and 60 m to the east and west of the culvert, respectively.

Based on Northern Ontario Engineering Geology Terrain Study (NOEGTS) mapping, the site lies in an outwash plain and valley train and the primary materials are sandy and gravelly soils, and bedrock knobs and outcrops. The site topography in the immediate vicinity of the culvert is of low relief consisting of plains and gullies and the surrounding area is generally described as moderate relief of a clifty volcanic rock signature.

Based on the OGS Map MRD126 titled “Bedrock Geology of Ontario”, dated 2011, the underlying bedrock at the site consists of mafic to intermediate metavolcanic rocks.



3. INVESTIGATION PROCEDURES

The field investigation and testing for this project was carried out between September 17 and October 19, 2022, and consisted of drilling and sampling five boreholes, designated as Boreholes 18289-01 to 18289-05, to depths of between 4.4 m and 15.7 m (Elev. 281.2 m and 273.7 m). Boreholes 18289-02 to 18289-04 were advanced through the existing highway embankment, while Boreholes 18289-01 and 18289-05 were advanced near the toe of the embankment near the existing inlet and outlet, respectively.

The Record of Borehole sheets for the boreholes are included in Appendix B.

Utility clearances were obtained prior to mobilization to the site. The ground surface elevations of the as-drilled borehole locations were surveyed in the field with a rod and level using a temporary benchmark identified as HCP 186 which is at an elevation of 289.23 m. The borehole co-ordinates were determined through off-set measurement from the highway centerline and existing culvert. The coordinate system MTM NAD 83, Zone 13 was used for the boreholes.

Boreholes 18289-02 to 18289-04 were drilled using a truck mounted CME 75 drill rig using 194 mm outside diameter hollow stem augers and/or wash boring technique with HQ casing and NQ coring equipment. Boreholes 18289-01 and 18289-05 were advanced with a portable drilling equipment also using wash boring technique but with BW casing and AW coring equipment. Soils samples were obtained at selected intervals using a split-spoon sampler in conjunction with Standard Penetration Testing (SPT) in general accordance with ASTM D1586. Soil sampling in Borehole 18289-05 employed a half-weight hammer lifted manually and as such, a correction factor has been applied for the reported SPT N-values and thus, they are less reliable.

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's technical staff, who logged the boreholes and processed the recovered soil and rock core samples for transport to Thurber's laboratory for further examination and testing.

The rock cores were logged, and the Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) and Fracture Index (FI) were determined.

Groundwater conditions observed in open boreholes are not considered stabilized due to the introduction of water throughout the drilling operation. Groundwater level observations and water level readings in casing are shown on the Record of Borehole sheets. The borehole completion details are summarized below:



Borehole	Depth and Elevation of Borehole Base (m)	Northing and Easting MTM NAD83 Zone 13	Completion Details
18289-01	4.4 / 279.9	N 5 177 562.9 E 293 879.2	Backfilled with bentonite holeplug to surface.
18289-02	15.7 / 273.7	N 5 177 568.3 E 293 863.6	Backfilled with bentonite holeplug and asphalt patch at surface.
18289-03	8.2 / 281.2	N 5 177 577.7 E 293 877.1	Backfilled with bentonite holeplug and asphalt patch at surface.
18289-04	10.9 / 278.5	N 5 177 575.4 E 293 867.7	Backfilled with bentonite holeplug and asphalt patch at surface.
18289-05	5.9 / 278.2	N 5 177 590.3 E 293 864.6	Backfilled with bentonite holeplug to surface.

4. LABORATORY TESTING

All recovered soil samples were subjected to visual identification (VI) and natural moisture content determination. Selected samples were subjected to grain size distribution analyses (sieve and/or hydrometer). The results of this testing program are summarized on the Record of Borehole sheets in Appendix B and are shown on the figures included in Appendix C.

Testing was carried out on a sample of the embankment fill to assess the potential for sulphate attack on buried concrete structures, as well as the potential for corrosion associated with buried steel elements of the structures. The results of the analytical testing are summarized in this report and presented in Appendix C.

5. DESCRIPTION OF SUBSURFACE CONDITIONS

Reference is made to the Record of Borehole sheets included in Appendix B. Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets and on the Borehole Locations and Soil Strata Drawing included in Appendix D. A description of the stratigraphy, based on the conditions encountered in the boreholes, is given in the following paragraphs. However, the factual data presented on the Record of Borehole sheets takes precedence over this general description and must be used for interpretation of the site conditions. It must be recognized and expected that soil conditions may vary between and beyond the borehole locations.



In general, the subsurface conditions encountered consisted of gravel to gravelly silty sand embankment fill containing cobbles and possible boulders, underlain by native deposits of silty sand and gravel to silty sand containing cobbles and boulders. The overburden material was underlain by andesite/gneiss bedrock.

5.1 Topsoil

A 100 mm thick layer of organic silty sand topsoil was encountered at ground surface at Borehole 18289-05 at the toe of the embankment. A moisture content of 61 percent was measured on a sample of the topsoil. The topsoil thickness may vary in other areas of the site.

5.2 Asphalt

Boreholes 18289-02 to 18289-04 were advanced through the paved portion of Highway 556, and the asphalt was measured to be between 25 mm and 50 mm thick.

5.3 Embankment Fill

Granular embankment fill ranging in composition from gravel to sandy silty gravel to gravelly sand, containing cobbles and possible boulders was encountered underlying the asphalt in Boreholes 18289-02 to 18289-04, and beneath the topsoil in Borehole 18289-05. Cobbles were encountered at varying depths throughout the embankment fill and were cored using an 'NQ' size rock core barrel. Photographs of the cobbles observed in embankment fill cuttings from advancing Borehole 18289-03 are shown in Photographs 8 and 9 in Appendix A. From the recovered cored cobbles and observations of particle sizes in the embankment fill cuttings, the cobbles recovered are up to about 175 mm in size. Boulders may be present as well in the fill.

The embankment fill ranged in thickness from 1.2 m to 5.8 m and extended to depths of between 1.3 m and 5.8 m (Elev. 284.1 m and 282.8 m).

SPT 'N' values in the embankment fill ranged from 8 blows per 0.3 m penetration to 70 blows per 0.03 m of penetration (with typical values recorded between 11 and 58 blows per 0.3 m of penetration), indicating a loose to very dense condition. The SPT 'N' values varied widely as a result of split-spoon refusal on coarse gravel and cobbles, which were present throughout the fill. The drill casing was grinding for 0.6 m to 1.2 m in Borehole 18289-02 indicating presence of cobbles and boulders. A SPT 'N' value of "weight of hammer" was measured near the bottom of the layer in Borehole 18289-02. The measured moisture contents generally ranged from 2 percent to 19 percent.



The results of grain size analyses conducted on selected samples of the embankment fill are provided on the Record of Borehole sheets in Appendix B and plotted in Figures C-1A and C-1B of Appendix C. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	20 to 50
Sand	43 to 69
Silt	5 to 9
Clay	0
Silt & Clay	5 to 11

5.4 Silty Sand to Sandy Silt

A heterogeneous deposit of silty sand to sandy silt, trace gravel to gravelly, trace clay, containing gravel and sand interlayers was encountered at ground surface at Borehole 18289-01, and beneath the embankment fill in Boreholes 18289-02 to 18289-05. Cobbles sized particles were measured up to about 100 mm in the deposit, with a 300 mm boulder cored at the bottom of Borehole 18289-05. In Borehole 18289-05, the silty sand encountered near surface contained organics and wood fragments. The cohesionless deposit extends to a depth of 12.7 m (Elev. 276.7 m) and was 6.9 m thick in Borehole 18289-02, where the deposit was full penetrated. Except for Boreholes 18289-02, all other boreholes were terminated within the silty sand deposit between depths of about 4.4 m and 10.9 m (Elev. 281.2 m and 278.2 m).

SPT 'N' values in the cohesionless deposit ranged from 6 blows per 0.3 m penetration to 100 blows per 0.15 m of penetration, indicating a very loose to very dense condition. Like the embankment fill, the variable SPT 'N' values are attributed to split-spoon refusal on coarse gravel, cobbles, and boulders. Where required, NQ rock coring techniques were required to advance the boreholes through the coarse gravel, cobbles, and boulders within the deposit. Casing grinding was noted in the several boreholes and their locations are recorded on the record of boreholes. Photographs of cobbles and boulders are included in Appendix C. The measured moisture contents in the deposit generally ranged between about 1 percent and 26 percent, with one sample having a moisture content of about 59 percent.

The results of grain size analyses conducted on selected samples of the silty sand to sandy silt deposit are provided on the Record of Borehole sheets in Appendix B and plotted in Figures C-2A and C-2B of Appendix C. The results summarized as follows:



Soil Particle	Percentage (%)
Gravel	8 to 24
Sand	30 to 57
Silt	22 to 55
Clay	2 to 7

Atterberg limit testing was completed on one sample of the deposit. The results are summarized below and are presented on the Record of Borehole sheets in Appendix B. The laboratory result indicates non-plastic behaviour.

5.4.1 Gravel to Sandy Silty Gravel Interlayer

Several interlayers were encountered within the silty sand deposit and are summarized below:

Borehole	Description	Depth Encountered (m)	Thickness (m)
18289-01	Sandy Silty Gravel	0.6 (Elev. 283.7 m)	1.7
18289-02	Gravel	5.8 (Elev. 283.6 m)	1.4
		10.1 (Elev. 279.3 m)	1.5
18289-04	Gravel and Sand	9.1 (Elev. 280.3 m)	1.8 ¹

Note 1: Prior to termination of borehole at a depth of 10.9 m below ground surface.

SPT 'N' values in the cohesionless deposit ranged from 23 blows per 0.3 m penetration to 50 blows per 0.075 m of penetration, indicating a compact to very dense condition. Coring was required to advance through this deposit in Borehole 18289-01 and 18289-04. The measured moisture contents in the deposit generally ranged between about 2 percent and 14 percent. The results of grain size analyses conducted on samples of the interlayers are provided on the Record of Borehole sheet in Appendix B, and plotted in Figure C-2C in Appendix C. The results are summarized as follows:

Soil Particle	Percentage (%)
Gravel	50 to 83
Sand	15 to 31
Silt	17
Clay	2
Silt & Clay	2

5.5 Bedrock

In Borehole 18289-02, bedrock was encountered at a depth of 12.7 m (Elev. 276.7 m) and was proven by coring.

The bedrock consisted of slightly weathered to fresh andesite transitioning to a mafic gneiss. The andesite is medium grained, crystalline, and grey in colour. The mafic gneiss is fine to medium grained, foliated, grey / black and pink. Photographs of the bedrock core are provided in Appendix C. The rock core quality parameters are summarized below:

Rock Core Quality Parameters	Range	Average
Total Core Recovery (TCR), %	100	100
Solid Core Recovery (SCR), %	53 to 63	58
Rock Quality Designation (RQD), %	58 to 62	60
Fracture Index (FI), per 0.3 m	1 to >10	4

The Rock Quality Designation (RQD) varied from 58 percent to 62 percent indicating a rock mass of fair quality.

Point load testing (PLT) was conducted on specimens of the bedrock recovered in Borehole 18289-02. Point Load Strength Index values, $I_{s(50)}$, were calculated in accordance with ASTM D5731 and are summarized as follows:

Lithology	Point Load Test	$I_{s(50)}$ Average (MPa)	$I_{s(50)}$ Range (MPa)	Number of Tests
Andesite to Mafic Gneiss	Diametral	8.3	3.1 – 10.8	7

Based on the ranges of $I_{s(50)}$, the gneiss bedrock is classified as strong (R4) to extremely strong (R6) in accordance with Table 3.5 in CFEM (2006).



5.6 Groundwater Conditions

Details of the water level observed in the boreholes upon completion of drilling are presented on the record of boreholes and summarized below.

Borehole	Date of Measurement	Groundwater Level (m)		Remark
		Depth	Elev.	
18289-01	October 14, 2022	0.3	284.0	Upon completion of drilling. ²
18289-02	September 22, 2022	4.1	285.3	Upon completion of drilling. ^{1,3}
18289-03	September 22, 2022	1.4	287.0	Upon completion of drilling. ^{1,3}
18289-04	October 19, 2022	2.2	287.2	Upon completion of drilling. ^{1,3}
18289-05	-	-	-	Not measured. ⁴

Note 1: Water level measured in casing.

Note 2: Water level measured in open borehole.

Note 3: Introduced water into borehole for drilling with wash boring methods and therefore, groundwater level at time of measurement was not considered stabilized.

Note 4: Introduced water into borehole for drilling with wash boring methods and therefore, groundwater level was not measured upon completion of drilling.

The water depth in the ditch at the inlet was observed at the time of the investigation and found to be less than 0.1 m deep. The ponded water near the outlet was found to be at approximately 0.3 m deep at the time of the investigation.

These groundwater levels are short-term observations and seasonal fluctuations of the groundwater levels are to be expected. In particular, the groundwater levels may be at a higher elevation during spring and after periods of significant or prolonged precipitation.

6. ANALYTICAL LABORATORY TESTING

One sample of the gravelly sand fill was submitted for analytical testing for corrosivity analysis and sulphide content. The analytical test results for the soil are presented in Appendix C and are summarized below.



Borehole	18289-04
Sample	SS6
Depth (m)	4.6 to 5.2
Elevation (m)	284.5
Sulphide (Na ₂ CO ₃) %	0.09
Chloride (µg/g)	68
Sulphate (µg/g)	156
pH	9.05
Conductivity (µS/cm)	386
Resistivity (Ohm-cm)	2,590

7. MISCELLANEOUS

Marathon Drilling of Greely, Ontario, OGS Inc. of Almonte, Ontario, and Forage Fusion Drilling of Hawkesbury, Ontario supplied and operated the drilling, sampling, and in-situ testing equipment for the field investigation. The field investigation was supervised on a full-time basis by Messrs. Ian Ross, B.A.Sc., Sergey Gladkiy, B.A.Sc., Arman Hasan, M.Eng., and Ibrahim Khan, M.Eng. The overall management of the field program was conducted by Ms. Alysha Kobylinski, P.Eng.

Geotechnical laboratory testing on soil samples was carried out in Thurber's geotechnical laboratories. Analytical laboratory testing was carried out by Paracel Laboratories Ltd., a CALA accredited analytical laboratory in Ottawa, Ontario.

Interpretation of the field data and preparation of this report was carried out by Ms. Alysha Kobylinski, P.Eng., and Mr. Christopher Ng, P.Eng. The report was reviewed by Messrs. Fred Griffiths, P.Eng., and P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects at Thurber.



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PART B: ENGINEERING DISCUSSION AND RECOMMENDATIONS

8. GENERAL

This report provides an interpretation of the geotechnical data in the foundation investigation report and presents foundation design recommendations for the proposed culvert replacement at STA 18+289 on Highway 556 in the Township of Deroche, Ontario.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, Ontario, and its designers, AECOM Canada Ltd. (AECOM), and shall not be used or relied upon for any other purposes or by any other parties including Contractors. Contractors must make their own interpretation based on the data provided in factual portion of the report (Part A). Where comments are made on construction, they are provided to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction must make their own interpretation of the information provided in Part A of this report as such interpretation may affect equipment selection, proposed construction methods, scheduling, and the like.

The highway embankment is up to 6 m high at the existing culvert location and as such, the proposed replacement culvert pipe is intended to be installed by trenchless methods due to constraints imposed by staged construction within the limited width of the right-of-way and the need for a deep excavation through the existing highway embankment.

It is understood that the diameter, and invert elevations at the inlet and outlet of the proposed culvert will be the same as the existing culvert; however, the location of the new culvert has not yet been determined but is expected to be located along the existing culvert alignment or to the east of the existing culvert. The invert elevations, diameter, and the soil types through which the culvert is anticipated to be installed are summarized below. The soil stratigraphy along the



assumed proposed pipe is shown on the Borehole Location and Soil Strata Drawing in Appendix D.

Assumed Invert Elevation at Inlet (m)	Assumed Invert Elevation at Outlet (m)	Assumed Culvert Size	Soil Type Around Pipe	Tunnelman's Ground Classification System
285.1 (south)	282.6 (north)	800 mm diameter	Ranging from Compact to Very Dense Gravel to Gravelly Sand Fill containing Cobbles and possible Boulders To Native Loose to Very Dense Gravelly Silty Sand to Silty Sand, containing Gravel to Silty Gravel Interlayers, Cobbles, and Boulders	Running / Flowing Running / Flowing

The finished highway grade of the highway is at approximately Elev. 289.4 m.

The Tunnelman's Ground Classification System is a framework for describing soil behaviour in an unsupported tunnel heading under atmospheric conditions. It was initially developed by Terzaghi in 1950 and later modified by Heuer in 1974. A summary of the Tunnelman's Ground Classification System according to Heuer, 1974, is presented in Appendix E.

The discussion and recommendations presented in this report are based on information provided by AECOM, and on the subsurface information obtained from the foundation investigation and laboratory testing.



9. CULVERT DESIGN CONSIDERATIONS

Based on the 30% Design Contract Drawings, dated February 16, 2023, the existing culvert at STA 18+289 is identified as needing replacement. Due to this location being a high fill embankment and considerations for traffic engineering and staged construction, replacement by trenchless methods is being considered.

9.1 Culvert Installation Methods

Based on the available subsurface information, the proposed culvert under Highway 556 at STA 18+289 will be installed through fill and native materials consisting of a mixture of loose to very dense gravel to gravelly sand to gravelly silty sand to silty sand, which contains cobbles and boulders. The water table is at or above the pipe invert.

For the proposed culvert replacement, several trenchless construction methods in addition to a cut and cover method were considered. Discussions of these methods are presented below.

- Hand Mining (Trenchless)

Hand mining is not considered practical for this project due to the relatively small tunnel diameter, worker safety, and time required for installation.

- Horizontal Directional Drilling (Trenchless)

Horizontal Directional Drilling (HDD) is not considered suitable for the installation of the replacement culvert at this site as it will be challenging to advance the HDD and maintain alignment through the cobbles and possible boulders within the embankment fill and/or native soils.

- Jack-and-Bore (Trenchless)

Jack-and-bore involves simultaneously jacking a casing while removing soil spoil by means of an auger. While this method may be capable of advancing through cobbles and smaller boulders, encountering any oversized obstructions (i.e., large boulders) within the fill and/or the native soils along the tunnel horizon would impede advancement and cause significant deviations to the alignment. As large obstructions are pushed aside and around the casing, ground heaving may occur. In addition, due to the unsupported tunnel face and the groundwater at or above the invert elevation, the embankment fill, and native soils could run/flow into the tunnel, resulting in ground loss, and/or sink holes. Therefore, this method is not recommended.



- Mechanical Tunnel Boring Machine (Trenchless)

Mechanical Tunnel Boring Machine (TBM) is feasible for various soil and groundwater conditions and has a steerable forward hood/shield for ground stabilization. However, it is typically used for large diameter tunnels (i.e., 2 m diameter or greater) and therefore, it is not recommended for this project.

- Pipe Ramming (Trenchless)

Pipe ramming involves driving a pipe from the access point to the exit point using the dynamic energy of a percussion hammer attached to the end of the pipe. After the casing installation is complete, the spoils inside are removed by augering. Compared to jack-and-bore method, pipe ramming may be more effective in advancing the tunnel through cobbles and small boulders. However, settlement of the embankment fill, and native soils may occur due to the loose conditions along the tunnel horizon and as a result of the percussive action of the hammer. In addition, there may be issues with misalignment if obstructions are encountered. A larger casing diameter could be considered to provide allowance for the removal of obstructions; however, larger equipment will also be required due to increased friction on the pipe. As such, this method is not recommended.

- Pipe Crushing/Swallowing (Trenchless)

Pipe crushing is a type of pipe ramming where an oversized casing is driven over the existing culvert instead of on a new alignment. The casing shoe is equipped with fins to crush the existing culvert during the casing installation. Once the installation is complete, the existing culvert is removed by steel cables and winch system, or by bursting tools. Similar to pipe ramming, settlement of the embankment fill, and native soils may occur due to the very loose to loose conditions along the tunnel horizon and the percussive action of the hammer. There are also risks associated with the existing culvert becoming an obstruction if the existing culvert has developed a sag due to settlement of the founding soils, or if there is a misalignment between the casing and the existing culvert. In addition, pipe crushing may require diversion of surface water during installation. As such, this method is not recommended.

- Microtunnelling (Trenchless)

Microtunnelling using a Microtunnelling Boring Machine (MTBM) (with face pressure balance if required) may be used to advance the bore after which the pipe can be installed. A wide variety of cutter heads make microtunnelling feasible for the soil and groundwater



conditions at this site. Microtunnelling is a steered technique which would be able to adjust for deflections in the alignment due to the presence of cobbles and possible boulders. A suitable cutter head will be required to advance through cobbles and possible boulders. A larger bore diameter of 1.2 m or greater should be considered for microtunnelling to facilitate installation through cobbles and possible boulders.

- Small Boring Unit (Trenchless)

Small boring unit (SBU) is a remote-controlled pipe jacking technique designed for smaller diameter boring. A SBU can advance through hard rock and other obstructions with appropriate cutter head. Like microtunnelling, SBU is technically feasible; however, a consideration should be given to selecting a suitable cutter head capable of advancing through cobbles and possible boulders and a larger bore diameter of a minimum of 1.2 m.

- Cut and Cover

Conventional open cut excavation is also feasible for the installation of replacement culvert; however, it will require a relatively deep excavation through the high fill embankment and will require the use of a robust temporary protection system. Unlike the other installation methods, cut and cover will cause some disruption to traffic during installation.

A comparison of the various installation methods is presented in Table F1 in Appendix F.

From the foundation engineering perspective with regards to the technical, constructability and, risk management of the proposed work, cut and cover is considered to carry the lowest risks. Should a trenchless installation method be chosen over the cut and cover method, microtunnelling, and SBU are the most feasible methods and carry less risk than other trenchless methods. Jack-and-bore, pipe ramming, and pipe swallowing carry a high degree of risk if obstructions are encountered and are not recommended for the proposed culvert installation.

9.2 Trenchless Installation

Where there are concerns with misalignment of the tunnel using trenchless installation, inaccuracies may be mitigated by installing a larger casing than the designed culvert diameter, into which the new culvert can be inserted, adjusted to the appropriate alignment, and the annular space between the casing and new culvert grouted. Larger casing diameters are also less likely to be deflected by obstructions and will allow for the removal of large obstructions (i.e., boulders) if a sufficiently large casing is used. On the other hand, a larger diameter tunnel implies reduced cover with an increase in risk that the tunnelling operations will be manifest as settlement or heave



at the roadway surface. In this case, even with a tunnel diameter of 1.2 m the cover to diameter ratio still exceeds 3 which is generally considered acceptable.

Selection of an appropriate method of trenchless installation is the responsibility of the Contractor and will depend upon the relative costs and risks associated with each method. The suitability of each method is subject to factors including soil types, groundwater conditions, equipment availability, and Contractor's expertise/experience. The experience of the Contractor is of primary importance, particularly for a trenchless installation. If a trenchless installation method is adopted by the Contractor, the Contractor must submit a detailed work plan, including the proposed methodology, maintenance of alignment, and disposal of cuttings, all in accordance with the requirements of the Non-Standard Special Provision (NSSP) "Pipe Installation by Trenchless Methods". A copy of this NSSP is attached in Appendix G.

Designer fill-ins for the NSSP "Pipe Installation by Trenchless Methods" are as follows:

Designer Fill-In	Designer Comment and Fill-In (as applicable)
* Insert the following fill-in: Any method that is not suitable shall be specified.	Add to Section 4.01.01 of the NSSP: "Hand mining, horizontal directional drilling, jack-and-bore, pipe ramming, and pipe crushing/swallowing shall not be utilized at this site."
** Insert the following fill-in: Specify minimum requirements commensurate with complexity.	<p>The Project Superintendent shall have a minimum of five (5) years of experience on projects with similar scope and complexity, which includes one (1) project involving trenchless installation through cohesionless overburden containing cobbles and boulders.</p> <p>During construction, the Project Superintendent shall not be changed without written permission from the Contract Administrator. A proposal to change the Project Superintendent shall be submitted at least one week prior to the actual change in Project Superintendent.</p>
*** Insert the following fill-in: Specify minimum requirements commensurate with complexity.	The Trenchless Contractor shall have a minimum of five (5) years of experience on projects with similar scope and complexity, which includes one (1) project involving trenchless installation through cohesionless overburden containing cobbles and boulders.
**** Insert the following fill-in: Subsurface Condition Baseline Reporting that includes	The Contractor is alerted that cobbles and boulders are expected within the soil deposits



Designer Fill-In	Designer Comment and Fill-In (as applicable)
Boulder Volume Ratio (BVR), Boulder Number Ratio (BNR) shall be project specific and included in the Foundation Engineering TOR as selected during the scoping of the project.	at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles and boulders with diameters less than 400 mm shall be expected to be routine and will not be considered obstructions. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered
***** Insert the following fill-in: Any known obstructions shall be specified.	Add to Section 7.01.12 of the NSSP: "The Contractor's methodology must not cause ground settlement around the trenchless installation."
***** 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.	The work specified in this section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability. The locations of the instruments are shown on the contract drawings and described below.
***** Insert the following fill-in: Project specific Review and Alert Levels shall be provided if required.	Project specific review and alert levels are not required. The review and alert levels in Section 7.08 of NSSP "Pipe Installation by Trenchless Methods" are applicable.
***** Insert the following fill-in: Payment for removal of boulders exceeding Boulder Volume Ratio (BVR) and Boulder Number Ratio (BNR) shall be by Time and Material.	Add the following to Section 10 of the NSSP: "Payment for removal of boulders with diameter 400 mm or greater shall be on a time and material basis."

9.2.1 Instrumentation and Monitoring Program

Instrumentation and monitoring for potential settlements on the highway should be implemented in accordance with Section 7.07 of the NSSP Pipe Installation by Trenchless Methods; a copy of which is included in Appendix G. The site-specific instrumentation plan is included in Appendix H.

The impact of the proposed installation on existing nearby structures and underground utilities should be assessed. In accordance with MTO's Guideline for Foundation Engineering – Tunnelling Specialty for Corridor Encroachment Permit Application, a pre-construction condition survey should be carried out for structures and facilities within 100 m of construction prior to the start of construction for the purpose of restoration. Monitoring of the roadway surface and underground utilities (where required) should be carried out during construction.



9.2.2 Temporary Pits

Clearing of trees and other vegetation in the immediate area surrounding the temporary pits must be carried out prior to the start of excavation.

The temporary pits are anticipated to be shallow at the launching and receiving points and therefore, sloped excavations should be feasible. Temporary launching and receiving pit excavations at either end of the crossing will extend through the dense gravel to sand fill (containing cobbles and possible boulders), and native loose to very dense silty sand (containing gravel interlayers, cobbles, and boulders). Bedrock was encountered at Elev. 276.7 m in Borehole 18289-02 and is not anticipated to be encountered during excavations for temporary staging pits.

Once the method of installation has been selected, and the design of launching and receiving pits is available, the impact of the launching and receiving pit excavations on the stability of the highway embankment must be assessed by the Contractor. The excavation of the temporary pits must not destabilize the highway embankment.

The equipment required and method of excavation should be capable of handling and removing cobbles and boulders present in the embankment fill and/or native soils.

9.3 Cut and Cover Installation

With typical culvert replacements, several cut and cover options are available, including:

- Open Cut with Full Road Closure and Temporary Detour
Installation of a new culvert using open cut techniques and a full road closure would allow for an expedited construction schedule and could reduce costs associated with roadway protection and tunnelling. However, it is anticipated that an acceptable detour option is not available, and therefore this option is not considered further.
- Open Cut with Staged Temporary Widening or Detour Embankment
Installation of a new culvert using open cut with a temporary widening and/or construction of a temporary detour embankment to accommodate passage of traffic during construction could be considered but would require an easement to facilitate the use of this option, due to the narrow right-of-way. Given the embankment height of approximately 6 m, presence of overhead utilities and nearby entrances, and the horizontal and vertical curvature of the highway, the feasibility of an open cut replacement with temporary widening or detour embankment will be limited.



- Open Cut with Staged Construction and Temporary Grade Lowering

Installation of a new culvert using an open cut staged replacement with grade lowering to maintain movement of traffic within the existing embankment footprint is considered a feasible option from a foundation perspective. Due to the nearby entrances and highway curves, temporary grade lowering on its own may not create a sufficiently wide platform geometrically; however, limited temporary grade lowering may be feasible and could be used in conjunction with a temporary protection system (as described below).

- Open Cut with Staged Construction and Temporary Protection System

Installation of a new culvert using an open cut staged replacement is considered feasible from a foundation perspective. The option would require roadway protection, as discussed further in Section 12, installed near the embankment centerline to maintain a single lane of traffic flow along the current highway embankment. However, the Contractor would need to consider the presence of cobbles and boulders within the embankment fill and/or native soils during the installation of roadway protection, as well as the depth to bedrock. To reduce lateral deflections of the protection system, anchoring and/or bracing may be required. Where permitted within the constraints of the highway, the height of the protection system and the depth of installation could be reduced when combined with a temporary grade lowering. Sheet pile would be difficult to install through potential obstruction (i.e., large boulders). A soldier pile and lagging system where the soldier piles are installed in pre-augered holes may be required.

- Open Cut with Temporary Modular Bridge

Installation of a new culvert using an open cut with a temporary modular bridge (TMB) to provide a single lane of traffic passage over the open excavation is generally considered feasible from a foundation perspective. The design length of the TMB must consider the need for stable excavation slopes and set-back between the TMB footing and the crest of the front and side slopes. In addition, consideration must be given to the presence of overhead utilities, the horizontal and vertical curvature of the highway, and the required length of the TMB when evaluating the feasibility of this option. Additional investigation is required at the abutments of the TMB to provide foundation design recommendations. It is anticipated that TPS would be required to allow construction of the TMB foundations. It is expected that this option would be more expensive than the other open cut methods, therefore it is not recommended.

From the foundation engineering perspective, an open cut method employing the use of temporary protection system and temporary grade lowering is recommended.

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E file: <https://thurberengineering.sharepoint.com/sites/31719/Shared Documents/Reports & Memos/02 - Culvert 18+289>

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9.3.1 Subgrade Preparation, Embedment, Bedding, Cover and Backfilling

The culvert shall be constructed in accordance with OPSS.PROV 401, and OPSS.PROV 421 for pipe culverts or OPSS.PROV 422 for box culverts.

Subgrade preparation for the culvert replacement should include excavation and removal of the existing culvert (if replaced along the same alignment). At the founding level, all organic material, soft or loose soils, disturbed soils, or otherwise deleterious materials shall be excavated within the plan limits of the culvert installation.

Following inspection and approval by qualified geotechnical personnel of the exposed subgrade, additional fill that may be required to raise the grade to the underside of the proposed bedding layer, shall consist of OPSS.PROV 1010 Granular A or B Type II.

Culvert construction, including placement of bedding, levelling, embedment, cover, and/or backfill should be carried out in accordance with the following standards associated with each culvert type:

Culvert Type	OPSD Reference	OPSS Reference
Corrugated Steel Pipe	OPSD 802.010 – Flexible Pipe Embedment and Backfill, Earth Excavation	OPSS.PROV 421 – Pipe Culvert Installation in Open Cut
Concrete Pipe	OPSD 802.030 – Rigid Pipe Bedding, Cover, and Backfill, Type 1 or 2 Soil – Earth Excavation OPSD 802.031 – Rigid Pipe Bedding, Cover, and Backfill, Type 3 Soil – Earth Excavation	OPSS.PROV 421 – Pipe Culvert Installation in Open Cut
Precast Concrete Box	OPSD 803.010 – Backfill and Cover for Concrete Culverts	OPSS.PROV 422 – Installation of Precast Reinforced Concrete Box Culverts with Span 3 m or Less in Open Cut

In accordance with OPSS.PROV 421 and OPSS.PROV 422, all work shall be protected from freezing and bedding material shall not be placed on frozen ground.

The bedding, cover, and backfill should be placed in lifts not exceeding 200 mm in loose thickness, and compacted in accordance with OPSS.PROV 501, as amended by Special Provision 105S22. For a precast concrete box culvert, a minimum 75 mm thick uncompacted levelling course should be placed over a 300 mm thick layer of prepared bedding.



The bedding, levelling, cover, and embedment materials should consist of granular fill meeting the specification of OPSS.PROV 1010 Granular A or B Type II with 100% passing the 26.5 mm sieve. The backfill material should consist of OPSS.PROV 1010 Granular A or Granular B Type II. Excavated soils should not be used as backfill.

In accordance with OPSD 3090.100, the depth of frost penetration is approximately 1.9 m.

10. CONTROL OF SURFACE WATER AND GROUNDWATER

Groundwater observations show the groundwater table at the time of the investigation is at or above the invert of the proposed pipe and therefore, seepage from the embankment and native soils during installation of the culvert should be anticipated. The embankment fill and native soils consist of a mixture of sands and silts, containing, gravels, cobbles, and possible boulders. These soils are expected to have high hydraulic conductivity and permeability.

For construction of temporary pits, it is expected pumping from properly filtered sumps should be adequate to handle groundwater and surface runoff entering the launching and receiving pit excavations if conditions at the time of construction are consistent with those observed during the investigation.

For open cut excavation, dewatering the subgrade may not be practical and as such, consideration may be given to preparing the culvert subgrade in the wet. An option to consider is the use of 53 mm clear stone meeting the specifications of OPSS.PROV 1004, wrapped in geotextile, as subgrade fill. Alternatively, small diameter rock fill (i.e., up to 150 mm diameter) can be used in place of clear stone. The geotextile should meet the specification for OPSS.PROV 1860 Class II, non-woven geotextile with a maximum fabric opening size (FOS) of 212 µm. Once the clear stone fill is above the water level, the remaining bedding should be placed in dry conditions and the culvert constructed in accordance with OPSS.PROV 401, OPSS.PROV 421 or OPSS.PROV 422 (as applicable) as detailed in Section 9.3.1.

Any ponded water at the inlet and in areas of proposed temporary pits should be drained prior to beginning of excavations and construction.

The dewatering system is to be designed in accordance with OPSS.PROV 517, as amended by Special Provision 517F01. Considering the excavation will be made in highly permeable soils, a design Engineer and design-checking Engineer with a minimum of 5 years of experience in designing systems of similar nature and scope to the required work is required, and thus Designer Fill-In ***** in Special Provision 517F01 should be "Yes".



Groundwater taking for construction dewatering is governed by the Ontario Water Resources Act (OWRA), Environmental Protection Act (EPA) and the Water Taking and Transfer Regulation 387/04, a regulation under the OWRA.

If the water taking rate for this project will be greater than 50,000 L/day and less than 400,000 L/day, registration on the Environmental Activity and Sector Registry (EASR) is required. If the water taking rate will be greater than 400,000 L/day, a Category 3 Permit-To-Take Water (PTTW) is required. The rate of water taking should be assessed by a qualified hydrogeologist once the preferred culvert installation method has been selected.

The groundwater level will fluctuate and the minimum groundwater elevation for the site at the time of the proposed works should be taken as the water level from the design storm period defined by the contract documents.

11. SCOUR AND EROSION PROTECTION

The Contractor shall provide silt fences and erosion control blankets as per OPSS.PROV 805 and OPSD 219.110 throughout the duration of construction to prevent transport of silt/sediment.

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the earth and granular embankment slopes. A vegetation cover shall be established on exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 803 and OPSS.PROV 804. Surface water shall be prevented from flowing on unprotected slopes. Vegetation shall be established as soon as practical after completion of the embankment fills to limit surficial erosion.

Particle size analysis on samples of the existing embankment fill and native soils indicate that the soils have a low to moderate potential for soil erodibility (Wischmeier Nomograph factor, K ranging from 0.05 to 0.35).

Scour and erosion protection should be provided for the culvert inlet and outlet areas. Effective scour and erosion protection should be provided along the waterline and ditches. Design of the erosion protection measures must consider hydrologic and hydraulic factors and shall be carried out by specialists experienced in this field. Typically, rock protection should be provided over all earth surfaces subjected to flowing water in accordance with OPSS.PROV 511. Treatment at the outlet should be in accordance with OPSD 810.010.

It is recommended that a clay seal be used for an open cut culvert replacement to minimize the potential for piping and erosion around the inlet of the culvert. The clay seal must extend to



approximately 300 mm above the high-water level and laterally for the width of the granular material and have a minimum thickness of 500 mm. The material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner could be considered for use as a clay seal.

12. TEMPORARY EXCAVATIONS AND PROTECTION SYSTEMS

All temporary excavations must be carried out in accordance with the current Occupational Health and Safety Act (OHSA) of Ontario and local regulations. If an excavation penetrates more than one soil type, the entire excavation must be completed in accordance with the more stringent requirement. The embankment fill, and native soils above the water table at this site are classified as Type 3 soils under OHSA. Below the water table they are classified as Type 4 soils; an open cut excavation extending below the water table will require 3H:1V side slopes. Given the depth of the anticipated cut and cover excavation at this site, it is recommended that temporary cut slopes in Type 3 soils be sloped at 1H:1V or flatter. Should excavations extend into the Type 4 soils, the entire cut slope should be at 3H:1V or flatter. Alternatively, excavation slopes should be supported with a temporary protection system.

Excavation should occur in a dewatered environment (see Section 10). Excavations must be planned and carried out in a manner that does not impact on the stability of existing roadway. The temporary cut slopes may have to be protected from precipitation and runoff to avoid surficial instabilities. The duration of temporary open excavations and cut slopes should be minimized to reduce the likelihood of causing instability concerns. Embankment and cut slope stability are the responsibility of the Contractor.

The excavation must be carried out in accordance with OPSS.PROV 401, OPSS.PROV 421 and OPSS 422 and will be carried out through existing embankment fill and into the underlying native soils. Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor.

Material stockpiling is a temporary construction measure and the associated stability implications are the responsibility of the Contractor. The selection and placement of construction equipment (such as cranes) and construction of temporary construction access roads are also the Contractor's responsibility. Placement of the crane or temporary stockpiling must not destabilize the embankment.

Temporary protection systems may be required at the launching and receiving pits to facilitate the installation of the new pipe by trenchless methods. Roadway protection will also be required for staging if cut and cover is chosen as the preferred installation method. Where required, temporary



protection systems should be designed and constructed in accordance with OPSS.PROV 539, as amended by Special Provision 105S09. The lateral movement of the temporary protection systems shall meet Performance Level 2 as specified in OPSS.PROV 539, provided that any existing adjacent utilities can tolerate the associated magnitude of deformation. The selection and design of the protection system will be the responsibility of the Contractor.

The subsurface conditions anticipated during installation of the protection system will include gravel to sand fill containing cobbles and possible boulders, and native silty sand, containing gravel interlayers, cobbles, and boulders. Options for temporary protection systems often include interlocking sheet piles or soldier pile-lagging system. Due to the presence of cobbles and boulders in the fill and/or native overburden, it will be difficult to drive sheet piles to sufficient depth and therefore, sheetpiles are not considered a feasible option. A soldier pile-lagging system is anticipated to be the other temporary protection system option. It may be possible for the soldier piles to be driven through the embankment fill and into the native soils; however, there will be risk associated with pile refusal on cobbles and boulders. As such, consideration could be given to installing soldier piles in pre-augered holes to a sufficient depth for the support of the temporary protection system. If a sufficient depth cannot be achieved in the overburden, the soldier piles may need to be pre-augered through the overburden and socketed into the underlying bedrock.

The design of the temporary protection system is the responsibility of the Contractor. Full hydrostatic pressure should be considered assuming a water level at least equal to the design storm period water level as defined by the contract documents. The actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors must be considered when designing the shoring system. All shoring systems should be designed by a Professional Engineer experienced in such designs, who will determine an appropriate support system.

The soil parameters presented below may apply for design of the temporary roadway protection system with horizontal backfill.

Stratigraphic Unit	Unit Weight of Material, γ' (kN/m ³)	Angle of Internal Friction, ϕ (kN/m ³)	Coefficient of Static Lateral Earth Pressure	
			Active, K_a	Passive, K_p
Existing Embankment Fill	20	32	0.31	3.3
Native Gravelly Silty Sand and Silty Sand	20	32	0.31	3.3

Note:

1. The lateral earth pressure coefficients presented above are based on static loading conditions and level backfill/ground surface behind the protection system. Where there is sloping ground behind the protection system, the coefficient of lateral earth pressure must be adjusted to account for the slope.
2. The total passive resistance below the base of excavation, if required, may be calculated based on the values of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.27 of the Canadian Highway Bridge Design Code (CHBDC, 2019) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

In accordance with OPSS.PROV 539, should the temporary protection systems be left in place after completion of the installation, the top shall be removed to at least 1.2 m below the finished grade or ground level, or at least 0.6 m below the streambed.

13. EMBANKMENT REINSTATEMENT

Both the overall south-facing and north-facing side slopes of the existing embankment are inclined at approximately 2H:1V; however, a section of the north-facing slope is as flat as 2.7H:1V with a local section at the toe of slope as steep as 0.5H:1V. The slopes did not show any visible signs of global instability at the time of the investigation.

Embankment reinstatement after construction of the replacement culvert should be carried out in accordance with OPSS.PROV 206 with embankment side slopes constructed to 2H:1V or flatter provided the reinstatement is completed with OPSS.PROV 1010 Granular B Type II. Embankment reinstatement with side slopes steeper than 2H:1V and as steep as 1.25H:1V must be constructed using rock fill. The fill placement and compaction should be carried out in accordance with OPSS.PROV 501, as amended by Special Provision 105S22.

Where newly placed embankment fill is placed against existing embankment slopes or on a sloping ground surface steeper than 3H:1V, benching of the existing slope should be carried out in accordance with OPSD 208.010.



If the permanent embankment envelope remains unchanged, foundation settlement is also expected to be negligible.

The magnitude of the embankment self-compression constructed with granular materials is in the order of 0.5% of the newly reconstructed embankment height and is expected to occur predominantly during fill placement.

If the existing culvert is to be abandoned in place, the abandonment should be carried out in accordance with OPSS.PROV 510. If the existing culvert is to be removed, the placement of backfill should be carried out with the procedure, material, and slopes as described above. Settlement of the native soils is estimated to be less than 10 mm upon completion of grouting or replacement with embankment fill.

14. CORROSION POTENTIAL

Based on results of corrosivity testing on a sample of the gravelly sand fill, the following statements can be made in reference to the MTO Gravity Pipe Design Guideline. However, the effects of road de-icing salts/chemicals should be considered when selecting pipe material and/or corrosion mitigation measures.

- The resistivity of the fill was measured to be 2,590 ohm-cm, which indicates the soil is of moderate corrosion potential ($2,000 \text{ ohm-cm} < R < 4,500 \text{ ohm-cm}$) according to Table 3.2 of the MTO Gravity Pipe Design Guideline.
- The sulphate concentration of the fill was measured to be 156 µg/g, which is considered to have a negligible degree of sulphate attack on concrete according to Table 7.2 of the MTO Gravity Pipe Design Guideline.
- The pH level of the fill was measured to be 9.05, and according to Section 7.1.1 of the MTO Gravity Pipe Design Guideline, pH levels greater than 8.5 is strongly alkaline and is indicative of an increased potential for corrosion.

15. CONSTRUCTION CONCERNS

Potential construction concerns that have been identified for this project include the following:

15.1 Loss of ground

The feasible trenchless methods discussed in Section 0 carry varying degrees of risk of loss of ground for tunnelling through mixed face conditions containing cobbles and possible boulders with groundwater table at or above the culvert invert. The Contractor is required to select a



suitable method for culvert installation such that the ground settlement review and alert levels of 10 mm and 15 mm, respectively, stipulated in the NSSP for Pipe Installation by Trenchless Method in Appendix G can be satisfied. In addition, contingency plans should be in place to manage any adverse impacts on Highway 556.

15.2 Obstructions

The existing highway embankment fill, and the native soils contain cobbles and boulders. The Contractor's equipment and methodology must be selected to handle such obstructions and successfully remove them without jeopardizing the performance or operation of the highway. The selected trenchless installation methodology should have mitigating potential for both horizontal and vertical pipe misalignments due to such obstructions. In addition, temporary protection systems must be selected considering the presence of cobbles and boulders in the embankment fill and native soils.

15.3 Existing Culvert and Other Buried Utilities


If a trenchless method is selected as the preferred method for the culvert replacement, the Contractor must accurately establish, in three dimensions, the locations of all buried utilities crossing or closely paralleling the path of the bore, including the existing 800 mm diameter culvert. It is recommended that the existing culvert be monitored during trenchless activities. Additionally, it is recommended that the proposed replacement culvert should be at least 2.4 m (or 2 bore diameters) clear distance away from the existing culvert. The existing culvert should be decommissioned by grouting. Given the small diameter of the existing culvert, the competency of the underlying soils and the amount of cover above the culvert, settlement induced by grouting will be minimal at the road surface.

16. CLOSURE

Engineering analysis and preparation of this report was carried out by Ms. Alysha Kobylinski, P.Eng., and Mr. Christopher Ng, P.Eng. The report was reviewed by Messrs. Fred Griffiths, P.Eng., and P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations Projects at Thurber.




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STATEMENT OF LIMITATIONS AND CONDITIONS

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This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

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The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

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5. INTERPRETATION OF THE REPORT

- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.
- b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.
- c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.
- d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

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The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.



Appendix A

Site Photographs



Photograph #1 – Highway 556 south embankment slope, facing East. Inlet at base of embankment slope surrounded by mixed forest (September 2022)



Photograph #2 – Toe of south embankment slope at culvert inlet facing West. Culvert visible in bottom corner (September 2022)



Photograph #3 – North-facing embankment slope from highway grade, facing West. Culvert not visible (September 2022)



Photograph #4 – North-facing embankment slope at highway grade, facing East. Culvert not visible (September 2022)



Photograph #5 – Surficial erosion of the unvegetated portion of the south-facing embankment slope, facing west.



Photograph #6 – Culvert inlet, covered by vegetation



Photograph #7 – Culvert outlet, surrounded by forest vegetation, facing south.



Photograph #8 – Soil cuttings from advancing borehole with augers in embankment fill at Borehole 18289-03. Note gravel and cobble-sized particles in soil cuttings.



Photograph #9 – Selection of gravel and cobble sized particles recovered from embankment fill soil cuttings from advancing borehole 18289-03 with augers. Largest cobble dimension in above photograph is approximately 175 mm.



Appendix B

Record of Borehole Sheets

SYMBOLS, ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES

1. TEXTURAL CLASSIFICATION OF SOILS

CLASSIFICATION	PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	Greater than 200mm	same
Cobbles	75 to 200mm	same
Gravel	4.75 to 75mm	5 to 75mm
Sand	0.075 to 4.75mm	Not visible particles to 5mm
Silt	0.002 to 0.075mm	Non-plastic particles, not visible to the naked eye
Clay	Less than 0.002mm	Plastic particles, not visible to the naked eye

2. COARSE GRAIN SOIL DESCRIPTION (50% greater than 0.075mm)

TERMINOLOGY	PROPORTION
Trace or Occasional	Less than 10%
Some	10 to 20%
Adjective (e.g. silty or sandy)	20 to 35%
And (e.g. sand and gravel)	35 to 50%

3. TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH (kPa)	APPROXIMATE SPT ⁽¹⁾ 'N' VALUE
Very Soft	12 or less	Less than 2
Soft	12 to 25	2 to 4
Firm	25 to 50	4 to 8
Stiff	50 to 100	8 to 15
Very Stiff	100 to 200	15 to 30
Hard	Greater than 200	Greater than 30

NOTE: Hierarchy of Soil Strength Prediction

- 1) Laboratory Triaxial Testing
- 2) Field Insitu Vane Testing
- 3) Laboratory Vane Testing
- 4) SPT value
- 5) Pocket Penetrometer

4. TERMS DESCRIBING DENSITY (COHESIONLESS SOILS ONLY)

DESCRIPTIVE TERM	SPT "N" VALUE
Very Loose	Less than 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very Dense	Greater than 50

5. LEGEND FOR RECORDS OF BOREHOLES

SYMBOLS AND ABBREVIATIONS FOR SAMPLE TYPE	SS Split Spoon Sample	WS Wash Sample	AS Auger (Grab) Sample
	TW Thin Wall Shelby Tube Sample	TP Thin Wall Piston Sample	
	PH Sampler Advanced by Hydraulic Pressure	PM Sampler Advanced by Manual Pressure	
	WH Sampler Advanced by Self Static Weight	RC Rock Core	SC Soil Core

$$\text{Sensitivity} = \frac{\text{Undisturbed Shear Strength}}{\text{Remoulded Shear Strength}}$$


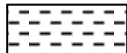



 Water Level
 Shear Strength Determination by Pocket Penetrometer

- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration of a 50 mm outside diameter, 60° conical steel point attached to "A" size rods driven by a 63.5 kg hammer free falling a height of 0.76 m. The resistance to cone penetration is the number of hammer blows required for each 0.3 m advance of the conical point into undisturbed ground.

UNIFIED SOILS CLASSIFICATION

MAJOR DIVISIONS		GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS W _L < 50%	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays. (W _L < 30%).
		CI	Inorganic clays of medium plasticity, silty clays. (30% < W _L < 50%).
		OL	Organic silts and organic silty-clays of low plasticity.
	SILTS AND CLAYS W _L > 50%	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils.
CLAY SHALE			
SANDSTONE			
SILTSTONE			
CLAYSTONE			
COAL			

EXPLANATION OF ROCK LOGGING TERMS

<u>ROCK WEATHERING CLASSIFICATION</u>		<u>SYMBOLS</u>	
Fresh (FR)	No visible signs of weathering.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

<u>DISCONTINUITY SPACING</u>		<u>STRENGTH CLASSIFICATION</u>			
Bedding	Bedding Plane Spacing	Rock Strength	Approximate Uniaxial Compressive Strength (MPa) (psi)	Field Estimation of Hardness*	
Very thickly bedded	Greater than 2m	Extremely Strong	Greater than 250	Greater than 36,000	Specimen can only be chipped with a geological hammer
Thickly bedded	0.6 to 2m				
Medium bedded	0.2 to 0.6m	Very Strong	100-250	15,000 to 36,000	Requires many blows of geological hammer to break
Thinly bedded	60mm to 0.2m	Strong	50-100	7,500 to 15,000	Requires more than one blow of geological hammer to break
Very thinly bedded	20 to 60mm				
Laminated	6 to 20mm	Medium Strong	25.0 to 50.0	3,500 to 7,500	Breaks under single blow of geological hammer.
Thinly Laminated	Less than 6mm				

<u>TERMS</u>					
Total Core Recovery: (TCR)	Core recovered as a percentage of total core run length.	Weak	5.0 to 25.0	750 to 3,500	Can be peeled by a pocket knife with difficulty
Solid Core Recovery: (SCR)	Percent Ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run.	Very Weak	1.0 to 5.0	150 to 750	Can be peeled by a pocket knife, crumbles under firm blows of geological pick.
Rock Quality Designation: (RQD)	Total length of sound core recovered in pieces 0.1m in length or larger as a percentage of total core run length.	Extremely Weak (Rock)	0.25 to 1.0	35 to 150	Indented by thumbnail
Uniaxial Compressive Strength (UCS)	Axial stress required to break the specimen				
Fracture Index: (FI)	Frequency of natural fractures per 0.3m of core run.				

RECORD OF BOREHOLE No 18289-01

1 OF 1

METRIC

W.P. 5221-18-00 LOCATION MTM Zone 13: N 5 177 562.9 E 293 879.2 ORIGINATED BY AH
DIST Algoma HWY 556 BOREHOLE TYPE Portable Drilling, Wash Boring, BW Casing Advance, AW Coring COMPILED BY AK
DATUM Geodetic DATE 2022.10.13 - 2022.10.14 LATITUDE 46.737549 LONGITUDE -84.142905 CHECKED BY CN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
284.3	GROUND SURFACE							20	40	60	80	100	PLASTIC LIMIT W P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W L	GR	SA	SI	CL
0.0	Sandy SILT , trace gravel, trace clay Compact Dark Brown Wet		1	SS	17		284							○		8	30	55	7
283.7																			Non-Plastic
0.6	Sandy silty GRAVEL , trace clay Compact to Dense Brown Moist Coring from a depth of 1.0 to 1.5 m		2	SS	23									○		50	31	17	2
			1	AW	-														
			2	AW	-		283												
			3	SS	31									○					
			3	AW	-														
282.0	Coring from a depth of 2.1 to 2.3 m						282							○					
2.3	Gravelly silty SAND , trace clay Very Dense Brownish Grey to Light Grey Wet Coring from a depth of 2.7 to 3.2 m		4	SS	82/0.25									○		24	50	22	4
			4	AW	-														
	Coring from a depth of 3.4 to 4.0 m		5	SS	50/0.075		281							○					
			5	AW	-														
	Coring from a depth of 4.1 to 4.4 m		6	SS	50/0.100									○					
			6	AW	-		280												
279.9																			
4.4	END OF BOREHOLE AT 4.4 m. BOREHOLE BACKFILLED WITH BENTONITE. NOTES: 1. The cored depth intervals and particle sizes of recovered gravels, and cobbles are summarized as follows Depth (m) Recovered 1.0 - 1.1 1 x 100 mm cobble 1.1 - 1.5 gravels up to 75 mm 1.5 - 2.3 gravels up to 50 mm 2.7 - 3.2 1 x 80 mm cobble, gravel up to 30 mm 3.4 - 4.0 gravels up to 50 mm 4.1 - 4.4 gravels up to 30 mm 2. Borehole terminated at a depth of 4.4 m as a result of casing refusal (seized casing) within the cobbles and boulder from a depth of 4.1 m to 4.4 m. 3. Water level at a depth of 0.3 m below ground surface (Elev. 284.0 m) in open borehole upon removal of casing, prior to abandonment.																		

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18289-02

1 OF 2

METRIC

W.P. 5221-18-00 LOCATION MTM Zone 13: N 5 177 568.3 E 293 863.6 ORIGINATED BY SG
DIST Algoma HWY 556 BOREHOLE TYPE CME 75, Wash Boring, HW Casing Advance, NQ Coring COMPILED BY AK
DATUM Geodetic DATE 2022.09.21 - 2022.09.22 LATITUDE 46.737597 LONGITUDE -84.143109 CHECKED BY CN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa				WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	20	40	60	80	100	W _P		
289.4	GROUND SURFACE						20	40	60	80	100					
0.8	ASPHALT: (25 mm)		1	SS	47/0.100							○				
	GRAVEL and SAND, trace non-plastic fines Compact Brown Wet (FILL)		2	SS	70/0.030							○				48 47 5 (SI+CL)
	Casing grinding from a depth of 0.6 m to 1.2 m		3	SS	30							○				
			4	SS	17							○				
286.4																
3.0	GRAVEL Loose Black Wet (FILL)		5	SS	8											
285.7	Casing grinding from a depth of 3.0 m to 3.7 m															
3.7	Gravelly SAND, trace non-plastic fines Very Loose to Very Dense Brown to Grey Wet (FILL)		6	SS	WH							○				34 57 9 (SI+CL)
	Casing grinding from a depth of 4.6 m to 5.8 m		7	SS	30							○	○			
283.6																
5.8	GRAVEL, trace sand Dense Dark Brown to Grey Wet		8	SS	33											
282.2																
7.2	Silty SAND, trace gravel, trace clay Very Dense Grey Wet		9	SS	60/0.075							○				9 57 31 3
			10	SS	39/0.075							○				
						</										

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18289-02

2 OF 2

METRIC

W.P. 5221-18-00 LOCATION MTM Zone 13: N 5 177 568.3 E 293 863.6 ORIGINATED BY SG
DIST Algoma HWY 556 BOREHOLE TYPE CME 75, Wash Boring, HW Casing Advance, NQ Coring COMPILED BY AK
DATUM Geodetic DATE 2022.09.21 - 2022.09.22 LATITUDE 46.737597 LONGITUDE -84.143109 CHECKED BY CN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				WATER CONTENT (%) w _P w w _L					
Continued From Previous Page								20 40 60 80 100				20 40 60				GR SA SI CL	
279.3 10.1	GRAVEL , some sand, trace non-plastic fines Very Dense Grey Wet		11	SS	50/0.120		279								83 15 2 (SI+CL)		
277.8 11.6	Silty SAND , trace gravel Very Dense Grey Wet		12	SS	11/0.750		277								FI >10 4 3 2 4 1 1 5 2 3		
276.7 12.7	Slightly weathered to fresh, massive, grey, medium grained, faintly porous strong ANDESITE		1	RUN	-		276								RUN #1 TCR=100% SCR=53% RQD=62%		
274.9 14.5	Fresh, foliated, grey and pink, fine-medium grained, faintly porous, strong MAFIC GNEISS		2	RUN	-		275								RUN #2 TCR=100% SCR=63% RQD=58%		
273.7 15.7	END OF BOREHOLE AT 15.8 m. BOREHOLE BACKFILLED WITH BENTONITE, ASPHALT PATCH AT SURFACE. NOTES: 1. Water level at a depth of 4.1 m below ground surface in cased borehole upon completion of drilling.						274										

+³, ×³: Numbers refer to Sensitivity
20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18289-03

1 OF 1

METRIC

W.P. 5221-18-00 LOCATION MTM Zone 13: N 5 177 577.7 E 293 877.1 ORIGINATED BY SG
DIST Algoma HWY 556 BOREHOLE TYPE CME 75, 194 mm OD HSA, Wash Boring, HW Casing Advance, NQ Coring COMPILED BY AK
DATUM Geodetic DATE 2022.09.22 - 2022.09.22 LATITUDE 46.737682 LONGITUDE -84.142933 CHECKED BY CN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
289.4	GROUND SURFACE							20 40 60 80 100						
0.0	ASPHALT: (25 mm)													
	GRAVEL and SAND, trace non-plastic fines Dense to Very Dense Brown Moist (FILL)		1	SS	82		289							
			2	SS	43									50 43 7 (SI+CL)
			3	SS	35		288							
287.2														
2.2	Gravelly SAND, trace non-plastic fines Compact to Very Dense Brown Moist (FILL)		4	SS	11		287							
			5	SS	43		286							26 66 8 (SI+CL)
			6	SS	98									
	Pockets of clayey silt from a depth of 4.5 to 5.6 m		7	SS	58		285							20 69 11 (SI+CL)
							284							
283.8														
5.6	Silty SAND, some gravel, trace clay Dense to Very Dense Grey Wet		8	SS	33		283							
	Auger grinding from a depth of 5.8 m to 6.1 m.													
			9	SS	62		282							18 55 23 4
281.2														
8.2	END OF BOREHOLE AT 8.2 m. BOREHOLE BACKFILLED WITH BENTONITE, ASPHALT PATCH AT SURFACE. NOTES: 1. Water level measured at a depth of 1.4 m below ground surface (Elev. 287.0 m) in cased borehole upon completion of drilling not representative due to introduction of water for casing advancement.													

+³, ×³: Numbers refer to Sensitivity
20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18289-04

1 OF 2

METRIC

W.P. 5221-18-00 LOCATION MTM Zone 13: N 5 177 575.4 E 293 867.7 ORIGINATED BY IR
DIST Algoma HWY 556 BOREHOLE TYPE CME 75, Wash Boring, HW Casing Advance, NQ Coring COMPILED BY AK
DATUM Geodetic DATE 2022.10.18 - 2022.10.19 LATITUDE 46.737661 LONGITUDE -84.143056 CHECKED BY CN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
289.4	GROUND SURFACE													
0.0	ASPHALT: (50 mm) Gravelly SAND , trace silt, containing cobbles Compact to Very Dense Brown Wet (FILL)		1	SS	38									
			2	SS	12									25 66 9 0
	No sample recovery from a depth of 2.3 to 2.9 m.		3	SS	26									
			4	SS	14									34 61 5 0
			5	SS	69/0.250									
			6	SS	45									
284.1														
5.3	Silty SAND , some gravel, trace clay Very Dense Brown to Grey Wet Coring from a depth of 5.4 m to 6.6 m.		1	NQ	-									
			7	SS	50/0.075									
			8	SS	54									11 48 38 3
280.3			9	SS	50/0.025									
9.1	GRAVEL and SAND , containing cobbles Very Dense Grey Wet Coring from a depth of 9.3 to 9.6 m		2	NQ	-									

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18289-04

2 OF 2

METRIC

W.P. 5221-18-00 LOCATION MTM Zone 13: N 5 177 575.4 E 293 867.7 ORIGINATED BY IR
DIST Algoma HWY 556 BOREHOLE TYPE CME 75, Wash Boring, HW Casing Advance, NQ Coring COMPILED BY AK
DATUM Geodetic DATE 2022.10.18 - 2022.10.19 LATITUDE 46.737661 LONGITUDE -84.143056 CHECKED BY CN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
	Continued From Previous Page																
278.5	GRAVEL and SAND, containing cobbles and boulders Very Dense Grey Wet		10	SS	50/0.075		279										
10.9	END OF BOREHOLE AT 10.9 m. BOREHOLE BACKFILLED WITH BENTONITE, SAND AND ASPHALT PATCH AT SURFACE. NOTES: 1. The cored depth intervals and particle sizes of recovered cobbles are summarized as follows: Depth (m) Recovered 5.4 - 6.7 125 mm cobble 6.7 - 7.6 gravels up to 75 mm 9.3 - 9.6 gravels up to 75 mm 2. Water level at a depth of 2.2 m below ground surface (Elev. 287.1 m) in cased borehole upon completion of drilling																

RECORD OF BOREHOLE No 18289-05

1 OF 1

METRIC

W.P. 5221-18-00 LOCATION MTM Zone 13: N 5 177 590.3 E 293 864.6 ORIGINATED BY IK
DIST Algoma HWY 556 BOREHOLE TYPE Portable Drilling, Wash Boring, BW Casing Advance, AW Coring COMPILED BY AK
DATUM Geodetic DATE 2022.09.17 - 2022.09.19 LATITUDE 46.737795 LONGITUDE -84.143097 CHECKED BY CN

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
284.1	GROUND SURFACE							20 40 60 80 100						
0.0	TOPSOIL: (100 mm)						284	20 40 60 80 100						
0.1	GRAVEL and sand, trace non-plastic fines Compact to Dense Brown Moist (FILL)		1	SS	47									
			2	SS	19									48 46 6 (SI+CL)
282.8							283							
1.3	Silty SAND, some gravel, containing organics and wood fragments Loose Dark Brown Wet		3	SS	6									13 44 39 4
282.3			1	AW	-									
1.8	Gravelly Silty SAND to Silty SAND, trace gravel, containing cobbles Very Dense Grey Wet		4	SS	98		282							24 37 37 2
			2	AW	-									
	Casing Grinding Intervals (m): 1.3 - 2.0 2.0 - 2.6 2.6 - 2.9 2.9 - 3.5 3.5 - 3.9 4.0 - 4.6 4.9 - 5.3		5	SS	96		281							
			3	AW	-									
			6	SS	121		280							8 48 39 5
			4	AW	-									
			7	SS	100/0.15									
			5	AW	-		279							
278.5														
5.6	GNEISS (BOULDER)		1	RUN	-									
278.2														
5.9	END OF BOREHOLE AT 5.9 m. BOREHOLE BACKFILLED WITH BENTONITE. NOTES: 1. A half-weight hammer was used to advance the split spoon sampler. The "N" values presented above have been adjusted to provide an estimate of the "N" value that would have been obtained with a standard hammer. 2. Borehole terminated at a depth of 5.9 m as a result of casing refusal (seized casing) 3. The cored depth intervals and particle sizes of recovered gravels, and cobbles are summarized as follows: Depth (m) Recovered 1.8 - 2.0 1 x 125 mm 1 x 60 mm 2.6 - 2.9 gravels up to 75 mm 3.5 - 4.0 gravels up to 75 mm 4.6 - 4.9 gravels up to 75 mm													

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 (%) STRAIN AT FAILURE



Appendix C

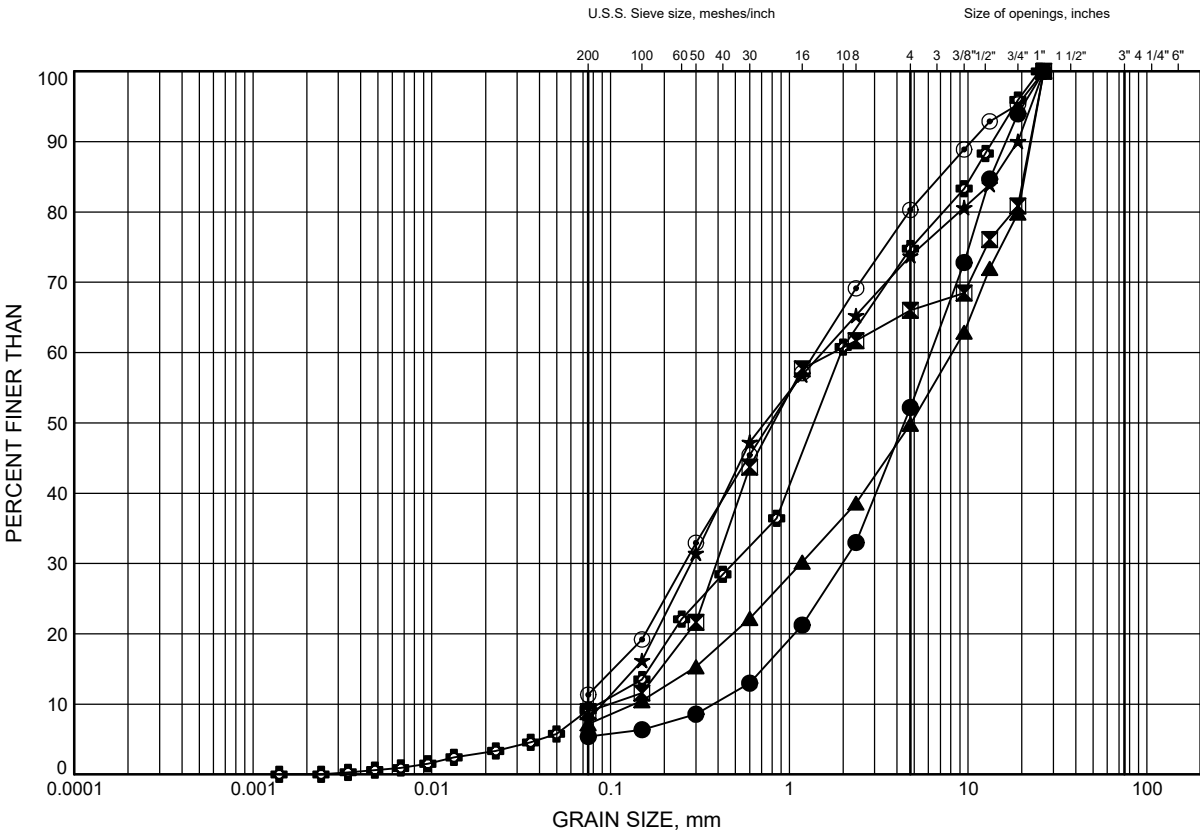
Geotechnical and Analytical Laboratory Test Results, and Core Photographs

Highway 556 Culvert Replacement at STA 18+289

GRAIN SIZE DISTRIBUTION

FIGURE C-1A

GRAVEL and SAND to SAND (FILL)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18289-02	0.99	288.41
⊠	18289-02	4.11	285.29
▲	18289-03	1.07	288.33
★	18289-03	3.28	286.12
⊙	18289-03	4.88	284.52
⊕	18289-04	1.83	287.57

Date January 2023

Project 31719



Prep'd AN

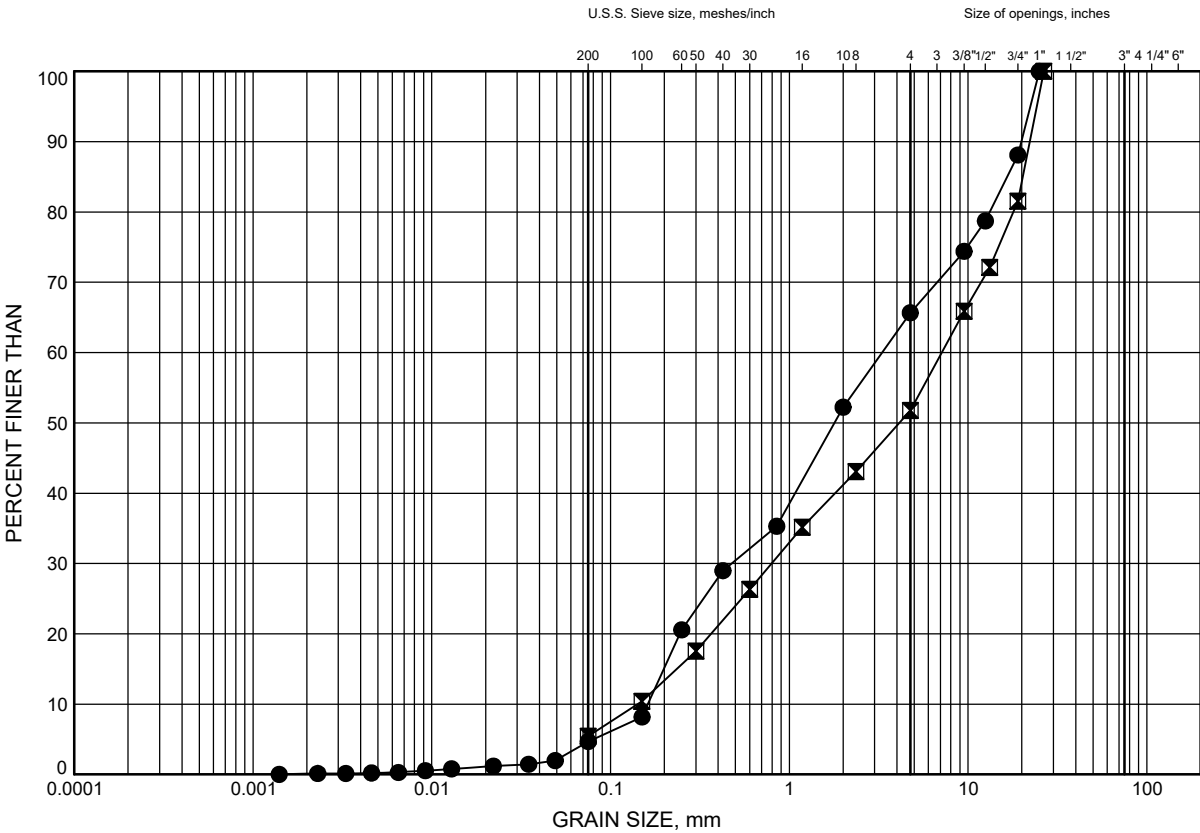
Chkd. AK

Highway 556 Culvert Replacement at STA 18+289

GRAIN SIZE DISTRIBUTION

FIGURE C-1B

GRAVEL and SAND to SAND (FILL)



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18289-04	3.35	286.05
⊠	18289-05	0.91	283.19

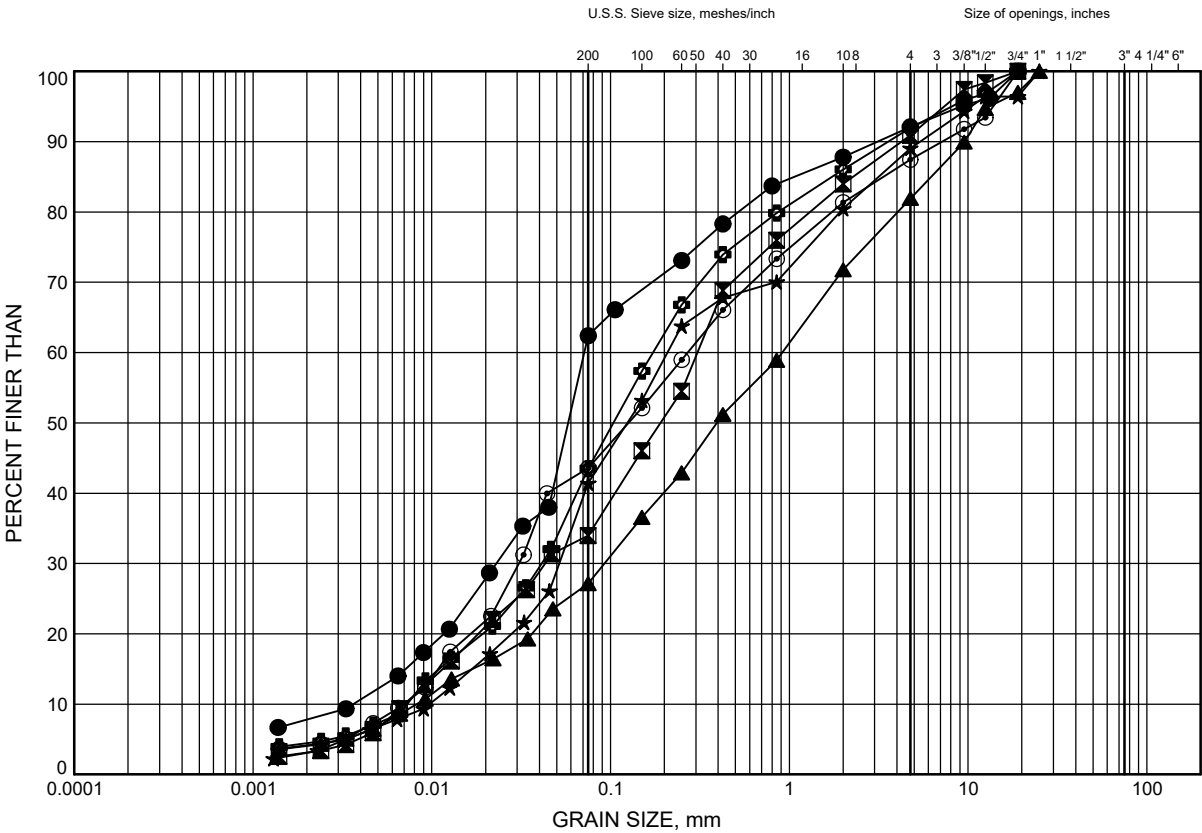
Date January 2023
Project 31719



Prep'd AN
Chkd. AK

GRAIN SIZE DISTRIBUTION

Silty SAND to Sandy SILT



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18289-01	0.30	284.00
⊠	18289-02	7.73	281.67
▲	18289-03	7.92	281.48
★	18289-04	7.92	281.48
⊙	18289-05	1.56	282.54
⊕	18289-05	4.27	279.83

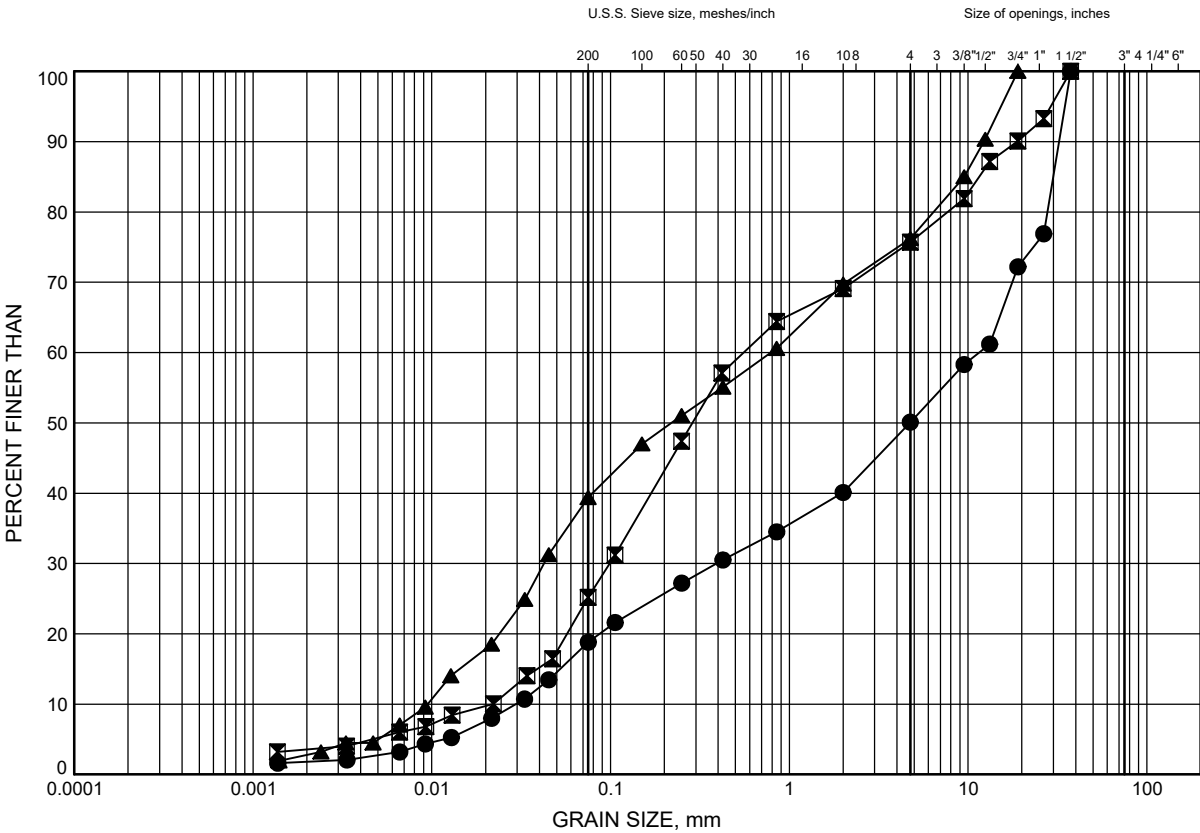
Date January 2023
Project 31719



Prep'd AN
Chkd. AK

GRAIN SIZE DISTRIBUTION

Sandy Silty GRAVEL to Gravelly Silty SAND



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18289-01	0.91	283.39
⊠	18289-01	2.49	281.81
▲	18289-05	2.29	281.81

Date April 2023
Project 31719

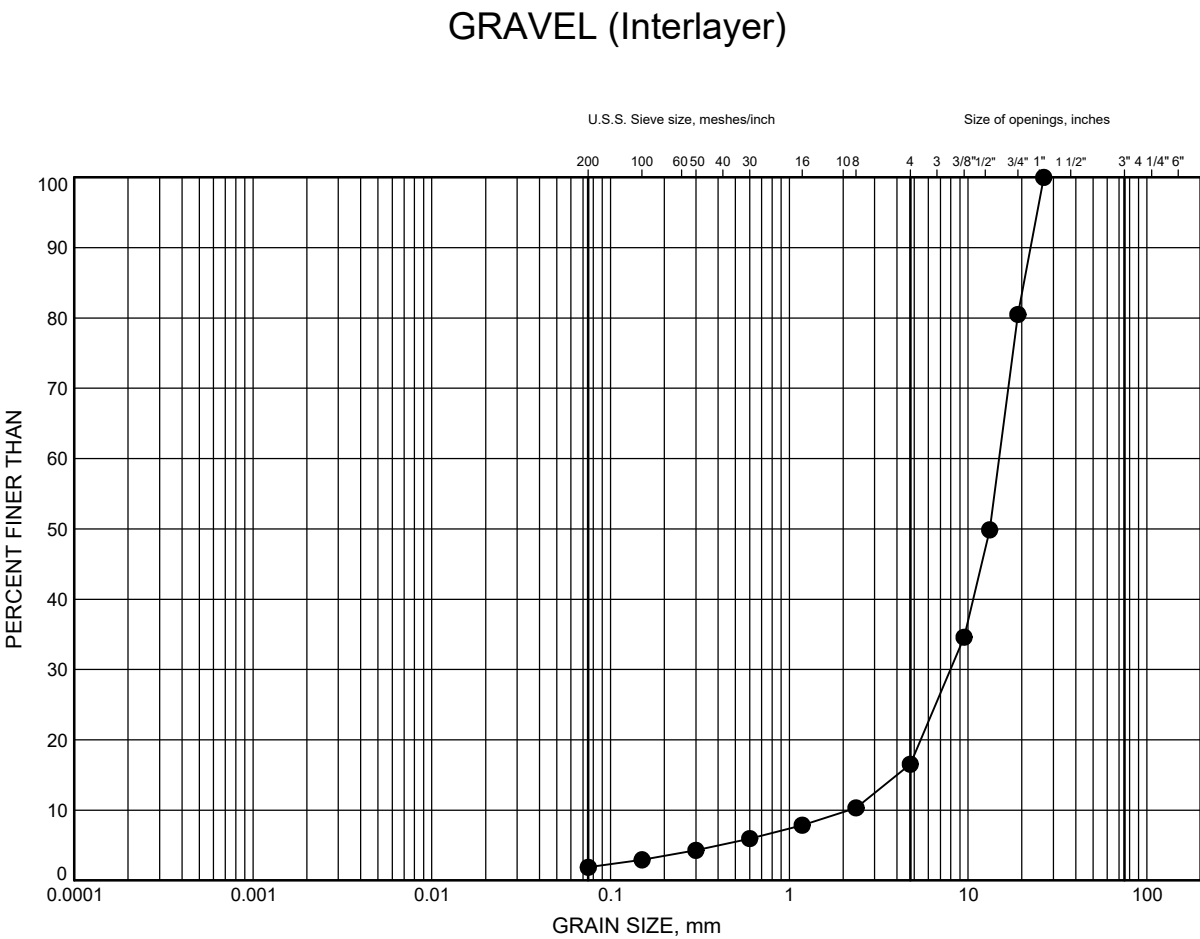


Prep'd AN
Chkd. AK

Highway 556 Culvert Replacement at STA 18+289

GRAIN SIZE DISTRIBUTION

FIGURE C-2C



SILT and CLAY	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE SIZE
FINE GRAINED	SAND			GRAVEL		

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	18289-02	10.82	278.58

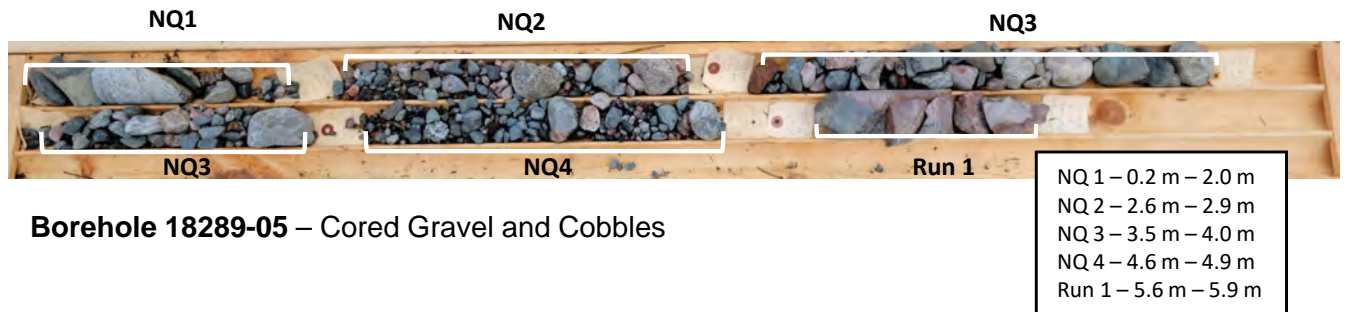
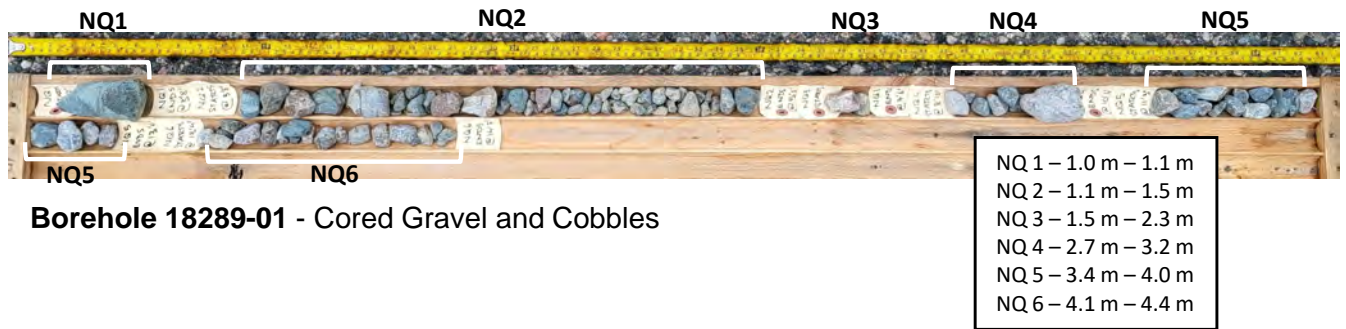
Date January 2023

Project 31719



Prep'd AN

Chkd. AK





THURBER ENGINEERING LTD.

POINT LOAD TEST SHEET
ASTM D5731

Job No: 31719
Project Name: HIGHWAY 556 CULVERT REPLACEMENT AT
STA 18+289
(TOWNSHIP OF DEROCHE)
Core Size: NQ **BH No :** 18289-02

Date Drilled: 21-Sep-22
Date Tested: 17-Feb-23
Tester: AK
Client: MTO

Test No.	Run No.	Depth (m)	Axial or Diametral	Gauge (MPa)	Diameter (mm)	Length (mm)	I _{s(50)} (MPa)	UCS ¹ (MPa)	Rock Type	Rock Strength ¹ (after 4th Ed CFEM)
1	1	13.1	D	20.9	45.0	73.8	9.3	214.6	Andesite to Mafic Gneiss	Very Strong
2	1	13.4	D	24.0	45.0	51.1	10.7	246.0	Andesite to Mafic Gneiss	Extremely Strong
3	1	13.7	D	15.5	45.0	49.7	6.9	159.4	Andesite to Mafic Gneiss	Very Strong
4	1	14.0	D	19.6	45.0	52.9	8.7	200.9	Andesite to Mafic Gneiss	Very Strong
5	2	14.3	D	24.2	45.0	49.5	10.8	248.3	Andesite to Mafic Gneiss	Extremely Strong
6	2	14.6	D	18.4	45.0	50.4	8.2	188.9	Andesite to Mafic Gneiss	Very Strong
7	2	14.9	D	6.9	45.0	48.2	3.1	70.9	Andesite to Mafic Gneiss	Strong

Note: 1 Correlation factor to obtain UCS values is 23.

Last Modified: March 6, 2023

Certificate of Analysis

Thurber Engineering Ltd. (Pickering)

1795 Ironstone Manor, Unit 1

Pickering, ON L1W 3W9

Attn: Ali Rajaei

Client PO: 31719/10

Project:

Custody: 65093

Report Date: 22-Nov-2022

Order Date: 4-Nov-2022

Order #: 2245456

This Certificate of Analysis contains analytical data applicable to the following samples as submitted:

Paracel ID	Client ID
2245456-01	18289-04 / SS#6
2245456-02	19640-01 / RUN#2
2245456-03	21258-03 / SS#9B

Approved By:



Milan Ralitsch, PhD

Senior Technical Manager

Certificate of Analysis

Report Date: 22-Nov-2022

Client: Thurber Engineering Ltd. (Pickering)

Order Date: 4-Nov-2022

Client PO: 31719/10

Project Description:

Analysis Summary Table

Analysis	Method Reference/Description	Extraction Date	Analysis Date
Anions	EPA 300.1 - IC, water extraction	17-Nov-22	17-Nov-22
Conductivity	MOE E3138 - probe @25 °C, water ext	18-Nov-22	18-Nov-22
pH, soil	EPA 150.1 - pH probe @ 25 °C, CaCl buffered ext.	14-Nov-22	15-Nov-22
Resistivity	EPA 120.1 - probe, water extraction	18-Nov-22	22-Nov-22
Solids, %	CWS Tier 1 - Gravimetric	14-Nov-22	15-Nov-22

Certificate of Analysis

Report Date: 22-Nov-2022

Client: Thurber Engineering Ltd. (Pickering)

Order Date: 4-Nov-2022

Client PO: 31719/10

Project Description:

Summary of Criteria Exceedances

(If this page is blank then there are no exceedances)

Only those criteria that a sample exceeds will be highlighted in red

Regulatory Comparison:

Paracel Laboratories has provided regulatory guidelines on this report for informational purposes only and makes no representations or warranties that the data is accurate or reflects the current regulatory values. The user is advised to consult with the appropriate official regulations to evaluate compliance. Sample results that are highlighted have exceeded the selected regulatory limit. Calculated uncertainty estimations have not been applied for determining regulatory exceedances.

Sample	Analyte	MDL / Units	Result	-	-
--------	---------	-------------	--------	---	---

Certificate of Analysis

Report Date: 22-Nov-2022

Client: Thurber Engineering Ltd. (Pickering)

Order Date: 4-Nov-2022

Client PO: 31719/10

Project Description:

Client ID:	18289-04 / SS#6	19640-01 / RUN#2	21258-03 / SS#9B	-	
Sample Date:	19-Oct-22 00:00	22-Oct-22 00:00	20-Oct-22 00:00	-	-
Sample ID:	2245456-01	2245456-02	2245456-03	-	
Matrix:	Rock	Rock	Soil	-	
MDL/Units					

Physical Characteristics

% Solids	0.1 % by Wt.	99.4	98.9	85.7	-	-
----------	--------------	------	------	------	---	---

General Inorganics

Conductivity	5 uS/cm	386 [1]	308	284	-	-
pH	0.05 pH Units	9.05	8.45	6.78	-	-
Resistivity	0.1 Ohm.m	25.9	32.4	35.2	-	-

Anions

Chloride	5 ug/g	68	23	26	-	-
Sulphate	5 ug/g	156	10	8	-	-

Certificate of Analysis

Report Date: 22-Nov-2022

Client: Thurber Engineering Ltd. (Pickering)

Order Date: 4-Nov-2022

Client PO: 31719/10

Project Description:

Method Quality Control: Blank

Analyte	Result	Reporting Limit	Units	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions								
Chloride	ND	5	ug/g					
Sulphate	ND	5	ug/g					
General Inorganics								
Conductivity	ND	5	uS/cm					
Resistivity	ND	0.10	Ohm.m					

Certificate of Analysis

Report Date: 22-Nov-2022

Client: Thurber Engineering Ltd. (Pickering)

Order Date: 4-Nov-2022

Client PO: 31719/10

Project Description:

Method Quality Control: Duplicate

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	158	5	ug/g	160			1.7	20	
Sulphate	82.2	5	ug/g	82.8			0.6	20	
General Inorganics									
Conductivity	242	5	uS/cm	242			0.2	5	
pH	12.34	0.05	pH Units	12.33			0.1	10	
Resistivity	41.4	0.10	Ohm.m	41.3			0.2	20	
Physical Characteristics									
% Solids	82.0	0.1	% by Wt.	82.3			0.4	25	

Certificate of Analysis

Report Date: 22-Nov-2022

Client: Thurber Engineering Ltd. (Pickering)

Order Date: 4-Nov-2022

Client PO: 31719/10

Project Description:

Method Quality Control: Spike

Analyte	Result	Reporting Limit	Units	Source Result	%REC	%REC Limit	RPD	RPD Limit	Notes
Anions									
Chloride	252	5	ug/g	160	91.8	82-118			
Sulphate	201	5	ug/g	82.8	118	80-120			

Certificate of Analysis

Report Date: 22-Nov-2022

Client: Thurber Engineering Ltd. (Pickering)

Order Date: 4-Nov-2022

Client PO: 31719/10

Project Description:

Qualifier Notes:**Sample Qualifiers :**

- 1: This analysis was conducted after the accepted holding time had been exceeded.

Sample Data Revisions:

None

Work Order Revisions / Comments:

None

Other Report Notes:

n/a: not applicable

ND: Not Detected

MDL: Method Detection Limit

Source Result: Data used as source for matrix and duplicate samples

%REC: Percent recovery.

RPD: Relative percent difference.

NC: Not Calculated

Soil results are reported on a dry weight basis unless otherwise noted.

Where %Solids is reported, moisture loss includes the loss of volatile hydrocarbons.

Any use of these results implies your agreement that our total liability in connection with this work, however arising, shall be limited to the amount paid by you for this work, and that our employees or agents shall not under any circumstances be liable to you in connection with this work.



Client Name: <i>Thurber Engineering Ltd.</i>	Project Ref:	Page <u> </u> of <u> </u>
Contact Name: <i>Ali Rajaei</i>	Quote #: <i>22-754</i>	Turnaround Time <input type="checkbox"/> 1 day <input type="checkbox"/> 3 day <input type="checkbox"/> 2 day <input checked="" type="checkbox"/> Regular
Address: <i>Unit 1, 1795 Ironstone Manor, Pickering, ON, L1W 3W9</i>	PO #: <i>31719/10</i>	
Telephone: <i>416-575-9069</i>	E-mail: <i>ARAJAEI@THURBER.CA</i> <i>CC: AKOBYLINSKI@THURBER.CA</i>	
Date Required: _____		

<input type="checkbox"/> REG 153/04 <input type="checkbox"/> REG 406/19 Other Regulation:		Matrix Type: S (Soil/Sed.) GW (Ground Water) SW (Surface Water) SS (Storm/Sanitary Sewer) P (Paint) A (Air) O (Other)		Required Analysis															
<input type="checkbox"/> Table 1 <input type="checkbox"/> Res/Park <input type="checkbox"/> Med/Fine <input type="checkbox"/> Table 2 <input type="checkbox"/> Ind/Comm <input type="checkbox"/> Coarse <input type="checkbox"/> Table 3 <input type="checkbox"/> Agri/Other <input type="checkbox"/> Table _____ For RSC: <input type="checkbox"/> Yes <input type="checkbox"/> No	<input type="checkbox"/> REG 558 <input type="checkbox"/> PWQO <input type="checkbox"/> CCME <input type="checkbox"/> MISA <input type="checkbox"/> SU - Sani <input type="checkbox"/> SU - Storm Mun: _____ <input type="checkbox"/> Other: _____	Matrix	Air Volume	# of Containers	Sample Taken	PH	Resistivity	Chloride	Sulphide	Sulphate	Conductivity								
Sample ID/Location Name					Date	Time													
1 <i>18289-04/SS#6</i>		<i>Rock</i>		<i>1</i>	<i>Oct 19/22</i>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>								
2 <i>19640-01/RUN#2</i>		<i>Rock</i>		<i>1</i>	<i>Oct 22/22</i>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>								
3 <i>21258-03/SS#9B</i>		<i>Soil</i>		<i>1</i>	<i>Oct 20/22</i>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>								
4																			
5																			
6																			
7																			
8																			
9																			
10																			

Comments: <i>Rock samples to be crushed/pulverized as per Paracel email (on Nov 2, 2022)</i>			Method of Delivery: <i>RABBEX</i>	
Relinquished By (Sign): <i>[Signature]</i>	Received By Driver/Depot: <i>[Signature]</i>	Received at Lab: <i>[Signature]</i>	Verified By: <i>[Signature]</i>	
Relinquished By (Print): <i>A. Rajaei</i>	Date/Time: <i>04-Nov-22 11:23</i>	Date/Time: <i>Nov 15/22 14:35</i>	Date/Time: <i>Nov 7 2022 8:36</i>	
Date/Time: <i>Nov 3, 2022</i>	Temperature: <i>21.4</i> °C	Temperature: <i>3.3</i> °C	pH Verified: <input type="checkbox"/> By: _____	

Subcontracted Analysis

Thurber Engineering Ltd. (Pickering)

1795 Ironstone Manor, Unit 1

Pickering, ON L1W 3W9

Attn: Ali Rajaei

Paracel Report No. **2245456**

Client Project(s):

Client PO: **31719/10**

Reference: **#22-754 Corrosivity**

CoC Number: **65093**

Order Date: 04-Nov-22

Report Date: 25-Nov-22

Sample(s) from this project were subcontracted for the listed parameters. A copy of the subcontractor's report is attached

Paracel ID	Client ID	Analysis
2245456-01	18289-04 / SS#6	Sulphide, solid
2245456-02	19640-01 / RUN#2	Sulphide, solid
2245456-03	21258-03 / SS#9B	Sulphide, solid

**SGS Canada Inc.**

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

Paracel Laboratories

Attn : Dale Robertson

300-2319 St.Laurent Blvd.
Ottawa, ON
K1G 4K6, Canada

Phone: 613-731-9577
Fax:613-731-9064

25-November-2022

Date Rec. : 15 November 2022
LR Report: CA12656-NOV22
Reference: Project#: 2245456

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

Sample ID	Sample Date & Time	Sulphide (Na ₂ CO ₃) %
1: Analysis Start Date		23-Nov-22
2: Analysis Start Time		15:05
3: Analysis Completed Date		25-Nov-22
4: Analysis Completed Time		09:27
5: QC - Blank		< 0.04
6: QC - STD % Recovery		118%
7: QC - DUP % RPD		10%
8: RL		0.02
9: 18289-04 / SS#6	19-Oct-22	0.09
10: 19640-01 / Run#2	22-Oct-22	< 0.04
11: 21258-03 / SS#9B	20-Oct-22	< 0.04

RL - SGS Reporting Limit

Note: Results may be unreliable if analysis was performed past the 28 day holding time.

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety








Appendix D

Borehole Locations and Soil Strata Drawing



KEYPLAN

LEGEND

	Borehole
	Borehole and Cone
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level
	Head Artesian Water
	Piezometer
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

[illegible]

-NOTES-

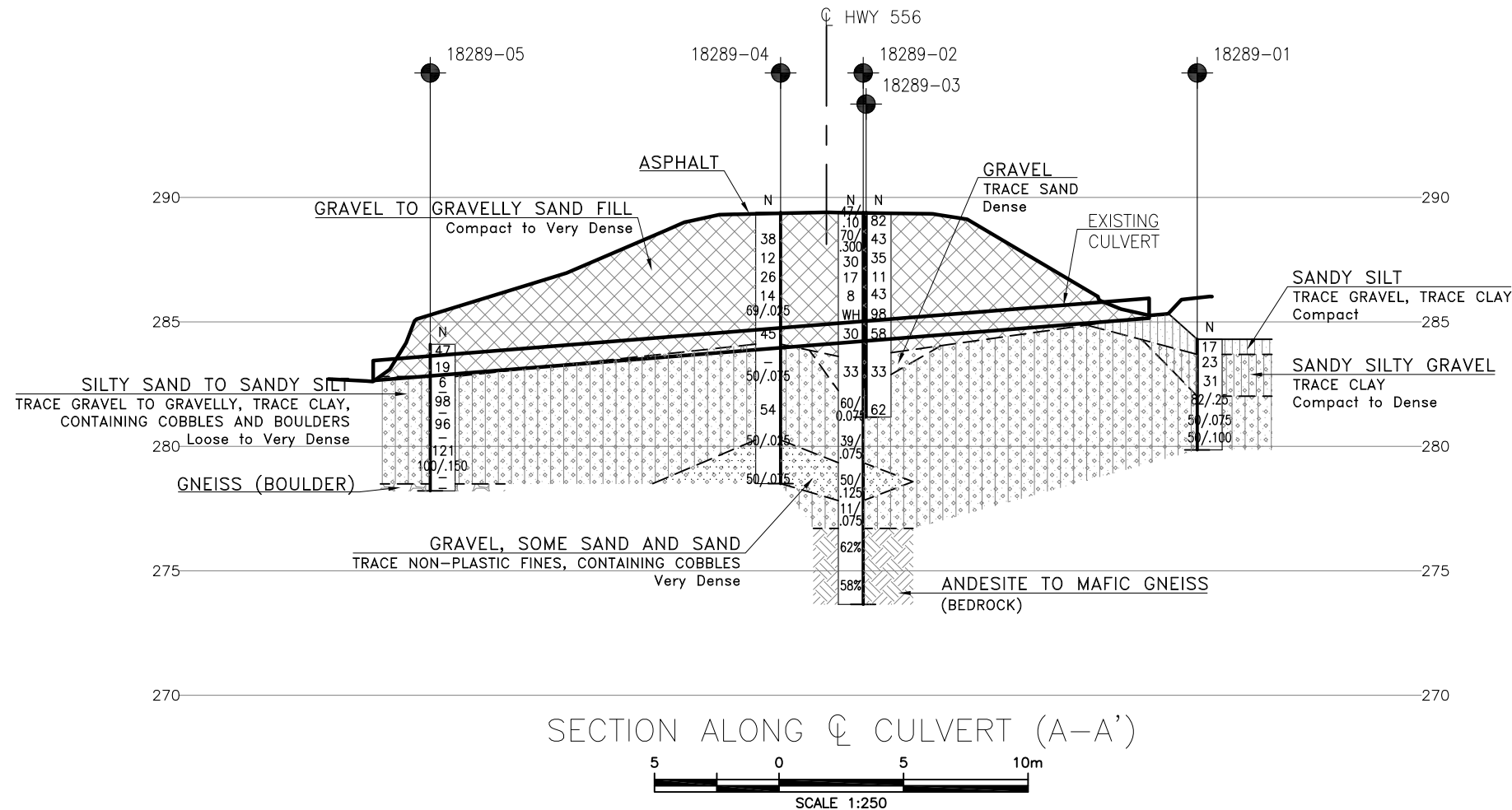
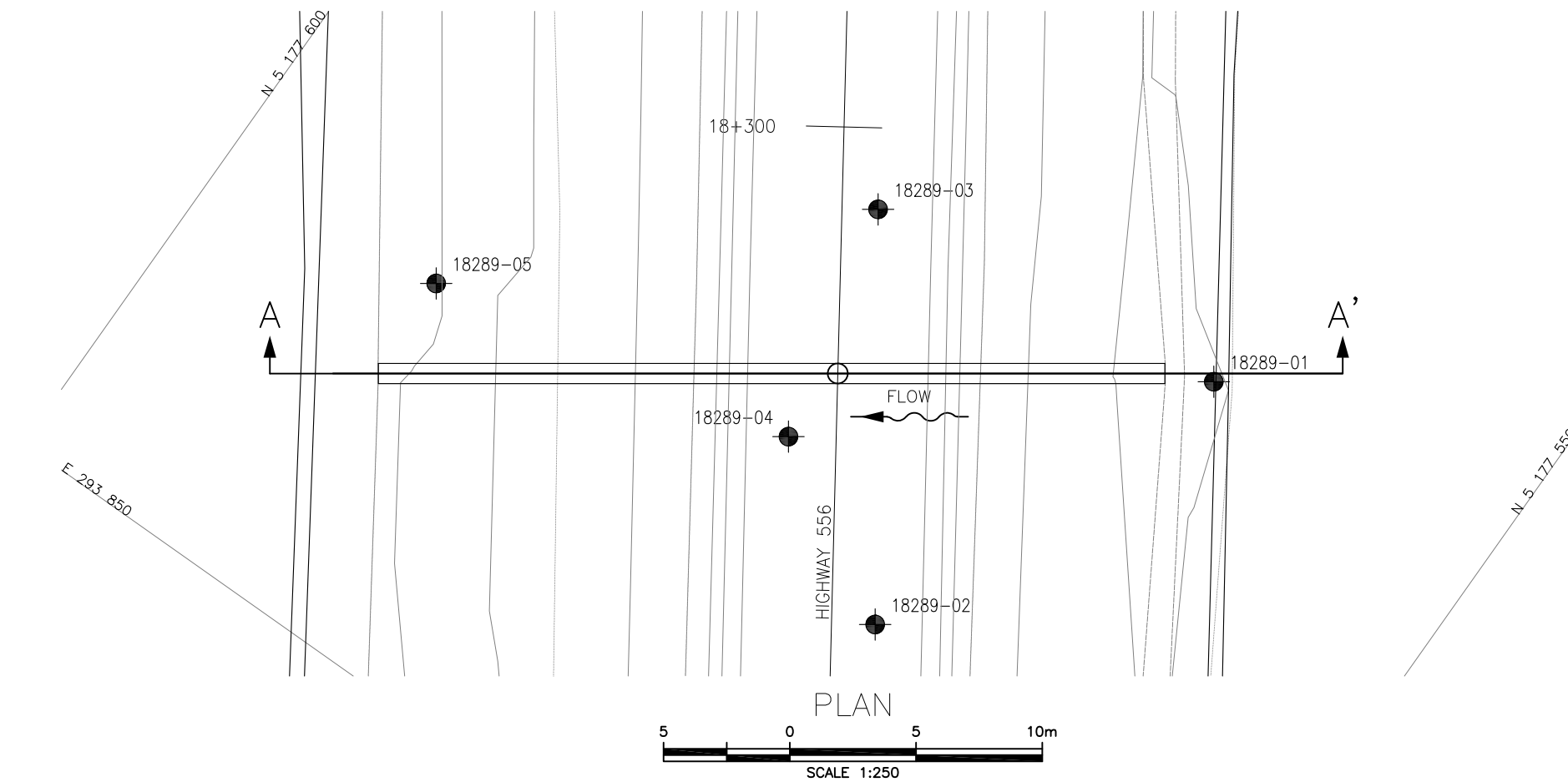
- 1) The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- 2) This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- 3) Coordinate system is MTM NAD 83 Zone 13.

GEOCRES No. 41K-123



REVISIONS								
	DATE	BY	DESCRIPTION					
DESIGN	AK	CHK	PKC	CODE	LOAD	DATE	APR 2023	
DRAWN	AN	CHK	AK	SITE	STRUCT	DWG	1	

FILENAME: H:\Drafting\31000\31719\TED-31719-PLPR-CUL.dwg
PLOTDATE: 4/4/2023 5:30 PM





Appendix E

Tunnelman's Ground Classification System

Tunnelman's Ground Classification System (Heuer, 1974 after Terzaghi, 1950)

Classification		Behaviour	Typical Soil Type
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	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.
	Fast Raveling		
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 with raveling at excavation surface and squeezing at depth behind surface.
Running	Cohesive Running	Granular materials without cohesion are unstable at a slope greater than their angle of repose (+/-30° to 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 behaviour is cohesive-running.
	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 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 pre-consolidated clay with plasticity index in excess of about 30, generally containing significant percentages of montmorillonite.

Reference: Heuer, R. E., 1974, Important Ground Parameters in Soft Ground Tunneling. New England College, Henniker, New Hampshire, American Society of Civil Engineers, New York, P 41-55.



Appendix F

Comparison of Culvert Installation Methods

Table F1 – Comparison of Culvert Installation Methods

Replacement Option	Jack-and-Bore	Mechanical TBM	Pipe Ramming Pipe Crushing/Swallowing	Microtunnelling (MTBM)	Small Boring Unit (SBU)	Cut and Cover
General Method Description	<ul style="list-style-type: none">• Horizontal boring through subsurface by simultaneously jacking ahead and rotating a cutter head, followed by removal of material from inside the bore by means of an auger	<ul style="list-style-type: none">• A steerable forward hood/shield extends beyond face for ground stabilization, while face excavation controlled by operator inside shield• Rock cutting cutter head may be required to advance through cobbles and boulders	<ul style="list-style-type: none">• Steel casing with cutter shoe at leading end of casing advanced using the energy from a percussion hammer; excavation at face by auger as required	<ul style="list-style-type: none">• Remotely controlled and guided pipe jacking technique that provides continuous support to the excavation face with slurry-type spoil removal• Rock cutting cutter head may be required to advance through cobbles and possible boulders	<ul style="list-style-type: none">• Remotely controlled and guided pipe jacking technique for smaller diameter boring that provides continuous support to the excavation face• Rock cutting cutter head may be required to advance through cobbles and possible boulders	<ul style="list-style-type: none">• Conventional open cut excavation
Advantages	<ul style="list-style-type: none">• Reduced traffic disruption• Equipment is readily available	<ul style="list-style-type: none">• Mechanical shield provides greater protection for ground stabilization than fully open face	<ul style="list-style-type: none">• Reduced traffic disruption• Equipment is readily available• Advancement past obstructions is possible by manual removal at the tunnel face but will be challenging due to limited tunnel diameter	<ul style="list-style-type: none">• Minimal traffic disruption• Does not require personnel entry into tunnel• Closed loop slurry system for cuttings removal	<ul style="list-style-type: none">• Minimal traffic disruption• Does not require personnel entry into tunnel• Cuttings removed with vacuum line and truck (slurry separation plant is not required)	<ul style="list-style-type: none">• Local contractors are readily available• Culvert alignment will not be an issue• Cobbles and boulders will be relatively simple to remove as compared to the other methods
Disadvantages	<ul style="list-style-type: none">• Difficulty in advancing through obstructions• Prone to misalignment if obstructions encountered• Open/unsupported face may lead to loss of ground and road settlement• Requires a thrust wall• Cannot penetrate bedrock• Minimum 1.2 m diameter bore is recommended	<ul style="list-style-type: none">• Typically used for larger diameter (2 m or greater) tunnels• Partially open excavation face• Requires entry into tunnel	<ul style="list-style-type: none">• Trouble maintaining alignment if obstructions are encountered, including the existing culvert for pipe crushing/swallowing• Settlement of the embankment fill may occur from percussive action of the hammer in loose soil conditions along the tunnel horizon• Surface water diversion may be required for pipe crushing/ swallowing• Cannot penetrate bedrock	<ul style="list-style-type: none">• Expensive• Limited contractor availability• Difficulty advancing if cobbles/boulders are greater than 30% of machine diameter• Requires a slurry separation plant• Requires a thrust wall• Minimum 1.2 m diameter bore is recommended	<ul style="list-style-type: none">• Expensive• Difficulty advancing if cobbles/boulders greater than 30% of machine diameter• Requires a thrust wall• Minimum 1.2 m diameter bore is recommended	<ul style="list-style-type: none">• Some disruption to traffic during installation• Will require staged construction, grade lowering, and robust temporary protection systems• Sheetpile walls protection system may not be practical due to the presence of boulders with the overburden and therefore, soldier pile and lagging wall would be more practical. However, soldier piles may require pre-augering and socketing into bedrock
Relative Cost	Moderate	High	Moderate	High	High	High
Relative Risks	<ul style="list-style-type: none">• Difficulty in handling unforeseen, oversized obstructions, potential for the installation time to increase if many obstructions are encountered• Greater settlement of the roadway is possible due to running/flowing sands and silts and lack of face support	<ul style="list-style-type: none">• Moderate risk due to the presence of cobbles and possible boulders, which may increase installation time if many obstructions are encountered• Settlement of the roadway is possible	<ul style="list-style-type: none">• Moderate risk due to the presence of cobbles and possible boulders, which may increase installation time and loss of alignment• Settlement of the roadway is possible• Heave of the roadway is possible if obstructions are encountered	<ul style="list-style-type: none">• Moderate risk due to the presence of cobbles and possible boulders, which may increase installation time if many obstructions are encountered• Settlement of the roadway is possible	<ul style="list-style-type: none">• Moderate risk due to the presence of cobbles and possible boulders, which may increase installation time if many obstructions are encountered• Settlement of the roadway is possible	<ul style="list-style-type: none">• Low to moderate risk of encountering boulders when installing soldier piles as part of the temporary protection system• Settlement of the roadway is possible along open cut location and protection system walls
Relative Risk vs. Cost Effectiveness (Note 1)	<ul style="list-style-type: none">• Very high risk if oversized obstructions are encountered• Higher cost if frequent obstructions are encountered	<ul style="list-style-type: none">• High risk; may not be feasible for design tunnel size• Cost ineffective	<ul style="list-style-type: none">• High risk if oversized obstructions are encountered• Cost effective	<ul style="list-style-type: none">• Medium risk• Higher cost if frequent obstructions are encountered	<ul style="list-style-type: none">• Medium risk• Higher cost if frequent obstructions are encountered	<ul style="list-style-type: none">• Low to moderate risk if oversized obstructions encountered
Summary	Not recommended			Challenging but feasible. Recommended for trenchless installation method.		Feasible installation method. Recommended to reduce risk.

Note: 1) The assessment of Cost Effectiveness is a relative term generally based rate of advancement/construction and capability of handling obstructions when encountered. It is assumed that slower progress and inefficiency in handling obstructions will result in higher cost.



Appendix G

List of OPSDs, OPSSs, and Special Provisions, and NSSP for Pipe Installation by Trenchless Methods



1. List of OPSDs, OPSSs, and Special Provisions referenced in this report

- OPSD 208.010 (Benching of Earth Slopes)
- OPSD 219.110 (Light-Duty, Silt Fence Barrier)
- OPSD 802.010 (Flexible Pipe Embedment and Backfill, Earth Excavation)
- OPSD 802.030 (Rigid Pipe Bedding, Cover and Backfill, Type 1 or 2 Soil – Earth Excavation)
- OPSD 802.031 (Rigid Pipe Bedding, Cover and Backfill, Type 3 Soil – Earth Excavation)
- OPSD 803.010 (Backfill and Cover for Concrete Culverts with Spans Less Than or Equal To 3.0 m)
- OPSD 810.010 (General Rip-Rap Layout for Sewer and Culvert Outlets)
- OPSD 3090.100 (Foundation – Frost Penetration Depths for Northern Ontario)
- OPSS.PROV 206 (Construction Specification for Grading)
- OPSS.PROV 401 (Construction Specification for Trenching, Backfilling, and Compacting)
- OPSS.PROV 421 (Construction Specification for Pipe Culvert Installation in Open Cut)
- OPSS.PROV 422 (Construction Specification for Installation of Precast Reinforced Concrete Box Culverts with Span 3 m or Less in Open Cut)
- OPSS PROV 501 (Construction Specification for Compacting)
- OPSS PROV 510 (Construction Specification for Removal)
- OPSS PROV 511 (Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting)
- OPSS.PROV 517 (Construction Specification for Dewatering of Pipeline, Utility, and Associated Structure Excavation)
- OPSS.PROV 539 (Construction Specification for Temporary Protection Systems)
- OPSS.PROV 803 (Construction Specification for Vegetative Cover)
- OPSS.PROV 804 (Construction Specification for Temporary Erosion Control)
- OPSS.PROV 805 (Construction Specification for Temporary Sediment Control)
- OPSS.PROV 1004 (Material Specification for Aggregates – Miscellaneous)
- OPSS.PROV 1010 (Material Specification for Aggregates, Base, Subbase, Select Subgrade, and Backfill Material)
- OPSS.PROV 1205 (Material Specification for Clay Seal)



- OPSS.PROV 1860 (Material Specification for Geotextiles)
- Special Provision 105S09 (Amendment to OPSS 539)
- Special Provision 105S22 (Amendment to OPSS 501)
- Special Provision 110S06 (Amendment to OPSS 1010)
- Special Provision 517F01 (Amendment to OPSS 517)
- Non-Standard Special Provision (Pipe Installation by Trenchless Methods)

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

1.0 SCOPE

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

2.0 REFERENCES

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

Ontario Provincial Standard Specifications, General

OPSS 180 General Specification for the Management of Excess Materials

Ontario Provincial Standard Specifications, Construction

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

Ontario Provincial Standard Specifications, Material

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

CSA Standards

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

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

American Society for Testing and Materials (ASTM) International Standards

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

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

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

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

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

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

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

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

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

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

Design Engineer means the Engineer retained by the Contractor who produces the design and Working Drawings and other engineering documents required of the Contractor. The Design Engineer shall be licensed to practice in the Province of Ontario.

Design Checking Engineer means the Engineer retained by the Contractor who checks the original design and Working Drawings.

Digger Shield/Hand Mining means a method of forming a horizontal bore in the subsurface by essentially simultaneously jacking a casing pipe, with or without a protective shield at the lead end, into the ground while tunnelling and removal of earth and rock is completed using manually-operated tools (e.g., pneumatic spades,

rams, shovels, breaker bars, etc.) or a “digger” type shield with a hydraulic excavator arm or “road-header” rock cutting machine to remove materials from inside the shield and liner pipe.

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

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

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

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

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

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

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

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

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

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

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

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

MTBM means a microtunnelling boring machine.

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

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

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

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

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

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

Reaming means a process for enlarging the bore path.

Rock means natural beds or massive fragments, or the hard, stable, cemented part of the earth's crust, igneous, metamorphic, or sedimentary in origin, which may or may not be weathered and includes boulders having a volume of 0.5 m³ or greater.

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

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

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

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

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

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

TBM means a tunnel boring machine.

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

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

Tunnelling means an underground method of constructing a passage using a tunnel boring machine (TBM) operated by personnel within the tunnel, a microtunnelling boring machine (MTBM) operated by personnel at a remote controlled 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.

Hand mining, horizontal directional drilling, jack-and-bore, pipe ramming, and pipe crushing/swallowing shall not be utilized at this site.

4.02 Submission Requirements

4.02.01 Qualifications

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

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of five (5) years experience on projects with similar scope and complexity, which includes one (1) project involving trenchless installation through cohesionless overburden containing cobbles and boulders.

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

4.02.01.02 Trenchless Contractor

The Trenchless Contractor shall have a minimum of five (5) years experience on projects with similar scope and complexity, which includes one (1) project involving trenchless installation through cohesionless overburden containing cobbles and boulders.

4.02.02 Working Drawings

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

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

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

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

a) Plans and Details:

- i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work.
- ii. A work plan outlining the materials, procedures, methods, and schedule to be used to execute the Work.
- iii. A list of personnel, including backup personnel, and their qualifications and experience.
- iv. A traffic control plan.
- v. A safety plan including the company safety manual and emergency procedures.
- vi. The Working Area layout.
- vii. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
- viii. A contingency plan with specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner.
- ix. A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan, detailing emergency procedures in the event that the fluid management plan fails.
- x. Lighting, ventilation, and fire safety details as may be required by applicable occupational health and safety regulations.
- xi. Excavated materials disposal plan.
- xii. Locations of protection systems.
- xiii. Contingency plans for the following potential conditions:
 - Unforeseen obstructions causing stoppage.
 - Deviation from required alignment and grade.
 - Extended service disruption.

- Damage to the existing Utilities and methods of repair.
- Soil heaving or settlement.
- Contaminated soil or water.
- Alignment passing through buried structures.

b) Designs:

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

c) Materials:

- Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application.
- Manufacturer data sheets for all drilling fluids and additives for use in Earth Pressure Balance (EPB), Slurry Pressure Balance (SPB).
- Manufacturer data sheets for drilling systems.
- Mix designs, target rheology criteria (e.g., viscosity, density, shear strength, gel time, pressure-filtration – fluid losses under pressure, etc.) and additive dosage rates for all slurries and Earth Pressure Balance (EPB) tunnel boring machine (TBM) and microtunnelling boring machine (MTBM) operations.
- The proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces.
- Compressive strength of concrete pipe products.
- Pipe class for all steel pipe products.
- Steel for Permanent Casings:
 - One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.
 - Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate.
 - The mill test certificates shall be stamped with the name of the Canadian testing laboratory and

appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory.

- ix. Slurry, drilling fluids, and tunnelling fluids:
 - Type, source, and physical and chemical properties of bentonite, polymer or other additives;
 - Source of water;
 - Method of mixing;
 - Water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;
 - Details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunneling fluids or EPB spoils; and
 - Method of disposal of the slurry, drilling fluids and associated spoil.
- d) Upstream/Downstream Portal Installation Procedure:
 - 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, Slurry Pressure Balance (SPB) and Earth Pressure Balance (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
 - x. 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
- iii. volume or weights of spoil;
- iv. Jacking forces on pipes, linings and cutting tools;
- v. Torque, total revolutions, and revolution rates on rotating equipment such as TBM or MTBM heads,
- vi. auger flights, drill bits, etc.
- vii. Grout injection pressures and volumes;
- viii. Longitudinal position of all casings and excavation cutting tools (auger flight heads, TBM face, drill
- ix. bit position, etc.); and
- x. Ground displacements (heave and settlement); and noise and ground vibrations induced by
- xi. trenchless construction.

4.02.03 As-Built Drawings

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

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

5.0 MATERIALS

5.01 Pipe

5.01.01 General

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

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

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

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

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

5.01.03 High Density Polyethylene Pipe

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

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

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

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

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

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

5.03 Steel Reinforcement

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

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the Working Drawings.

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

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

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

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

5.06 Grout

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

6.0 EQUIPMENT

6.01 Auger Jack & Bore

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

Pipe Auger Jack & Bore equipment shall be determined by the Contractor and shall be identified in the submission requirements specified herein.

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

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

6.02 Pipe Ramming

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

The Pipe Ramming hammer(s) shall be capable of driving the pipe casing from the entry pit to the exit pit through the existing subsurface conditions at the site without removal of soil from within the casing until the lead end of the pipe is outside the zone of influence for any overlying infrastructure.

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

6.03 Horizontal Directional Drilling

6.03.01 General

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

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

- a) Consist of a leak free hydraulically powered boring system to rotate, push, and pull hollow drill pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head.
- b) Have drill rod that is suitable for both the drill and the product pipe installation.
- c) Contain a drill head that is steerable, equipped with the necessary cutting surfaces and fluid jets, and be suitable for the anticipated ground conditions.
- d) Have adequate reamers and down-bore tooling equipped with the necessary cutting surfaces and fluid jets to facilitate the product installation and be suitable for the anticipated ground conditions.
- e) Contain a guidance system to accurately guide boring operations.
- f) Be anchored to the ground to withstand the rotating, pushing, and pulling forces required to complete the product installation.
- g) Be grounded during all operations unless otherwise specified by the drilling rig manufacturer.

6.03.03 Drill Head

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

6.03.04 Guidance System

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

6.03.05 Drilling Fluid Mixing System

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

6.03.06 Drilling Fluid Delivery System

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

6.04 Tunnelling

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

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

Use of rock fracturing chemicals shall only be considered subject to a field demonstration satisfactory to the Ministry prior to its use. Use of explosives is prohibited without specific application and acceptance by the Ministry prior to construction.

6.05 Microtunnelling Equipment

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

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

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

- a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:
 - i. Allows for operation of the system without the need for personnel to enter the microtunnel.
 - ii. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance, and installed length.
 - iii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by product pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.
 - iv. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
 - v. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
 - vi. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
 - vii. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
 - viii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the workspace available at each work area.
 - ix. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.
- b) Active Direction Control – The Contractor shall provide a MTBM that includes an active direction control system with the following features:
 - i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference.
 - ii. Provides active steering information that shall be monitored and transmitted to the operating console and recorded.

- iii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

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

6.05.02 Spoil Separation System

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

6.05.03 Electrical Equipment, Fixtures and Systems

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

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

7.0 CONSTRUCTION

7.01 General

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

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

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

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

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

7.01.01 Layout, Alignment and Depth Control

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

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

The Contractor shall calibrate tracking and locating equipment at the beginning of each Working Day, and shall monitor and record the alignment and depth readings provided by the tracking system every 2 m.

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

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

7.01.02 Construction Shafts

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

The construction of all protection systems shall be according to OPSS 539.

Where the stability, safety, or function of an existing roadway, railway, watercourse, other works, ESA's, or proposed works may be impaired due to the method of operation, protection shall be provided. Protection may include sheathing, shoring, and piles where necessary to prevent damage to such works or proposed works.

7.01.04 Settlement or Heave

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

7.01.05 Stability of Excavation

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

The construction methods, plant, procedures, and materials employed shall prevent the migration of soil and/or

rock material into the excavation from adjacent ground.

7.01.06 Preservation and Protection of Existing Facilities

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

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

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

7.01.07 Transporting, Unloading, Storing and Handling Materials

The manufacturer's recommendations for transporting, unloading, storing, and handling of materials shall be followed.

7.01.08 Trenching, Backfilling and Compacting

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

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

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

7.01.10 Dewatering

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

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

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

Should water enter the excavation in amounts that could adversely affect the performance of the work or could cause loss of ground, the Contractor shall take immediate steps to control the inflow.

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

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

The Contractor is alerted that cobbles and boulders are expected within the soil deposits at the site. Accordingly, the Contractor shall address the removal of cobbles and boulders in the proposed method of construction. Removal of cobbles and boulders with diameters less than 400 mm shall be expected to be routine and will not be considered obstruction. The Contractor shall immediately inform the Contract Administrator of any obstruction encountered.

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 and the like 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. The Contractor's methodology must not cause ground settlement around the trenchless installation.

7.01.13 Management of Excess Material

Management of excess material shall be according to OPSS 180.

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

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

- a) Hydraulically operated jacks of adequate number and capacity shall be provided to ensure smooth and uniform advancement without over-stressing of the pipe.
- b) A suitably padded jacking head or collar shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- c) The jacking pipe shall be fully supported in the jacking pit at the specified line and grade.
- d) Selection of the excavation method and jacking equipment shall take into consideration the conditions at each pipe crossing.

7.02.02 Pipe Installation

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

During the jacking of the liner, the space between the liner and the wall of the excavated volume (e.g., maximum cut diameter) shall be kept filled with bentonite slurry. Upon completion of jacking, the space between the liner and the wall of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

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

7.03 Pipe Ramming Installation

For Pipe Ramming installation the following requirements apply:

- Only smooth walled steel pipe shall be used. Butt welding of pipe joints shall conform to CSA W59.
- Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform advancement between the shafts/pits without overstressing of the pipe. Delays shall be avoided between ramming operations.
- A Ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.
- Removal of materials from within the pipe shall not be undertaken until the lead end of the pipe has passed fully through and beyond the zone of influence of any overlying infrastructure.
- Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator.
- Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed.
- The annular space between the liner pipe and the product shall be fully grouted with a watertight, expandable, and stable grout.

7.04 Horizontal Directional Drilling Installation

7.04.01 General

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

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

7.04.02 Site Preparation

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

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

7.04.03 Pilot Bore

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

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

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

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

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

7.04.04 Drilling Fluid Losses to Surface ("Frac-Out")

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

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

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.01 General

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

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

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

Product shall be allowed to recover to static conditions from thermal and installation stresses before connections to new or existing facility are made. Product recovery time shall be according to manufacturers recommendations.

7.04.06.02 Pullback and Grouting

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

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

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

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

The space between the pipe and the walls of the excavated volume shall be filled with grout or slurry with gel strength properties demonstrated to be sufficient to form a semi-solid or solid gap filling material, prevent ground convergence around the pipe and subsequent ground surface subsidence and prevent long-term water flow at the outside boundary of any pipe and ground.

7. 05 Tunnelling Installation

7.05.01 General

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

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

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

The Contractor shall provide ventilation and lighting in accordance with OHSa requirements for the entire length of the tunnel installed as tunneling progresses.

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

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

If excavation threatens to endanger personnel, the Work, or adjacent property, the Contractor shall cease excavation and make the excavation face secure. The Contractor shall then evaluate methods of construction and revise as necessary to ensure the safe continuation of the Work.

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

7.05.02 Tunnelling Method

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

7.05.03 Primary Liner (Support System)

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

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

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

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

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

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

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

7.05.04 Secondary Liner

7.05.04.01 Placing of Grout

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

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

7.06 Microtunnelling

7.06.01 General

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

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

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

The Contractor shall maintain clean working conditions at all times.

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

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

7.06.02 Method of Installation

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

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

7.06.03 Casing Installation

Casing must withstand the jacking forces determined by the Contractor.

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

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

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

7.07 Instrumentation and Monitoring

The work specified in this section includes furnishing and installing instruments for monitoring of settlement (and heave) and ground stability. The locations of the instruments are shown on the contract drawings and described below.

7.07.01 General

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

The equipment and procedures used for settlement monitoring during construction must be capable of surveying the settlement point elevations to within a repeatability (combined accuracy and precision of equipment and methods) ± 2 mm of the actual elevation.

7.07.02 Surface Settlement Monitoring Points

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

Surface settlement monitoring points shall be hardened steel markers treated or coated to resist corrosion, with an exposed convex head having a minimum diameter of 12 mm and similar to surveyor's PK nails. Markers shall be rigidly affixed so as not to move relative to the surface to which it is attached. Traffic shall be managed by the Contractor using short-term lane closures in accordance with the Ontario Traffic Manual (OTM). Surface markers shall be recessed or otherwise designed for safe passage of vehicles at highway speeds and protected from snow removal equipment in the event that work occurs during snow removal seasons.

7.07.03 In-Ground Settlement Monitoring Points

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

In-ground settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set

to a depth of 1.5 m below ground surface or below frost penetration depth, whichever is greater. The assembly shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.04 Installation, Replacement and Abandonment

The Contractor shall install all settlement monitoring points a minimum of two (2) weeks prior to the start of work 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

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

- a) Review Level: If a maximum value of 10 mm relative to the baseline readings is reached, the Contractor shall review or modify the method, rate or sequence of construction or ground stabilization measures to mitigate further ground displacement. If this Review Level is exceeded, the Contractor shall immediately notify the Contract Administrator and review and discuss response actions. The Contractor shall submit a plan of action to prevent Alert Levels from being reached. All construction work shall be continued such that the Alert Level is not reached.

- b) Alert Level: If a maximum value of 15 mm relative to the baseline readings is reached, the Contractor shall cease construction operations, inform the Contract Administrator and execute pre-planned measures to secure the site, to mitigate further movements and to assure safety of public and maintain traffic. No construction shall take place until all of the following conditions are satisfied:
- i. The cause of the settlement has been identified.
 - ii. The Contractor submits a corrective/preventive plan complete with a Request to Proceed.
 - iii. Any approved corrective and/or preventive measure deemed necessary by the Contractor is implemented.
 - iv. Operations shall not proceed until the Contract Administrator has issued a Notice to Proceed for each corrective/preventive plan.

7.09 Certificate of Conformance

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

8.0 QUALITY ASSURANCE – Not Used

9.0 MEASUREMENT FOR PAYMENT

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

10.0 BASIS OF PAYMENT

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

If a pipe is installed inside the pipe liner, payment for the pipe shall be paid separately under the appropriate tender items.

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

Payment for removal of boulders with diameter 400 mm or greater shall be on a time and material basis.

WARRANT: Always with this specification.



Appendix H

Instrumentation Plan

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