



THURBER ENGINEERING LTD.

**FOUNDATION INVESTIGATION AND DESIGN REPORT
DEEP FILL CULVERT
HIGHWAY 101, 7.3 KM EAST OF HIGHWAY 672 JUNCTION,
STA. 12+700, HOLLOWAY TOWNSHIP
ASSIGNMENT NO. 5018-E-0010, WORK ITEM NO. 9**

GEOCRES NO.: 32D-36

Report to:

Ministry of Transportation Ontario, Northeastern Region

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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed at a deep fill culvert located near Station 12+700 on Highway 101, approximately 7.3 km east of the Highway 672 Junction in Holloway Township. Thurber Engineering Ltd. (Thurber) carried out this investigation as a consultant to the Ministry of Transportation Ontario (MTO, or the Ministry) Northeastern Region under Assignment No. 5018-E-0010, Work Item No. 9.

The purpose of this investigation was to explore the subsurface conditions at the site and based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results, and a written description of the subsurface conditions. A model of the subsurface conditions influencing design and construction was developed in the course of the current investigation. No historical foundation investigation reports were available for this site within the online Geocres library.

2 SITE DESCRIPTION

The existing culvert is described as a 37 m long corrugated steel pipe (CSP) with a diameter of 900 mm. The embankment at this location is approximately 5.2 m high and the side slopes are inclined at approximately 2.5H:1V to 3H:1V.

At the location of the culvert, Highway 101 is a two-lane wide asphalt paved roadway with narrow paved shoulders. It is understood that the AADT for this portion of Highway 101 in 2016 was approximately 500 including 150 trucks. Steel cable guiderails with wooden posts are present along both sides of the highway. The land area adjacent to the highway is undeveloped and heavily vegetated with trees and shrubs.

The depth of water in the creek was approximately 20 mm at the time of the investigation. An erosion-derived void was present approximately 250 mm below the upstream invert, and it appears that surface water flow from the creek was flowing through the embankment rather than the culvert. The pipe inlet was also significantly deformed. No other signs of distress were



observed on the embankment side slopes. The upstream and downstream invert elevations were surveyed to be approximately 291.1 and 290.4 m, respectively. The elevation of the road surface was surveyed to be approximately 296.3 m.

Select photographs showing the existing conditions at the time of the field investigation are included in Appendix D for reference.

3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out between July 20 and 22, 2021. The field investigation consisted of advancing two on-road foundation boreholes (identified as 21-01 and 21-02), two off-road foundation boreholes (identified as 21-03 and 21-04), and four on-road pavement augerholes (identified as 21-05 through 21-08). Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

A summary of the borehole locations, ground surface elevations, and termination depths is provided in Table 3-1. The borehole elevations were surveyed with a Nikon AP-8 auto level, with a reported accuracy of 1.5 mm. The elevations were surveyed relative to the obvert of the culvert at the downstream end, which has a geodetic elevation of approximately 291.2 m (per the MTO). The site is within MTM Zone 12.

Table 3-1: Borehole Summary

| Borehole ID. | Drilled Location | Northing (m) (Latitude°) | Easting (m) (Longitude°) | Existing Ground Surface Elevation (m) | Termination Depth Below Existing Ground Surface (m) |
|--------------|--------------------------------|-----------------------------|-----------------------------|---------------------------------------|---|
| 21-01 | 1 m west of culvert (WB lane) | 5 376 650.1 (48.52134°) | 399 243.7 (79.72135°) | 296.3 | 16.1 |
| 21-02 | 4 m east of culvert (EB lane) | 5 376 646.9 (48.52131°) | 399 241.4 (79.72139°) | 296.3 | 14.2 |
| 21-03 | culvert outlet | 5 376 629.4 (48.52115°) | 399 250.6 (79.72126°) | 290.4 | 1.5 |
| 21-04 | culvert inlet | 5 376 664.7 (48.52147°) | 399 240.8 (79.72139°) | 291.1 | 1.5 |
| 21-05 | 30 m west of culvert (WB lane) | 5 376 644.4 (48.52129) | 399 215.3 (79.72174) | 296.8 | 1.2 |
| 21-06 | 70 m west of culvert (WB lane) | 5 376 637.3 (48.52123) | 399 175.9 (79.72227) | 297.3 | 2.8 |
| 21-07 | 70 m east of culvert (WB lane) | 5 376 664.1 (48.52145) | 399 313.4 (79.72041) | 296.5 | 0.9 |
| 21-08 | 30 m east of culvert (WB lane) | 5 376 656.5 (48.52139) | 399 274.2 (79.72094) | 296.3 | 2.7 |



The on-road foundation boreholes and pavement augerholes were advanced with a truck mounted CME 75 drill rig. The off-road boreholes were advanced with a manual hand-auger.

Within Boreholes 21-01 and 21-02, soil samples were obtained at near continuous intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in accordance with ASTM D 1586. At the remaining boreholes, soil samples were collected as grab samples from the auger flights. Upon achieving practical refusal in Borehole 21-01, the bedrock was cored using HQ sized bedrock coring equipment.

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

The boreholes were backfilled with bentonite holeplug and sealed with cold patch at the road surface.

The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawing included in Appendix A. The coordinates and elevations of the boreholes are provided on this drawing, Table 3-1 above, and on the Record of Borehole sheets included in Appendix B.

4 LABORATORY TESTING

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. Grain size distribution and Atterberg limits testing was also carried out on selected samples to MTO and ASTM standards. All rock cores were photographed and their total core recovery (TCR), solid core recovery (SCR) and rock quality designation (RQD) were measured. Chemical analysis for determination of pH, conductivity, resistivity, sulphate, sulphide and chloride concentrations was carried out on one sample.

The results of the geotechnical tests are summarized on the Record of Borehole sheets included in Appendix B and all laboratory results are presented on the figures included in Appendix C.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata drawing included in Appendix A. A general 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 for interpretation of the site conditions. It must be recognized that the soil, bedrock and groundwater conditions will vary between and beyond borehole locations.



In general terms, the encountered stratigraphy consisted of asphalt and embankment fill overlying native deposits of clay and glacial till, which in turn is underlain by greenschist bedrock.

The soil classifications in this report are in accordance with ASTM D2487. Cohesive soils are described per current MTO protocols.

5.1 Asphalt

The asphalt encountered in Boreholes 21-01, 21-02, and 21-05 through 21-08 ranged in thickness from 90 to 110 mm. A 50 to 60 mm thick layer of buried asphalt was also encountered in Boreholes 21-06, 21-07 and 21-08 at a depth of approximately 0.3 to 0.5 m.

5.2 Embankment Fill

5.2.1 Granular Fill

Granular embankment fill ranging in composition from gravelly sand with silt, to silty gravel, to silty sand with gravel, to sand with silt and gravel was encountered below the asphalt in all of the on-road boreholes (21-01, 21-02, and 21-05 through 21-08). Occasional cobbles, boulders and recycled asphalt were noted in the granular fill. The granular fill varied in thickness from approximately 0.9 to 2.0 m and extended to base elevations ranging from approximately 294.2 to 296.4 m.

SPT N-Values within the granular fill generally ranged from 17 to 93 blows, indicating a compact to very dense relative density. One SPT refusal indicating 100 blows for 125 mm of penetration was also recorded within the fill; however, this refusal may represent the presence of cobbles or a boulder within the fill rather than the relative density of the soil matrix. Refusal on cobbles, boulders or rock fill was encountered in Boreholes 21-05 and 21-07 at depths of 1.2 and 0.9 m, respectively.

Recorded moisture contents of the granular fill ranged from 4 to 20%. The gradation analyses completed on two samples of the granular fill are illustrated on Figure C1 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

| Soil Particle | Percentage (%) |
|---------------|----------------|
| Gravel | 30 - 40 |
| Sand | 53 - 62 |
| Silt | 7 - 8 |
| Clay | |



5.2.2 Clay Fill

A layer of clay fill, classified as clay with gravel to clayey gravel, was encountered below the granular fill in Boreholes 21-01, 21-02, 21-04, 21-06, and 21-08. The clay fill had a thickness ranging from approximately 0.2 to 2.3 m with a base depth ranging from approximately 0.4 to 3.8 m below the existing ground surface (elevation 290.7 to 295.3 m).

A 200 mm nominally sized boulder was encountered within the clay fill layer in Borehole 21-01 at a depth of approximately 3.0 m (elevation 293.3 m). Rotary diamond drilling techniques were required to advance the borehole past this boulder.

SPT N-Values within the clay fill ranged from 7 to 13 blows.

Recorded moisture contents of the clay fill ranged from 36 to 48%.

The gradation analyses completed on two samples of the clay fill are illustrated on Figure C2 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

| Soil Particle | Percentage (%) |
|---------------|----------------|
| Gravel | 21 - 46 |
| Sand | 5 - 6 |
| Silt | 13 - 21 |
| Clay | 36 - 52 |

Atterberg Limit testing was completed on two samples of the clay fill. The results of the Atterberg Limit testing are summarized below and are illustrated on Figure C5 in Appendix C. The test results are also presented on the corresponding Record of Borehole sheets in Appendix B. The laboratory results indicate that the clay fill samples that were tested are of high plasticity.

| Parameter | Value |
|------------------|---------|
| Liquid Limit | 62 - 66 |
| Plastic Limit | 25 - 26 |
| Plasticity Index | 37 - 40 |

5.3 Topsoil

Surficial topsoil was encountered at off-road Boreholes 21-03 and 21-04. The thickness of the topsoil at these locations ranged was approximately 150 to 200 mm.

5.4 (CI/CH) Clay

A native deposit of clay was encountered below the embankment fill in Boreholes 21-01, 21-02, 21-03, 21-04, 21-06 and 21-08. Where fully penetrated (in Boreholes 21-01 and 21-02), the clay deposit had a thickness ranging from approximately 6.3 to 6.6 m, with a base depth of approximately 10.1 to 10.4 m below the existing ground surface (elevation 285.9 to 286.2 m). The clay was not fully penetrated in Boreholes 21-03, 21-04, 21-06, or 21-08 where the clay extended deeper than the target borehole depth (1.5 to 2.8 m below the existing ground surface).

The upper portion of the clay has generally been weathered to a grey-brown crust. SPT tests conducted in the grey-brown weathered crust gave N-values ranging from 4 to 6 blows, indicating a very stiff consistency for the weathered crust. Recorded moisture contents of the weathered crust ranged from 32% to 68%.

Unweathered grey clay was encountered beneath the weathered crust in Boreholes 21-01 and 21-02. SPT tests conducted in the grey clay gave N-values ranging from Weight of Hammer (WH) to 7 blows. Field vane testing carried out within the grey clay gave undrained shear strength values ranging from 44 to 52 kPa, indicating a firm to stiff consistency. Remolded field vane testing indicates that the clay is sensitive to extra-sensitive. Recorded moisture contents of the grey clay ranged from 28 to 59%.

The gradation analyses completed on four samples of the clay (two on weathered crust and two on unweathered grey clay) are illustrated on Figure C3 of Appendix C. The results of the tests are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

| Soil Particle | Percentage (%) |
|---------------|----------------|
| Gravel | 0 |
| Sand | 0 - 3 |
| Silt | 28 - 55 |
| Clay | 45 - 71 |

Atterberg Limit testing was completed on four samples of the clay (two on the weathered crust and two on the unweathered grey clay). The results of the Atterberg Limit testing are summarized below and are illustrated on Figure C6 in Appendix C. The test results are also presented on the corresponding Record of Borehole sheets in Appendix B. The laboratory results indicate that the clay samples that were tested are of intermediate to high plasticity (CI/CH).

| Parameter | Value |
|------------------|---------|
| Liquid Limit | 35 - 65 |
| Plastic Limit | 21 - 29 |
| Plasticity Index | 14 - 39 |

5.5 (SM) Silty Sand trace to with gravel and (SP-SM) Sand with Silt and Gravel – Till

A deposit of glacial till was encountered below the clay in Boreholes 21-01 and 21-02. The till deposit was approximately 3.8 to 4.5 m thick with a base depth of approximately 14.2 to 14.6 m (elevation 281.7 to 282.1 m). The till varied in composition from silty sand trace to with gravel, to sand with silt and gravel, and contained occasional cobbles and boulders.

SPT N-values ranged from 28 blows for 300 mm penetration to 100 blows for 225 mm penetration, indicating a compact to very dense relative density. Recorded moisture contents ranged from 4 to 16%.

The results of a grain size analysis completed on two samples from this deposit are illustrated on Figure C4 of Appendix C. The results are summarized below and are presented on the corresponding Record of Borehole sheets in Appendix B.

| Soil Particle | Percentage (%) |
|---------------|----------------|
| Gravel | 4 - 28 |
| Sand | 61 - 63 |
| Silt | 10 - 30 |
| Clay | 1 - 3 |

5.6 Refusal and Bedrock

Bedrock underlying the overburden was proven by coring in Borehole 21-01. Practical refusal to borehole advancement was encountered at a similar elevation in Borehole 21-02 and is therefore inferred to represent the bedrock surface; however, it should be noted that practical refusal may also be due to a boulder within the glacial till. The depths and elevations of the bedrock surface is summarized in the following table:

| Borehole No. | Depth to Bedrock (mbgs) | Bedrock Surface Elevation (m) |
|--------------|-------------------------|-------------------------------|
| 21-01 | 14.6 | 281.7 |
| 21-02 | 14.2* | 282.1* |

* inferred from practical refusal to borehole advancement

The bedrock encountered consisted of fresh greenschist. The Total Core Recovery (TCR) measured on the recovered bedrock core was 98%, the Solid Core Recovery (SCR) was 62% and the Rock Quality Designation (RQD) was 62%. Based on the measured RQD values, the bedrock quality is classified as fair. Photographs of the bedrock core are provided in Appendix C.

5.7 Groundwater

Wash-boring techniques were used to advance the boreholes and therefore accurate groundwater levels could not be observed in the open boreholes during the investigation due to the water that was introduced to the boreholes. The water depth in the creek at the culvert outlet was observed to be approximately 0.1 m at the time of the investigation which corresponds to an approximate elevation of 290.3 m. These observations are considered short term and it should be noted that the level at the time of construction may be different and seasonal fluctuations of the groundwater and surface water level are to be expected. In particular, the levels may be at a higher elevation after periods of significant and/or prolonged precipitation

5.8 Results of Analytical Tests

One soil sample was selected and submitted for analysis of pH, sulphate, sulphide and chloride concentrations, and resistivity. The analysis results are included in Appendix C and are summarized in the following table.

| | |
|----------------------|-----------|
| Borehole | 21-01 |
| Sample | SS5 |
| Depth (m) | 3.8 – 4.4 |
| Elevation (m) | 292.2 |
| Material | Clay |
| pH (-) | 7.39 |
| Resistivity (Ohm-cm) | 2,250 |
| Chloride (ug/g) | 108 |
| Sulphate (ug/g) | 12 |
| Sulphide (%) | <0.04 |



6 MISCELLANEOUS

Borehole locations were selected relative to existing site features and anticipated foundation locations. Ground surface elevations at the investigated locations were recorded in relation to the obvert of the existing culvert, the geodetic elevation of which was provided by the MTO.

George Downing Estate Drilling from Hawkesbury, Ontario supplied and operated the drill rig to carry out the drilling, sampling, in-situ testing, and borehole decommissioning. Traffic control was provided by Beacon Lite of Kirkland Lake, Ontario. The field investigations were supervised by Anderson de Oliveira, EIT, of Thurber. Overall supervision of the investigation program was conducted by Stephen Dunlop, P.Eng. Routine geotechnical laboratory testing was carried out by Thurber's geotechnical laboratory in Ottawa, Ontario. Analytical testing was carried out by Paracel Laboratories Ltd. in Ottawa, Ontario. Interpretation of the data and preparation of this report were carried out by Lena Bryan, EIT, and Stephen Dunlop, P.Eng. The report was reviewed by Dr. Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

Lena Bryan
Geo-environmental EIT



Stephen Dunlop, M.A.Sc., P.Eng.
Associate, Senior Geotechnical Engineer



Fred Griffiths, P.Eng., Ph.D.
Senior Associate
Senior Geotechnical Engineer



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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 GENERAL

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents foundation design recommendations to assist the Ministry in the design of the proposed replacement of the existing deep fill culvert crossing Highway 101 located approximately 7.3 km east of the Highway 672 junction. The discussion and recommendations presented in this report are based on the information provided by the Ministry and on the factual data obtained during the course of the investigation.

This foundation investigation and design report with the interpretation and recommendations provided herein are intended for the use of the Ministry and shall not be used or relied upon for any other purposes or by any other parties including the construction or design-build contractor. The construction or design-build contractor must make their own interpretation based on the factual data in Part 1 of the report. Where comments are made on construction, they are provided only in order to highlight those aspects which could affect the design of the project. Contractors must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

7.1 Proposed Structure

It is understood that proposed replacement culvert will consist of one of the following three options. It is assumed that all three options would include a new pipe culvert with a similar diameter (900 mm) and invert level (approximate elevation 290 to 291 m) as the existing culvert.

- 1) An open-cut staged replacement with temporary roadway protection along the centreline, with the replacement culvert on the same alignment as the existing culvert.
- 2) An open-cut staged replacement with grade lowering and unsupported excavation, with the replacement culvert on the same alignment as the existing culvert.
- 3) Trenchless installation offset approximately 2 m to the west of the existing culvert.

8 DESIGN OPTIONS

8.1 Design Considerations

Geotechnical design considerations for the proposed culvert replacement include the following:

- The borehole records from the current investigation indicate that the embankment was constructed with granular fill over clay fill. Occasional cobbles and boulders were noted within both types of fill, which could potentially obstruct a trenchless installation. However, the bottom of the fill in Boreholes 21-01 and 21-02, which straddle the proposed trenchless alignment 2 m west of the existing culvert, was noted to be at an elevation of approximately 292.5 m, which is higher than the anticipated tunnel horizon (elevation 290 to 292 m).
- The clay encountered within the anticipated tunnel horizon in Boreholes 21-01 and 21-02 is considered favourable for a trenchless installation. Several trenchless installation methods could be considered, including jack-and-bore, pipe ramming, and pipe jacking. However, it must be recognized that the boreholes advanced for this investigation represent only discreet locations beside the proposed alignment. Differing conditions that include possible obstructions (cobbles, boulders, roots, etc.) could be encountered, particularly beneath the embankment side slopes.
- If a trenchless installation is attempted, the native clay cover (i.e., the vertical distance between the tunnel crown and the overlying clay fill) will be limited. As such, there is a risk of tunnel face instability for an open-faced tunnel with no leading plug or face pressure; the weight of the overlying fill, which contains gravel, cobbles, and boulders, may result in obstructions entering the tunnel in an uncontrolled manner, which could also cause settlement at the road surface. This risk can be reduced by lowering the elevation of the culvert as much as possible. The trenchless method will also need to be carefully selected to maintain the tunnel face while also managing potential obstructions. Consideration could be given to using an oversized casing that is at least 1.8 m in diameter to allow for personnel entry to remove potential obstructions. It is noted that an increase in installation diameter increases the likelihood of encountering obstructions as well as the risk of tunnel face instability due to mixed face conditions.
- Adequate space for entry and exit pits is required for trenchless techniques and must be considered.
- If a trenchless installation is not preferred due to the associated risks with obstructions, the foundation soil (firm clay) is considered suitable to support a circular pipe within an open-cut excavation.

Design considerations, including ground conditions, are discussed further in Section 8.3 and Appendix E.

8.2 Culvert Type and Foundation Alternatives

It is anticipated that the replacement culvert will be a circular pipe (concrete, HDPE, or steel).

8.3 Construction Methodology Alternatives

For the proposed culvert replacement, the following construction methods were considered:

- Trenchless Techniques

Trenchless techniques would have the advantage of minimum disruption to traffic, but would come with higher risks than the open cut options. The native clay soil present within the anticipated tunnel horizon is suitable for several trenchless techniques, including jack-and-bore, pipe ramming, and pipe jacking; however, there is a risk of encountering obstructions under the embankment side slopes and from the overlying fill due to the limited cover.

- Open Cut with Staged Replacement

The use of open cut techniques in conjunction with a staged culvert replacement (one side of the highway at a time) is a technically feasible construction option from a geotechnical perspective. It is noted that the width of the highway is limited (about 9 m), such that there is not enough space available to carry out an excavation using unsupported side slopes. For a staged replacement to be feasible, consideration will need to be given to one of the following two options:

- A temporary protection system. This would be installed parallel to the highway, along the centreline of the road, to allow for the culvert replacement to take place within an open cut. Each side of the embankment would be completed as a separate stage. Conceptually, either an interlocking steel sheet pile wall or soldier pile and lagging system would be technically feasible. However, it is noted that the till underlying the clay is very dense and contains cobbles and boulders. It is anticipated that sheet piles may not be able to penetrate this material. Soldier piles may also have difficulty penetrating the obstructions and in some cases may require pre-drilling to advance to the underlying bedrock. In order to provide adequate lateral support, it is anticipated that either system would require rakers or bedrock anchors.
- A temporary embankment lowering. It is anticipated that sufficient embankment width could be achieved for two open cut stages if the grades were lowered temporarily by approximately 2.3 m. It is estimated this would require temporarily reprofiling more than 400 m of the highway. The extent of the construction zone could be reduced to approximately 260 m in length by combining a grade lowering of approximately 1.2 m with temporary platform widening of approximately 4 m on either side. The temporary platform widening would need to be constructed with OPSS Granular B Type II placed at 1.5H:1V slopes to prevent widening of the embankment beyond the current toe of slope. It is noted that practical refusal was encountered in two of the pavement boreholes on



boulders/rockfill as shallow as 0.9 m below existing pavement. Over-excavation will be required to allow construction of a temporary pavement structure.

A detailed comparison of various trenchless and open cut methods are included in Appendix E.

8.4 Recommended Approach for the Culvert Replacement

The recommended option for replacing the existing culvert from a foundation engineering perspective is to install a new circular pipe culvert using trenchless techniques on a new alignment with a minimum separation distance of 2 m to the west of the existing culvert, provided that waterflow realignment is feasible. The existing culvert would need to be decommissioned.

Replacing the culvert within an open-cut excavation using a staged approach is also considered technically feasible and can be considered if a trenchless installation is not preferred due to the inherent risks with encountering obstructions (cobbles, boulder, roots, etc.). Both a temporary protection system and temporary embankment lowering/widening are considered technically feasible staging options; however, a temporary protection system will be subject to additional risks due to the potential difficulty penetrating the underlying very dense glacial till, which contains cobbles and boulders.

9 TRENCHLESS RECOMMENDATIONS

It is anticipated that the soils that will be encountered during tunneling will consist primarily of clay crust containing trace organics and roots, and clay fill which may contain cobbles and boulders. Based on the Tunnelman's Ground Classification System (modified by Heuer 1974 from Terzaghi 1950) the clay soils are described as 'squeezing' to 'slow raveling'. Due to the potential for the overlying fill to move into an open-faced tunnel, closed face techniques are preferred.

Trenchless methods that are typically considered to install culvert pipes under highways include: jack-and-bore, pipe jacking, pipe ramming, microtunneling (MTBM), and hand mining. A table with comparisons of the different trenchless installation methods has been provided in Appendix E. Selection of the appropriate trenchless method is the responsibility of the Contractor and will depend on the relative costs associated with each method. The experience of the Contractor is of primary importance for trenchless installation. Based on the results of the investigation, the size of the culvert, and the potential for obstructions, it is anticipated that pipe ramming will be the preferred trenchless technique; however, jack-and-bore and pipe jacking are also considered feasible. MTBM and hand mining (with appropriate tunnel support) are considered technically feasible, but likely would not be cost-competitive with the other trenchless options.

Given the 200 mm boulder observed in the clayey gravel fill in Borehole 21-01, consideration should be given to oversizing the trenchless casing pipe to facilitate personnel entry to remove potential obstructions. A minimum pipe diameter of 1.8 m is recommended to facilitate safe entry.



It is noted that an increase in installation diameter increases the likelihood of encountering obstructions as well as the risk of tunnel face instability due to mixed face conditions.

A minimum clear separation distance of 2.0 m should be provided between the tunnel casing and the existing culvert.

Trenchless installation should be completed in accordance with the requirements of the Non-Standard Special Provision (NSSP) "Pipe Installation by Trenchless Method" provided in Appendix G. Amongst the important issues discussed in the NSSP are maintenance of alignment, handling of obstructions and disposal of cuttings. It is recommended that the following methods be excluded from consideration during bidding for a 900 mm diameter culvert: directional drilling, microtunneling, and hand mining.

Monitoring of the roadway surface will be required during trenchless installation. The settlement monitoring program and condition survey should follow Section 7.06 of the NSSP in Appendix G.

The design of safe and stable entry and exit pits for the trenchless installation is also the responsibility of the Contractor. Geotechnical parameters for the design of the entry and exit pits are provided in Section 12. Dewatering and surface water control must be employed as necessary to keep the entry and exit pits dry as discussed further in Section 12.5.

10 FOUNDATION DESIGN RECOMMENDATIONS

10.1 Trenchless Replacement

If the replacement culvert is constructed using trenchless techniques and the grade of the embankment is not increased or widened (temporarily or permanently), it is anticipated that the subgrade soils within the culvert footprint will not be subjected to any significant additional loading. Guidelines for temporary foundations for the entry and exit pits are provided in Section 12.2.

10.2 Open-Cut Replacement

10.2.1 Subgrade Preparation, Bedding and Backfilling

Culvert installation in an open cut should be completed in accordance with OPSS.PROV 421. Site preparation should be carried out in accordance with OPSS.PROV 490.

For a replacement culvert constructed along the same alignment as the current culvert, the existing culvert and embedment materials should be removed. After excavation and removal of the existing culvert and existing fill, unsuitable materials at the subgrade level should be sub-excavated and backfilled with granular fill consisting of OPSS.PROV 1010 Granular A material as soon as practical to protect the subgrade from disturbance during construction.



The clay subgrade will be easily disturbed; therefore, construction equipment should not travel on the exposed subgrade. The compaction of granular material directly above the clay subgrade may result in disturbance of the material with pumping of fines into the granulars and difficulty achieving the specified degree of compaction. Protection of the subgrade should include installation of Class II non-woven geotextile with a maximum FOS of 75 to 150 μm (OPSS 1860) installed beneath the Granular layer. The geotextile should have overlapping joints and be placed as soon as possible after reaching the subgrade level.

A minimum of 300 mm of OPSS Granular A should be used as culvert bedding material. The backfill requirements for the replacement culvert above the bedding should be consistent with OPSD 802.010 (for flexible circular pipes) and OPSD 802.031 (for rigid circular pipes). The drawings for Type 3 soil should be used. Culvert embedment/cover material should consist of OPSS Granular A, which should be placed in accordance with the applicable OPSD drawing discussed above and OPSS.PROV 401.

Construction of the culvert will need to take place in the dry. At the time of investigation, minimal surface water was encountered near the inlet and outlet; however, construction will extend below the invert elevation and seasonal fluctuations may occur. Water diversion and dewatering may be required to prepare the subgrade in the dry. Additional comments on groundwater and surface water control are provided in Section 12.5.

10.2.2 Embankment Reinstatement

Embankment reconstruction after an open-cut culvert replacement should be carried out in accordance with OPSS.PROV 206.

It is recommended that the culvert backfill above the granular cover consist of non frost-susceptible granular fill consisting of imported OPSS Select Subgrade Material (SSM) or Granular B Type I. Gradation testing on the existing granular fill encountered in the upper 0.9 to 2.0 m met these requirements thus the existing granular fill is considered suitable for this purpose provided it can achieve compaction requirements at the time of placement. The clayey fill and the native clay are not considered suitable for re-use as backfill.

The embankment should be reinstated with side slopes to match the existing condition (or flatter) if constructed using Granular B Type I or SSM; however, in no case should the side slopes be steeper than 2H:1V. The fill should be placed and compacted in accordance with OPSS.PROV 401.

10.2.3 Temporary Embankment Settlement and Stability

The condition of the existing embankment slopes was examined in the field during the field investigation and no evidence of instability (tension cracks etc.) was noted at that time. The embankment slopes were vegetated with grass.

As discussed in Section 8.3, a temporary embankment lowering is considered a feasible means of construction staging. It is anticipated that sufficient embankment width could be achieved for two open cut stages if the grades were lowered temporarily by approximately 2.3 m. It is estimated this would require temporarily reprofiling more than 400 m of the highway. This option would result in negligible settlement and the embankments would be considered stable from a global stability perspective.

Alternatively, the extent of the construction zone could be reduced to approximately 260 m in length by combining a grade lowering of approximately 1.2 m with temporary platform widening of approximately 4 m on either side. The temporary platform widening would need to be constructed with OPSS Granular B Type II placed at 1.5H:1V slopes to prevent widening of the embankment beyond the current toe of slope. In this case, the temporary widening would result in additional load on the foundation soils, which is estimated to result in 10 to 25 mm of foundation settlement during construction, which is considered acceptable. In the worst-case, the contractor may need to add additional granular to level out areas of noticeable differential settlement. Temporary side slopes inclined at 1.5H:1V and constructed with compacted Granular B Type II will have a factor of safety against global instability of 1.3, which is considered acceptable for a temporary condition.

10.2.4 Permanent Embankment Settlement and Stability

It is understood that no permanent grade raise or embankment widening is required at this site and therefore negligible settlement of the soils beneath the embankment is expected to occur.

The magnitude of compression for embankment fill materials is in the order of 0.5% of the embankment height and is expected to occur following fill placement.

Provided no grade raise or permanent embankment widening is required and proper construction methods are used, no long term or global stability issues are anticipated for embankments re-built at this site. Material stockpiling above the existing grades is a temporary construction measure and the associated stability/settlement implications are the responsibility of the Contractor. The selection and placement of construction equipment (such as heavy cranes) are also the Contractor's responsibility.

10.3 Frost Depth

The depth of frost penetration at this site is 2.4 m as per OPSD 3090.101. However, the culvert is located below the frost penetration depth and the soils within the depth of excavation have a low susceptibility to frost heave per MTO guidelines; therefore, a frost treatment is not considered necessary for this culvert replacement.

10.4 Cement Type and Corrosion Potential

Analytical tests were completed to determine the potential for degradation of the concrete in the presence of soluble sulphates and the potential for corrosion of exposed steel. The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with soil and groundwater at the site. Soluble sulphate concentrations less than 1000 µg/g generally indicate that a low degree of sulphate attack is expected for concrete in contact with soil and groundwater. The class of concrete selected should consider the effects of road de-icing salts.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The tests results provided in Section 5.8 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosive effects of road de-icing salts should also be considered.

10.5 Pavement Design

Temporary pavements required during construction lasting less than a year should consist of 250 mm of OPSS Granular B Type I and 150 mm of OPSS Granular A. Where a paved surface is required, it should consist of temporary hot mix 50 mm in thickness.

Pavement should be reinstated to generally match existing conditions. The following materials and lifts are recommended:

- 40 mm of SP 12.5
- 50 mm of SP 12.5
- 150 mm of OPSS Granular A
- 450 mm of OPSS Granular B Type I

The pavement transition at the ends of construction should include a step joint with the 40 mm surface course extending 5 m onto a milled surface in the existing adjoining asphalt. Within the granular fill, the new subbase and base layers should be tapered out at 1H:1V.

11 SEISMIC CONSIDERATIONS

11.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth-generation seismic model developed by the Geological Survey of Canada (GSC). The seismic hazard for this site has been obtained from the GSC online calculator. The data includes a peak ground acceleration (PGA), peak ground velocity (PGV) and the 5% spectral response acceleration values (Sa(T)) for the *reference* ground condition (Site Class C) for a range of periods (T) and for a range of return periods



including 475-year, 975-year and 2475-year events. The GSC seismic hazard calculated data sheet for this site is included in Appendix F.

The site coefficients used to determine the design spectral acceleration and displacement values are a function of the Site Class and the peak ground acceleration (PGA). The PGA at this site for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.080g. This value is to be scaled by the $F(PGA)$ based on the site-specific Site Class.

11.2 Seismic Liquefaction Potential

Based on the depth of ground water, the low reference PGA, the subsurface conditions encountered at the drilled locations at this site and using the Seed & Idriss Simplified Method for liquefaction assessment, the soils below the culvert inverts are not considered susceptible to liquefaction during a design seismic event. Some local slope instability may be noted at the culvert inlet and outlet for a design seismic event during a period of higher water levels.

12 CONSTRUCTION CONSIDERATIONS

12.1 Excavations

Excavations for entry and exit pits must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the soils at this site may be classified as Type 3.

If there is not enough space to carry out the excavations using unsupported side slopes, the excavations will need to be carried out using temporary shoring. Further discussion on shoring is presented in Section 0.

It is recommended that an NSSP be included in the tender documents to alert the Contractor to the potential for encountering cobbles and boulders and obstructions within the fill and glacial till deposits during excavation. Sample text for this NSSP is provided in Appendix G.

12.2 Bearing Resistances

The design of foundations required for the entry or exit pits is the responsibility of the contractor. However, for preliminary planning purposes, the following geotechnical resistances can be used assuming a raft foundation footprint up to 6 m wide and 6 m long and a foundation that is founded on an undisturbed native subgrade. The bearing resistance values are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.3 and Clause 6.10.4. Foundation settlement, based on the supplied SLS resistance, is expected to be less than 25 mm.

- Factored Geotechnical Resistance at ULS of 135 kPa
- Factored Geotechnical Resistance at SLS of 90 kPa

The factored geotechnical resistances include the following factors:

- Consequence factor (Ψ) of 1.0 (as per CHBDC Table 6.1)
- Geotechnical resistance factors (as per CHBDC Table 6.2):
 - $\phi_{gu} = 0.5$ (static analysis; typical degree of understanding)
 - $\phi_{gs} = 0.8$ (static analysis; typical degree of understanding)

A pad of engineered fill, if required to raise the founding elevation, should consist of OPSS.PROV 1010 Granular A or Granular B Type II material that is compacted as per OPSS.PROV 501 in lifts no thicker than 300 mm. The granular fill should be placed as soon as practical to protect the subgrade from disturbance during construction.

It is noted that the clay, if used as a subgrade, is sensitive to disturbance (such as from construction traffic). Therefore, a clay subgrade should be covered as soon as possible with a mud slab of lean concrete with a thickness of at least 50 mm. Excavations to expose the clay subgrade should be carried out using a smooth-edged excavator bucket (no teeth) to minimize disturbance.

Surface water diversion and dewatering (Section 12.5) will be required to prevent disturbance of the subgrade.

12.3 Sliding Resistance

The following unfactored parameters can be used to assess the sliding resistance between the base foundation/slab and the subgrade soil. If a jacking technique is used to advance a trenchless installation, it is anticipated that additional lateral resistance will need to be provided by means of a thrust wall (Section 0).

| Interface and Loading Conditions | Parameter |
|--|-----------------------------------|
| Concrete – Granular pad; short or long term loading | Coefficient of Friction = 0.55 |
| Concrete – Clay subgrade; long term loading | Coefficient of Friction = 0.35 |
| Concrete – Clay subgrade; short term loading | Undrained Shear Strength = 50 kPa |



12.4 Temporary Protection Systems and Thrust Walls

Temporary Protection Systems (TPS) may be required during various stages of construction and must be implemented in accordance with OPSS.PROV 539 and designed for Performance Level 2 (maximum 25 mm horizontal deflection). The protection system near the culvert could be left in place and cut off in accordance with OPSS.PROV 539 to limit the disturbance of subgrade under the new culvert during removal of the TPS.

In addition, a thrust wall may be required at the rear of the entry pit if a jacking trenchless technique is used to install the culvert.

The actual pressure distribution acting on the TPS/wall is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the wall. Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design of the TPS/thrust wall through the existing soils, assuming a vertical wall and a level ground surface above the wall, are given below:

Existing Fill

| | | | |
|----------|---|------|--|
| γ | = | 21 | (kN/m ³ , bulk unit weight of soil) |
| K_A | = | 0.33 | |
| K_P | = | 3.0 | |

Native Clay

| | | | |
|----------|---|------|--|
| γ | = | 18.5 | (kN/m ³ , bulk unit weight of soil, unadjusted for water table) |
|----------|---|------|--|

Drained Parameters

| | | |
|-------|---|-------|
| K_A | = | 0.4 |
| K_P | = | 2.5 |
| c' | = | 5 kPa |

Undrained Parameters

| | | |
|-------|---|--------|
| K_A | = | 1 |
| K_P | = | 1 |
| c' | = | 45 kPa |

Glacial Till

| | | | |
|----------|---|------|--|
| γ | = | 21 | (kN/m ³ , bulk unit weight of soil) |
| K_A | = | 0.27 | |
| K_P | = | 3.7 | |

TPS and thrust walls are the responsibility of the Contractor and should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. A suitable bracing system may need to be incorporated into the design to resist the lateral loadings including surcharge loading due to construction equipment and operations. Additional lateral support may be required for a thrust wall (if a jacking trenchless technique is used), which may include bedrock anchors and/or soldier piles that are socketed into the bedrock. The depth of the temporary shoring/protection system must include consideration of the groundwater control plan.



12.5 Surface and Groundwater Control

At the time of the borehole investigation, there was minimal surface water at the inlet and outlet and there was no flow through the culvert. However, creek diversion may be required depending on the surface water depth at the time of construction. Water from surface flow and/or groundwater must be diverted away from excavation(s) at all times. Groundwater perched within the embankment and surface water will tend to seep into and accumulate in excavations. The Contractor must be prepared to control the groundwater and surface water at the site to permit construction in a dry and stable environment. Construction of cofferdams may be required to divert flow away from the trenchless entry and exit pits.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility.

For non-structural pipe culverts, the dewatering system is to be designed in accordance with OPSS.PROV 517 and SP 517F01. The hydrogeology is not considered to be complex at this site, thus Designer Fill-In ***** in SP 517F01 should be "No". A preconstruction survey is not recommended.

The groundwater level will fluctuate and the minimum groundwater elevation for the site at the time of construction should be taken as the water level from the design storm period defined in SP 517F01.

Construction of cofferdams may be required to divert flow away from the area of the culvert. A sand bag cofferdam and sump pump system would likely be sufficient.

Excavation below the groundwater level to replace the existing culvert without prior dewatering is not recommended since the inflow of groundwater will make it difficult to maintain a dry, sound base on which to work. The groundwater level should be lowered to 0.5 m below the planned base of each excavation stage.

The need for a Permit to Take Water (PTTW) should be carried out by specialists experienced in this field.

Surface water and groundwater management will be necessary to maintain dry working conditions in the required excavations. It is noted that no water flow was observed through the culvert at the time of the investigation. Provided the existing culvert is maintained operational during construction, a temporary flow passage is not expected to be required to convey flow around the construction site. Construction of cofferdams may be required to divert flow away from the trenchless entry and exit pits.



12.6 Scour Protection and Erosion Control

Scour and erosion protection should be provided for the culvert inlet and outlet areas. Design of the scour and erosion protection measures must consider hydrologic and hydraulic concerns and should be carried out by specialists experienced in this field.

Typically, rock protection should be provided over all earth surfaces subjected to flowing water. Treatment at the outlet should be in accordance with OPSD 810.010. A vegetation cover should be established on all other exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 804.

12.7 Construction Concerns

Potential construction concerns include, but are not necessarily limited to:

- Disturbance of the soil subgrade within the trenchless entry and exit pits. The water level may be high at the time of construction, resulting in moisture sensitive subgrade conditions that may become heavily disturbed when subjected to construction traffic. Site and subgrade drainage will be critical to maintain subgrade conditions. The Contractor must be aware of the issue so that he may adjust his operations to suit the subgrade conditions.
- Cobbles and boulders were encountered within the fill and glacial till while drilling. Roots were also encountered in the native clay. Buried obstructions may be encountered during excavations as well as during construction of temporary shoring/protection systems, cofferdams, and the trenchless culvert installation.
- Groundwater levels may fluctuate. Excavation will involve lowering the groundwater level below the excavation base to maintain a reasonably dry excavation and stable side slopes.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing embankment to support the proposed construction equipment.

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction.



13 CLOSURE

Engineering analysis and preparation of this report were carried out by Stephen Dunlop, P.Eng. The report was reviewed Dr. Fred Griffiths, P.Eng the Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:



Stephen Dunlop, M.A.Sc., P.Eng.
Associate, Senior Geotechnical Engineer



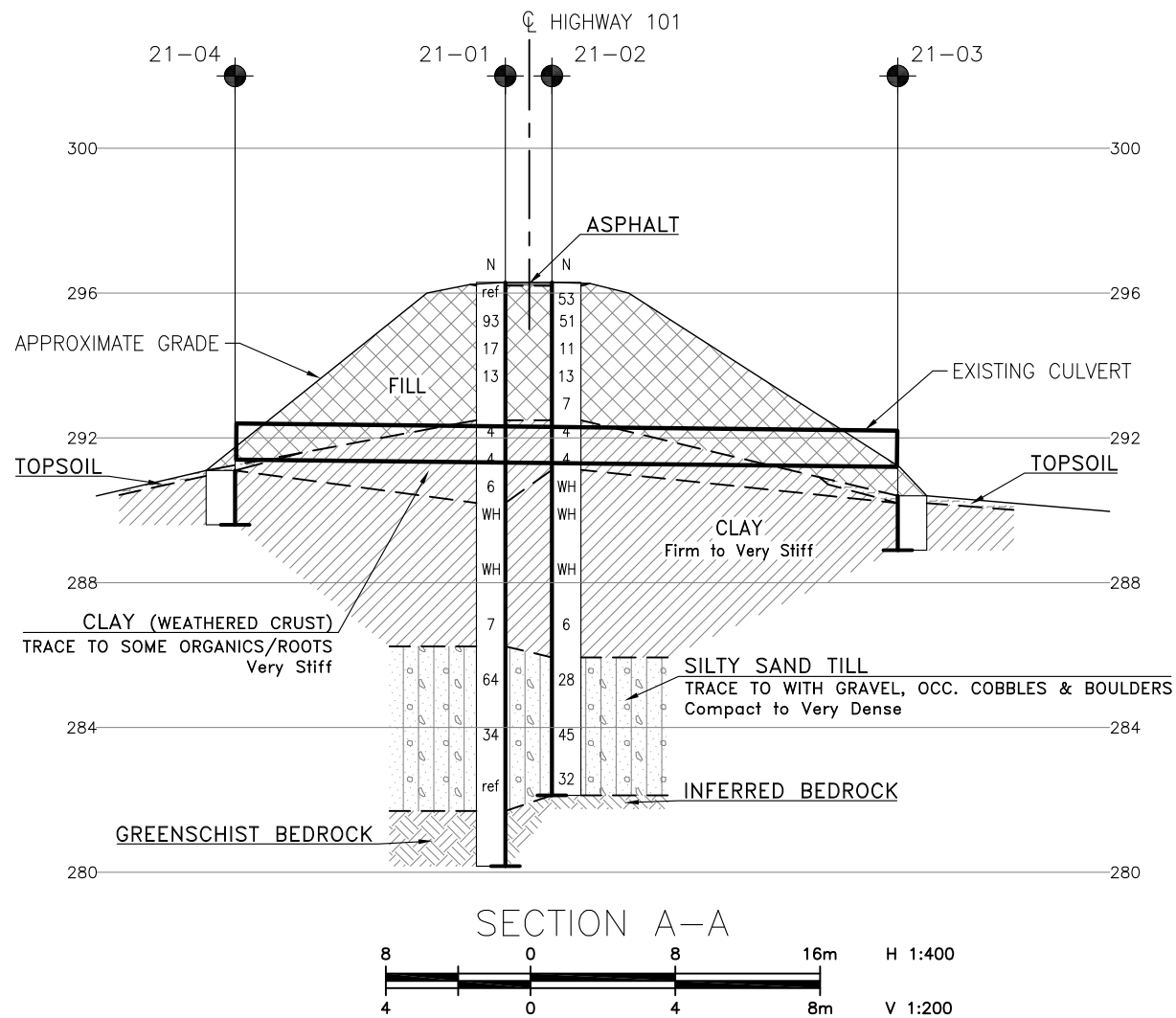
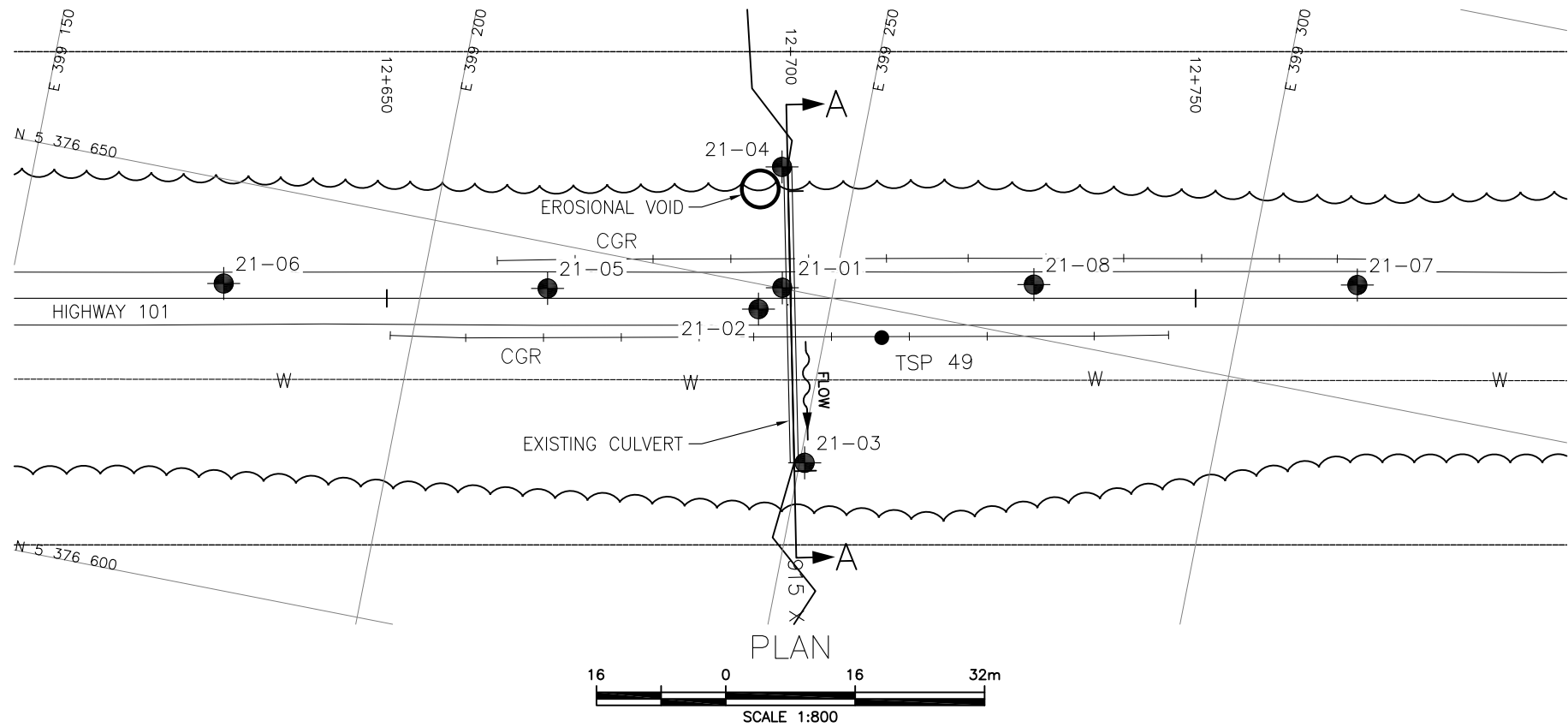
Fred Griffiths, P.Eng., Ph.D.
Senior Associate
Senior Geotechnical Engineer



Appendix A.

Drawings

Client: Ministry of Transportation Ontario, Northeastern Region
File No. 31935
e-File: 31935 tel fidr hwy101 culvert_final_2



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

CONT No
WP No

HIGHWAY 101
DEEP FILL
CULVERT REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA



SHEET



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 |

| NO | ELEVATION | NORTHING | EASTING |
|-------|-----------|-------------|-----------|
| 21-01 | 296.3 | 5 376 650.1 | 399 243.7 |
| 21-02 | 296.3 | 5 376 646.9 | 399 241.4 |
| 21-03 | 290.4 | 5 376 629.4 | 399 250.6 |
| 21-04 | 291.1 | 5 376 664.7 | 399 240.8 |
| 21-05 | 296.8 | 5 376 644.4 | 399 215.3 |
| 21-06 | 297.3 | 5 376 637.3 | 399 175.9 |
| 21-07 | 296.5 | 5 376 664.1 | 399 313.4 |
| 21-08 | 296.3 | 5 376 656.5 | 399 274.2 |

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 12.

GEOCRES No. 32D-36

| REVISIONS | DATE | BY | DESCRIPTION |
|-----------|------|----------|-------------|
| DESIGN | AO | CHK SD | CODE |
| DRAWN | MFA | CHK LB | SITE |
| LOAD | DATE | DEC 2021 | DWG 1 |



Appendix B.

Record of Borehole Sheets

Client: Ministry of Transportation Ontario, Northeastern Region
File No. 31935
e-File: 31935 tel fidr hwy101 culvert_final_2



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

| | |
|---------|--|
| Topsoil | mixture of soil and humus capable of supporting vegetative growth |
| Peat | mixture of fragments of decayed organic matter |
| Till | unstratified glacial deposit which may include particles ranging in sizes from clay to boulder |
| Fill | material below the surface identified as placed by humans (excluding buried services) |

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

| | |
|------------|---|
| Desiccated | having visible signs of weathering by oxidization of clay materials, shrinkage cracks, etc. |
| Fissured | having cracks, and hence a blocky structure |
| Varved | composed of alternating layers of silt and clay |
| Stratified | composed of alternating successions of different soil types, e.g. silt and sand |
| Layer | > 75 mm in thickness |
| Seam | 2 mm to 75 mm in thickness |
| Parting | < 2 mm in thickness |

RECOVERY:

For soil samples, the recovery is recorded as the length of the soil sample recovered.

N-VALUE:

Numbers in this column are the field results of the Standard Penetration Test: the number of blows of a 63.5 kg hammer falling 0.76 m, required to drive a 50 mm O.D. split spoon sampler 0.3 m into undisturbed soil. For samples where insufficient penetration was achieved and N-value cannot be presented, the number of blows are reported over the sampler penetration in millimetres (e.g. 50/75).

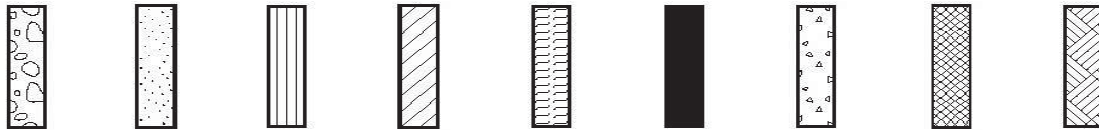
DYNAMIC CONE PENETRATION TEST (DCPT):

Dynamic cone penetration tests are performed using a standard 60 degree apex cone connected to an "A" size drill rods with the same standard fall height and weight as the Standard Penetration Test. The DCPT value is the number of blows of the hammer required to drive the cone 0.3 m into the soil. The DCPT is used as a probe to assess soil variability.



STRATA PLOT:

Strata plots symbolize the soil and bedrock description. They are combinations of the following basic symbols. The dimensions within the strata symbols are not indicative of the particle size, layer thickness, etc.



Boulders
Cobbles
Gravel Sand Silt Clay Organics Asphalt Concrete Fill Bedrock

TEXTURING CLASSIFICATION OF SOILS

| Classification | Particle Size |
|----------------|---------------------|
| Boulders | Greater than 200 mm |
| Cobbles | 75 – 200 mm |
| Gravel | 4.75 – 75 mm |
| Sand | 0.075 – 4.75 mm |
| Silt | 0.002 – 0.075 mm |
| Clay | Less than 0.002 mm |

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

| Descriptive Term | Undrained Shear Strength (kPa) |
|------------------|--------------------------------|
| Very Soft | 12 or less |
| Soft | 12 – 25 |
| Firm | 25 – 50 |
| Stiff | 50 – 100 |
| Very Stiff | 100 – 200 |
| Hard | Greater than 200 |

NOTE: Clay sensitivity is defined as the ratio of the undisturbed strength over the remolded strength.

SAMPLE TYPES

| | |
|-----------------|--|
| SS | Split spoon samples |
| ST | Shelby tube or thin wall tube |
| DP | Direct push sample |
| PS | Piston sample |
| BS | Bulk sample |
| WS | Wash sample |
| HQ, NQ, BQ etc. | Rock core sample obtained with the use of standard size diamond coring equipment |

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

| Descriptive Term | SPT “N” Value |
|------------------|-----------------|
| Very Loose | Less than 4 |
| Loose | 4 – 10 |
| Compact | 10 – 30 |
| Dense | 30 – 50 |
| Very Dense | Greater than 50 |

MODIFIED UNIFIED SOIL CLASSIFICATION

| Major Divisions | | Group Symbol | Typical Description |
|----------------------|--|--------------|--|
| COARSE GRAINED SOIL | 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 | SILT AND CLAY SOILS $W_L < 35\%$ | ML | Inorganic silts, 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. |
| | | OL | Organic silts and organic silty-clays of low plasticity. |
| | SILT AND CLAY SOILS $35\% < W_L < 50\%$ | MI | Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts. |
| | | CI | Inorganic clays of medium plasticity, silty clays. |
| | | OI | Organic silty clays of medium plasticity. |
| | SILT AND CLAY SOILS $W_L > 50\%$ | MH | Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts. |
| | | CH | Inorganic clays of high plasticity, fat clays. |
| | | OH | Organic clays of high plasticity, organic silts. |
| HIGHLY ORGANIC SOILS | | Pt | Peat and other organic soils. |

Note - W_L = Liquid Limit



EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

| | |
|---------------------------|--|
| Fresh (FR) | No visible signs of weathering. |
| Fresh Jointed (FJ) | Weathering limited to surface of major discontinuities. |
| Slightly Weathered (SW) | Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock materials. |
| Moderately Weathered (MW) | Weathering extends throughout the rock mass, but the rock material is not friable. |
| Highly Weathered (HW) | Weathering extends throughout the rock mass and the rock is partly friable. |
| Completely Weathered (CW) | Rock is wholly decomposed and in a friable condition, but the rock texture and structures are preserved. |

TERMS

| | |
|--|--|
| Total Core Recovery: (TCR) | Core recovered as a percentage of total core run length. |
| Solid Core Recovery: (SCR) | Percent ratio of solid core of full cylindrical shape recovered. Expressed with respect to the total length of core run. |
| Rock Quality Designation: (RQD) | Total length of sound core recovered in pieces 0.1 m in length or larger, as a percentage of total core length |
| Unconfined Compressive Strength: (UCS) | Axial stress required to break the specimen. |
| Fracture Index: (FI) | Frequency of natural fractures per 0.3 m of core run. |

DISCONTINUITY SPACING

| Bedding | Bedding Plane Spacing |
|---------------------|-----------------------|
| Very thickly bedded | Greater than 2 m |
| Thickly bedded | 0.6 to 2 m |
| Medium bedded | 0.2 to 0.6 m |
| Thinly bedded | 60 mm to 0.2 m |
| Very thinly bedded | 20 to 60 mm |
| Laminated | 6 to 20 mm |
| Thinly laminated | Less than 6 mm |

STRENGTH CLASSIFICATION

| Rock Strength | Approximate Uniaxial Compressive Strength (MPa) |
|------------------|---|
| Extremely Strong | Greater than 250 |
| Very Strong | 100 – 250 |
| Strong | 50 – 100 |
| Medium Strong | 25 – 50 |
| Weak | 5 – 25 |
| Very Weak | 1 – 5 |
| Extremely Weak | 0.25 – 1 |

METRIC

CHECKED BY SD

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 21-01

2 OF 2

METRIC

Lat: 48.52134°, Long: 79.72135°
MTM Zone 12: N 5 376 650.1 E 399 243.7

LOCATION

ORIGINATED BY AO

HWY 101

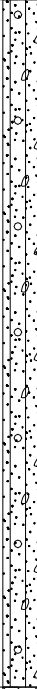

BOREHOLE TYPE Wash-boring with H-sized casing/NQ coring

COMPILED BY LB

DATUM Geodetic

DATE 2021.07.20 - 2021.07.21

CHECKED BY SD

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | PLASTIC LIMIT NATURAL LIMIT MOISTURE LIQUID CONTENT LIMIT | | | 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 | | | | WATER CONTENT (%) | | | | |
| | | | | | | | | 20 40 60 80 100 | | | | W _p W W _L | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | | | | | | | | |
| 286.2 | Continued From Previous Page | | | | | | | | | | | | | | | |
| 10.1 | (SM) SILTY SAND trace to with gravel grey dense to very dense occasional cobbles and boulders TILL |  | 11 | SS | 64 | | 286 | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | 285 | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| | | | 12 | SS | 34 | | 284 | | | | | | | | 4 63 30 3 | |
| | | | | | | | | | | | | | | | | |
| | | | | | | | 283 | | | | | | | | | |
| | | | 13 | SS | 100/ 225 mm | | | | | | | | | | | |
| | | | | | | | 282 | | | | | | | | | |
| 281.7 | GREENSCHIST BEDROCK fresh grey-green medium grained strong to very strong with quartz veins |  | 1 | RUN | - | | 281 | | | | | | FI 2 >10 3 1 6 | RUN #1 TCR=98% SCR=62% RQD=62% | | |
| 280.2 | End of Borehole | | | | | | | | | | | | | | | |
| 16.1 | Backfilled with bentonite to surface. Sealed with cold patch. | | | | | | | | | | | | | | | |

DOUBLE LINE TEMPLATE: HWY 101.GPJ 2012TEMPLATE(MTO).GDT 14/9/21

METRIC

CHECKED BY SD

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 21-02

2 OF 2

METRIC

Lat: 48.52131°, Long: 79.72139°
MTM Zone 12: N 5 376 646.9 E 399 241.4

LOCATION

ORIGINATED BY AO

HWY 101

BOREHOLE TYPE Wash-boring with H-sized casing

COMPILED BY LB

DATUM Geodetic

DATE 2021.07.21 - 2021.07.21

CHECKED BY SD

| 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 (%) GR SA SI CL | |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|--|--|--|--|---|---|--|---|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | W P W W L | | | | | |
| | | | | | | | | 20 40 60 80 100 | | | | 20 40 60 | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | | | | WATER CONTENT (%) | | | | | |
| | Continued From Previous Page | | | | | | | | | | | | | | | | |
| 285.9 | | | | | | | 286 | | | | | | | | | | |
| 10.4 | (SP-SM) SAND with silt and gravel grey compact to dense occasional cobbles and boulders TILL | | 1 | NQ | - | | | | | | | | | | | | |
| | | | 12 | SS | 28 | | | | | | | | o | | 28 61 10 1 | | |
| | | | | | | | 285 | | | | | | | | | | |
| | | | | | | | 284 | | | | | | o | | | | |
| | | | 13 | SS | 45 | | | | | | | | | | | | |
| | | | | | | | 283 | | | | | | o | | | | |
| | | | 14 | SS | 32 | | | | | | | | | | | | |
| 282.1 | | | | | | | | | | | | | | | | | |
| 14.2 | End of Borehole - refusal on inferred bedrock Backfilled with bentonite to surface. Sealed with cold patch. | | | | | | | | | | | | | | | | |

+³, ×³: Numbers refer to
Sensitivity

20
15
10

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 21-03

1 OF 1

METRIC

Lat: 48.52115°, Long: 79.72126°
MTM Zone 12: N 5 376 629.4 E 399 250.6

LOCATION

ORIGINATED BY AO

HWY 101

BOREHOLE TYPE Hand Auger

COMPILED BY LB

DATUM Geodetic

DATE 2021.07.20 - 2021.07.20

CHECKED BY SD

| 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 (%) GR SA SI CL |
|---------------|--|------------|---------|------|------------|----------------------------|-----------------|---|----|----|-----|----------------|---|----------------|--|-----------------|--|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | WATER CONTENT (%) | | | | | |
| | | | | | | | 20 | 40 | 60 | 80 | 100 | W _p | W | W _L | | | | |
| 290.4 | | | | | | | | | | | | | | | | | | |
| 0.0 | TOPSOIL (200 mm) brown | | 1 | GS | - | | | | | | | | | | | | | |
| 0.2 | (Cl) CLAY trace roots, trace sand brown-grey firm to stiff | | 2 | GS | - | 290 | | | | | | | | | | | | |
| 288.9 | | | | | | 289 | | | | | | | | | | | | |
| 1.5 | | | | | | | | | | | | | | | | | | |

RECORD OF BOREHOLE No 21-04

1 OF 1

METRIC

Lat: 48.52147°, Long: 79.72139°
MTM Zone 12: N 5 376 664.7 E 399 240.8

LOCATION

ORIGINATED BY AO

HWY 101

BOREHOLE TYPE Hand Auger

COMPILED BY LB

DATUM Geodetic

DATE 2021.07.20 - 2021.07.20

CHECKED BY SD

| 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 | WATER CONTENT (%) | | | | | |
| 291.1 | | | | | | | | | | | | | | |
| 0.0 | TOPSOIL (150 mm) dark brown | | 1 | GS | - | | | | | | | | | |
| 290.7 | | | 2 | GS | - | | | | | | | | | |
| 0.4 | CLAY trace roots, sand and gravel brown FILL (Cl) CLAY trace roots grey firm to stiff | | 3 | GS | - | | | | | | | | | |
| 289.6 | | | | | | | | | | | | | | |
| 1.5 | | | | | | | | | | | | | | |

**Highway 101 Deep Fill Culvert
Holloway Township
Assignment No.: 5018-E-0034, Work Item No. 9**

Pavement Borehole Records

Page 1 of 1

**BH21-05 2 LT C/L (WB) (El. 296.8 m)
30 m west of culvert**

| | | |
|-----|-------|---|
| 0 | - 110 | Asph |
| 110 | - 350 | Gry-Br Gr(y) Sa W Si and RAP, moist, very D |
| 350 | - 700 | Br Gr(y) Sa W Si, moist, very D |
| 700 | - 1.2 | Dk Br Si(y) Sa W Gr, moist, Comp |
| 1.2 | - NFP | Cob/Blds/RF |

**BH21-06 2 LT CL (WB) (El. 297.3 m)
70 m west of culvert**

| | | |
|-----|-------|--|
| 0 | - 110 | Asph |
| 110 | - 260 | Dk Br Gr(y) Sa W Si and RAP, moist, very D |
| 260 | - 500 | Br Sa W Si and Gr, moist, very D |
| 500 | - 560 | Asph |
| 560 | - 900 | Dk Br Gr(y) Sa W Si, moist, very D |
| 900 | - 2.0 | Br Si(y) Cl, tr Gr, moist |
| 2.0 | - 2.8 | Lt Br Cl, moist, very stiff (native) |

**BH21-07 2 LT CL (WB) (El. 296.5 m)
70 m east of culvert**

| | | |
|-----|-------|------------------------------------|
| 0 | - 90 | Asph |
| 90 | - 300 | Dk Br Gr(y) Sa W Si, moist, very D |
| 300 | - 350 | Asph |
| 350 | - 600 | Br Gr(y) Sa W Si, moist, very D |
| 600 | - 900 | Dk Br Gr(y) Sa W Si, moist, very D |
| 900 | - NFP | Cob/Blds/RF |

**BH21-08 2 LT CL (WB) (El. 296.3 m)
30 m east of culvert**

| | | |
|-----|-------|---|
| 0 | - 90 | Asph |
| 90 | - 200 | Br Gr(y) Sa W Si, moist, very D |
| 200 | - 350 | Dk Br Gr(y) Sa W Si, moist, very D |
| 350 | - 400 | Asph |
| 400 | - 650 | Br Gr(y) Sa W Si, moist, very D |
| 650 | - 900 | Dk Br Gr(y) Sa W Si, Occ Cob and Asph, moist, D |
| 900 | - 2.2 | Br Si(y) Cl, tr Sa and Gr, moist |
| 2.2 | - 2.7 | Br Cl, moist, very stiff (native) |



Appendix C.

Laboratory Testing



Appendix C.1

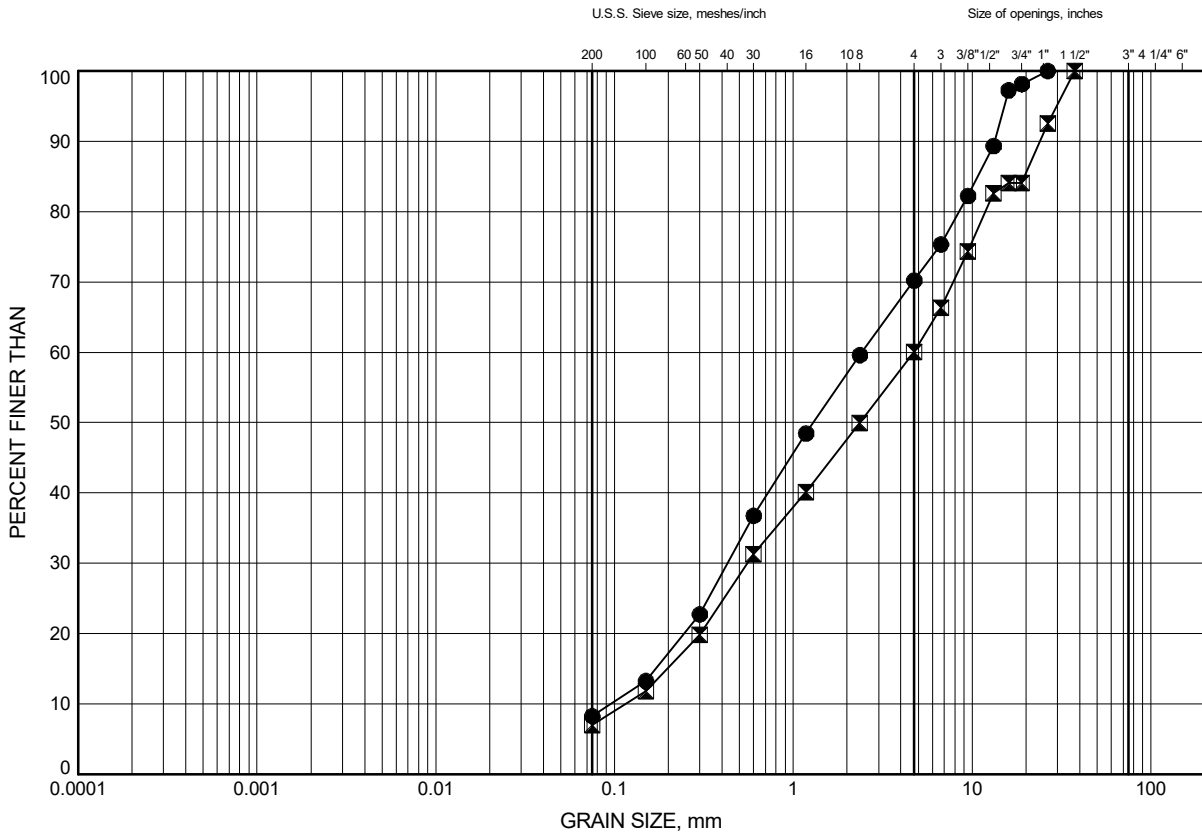
Particle Size Analysis and Atterberg Limits

Client: Ministry of Transportation Ontario, Northeastern Region
File No. 31935
e-File: 31935 tel fidr hwy101 culvert_final_2

Highway 101 Deep Fill Culvert GRAIN SIZE DISTRIBUTION

FIGURE C1

GRAVELLY SAND FILL



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

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 21-01 | 1.1 | 295.2 |
| ◻ | 21-02 | 1.1 | 295.2 |

Date December 2021
.....

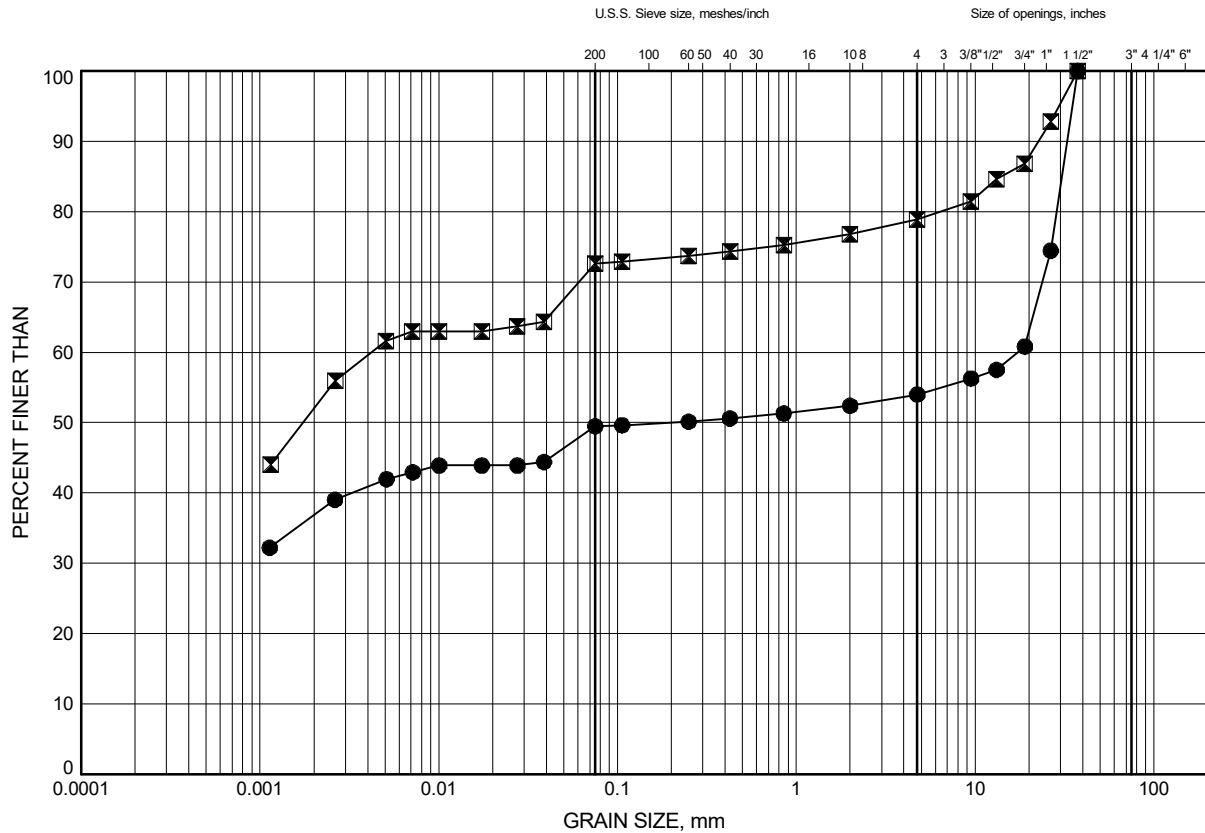


Prep'd SH
Chkd. SD

Highway 101 Deep Fill Culvert GRAIN SIZE DISTRIBUTION

FIGURE C2

CLAY with gravel FILL



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

LEGEND

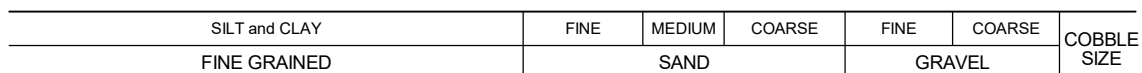
| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 21-01 | 2.6 | 293.7 |
| ⊠ | 21-02 | 1.8 | 294.5 |

Date December 2021
.....



Prep'd SH
Chkd. SD

FIGURE C3



| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 21-01 | 4.9 | 291.4 |
| ☒ | 21-01 | 7.9 | 288.4 |
| ▲ | 21-02 | 4.1 | 292.2 |
| ★ | 21-02 | 7.9 | 288.4 |

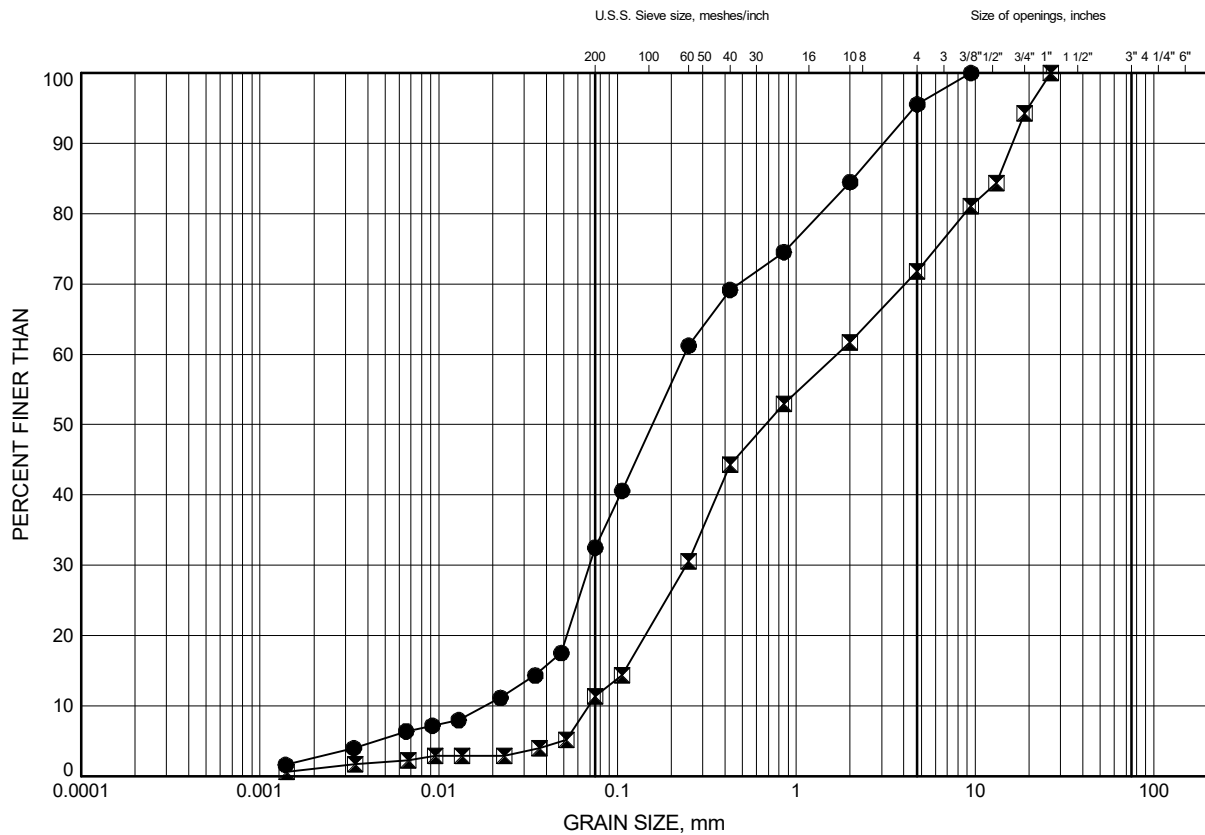


Prep'dSH.....
Chkd.SD.....

Highway 101 Deep Fill Culvert GRAIN SIZE DISTRIBUTION

FIGURE C4

SAND with silt and gravel (TILL)



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

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 21-01 | 12.5 | 283.8 |
| ⊠ | 21-02 | 11.0 | 285.3 |

Date December 2021

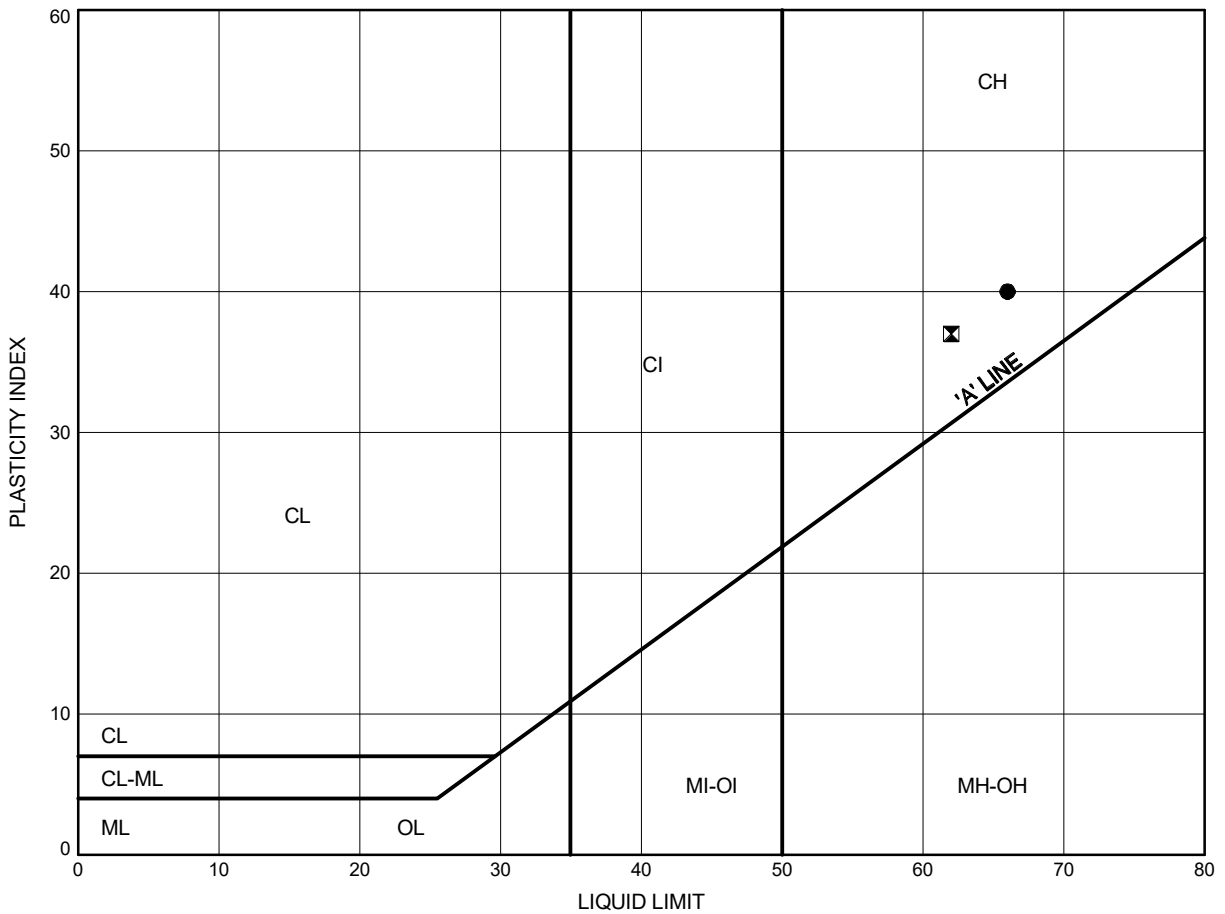


Prep'd SH
Chkd. SD

Highway 101 Deep Fill Culvert ATTERBERG LIMITS TEST RESULTS

FIGURE C5

CLAY FILL



LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 21-01 | 2.6 | 293.7 |
| ⊠ | 21-02 | 1.8 | 294.5 |

Date December 2021

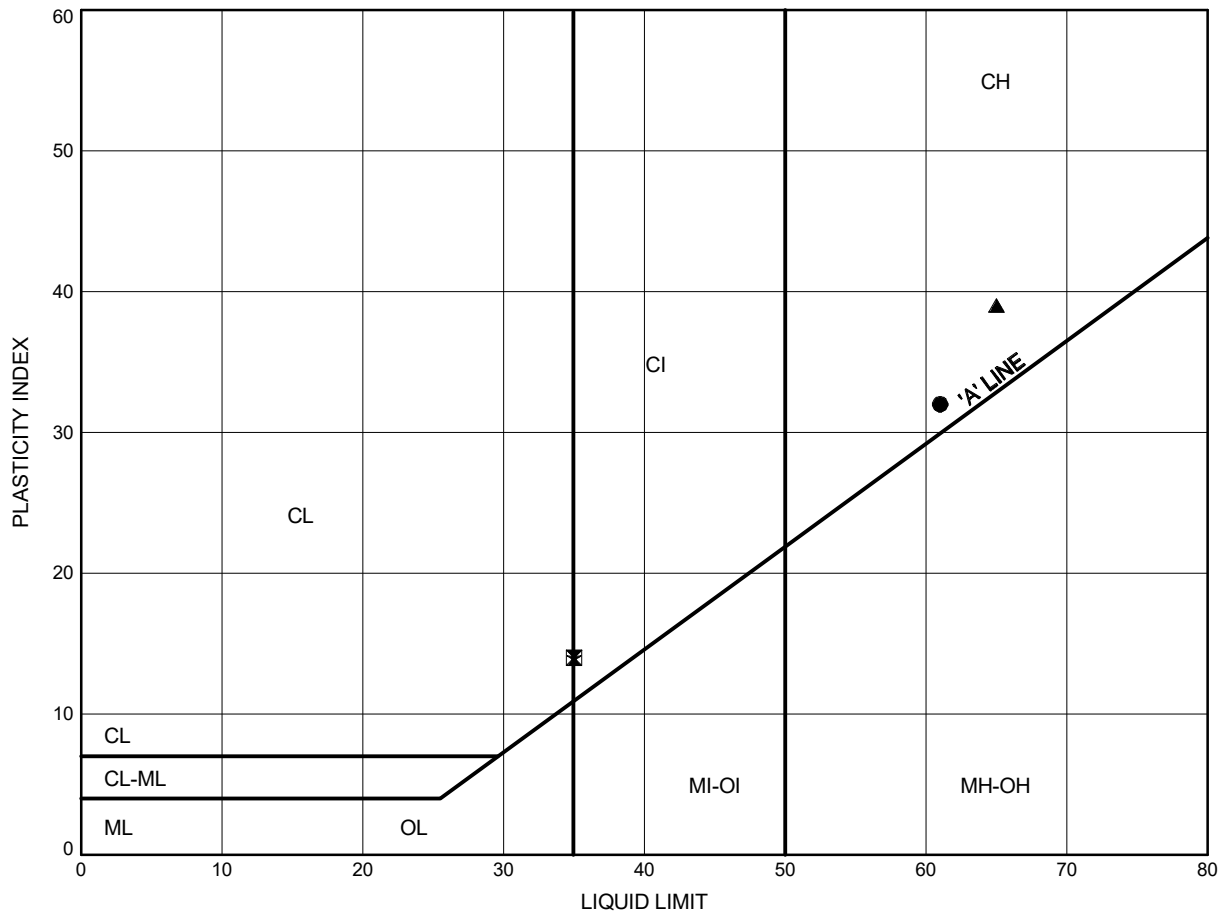


Prep'd SH
Chkd. SD

Highway 101 Deep Fill Culvert ATTERBERG LIMITS TEST RESULTS

FIGURE C6

CLAY



LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 21-01 | 4.9 | 291.4 |
| ⊠ | 21-01 | 7.9 | 288.4 |
| ▲ | 21-02 | 4.1 | 292.2 |
| ★ | 21-02 | 7.9 | 288.4 |

Date December 2021



Prep'd SH
Chkd. SD



Appendix C.2

Analytical Testing Results

Client: Ministry of Transportation Ontario, Northeastern Region
File No. 31935
e-File: 31935 tel fidr hwy101 culvert_final_2

Certificate of Analysis

Report Date: 09-Aug-2021

Client: Thurber Engineering Ltd.

Order Date: 3-Aug-2021

Client PO:

Project Description: 31935

| | | | | |
|--------------|-----------------|---|---|---|
| Client ID: | 21-01 SS5 | - | - | - |
| Sample Date: | 20-Jul-21 09:00 | - | - | - |
| Sample ID: | 2132161-01 | - | - | - |
| MDL/Units | Soil | - | - | - |

Physical Characteristics

| | | | | | |
|----------|--------------|------|---|---|---|
| % Solids | 0.1 % by Wt. | 69.7 | - | - | - |
|----------|--------------|------|---|---|---|

General Inorganics

| | | | | | |
|-------------|---------------|------|---|---|---|
| pH | 0.05 pH Units | 7.39 | - | - | - |
| Resistivity | 0.10 Ohm.m | 22.5 | - | - | - |

Anions

| | | | | | |
|----------|------------|-----|---|---|---|
| Chloride | 5 ug/g dry | 108 | - | - | - |
| Sulphate | 5 ug/g dry | 12 | - | - | - |

**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

24-August-2021

Date Rec. : 05 August 2021
LR Report: CA12119-AUG21
Reference: Project#: 2132161

Copy: #1

CERTIFICATE OF ANALYSIS

Final Report

| Sample ID | Sample Date & Time | Sulphide (Na ₂ CO ₃) % |
|----------------------------|--------------------|---|
| 1: Analysis Start Date | | 23-Aug-21 |
| 2: Analysis Start Time | | 12:55 |
| 3: Analysis Completed Date | | 23-Aug-21 |
| 4: Analysis Completed Time | | 17:06 |
| 5: QC - Blank | | < 0.04 |
| 6: QC - STD % Recovery | | 106% |
| 7: QC - DUP % RPD | | ND |
| 8: RL | | 0.02 |
| 9: 21-01 SS5 | 20-Jul-21 09:00 | < 0.04 |

RL - SGS Reporting Limit
ND - Not Detected

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety



Appendix C.2

Rock Core Photographs

21-01

Run 1 to 1 (of 1)

Elevation 281.7 m to 280.2 m

Run 1 Start
elev. 281.7m

Run 1 End
elev. 280.2m





Appendix D.

Site Photographs



Photo 1. Void under upstream culvert inlet. [July 20, 2021]



Photo 2. Culvert deformed at inlet. [July 20, 2021]



Photo 3. Culvert outlet [July 20, 2021]



Photo 4. South (downstream) embankment slope. [July 20, 2021]



Photo 5. North (upstream) embankment slope. [July 20, 2021]



Photo 6. Highway 101 looking west from the culvert. [July 20, 2021]

Client: Ministry of Transportation Ontario, Northeastern Region
File No. 31935
e-File: 31935 tel fidr hwy101 culvert_final_2



Appendix E.

Comparison of Culvert Installation Options

Client: Ministry of Transportation Ontario, Northeastern Region
File No. 31935
e-File: 31935 tel fidr hwy101 culvert_final_2

COMPARISON OF CULVERT INSTALLATION METHODS FOR 900 MM DIAMETER REPLACEMENT CULVERT

| Replacement Option | Open Cut Methods | | Trenchless Methods – New Alignment (2 m West of Existing Culvert) | | | | |
|---------------------------|--|---|---|--|---|---|---|
| | Temporary Protection System | Temporary Embankment Lowering | Jack and Bore | Pipe Ramming | Pipe Jacking with Open-Faced TBM | Microtunneling | Hand Mining |
| Advantages | <ul style="list-style-type: none">• Simple construction; a specialist contractor is not required | <ul style="list-style-type: none">• Simple construction; a specialist contractor is not required• Less costly than TPS• Not subjected to possible obstructions. | <ul style="list-style-type: none">• Minimal traffic disruption• Readily available equipment | <ul style="list-style-type: none">• Reduced traffic disruption• Advancement past obstructions is possible by manual removal at the tunnel face but will be challenging due to limited tunnel height | <ul style="list-style-type: none">• Reduced traffic disruption• Advancement past obstructions is possible by manual removal at the tunnel face but will be challenging due to limited tunnel height | <ul style="list-style-type: none">• Minimal traffic disruption | <ul style="list-style-type: none">• Reduced traffic disruption• Advancement past obstructions is possible by manual removal at the tunnel face but will be challenging due to limited tunnel height |
| Disadvantages | <ul style="list-style-type: none">• Requires lane closures, likely with a narrow lane and reduced speeds• Requires waterflow management with potential by-pass pumping• Obstructions in the fill and glacial till may make installation of TPS challenging | <ul style="list-style-type: none">• Requires lane closures, likely with a narrow lane and reduced speeds• Requires waterflow management with potential by-pass pumping | <ul style="list-style-type: none">• Incapable of advancing through oversize obstructions• Prone to misalignment if obstructions encountered• Requires entry/exit pits and access• Requires a thrust wall | <ul style="list-style-type: none">• Trouble maintaining alignment if obstructions encountered• Requires entry/exit pits and access | <ul style="list-style-type: none">• Removing obstructions will be very slow• Limited contractor availability• Requires entry/exit pits and access• Requires a thrust wall | <ul style="list-style-type: none">• Expensive• Limited contractor availability• Difficulty advancing if cobbles/boulders > 30% of machine diameter• Requires entry/exit pits and access• Requires a thrust wall | <ul style="list-style-type: none">• Expensive• High risk for workers that need to access the tunnel face• Very slow progress |
| Relative Cost | Low to Moderate | Low | Moderate | Moderate | High | High | High |
| Relative Risks | <ul style="list-style-type: none">• Low to moderate risk, with some potential for the duration of the lane closures to increase if many obstructions are encountered or if water is inadequately managed | <ul style="list-style-type: none">• Low risk | <ul style="list-style-type: none">• Moderate risk due to potential for encountering obstructions. Potential for the duration to increase if many obstructions are encountered. In the worst-case a portion of the culvert may need to be replaced by open-cut.• Settlement of the roadway is possible. | <ul style="list-style-type: none">• Moderate risk due to potential for encountering obstructions. Potential for the duration to increase if many obstructions are encountered. In the worst-case a portion of the culvert may need to be replaced by open-cut.• Settlement or heave of the roadway is possible. | <ul style="list-style-type: none">• Moderate risk due to potential for encountering obstructions. Potential for the duration to increase if many obstructions are encountered. In the worst-case a portion of the culvert may need to be replaced by open-cut.• Settlement of the roadway is possible. | <ul style="list-style-type: none">• Moderate risk due to potential for encountering obstructions. Potential for the duration to increase if many obstructions are encountered. In the worst-case a portion of the culvert may need to be replaced by open-cut.• Settlement of the roadway is possible. | <ul style="list-style-type: none">• Moderate risk due to potential for encountering obstructions. Potential for the duration to increase if many obstructions are encountered. In the worst-case a portion of the culvert may need to be replaced by open-cut.• Settlement of the roadway is possible. |
| Summary | Technically feasible but with higher risks and costs than temporary embankment lowering | Feasible and least risk, but with significant traffic disruption. Recommended if trenchless is not preferred | Feasible, recommended to reduce traffic disruption | | | Feasible, but not recommended | |





THURBER ENGINEERING LTD.

Appendix F.

GSC Seismic Hazard Calculation

Client: Ministry of Transportation Ontario, Northeastern Region

File No. 31935

e-File: 31935 tel fidr hwy101 culvert_final_2

104, 2480 Lancaster Road, Ottawa ON K1B 4S5 T. 613 247 2121 F. 613 247 2185

thurber.ca

2015 National Building Code Seismic Hazard Calculation

INFORMATION: Eastern Canada English (613) 995-5548 français (613) 995-0600 Facsimile (613) 992-8836
Western Canada English (250) 363-6500 Facsimile (250) 363-6565

Site: 48.521N 79.721W

User File Reference: Hwy 101 Culvert

2021-08-31 17:37 UT

Requested by: Stephen Dunlop, Thurber Engineering Ltd.

| | | | | |
|---------------------------------------|----------|-------|--------|-------|
| Probability of exceedance per annum | 0.000404 | 0.001 | 0.0021 | 0.01 |
| Probability of exceedance in 50 years | 2 % | 5 % | 10 % | 40 % |
| Sa (0.05) | 0.109 | 0.061 | 0.037 | 0.011 |
| Sa (0.1) | 0.144 | 0.085 | 0.053 | 0.017 |
| Sa (0.2) | 0.131 | 0.081 | 0.053 | 0.019 |
| Sa (0.3) | 0.107 | 0.068 | 0.045 | 0.017 |
| Sa (0.5) | 0.084 | 0.054 | 0.036 | 0.013 |
| Sa (1.0) | 0.049 | 0.031 | 0.021 | 0.006 |
| Sa (2.0) | 0.025 | 0.016 | 0.010 | 0.003 |
| Sa (5.0) | 0.006 | 0.004 | 0.002 | 0.001 |
| Sa (10.0) | 0.003 | 0.002 | 0.001 | 0.000 |
| PGA (g) | 0.080 | 0.047 | 0.030 | 0.010 |
| PGV (m/s) | 0.068 | 0.041 | 0.026 | 0.008 |

Notes: Spectral ($S_a(T)$, where T is the period in seconds) and peak ground acceleration (PGA) values are given in units of g (9.81 m/s^2). Peak ground velocity is given in m/s . Values are for "firm ground" (NBCC2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are highlighted in yellow. Three additional periods are provided - their use is discussed in the NBCC2015 Commentary. Only 2 significant figures are to be used. **These values have been interpolated from a 10-km-spaced grid of points. Depending on the gradient of the nearby points, values at this location calculated directly from the hazard program may vary. More than 95 percent of interpolated values are within 2 percent of the directly calculated values.**

References

National Building Code of Canada 2015 NRCC no. 56190; Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

Structural Commentaries (User's Guide - NBC 2015: Part 4 of Division B)
Commentary J: Design for Seismic Effects

Geological Survey of Canada Open File 7893 Fifth Generation Seismic Hazard Model for Canada: Grid values of mean hazard to be used with the 2015 National Building Code of Canada

See the websites www.EarthquakesCanada.ca and www.nationalcodes.ca for more information



Natural Resources
Canada

Ressources naturelles
Canada

Canada



THURBER ENGINEERING LTD.

Appendix G.

List of Special Provisions and OPSS Documents Referenced in this Report

Client: Ministry of Transportation Ontario, Northeastern Region

File No. 31935

e-File: 31935 tel fidr hwy101 culvert_final_2

104, 2460 Lancaster Road, Ottawa ON K1B 4S5 T. 613 247 2121 F. 613 247 2185

thurber.ca

1. The following Special Provisions and OPSS Documents are reference in this report:

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| OPSS 511 | Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting |
| OPSS 902 | Construction Specification for Excavating and Backfilling Structures |
| OPSS 1860 | Material Specification for Geotextile |
| OPSS.PROV 1010 | Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material |
| OPSS.PROV 180 | Construction Specification for the Management of Excess Materials |
| 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 Precast Reinforced Concrete Box Culverts in Open Cut |
| OPSS.PROV 501 | Construction Specification for Compacting |
| OPSS.PROV 517 | Construction Specification for Dewatering |
| OPSS.PROV 539 | Construction Specification for Temporary Protection Systems |
| OPSS.PROV 804 | Construction Specification for Seed and Cover |
| OPSS.PROV 805 | Construction Specification for Temporary Erosion and Sediment Control Measures |
| OPSD 208.010 | Benching of Earth Slopes |
| OPSD 802.010 | Flexible Pipe Embedment and Backfill 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 803.031 | Frost Treatment – Pipe Culverts Frost Penetration Line Between Top of Pipe and Bedding Grade |
| OPSD 810.010 | General Rip-Rap Layout for Sewer and Culvert Outlets |
| OPSD 3090.100 | Foundation Frost Depths for Northern Ontario |
| SP 517F01 | Amendment to OPSS 517 - Construction Specification for Dewatering |

2. Suggested text for a NSSP on “Buried Obstructions”

“The contractor is advised that obstructions (cobbles and boulders) were encountered within the embankment fill and native glacial till and may be encountered during excavation and installation of temporary protection systems. Such obstructions may impede the work from reaching design depth of installation. The constructor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the work to the design depths.

**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

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

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|---------|--|
| 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)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

MTBM means a microtunnelling boring machine.

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

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

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

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

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

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

Reaming means a process for enlarging the bore path.

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

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

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

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

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

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

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

TBM means a tunnel boring machine.

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

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

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

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

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Design

4.01.01 General

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

The trenchless installation method selected for each pipe crossing shall be designed for the subsurface conditions in accordance with the Contract Documents. Specifically, the trenchless contractor is alerted of the following conditions:

- **Mixed-Face Conditions:** a significant portion of the tunnel path is anticipated to be within the very stiff weathered clay just below the embankment fill; however, the tunnel crown may encounter embankment fill consisting of variable clayey gravel fill containing cobbles and boulders.
- **Obstructions:** A boulder was encountered in the clayey gravel fill in Borehole 21-01. The presence of cobbles and boulders and debris in the fill, and potentially tree stumps, roots or other woody debris / organics at and near the interface between fill and native soils from clearing and grubbing that may not have fully been removed at the time of construction of the highway, should be anticipated. In addition, the previous Creek bed may have been located west or east of the existing culvert (typically culverts are installed beside a creek crossing and then the creek diverted through the culvert) where the proposed new crossings are located; thus, trees / wood and other debris either remaining from original site clearing and preparation or carried down the stream may be present near the fill / native interface.

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

A soil cover to cut tunnel diameter ratio of 2 shall be maintained below the travelled portion of Highway 101 and top of the cut tunnel diameter shall not be higher than Elevation 292.7 m. The overcut dimension (difference between cutterhead diameter and outside pipe diameter) shall be limited such that ground surface settlements are within the tolerances provided in Section 7.08.

The trenchless installation shall be carried out continuously (24-hour operation) without any stoppage until the crossing is completed.

4.02 Submission Requirements

4.02.01 Qualifications

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

4.02.01.01 Project Superintendent

The Project Superintendent shall have a minimum of ten years' experience on projects with similar geology, scope and complexity, using the similar type of equipment required for this project. At least two projects shall demonstrate trenchless installation of similar pipe size or greater in similar ground conditions.

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 ten years' experience on projects with similar geology, scope and complexity, using the similar type of equipment and materials that meet the minimum requirements for this project. At least two projects shall demonstrate trenchless installation of similar pipe size or greater in similar ground conditions.

4.02.02 Working Drawings

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

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

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

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

a) Plans and Details:

- i. Plans and profiles defining all horizontal and vertical alignment positions and positions of all utilities and other infrastructure within the zone of influence of the work.
- ii. A work plan outlining the materials, procedures, methods and schedule to be used to execute the Work.
- iii. A list of personnel, including backup personnel, and their qualifications and experience.
- iv. A traffic control plan.
- v. A safety plan including the company safety manual and emergency procedures.
- vi. The Working Area layout.

- vii. An erosion and sediment control plan that includes a contingency plan in the event the erosion and sediment control measures fail.
- viii. A contingency plan with specific details of the manner in which rock or boulders will be broken and removed from the face and the face will be protected to prevent soil loss into the liner.
- ix. A drilling fluid management plan, if applicable, that addresses control of frac-out pressures, any potential environmental impacts and includes a contingency plan, detailing emergency procedures in the event that the fluid management plan fails.
- x. Lighting, ventilation and fire safety details as may be required by applicable occupational health and safety regulations.
- xi. Excavated materials disposal plan.
- xii. Locations of protection systems.
- xiii. Contingency plans for the following potential conditions:
 - Unforeseen obstructions causing stoppage.
 - Deviation from required alignment and grade.
 - Extended service disruption.
 - Damage to the existing Utilities and methods of repair.
 - Soil heaving or settlement.
 - Contaminated soil or water.
 - Alignment passing through buried structures.

b) Designs:

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

c) Materials:

- i. Certification from the manufacturer that the product furnished on the contract meets the specifications cited in the manufacturer's product specification and that the materials supplied are suitable for the application.
- ii. Manufacturer data sheets for all drilling fluids and additives for use in Earth Pressure Balance (EPB), Slurry Pressure Balance (SPB).
- iii. Manufacturer data sheets for drilling systems.
- iv. Mix designs, target rheology criteria (e.g., viscosity, density, shear strength, gel time, pressure-filtration – fluid losses under pressure, etc.) and additive dosage rates for all slurries and Earth Pressure Balance (EPB) tunnel boring machine (TBM) and microtunnelling boring machine (MTBM) operations.

- v. The proposed grout mix design for grouts to be used for lubricating jacking pipe and for filling of voids and annular spaces.
- vi. Compressive strength of concrete pipe products.
- vii. Pipe class for all steel pipe products.
- viii. Steel for Permanent Casings:
 - One copy of a mill test certificate certifying that the steel meets the requirements for the appropriate standards for permanent casings shall be submitted to the Contract Administrator at the time of delivery.
 - Where mill test certificates originate from a mill outside Canada or the United States of America, the information on the mill certificates shall be verified by testing by a Canadian laboratory. The laboratory shall be certified by an organization accredited by the Standards Council of Canada to comply with the requirements of ISO/IEC 17025 for the specific tests or type of tests required by the material standard specified on the mill test certificate.
 - The mill test certificates shall be stamped with the name of the Canadian testing laboratory and appropriate wording stating that the material conforms to the specified material requirements. The stamp shall include the appropriate material specification number, the date (i.e., yyyy-mm-dd), and the signature of an authorized officer of the Canadian testing laboratory.
- ix. Slurry, drilling fluids, and tunnelling fluids:
 - Type, source, and physical and chemical properties of bentonite, polymer or other additives;
 - Source of water;
 - Method of mixing;
 - Water to solids ratio and the mass and volumes of the constituent parts, including any chemical admixtures or physical treatment employed to achieve required physical properties;
 - Details of procedure to be used for monitoring physical properties of slurry, drilling fluids and tunnelling 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 Auger Jack & Bore, for advancing the lead end of the casing ahead of the lead end of the auger cutting tools.

g) Monitoring Method:

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

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

4.02.03 As-Built Drawings

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

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

5.0 MATERIALS

5.01 Pipe

5.01.01 General

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

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

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

All fittings shall be designed to be watertight.

5.01.02 Steel Pipe

Steel pipe shall be according to ASTM A252.

All steel casing pipe shall be square cut.

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

5.01.03 High Density Polyethylene Pipe

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

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

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

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

5.01.04 Concrete Pipe

Concrete pipe shall be according to OPSS 1820.

5.02 Concrete

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

5.03 Steel Reinforcement

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

5.04 Wood

Wood shall be according to OPSS 1601.

5.05 Drilling Fluids

Drilling fluid shall be mixed according to the Working Drawings.

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

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

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

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

5.06 Grout

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

6.0 EQUIPMENT

6.01 Auger Jack & Bore

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

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

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

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

6.02 Pipe Ramming

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

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

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

6.03 Horizontal Directional Drilling

6.03.01 General

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

6.03.02 Drilling Rig

The horizontal directional drilling rig shall:

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

6.03.03 Drill Head

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

6.03.04 Guidance System

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

6.03.05 Drilling Fluid Mixing System

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

6.03.06 Drilling Fluid Delivery System

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

6.04 Tunnelling

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

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

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

6.05 Microtunnelling Equipment

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

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

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

- a) Remote Control System – The Contractor shall provide a MTBM that includes a remote control system with the following features:
 - i. Allows for operation of the system without the need for personnel to enter the microtunnel.
 - ii. Has a display available to the operator, at a remote operation console, showing the position of the shield in relation to a design reference together with other information such as face pressure, roll, pitch, steering attitude, valve positions, thrust force cutter head torque, rate of advance and installed length.
 - iii. Integrates the system of excavation and removal of spoil and its simultaneous replacement by product pipe. As each pipe section is jacked forward, the control system shall synchronize all of the operational functions of the system.

- iv. The system shall be capable of adjusting the face pressure to maintain face stability for the particular soil condition encountered.
 - v. The system shall monitor and continuously balance the soil and ground water pressure to prevent loss of soil or uncontrolled ground water inflow.
 - vi. The pressure at the excavation face shall be managed by controlling the volume of spoil removal with respect to the advance rate.
 - vii. The system shall include a separation process designed to provide adequate separation of the spoil from the slurry so that slurry with a sediment content within the limits required for successful microtunnelling, can be returned to the cutting face for reuse. Appropriately contain spoil at the site prior to disposal.
 - viii. The type of separation process shall be suited to the size of microtunnel being constructed, the soil type being excavated, and the work space available at each work area.
 - ix. The system shall allow the composition of the slurry to be monitored to maintain the slurry weight and viscosity limits required.
- b) Active Direction Control – The Contractor shall provide a MTBM that includes an active direction control system with the following features:
- i. Controls line and grade by a guidance system that relates the actual position of the MTBM to a design reference.
 - ii. Provides active steering information that shall be monitored and transmitted to the operating console and recorded.
 - iii. Provides positioning and operation information to the operator on the control console.

6.05.01 Pipe Jacking Equipment

Provide a pipe jacking system with the following features:

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

6.05.02 Spoil Separation System

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

6.05.03 Electrical Equipment, Fixtures and Systems

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

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

7.0 CONSTRUCTION

7.01 General

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

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

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

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

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

7.01.01 Layout, Alignment and Depth Control

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

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

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

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

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

7.01.02 Construction Shafts

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

Shafts shall be maintained in a drained condition.

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

7.01.03 Protection Systems

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

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

7.01.04 Settlement or Heave

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

7.01.05 Stability of Excavation

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

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

7.01.06 Preservation and Protection of Existing Facilities

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

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

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

7.01.07 Transporting, Unloading, Storing and Handling Materials

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

7.01.08 Trenching, Backfilling and Compacting

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

7.01.09 Support Systems

Support systems shall be according to OPSS 404.

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

7.01.10 Dewatering

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

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

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

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

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

Dewatering shall be according to OPSS 517.

7.01.11 Removal of Cobbles and Boulders

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

7.01.12 Removal of Obstructions

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

A 200 mm sized boulder was encountered in the clayey gravel fill in Borehole 21-01.

7.01.13 Management of Excess Material

Management of excess material shall be according to OPSS 180.

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

7.01.14 Site Restoration

Site restoration shall be according to OPSS 492.

7.02 Auger Jack & Bore Installation

7.02.01 Method of Installation Procedure

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

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

7.02.02 Pipe Installation

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

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

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

7.03 Pipe Ramming Installation

For Pipe Ramming installation the following requirements apply:

- Only smooth walled steel pipe shall be used. Butt welding of pipe joints shall conform to CSA W59.
- Ramming equipment of adequate capacity shall be provided to ensure smooth and uniform

advancement between the shafts/pits without overstressing of the pipe. Delays shall be avoided between ramming operations.

- A Ramming head shall be provided to transfer and distribute jacking pressure uniformly over the entire end bearing area of the pipe.
- Two or more lubricated guide rails or sills shall be provided of sufficient length to fully support the pipe at the specified line and grade in the ramming pit. Pipe shall be installed to the line and grade specified.
- Removal of materials from within the pipe shall not be undertaken until the lead end of the pipe has passed fully through and beyond the zone of influence of any overlying infrastructure.
- Following installation of the liner pipe, all material shall be removed from the pipe to the satisfaction of the Contract Administrator.
- Any voids remaining between the pipe and the excavation wall shall be grouted as soon as the pipe is rammed.
- The annular space between the liner pipe and the product shall be fully grouted with a watertight, expandable, and stable grout.

7.04 Horizontal Directional Drilling Installation

7.04.01 General

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

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

7.04.02 Site Preparation

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

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

7.04.03 Pilot Bore

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

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

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

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

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

7.04.04 Drilling Fluid Losses to Surface (“Frac-Out”)

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

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

7.04.05 Reaming

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

7.04.06 Product Installation

7.04.06.01 General

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

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

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

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

7.04.06.02 Pullback and Grouting

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

A swivel shall be used between the reamer and the product being installed to prevent rotational forces from

being transferred to the product. A weak link or breakaway connector shall be used to prevent excess pulling force from damaging the product.

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

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

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

7.05 Tunnelling Installation

7.05.01 General

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

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

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

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

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

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

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

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

7.05.02 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

7.07.01 General

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

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

7.07.02 Surface Settlement Monitoring Points

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

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

7.07.03 In-Ground Settlement Monitoring Points

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

In-ground settlement monitoring points shall be 12-18 mm rebar encased in a 50-70 mm, SCH40 PVC pipe, set to a depth of 1.5 m below ground surface or below frost penetration depth, whichever is greater. The assembly shall be placed in a drill hole, backfilled with uniform sand and provided with protective covers suitable for high vehicular traffic areas.

7.07.04 Installation, Replacement and Abandonment

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

7.07.05 Monitoring and Reporting Frequency

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

- a) Three consecutive readings at least one week prior to commencement of the work (Baseline Reading);
- b) Once per shift or once daily during tunnelling operations period whichever results in the more frequent reading intervals; and
- c) Weekly after completion of the work for one month, or until such time at which all parties agree that further movement has stopped.

All readings shall be submitted to the Contract Administrator for information purposes on a weekly basis.

Each report shall include all survey data collected in tabular and graphical format as plots of time versus settlement in comparison to survey data collected prior to commencement of the work.

7.07.06 Benchmarks

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

7.08 Criteria for Assessment of Roadway Subsidence/Heave

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

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

7.09 Certificate of Conformance

A Certificate of Conformance shall be submitted to the Contract Administrator upon completion of the

installation of the pipe at each location. In addition, upon completion of the installation of the pipe at each location, the Contractor shall submit to the Contract Administrator a final Quality Control Certificate sealed and signed by the Design 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 – N/A

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.

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 rock boulders having a volume of 0.5 m³ or greater shall be by Time and Material.