



THURBER ENGINEERING LTD.

FINAL
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 523 BARK LAKE CULVERT REPLACEMENT
7.4 KM SOUTH OF HIGHWAY 60, TOWNSHIP OF LYELL
AGREEMENT NO. 5015-E-0043

W.P. 5464-15-01

Geocres No.: 31F-198

Report to:

McIntosh Perry Consulting Engineers Limited

Latitude: 45.475836
Longitude: -77.908250

April 2019
Thurber File: 16284

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**W.P. 5464-15-01
Geocres No.: 31F-198**

PART 1. FACTUAL INFORMATION

1 INTRODUCTION

This section of the report presents the factual findings obtained from a foundation investigation completed for the proposed culvert replacement at the Highway 523 crossing of Bark Lake (Wolf Creek). The culvert is located approximately 7.4 km south of Highway 60 within the Township of Lyell. Thurber Engineering Limited (Thurber) carried out the current investigation as a sub-consultant to McIntosh Perry Consulting Engineers Ltd. (MPCE) under Agreement No. 5015-E-0043.

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 previous foundation investigation information was available for the subject culvert site within the online Geocres Library.

2 SITE DESCRIPTION

The existing culvert, conveying Bark Lake under Highway 523, is a single span structural plate corrugated steel pipe culvert with an unknown construction date. A site survey plan from MPCE indicates that the culvert is 1.85 m diameter and approximately 20.70 m long. The culvert alignment is generally west to east with the flow through the culvert toward the east. A CSP overflow culvert, reported to be 1.20 m diameter and 22.80 m long, is located approximately 8.75 m to the north of the main culvert.

At the location of the culvert, Highway 523 is a two-lane highway with a rural cross-section and gravel shoulders. Lake water was present along both sides of the highway at the time of the field investigations. The culvert was nearly full and appears to operate as an equalizer pipe as flow of water was not apparent. The Highway 523 embankment fill height varies from 4.1 m on the west side to 6.4 m on the east side with the road surface at approximate elevation of 315.5 m. The existing embankment side slopes are inclined at approximately 1.5 to 2H:1V. Wooden posts with steel cable guiderails are present on both sides of the highway on each side the culvert. The land adjacent to the highway and waters edge is undeveloped and densely vegetated with trees. Traffic volumes are understood to be 520 AADT (2012).

Select photographs showing the existing conditions in the area of the culvert are included in Appendix D for reference.

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3 SITE INVESTIGATION AND FIELD TESTING

The site investigation and field testing program was carried out between May 3rd and May 4th and between August 8th and August 10th, 2017. Drilling consisted of advancing six boreholes identified as 17-1 through 17-6. The drilling was carried out using a raft and portable equipment in the lake for Boreholes 17-3 through 17-6, and a truck mounted drill rig for on-road Boreholes 17-1 and 17-2. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT). Borehole 17-3 through 17-6 were drilled with portable equipment and a full-weight hammer for SPT testing. The boreholes were sampled to refusal which was encountered at elevations ranging from 308.0 to 306.2 m. Bedrock was cored in on-road borehole 17-2.

The drilling and sampling operations were supervised on a full-time basis by a member of Thurber's technical staff. The drilling supervisor logged the boreholes and processed the recovered soil samples for transport for further laboratory examination and testing. Following completion of the field investigation the boreholes were backfilled in general accordance with MOEE requirements (O.Reg. 903). Boreholes 17-1 and 17-2 were capped with cold patch asphalt to reinstate the traveling surface.

The approximate borehole locations are shown on the Borehole Locations and Soil Strata Drawing included in Appendix A. The coordinates and elevation of the boreholes are provided on this drawing and on the individual Record of Borehole sheets.

4 LABORATORY TESTING

The recovered soil samples were subjected to visual identification and to natural moisture content determination. Selected samples were also subjected to gradation analysis (sieve). The results of these tests are summarized on the Record of Borehole sheets included in Appendix B. Two samples of soil recovered from within the boreholes were submitted for analytical testing of corrosivity parameters and sulphate content. All laboratory test results from the field investigation are provided 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 Locations 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 and groundwater conditions may vary between and beyond borehole locations.

In general terms, the site was found to be underlain by a pavement structure and granular embankment fill overlying deposits of native, non-cohesive soils over bedrock.

5.1 Embankment

5.1.1 Asphalt

Boreholes 17-1 and 17-2 were drilled through the existing Highway 523 embankment and encountered a layer of asphalt with a thickness of 80 mm.

5.1.2 Fill: Sand

Below the asphalt pavement within the on-road boreholes was a layer of non-cohesive embankment fill consisting of sand with silt and gravel, to sand some gravel. Cobbles and boulders were noted within the embankment fill. All four off-road boreholes also encountered a fill layer consisting of gravel with sand. The underside of the embankment fill was at 4.5 to 4.6 m (elev. 311.0 to 310.9 m) below the existing roadway surface. The underside of the fill in the off-road boreholes was encountered 0.6 to 2.7 m below lake bed surface (elev. 309.1 to 311.4 m)

The SPT tests conducted in the fill typically gave N-values ranging from 2 to 44 blows indicating a relative density of very loose to dense. Recorded moisture contents ranged from 5 to 32%.

Gradation analyses were completed on five samples of the granular fill layer. The grain size distribution curves for these samples are included in 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 (%) | |
|---------------|---------------------------|------------------|
| | Sand with silt and gravel | Gravel with sand |
| Gravel | 11 - 33 | 52 - 60 |
| Sand | 57 - 84 | 39 - 46 |
| Silt and Clay | 5 - 10 | 1 - 2 |

5.2 Silt

Below the fill in Borehole 17-3 was a native layer of silt with organics. The silt layer was 0.8 m thick with an underside depth of 2.4 m below lake bed surface (elev. 310.7 m). A single SPT test conducted in the silt gave a N-value of 3 blows indicating a very loose consistency. A moisture content of 68% was measured.

5.3 Sand with Silt

Below the fill was a non-cohesive layer of sand with silt which included wood fragments, cobbles and boulders. An obstruction was encountered in Borehole 17-01 which prohibited the core barrel from advancing past elevation 309.9 m and therefore the borehole was terminated at this elevation.

SPT test N-values ranging from 27 to 78 blows were recorded within the layer indicating a compact to very dense relative density. The recorded moisture contents ranged from 22 to 25%.

A gradation analysis was completed on a sample of the sand layer. The grain size distribution curve is included in 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 | 14 |
| Sand | 79 |
| Silt and Clay | 7 |

5.4 Silty Sand to Gravel with Silt Till

Below the fill, silt and sand with silt layers were non-cohesive layers varying from silty sand with gravel to gravel with silt till. Boulders were noted in the till in Boreholes 17-02 and 17-06. Boreholes 17-03 through 17-06 were terminated in this layer at a base elevation of 308.0 to 306.3 m upon SPT and/or casing advancement refusal.

SPT test N-values ranging from 35 to 103 blows were recorded within the till layers indicating a dense to very dense relative density. Refusal blow counts were recorded on inferred boulders within the layer and at the borehole termination depth on inferred bedrock with N-values recorded as high as 100 blows per 100 mm of penetration. The recorded moisture contents ranged from 5 to 18%.

Gradation analyses were completed on five samples of the till layers. The grain size distribution curves are included in 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 (%) | |
|---------------|---------------------------|-------------|
| | Sand with silt and gravel | Gravel/Sand |
| Gravel | 36 - 43 | 43 - 66 |
| Sand | 44 - 55 | 28 - 44 |
| Silt and Clay | 13 | 6 - 13 |

5.5 Bedrock

Bedrock was proven by coring in Borehole 17-02 and was inferred at SPT refusal in Boreholes 17-04 through 17-06. The proven and inferred bedrock surface ranged from elevation 307.9 to 306.2 m. The Total Core Recovery (TCR) was 100%, the Solid Core Recovery (SCR) ranged from 98 to 100% and the Rock Quality Designation (RQD) ranged from 93 to 97% indicating excellent rock quality.

5.6 Groundwater

The groundwater level was not measured in the on-road boreholes due to water being introduced into the borehole during coring operations. It is expected that, based on the foundation soils encountered at this site, the groundwater level will largely be controlled by the water level in the adjacent lake which was noted at elevation 313.8 to 313.9 m during the August 2017 field investigation.

It should be noted that the groundwater level at the time of construction may be higher and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation. It is understood that the lake water level is regulated by a water control structure and will change over time.

5.7 Analytical Testing

Two samples of the native soils were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate and chloride concentrations, resistivity and conductivity. The analysis results are provided in Appendix C and are summarized in the table below:

| Borehole | Sample | Depth(*) (m) | Sulphate (µg/g) | pH (-) | Resistivity (Ohm-cm) | Chloride (µg/g) |
|----------|--------|-----------------|--------------------|-------------|-------------------------|--------------------|
| 17-3 | SS3 | 3.0 – 3.7 | 176 | 4.9 | 4610 | 6 |
| 17-6 | SS2 | 4.6 – 5.2 | 26 | 5.7 | 15800 | 7 |

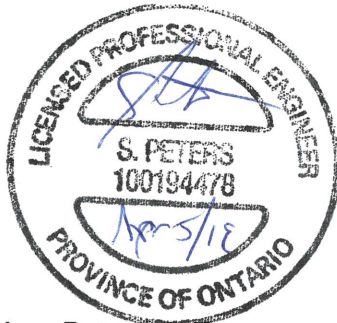
Note: (*) depth relative to top of raft at time of drilling.

6 MISCELLANEOUS

Borehole locations were selected by Thurber relative to the existing culvert and the existing site features. The as-drilled locations and ground surface elevations for the on-road boreholes were surveyed by McIntosh Perry following completion of the field program. The off-road boreholes were surveyed by Thurber.

George Downing Estate Drilling Ltd. of Hawkesbury, Ontario and Forage M3 Drilling also of Hawkesbury, Ontario supplied and operated the drilling equipment to carry out the drilling, soil sampling, in-situ testing and borehole decommissioning. The field investigation was supervised on a full time basis by Mr. Jeff Morrison, E.I.T. and Mr. Chris Murray, E.I.T., of Thurber. Overall supervision of the investigation program was conducted by Mr. Stephen Peters, P.Eng.

Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Analytical testing was completed by Paracel Laboratories in Ottawa, Ontario. Interpretation of the factual data and preparation of this report were carried out by Dr. Fred Griffiths, P.Eng. and Mr. Stephen Peters P.Eng. The report was reviewed by Dr. P.K. Chatterji, P.Eng. a Designated Principal Contact for MTO Foundation Projects.



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PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

This section of the report provides an interpretation of the factual data from Part 1 of this report and presents geotechnical recommendations to assist the design team in designing a suitable foundation for the proposed replacement of the existing Bark Lake (Wolf Creek) culvert crossing Highway 523. The discussion and recommendations presented in this report are based on the information provided by MPCE and on the factual data obtained during the course of the investigation.

This foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation, 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.

The existing culvert, conveying Bark Lake under Highway 523, is a single span structural plate corrugated steel pipe culvert with an unknown construction date. A site survey plan from MPCE indicates that the culvert is 1.85 m diameter and approximately 20.70 m long. The invert of the existing culvert on the survey plan is reported to be at elevation 312.36 m and 312.06 m at the inlet and outlet, respectively. A CSP overflow culvert, reported to be 1.20 m in diameter and 22.80 m long, is approximately 8.75 m north of the main culvert. The embankment fill height is in the order of 4.1 m on the west side with the road surface at approximate elevation 315.5 m. Lake water was present along both sides of the highway at the time of the field investigations. The culvert was nearly full and appears to operate as an equalizer pipe as flow of water was not apparent.

No previous foundation investigation information for the subject culvert was available in the online Geocres Library.

7.1 Proposed Structure

At the time of preparation of the final Foundation Investigation and Design Report, the General Arrangement (GA) drawing dated April 2018 indicates that the existing culvert is to be replaced by a precast concrete box culvert with a total length of 23.9 m, a 2.4 m span

and a 3.0 m rise. The invert of the proposed culvert is to be at elevation 311.40 m and 311.25 m at the inlet and outlet, respectively. Headwalls and wingwalls are not proposed; the new culvert will be longer than the existing. The overflow culvert is indicated to be removed following construction but may be used for temporary flow control during construction.

The lake water level on the GA drawing is indicated to be at elevation 313.85 m (May 2017). The culvert subgrade could be as much as 3.2 m below the lake water level

7.2 Applicable Codes and Design Considerations

The geotechnical assessment presented below has been prepared based on the available data regarding the proposed foundations and existing ground conditions and in accordance with the Canadian Highway Bridge Design Code (CHBDC), version CSA S6-14.

It is understood that the proposed culvert structure has a consequence classification of *Typical Consequence*, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances. If the consequence classification changes, the geotechnical assessment will need to be reviewed and revised.

The frost penetration depth and associated recommendations are provided in Section 10.3.

8 SEISMIC CONSIDERATIONS

8.1 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 calculator. The data includes a peak ground acceleration (PGA), peak ground velocity (PGV) and the 5% spectral response acceleration values ($S_a(T)$) 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 *reference* peak ground acceleration (PGA), which is 0.118g at this site. This PGA is to be scaled based on the site-specific Site Class.

8.2 CHBDC Seismic Site Classification

In accordance with the CHBDC, the selection of the seismic site classification is based on the soil conditions encountered in the upper 30 m of the stratigraphy.

Based on the soil conditions encountered below the anticipated culvert foundation elevation, the site has been classified as a Site Class D in accordance with Section 4.4.3.2 of the CHBDC (S6-14).

8.3 Seismic Liquefaction

Based on the PGA value and the subsurface conditions encountered at the drilled locations at this site, the native foundation soils beneath the embankment are considered not susceptible to liquefaction during a seismic event.

9 DESIGN OPTIONS

9.1 Culvert Type and Foundation Alternatives

Selection of the culvert type must consider the proposed construction procedures, staging requirement, geotechnical resistance available in the foundation soils, the depth to suitable bearing stratum and post-construction settlement criteria. It should be noted that construction of the replacement culvert will be carried out adjacent to a lake. From a geotechnical perspective, the following culvert types were considered:

- Circular Pipes (Concrete, HDPE, Steel)
From a foundation engineering perspective, pipe culverts are a feasible alternative. It is anticipated that a pipe with an internal diameter of 3.0 m or greater will be required as the RFP indicates a design change away from the existing dual culvert arrangement.
- Open Bottom Culvert (Box, Arch)
Open bottom culverts are considered feasible for this site from a foundation engineering perspective but would require greater excavation and dewatering efforts during construction to place the foundation in the dry.
- Closed Bottom Culvert (Box)
A precast segmental box culvert in an open cut construction is considered a feasible option from a foundation engineering perspective. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the founding soils during installation. Subgrade preparation for a box culvert can be completed in wet conditions if necessary, however compacting bedding materials under water will not be possible and is not recommended.
- Steel Sheet Pile Walls with Precast Concrete Slab
A culvert consisting of two rows of parallel sheet pile walls supporting precast concrete slabs is considered feasible at this site. It is recommended that the sheet piles would be driven to refusal and the potential to encountered cobbles and boulders during installation would need to be considered in design.

A comparison of these alternatives, based on their respective advantages and disadvantages, is included in Appendix E. It is not considered to be economical or practical to support a culvert on deep foundations at this site and therefore this option is not presented in this report.

9.2 Construction Methodology Alternative

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

- Open Cut with Full Road Closure and Temporary Detour
Installation of a new culvert using open cut techniques and a full road closure would allow for an expedited construction schedule and could reduce costs associated with requiring roadway protection and lake water control. However, it is understood that an acceptable detour route is not available and therefore this option is not feasible.
- Open Cut with Temporary Modular Bridge Spanning Excavation
It is not considered feasible at this site to complete a culvert replacement within a full width open cut excavation with a single lane temporary modular bridge (TMB) spanning the excavation since the fill heights are not high enough to allow working space below the TMB.
- Open Cut with Staged Temporary Widening
Widening of the existing highway and/or construction of a temporary detour embankment to accommodate traffic passage during construction is considered feasible from a geotechnical perspective with a preference for widening to the west of the existing embankment. However, placement of new fill on the west side of the embankment could generate settlement under the footprint of the embankment widening as well as the existing embankment. A review of the environmental acceptability for placing fill within the lake, the requirement for property acquisition and alteration to highway geometry is also needed to assess this option.
- Open Cut with Staged Replacement and Temporary Protection System
The use of open cut techniques in conjunction with staged culvert replacement is a feasible construction option from a geotechnical perspective. This option will require roadway protection, as discussed further in Section 11.2, installed along the embankment centerline to maintain a single lane of traffic flow along the current highway alignment. The Contractor will need to consider the potential for encountering cobbles/obstructions in the embankment fill during the design and installation of roadway protection. It should also be noted that installation of sheet piles could be difficult through dense till with cobbles and boulders. Due to the required height of soil to be retained, the roadway protection may need enhanced lateral support from bracing, struts, deadman and/or anchors.
- Trenchless Techniques
Trenchless techniques would have the advantage of minimum disruption to traffic and would avoid a large excavation through the existing highway embankment. However, the presence of cobbles, boulders and cohesionless soils limits the available techniques. The anticipated size of replacement culvert will also limit the available installation methods. The available low cover is also problematic. Furthermore, lake water was observed at the inlet and outlet and would require cofferdams around the entry and exit pits. A trenchless installation is not recommended at this site.

9.3 Recommended Approach for the Culvert Replacement

From a foundation engineering perspective, the alternative of replacing the existing culvert with a precast segmental box culvert using open cut techniques is the recommended culvert replacement option. Temporary protection systems (TPS) would be needed to allow one

lane of traffic during construction. A closed box culvert is recommended. An open bottom culvert is not recommended as it requires deeper excavation and more robust dewatering efforts in a lake environment.

10 OPEN CUT FOUNDATIONS DESIGN RECOMMENDATIONS

Foundation design aspects for the replacement culvert includes subgrade conditions, geotechnical resistances, settlement of the founding soils, imposed loading pressures, erosion control, protection system design, groundwater control and stability of stage construction. The culvert must be designed to resist loading including lateral earth pressures, hydrostatic pressure, weight of embankment fill, traffic loading and any surcharge due to construction equipment and activities under static and seismic conditions.

10.1 Culvert Foundation Bearing Resistances – Closed Box Culvert

A closed pre-cast box culvert should be founded on a bedding layer (see Section 10.2). Subgrade preparation should follow the recommendations provided in Section 10.2 in order to provide a suitable subgrade for the bedding layer.

The existing stratigraphy at culvert subgrade elevations of 310.7 m consists of loose to compact sand fill, compact to dense sand and dense till. A closed box culvert would not need to be founded below the depth of frost (Section 10.3). For a box culvert with a 2.4 m span, the design can be based on the factored geotechnical resistance values as follows.

- Factored Geotechnical Resistance at ULS of 200 kPa
- Factored Geotechnical Resistance at SLS of 125 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)

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 up to 25 mm. Organic silt will be encountered in the area of the culvert inlet. The bearing resistances provided above are based on the assumption that this organic material, where encountered at the subgrade layer, will be removed down to competent inorganic soils and replaced with well compacted granular fill.

Resistance to lateral forces/sliding resistance between concrete and native granular or the underlying Granular 'A' bedding (Section 10.2) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of 0.45 for precast concrete and 0.5 for cast-in-place concrete.

It is noted that construction will extend below the observed lake water level. Water diversion and dewatering (Section 11.3) will be required to place the bedding material and install the culvert in the dry. It is anticipated that dewatering will be difficult at this site; accordingly,

recommendations for subgrade preparation in the wet are provide in Sections 10.2 and 11.3.

10.2 Subgrade Preparation, Bedding and Backfilling

Subgrade preparation for the culvert replacement should include excavation and removal of the existing culvert and backfill materials. All organics, existing loose fill, soft or loose deposits, disturbed soils, alluvial deposits and deleterious materials must be stripped from the footprint of the foundation to expose competent subgrade at or below the desired founding elevations. It should be noted that unsuitable organic silt materials were observed in the off-road borehole 17-3 to as deep as elevation 310.7 m. This organic silt must be removed from the culvert subgrade and replaced with compacted granular fill.

The subgrade may be easily disturbed when saturated and should be protected from disturbance from both construction traffic and weather. Construction equipment should not be permitted to travel on the exposed subgrade.

It is noted that construction will extend well below the lake water level. Granular fill must not be used to backfill excavations below water. Due to the anticipated difficulty in dewatering adjacent to the lake, where the lake water level is approximately 2.6 m above the proposed culvert invert level, consideration may be given to preparing the subgrade in the wet by sub-excavating to 300 mm below the bedding layer and backfilling with coarse 53 mm clear stone meeting the requirements of OPSS.PROV 1004. A separation layer consisting of non-woven geotextile should be placed between the native soils and clear stone as soon as practical after reaching the subgrade level. The geotextile should meet the specifications of OPSS.PROV 1860 Class II and have a FOS not greater than 212 μm . The clear stone should be completely wrapped with the geotextile to minimize migration of the fines into the clear stone. Clear stone above the water level must be compacted as per OPSS.PROV 206.

In order to provide a more uniform foundation subgrade condition for the closed box culvert, bedding material conforming to OPSS.PROV 1010 Granular A requirements must be provided under the base of the culvert as per OPSS 422 and OPSD 803.010. The Granular A bedding layer placed above the clear stone should be a minimum of 150 mm thick. Dewatering will be required to place the bedding in the dry. It is anticipated that dewatering could be difficult at this site, please refer to Section 11.3 for additional comments on groundwater and surface water control.

It is recommended that culvert cover consist of free-draining, non-frost susceptible granular materials such as Granular A material meeting the requirements of OPSS.PROV 1010. The cover must be in accordance with OPSS 902.

Culvert backfill above the granular cover should be in accordance with OPSS 902 and consist of material meeting the requirements of OPSS Select Subgrade Material or better and should be compacted in regular lifts as per OPSS.PROV 501. Heavy compaction equipment, used adjacent to the structure, must be restricted in accordance with OPSS.PROV 501. Care must be exercised when compacting the fill adjacent to and above the culvert in order not to damage the culvert.

10.3 Frost Depth

The depth of frost penetration at this site is 1.9 m and would affect foundation depth for an open bottom culvert. It is not necessary to found a closed box culvert at a depth below frost penetration. However, frost taper treatment, if required, should be as per OPSD 803.010 and as directed within the Pavement Design Report.

10.4 Backfill and Earth Pressure

Lateral earth pressure provided in the equations in the sections below are based on the assumption that the backfill is fully drained so that there are no unbalanced hydrostatic pressures. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in design.

10.4.1 Static Lateral Earth Pressure Coefficients

Lateral earth pressures acting on structures should be computed in accordance with the CHBDC but under drained conditions are generally given by the following expression:

$$\sigma_h = K * (\gamma d + q)$$

where:

| | | |
|------------|---|----------------------------------------------------------------------------|
| σ_h | = | lateral earth pressure on the wall at depth d (kPa) |
| K | = | static earth pressure coefficient (see table below) |
| γ | = | unit weight of retained soil (see table below), adjusted below water level |
| d | = | depth below top of fill where pressure is computed (m) |
| q | = | value of any surcharge (kPa) |

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Clause 6.12.3 of the CHBDC. Typical earth pressure coefficients for vertical walls for a variety of backfill materials are shown in Table 10-1.

Table 10-1. Static Earth Pressure Coefficients

| Condition | Earth Pressure Coefficient (K) | | | | | |
|------------------------------------------------------|-----------------------------------------------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------------------|----------------------------------------------|------------------------------------------------------------------------------------------|----------------------------------------------|
| | OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$ | | OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$ | | OPSS SSM and Existing Sand Fill $\phi = 30^\circ, \gamma = 21.0 \text{ kN/m}^3$ | |
| | Horizontal Surface Behind Wall | Sloping Surface Behind Wall (2H:1V) | Horizontal Surface Behind Wall | Sloping Surface Behind Wall (2H:1V) | Horizontal Surface Behind Wall | Sloping Surface Behind Wall (2H:1V) |
| Active, K_A (Yielding Wall) | 0.27 | 0.40 | 0.31 | 0.48 | 0.33 | 0.54 |
| At Rest, K_O (Non-Yielding Wall) | 0.43 | - | 0.47 | - | 0.50 | - |
| Passive, K_P (Movement towards Soil Mass) | 3.7 | - | 3.3 | - | 3.0 | - |
| Soil Group(*) | "medium dense sand" | | "loose to medium dense sand" | | "loose sand" | |

Note: (*) For use with figure C6.16 of the Commentary to the CHBDC.

A geotechnical resistance factor of 0.5 (ϕ_{gu}) should be applied in static design to the passive earth pressures in accordance with Table 6.2 of the CHBDC.

The use of a material with a high friction angle and low active pressure coefficient (Granular A or Granular B Type II) is preferred as it results in lower earth pressures acting on the culvert.

The parameters in the table correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The values to be used in design can be assessed from Figure C6.16 of the Commentary to the CHBDC using the soil group designation as outlined in Table 10-1. Active earth pressures should be used for any head walls or unrestrained walls. For rigid structures such as a concrete box culvert, it is recommended that at-rest horizontal earth pressures be used for design. Where ground surfaces are sloped behind the walls, the corresponding coefficients provided in the Table 10-1 should be used.

The culvert must be designed to withstand full hydrostatic pressure assuming a water level at least equal to the design lake water level. This is applicable when the water level behind the culvert is higher than the lake level.

10.4.2 Combined Static and Seismic Lateral Earth Pressure Parameters

In accordance with Clause 4.6.5 of the CHBDC (S6-14), retaining structures should be designed using dynamic earth pressure coefficients that incorporate the effects of earthquake loading. The following recommendations are per Section C4.6.5 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using Mononobe-Okabe Method with:

- $k_h = \frac{1}{2} * F(PGA) * PGA$, for structures that allow 25 to 50 mm of movement, and
- $k_h = F(PGA) * PGA$, for non-yielding walls

The coefficients of horizontal earth pressure for seismic loading presented in Table 10-2 may be used for vertical walls. The provided earth pressure coefficients are based on a Seismic Site Class D, *reference* PGA with a 2% probability of exceedance in 50 years of 0.118g (Geological Survey of Canada – Fifth Generation) and a $F(PGA)$ of 1.29 as per Table 4.8 of the CHBDC (S6-14).

Table 10-2. Combined Static and Seismic Earth Pressure Coefficients

| Condition | Earth Pressure Coefficient (K) | | | |
|---------------------------------------|--------------------------------------------------------------------------------------------------|-----------------------------------------|---------------------------------------------------------------------------|-----------------------------------------|
| | OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$ | | OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$ | |
| | Horizontal Surface Behind Wall | Slope Surface Behind Wall (2H:1V) | Horizontal Surface Behind Wall | Slope Surface Behind Wall (2H:1V) |
| Active, K_{AE} Yielding Wall | 0.31 | 0.56 | 0.35 | 0.60 |
| Active, K_{AE} Non-Yielding Wall | 0.36 | 0.61 | 0.40 | 0.65 |

The total pressure due to combined static and seismic loads acting at a specific depth below the top of the wall may be determined using the following equation that includes consideration of material properties and the soils profile.

$$\sigma_h = K * \gamma * d + (K_{AE} - K_A) * \gamma * (H - d)$$

where:

| | | |
|------------|---|------------------------------------------------------------------------------------------------|
| σ_h | = | lateral earth pressure on wall at depth d (kPa) |
| d | = | depth below the top of the wall (m) |
| K | = | static earth pressure coefficient (K_A for yielding walls, K_o for non-yielding walls) |
| γ | = | unit weight of retained soil, adjusted for water level |
| K_{AE} | = | combined static and seismic earth pressure coefficient |
| H | = | total height of the wall (m) |

10.5 Embankment Design and Reinstatement

10.5.1 Embankment Reconstruction

Embankment reconstruction after culvert replacement should be carried out in accordance with OPSS.PROV 206. The embankment should be reinstated with side slopes of 2H:1V (or flatter) if constructed using Select Subgrade Material (SSM) or Granular B Type I. The fill should be placed and compacted in accordance with OPSS.PROV 501

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

Provided the subgrade is prepared as outlined above and construction of the embankment is carried out in accordance with recommendations provided within this report, the embankment side slopes should remain stable.

It is understood that no grade raise or widening is anticipated along the alignment of Highway 523. It is understood that local regrading of the embankment slopes will be completed as part of the embankment reconstruction without widening the embankment footprint. Therefore negligible foundation settlement is expected to occur. Further assessment of foundation stability and settlement should be carried out where construction staging dictates the requirement for additional loading or if a temporary alignment is constructed.

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

10.5.2 Temporary Detour

A foundation investigation was not completed for a temporary detour embankment as part of the current assignment. Further assessment of the existing Highway 523 embankment should be carried out where construction staging dictates that a temporary detour embankment is needed and additional field investigations with recommendations may be required.

10.6 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 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 test results provided in Section 5.7 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects. The corrosion effects of road de-icing salts should also be considered.

11 CONSTRUCTION CONSIDERATIONS

11.1 Excavation

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of OHSA, the fills and native cohesionless soils above the water table may be classified as Type 3 soil. The organic silt, alluvial deposits and native cohesionless soils below the groundwater level are classified as Type 4 soils. All

excavations must not encroach within an area encompassed within 1H:1V from the base of the excavation to the by-pass culvert so as to not undermine that installation.

Excavation for the culvert replacement must be carried out in accordance with OPSS 902 and will be carried out through the existing embankment fill and extend into the underlying native deposits. Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. Stockpiling or surface surcharge should not be allowed on the embankment or side slopes.

At locations where there are space restrictions or where a slope has to be retained, the excavations will need to be carried out within a protection system. Further discussion on temporary protection systems (TPS) is presented in Section 11.2.

11.2 Temporary Protection Systems

Temporary Protection Systems will 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 actual pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall and these factors must be considered when designing the shoring system.

The design of roadway protection is the responsibility of the Contractor. All protection systems should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. The design of the roadway protection system must incorporate traffic loading and surcharge loading due to construction equipment and operations.

It is recommended that an NSSP be included in the tender documents to alert the Contractor to the potential for wood, cobbles, boulders and obstructions within the fill and native soils.

The protection system should be installed at a sufficient distance away from the new culvert to limit the disturbance to subgrade associated with removal of the protection system following complete of construction. Alternatively, the protection system near the culvert could be left in place and cut off in accordance with OPSS.PROV 539.

Lateral earth pressure coefficients, under fully mobilized conditions, that can be used in design of the protection system installed through the embankment fill and culvert backfill are provided in Table 10-1. The lateral earth pressure coefficient for the existing native non-cohesive foundation soils are given below:

| | | |
|----------|---|----------------------------------------------------------|
| γ | = | 20 (kN/m ³ bulk unit weight of retained soil) |
| K_A | = | 0.29 |
| K_P | = | 3.4 |

11.3 Water Control

The depth of excavation will extend below the lake water level observed at the time of investigation. 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. The water level must be lowered below the top of the clear stone to allow placement of the bedding in the dry.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the dewatering systems in accordance with SP FOUN0003 which amends OPSS 902. A preconstruction survey is not required, thus Designer Fill-In ** in SP FOUN0003 should be "N/A".

In accordance with SP FOUN0003, the dewatering system is to be designed in accordance with OPSS.PROV 517 and SP517F01. It is recommended that the design Engineer and design-checking Engineer for both temporary flow passage and dewatering systems have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work, thus Designer Fill-In ***** in SP517F01 Table A should be "Yes". A preconstruction survey is not required, thus Designer Fill-In ***** in Table A should be "N/A".

The water level will fluctuate and the minimum groundwater elevation for the site at the time of the proposed culvert replacement should be taken as the expected high water level in the lake. Excavation below the lake level to construct the culvert foundation will be required and excavation below the lake level without prior dewatering is not recommended since the inflow of water will cause base heave/boiling and sloughing of the soil below the water level, making it difficult to prepare the subgrade.

It is expected that the existing overflow culvert located north of the existing main culvert can be maintained operational during construction to facilitate flow around the construction site. Construction of cofferdams will be required to divert the lake flow away from the culvert subgrade area. It is recommended that excavations be within a water tight enclosure. This will require deep installation of sheet piles driven to bedrock. A sheet piled cofferdam can be designed following the recommendations provided in Sections 11.1 and 11.2. The groundwater level within the enclosure should be lowered by pumping from sumps prior to excavation. Further assessment of dewatering requirements and the need for a PTTW should be carried out by specialists experienced in this field.

Since the subsurface soil conditions consist of permeable soils, underlain by relatively shallow and sloping bedrock, an interlocking sheet pile cofferdam system may not be effective to cut-off the groundwater flow and pumping within the sheet pile enclosure may not be effective in lowering the water table. Therefore a clear stone stabilizing pad can be constructed in the wet, as described in Section 10.2. Pumping from the clear stone should continue until control of inflow is achieved and the Granular A bedding and culvert can be placed in a dry and stable environment.

11.4 Scour Protection and Erosion Control

The Contractor should provide silt fences and erosion control blankets as per OPSS 805 throughout the duration of construction to prevent transport of silt/sediment. Slope protection and drainage measures will be required to ensure the long-term surficial stability of the embankment slopes. Slope vegetation should be established as soon as possible after completion of the embankment fills in order to limit surficial erosion.

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 in accordance with OPSS 511. 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.

It is recommended that a clay seal and a concrete cut-off wall be used to minimize the potential for piping and erosion around the inlet of the culvert. The clay seal must extend to approximately 300 mm above the high water level and laterally for the width of the granular material, and have a minimum thickness of 500 mm. The material requirements should be in accordance with OPSS.PROV 1205. A geosynthetic clay liner may be used as a clay seal.

12 CONSTRUCTION CONCERNS

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

- Wood/cobbles/boulders and/or buried obstructions may be encountered in the existing embankment fill and in the native tills at this site and could interfere with installation of the roadway protection installation.
- Lake water levels will fluctuate. A suitable dewatering / unwatering system must be employed to enable control of the groundwater seepage. The dewatering scheme will be critical for culvert construction at this site. The Contractor should be prepared to take appropriate measures to construct the bedding layer and place the culvert in a dry and stable environment.
- A high volume of discharge water could be generated.
- 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 and any temporary structure fill (i.e., as a pad for crane support).

The successful performance of the culvert will depend largely upon good workmanship and quality control during construction. Subgrade examination should be carried out by qualified geotechnical personnel during construction in accordance with SP109S12 to confirm that foundation recommendations are correctly implemented and material specifications are met.

13 CLOSURE

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

Thurber Engineering Ltd.
Report Prepared By:



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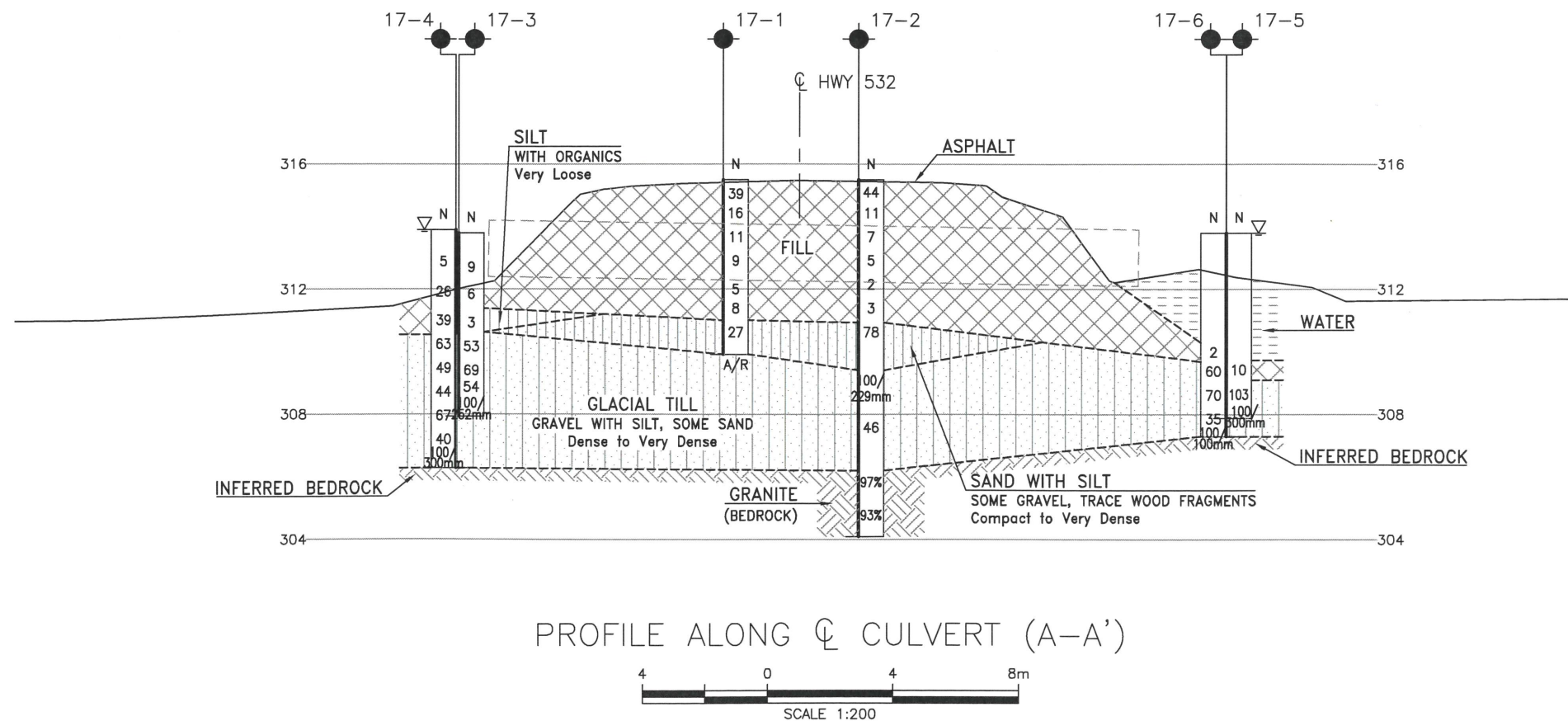
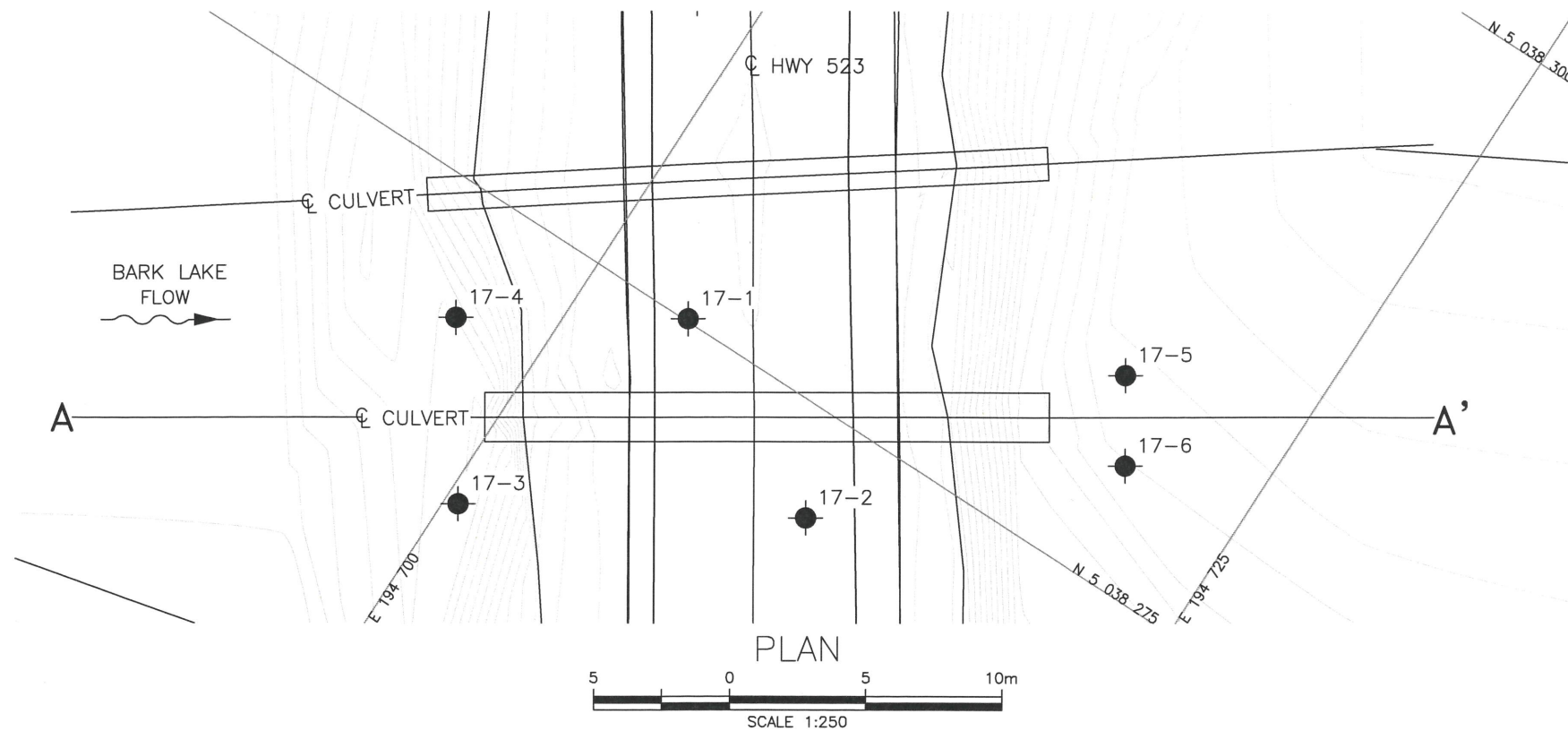


Dr. P.K. Chatterji, P.Eng.
Review Principal,
Senior Geotechnical Engineer

HIGHWAY 523 BARK LAKE CULVERT REPLACEMENT
7.4 KM SOUTH OF HIGHWAY 60, TOWNSHIP OF LYELL

Appendix A.

Borehole Location Plan and Stratigraphic Drawings



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



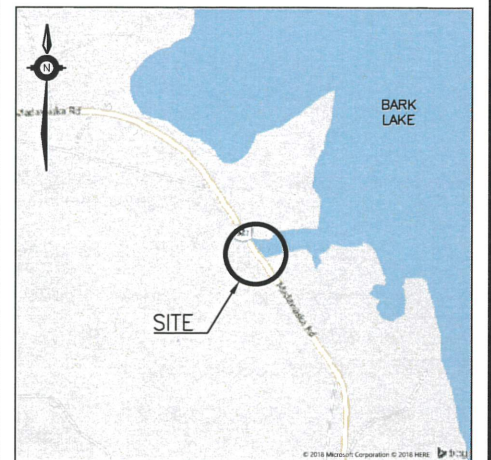
CONT No
WP No 5464-15-01

HIGHWAY 523
BARK LAKE CULVERT
REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

McINTOSH PERRY



THURBER ENGINEERING LTD.



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 |

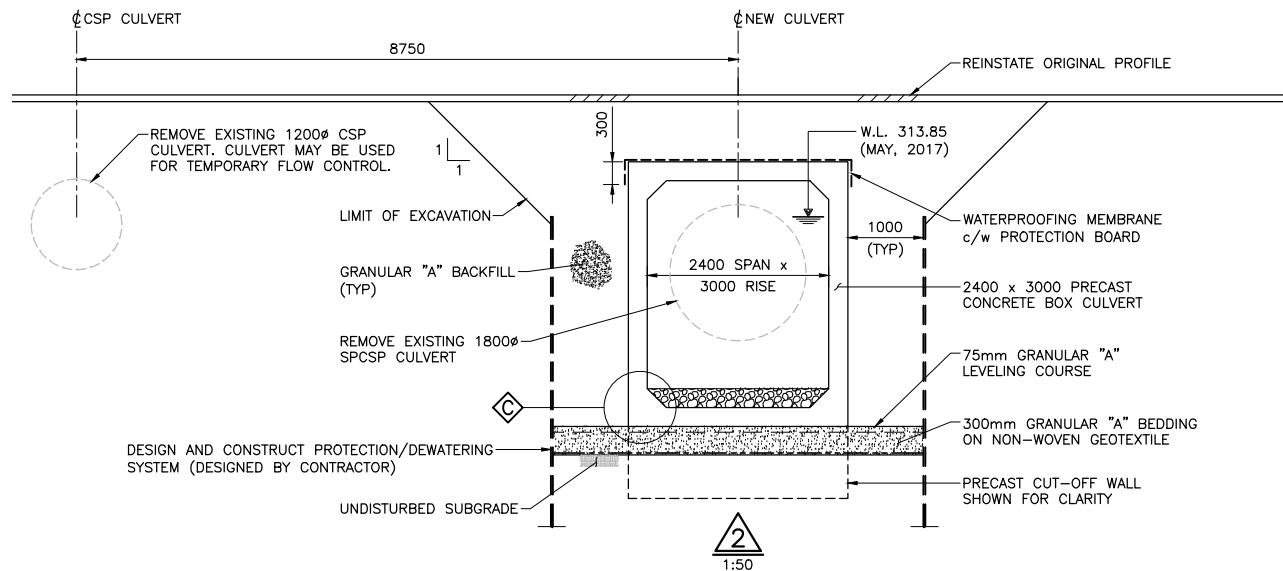
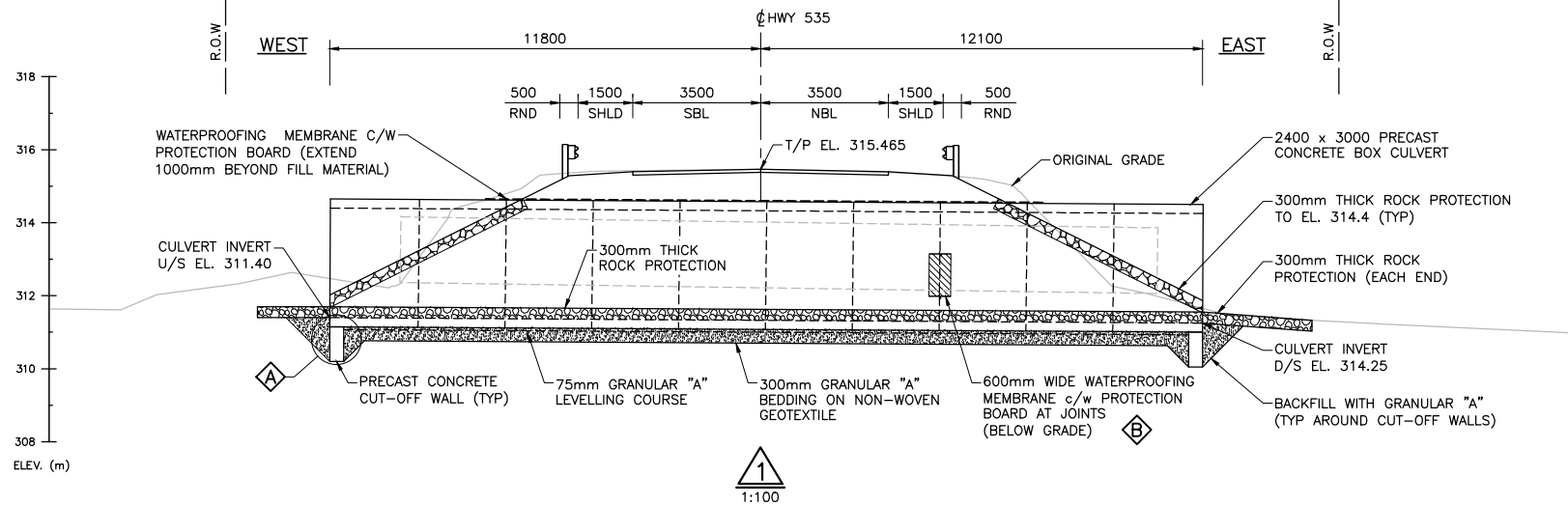
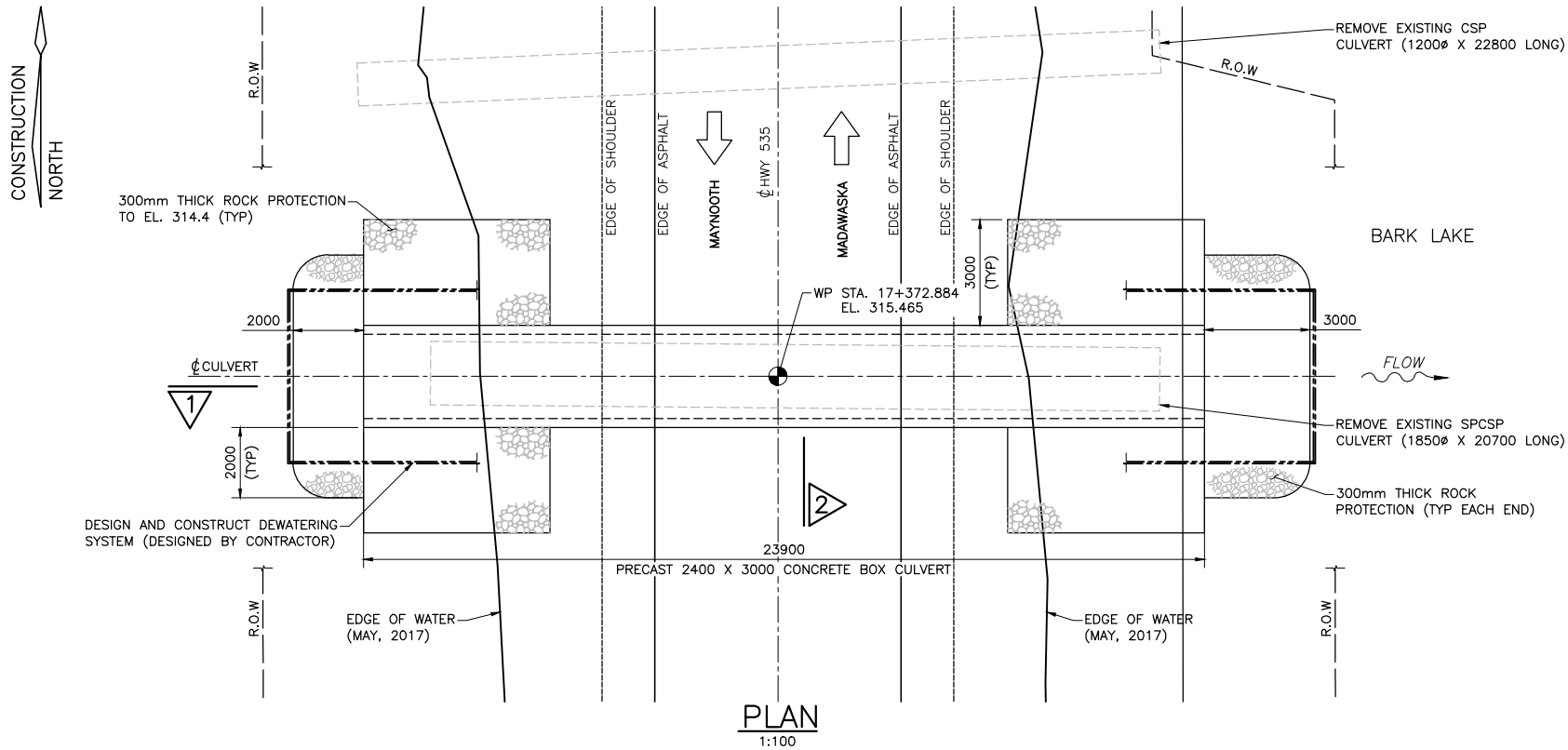
| NO | ELEVATION | NORTHING | EASTING |
|------|-----------|-------------|-----------|
| 17-1 | 315.5 | 5 038 275.1 | 194 703.9 |
| 17-2 | 315.5 | 5 038 271.3 | 194 711.5 |
| 17-3 | 313.8 | 5 038 264.8 | 194 700.5 |
| 17-4 | 313.9 | 5 038 270.5 | 194 696.7 |
| 17-5 | 313.8 | 5 038 282.1 | 194 718.5 |
| 17-6 | 313.8 | 5 038 279.3 | 194 720.3 |

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.

GEOCRES No. 31F-198

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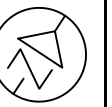


LEGEND:

- GRANULAR "A" BEDDING
- GRANULAR "A" BACKFILL
- ROCK PROTECTION

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

HIGHWAY 523
CONT. No. 2018-XXXX
WP No. 5464-15-01



SHEET

18

McINTOSH PERRY

GENERAL NOTES:

- CLASS OF CONCRETE
PRECAST 40 MPa

CLEAR COVER TO REINFORCING STEEL
- PRECAST 50 ± 10mm

REINFORCING NOTES:

- REINFORCING STEEL SHALL BE GRADE 400W UNLESS OTHERWISE SPECIFIED.
- UNLESS SHOWN OTHERWISE, TENSION LAP SPLICES SHALL BE CLASS B.
- BAR HOOKS SHALL HAVE STANDARD HOOK DIMENSIONS USING MINIMUM BEND DIAMETERS, WHILE STIRRUP AND TIES SHALL BE IN ACCORDANCE WITH THE STRUCTURAL STANDARD DRAWING SS12-1, UNLESS INDICATED OTHERWISE.

GEOTEXTILE:

- NON-WOVEN, CLASS II, FOS 75 TO 150um. AND FREE OF FOLDS, TEARS AND WRINKLES.

CONSTRUCTION NOTES:

- THE CONTRACTOR SHALL CHECK AND VERIFY ALL DIMENSIONS AND SITE CONDITIONS BEFORE PROCEEDING WITH WORK AND REPORT ANY DISCREPANCIES TO THE CONTRACT ADMINISTRATOR BEFORE COMMENCING THE WORK.
- THE TEMPORARY FLOW CONTROL SHALL BE DESIGNED FOR A TWO (2) YEAR DESIGN STORM RETURN PERIOD OF 2.74 m³/s.
- THE CONTRACTOR IS ADVISED THAT THE WATER LEVEL AT THIS SITE IS DAM CONTROLLED BY THE BARK LAKE DAM. THE NORMAL OPERATING RANGE IS 304.7m to 313.94m WITH A SUMMER MINIMUM OF 313.62m.
- LENGTH OF PRECAST UNITS MAY BE MODIFIED AS PER MANUFACTURERS REQUIREMENTS. TOTAL LENGTH OF THE CULVERT SHALL NOT BE LESS THAN WHAT IS SHOWN AND MAXIMUM LENGTH OF CULVERT WILL BE WITHIN 300mm OF WHAT IS SHOWN.
- THE CONTRACTOR SHALL ADJUST ALL NECESSARY DIMENSIONS TO ACCOMMODATE ANY CHANGES TO THE DIMENSIONS OF THE PRECAST UNITS, AT NO COST TO THE OWNER.
- THE CONTRACTOR SHALL DESIGN AND SUPPLY ANY TEMPORARY SUPPORT REQUIRED FOR THE REMOVAL OF THE EXISTING STRUCTURE IN ACCORDANCE WITH OPSS 919.
- BACKFILL SHALL BE PLACED SIMULTANEOUSLY BEHIND BOTH CULVERT WALLS KEEPING THE HEIGHT OF THE BACKFILL APPROXIMATELY THE SAME. AT NO TIME SHALL THE DIFFERENCE IN THE ELEVATION BE GREATER THAN 500mm.
- LOCATION AND DESIGN FOR ALL LIFTING DEVICES SHALL BE PROVIDED BY THE PRECAST MANUFACTURER. LIFTING DEVICES SHALL BE FILLED WITH REPAIR MORTAR AND MADE TO BE FLUSH WITH THE TOP OF THE BOX CULVERT SECTION.
- PROVIDE 25x25 CHAMFER TO ALL CORNERS OF NEW CONCRETE.
- ALL AREAS AFFECTED BY CONSTRUCTION ACTIVITIES SHALL BE FULLY REINSTATED TO PRE-CONSTRUCTION OR BETTER CONDITIONS TO THE SATISFACTION OF THE CONTRACT ADMINISTRATOR INCLUDING THE REINSTATEMENT OF ALL VEGETATION, PATHWAYS, FENCES, AND AREAS USED FOR SITE ACCESS.

APPLICABLE STANDARD DRAWINGS:

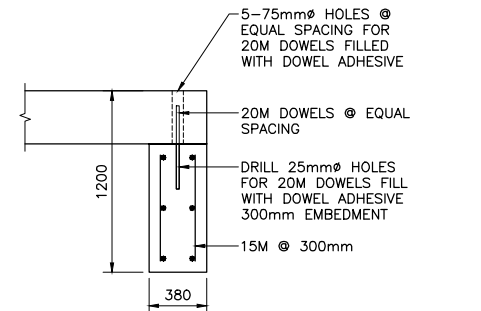
OPSD 3941.200 - FIGURES IN CONCRETE SITE NUMBER AND LAYOUT

LIST OF DRAWINGS:

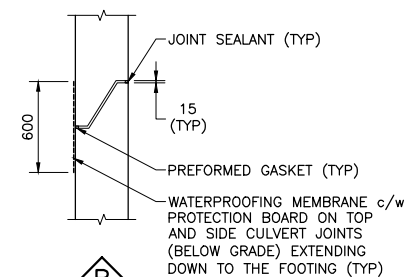
- GENERAL ARRANGEMENT
- BOREHOLE LOCATIONS AND SOIL STRATA

LIST OF ABBREVIATIONS:

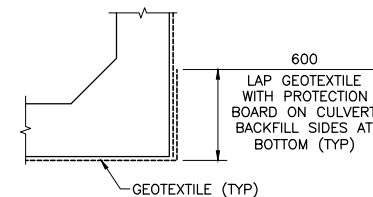
| | | | |
|------|--------------------|--------|--------------|
| CL | CENTRELINE | MIN. | MINIMUM |
| DWG. | DRAWINGS | STA. | STATION |
| EL. | ELEVATION (METRES) | W.L. | WATER LEVEL |
| EX. | EXISTING | TYP | TYPICAL |
| U/S | UPSTREAM | D/S | DOWNSTREAM |
| OG | ORIGINAL GROUND | R.O.W. | RIGHT OF WAY |



A
N.T.S.



B
N.T.S.



C
N.T.S.

DRAWING NOT TO BE SCALED
100mm ON ORIGINAL DRAWING

| REVISIONS | | DATE | BY | REV | DESCRIPTION |
|-----------|----|------|----|------|------------------------------------------|
| DESIGN | LD | CHK | QI | CODE | CHBDC-14 LOAD CL-625-ONT DATE APR/18 |
| DRAWN | JM | CHK | LD | SITE | 43-XXX/C STRUCT SCHEME DWG 1 |

HIGHWAY 523 BARK LAKE CULVERT REPLACEMENT
7.4 KM SOUTH OF HIGHWAY 60, TOWNSHIP OF LYELL

Appendix B.

Record of Borehole Sheets



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).

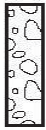
DYNAMIC CONE PENETRATION TEST (DCPT):

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 |

RECORD OF BOREHOLE No 17-1

1 OF 1

METRIC

WP# 5464-15-01 LOCATION Lat: 45.475720°, Long: -77.908171° Bark Lake Culvert, MTM z9: N 5 038 275.1 E 194 703.9 ORIGINATED BY JM/KE
HWY 523 BOREHOLE TYPE NW Casing COMPILED BY KE
DATUM Geodetic DATE 2017.05.03 - 2017.05.03 CHECKED BY SP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|---------------------------------------------------------------------------------------------------------|------------|---------|------|------------|----------------------------|-----------------|---------------------------------------------|--|--|--|--|-----------------------------------------------------|----------------------------------------------------------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | |
| | | | | | | | | 20 40 60 80 100 | | | | | | |
| | | | | | | | | 20 40 60 80 100 | | | | | | |
| 315.5 | | | | | | | | | | | | | | |
| 0.0 | ASPHALT 80 mm | | | | | | | | | | | | | |
| 0.1 | SAND with silt and gravel Dense to loose Brown FILL | | 1 | SS | 39 | | 315 | | | | | | 33 57 10 (SI+CL) | |
| | | | 2 | SS | 16 | | | | | | | | | |
| | | | 3 | SS | 11 | | 314 | | | | | | | |
| | | | 4 | SS | 9 | | 313 | | | | | | | |
| | - Frequent cobbles and boulders below 3.0 m, switch to coring | | 5 | SS | 5 | | 312 | | | | | | | |
| | | | 6 | SS | 8 | | | | | | | | 33 58 9 (SI+CL) | |
| 311.0 | | | | | | | 311 | | | | | | | |
| 4.5 | SAND with silt and gravel frequent cobbles and boulders, trace wood fragments Compact Brown | | 7 | SS | 27 | | | | | | | | | |
| 309.9 | | | | | | | 310 | | | | | | | |
| 5.6 | End of Borehole - obstruction encountered at 5.6 m | | | | | | | | | | | | | |

DOUBLE LINE 16284 BARK LAKE CULVERT.GPJ 2012TEMPLATE(MTO).GDT 8/4/19


RECORD OF BOREHOLE No 17-2

1 OF 2

METRIC

WP# 5464-15-01 LOCATION Lat: 45.475687°, Long: -77.908074° Bark Lake Culvert, MTM z9: N 5 038 271.3 E 194 711.5 ORIGINATED BY JM/KE
 HWY 523 BOREHOLE TYPE NW Casing COMPILED BY KE
 DATUM Geodetic DATE 2017.05.04 - 2017.05.04 CHECKED BY SP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL |
|---------------|--------------------------------------------------------------------------------------------------------------------|------------|---------|---------------|------------|----------------------------|-----------------|---------------------------------------------|--|--|--|--------------------------------------------------|----------------------------------------------------------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | |
| | | | | | | | | WATER CONTENT (%) | | | | | |
| | | | | | | | | | | | | | |
| 315.5 | | | | | | | | | | | | | |
| 0.0 | ASPHALT 80 mm | | | | | | | | | | | | |
| 0.1 | SAND with silt some gravel to SAND some gravel Dense to loose Brown - occasional cobbles FILL | | 1 | SS | 44 | | | | | | | | |
| | | | 2 | SS | 11 | | | | | | | | |
| | | | 3 | SS | 7 | | | | | | | | |
| | | | 4 | SS | 5 | | | | | | | | |
| | | | 5 | SS | 2 | | | | | | | | |
| | | | 6 | SS | 3 | | | | | | | | |
| 310.9 | | | | | | | | | | | | | |
| 4.6 | SAND with silt some gravel, trace wood fragments Very dense Grey-brown - Boulders present below 5.18 m | | 7 | SS | 78 | | | | | | | | |
| | | | | | | | | | | | | | |
| 309.4 | | | | | | | | | | | | | |
| 6.1 | GRAVELwith silt GLACIAL TILL some sand Very dense Grey Cobbles and Boulders throughout | | 8 | S900 / 229 mm | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | 9 | SS | 46 | | | | | | | | |
| | | | | | | | | | | | | | |
| 306.2 | | | | | | | | | | | | | |
| 9.3 | BEDROCK Granite Fresh Grey-pink | | 1 | NQ | | | | | | | | | |
| | | | | | | | | | | | | | |

| | | | | |
|------------------------------------------------------------------------------------|--------------|-----|----|-----|
| DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | |
|  | | | | |
| 20 | 40 | 60 | 80 | 100 |
| SHEAR STRENGTH kPa | | | | |
| ○ UNCONFINED | + FIELD VANE | | | |
| ● QUICK TRIAXIAL | × LAB VANE | | | |
| 20 | 40 | 60 | 80 | 100 |
| WATER CONTENT (%) | | | | |
| W P | W | W L | | |
| 20 | 40 | 60 | | |

| | | | |
|----|----|---|---------|
| 11 | 84 | 5 | (SI+CL) |
| 14 | 79 | 7 | (SI+CL) |
| 66 | 28 | 6 | (SI+CL) |

| | | | |
|-------------------------------------------|--|--|--|
| RUN #1 TCR=100% SCR=100% RQD=97% | | | |
|-------------------------------------------|--|--|--|

DOUBLE LINE 16284 BARK LAKE CULVERT.GPJ 2012TEMPLATE(MTO).GDT 8/4/19

Continued Next Page


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

RECORD OF BOREHOLE No 17-2

2 OF 2

METRIC

WP# 5464-15-01 LOCATION Lat: 45.475687°, Long: -77.908074° ORIGINATED BY JM/KE
 HWY 523 BOREHOLE TYPE NW Casing COMPILED BY KE
 DATUM Geodetic DATE 2017.05.04 - 2017.05.04 CHECKED BY SP

| 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 | REMARKS & GRAIN SIZE DISTRIBUTION (%) |
|--------------|-------------------------------------------------|-----------------------------------------------------------------------------------|---------|------|------------|-------------------------|-----------------|------------------------------------------|----|----|-----|----|---------------------------------|-------------------------------|--------------------------------|------------------------------------------|---------------------------------------|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | | | | |
| | | | | | | | 20 | 40 | 60 | 80 | 100 | 20 | 40 | 60 | | | |
| | Continued From Previous Page | | | | | | | | | | | | | | | | |
| 304.1 | BEDROCK Granite Fresh Grey-pink |  | 2 | NQ | | 305 | | | | | | | | | | RUN #2 TCR=100% SCR=98% RQD=93% | |
| 11.4 | End of Borehole | | | | | | | | | | | | | | | | |





DOUBLE LINE 16284 BARK LAKE CULVERT.GPJ 2012TEMPLATE(MTO).GDT 8/4/19

RECORD OF BOREHOLE No 17-3

1 OF 1

METRIC

WP# 5464-15-01 LOCATION Lat: 45.475627°, Long: -77.908213° Bark Lake Culvert, MTM z9: N 5 038 264.8 E 194 700.5 ORIGINATED BY CM
 HWY 523 BOREHOLE TYPE Portable Raft / NW Casing COMPILED BY KE
 DATUM Geodetic DATE 2017.08.08 - 2017.08.08 CHECKED BY SP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | | PLASTIC LIMIT NATURAL LIMIT MOISTURE CONTENT | | | 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 (%) | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| 313.8 | | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | | |
| 0.0 | WATER |  | | | | | | | | | | | | | | | | |
| 313.1 | | | | | | | | | | | | | | | | | | |
| 0.8 | GRAVEL with sand Loose Brown FILL |  | 1 | SS | 9 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | 2 | SS | 6 | | | | | | | | | | | | | |
| 311.4 | | | | | | | | | | | | | | | | | | |
| 2.4 | SILT with Organics Very Loose Dark Brown |  | 3 | SS | 3 | | | | | | | | | | | | | |
| 310.7 | | | | | | | | | | | | | | | | | | |
| 3.2 | SILTY SAND with Gravel GLACIAL TILL Very Dense Grey |  | | | | | | | | | | | | | | | | |
| | | | 4 | SS | 53 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | 5 | SS | 69 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | 6 | SS | 54 | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| 308.0 | | | 7 | SS | 100/ | | | | | | | | | | | | | |
| 5.9 | End of Borehole Borehole terminated within very dense Glacial Till | | | | 252 mm | | | | | | | | | | | | | |

DOUBLE LINE 16284 BARK LAKE CULVERT.GPJ 2012TEMPLATE(MTO).GDT 8/4/19

RECORD OF BOREHOLE No 17-4

1 OF 1

METRIC

WP# 5464-15-01 LOCATION Lat: 45.475678°, Long: -77.908263° Bark Lake Culvert, MTM z9: N 5 038 270.5 E 194 696.7 ORIGINATED BY CM
HWY 523 BOREHOLE TYPE Portable Raft / NW Casing COMPILED BY KE
DATUM Geodetic DATE 2017.08.08 - 2017.08.09 CHECKED BY SP

| 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 (%) | | | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | | | | w _p w w _L | | | | | | | |
| 313.9 | | | | | | | | 20 | 40 | 60 | 80 | 100 | | | | | | | |
| 0.0 | WATER | | | | | | | | | | | | | | | | | | |
| 313.2 | | | | | | | | | | | | | | | | | | | |
| 0.7 | GRAVEL with sand Loose to Dense Brown FILL | | 1 | SS | 5 | | 313 | | | | | | | ○ | | | | | |
| | | | 2 | SS | 26 | | 312 | | | | | | | ○ | | | | | |
| | | | 3 | SS | 39 | | 311 | | | | | | | ○ | | | | | |
| 310.5 | | | | | | | | | | | | | | | | | | | |
| 3.4 | SAND with silt and gravel to SILTY SAND with Gravel GLACIAL TILL Dense to Very Dense Grey | | 4 | SS | 63 | | 310 | | | | | | | ○ | | | | 36 55 9 (SI+CL) | |
| | | | 5 | SS | 49 | | 309 | | | | | | | ○ | | | | | |
| | | | 6 | SS | 44 | | 308 | | | | | | | ○ | | | | | |
| | | | 7 | SS | 67 | | 307 | | | | | | | ○ | | | | 26 61 13 (SI+CL) | |
| | | | 8 | SS | 40 | | | | | | | | | ○ | | | | | |
| | | | 9 | SS | 100/ 300 mm | | | | | | | | | ○ | | | | | |
| 306.3 | | | | | | | | | | | | | | | | | | | |
| 7.6 | End of Borehole on inferred Bedrock | | | | | | | | | | | | | | | | | | |

DOUBLE LINE 16284 BARK LAKE CULVERT GPJ 2012TEMPLATE(MTO).GDT 8/4/19

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 5 10 15 20 (%) STRAIN AT FAILURE

METRIC

| SOIL PROFILE | | | | SAMPLES | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT | | | 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 L | | | | | |
| 313.8 0.0 | WATER | | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | | | | | | |
| 309.8 | - Cobbles and Boulders on Ground Surface | | | | | | 313 | | | | | | | |
| 4.1 | GRAVEL with sand Compact Brown FILL | | 1 | SS | 10 | | 312 | | | | | | | |
| 309.1 | SILTY SAND with Gravel GLACIAL TILL Very Dense Grey | | 2 | SS | 103 | | 311 | | | | | | | |
| 4.7 | | | 3 | SS | 100/ | | 310 | | | | | | | |
| 307.9 | End of Borehole on inferred Bedrock | | | | | | 309 | | | | | | | |
| 5.9 | | | | | | | 308 | | | | | | | |

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 17-6

1 OF 1

METRIC

WP# 5464-15-01 LOCATION Lat: 45.475760°, Long: -77.907963° Bark Lake Culvert, MTM z9: N 5 038 279.3 E 194 720.3 ORIGINATED BY CM
 HWY 523 BOREHOLE TYPE Portable Raft / NW Casing COMPILED BY KE
 DATUM Geodetic DATE 2017.08.09 - 2017.08.10 CHECKED BY SP

| SOIL PROFILE | | | SAMPLES | | | GROUND WATER CONDITIONS | ELEVATION SCALE | DYNAMIC CONE PENETRATION RESISTANCE PLOT | | | | UNIT WEIGHT γ kN/m ³ | REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL | |
|-----------------------------------------------------------|------------------------------------------------------------------------------------------------|------------|---------|-----------|------------|----------------------------|-----------------|----------------------------------------------------------|--|--|--|-----------------------------------------------------|----------------------------------------------------------------------|--|
| ELEV DEPTH | DESCRIPTION | STRAT PLOT | NUMBER | TYPE | "N" VALUES | | | SHEAR STRENGTH kPa | | | | | | |
| | | | | | | | | 20 40 60 80 100 | | | | | | |
| | | | | | | | | ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE | | | | | | |
| PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT | | | | W P W W L | | | | | | | | | | |
| WATER CONTENT (%) | | | | 20 40 60 | | | | | | | | | | |
| 313.8 | | | | | | | | | | | | | | |
| 0.0 | WATER | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| 310.3 | - Cobbles and Boulders on Ground Surface | | | | | | | | | | | | | |
| 3.5 | GRAVEL with sand Compact Brown | | 1 | SS | 2 | | | | | | | | | |
| 309.7 | FILL | | | | | | | | | | | | | |
| 4.1 | GRAVEL with silt and sand GLACIAL TILL Very Dense to Dense Grey - Boulder at 4.7 m | | 2 | SS | 60 | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | 3 | SS | 70 | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | 4 | SS | 35 | | | | | | | | | |
| | | | | | | | | | | | | | | |
| 307.3 | | | 5 | SS | 100/ | | | | | | | | | |
| 6.5 | End of Borehole on inferred Bedrock | | | | 100mm | | | | | | | | | |

DOUBLE LINE 16284 BARK LAKE CULVERT.GPJ 2012TEMPLATE(MTO).GDT 8/4/19

Borehole 17-2
Core Box 1 of 1
Elevation 306.2 m to 304.1 m

Run 1 Start
elev. 306.2 m



Run 1 End
elev. 305.5 m

Run 2 Start
elev. 305.5 m

Run 2 End
elev. 304.1 m

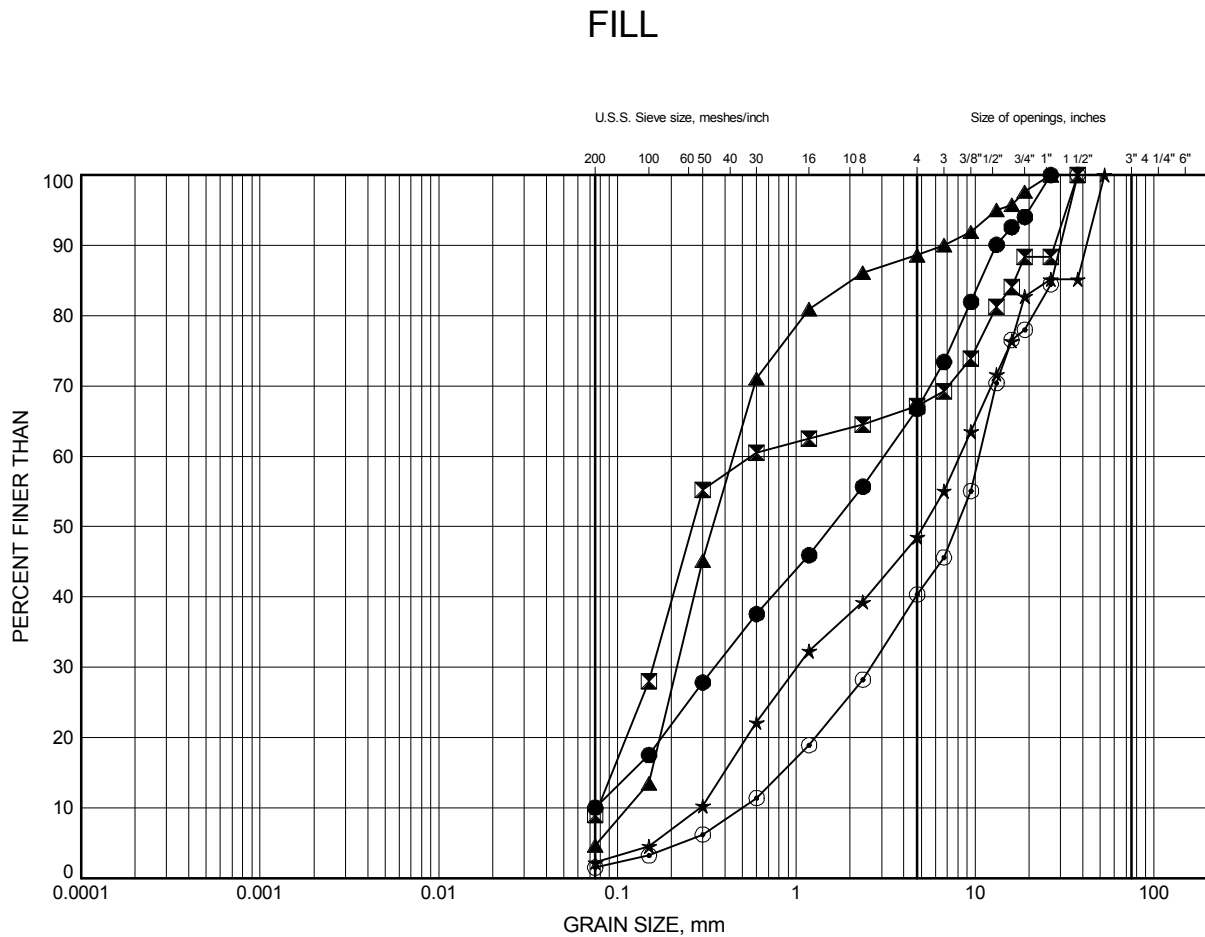
Appendix C.

Laboratory Testing

Bark Lake Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C1



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

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 17-1 | 0.46 | 315.05 |
| ⊠ | 17-1 | 4.11 | 311.39 |
| ▲ | 17-2 | 1.07 | 314.42 |
| ★ | 17-3 | 1.09 | 312.76 |
| ⊙ | 17-5 | 4.37 | 309.47 |

Date ..April 2019.....
 WP# ..5464-15-01.....

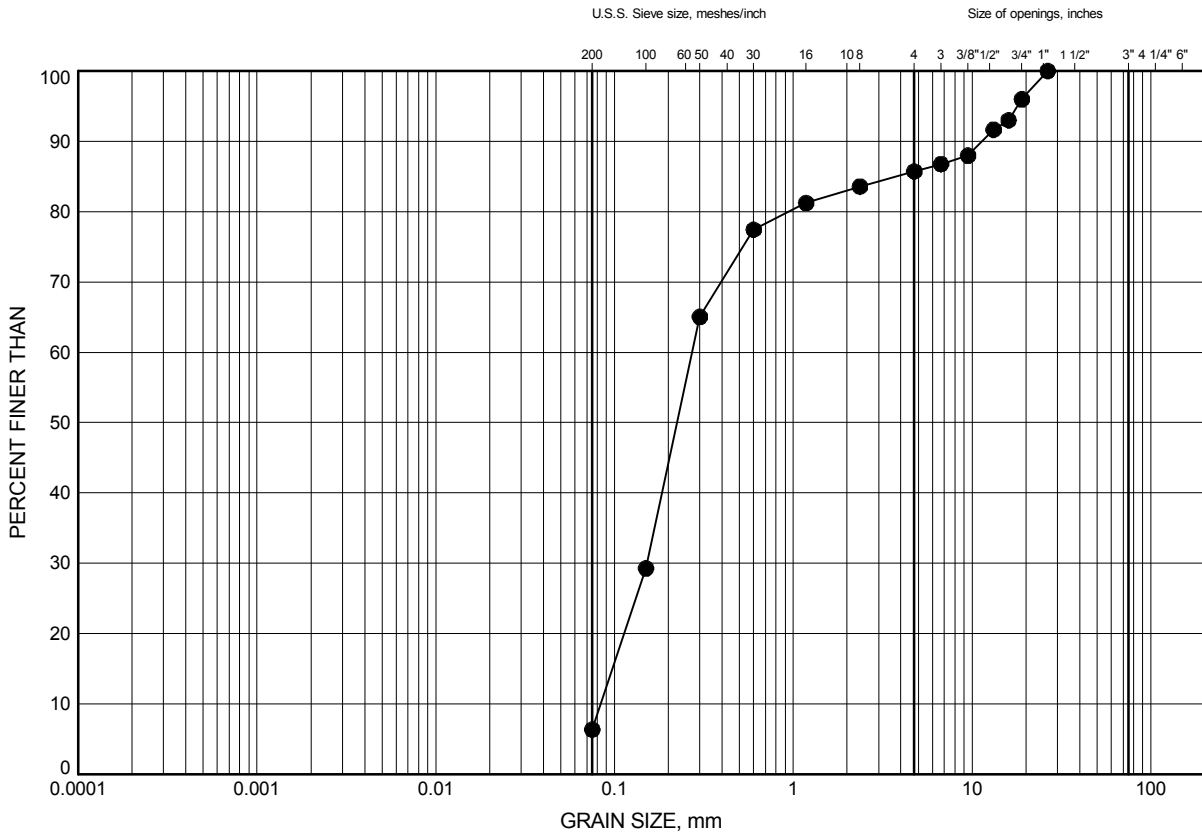


Prep'dAC.....
 Chkd.SBP.....

Bark Lake Culvert GRAIN SIZE DISTRIBUTION

FIGURE C2

SAND with Silt



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

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 17-2 | 4.88 | 310.61 |

Date April 2019
WP# 5464-15-01



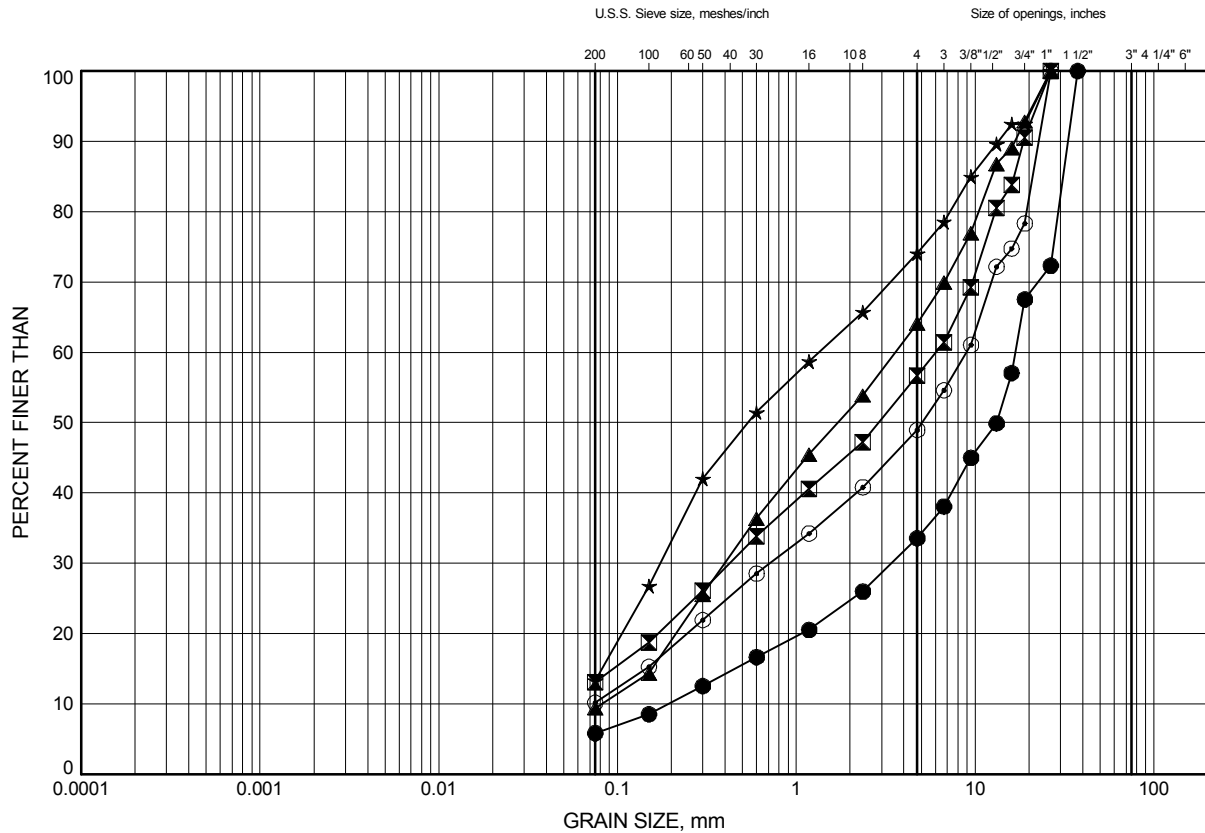
Prep'd AC
Chkd. SBP

Bark Lake Culvert

GRAIN SIZE DISTRIBUTION

FIGURE C3

Silty SAND with Gravel to GRAVEL with Silt (TILL)



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

LEGEND

| SYMBOL | BOREHOLE | DEPTH (m) | ELEV. (m) |
|--------|----------|-----------|-----------|
| ● | 17-2 | 6.41 | 309.07 |
| ⊠ | 17-3 | 4.40 | 309.45 |
| ▲ | 17-4 | 3.66 | 310.22 |
| ★ | 17-4 | 6.71 | 307.17 |
| ⊙ | 17-6 | 5.18 | 308.66 |

Date April 2019
 WP# 5464-15-01



Prep'd AC
 Chkd. SBP

Certificate of Analysis

Thurber Engineering Ltd.

2460 Lancaster Rd, Suite 104
Ottawa, ON K1B4S5
Attn: Stephen Peters

Client PO: 16284
Project: Hwy 35/523
Custody: 38404

Report Date: 29-Aug-2017
Order Date: 23-Aug-2017

Order #: 1734260

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

| Paracel ID | Client ID |
|-----------------------|-----------------------------------------------|
| 1734260-01 | Black Creek 17-3 SS#2 7.83-9.83' |
| 1734260-02 | Black Creek 17-5 SS#3 10.17-12.17' |
| 1734260-03 | Miner's Bay 17-3 SS#1 0-1.25' |
| 1734260-04 | Bark Lake 17-3 SS#3 10-12' |
| 1734260-05 | Bark Lake 17-6 SS#2 15-17' |

Approved By:



Dale Robertson, BSc
Laboratory Director

Certificate of Analysis
 Client: Thurber Engineering Ltd.
 Client PO: 16284

Report Date: 29-Aug-2017
 Order Date: 23-Aug-2017
 Project Description: Hwy 35/523

| | | | | |
|---------------------|-----------------------------|-----------------------------|-----------------------------|----------------|
| Client ID: | Black Creek 17-3 | Black Creek 17-5 | Miner's Bay 17-3 | Bark Lake 17-3 |
| Sample Date: | SS#2 7.83-9.83' | SS#3 10.17-12.17' | SS#1 0-1.25' | SS#3 10-12' |
| Sample ID: | 14-Aug-17 | 16-Aug-17 | 10-Aug-17 | 08-Aug-17 |
| | 1734260-01 | 1734260-02 | 1734260-03 | 1734260-04 |
| MDL/Units | Soil | Soil | Soil | Soil |

Physical Characteristics

| | | | | | |
|----------|--------------|------|------|------|------|
| % Solids | 0.1 % by Wt. | 73.7 | 76.1 | 91.0 | 70.4 |
|----------|--------------|------|------|------|------|

General Inorganics

| | | | | | |
|--------------|---------------|------|------|------|------|
| Conductivity | 5 uS/cm | 99 | 176 | 220 | 217 |
| pH | 0.05 pH Units | 8.33 | 8.05 | 7.85 | 4.91 |
| Resistivity | 0.10 Ohm.m | 101 | 56.8 | 45.5 | 46.1 |

Anions

| | | | | | |
|----------|------------|----|----|----|-----|
| Chloride | 5 ug/g dry | 11 | 51 | 8 | 6 |
| Sulphate | 5 ug/g dry | 23 | 25 | 23 | 176 |

| | | | | |
|---------------------|---------------------|---|---|---|
| Client ID: | Bark Lake 17-6 SS#2 | - | - | - |
| Sample Date: | 15-17' | - | - | - |
| Sample ID: | 09-Aug-17 | - | - | - |
| | 1734260-05 | - | - | - |
| MDL/Units | Soil | - | - | - |

Physical Characteristics

| | | | | | |
|----------|--------------|------|---|---|---|
| % Solids | 0.1 % by Wt. | 88.8 | - | - | - |
|----------|--------------|------|---|---|---|

General Inorganics

| | | | | | |
|--------------|---------------|------|---|---|---|
| Conductivity | 5 uS/cm | 63 | - | - | - |
| pH | 0.05 pH Units | 5.70 | - | - | - |
| Resistivity | 0.10 Ohm.m | 158 | - | - | - |

Anions

| | | | | | |
|----------|------------|----|---|---|---|
| Chloride | 5 ug/g dry | 7 | - | - | - |
| Sulphate | 5 ug/g dry | 26 | - | - | - |

HIGHWAY 523 BARK LAKE CULVERT REPLACEMENT
7.4 KM SOUTH OF HIGHWAY 60, TOWNSHIP OF LYELL

Appendix D.

Site Photographs

HIGHWAY 523 BARK LAKE CULVERT REPLACEMENT
7.4 KM SOUTH OF HIGHWAY 60, TOWNSHIP OF LYELL



Photo 1. Looking southward at culvert inlet (2017/08/10)



Photo 2. Looking southward of outlets of by-pass and main culvert (2017/08/10)

HIGHWAY 523 BARK LAKE CULVERT REPLACEMENT
7.4 KM SOUTH OF HIGHWAY 60, TOWNSHIP OF LYELL



Photo 3. Looking north along Highway 523 (2017/08/10)



Photo 4. Looking south along Highway 523 (2017/08/10)

Appendix E.

Foundation Comparison

COMPARISON OF ALTERNATIVE FOUNDATION TYPES

| Type | Closed Box Culvert | Circular Pipe Culvert | Open Bottom Culvert | Precast Concrete Slab on Sheet Pile Culvert |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Advantages | Typically least costly culvert type. Relatively expedient installation if precast units are used. Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade. Minimized differential settlement between culvert and approach fills. | Can tolerate larger magnitude of settlement than concrete (rigid frame) culverts. | Relatively expedient installation if precast units are used. Culvert founded at same elevation | Potentially minimized volume of excavation and roadway protection. Allows for winter construction. |
| Disadvantages | Requires large excavation and roadway protection. Requires compacted granular pad on subgrade. | Feasibility also depends on flow capacity and other hydraulic properties. May need a second pipe. | Requires deeper excavation increasing excavation volume and dewatering efforts. Potential for post construction settlement. | Quantity and cost of sheet piles. Unconventional design. Differential settlement will occur between non-yielding culvert and approach fills. |
| Risks/ Consequences | Groundwater control will require enclosed excavation. | Groundwater control will require enclosed excavation. Possibility of encountering obstructions. | Groundwater control will require enclosed excavation. Increased risk of basal instability of footing excavation due to depth of excavation below water table. | Possibility of encountering obstructions and inadequate lateral support due to a shallow refusal. |
| Relative Cost | Low | Low | Medium | Medium to High |
| Recommendation | Preferred | Feasible | Feasible | Generally Feasible |

Appendix F.

GSC Seismic Hazard Calculation

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

September 15, 2017

Site: 45.4756 N, 77.908 W User File Reference: Highway 523

Requested by: Bark Lake (Wolf Creek), FIDR

National Building Code ground motions: 2% probability of exceedance in 50 years (0.000404 per annum)

| Sa(0.05) | Sa(0.1) | Sa(0.2) | Sa(0.3) | Sa(0.5) | Sa(1.0) | Sa(2.0) | Sa(5.0) | Sa(10.0) | PGA (g) | PGV (m/s) |
|----------|---------|----------------|---------|----------------|----------------|----------------|----------------|-----------------|----------------|------------------|
| 0.160 | 0.208 | 0.192 | 0.158 | 0.123 | 0.071 | 0.036 | 0.0099 | 0.0039 | 0.118 | 0.104 |

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" (NBCC 2015 Site Class C, average shear wave velocity 450 m/s). NBCC2015 and CSAS6-14 values are specified in **bold** font. 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.*

Ground motions for other probabilities:

| | | | |
|---------------------------------------|--------|--------|--------|
| Probability of exceedance per annum | 0.010 | 0.0021 | 0.001 |
| Probability of exceedance in 50 years | 40% | 10% | 5% |
| Sa(0.05) | 0.021 | 0.063 | 0.097 |
| Sa(0.1) | 0.032 | 0.087 | 0.131 |
| Sa(0.2) | 0.032 | 0.083 | 0.123 |
| Sa(0.3) | 0.027 | 0.070 | 0.102 |
| Sa(0.5) | 0.021 | 0.054 | 0.080 |
| Sa(1.0) | 0.011 | 0.031 | 0.046 |
| Sa(2.0) | 0.0045 | 0.015 | 0.023 |
| Sa(5.0) | 0.0009 | 0.0035 | 0.0056 |
| Sa(10.0) | 0.0005 | 0.0015 | 0.0024 |
| PGA | 0.018 | 0.049 | 0.074 |
| PGV | 0.014 | 0.041 | 0.064 |

References

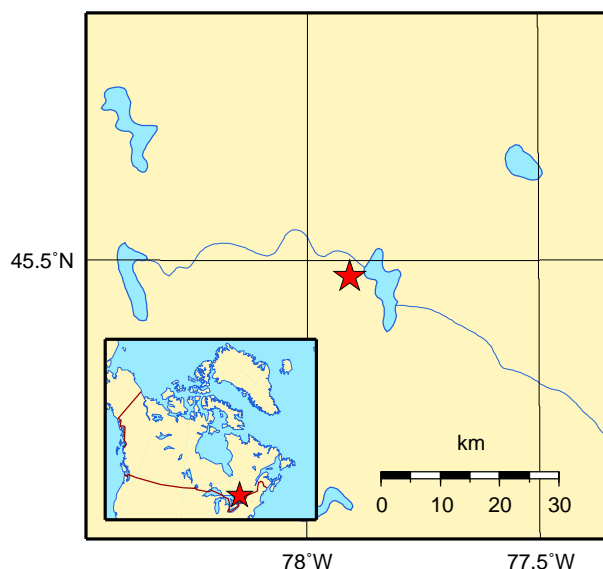
National Building Code of Canada 2015 NRCC no. 56190;
Appendix C: Table C-3, Seismic Design Data for Selected Locations in Canada

User's Guide - NBC 2015, Structural Commentaries NRCC no. xxxxxx (in preparation)
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

Aussi disponible en français



Natural Resources
Canada

Ressources naturelles
Canada

Canada

Appendix G.

List of Special Provisions and OPSS Documents Referenced in this Report

HIGHWAY 523 BARK LAKE CULVERT REPLACEMENT
7.4 KM SOUTH OF HIGHWAY 60, TOWNSHIP OF LYELL

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

| | |
|----------------|---------------------------------------------------------------------------------------------|
| OPSS.PROV 206 | Construction Specification for Grading |
| OPSS.PROV 501 | Construction Specification for Compacting |
| OPSS 422 | Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cuts |
| OPSS 511 | Construction Specification for Rip-rap, Rock Protection and Granular Sheeting |
| 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 805 | Construction Specifications for Temporary Erosion and Sediment Control Measures |
| OPSS 902 | Construction Specification for Excavating and Backfilling Structures |
| OPSS.PROV 1010 | Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material |
| OPSS.PROV 1205 | Material Specification for Clay Seal |
| OPSS 1860 | Material Specification for Geotextile |
| OPSD 208.010 | Benching of Earth Slopes |
| OPSD 803.010 | Backfill and Cover for Concrete Culverts with Span Less than or Equal to 3.0 m |
| OPSD 810.010 | General Rip-Rap Layout for Sewer and Culvert Outlets |
| NSSP FOUN0003 | Dewatering Structure Excavations |
| SP 517F01 | Design Storm Return Period and Preconstruction Survey |
| SP 109S12 | QVE, Backfilling, Compaction, and Certificate of Conformance |

2. Suggested text for a NSSP on "Obstructions"

Installation of roadway protection system and coffer dams will encounter obstructions such as wood, cobbles and boulders embedded in the fill and native soils. Such obstructions may impede the work from reaching the design depth of installation. The Contractor shall be prepared to remove, drill through and/or penetrate these obstructions and extend the work to the design depths.