



February 28, 2017

## FOUNDATION INVESTIGATION AND DESIGN REPORT

**KENETOGAMI CREEK CULVERT - SITE NO. 46-417/C  
HIGHWAY 144, SUDBURY UNORGANIZED (NORTH PART) DISTRICT  
TOWNSHIP OF STETHAM  
MINISTRY OF TRANSPORTATION, ONTARIO  
G.W.P 5384-11-00 W.P. 5384-11-01**

**Submitted to:**

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1 PDF: Golder Associates Ltd., Sudbury, Ontario

REPORT







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## **DETAIL FOUNDATION REPORT KENETOGAMI CREEK CULVERT - SITE NO. 46-417/C**

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# **PART A**

**DETAIL FOUNDATION INVESTIGATION REPORT  
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HIGHWAY 144, SUDBURY UNORGANIZED (NORTH PART) DISTRICT  
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## **1.0 INTRODUCTION**

Golder Associates Ltd. (Golder) has been retained by AECOM Canada Ltd. (AECOM), on behalf of the Ministry of Transportation, Ontario (MTO) to provide detail foundation engineering services for the replacement of the Kenetogami Creek culvert (Site No. 46-417/C). The Kenetogami Creek culvert is located in the Sudbury Unorganized (North Part) District, in the Township of Stetham on Highway 144 at STA 10+917, approximately 12.2 km north of the Highway 661. The key plan showing the general location of this section of Highway 144 and the location of the investigated area are shown on Drawing 1.

## **2.0 SITE DESCRIPTION**

The existing Kenetogami Creek culvert consists of a single, steel plate corrugate steel pipe arch (SPCSPA), the details of which (i.e., width, height, length, etc.) are summarized in Table 1 following the text of the report.

It should be noted that the orientation (i.e., north, south, east, west) stated in the text of the report is referenced to project north and therefore may differ from magnetic north shown on the drawing. For the purpose of this report, Highway 144 is oriented in a north-south direction (for this section of roadway) with the culvert perpendicular to the highway in a west-east orientation.

In general, the topography in the area of the culvert consists of low-lying swampy terrain on both sides of Highway 144, with moderate to dense tree cover beyond the creek banks and/or edges of the swamp. At the culvert location, the highway grade is at Elevation 359.0 m and the existing culvert invert, as provided by AECOM, is at Elevation 355.2 m at both the inlet (west end) and outlet (east end). The creek water level was surveyed by Golder on October 6, 2016 at Elevation 356.2 m at both the inlet and outlet ends. Surface conditions in the area of the culvert inlet and outlet are shown on Photographs 1 to 4.

## **3.0 INVESTIGATION PROCEDURES**

The field work for this subsurface investigation was carried out between October 3 and 6, 2016, during which time four boreholes (Boreholes KC-1 to KC-4) were advanced at approximately the locations shown on Drawing 1. Auger refusal on inferred cobbles/boulders was encountered at the original Borehole KC-1 location at shallow depth and the borehole was abandoned. A subsequent Borehole KC-1 was advanced approximately 0.3 m east of the original location. Both location as shown on Drawing 1.

Boreholes KC-1 and KC-4 were advanced at the toe of embankment slope near the culvert inlet and outlet, respectively, and Boreholes KC-2 and KC-3 were advanced from the existing highway platform. All boreholes were advanced using a track mounted CME-55 drill rig supplied and operated by Landcore Drilling of Chelmsford Ontario. All boreholes were advanced using 108 mm inside diameter hollow stem augers, NW casing with washing boring techniques, and NQ coring as required.

Soil samples were obtained in the boreholes at 0.75 m and 1.5 m intervals of depth using 50 mm outer diameter split-spoon samplers driven by an automatic hammer, in accordance with the Standard Penetration Test (SPT) procedures (ASTM D1586). The groundwater level in the open boreholes was observed during the drilling operations as described on the Record of Borehole sheets in Appendix A. The boreholes were backfilled upon completion in accordance with Ontario Regulation 903 Wells (as amended).





## DETAIL FOUNDATION REPORT KENETOGAMI CREEK CULVERT - SITE NO. 46-417/C

The field work was monitored on a full-time basis by members of Golder's technical staff who: located the boreholes in the field; arranged for the clearance of underground services; supervised the drilling and sampling operations; logged the boreholes; and examined and cared for the soil samples. The soil samples were identified in the field, placed in labelled containers and transported to Golder's geotechnical laboratory in Sudbury for further examination and laboratory testing. Index and classification testing consisting of water content determinations and grain size distributions were carried out on selected soil samples. The geotechnical laboratory testing was completed according to MTO LS standards.

A soil sample was obtained from Borehole KC-4 using appropriate sampling protocols and submitted to a specialist analytical laboratory under chain of custody procedures for testing for a suite of parameters including pH, resistivity, conductivity, sulphate and chloride. The results of the analytical testing are presented in Table B1 in Appendix B.

The as-drilled borehole locations and ground surface elevations were measured and surveyed by members of our technical staff, referenced to the highway centerline and existing culvert and converted into northing/easting coordinates on the plan drawing. The ground surface elevation of the highway centerline was obtained from the profile drawing provided by AECOM (drawing b0351144001.dwg). The MTM NAD83 Zone 12 northing and easting coordinates and geographical coordinates, ground surface elevations referenced to Geodetic datum, and borehole depths at each borehole location are presented on the Record of Borehole sheets in Appendix A and summarized below.

Borehole Number	MTM NAD83 Northing (Latitude)	MTM NAD83 Easting (Longitude)	Ground Surface Elevation	Borehole Depth (m)
KC-1	5291289.5 m (47.7590311°)	258610.1 m (-81.6161565°)	356.6 m	9.8
KC-2	5291280.9 m (47.7589542°)	258615.8 m (-81.6160798°)	358.7 m	14.3
KC-3	5291270.2 m (47.7588579°)	258609.6 m (-81.6161606°)	359.1 m	14.0
KC-4	5291268.5 m (47.7588433°)	258626.4 m (-81.6159371°)	356.3 m	9.8

## 4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

### 4.1 Regional Geology

Based on Northern Ontario Engineering Geology Terrain (NOEGTS)<sup>1</sup> mapping, the Kenetogami Creek culvert site is located within an outwash plain deposit consisting primarily of sand and gravel soils, bordered by bedrock knobs.

Based on geological mapping by the Ontario Ministry of Northern Development and Mines (MNDM)<sup>2</sup>, the site is underlain by gneissic tonalite rocks comprised of tonalite to granodiorite (foliated to gneissic) with minor supracrustal inclusions.

<sup>1</sup> Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41PNW





## DETAIL FOUNDATION REPORT KENETOGAMI CREEK CULVERT - SITE NO. 46-417/C

### 4.2 Subsurface Conditions

The detailed subsurface soil and groundwater conditions encountered in the boreholes and the results of in situ and laboratory testing are given on the Record of Borehole sheets contained in Appendix A. The detailed results of geotechnical laboratory testing are contained in Appendix B. The results of the in situ field tests (i.e., SPT 'N' values) as presented on the Record of Borehole sheets and in Section 4 are uncorrected. The stratigraphic boundaries shown on the Record of Borehole sheets and on the interpreted stratigraphic profile on Drawing 1 is inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of geological change. The subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoil conditions encountered at the site consist of asphalt, granular and reclaimed asphalt pavement (RAP) mix and granular fill (for boreholes advanced through the embankment) or topsoil, underlain by granular fill (for boreholes advanced beyond the embankment toe of slope), underlain by a deposit of sand to sand and gravel. A more detailed description of the soil deposits and groundwater conditions encountered in the boreholes is provided below.

Deposit/Layer Description	Boreholes	Deposit Surface Elevation (m)	Deposit Thickness (m)	N Values (blows)	Laboratory Testing
				Relative Density	
<b>Asphalt</b>	KC-2 & KC-3	358.7 & 359.1	~ 0.08	n/a	n/a
<b>Granular and RAP Mix</b>	KC-2 & KC-3	358.6 & 359.0	~ 0.12 & 0.17	n/a	n/a
<b>Topsoil</b>	KC-1 & KC-4	356.6 & 356.3	0.1	n/a	n/a
<b>(FILL)</b> Gravelly sand trace to some silt; brown; moist to wet	KC-1 to KC-4	358.8 – 356.2	0.6 – 3.8	N = 4 - 28	w = 2% – 10% 2 – M (Fig. B1)
				<b>Loose to Compact</b>	
<b>Sand to Sand and Gravel</b> trace to some silt; brown to grey; moist to wet	KC-1 to KC-4	355.9 – 355.0	8.9 – 11.3 (boreholes terminated in this deposit)	N = 1 – 110	w = 8% - 23% 12 – M (Fig. B2.1 and B2.2)
				<b>Very Loose to Very Dense</b>	

**Where:**

N = SPT 'N' values; number of blows for 0.3 m of penetration

M = Sieve analysis

w = Natural moisture content (%)

### Asphalt and Granular and RAP Mix

The two boreholes penetrated a pavement layer comprised of a surficial asphalt layer underlain by a layer of mixed granular material and reclaimed asphalt pavement (RAP). The interface between the asphalt layer and the compacted granular and RAP mix layer were difficult to distinguish in the field. The combined layers are 200 mm and 250 mm thick in Boreholes KC-2 and KC-3, respectively. Based on the as-built contract drawings (Contract No. 2009-5104), we understand that the previous pavement rehabilitation strategy included milling and pulverizing the asphalt and re-paving with an 80 mm thick layer of new hot mix asphalt overlay. The approximate

<sup>2</sup> Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2543





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thickness of the asphalt layer and the granular and RAP mix layer encountered in Boreholes KC-2 and KC-3 are based on field measurements and the information provided in the as-built drawings, and the actual thicknesses of the individual layers may vary.

### Gravelly Sand Fill

Traces of asphalt and wood fragments were encountered within the gravelly sand fill in Borehole KC-1. In one instance, the split spoon sampler did not penetrate the entire SPT depth. An SPT 'N'-value of 89 blows per 0.3 m of penetration was measured in Borehole KC-2 with subsequent split spoon refusal (i.e. spoon bouncing). This relatively high blow count is inferred to be due to the presence of cobbles/boulders within the fill material and is not considered to be representative of the relative density of the fill material. The presence of the inferred cobbles/boulders is further evidenced by auger grinding as noted in Boreholes KC-2, KC-3 and KC-4.

### Sand to Sand and Gravel

Trace organics was noted near the surface of the sand to sand and gravel deposit. In addition, a sandy silt seam and a silty sand zone were noted in Boreholes KC-1 and KC-2, respectively, at depths of about 3.0 m and 12.2 m below ground surface (Elevations 353.6 m and 346.5 m) in the respective boreholes.

An SPT 'N'-value of 60 blows per 0.3 m of penetration was measured in Borehole KC-3 with subsequent split spoon refusal (i.e. spoon bouncing). In Borehole KC-4 at 7.6 m depth (Elev. 348.7 m), the split spoon was noted to be bouncing at the start of the SPT with no penetration. Further, NQ coring was required in three instances to advance Borehole KC-4 through the sand to sand and gravel deposit and approximately 75 mm and 250 mm diameter cobbles were recovered from the core barrel at the various depths as noted on the Record of Borehole Sheet.

### Groundwater Conditions

Unstabilized groundwater levels measured in the open boreholes upon completion of drilling are summarized below. The creek water level was surveyed at Elevation 356.2 m on October 6, 2016 at both the inlet and outlet ends of the culvert. Groundwater and creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events.

Borehole No.	Depth to Groundwater Level (m)	Groundwater Elevation (m)
KC-1	0.6	356.0
KC-2	3.1	355.6
KC-3	1.7	357.4
KC-4	0.3	356.0

\*Borehole KC-4 was advanced using NW casing and wash boring techniques (with NQ coring as required) and as such, the measured groundwater level may not be representative of the in-situ groundwater condition.





## **5.0 CLOSURE**

The field drilling program was carried out under the supervision of Mr. Tibor Berecz, under the overall direction of Mr. David Muldowney, P.Eng. This Detail Foundation Investigation Report was prepared by Mr. Adam Core, P.Eng., and Mr. David Muldowney, P.Eng., provided a technical review of the report. Mr. Jorge M. A. Costa, P.Eng., a Senior Consultant with and Designated MTO Foundations Contact for Golder, conducted an independent quality control review of this report.





## Report Signature Page

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AC/DAM/JMAC/ms

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# **PART B**

**DETAIL FOUNDATION INVESTIGATION REPORT  
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## **6.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS**

This section of the report provides foundation design recommendations for the proposed replacement of the Kenetogami Creek culvert. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the subsurface investigation. The discussion and recommendations presented are intended to provide the designer with sufficient information to assess the feasible foundation alternatives and carry out the design of the structure foundations, as may be required. The foundation investigation report, discussion and recommendations are intended for the use of the Ministry of Transportation and shall not be used or relied upon for any other purpose or by any other parties, including the construction or design-build contractor. The contractor must make their own interpretation based on the factual data in Part A of the report. Where comments are made on construction, they are provided only to highlight those aspects that could affect the detail design of the project and for which special provisions may be required in the Contract Documents. Those requiring information on the aspects of construction must make their own interpretation of the factual information provided as such interpretation may affect equipment selection, proposed construction methods, scheduling and the like.

### **6.1 General**

The Kenetogami Creek culvert is located in the Sudbury Unorganized (North Part) District in the Township of Stetham on Highway 144 at about STA 10+917, approximately 12.2 km north of Highway 661. The highway embankment is constructed of granular fill and is about 3.9 m high relative to the existing culvert invert, with approximately 1.0 m of soil cover over the existing SPCSPA culvert. The details (i.e., width, height, length, etc.) of the existing corrugated steel pipe culvert are summarized in Table 1.

A box culvert, open footing culvert or pipe culvert are all considered feasible alternatives for replacement of the existing culvert. Although feasible, an open footing culvert presents additional challenges as it will extend the construction schedule and increase the depth of excavation, dewatering and shoring requirements compared a box culvert. Given the relatively low embankment height and limited soil cover, multiple pipe culverts would likely be required to provide a similar flow-through capacity compared to a box or open footing culvert and, if constructed from steel, a pipe culvert will likely have a shorter design life as the replacement structure for this site. From a foundation perspective, a closed-bottom box culvert sufficiently wide to handle the creek flow is preferred. A different culvert type may be preferred due to other considerations such as fisheries requirements related to natural channel substrate. A comparison of culvert types based on advantages, disadvantages and risks/consequences is presented in Table 2.

As outlined in the Request For Proposal (RFP) and as shown on the General Arrangement (GA) drawing provided by AECOM on December 15, 2016, we understand that the proposed replacement culvert is to consist of a pre-cast, single-cell, concrete box approximately 6.0 m wide by 3.0 m high (exterior dimensions) with the invert at about Elevation 354.9 m at both the inlet and outlet ends. The proposed culvert is to be constructed along the current (existing) culvert alignment and we understand that there is no permanent embankment grade raise or widening being proposed as part of the Highway 144 reinstatement. We further understand that temporary widening of the roadway embankment will be required along the existing shoulders to facilitate staged construction. Based on discussions with AECOM, we understand that the existing sideslopes will be modified to accommodate the temporary widening within the footprint of the existing roadway embankment (i.e. no widening beyond the existing toe of embankment slope).





## **6.2 Consequence and Site Understanding Classification**

As the proposed replacement culvert crosses Highway 144 and will carry large volumes of traffic with the potential to impact alternative transportation corridors, a “typical consequence level” is considered appropriate as outlined in Section 6.5 of the Canadian Highway Bridge Design Code (CHBDC 2014) and its Commentary. Further, given the scope of work of the foundation field investigation and laboratory testing program as outlined in Sections 3.0 and 4.0, a “typical degree of site and prediction model understanding” has been utilized. Accordingly, the appropriate corresponding ULS and SLS consequence factor,  $\Psi$ , and geotechnical resistance factors,  $\phi_{gu}$  and  $\phi_{gs}$ , from Tables 6.1 and 6.2 of the CHBDC have been used for design.

## **6.3 Geotechnical Resistances**

Prior to placing the bedding/levelling pad and replacement culvert, it is recommended that any organic material (i.e., topsoil or mixed organic soil) encountered below the culvert footprint be sub-excavated and replaced with Ontario Provincial Standard Specification, Provincial Oriented (OPSS.PROV) 1010 Granular ‘B’ Type II engineered fill, which is more suitable for use in wet ground conditions.

For a proposed 6.0 m wide box culvert founded on a properly prepared granular bedding/levelling pad overlying the native subgrade soils at approximately Elevation 354.2 m (taking into account the culvert invert elevation, a 300 mm thick concrete box bottom slab, a 75 mm levelling course and a 300 mm thick bedding layer), a factored ultimate geotechnical resistance at Ultimate Limit States (ULS) of 850 kPa and a factored serviceability geotechnical resistance at Serviceability Limit States (SLS), based on 25 mm of settlement, of 150 kPa may be used for design.

In the event that an open footing culvert is selected as the replacement option, factored geotechnical resistances of 250 kPa at ULS and 200 kPa SLS may be used for an assumed 1.2 m wide footing founded at/or below Elev. 352.6 m to provide for a minimum 2.3 m of soil cover for protection against frost penetration, as interpreted from OPSS 3090.100 (Foundation, Frost Penetration Depths for Northern Ontario).

The factored geotechnical resistances provided above are based on the loading applied perpendicular to the base of the culvert/footings; where applicable, inclination of the load should be taken into account in accordance with Section 6.10.4 and Section C6.10.4 of the CHBDC and its Commentary.

## **6.4 Resistance to Lateral Loads/Sliding Resistance**

Resistance to lateral forces/sliding resistance should be calculated in accordance with Section 6.10.5 of the CHBDC (2014) applying the appropriate consequence and degree of site understanding factors as noted in Section 6.2. A coefficient of friction,  $\tan \delta'_i$ , of 0.45 may be used at the interface between the base of the pre-cast box culvert segments and the granular bedding/levelling material. In the event that an open footing culvert is chosen as the replacement option, a coefficient of friction,  $\tan \delta'_i$ , of 0.50 may be used or between the base of the cast-in-place strip footing and the native subgrade soils.





## **6.5 Stability, Settlement and Horizontal Strain**

For the subsurface conditions and the proposed reconstructed embankment height up to about 3 m above the existing ground surface along the embankment toe of slope (or about 4.2 m high relative to the invert of the replacement culvert), granular fill embankments at this site will be stable at side slopes inclined at 2 horizontal to 1 vertical (2H:1V) or flatter. For temporary widening using granular fill, side slopes of 1.5H:1V will result in a factor of safety of 1.3 in a temporary condition. Surficial sloughing may occur and flatter side slopes may be required.

Given that the existing embankment is generally being maintained with no proposed grade raise and only minor temporary widening along the existing shoulders to facilitate stage construction, the existing native soils will not experience any appreciable additional loads, and therefore, settlement of the culvert is expected to be less than 25 mm. Further, given the cohesionless nature of the subgrade soils, settlement of the culvert is anticipated to occur immediately during construction and as such, post-construction settlement following the embankment reconstruction is not anticipated.

Horizontal strain is not expected to occur as the permanent embankment geometry is not changing from the current (existing) geometry. As a result, culvert construction concurrent with the embankment construction can be carried out without the need for any foundation mitigation measures or provisions for a culvert camber.

## **6.6 Lateral Earth Pressures**

The lateral earth pressures acting on the side walls of the culvert will depend on the type and method of placement of backfill materials, the nature of the soils/embankment fill behind the backfill, the magnitude of surcharge including construction loadings, the freedom of lateral movement of the structure, and the drainage conditions behind the walls.

The following recommendations are made concerning the design of the replacement culvert. It should be noted that these design recommendations and parameters are applicable to level backfill and ground surface behind the walls. Where there is sloping ground behind the walls, the coefficient of lateral earth pressure must be adjusted to account for the slope.

- Select, free draining granular fill meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III should be used as backfill behind the culvert walls and on top of the culvert for a thickness of up to 300 mm in a similar configuration to OPSD 803.010 (Backfill and Covert for Concrete Culverts), which in effect is also similar to the previous (1994) MTOD for precast concrete box culverts. Backfill should be placed in maximum 200 mm loose lift thickness and compacted to 98 per cent of the SPMD of the material.
- For this site, given the cohesionless (granular) composition of the embankment fill material, the granular backfill to the culvert does not need to be increased to the thickness equivalent to the depth of frost penetration.
- The lateral earth pressures acting against the culvert walls are based on the proposed backfill material against the walls and the following parameters (unfactored) may be used:





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Fill Type	Internal Angle of Friction ( $\phi$ )	Unit Weight	Coefficients of Static Lateral Earth Pressure		
			Active, $K_a$	At-Rest, $K_o$	Passive, $K_p$
Granular 'A'	35°	22 kN/m <sup>3</sup>	0.27	0.43	3.69
Granular 'B' Type II	35°	21 kN/m <sup>3</sup>	0.27	0.43	3.69
Granular 'B' Type I or III	32°	21 kN/m <sup>3</sup>	0.31	0.47	3.25

## 6.7 Culvert Construction Considerations

### 6.7.1 Temporary Roadway Protection

Temporary excavations for the culvert replacement will extend through the existing embankment granular fill and into the native soils, which are comprised of very loose to very dense sand to sand and gravel deposit. All excavations must be carried out in accordance with Ontario Regulation 213, Ontario *Occupational Health and Safety Act* for Construction Projects (as amended). The granular fill and native soils are considered to be Type 3 soil above the groundwater table and Type 4 soil below the groundwater table. Temporary open-cut excavations in Type 3 soils should remain stable if side slopes are formed no steeper than 1H:1V. In Type 4 soils, the side slopes should be formed no steeper than 3H:1V.

It is anticipated that temporary support systems will be required along the highway to facilitate staging during construction of the replacement culvert. The temporary support systems could consist of either driven sheet-piling or soldier piles and lagging. Support to the system could be in the form of struts and wales and rakers or anchors. Although soldier piles could be driven to a suitable depth, it will be difficult to install the lagging below the groundwater level. Installation of sheet-piles for temporary shoring, however, could be impeded by the presence of wood and/or cobbles within the existing granular embankment fill and/or native subgrade soils as inferred to be present by coring and auger grinding in Boreholes KC-2 and KC-4. It is recommended that an NSSP be included in the contract documents to address obstructions; a sample NSSP is included in Appendix C.

If sheet piling is used, it may be necessary select a heavier sheet-pile section in attempt to drive through the obstruction or to excavate and replace the existing fill and/or native soils (where practical) in a series of narrow trenches of limited length to remove obstructions in the areas of the sheet pile installation. In general, the narrowest suitable excavator bucket should be used. The replacement fill could consist of excavated fill material or imported granular material such as OPSS.PROV 1010 Granular 'A' or Granular 'B' Type I, II or III provided that 100 per cent of the material passes the 75 mm size. Excavation and replacement fill placement should be carried out in the same day to avoid leaving any trench open overnight

Where required, temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems). Temporary excavation support systems should be designed to Performance Level 2 for any excavation adjacent to existing roadway. Design of the temporary support system should include an evaluation of base stability, soil squeezing stability and hydraulic uplift stability as defined in the Canadian Foundation Engineering Manual (CFEM 2006). The design of the temporary support





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systems, as may be required for the temporary staging, is the responsibility of the Contractor, and may be designed using the following parameters:

Soil Type	Unit Weight	Internal Angle of Friction	Coefficient of Earth Pressure		
	( $\gamma$ , kN/m <sup>3</sup> )	( $\phi$ , degrees)	Active, $K_a$	At Rest, $K_o$	Passive, $K_p$
<b>Existing Granular FILL</b> (Loose to Compact)	20	30	0.33	0.50	3.00
<b>Sand to Sand and Gravel</b> (Very Loose to Very Dense)	20	30	0.33	0.50	3.00

The earth pressure coefficients noted above are based on a horizontal surface adjacent to the excavation. If sloped surfaces are present, the coefficient of earth pressure should be adjusted accordingly.

### 6.7.2 Excavation and Replacement Fill Below Culvert

Prior to placement of any bedding/levelling material or granular backfill, all organic materials (including topsoil and mixed organic soil) and any disturbed granular soils, should be sub-excavated or re-compacted from below the plan limits of the proposed works.

The subgrade for the box culvert should be inspected following sub-excavation to ensure that all organics and other unsuitable materials have been removed, in accordance with OPSS 422 (Precast Reinforced Concrete Box Culverts). Following inspection, the sub-excavated area should be backfilled in a timely manner with granular material meeting the specification of OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type (I, II or III) that is placed and compacted in accordance with OPSS.PROV 501 (Compacting). For backfilling below the water level, if required, we recommend that only Granular B Type II be utilized.

### 6.7.3 Control of Groundwater and Surface Water

Temporary excavations along the culvert alignment will be required to remove the existing embankment fill, organic materials (where present) and a portion of the native soils to achieve the required excavation depth prior to placement of bedding/level pad, the actual culvert, backfill and roadway pavement structure.

As a result of the excavation, groundwater flow into the excavations can be expected due to the relatively permeable nature of the embankment fill and the native soils at this site. Based on the GA drawing provided by AECOM, we understand that a temporary sheet-pile cut-off wall is to be installed to direct the creek (surface water) flows towards a temporary bypass pipe to be located about 5 m to the south of the existing culvert.

For the construction to be carried out in dry conditions, a completely enclosed sheet-pile cofferdam would be required to control groundwater inflows from the adjacent granular embankment fill. Further, the sheet-pile cofferdam would need to be installed to a sufficient depth to mitigate groundwater inflows through the base of the





excavation. Given the potential obstructions (i.e. wood and/or cobbles) within the embankment fill and native soils at this site, it may be difficult to install sheet piles to a sufficient tip elevation to control groundwater. As an alternative to a fully enclosed cofferdam, the granular bedding/levelling pad and replacement box culvert may be placed in wet conditions, within an unwatered excavation to the extent practicable, behind a sheet-pile cut-off wall.

Dewatering of all excavations (if required) should be carried out in accordance with OPSS.PROV 517 (Dewatering). Consideration should be given to include an NSSP in the contract to alert the Contractor to the unwatering issues at this site; a sample NSSP is included in Appendix C.

Provided the creek water flow is diverted during construction, it is anticipated that under the recently introduced changes to the *Environmental Protection Act* by the Ontario Ministry of the Environment and Climate Change, an Environmental Activity Section Registry (EASR) for construction dewatering will not be required.

#### **6.7.4 Culvert Bedding**

Based on discussions with AECOM, we understand that a Non-Standard Special Provision (NSSP) for the construction of a Precast Concrete Box/Open Footings Culvert has been developed, which includes requirements for excavation, bedding, backfilling and cover, as well as requirements for the structural components of the precast culvert. This NSSP, of copy of which is included in Appendix C, is generally consistent with the excavation, bedding, backfilling and cover requirements outlined in OPSS 422 (Precast Reinforced Concrete Box Culverts).

The bedding/levelling pad and granular backfill requirements for a pre-cast box culvert should be accordance with the NSSP for a Precast Concrete Box/Open Footing Culvert modifying OPSS 422. Given the potential for surface water flow and some groundwater seepage through the embankment fill and native soils during excavation to the invert and bedding level, it is recommended that a minimum 150 mm thick layer of OPSS.PROV 1010 (Aggregates) Granular 'B' Type II material be used for bedding and sub-excavation backfilling purposes. Given the potential presence of groundwater/surface water, we do not recommend that Granular B Type I or III, nor any materials from the Group II list in OPSS 422, be used for bedding purposes.

Granular 'B' Type II fill should be placed in maximum 200 mm thick loose lifts utilizing the construction equipment such as tamping with the excavator and/or passes of the bulldozer. In addition, a 75 mm thick uncompacted levelling pad consisting of OPSS.PROV 1010 (Aggregates) Granular 'A' or concrete fine aggregate meeting the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be provided similar to that presented on OPSD 803.010 (Backfill and Cover for Concrete Culverts). For placement of the levelling pad below water, a tremie concrete work slab may be used in lieu of the Granular 'A' or concrete fine aggregate. The working slab should be a minimum of 100 mm thick with a minimum 28 day compressive strength of 20 MPa.

Based on discussions with AECOM, we understand that OPSS.PROV 1004 (Aggregate - Miscellaneous) clear stone has been previously used as bedding material in lieu of Granular 'B' Type II on similar MTO Northeast Region projects for replacement box culverts constructed in wet conditions. Although not recommended from a foundations perspective, we understand that this approach has been accepted by the MTO and the culvert/pavement performance has been satisfactory based on MTOs experience.





Clear stone is a poorly graded material with a fairly high void content in comparison to a OPSS 1010 Granular 'A' or Granular 'B' Type II material and as such there is potential for the adjacent embankment fill and the underlying subgrade soil to migrate and infill the voids, potentially resulting in post-construction settlement (total and/or differential) of the culvert and/or the pavement structure. Based on discussions with AECOM, we understand that a non-woven geotextile has typically been placed between the clear stone bedding and the underlying native soil and/or adjacent embankment fill to mitigate the risk of loose of fines from the adjacent fill/soils and potential occurrence of post-construction settlement. However, depending on the groundwater conditions at the time of the construction and the temporary dewatering strategy adopted by the Contractor, proper placement of the geotextile (in wet conditions) may be difficult at this site. Further, given the course/uniform gradation of the clear stone bedding and angular nature of the gravel size particles within the native subgrade and embankment fill, there is a risk that the geotextile will be punctured or ripped during placement/compaction of the bedding layer.

Given the gravelly sand gradation/composition of the embankment fill and the sand to sand and gravel subgrade soils (as encountered in Boreholes KC-1 to KC-4), clear stone is considered suitable for bedding material at this site provided that the risk associated with the potential loss of fines from the adjacent soils into the clear stone bedding is considered acceptable by the MTO. To minimize the potential for loss of fines into the clear stone bedding, the thickness of the bedding layer should be restricted to a maximum of 300 mm. If a greater thickness of bedding/backfill is required, Granular 'B' Type II should be used.

The clear stone bedding should be placed in maximum 200 mm thick loose lifts utilizing the construction equipment such as tamping with the excavator and/or passes of the bulldozer. Given the poorly graded nature of the material, the clear stone bedding will be prone to loosening as a result of construction traffic. Where loosened bedding material is noted, additional regrading will be required prior to placing the replacement box culvert segments.

Based on discussions with AECOM, we also understand that clear stone may also be used for the levelling course. Provided the nominal maximum aggregate size is less than 26.5 mm, clear stone is considered to be suitable for use as a levelling pad between the bedding layer and the replacement box culvert segments.

Inspection of the subgrade and placed bedding should be carried out by qualified geotechnical personnel during all engineered fill placement operations to ensure that appropriate materials are used and that adequate levels of compaction by the construction equipment have been achieved.

#### **6.7.5 Backfill**

Backfill above/behind the culvert walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular 'A' or Granular 'B' Type I, II or III. The use of Granular 'B' Type II is recommended in wet ground conditions or below water.

The granular backfill should be placed in maximum 200 mm thick loose lifts and be compacted to at least 98 per cent of the SPMDD of the materials in accordance with OPSS.PROV 501 (Compacting). The fill should also be placed concurrently on both sides of the culvert, ensuring that the backfill depth on one side does not exceed the other side by more than 500 mm as per the NSSP (Precast Concrete Box/Open Footing Culvert).

As the existing granular embankment fill material, which is considered to have a relatively low susceptibility to frost heaving (based on MTO Pavement Design and Rehabilitation Manual, 2013), extends below the estimated





2.3 m depth of frost penetration, a frost taper (similar to the configuration as outlined in OPSD 803.010) is not necessary at this site.

Backfill placement for reconstruction of the roadway embankments along and over the culvert should be carried out as per OPSD 208.010 (Benching of Earth Slopes) to integrate the existing embankment fill and new fill along the cut faces.

Inspection and field density testing should be carried out by qualified geotechnical personnel during all engineered fill placement operations to ensure that appropriate materials are used and that adequate levels of compaction have been achieved.

### **6.7.6 Erosion Protection**

Provision should be made for scour and erosion protection at the box culvert location. To prevent surface water from flowing either beneath the box culvert (potentially causing undermining and scouring) or around the culvert (creating seepage through the embankment fill and potentially causing erosion and loss of fine soil particles), a concrete cut-off wall and/or clay seal should be provided at the upstream and downstream ends of the box culvert.

Based on the GA drawing provided by AECOM, we understand that a concrete cut-off wall will be used to mitigate undermining and/or scour below the proposed replacement box culvert. If a clay seal alternative is used to mitigate surface water flow under and along the culvert, the clay material should meet the requirements of OPSS.PROV 1205 (Clay Seal) and the seal should be a minimum of 1 m, thick if constructed of natural clay or soil bentonite mix. The clay seal should extend from a depth of 1 m below the scour level to a minimum vertical height equivalent to the high water level. A clay seal or blanket should also extend a minimum horizontal distance equal to the frost penetration depth on either side of the culvert inlet opening and on the embankment side slopes up to the higher water level and be covered with a 0.3 m thick layer of granular fill and the requisite slope erosion protection material (i.e. rip rap). Similarly, if a geosynthetic clay liner (GCL) is utilized in lieu of the clay seal, a 0.3 m thick layer of granular (embankment) fill cover should be placed over the GCL to provide for protection from the requisite overlying erosion protection material.

The requirements for and design of erosion protection measures for the inlet and outlet of the culvert should be assessed by the hydraulics design engineer. As a minimum, rip-rap treatment for the outlet of the culvert should be consistent with the standard presented in OPSD 810.010 (Rip-Rap Treatment). Erosion protection for the inlet of the culvert should also follow the standard presented in OPSD 810.010 (Rip-Rap Treatment) similar to the outlet but with the rip rap placed up to the toe of slope level, in combination with the cut-off measures noted above. Similarly, rip rap should be provided over the full extent of the clay sea/blanket or GCL.

### **6.7.7 Obstructions**

The contractor should be alerted to the presence of wood fragments encountered within the embankment fill in Borehole KC-3 as well as the potential for cobbles as inferred to be present based on instances of auger grinding in Boreholes KC-2, KC-3 and KC-4 and split-spoon refusal in Borehole KC-2.





The contractor should also be alerted to the presence of cobbles within the native soils as encountered (cored) in Borehole KC-4 and as inferred from auger grinding in Boreholes KC-1 to KC-4 and split-spoon refusal in Borehole KC-4. A sample NSSP is included in Appendix C.

### **6.7.8 Analytical Testing for Construction Materials**

The results of an analytical test carried out on a soil sample from Borehole KC-4 is presented in Table B1 in Appendix B. The suite of parameters tested is intended to allow the design engineer to assess the requirements for the appropriate type of cement to be used in construction and the need for corrosion protection of steel reinforcing elements.

For potential sulphate attack on concrete, the results of the soil analysis were compared to Table 3 in CSA A23-1-09, and indicate that the relative degree of sulphate attack is low (less than the moderate range). However, given that the culvert is located on Highway 144 and will be exposed to de-icing salts it is recommended that C-1 class exposure concrete be considered for the pre-cast culvert units. Further, the resistivity results indicate that the soil has a very low degree of corrosiveness potential based on the Transportation Research Board Guidelines (Transportation Research Board, National Research Council, 1998 as referenced in the MTO Gravity Pipe Design Guidelines, 2014).

It should be noted that the creek water levels in the area are subject to seasonal fluctuations and variations due to precipitation events and the water and/or soil chemistry could also be variable. These recommendations are provided as guidance only; the structural designer should take the results of the laboratory testing and the potential for corrosion into consideration when selecting materials for culvert construction.

## **7.0 CLOSURE**

This Detail Foundation Design Report was prepared by Mr. Adam Core, P.Eng., and the technical aspects were reviewed by Mr. David Muldowney, P.Eng., Mr. Jorge M. A. Costa, P.Eng., a Senior Consultant with and Designated MTO Foundations Contact for Golder, conducted an independent quality control review of this report.





## DETAIL FOUNDATION REPORT KENETOGAMI CREEK CULVERT - SITE NO. 46-417/C

### Report Signature Page

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## REFERENCES

Canadian Foundation Engineering Manual 2006, 4<sup>th</sup> Edition, Canadian Geotechnical Society.

Canadian Standards Association (CSA), 2014. Canadian Highway Bridge Design Code and Commentary on CAN/CSA S6-14.

Canadian Standards Association (CSA), 2014. CSA A23.1-09 Concrete Materials and Methods of Construction (R2014)

Occupational Health and Safety Act and Regulation for Construction Projects, O. Reg 213 (as amended).

Ministry of Northern Development of Mines. Bedrock Geology of Ontario – East Central Sheet, Ontario Geological Survey – Map 2543.

Ministry of Transportation, MTO Gravity Pipe Design Guidelines, MTO Drainage and Hydrology Design and Contract Standards Office, May 2014

Ministry of Transportation, MTO Pavement Design and Rehabilitation Manual, MTO Materials Engineering and Research Office, Second Edition 2013.

Transportation Research Board, National Research Council, 1998. Service Life Drainage Pipe, National Cooperative Highway Research Program (NCHRP) Synthesis 254.

Northern Ontario Engineering Geology Terrain Study. Ontario Geological Society Electronic Mapping. Map 41PNW.

ASTM International:

ASTM D1586 Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils

Ontario Provincial Standard Specifications (OPSS)

OPSS 422 Construction Specification for Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut

OPSS 1860 Material Specification for Geotextiles

Ontario Provincial Standard Specifications (OPSS) – Provincial Oriented

OPSS.PROV 501 Construction Specification for Compacting

OPSS.PROV 517 Construction Specification for Dewatering

OPSS.PROV 539 Construction Specification for Temporary Protection Systems

OPSS.PROV 1002 Material Specification for Aggregates – Concrete

OPSS.PROV 1004 Material Specification for Aggregates – Miscellaneous

OPSS.PROV 1010 Material Specification for Aggregates – Base, Subbase, Select Subgrade and Backfill Material

OPSS.PROV 1205 Material Specification for Clay Seal

Ontario Provincial Standard Drawings (OPSD)

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## DETAIL FOUNDATION REPORT KENETOGAMI CREEK CULVERT - SITE NO. 46-417/C

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OPSD 208.010	Benching of Earth Slopes
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal to 3.0 m
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.100	Foundation, Frost Penetration Depths for Northern Ontario
Ontario Water Resource Act:	
Regulation 903	Wells (as amended)





## DETAIL FOUNDATION REPORT KENETOGAMI CREEK CULVERT - SITE NO. 46-417/C

Table 1: Summary Details of Existing Culvert

Culvert Location	Site #	Approximate Height of Embankment <sup>1</sup> (m)	Existing Culvert			Approximate Existing Invert Elevation <sup>2</sup>	
			Type	Approximate Dimension <sup>2</sup>	Approximate Length	North End of Culvert	South End of Culvert
Hwy 144 STA 10+917	46-417/C	3.9	SPCSPA	4.4 m wide by 2.9 m high	26.2 m	355.2 m	355.2 m

- Notes:
1. Embankment height is relative to existing ground surface at the centreline of the roadway and the culvert invert.
  2. Culvert dimensions and invert elevations are based on the plan and profile drawings provided by AECOM (GA Kenetogami Cr Culvert.dwg).

Prepared by: AC  
Checked by: DAM  
Reviewed by: JMAC





## DETAIL FOUNDATION REPORT KENETOGAMI CREEK CULVERT - SITE NO. 46-417/C

**Table 2: Comparison of Alternative Culvert Types**

Option	Advantages	Disadvantages	Risks/Consequences
Box Culvert	<ul style="list-style-type: none"> <li>■ Minimizes depth of excavation, protection system and dewatering requirements compared to open footing option.</li> <li>■ Allows faster construction resulting in shorter duration for dewatering and surface water pumping.</li> <li>■ Backfill/bedding under the culvert may be placed in water or in wet conditions (i.e., Granular 'B' Type II) minimizing or reducing water pumping requirements.</li> <li>■ More tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site or if heave/settlement occurs resulting from freeze/thaw of the subgrade.</li> </ul>	<ul style="list-style-type: none"> <li>■ May not satisfy fisheries requirements related to natural channel substrate, if applicable.</li> <li>■ Cut-off wall (or clay seal) required at inlet end and potentially at the outlet end to mitigate potential scour under culvert.</li> <li>■ Transportation to and on-site lifting of large pre-cast sections will be required.</li> <li>■ May require water diversion of a relatively wide creek channel.</li> </ul>	<ul style="list-style-type: none"> <li>■ Low risk related to settlement performance as box segments can accommodate some total and differential settlement.</li> <li>■ Low risk of disturbance of the native sand to sand and gravel deposit during construction; can be mitigated with use of a Granular B Type II working pad (if required).</li> </ul>
Open Footing Culvert	<ul style="list-style-type: none"> <li>■ Would likely satisfy fisheries requirements related to natural channel substrate, if applicable.</li> <li>■ Readily suitable for construction using concrete or metal sections.</li> <li>■ May be feasible to construct the culvert on pre-cast footing sections to accelerate construction schedule and reduce time for dewatering/unwatering (pumping) of surface water.</li> </ul>	<ul style="list-style-type: none"> <li>■ Excavation depths are greater than for a box culvert option, resulting in increased excavation support and dewatering requirements and additional spoil material to be disposed off-site.</li> <li>■ Will require a fully enclosed sheet-pile cofferdam to allow for construction in the dry.</li> <li>■ Constructing footings in the dry will take longer due to requirements for installation of a groundwater and surface water control system, dewatering and surface water pumping and excavation in a confined space.</li> <li>■ Less tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site or if heave/settlement occurs resulting from freeze/thaw of the subgrade.</li> <li>■ Arch sections supported on concrete strip footings may not allow for adequate soil cover to be placed including roadway pavement structure.</li> </ul>	<ul style="list-style-type: none"> <li>■ Moderate to high risk that sheet piles may be impeded by obstructions, such as cobbles and possible boulders as encountered in Borehole KC-4.</li> <li>■ Moderate to high risk that sheet piles will not be advanced to sufficient depth to allow for footing construction in the dry; can be mitigated with the use of pre-cast footings for construction in wet conditions or through the use of a tremie concrete plug although such construction could be onerous.</li> <li>■ Culvert joints may be required to accommodate total and differential settlement.</li> <li>■ Moderate risk of disturbance of the native sand to sand and gravel deposit if the sheet-piles cofferdam is not advanced to a sufficient depth during construction; can be mitigated with use of a tremie concrete plug (if required).</li> </ul>

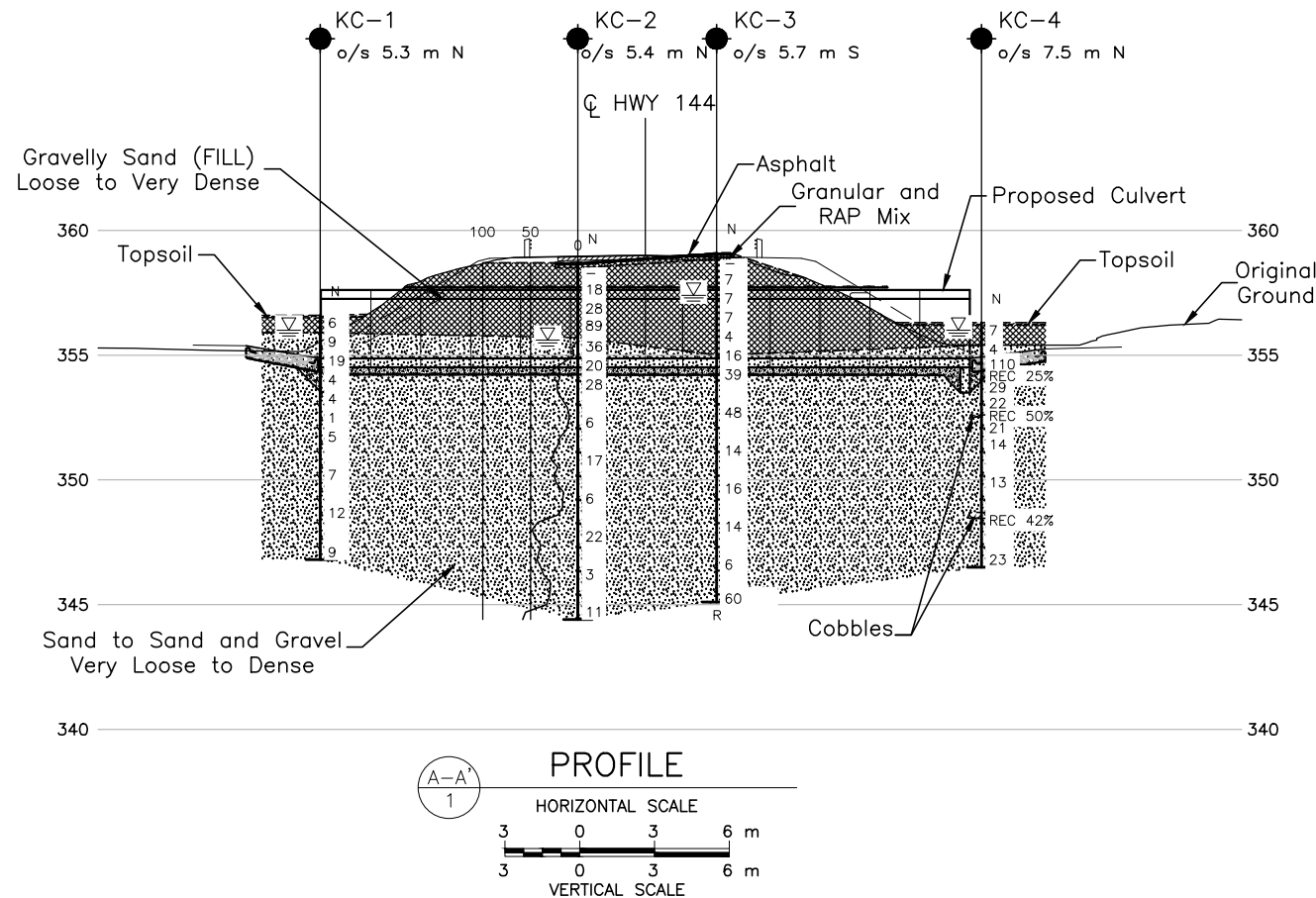
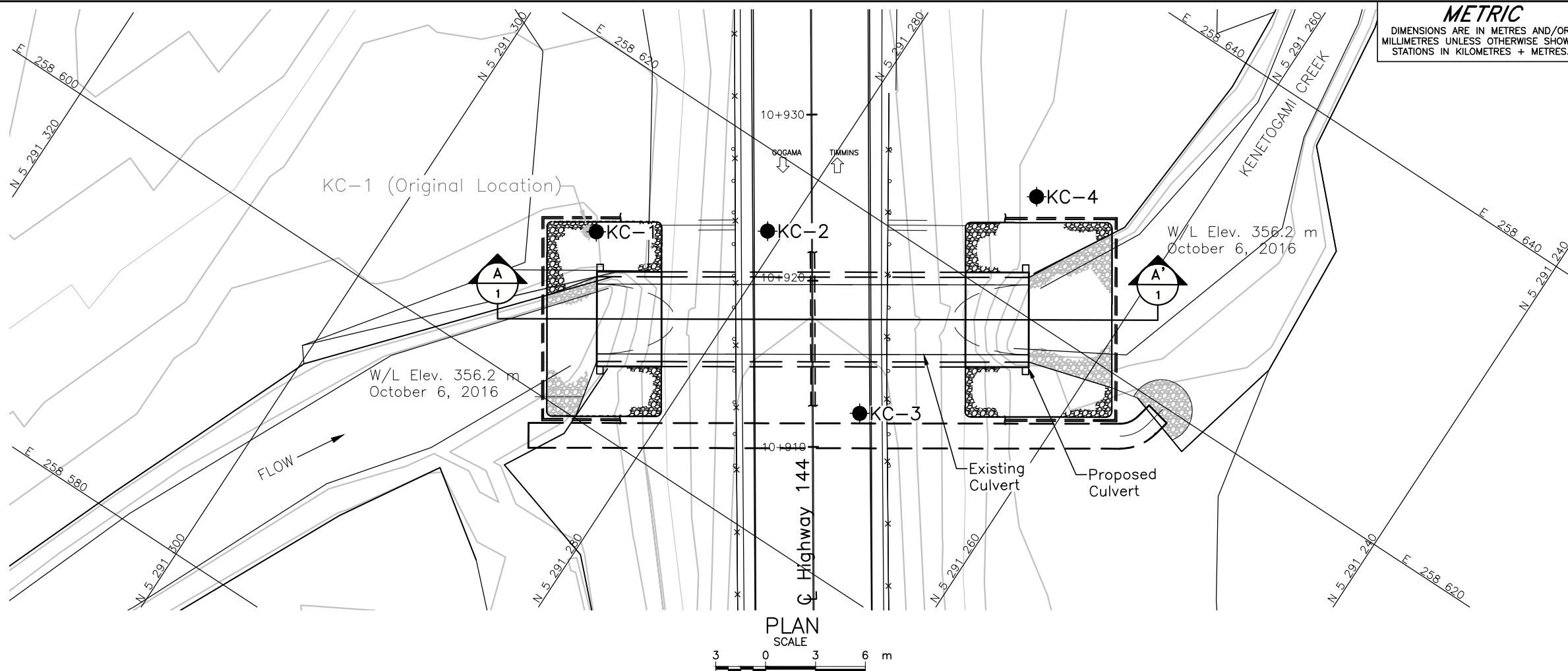




**DETAIL FOUNDATION REPORT**  
**KENETOGAMI CREEK CULVERT - SITE NO. 46-417/C**

Option	Advantages	Disadvantages	Risks/Consequences
Pipe Culvert(s)	<ul style="list-style-type: none"><li>■ Allows for faster construction resulting in shorter duration for dewatering and surface pumping compared to an open footing culvert.</li><li>■ More tolerant of total and differential settlement if the highway embankment is raised or widened at the culvert site or if heave/settlement occurs resulting from freeze/thaw of the subgrade.</li><li>■ Backfill/bedding under the culvert may be placed in water or in wet conditions (i.e., Granular 'B' Type II) minimizing or reducing water pumping requirements.</li></ul>	<ul style="list-style-type: none"><li>■ Reduced flow-through capacity compared to box culvert and open footing options with a similar span – additional flow through capacity may have to be provided by multiple pipes.</li><li>■ Cut-off wall or clay seal may be required at inlet to mitigate potential scour under culvert(s).</li><li>■ Difficult to shape and compact backfill materials to level of culvert springline, particularly if carried out underwater.</li><li>■ CSP does not have as long of design life compared to concrete options.</li></ul>	<ul style="list-style-type: none"><li>■ Low risk related to anticipated differential settlement compared to open footing option.</li><li>■ Low risk of disturbance of the native sand to sand and gravel deposit during construction; can be mitigated with use of a tremie concrete working slab or Granular B Type II working pad (if required).</li></ul>

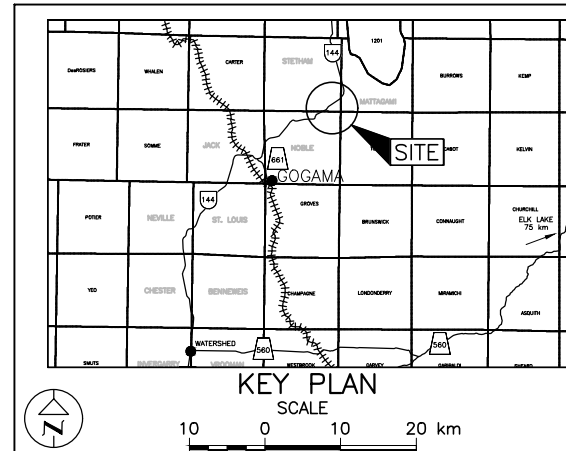




**METRIC**  
DIMENSIONS ARE IN METRES AND/OR  
MILLIMETRES UNLESS OTHERWISE SHOWN.  
STATIONS IN KILOMETRES + METRES.

CONT No. WP No. 5384-11-01

**HIGHWAY 144**  
KENETOGAMI CREEK CULVERT STA 10+917  
**BOREHOLE LOCATIONS AND SOIL STRATA**



LEGEND	
	Borehole - Current Investigation
N	Standard Penetration Test Value
16	Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
	WL upon completion of drilling
R	Refusal

BOREHOLE CO-ORDINATES			
No.	ELEVATION	NORTHING	EASTING
KC-1	356.6	5291289.5	258610.1
KC-2	358.7	5291280.9	258615.8
KC-3	359.1	5291270.2	258609.6
KC-4	356.3	5291268.5	258626.4

**NOTES**

This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

**REFERENCE**

Base plan provided in digital format by AECOM, drawing file no. b0351144001.dwg, received NOV 25, 2016 and GA Kenetogami Cr Culvert.dwg, received DEC 15, 2016.



NO.	DATE	BY	REVISION
Geocres No. 41P-70			
HWY. 144	PROJECT NO. 1655149		DIST. .
SUBM'D.	CHKD. AC	DATE: 2/28/2017	SITE: 46-417/C
DRAWN: TB	CHKD. DAM	APPD. JMAC	DWG. 1





## PHOTOGRAPHS

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**Photograph 1: Kenetogami Creek Culvert  
Looking West at Inlet (October 2016)**



**Photograph 2: Kenetogami Creek Culvert  
Looking Northwest at Outlet (October 2016)**







## PHOTOGRAPHS

**Photograph 3: Kenetogami Creek Culvert  
Looking South towards Culvert (August 2015)**



**Photograph 4: Kenetogami Creek Culvert  
Looking North from Culvert (August 2015)**







# **APPENDIX A**

## **Record of Boreholes**





## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

### I. GENERAL

$\pi$	3.1416
$\ln x$ ,	natural logarithm of x
$\log_{10}$	x or log x, logarithm of x to base 10
g	acceleration due to gravity
t	time
FoS	factor of safety

### II. STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\varepsilon$	linear strain
$\varepsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stress (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

### III. SOIL PROPERTIES

<b>(a)</b>	<b>Index Properties</b>
$\rho(\gamma)$	bulk density (bulk unit weight)*
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
e	void ratio
n	porosity
S	degree of saturation

### (a) Index Properties (continued)

w	water content
$w_l$ or LL	liquid limit
$w_p$ or PL	plastic limit
$I_p$ or PI	plasticity index = $(w_l - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index = $(w - w_p) / I_p$
$I_C$	consistency index = $(w_l - w) / I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

### (b) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

### (c) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (over-consolidated range)
$C_s$	swelling index
$C_\alpha$	secondary compression index
$m_v$	coefficient of volume change
$C_v$	coefficient of consolidation (vertical direction)
$C_h$	coefficient of consolidation (horizontal direction)
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation stress
OCR	over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$

### (d) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	coefficient of friction = $\tan \delta$
$c'$	effective cohesion
$c_u, s_u$	undrained shear strength ( $\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
$p'$	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
$q_u$	compressive strength $(\sigma_1 - \sigma_3)$
$S_t$	sensitivity

\* Density symbol is  $\rho$ . Unit weight symbol is  $\gamma$  where  $\gamma = \rho g$  (i.e. mass density multiplied by acceleration due to gravity)

Notes: 1  
2

$$\tau = c' + \sigma' \tan \phi'$$

$$\text{shear strength} = (\text{compressive strength})/2$$





## LIST OF ABBREVIATIONS

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

### I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
SS	Split-spoon
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

### II. PENETRATION RESISTANCE

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

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

#### Dynamic Cone Penetration Resistance (DCPT); $N_d$ :

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

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ( $Q_t$ ), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

### III. SOIL DESCRIPTION

#### (a) Non-Cohesive (Cohesionless) Soils

Density Index	N
Relative Density	Blows/300 mm or Blows/ft
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils Consistency

	$c_u, s_u$	
	kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

### IV. SOIL TESTS

w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	relative density (specific gravity, $G_s$ )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO <sub>4</sub>	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
$\gamma$	unit weight

**Note:** 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

### V. MINOR SOIL CONSTITUENTS

Per cent by Weight	Modifier	Example
0 to 5	Trace	Trace sand
5 to 12	Trace to Some (or Little)	Trace to some sand
12 to 20	Some	Some sand
20 to 30	(ey) or (y)	Sandy
over 30	And (non-cohesive (cohesionless)) or With (cohesive)	Sand and Gravel Silty Clay with sand / Clayey Silt with sand



<b>PROJECT</b> 1655149		<b>RECORD OF BOREHOLE No KC-1</b>		1 OF 1 <b>METRIC</b>	
<b>G.W.P.</b> 5384-11-00		<b>LOCATION</b> N 5291289.5; E 258610.1 (LAT. 47.7590311; LONG. -81.6161565)		<b>ORIGINATED BY</b> TB	
<b>DIST</b> _____ <b>HWY</b> 144		<b>BOREHOLE TYPE</b> 108 mm I.D. Hollow Stem Augers (Auto Hammer)		<b>COMPILED BY</b> AC	
<b>DATUM</b> GEODETIC		<b>DATE</b> October 3, 2016		<b>CHECKED BY</b> DAM	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)				
								20 40 60 80 100					W <sub>p</sub> W W <sub>L</sub>				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED									
356.6	GROUND SURFACE						356										
0.0	TOPSOIL		1	SS	6												
0.1	Gravelly sand (FILL) Loose Brown Moist																
355.9	SAND to SAND and GRAVEL, trace to some silt Very loose to compact Brown to grey Moist to wet		2	SS	9												
0.7																	
			3	SS	19												33 60 (7)
	Approximately 0.1 m to 1.2 m of heave within augers below 2.3 m depth.		4	SS	4												
			5	SS	4												
	Sandy silt seams between 3.0 m and 3.7 m depth.		6	SS	1											2 79 (19)	
			7	SS	5												
			8	SS	7											12 76 (12)	
			9	SS	12												
			10	SS	9												
346.8	END OF BOREHOLE																
9.8	Note:  1. Water level at a depth of 0.6 m below ground surface (Elev. 356.0 m) upon completion of drilling.  2. Auger refusal encountered at 0.6 m depth. Advanced new borehole 0.3 m east of Borehole KC-1. No sampling in the upper 0.6 m.																

SUD-MTO 001 LAT/LONG 1655149.GPJ GAL-MISS.GDT 22/02/17 DATA INPUT:



PROJECT 1655149			<b>RECORD OF BOREHOLE No KC-2</b>			1 OF 2 <b>METRIC</b>		
G.W.P. 5384-11-00			LOCATION N 5291280.9; E 258615.8 (LAT. 47.7589542; LONG. -81.6160798)			ORIGINATED BY TB		
DIST _____ HWY 144			BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers (Auto Hammer)			COMPILED BY AC		
DATUM GEODETIC			DATE October 4, 2016			CHECKED BY DAM		
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100 20 40 60 80 100 PLASTIC LIMIT W <sub>p</sub> NATURAL MOISTURE CONTENT W LIQUID LIMIT W <sub>L</sub> WATER CONTENT (%) 20 40 60
358.7	GROUND SURFACE							
0.0	ASPHALT (~80 mm)							
0.2	Granular and RAP Mix (~120 mm)							
	Gravelly sand, trace silt (FILL) Compact to very dense Brown Moist to wet  Augers grinding below 1.5 m depth.		1	AS	-		358	
			2	SS	18			
			3	SS	28		357	
			4	SS	89			
	Split-spoon refusal (ie. hammer bouncing) at 2.7 m depth.						356	
355.7								
3.0	SAND to SAND and GRAVEL, trace silt Very loose to dense Grey Wet  Trace organics in Sample 5.  Augers grinding from 3.0 m to 3.8 m and 6.1 m to 7.6 m depth.  Approximately 0.2 m to 0.5 m of heave encountered between 4.6 m and 7.6 m depth.		5	SS	36		355	
			6	SS	20			
			7	SS	28		354	
			8	SS	6		353	
							352	
			9	SS	17		351	
			10	SS	6		350	
							349	
			11	SS	22		348	
							347	

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

SUD-MTO 001 LAT/LONG 1655149.GPJ GAL-MISS.GDT 22/02/17 DATA INPUT:



PROJECT 1655149		<b>RECORD OF BOREHOLE No KC-2</b>				2 OF 2 <b>METRIC</b>												
G.W.P. 5384-11-00		LOCATION N 5291280.9; E 258615.8 (LAT. 47.7589542; LONG. -81.6160798)				ORIGINATED BY TB												
DIST _____ HWY 144		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers (Auto Hammer)				COMPILED BY AC												
DATUM GEODETIC		DATE October 4, 2016				CHECKED BY DAM												
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa										
	--- CONTINUED FROM PREVIOUS PAGE ---						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100					WATER CONTENT (%) 20 40 60						
344.4	SAND to SAND and GRAVEL, trace silt Very loose to dense Grey Wet  A silty sand zone was encountered at 12.2 m depth.		12	SS	3												0 79 (21)	
14.3																		
14.3	END OF BOREHOLE AND DYNAMIC CONE PENETRATION TEST Notes:  1. Water level at a depth of 3.1 m below ground surface (Elev. 355.6 m) upon completion of drilling.  2. Advanced DCPT 2.0 m south of Borehole KC-2.																	

SUD-MTO 001 LAT/LONG 1655149.GPJ GAL-MISS.GDT 22/02/17 DATA INPUT:



PROJECT 1655149			<b>RECORD OF BOREHOLE No KC-3</b>				1 OF 2 <b>METRIC</b>							
G.W.P. 5384-11-00		LOCATION N 5291270.2; E 258609.6 (LAT. 47.7588579; LONG. -81.6161606)				ORIGINATED BY TB								
DIST _____ HWY 144		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers (Auto Hammer)				COMPILED BY AC								
DATUM GEODETIC		DATE October 5 and 6, 2016				CHECKED BY DAM								
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
359.1	GROUND SURFACE							20 40 60 80 100	20 40 60					
0.0	ASPHALT (~80 mm)						359							
0.3	Granular and RAP Mix (~170 mm)		1	AS	-									
	Gravelly sand, trace to some silt (FILL) Loose Brown Moist to wet		2	SS	7		358							
	Trace asphalt in Sample 3.		3	SS	7		357							
	Augers grinding below 1.5 m depth.		4	SS	7		356			○				27 68 (5)
			5	SS	4		355			○				
	Trace wood encountered at 4.0 m depth.		A	SS	16		355							
355.0			B	SS	16		354			○				48 44 (8)
4.1	Gravelly SAND to SAND and GRAVEL, trace to some silt Compact to very dense Grey Wet		7	SS	39		353							
	Trace organics in Sample 6B.		8	SS	48		352							
	Augers grinding from 4.1 m to 6.1 m and 9.1 m to 10.7 m depth.		9	SS	14		351			○				21 71 (8)
			10	SS	16		350							
			11	SS	14		349							
	Approximately 0.1 m of heave encountered at 10.7 m depth.						348			○				30 65 (5)

SUD-MTO 001 LAT/LONG 1655149.GPJ GAL-MISS.GDT 22/02/17 DATA INPUT:

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE



PROJECT 1655149		<b>RECORD OF BOREHOLE No KC-3</b>				2 OF 2 <b>METRIC</b>												
G.W.P. 5384-11-00		LOCATION N 5291270.2; E 258609.6 (LAT. 47.7588579; LONG. -81.6161606)				ORIGINATED BY TB												
DIST _____ HWY 144		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers (Auto Hammer)				COMPILED BY AC												
DATUM GEODETIC		DATE October 5 and 6, 2016				CHECKED BY DAM												
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)					
	--- CONTINUED FROM PREVIOUS PAGE ---						<div style="display: flex; justify-content: space-between;"> <span>20 40 60 80 100</span> <span>20 40 60 80 100</span> </div> <div style="display: flex; justify-content: space-between;"> <span>○ UNCONFINED + FIELD VANE</span> <span>● QUICK TRIAXIAL × REMOULDED</span> </div>					<div style="display: flex; justify-content: space-between;"> <span>W<sub>p</sub></span> <span>W</span> <span>W<sub>L</sub></span> </div>						
345.1	Gravelly SAND to SAND and GRAVEL, trace to some silt Compact to very dense Grey Wet  Augers grinding below 13.7 m depth.		12	SS	6													
14.0	END OF BOREHOLE SPLIT-SPOON REFUSAL (ie. Spoon Bouncing)  Note:  1. Water level at a depth of 1.7 m below ground surface (Elev. 357.4 m) upon completion of drilling.		13	SS	60													

SUD-MTO 001 LATILONG 1655149.GPJ GAL-MISS.GDT 22/02/17 DATA INPUT:



PROJECT 1655149		<b>RECORD OF BOREHOLE No KC-4</b>				1 OF 1 <b>METRIC</b>											
G.W.P. 5384-11-00		LOCATION N 5291268.5; E 258626.4 (LAT. 47.7588433; LONG. -81.6159371)				ORIGINATED BY TB											
DIST _____ HWY 144		BOREHOLE TYPE 108 mm I.D. Hollow Stem Augers, NW Casing and NQ Coring				COMPILED BY AC											
DATUM GEODETIC		DATE October 6, 2016				CHECKED BY DAM											
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
356.3	GROUND SURFACE							20	40	60	80	100					
0.0	TOPSOIL																
0.1	Gravelly sand, trace silt (FILL) Loose Brown Moist		1	SS	7	▽	356										
355.4	Augers grinding throughout. SAND to SAND and GRAVEL, trace to some silt Loose to very dense Brow to grey Wet		2	SS	4		355										
0.9			3	SS	110												
	Switched to NW casing at 1.5 m depth. Switched to NQ coring at 1.8 m depth. Recovered coarse gravel up to 65 mm diameter during coring.		4	RC	REC 25%		354										
			5	SS	29												
			6	SS	22		353										
	Switched to NQ coring at 3.7 m depth. A 75 mm diameter cobble recovered during coring.		7	RC	REC 50%												
			8	SS	21		352										
			9	SS	14												
							351										
			10	SS	13		350										
							349										
	Split-spoon refusal (i.e. spoon bouncing) at 7.6 m depth. Switched to NQ coring. A 250 mm diameter cobble recovered during coring.		11	RC	REC 42%		348										
			12	SS	23		347										
346.5	END OF BOREHOLE																
9.8	Note:  1. Water level at a depth of 0.3 m below ground surface (Elev. 356.0 m) upon completion of drilling.																

SUD-MTO 001 LATILONG 1655149.GPJ GAL-MISS.GDT 22/02/17 DATA INPUT:





# **APPENDIX B**

## **Laboratory Test Results**





## DETAIL FOUNDATION REPORT KENETOGAMI CREEK CULVERT - SITE NO. 46-417/C

**Table B1: Summary of Analytical Testing of Kenetogami Creek Soil Sample**

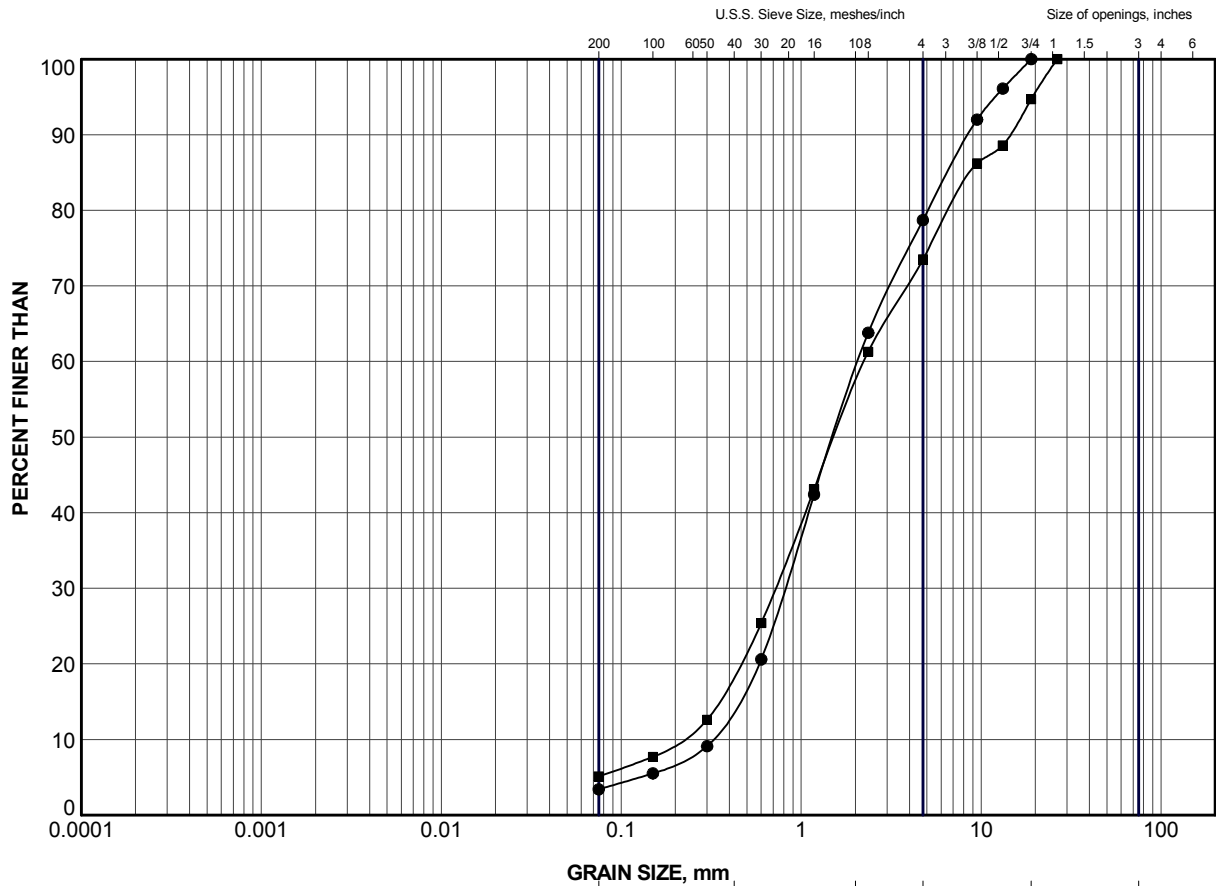
Parameter	Units	Result
Chloride (CL)	µg/g	22
Sulphate (SO <sub>4</sub> )	µg/g	ND
Conductivity (EC)	umho/cm	92
Resistivity	ohm-cm	11,000
pH	n/a	5.47

Notes:

1. Borehole KC-4, Sample 2 obtained on October 5, 2016.
2. Analytical testing carried out by Maxxam Analytics
3. ND = Not Detected

Prepared by: AC  
Checked by: DAM  
Reviewed by: JMAC





CLAY AND SILT	fine	medium	coarse	fine	coarse	Cobble Size
	SAND SIZE			GRAVEL SIZE		

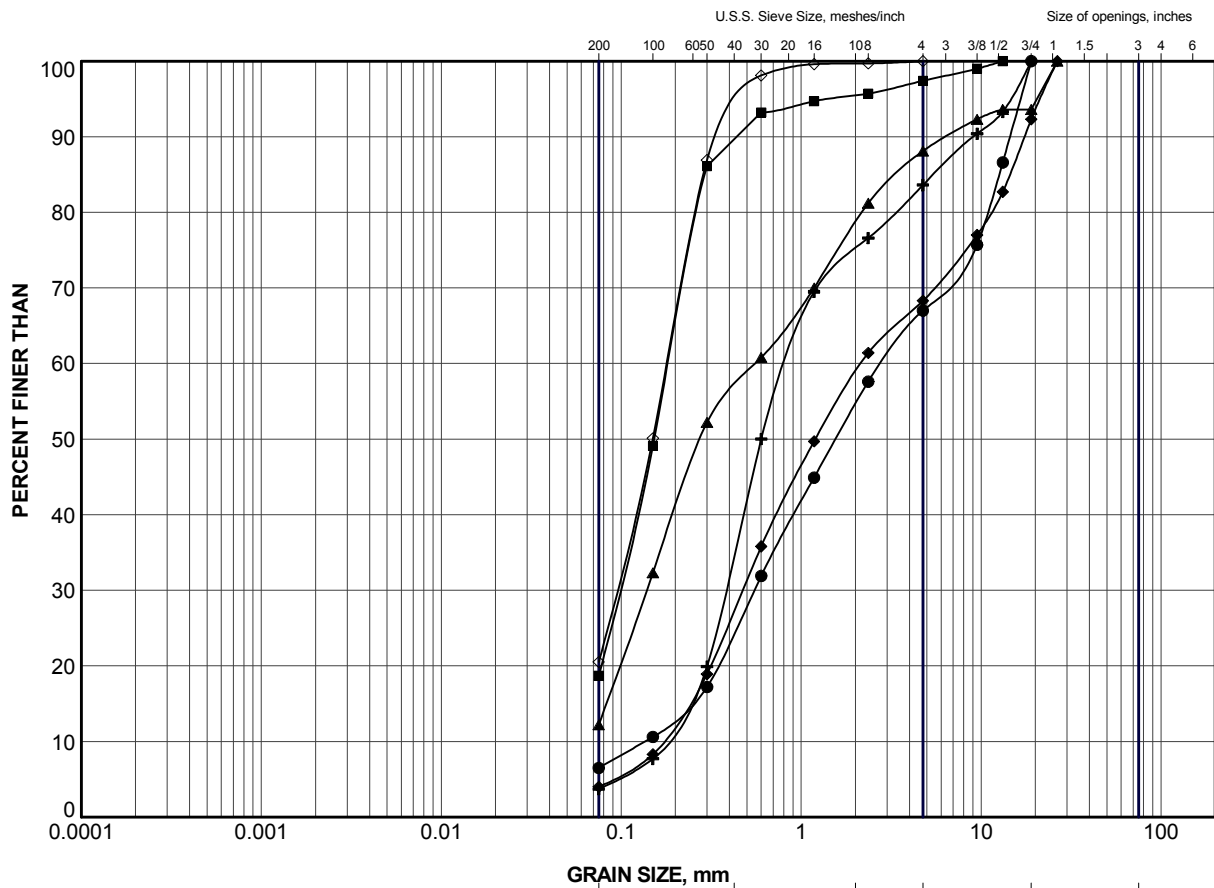
### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	KC-2	2	357.6
■	KC-3	4	356.5

PROJECT					
HIGHWAY 144 KENETOGAMI CREEK CULVERT REPLACEMENT					
TITLE					
GRAIN SIZE DISTRIBUTION GRAVELLY SAND (FILL)					
PROJECT No.		1655149		FILE No. 1655149.GPJ	
DRAWN	TB	Nov 2016	SCALE	N/A	REV.
CHECK	AC	Nov 2016	FIGURE B1		
APPR	DAM	Nov 2016			






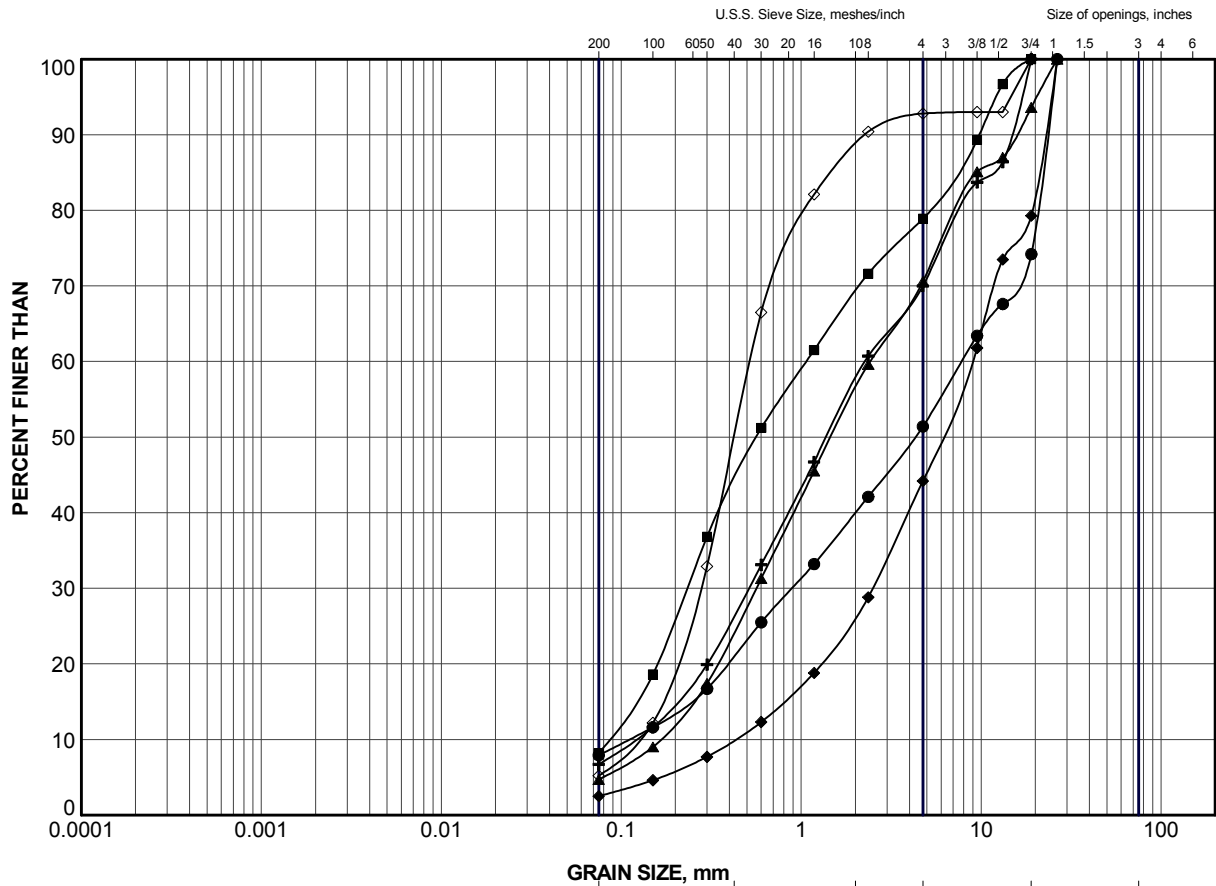


### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	KC-1	3	354.8
■	KC-1	6	352.5
▲	KC-1	8	350.2
+	KC-2	6	354.6
◆	KC-2	8	352.3
◇	KC-2	12	346.2

PROJECT					
HIGHWAY 144 KENETOGAMI CREEK CULVERT REPLACEMENT					
TITLE					
GRAIN SIZE DISTRIBUTION SAND to SAND and GRAVEL					
PROJECT No.		1655149		FILE No. 1655149.GPJ	
DRAWN	TB	Nov 2016	SCALE	N/A	REV.
CHECK	AC	Nov 2016			
APPR	DAM	Nov 2016			
 <b>Golder Associates</b> SUDBURY, ONTARIO			<b>FIGURE B2.1</b>		





CLAY AND SILT	GRAVEL SIZE, mm					Cobble Size
	fine	medium	coarse	fine	coarse	
	SAND SIZE			GRAVEL SIZE		

#### LEGEND

SYMBOL	BOREHOLE	SAMPLE	ELEV (m)
●	KC-3	7	354.2
■	KC-3	9	351.2
▲	KC-3	11	348.1
+	KC-4	3	354.6
◆	KC-4	8	352.2
◇	KC-4	12	346.8

PROJECT

HIGHWAY 144  
KENETOGAMI CREEK CULVERT REPLACEMENT

TITLE

## GRAIN SIZE DISTRIBUTION

SAND to SAND and GRAVEL



**Golder Associates**  
SUDBURY, ONTARIO

PROJECT No.		1655149	FILE No.		1655149.GPJ
DRAWN	TB	Dec 2016	SCALE	N/A	REV.
CHECK	AC	Dec 2016	<b>FIGURE B2.2</b>		
APPR	DAM	Dec 2016			





# **APPENDIX C**

## **Non Standard Special Provisions**



**“SIZE” PRECAST CONCRETE “INSERT THE SHAPE BOX/OPEN FOOTING” CULVERT – Item No.**

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Special Provision

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<b>1.0</b>	<b>SCOPE</b>
<b>2.0</b>	<b>REFERENCES</b>
<b>3.0</b>	<b>DEFINITIONS</b>
<b>4.0</b>	<b>DESIGN AND SUBMISSION REQUIREMENTS</b>
<b>5.0</b>	<b>MATERIALS</b>
<b>6.0</b>	<b>EQUIPMENT</b>
<b>7.0</b>	<b>PRODUCTION</b>
<b>8.0</b>	<b>QUALITY ASSURANCE</b>
<b>9.0</b>	<b>MEASUREMENT FOR PAYMENT - Not Used</b>
<b>10.0</b>	<b>BASIS OF PAYMENT</b>

**1.0 SCOPE**

This specification covers the requirements for the installation of precast reinforced concrete “**insert shape Box/Open Footing**” culverts and associated precast concrete appurtenances in open cut, and includes the requirements for excavation, bedding, backfilling, and cover material. The requirements include certification of production facilities, production, storage, transportation, and installation of the precast elements.

**2.0 REFERENCES**

This specification refers to the following standards specifications or publications:

**Ontario Provincial Standard Specifications, General**

OPSS 180 Management and Disposal of Excess Material

**Ontario Provincial Standard Specifications, Construction**

OPSS 209	Embankments Over Swamps
OPSS 404	Support Systems
OPSS 501	Compacting
OPSS 517	Dewatering of Pipeline, Utility and Associated Structure Excavation



OPSS 539	Temporary Protection Systems
OPSS 902	Excavating and Backfilling - Structures
OPSS 904	Concrete Structures
OPSS 905	Steel Reinforcement for Concrete
OPSS 914	Waterproofing Bridge Decks with Hot Applied Asphalt Membrane
OPSS 929	Abrasive Blast Cleaning – Concrete Construction
OPSS 930	Construction Specification for Structure Rehabilitation – Concrete Patches, Refacing and Overlays
OPSS 932	Crack Repair – Concrete

### **Ontario Provincial Standard Specifications, Materials**

OPSS 1002	Aggregates - Concrete
OPSS 1004	Aggregates - Miscellaneous
OPSS 1010	Aggregates - Base, Subbase, Select Subgrade, and Backfill Material
OPSS 1205	Clay Seal
OPSS 1213	Hot Applied Rubberized Asphalt Waterproofing Membrane
OPSS 1215	Protection Board
OPSS 1301	Cementing Materials
OPSS 1302	Water
OPSS 1350	Concrete - Materials and Production
OPSS 1440	Steel Reinforcement for Concrete
OPSS 1860	Geotextiles

### **Ontario Ministry of Transportation Publications:**

Structural Manual  
Specification for Self-Consolidating Concrete in Precast Products

Laboratory Testing Manual:

LS-706	Moisture - Density Relationship of Soils Using 2.5 kg Rammer and a 305 mm Drop
LS-432	Method of Test for Microscopical Determination of Air Void System Parameters in Hardened Concrete
LS-433	Method of Test for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration

### **CSA Standards**

A23.2-14C	Obtaining and Testing Drilled Cores for Compressive Strength Testing* *[Part of A23.1-09/A23.2-09 - Concrete Materials and Methods of Concrete Construction/Methods of Test and Standard Practices for Concrete]
A23.4-09	Precast Concrete Material and Construction
S6-06	Canadian Highway Bridge Design Code
W47.1-09	Certification of Companies for Fusion Welding of Steel Structures
W59-03 (R2008)	Welded Steel Construction (Metal Arc Welding)
W186-90 (R2007)	Welding of Reinforcing Bars in Reinforced Concrete Construction

### **ASTM International**

A153 - 09	Zinc Coating (Hot-Dip) on Iron and Steel Hardware
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B633 - 07	Electrodeposited Coatings of Zinc on Iron and Steel
C171 - 07	Sheet Materials for Curing Concrete
C403 - 08	Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
D 2487-00	Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D 2488-00	Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)
D 2922-01	Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
D 3017-01	Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)
D 75-94	Standard Practice for Random Sampling of Construction Material
D 3665-94	Standard Practice for Sampling Aggregates

### **American Association of State Highway and Transportation Officials (AASHTO)**

M 182 - 05	Standard Specification for Burlap Cloth made from Jute or Kenaf and Cotton Mats
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## **3.0 DEFINITIONS**

For the purpose of this specification, the following definitions apply:

**Backfill** means earth, rock, or granular material used as fill within the excavation placed beyond the limits of bedding and cover below the subgrade elevation, including frost tapers.

**Bed** means the assembly consisting of platform, forms and end blocks in which the elements are cast.

**Bedding** means the material used to support the bottom of the box unit.

**Box Culvert** means a culvert constructed of precast reinforced concrete box units rectangular in cross-section.

**Box Unit** means a single precast reinforced concrete box unit of a box culvert or box sewer.

**Cold Weather** means those conditions when the air temperature is at or below 5 °C. It is also considered to exist when the air temperature is at or is likely to fall below 5 °C within 96 hours after concrete placement. Temperature refers to shade temperature.

**Concrete Appurtenances** means head walls, cut-off walls, aprons, collars, and any other concrete fixtures associated with the box culverts and box sewers, excluding concrete bedding or concrete structures covered elsewhere in the Contract Documents and specified as such.

**Cover** means the material placed as a protective layer around the box unit to prevent damage to the box unit.

**Element Type** means an element defined by function and cross-sectional shape.

**Engineer** means a professional engineer licensed by the Professional Engineers Ontario to practice in the Province of Ontario.

**Excavation, Earth and Rock** means the excavation material classified as earth and rock according to OPSS 902.



**Excavation, Swamp** means swamp excavation as defined in OPSS 209.

**Geotechnical Engineer** means a professional engineer licensed by the Professional Engineers of Ontario to practice in the Province of Ontario who is responsible for the work related to earth and rock, including site investigation, foundation recommendations, inspection, and quality control with respect to the design and installation of box culverts and sewers.

**Honeycombing** means a rough and stony concrete surface with voids where the mortar did not fill the spaces between the coarse aggregate particles.

**Lot** consists of all of the same element types, of the same mix design produced over seven consecutive Days.

**Low Permeability Concrete** means concrete typically containing silica fume and having rapid chloride permeability of 1000 coulombs or less when tested according to LS-433.

**Native Material** means the original material removed to form an excavation and which is acceptable to the Contract Administrator for return to the same or other excavation as backfill or cover.

**Precaster** means the producer of the precast concrete elements.

**Precast Element** means an individual precast section of the prefabricated structure. For the purposes of this specification, precast elements do not include precast girders but may include precast footings, columns, shafts, abutments, ballast walls, wingwalls, pier caps, box culverts, cut-off walls, and bridge deck elements. "Precast element" is used interchangeably with "element".

**Regular Permeability Concrete** means concrete typically containing no silica fume and having rapid chloride permeability of 2500 coulombs or less when tested according to LS-433.

**Segregation** means visible separation of the mortar and coarse aggregate particles in the concrete, resulting in concrete that is not uniform in appearance or proportions.

**Soil** means soil as defined in OPSS 902.

**Steel Reinforcement** means a general term which includes reinforcing steel bars, stainless steel reinforcing bars, splice bars, welded steel wire fabric and prestressing tendons.

## **4.0 DESIGN AND SUBMISSION REQUIREMENTS**

### **4.01 Design Requirements**

#### **4.01.01 General**

The design shall be according to CAN/CSA S6 and the Structural Manual where design is required.

### **4.02 Submission Requirements**

#### **4.02.01 Working Drawings**

Working Drawings shall include shop drawings and drawings for handling and installation of the elements



The Contractor shall prepare and submit 3 sets of Working Drawings and all supporting documentation, to the Contract Administrator at least 5 Business Days prior to commencement of fabrication of the elements, for information purposes only. Prior to making a submission, the design Engineer and the design-checking Engineer shall affix their seals and signatures on the Working Drawings verifying that the drawings are consistent with the Contract Documents.

The Working Drawings shall include the following information:

- a) Element details.
- b) Steel reinforcement schedules.
- c) Lifting point locations.
- d) Details and location of all temporary supports.
- e) All other applicable details.

The supporting documents shall include the following information:

- a) Handling and installation procedures including calculations and lifting point locations.
- b) Details of bracing installed to provide adequate support and stability to the element during construction.

When other authorities are involved in the approval of the design or construction of a highway structure, submissions shall be made at least 5 weeks prior to commencement of work and one additional copy of the submission shall be provided for each authority. The requirements, as stated elsewhere in the Contract Documents of each authority and the Owner shall be satisfied prior to commencement of the Work.

#### **4.02.02 Concrete Mix Design**

The Contractor shall submit the concrete mix design to the Contract Administrator according to the Mix Design requirements of OPSS 1350.

When self consolidated concrete (SCC) is proposed to be used by the Contractor, and its use accepted by the Ministry, the requirements for submission shall be according to the Specification for Self-Consolidated Concrete in Precast Products available from the Ministry's Materials Engineering and Research Office.

##### **4.02.02.01 Concrete Plant Certification**

The precast concrete plant certificate verifying compliance with the certification requirements specified in the Production Facility subsection shall be submitted to the Contract Administrator with the concrete mix design.

Documentation verifying certification of the concrete production facility by the Ready-Mixed Concrete Association of Ontario shall be submitted when concrete is supplied by an external concrete supplier.

#### **4.02.03 Product Report**

A product report shall be submitted to the Contract Administrator for each shipment of elements, prior to shipping the elements.



The report shall contain the following information:

- a) List of elements including their ID number and description.
- b) Documentation of defects or deficiencies other than those listed in Table 1, and all related repair proposals.

The following documentation shall be made available upon request:

- a) The mill certificates for the steel reinforcement used in the elements.
- b) Temperature control records including location of thermocouple wires.
- c) Copies of all measurements and inspections carried out by the Contractor to verify compliance with this specification, including the concrete cover over steel reinforcement , crack measurement summary, tolerances, and surveys for geometric control.
- d) Documentation verifying that all repairable defects have been identified, evaluated and corrected as detailed elsewhere in the specification.

## **5.0 MATERIALS**

### **5.01 Concrete**

Concrete materials and production shall be according to OPSS 1350 with the following exceptions and amendments:

- a) Rapid chloride permeability shall meet the requirements found in Table 2 for each specified precast element listed.

**TABLE 2**  
**Rapid Chloride Permeability (RCP) Requirements**

Precast Element	Low Permeability Concrete (RCP $\leq$ 1000 Coulombs) Yes/No	Regular Permeability Concrete (RCP $\leq$ 2500 Coulombs) Yes/No
Precast Culvert(s) and Appurtenance(s)	Yes/No	Yes/No

Designer is to select the RCP requirements in consultation with what Industry is currently capable of producing. This table cannot be deleted or left blank.

- b) The air void system in hardened concrete when tested according to LS-432 shall be:
  - i. Air Content: 3.0% minimum
  - ii. Spacing Factor: 0.200 mm maximum
- c) Aggregates shall be according to OPSS 1002 with the exception that the maximum nominal size of coarse aggregate shall not exceed 19.0 mm.
- d) Slag aggregate shall not be used.
- e) Superplasticizer may be added to the mix at time of batching for all types of concrete.



- f) After the addition of superplasticizer the slump shall not exceed a maximum of 230mm.
- g) Self consolidated concrete will be considered subject to the Ministry's approval. The Contractor's proposal shall be consistent with the Specification for Self-Consolidating Concrete in Precast Products.

#### **5.02 Concrete Sealers**

Concrete sealers shall be from the Owner's list of acceptable sealers. The list of concrete sealers shall be obtained from the Contract Administrator.

#### **5.03 Elastomeric Coating**

Elastomeric coating shall be according to OPSS 1213

#### **5.04 Forms**

All forms shall be according to CAN/CSA A23.4. Forms shall be fabricated to meet the dimensional tolerances and finishes required by this specification.

#### **5.05 Hardware**

All hardware shall be non-corroding or galvanized according to ASTM A153.

Surfaces of hardware located within 40 mm of the concrete surface shall be chromate coated over an electro-deposited coating of zinc according to ASTM B633.

#### **5.06 Materials for Moist Curing**

Burlap cloth and cotton mats for wet curing shall be according to AASHTO M 182. When burlap is used, it shall be Class 4.

#### **5.07 Proprietary Patching Materials**

Proprietary patching materials shall be from the Owner's list of acceptable concrete patching materials. The list of proprietary patching materials shall be obtained from the Contract Administrator.

#### **5.08 Steel Reinforcement**

Steel reinforcement shall be according to OPSS 905, and OPSS 1440.

#### **5.09 Granulars**

Granulars shall be according to OPSS 1010.

#### **5.10 Fine Aggregates for Levelling Course**

Fine aggregate for levelling courses shall be according to OPSS 1002.

#### **5.11 Clay Seal**



Clay seal shall be according to OPSS 1205.

**5.12 Steel Reinforcement**

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

**5.13 Mortar**

Mortar for joints shall be according to OPSS 904. The normal Portland cement shall be according to OPSS 1301, mortar sand shall be according to OPSS 1004, and water shall be according to OPSS 1302.

**5.14 Protection Board**

Protection board shall be according to OPSS 914, and OPSS 1215.

**5.15 Preformed Gasket**

Preformed gaskets shall be as specified by the precaster.

**5.16 Joint Sealing Compound**

Joint sealing compound shall be as specified by the precaster.

**5.17 Grout**

Grout shall be non-shrink and non-staining.

**5.18 Geotextile**

Geotextile type shall be as specified in the Contract Documents and according to OPSS 1860.

**5.19 Native Material**

Native material shall be classified according to the Unified Soil Classification System using the procedures prescribed in ASTM D 2488. When precise classification of native material is required, ASTM D 2487 shall be used.

**5.20 Bedding**

Bedding shall be as specified in the Contract Documents. The maximum particle size for bedding shall not exceed 25 mm in diameter, unless the bedding layer has a thickness of 150 mm or greater, in which case the maximum particle size shall not exceed 38 mm in diameter.

**5.21 Backfill**

Backfill shall be according to OPSS 902.

**5.22 Cover**

Unless otherwise specified, cover material shall be earth or granular and free from stones exceeding 75 mm and frozen material.



**5.23                                      Waterproofing – see Designer notes at end of this NSSP**

Self adhesive waterproofing membrane sheet shall be as specified by the precaster.

**6.0                                        EQUIPMENT**

**6.01                                      Chipping Hammers**

Chipping hammers shall have a maximum weight of 9.0 kg and a maximum piston stroke of 102 mm. All hammers shall have the manufacturer's name and model number engraved on them by the manufacturer. All information must be legible.

**6.02                                      Thermocouples and Dataloggers**

Thermocouples and associated instrumentation shall have an accuracy of  $\pm 1.5$  °C and shall be capable of recording and displaying the temperature. The instrumentation shall include dataloggers with a minimum recording frequency of 30 minutes or less and shall be capable of storing all data for the temperature monitoring period.

**7.0                                        CONSTRUCTION**

**7.01                                      General**

The work shall consist of fabrication, curing, storage, transportation and installation of precast elements and associated concrete appurtenances.

Fabrication shall include the installation of the site numbers and date figures in each end of the culvert. The site and date numbers will be supplied by MTO.

The Contractor shall notify the Contract Administrator in writing at least 5 Business Days prior to commencement of fabrication.

The Contractor shall be responsible for all quality control inspection and testing to ensure that the precast concrete elements are fabricated to meet the requirements of this specification and the Contract Documents.

**7.02                                      Precast Concrete Elements**

**7.02.01                                  General**

Precast elements of the same type and for a given component shall be fabricated from the same mix design regardless of whether or not they are cast in the same facility.

**7.02.02                                  Element Identification**

Each precast element shall be identified with a tamper-resistant, permanently-affixed means of identification which includes a unique identification number, date of casting and location of the production facility.



### **7.02.03 Dimensional Tolerances**

All elements shall meet the dimensional tolerance requirements of CSA 23.4 unless otherwise specified in the Contract Documents. For dimensional tolerances not specified, the maximum allowable dimensional variation shall be 1:800 or  $\pm 5$  mm, whichever is greater.

### **7.02.04 Concrete Cover**

All elements shall meet the cover requirements of the Contract Documents.

### **7.02.05 Surface Tolerance**

Formed and unformed surfaces shall be such that, when tested with a 3 m long straight edge placed anywhere in any direction on the surface, there shall be no gap greater than 6 mm between the bottom of the straight edge and the surface of the concrete. When the straight edge is placed across a closure strip the gap between the straight edge and the surface of the concrete shall not be greater than 6 mm.

### **7.03 Production Facility**

The precast elements shall be fabricated in a facility that is certified to the requirements of:

- a) Canadian Standards Association (CSA A23.4) under the category Precast Concrete Products-Structural, Non-Prestressed and Prestressed, or
- b) Canadian Precast/Prestressed Concrete Institute (CPCI), Group B, Bridge Products and Group BA, Bridge Products with Architectural Finishes, Category, B1, or BA1, Precast Concrete Bridge Products

### **7.04 Welding**

Welding of steel hardware including shear studs shall be according to the Contract Documents and CSA W59. Welding shall be performed by a qualified welder working for a company certified by the Canadian Welding Bureau according to CSA W47.1.

Welding of steel reinforcement shall be according to the Contract Documents and to CSA W186. Welding shall be performed by a qualified welder working for a company certified by the Canadian Welding Bureau according to CSA W186.

### **7.05 Steel Reinforcement**

The placement of reinforcement shall be according to OPSS 905.

### **7.06 Placing Concrete**

The placing and consolidation of concrete shall be according to OPSS 904 with the exception that the temperature of the formwork, steel reinforcement or the material on which the concrete is to be placed shall be at a minimum temperature of 5 °C immediately prior to the placing operation.



## **7.07 Sampling and Testing of Plastic Concrete**

### **7.07.01 Testing**

Sampling and testing of slump, air content and temperature of plastic concrete shall be carried out by a person holding either of the following certifications:

- a) CCIL Certified Concrete Testing Technician; or
- b) ACI Concrete Field Testing Technician – Grade 1

This person shall have a valid, original card issued by the certifying agency in his or her possession at all times.

### **7.07.02 Frequency**

The Contractor shall be responsible for all aspects of sampling and testing of the plastic concrete for slump, air content and temperature according to OPSS 1350 and the results of these tests shall be recorded. The minimum frequency of testing shall be at least once for each load of concrete delivered by a truck mixer, or once for every batch of concrete produced by other mixers, until satisfactory control is established.

Satisfactory control is established when three consecutive tests of concrete are within the specified requirements without adjustments. If any adjustments are required, testing shall continue until three consecutive tests meet the requirements with no field adjustments.

After satisfactory control has been established, testing shall be carried out on every third load delivered by a truck mixer, or at a delivery frequency of 21 m<sup>3</sup> of concrete for concrete produced by other mixers.

Satisfactory control shall be re-established each day or when there is a break in production longer than 1 hour.

## **7.08 Concrete Finishing**

Concrete finishing shall be according to OPSS 904 with the exception that the use of a bridge deck finishing machine is not required.

## **7.09 Curing and Protection**

### **7.09.01 Curing-General**

Concrete elements shall be moist cured for 96 hours. Concrete elements containing silica fume shall be moist cured for 7 Days.

During the moist curing period, elements may be exposed to ambient conditions for no more than a cumulative total of 3 hours for the purposes of form removal, filling of bug holes, inspection, and storage.

### **7.09.02 Moist Curing**

Moist curing of exposed surfaces shall commence immediately after concrete placement using one of the following methods:

- a) Saturated material for moist curing;



- b) Water misting;
- c) Steam; or
- d) Other means of maintaining 100% relative humidity next to the concrete surface.

Forms shall be removed from bridge deck elements within 24 hours of concrete placement and all surfaces previously covered by forms shall be immediately moist cured as above for the remainder of the 96 hours.

Other formed surfaces shall require no additional curing where the formwork is left in place for the minimum specified curing period. Where the formwork is removed before the curing period is completed, formed surfaces shall be cured with moist curing material for the remainder of the minimum curing period

Application of heat may be used to accelerate curing, but raising the ambient temperature above 30 °C shall not be allowed until after concrete has reached initial set. The Contractor shall determine the time of initial set of the concrete according to ASTM C403, using the same mix design, placement method, concrete temperature and curing procedures as the elements.

Steam, heat or forced air shall not be directed on the concrete, forms or steel reinforcement. There shall be free circulation of steam, heat and forced air around the top, sides and ends of the elements. The elements shall be heated evenly.

Concrete surfaces shall not be exposed to combustion gases.

#### **7.09.03 Protection Period**

After moist curing, elements that will be exposed to air temperatures less than 5 °C shall be protected from moisture loss for a minimum of 3 days, prior to full exposure. The protection period shall be extended beyond 3 days if required to meet the requirements specified in the Control of Temperature subsection.

All elements must be dry before exposing them to air temperature below 0 °C.

#### **7.10 Control of Temperature**

During production, moist curing, and protection periods, the following temperature requirements shall be met:

- a) The concrete temperature shall not exceed 60 °C.
- b) The concrete temperature shall not fall below 10 °C before the end of moist curing.
- c) The concrete temperature shall not fall below 0 °C before the end of the protection period
- d) The temperature difference between the concrete temperature of the element, and the conditions to which it is to be exposed, shall not exceed 20 °C in any part of the element.

##### **7.10.01 Temperature Records**

Thermocouples, dataloggers, handhelds units, and associated hardware shall be used to monitor the temperature of the element and the ambient conditions to which the element is exposed.



Recording of the concrete temperatures shall begin at the start of the placing operation and continue until the moist curing and protection period are complete. For each element, the following temperatures shall be recorded at intervals of 30 minutes or less.

A sufficient number of thermocouples and thermocouple wires for each element type shall be installed to ensure compliance with the standard. As a minimum, thermocouples shall be installed to measure:

- a) Air temperature that the element is exposed, or will be exposed, to.
- b) Concrete temperatures located centrally within the element and the section thickness.

The Contract Administrator shall be provided the necessary access, instrumentation and equipment to verify temperature readings instantaneously. The thermocouples and dataloggers shall be left in place until the end of the curing and protection period.

#### **7.11 Access for Concrete Cover Measurement**

The Contractor shall clear all debris and obstructions and provide unhindered access to allow the Contract Administrator to carry out the concrete covermeter survey as specified in the Concrete Cover subsection of the Quality Assurance section. The Contractor shall notify the Contract Administrator in writing when the test area is ready for the concrete covermeter survey.

The Contractor shall allow the Contract Administrator a time period of 3 Business Days to complete the survey. This time period shall commence upon receipt of the Contractor's written notification of readiness for the survey. The time period required to complete the concrete survey shall be extended if inclement weather or the ambient air temperatures below 5 °C fall within that time period.

#### **7.12 Storage, Transportation, and Installation**

Storage, transportation, and installation shall be according to CSA 23.4.

Storage includes, but is not limited to, storage while awaiting delivery, in temporary locations, or at the job site.

The Contractor shall notify the Contract Administrator in writing at least 3 Days prior to delivery of the elements.

Advertising by means of removable signing is permitted on elements only while in transit to the specified site. Any other markings on a surface that would be visible after installation shall not be permitted.

The Contractor shall notify the Contract Administrator in writing of the installation date at least 3 Days prior to the commencement of field installation operations.

Pockets such as those that facilitate cutting of temporary strands for shipping and handling shall be reinstated with a proprietary patching material.

The Contractor shall inspect the elements for defects before installation.



#### **7.12.01                      Excavation**

The excavation for the installation of the box units shall be according to OPSS 902, including frost tapers and culvert end treatments.

Sideway stability shall be maintained throughout the excavation and box unit installation. Soil cave-in into the excavation hole shall be prevented.

#### **7.12.02                      Support Systems**

Support systems shall be according to OPSS 404.

#### **7.12.03                      Dewatering**

Dewatering shall be according to OPSS 517 and as outlined elsewhere in the Contract Documents.

#### **7.12.04                      Temporary Protection Systems**

Temporary protection systems shall be according to OPSS 539.

#### **7.12.05                      Foundations**

The box units shall be founded on competent in situ soil or compacted backfill, or as specified in the Contract Documents.

When unsuitable material is encountered during excavation for the box units' foundation, the unsuitable material shall be removed to competent stratum and replaced to the foundation grade with compacted Granular B, Type II.

The final founding elevations shall be as specified in the Contract Documents or an elevation approved in writing by the Contract Administrator.

#### **7.12.06                      Bedding**

Bedding shall be placed to the dimensions shown in the Contract Documents.

The bedding shall be placed as uniformly as possible. Bedding under the middle third of the box unit base shall be loosely placed and uncompacted. Bedding requiring compaction shall be placed in layers not exceeding 200 mm in thickness, loose measurement, and each layer shall be compacted according to OPSS 501.

Bedding shall not be placed on frozen earth grade.

#### **7.12.07                      Levelling**

The surface prepared to support the box units shall have a 75 mm minimum thickness top levelling course of uncompacted Granular A or fine aggregates.

#### **7.12.08                      Waterproofing**



Waterproofing and protection board shall be applied to the top surface of the top slab of all structural concrete culverts with fill heights less than or equal to 1000 mm. The waterproofing and protection board shall be continuous down the vertical exterior wall faces to a depth of 300 mm from the top surface of the top slab. In the longitudinal direction of the culvert, the waterproofing shall extend 1000 mm beyond the extent of the granular fill.

At precast culvert section joints, a 600 mm strip of waterproofing and protection board shall extend from top to bottom of culvert on the outside faces of the culvert as shown on the Contract Documents.

The exterior face of the box culvert units to receive any of the waterproofing joint treatments noted above shall be abrasive blast cleaned to remove all contaminants and laitance in accordance with OPSS 929. Any spent abrasive, dust and debris shall be removed from the joint gap and surrounding concrete surfaces using compressed air prior to applying any sealant or waterproofing treatments.

Application of joint sealant (including backer rod material/size/installation, and depth and width of sealant for given gap dimension) shall be in accordance with the sealant manufacturer's recommendations. Waterproofing membrane protection materials shall be 6 mm thick (minimum) and shall be secured to the culvert as per the precaster's recommendations.

#### **7.12.09                      Installing Box Units**

##### **7.12.09.01                  Box Units**

Box units shall be installed to the alignment and grade specified in the Contract Documents.

Box units shall not be installed on bedding containing frozen material.

End units to accommodate concrete appurtenances shall be as specified in the Contract Documents. End units shall be 2.44 m in length; all other units shall be a minimum of 0.914 m in length.

All precast box unit joints shall be provided with articulated ends such as bell and spigot. The box units shall be installed to make a continuous line forming a box culvert or box sewer. The gap at the box unit joints shall not exceed 15 mm.

For box units placed in parallel for multiple cell installations, a 60 mm  $\pm$  10 mm gap filled with grout between adjacent cells shall be provided.

Installation of the box units shall commence at the outlet end and proceed in the upstream direction with the bell ends of the box units facing upgrade. The box units shall be placed with the base of each box unit in uniform contact with the prepared bedding throughout its full length. The ends of the box units shall be joined so there is no unevenness along the inside. The box units and joint surfaces shall be kept clean as work progresses. Water shall not be allowed to flow through the box units during installation. The excavation shall be kept dry and the box units shall not be installed in water.

##### **7.12.09.02                  Joint Cover**

The Contractor shall ensure that the joints are effectively covered to prevent influx of material from the backfill and/or native soil through the joints with a 600mm (minimum) wide coverage strip. Unless otherwise specified, material for the joint cover shall be geotextile.

The geotextile and the seam requirements at the joints shall be according to OPSS 1860.



#### **7.12.09.03 Mortared Joints**

When mortared joints are specified in the Contract Documents, all joints shall be thoroughly cleaned and wetted. Mortar shall then be applied over the joint around the inner and outer perimeter. After the mortar joint is complete the joint inside shall be wiped clean and smooth.

#### **7.12.09.04 Preformed Gasket**

When a preformed gasket is specified in the Contract Documents for sealing the joint between the box units, it shall be placed according to the precaster's recommendations.

#### **7.12.09.05 Joint Sealing Compound**

When joint sealing compound is specified in the Contract Documents for sealing the joint between the box units, it shall be applied according to the precaster's recommendations.

#### **7.12.09.06 Lift Holes**

All lift holes shall be filled with mortar after installation of the box unit.

#### **7.13 Concrete Appurtenances**

Concrete placement, sampling, and testing shall be according to OPSS 904. Reinforcing steel shall be placed according to OPSS 905. Steel grating shall be provided as specified in the Contract Documents.

#### **7.14 Backfill**

Backfill shall be placed in layers not exceeding 200 mm in thickness, loose measurement. Compaction shall be according to OPSS 501.

The Contractor shall be responsible for placing the backfill without any damage to or movement of the box culvert or box sewer.

Backfill on each side of the box units shall be completed simultaneously. At no time shall the levels on each side differ by more than a 500 mm.

When native material is specified as backfill in the Contract Documents, earth material may be substituted, when approved by the Contract Administrator. In areas within the roadway, for a depth equal to the frost treatment, earth backfill shall have frost susceptibility characteristics similar to the native material. The Contract Administrator shall decide on the suitability of the earth backfill that the Contractor proposes to substitute.

Rock may be used as backfill provided the installed box units are protected by a minimum thickness of cover material as specified in the Contract Documents.

Box unit installation and backfill shall be completed prior to the start of any subbase and base course construction over the box unit location.

Shoring and bracing shall be withdrawn and removed as the excavation is being backfilled.

#### **7.15 Cover**



Cover shall be placed in layers not exceeding 200 mm in thickness, loose measurement, and each layer shall be compacted according to OPSS 501.

Cover in trenches and in other locations where pavements require controlled differential settlement shall be of a type and compaction level to control pavement differential settlement within acceptable limits for the specified type of pavement.

The Contractor shall be responsible for placing the cover material without any damage to or movement of the box culvert or box sewer.

#### **7.16 Clay Seal**

When a clay seal is specified in the Contract Documents, the clay seal shall be placed to the dimensions specified in the Contract Documents and compacted to a minimum of 95% of the maximum dry density (MDD). The MDD shall be determined from LS-706, carried out on a single representative sample. Field density and field moisture determinations shall be made according to ASTM D 2922 and ASTM D 3017.

#### **7.17 Geotechnical Testing**

When specified in the Contract Documents, compliance of earth backfill material type and compaction with the requirements of this specification shall be verified by a Geotechnical Engineer approved by the Contract Administrator.

#### **7.18 Certificate of Conformance**

For each shipment of elements the Contractor shall issue the following Certificates of Conformance to the Contract Administrator:

- a) Certificate of Conformance verifying the elements have been fabricated in general conformance with the signed and sealed documents which include the Contract Documents, supporting documents, and Working Drawings.
- b) Certificate of Conformance verifying that storage and transportation were in general conformance with the signed and sealed documents which include the Contract Documents, supporting documents, and Working Drawings.

Within 5 Business Days of installing all the elements within a stage, the Contractor shall submit to the Contract Administrator a Certificate of Conformance verifying the installation of the elements has been carried out in general conformance with the signed and sealed documents which include the Contract Documents, supporting documents, and Working Drawings.

Each certificate shall identify the element or group of elements it addresses.

#### **7.19 Defects and Deficiencies Repairable by Standard Methods**

Any individual element having one or more defects and deficiencies identified in Table 1 shall be repaired according to the method specified. Such repairs do not require proposals or prior approval by the Owner. All causes, preventative actions, and correction actions including repairs, methods and materials used shall be documented and submitted to the Contract Administrator.



### **7.19.01 All Other Defects and Deficiencies**

For elements with defects or deficiencies not identified as rejectable or listed in Table 1 the Contractor shall submit a proposal for repair to the Contract Administrator for review. The Contract Administrator shall respond to the Contractor within 5 Business Days of receipt of the complete repair proposal.

The repair proposal, signed and sealed by an Engineer, shall include as a minimum:

- a) Description of the element and identification of the defects or deficiencies.
- b) Detailed sketches, width, length, depths, location and nature and frequency of any defects.
- c) Assessment of any impact of the repaired defect(s) on durability, structural adequacy and integrity of the element or on the structure.
- d) A detailed repair plan including materials, method and equipment to be used.
- e) Verification that the repair plan complies with the applicable standards for the type of work.
- f) All relevant supporting information, including material test results, field measurements and observations, production records, photographs, and structural analysis calculations, used for determining that the performance and function originally expected from the element shall be met.
- g) Cause(s) of the defect and corrective action to be taken to prevent recurrence of the defect in future production, delivery or installation.
- h) Justification for partial payment.

If the repair proposal is deemed acceptable by the Owner, the element(s) shall be repaired according to the proposal. The Contractor shall not carry out any repairs without the acceptance of the proposal by the Contract Administrator. If the repair proposal is deemed unacceptable by the Owner, the element(s) shall be rejected and shall not be incorporated into the work.

## **7.20 Sampling for Quality Assurance**

### **7.20.01 Sampling of Reinforcement**

The Contractor shall provide samples of steel reinforcement according to OPSS 905 when requested by the Owner. Samples shall be delivered by the Contractor to the Ministry (Head, Concrete Section, Building C, Room 15, 1201 Wilson Avenue, Downsview, Ontario, M3M 1J8).

### **7.20.02 Sampling of Hardened Concrete**

#### **7.20.02.01 General**

Precast concrete products shall be sampled on a lot basis for each element type.

The Contractor shall be responsible for removing cores from the precast elements for testing by the Owner.



#### **7.20.02.02 Notification**

The Contractor shall be responsible to notify the Contract Administrator within 24 hours of completion of a lot by providing the list of elements and their identification numbers

#### **7.20.02.03 Coring**

One set of cores shall be obtained from each lot for Quality Assurance testing as directed by the Contract Administrator. A set of cores shall consist of six 100 mm x 200 mm cores.

The Contract Administrator shall identify to the Contractor the specific element to be cored. All cores of the same set shall be removed at a location no more than 2 meters from the location of the first core for that set.

For each lot, coring shall be carried out according to CSA A23.2-14C when the concrete is between 4 to 14 days of age, and prior to application of any sealer and/or waterproofing membrane. No core shall be taken within 250 mm of any joint or element edge.

Cores shall not contain steel reinforcement or other embedded material.

#### **7.20.02.04 Identification of Cores**

The Contract number, lot number, element identification number and exact location of each individual core shall be marked legibly on the core with durable ink.

#### **7.20.02.05 Transportation of Cores**

The Contractor is responsible for transporting all cores in a safe manner to avoid damage to the cores. Each core shall be placed in a plastic bag, sealed to prevent loss of moisture. The cores shall be protected from extremes in temperature from the time they are removed until they are delivered to the Regional Quality Assurance laboratory. The cores shall be delivered to the Regional Quality Assurance laboratory designated by the Contract Administrator with a transmittal form and form PH-CC-433A of the concrete mix design for the element within 24 hours of coring.

#### **7.21 Filling of Core Holes**

The Contractor shall fill each core hole immediately after coring with a proprietary patching material from the Owner's pre-qualified products list or with concrete from the same mix design. The patching material shall be mixed, handled, and cured according to the manufacturer's instructions. Immediately before filling, the inside surface of each core hole shall be cleaned of the paste left from the coring operation by nylon brushing and all free water shall be removed. The patch shall be finished flush with the surface of the surrounding concrete. All excess material shall be removed from the surface of the concrete.

#### **7.22 Management and Disposal of Excess Material**

Management and disposal of excess material shall be according to OPSS 180.

### **8.0 QUALITY ASSURANCE**

#### **8.01 General**

Precast concrete products shall be accepted on a lot basis for each element type.



## **8.02 Acceptance of Concrete Compressive Strength**

Three cores shall be tested to determine the acceptability of compressive strength of the lot. Twenty-eight (28) day concrete compressive strength of a lot shall be considered acceptable when it meets all of the following:

- a) The average of three individual compressive strength tests shall be equal to or greater than the specified strength.
- b) No individual core test shall be more than 4.0 MPa below the specified strength.

Unacceptable lots shall be removed and replaced at the Contractor's expense.

Compressive strength shall be determined according to CSA A23.2-14C in a moist condition.

The compressive strength result of the lot shall be the average of one set of three acceptance cores rounded to one decimal place.

The individual test results shall be forwarded to the Contractor as they become available.

### **8.02.01 Referee Testing, Compressive Strength**

The Contractor may invoke referee testing of an individual test result within five business days of receiving the test result.

For referee testing, the Contractor shall obtain a new set of cores. A set of referee cores for compressive strength shall consist of three individual cores taken from the same element from which disputed acceptance samples originated. The new set shall be obtained within 5 business days of invoking referee testing.

The referee laboratory shall be designated by the Owner based on the applicable roster. Referee test results shall be forwarded to the Contractor as they become available.

If the difference between the referee test result and the acceptance test result is less than the confirmation value, then the acceptance test result is confirmed, and the acceptance test result shall be used in the determination of acceptance of the concrete. If the difference between the referee test result and the acceptance test result is greater than the confirmation value, the acceptance test result is not confirmed, and the acceptance test result shall be disregarded and replaced by referee test result in the determination of acceptance of the concrete.

The confirmation value for confirming the acceptance test result shall be the greater of 10% of the specified strength or 10% of the strength of the acceptance cores, expressed to one decimal place.

### **8.02.02 Referee Testing Cost, Compressive Strength**

The cost of referee testing of compressive strength shall be according to OPSS 1350.

## **8.03 Acceptance of Air Void System in Hardened Concrete**

One half of a core shall be tested to determine the acceptability of the lot. The core shall be tested according to LS-432. The other half of the core shall be retained by the Owner for audit purposes.



Individual test results shall be forwarded to the Contractor as they become available.

For a lot to be considered acceptable, the core shall have air content of 3.0% or more and spacing factor of 0.200 mm or less. Acceptable lots shall be subject to full payment.

Lots with a spacing factor between 0.200 mm and 0.250 mm shall be considered unacceptable and shall be repaired as identified in Table 1.

Lots with spacing factor more than 0.250 mm or air content less than 3% shall be rejected and replaced at the Contractor's expense.

#### **8.03.01 Referee Testing Air Void System in Hardened Concrete**

Referee testing of air void system parameters shall be according to OPSS 1350.

#### **8.03.02 Referee Testing Cost of Air Void System in Hardened Concrete**

The cost of air void system referee testing shall be according to OPSS 1350.

#### **8.04 Acceptance of Rapid Chloride Permeability**

One core per lot shall be tested according to LS-433. Acceptance testing shall be carried out at 28 to 32 Days. Two samples 50 mm long shall be cut from the core representing a lot, and tested to determine the acceptance of the lot. Another core shall be retained for referee testing.

Individual test results shall be forwarded to the Contractor as they become available.

Acceptance of rapid chloride permeability shall be based on the result obtained on the core representing the lot.

Where rapid chloride permeability of 2500 coulombs or less is specified, lots with a rapid chloride permeability result less than or equal to 2500 coulombs shall be considered acceptable. Lots with a rapid chloride permeability result greater than 2500 coulombs and less than or equal to 3500 coulombs shall be considered unacceptable and shall be repaired as identified in Table 1. Lots with rapid chloride permeability results exceeding 3500 coulombs shall be rejected and replaced at the Contractor's expense.

Where rapid chloride permeability of 1000 coulombs or less is specified, lots with a rapid chloride permeability result less than or equal to 1000 coulombs shall be considered acceptable. Lots containing silica fume with a rapid chloride permeability result greater than 1000 coulombs and less than or equal to 2000 coulombs shall be considered unacceptable and shall be repaired as identified in Table 1. Lots containing silica fume with a rapid chloride permeability results exceeding 2000 coulombs shall be rejected and replaced at the Contractor's expense.

#### **8.04.01 Referee Testing of Rapid Chloride Permeability**

Referee testing of rapid chloride permeability may only be invoked by the Contractor within 5 Business Days of receipt of the acceptance test result.

Referee testing shall be carried out on 2-50 mm samples obtained from the reserved core representing the lot for which referee testing was invoked, and the results shall be averaged to obtain the test result for the lot.



The referee laboratory shall be designated by Owner based on the applicable roster and cores shall be tested according to LS 433 by that laboratory.

Referee test results shall be forwarded to the Contractor as they become available.

When the referee result is greater than the acceptance test result or no more than 200 Coulombs below the acceptance test result, then the acceptance test result is confirmed and shall remain valid. When the referee test result for the lot is more than 200 Coulombs below the acceptance test result, the acceptance test result is not confirmed, and the referee test result shall replace the acceptance test result in the acceptance requirements of this specification.

#### **8.04.02 Referee Testing Cost of Rapid Chloride Permeability**

The cost of referee testing of rapid chloride permeability for all concrete shall be according to OPSS 1350 Acceptance of Rapid Chloride Permeability for Silica Fume Overlays and High Performance Concrete.

#### **8.05 Dimensional Verification**

The Contractor Administrator shall carry out measurements on each element to determine compliance with tolerance requirements of CSA A23.4 and the Contract Documents.

#### **8.06 Concrete Cover Measurement**

Concrete cover measurements shall be made by the Contractor Administrator on two elements, selected at random from the lot.

The measurements shall be obtained on a one metre grid on all surfaces of the element.

The Contract Administrator shall provide the survey report to the Contractor.

Where the cover does not meet the Contract requirements, the lot shall be rejected and not be incorporated into the work.

#### **8.07 Rejection of Individual Members**

An element having any one of the following defects and deficiencies shall be rejected:

- a) If concrete temperature exceeds 60 °C at any time during the curing period.
- b) If concrete temperature falls below 0°C during the moist curing and protection period.
- c) If there is honeycombing, voids, cavities, spalls, delaminations, or cracks, in the concrete that exceed the conditions described in Table 1.
- d) If there is a crack that extends through to the opposite face.
- e) If cover to steel reinforcement is less than the lower limit of cover by 5mm anywhere on the element
- f) Tolerances exceed the requirements of this specification.



If the element is deemed rejectable, the element shall not be incorporated into the Work.

#### **8.08                      Assessment of Repairs**

At the discretion of the Owner, where defects or deficiencies have been repaired by either standard methods or by Contractor proposal documentation shall be provided to the Contract Administrator for review and assessment.

The Contract Administrator shall conduct a visual inspection and/or other measures as required, including requesting additional coring, covermeter surveys or any other testing deemed necessary to assess the effectiveness of the repairs.

### **9.0                      MEASUREMENT FOR PAYMENT**

#### **9.01                      Actual Measurement**

##### **9.01.01                      Precast Reinforced Concrete Box Culverts**

Measurement of the actual length of box culvert installed shall be made in metres along the centreline of the invert of the box culvert.

##### **9.01.02                      Granular**

Measurement of granular material used for bedding, backfill and cover material shall be in tonnes according to OPSS 902.

##### **9.01.03                      Earth and Rock Excavation**

Measurement for earth and rock excavation for precast box units and concrete appurtenances shall be by volume in cubic metres according to OPSS 902.

#### **9.02                      Plan Quantity Measurement**

When measurement is by Plan Quantity, such measurement shall be based on the units shown in the clause under Actual Measurement.

### **10.0                      BASIS OF PAYMENT**

#### **10.01                      “size” Precast Concrete “insert shape Box/Open Footing” Culvert - Item**

Payment at the Contract price for the above tender items shall be full compensation for all labour, Equipment, and Material to do the work.

##### **10.02                      Clay Seal**

Payment for clay seal shall be according to OPSS 902.

##### **10.03                      Granular**

Granular material used for bedding and levelling courses, backfill, cover, and frost tapers shall be paid for under the appropriate granular items specified in the Contract Documents.



Payment will not be made for granular used to fill any area excavated beyond the lines specified in the Contract Documents or used as cover when acceptable earth cover is available.

**10.04                      Excavation for Box Culverts**

Payment for earth and rock excavation shall be according to OPSS 902.

**10.05                      Swamp Excavation**

Where swamp excavation is required to place precast concrete box culverts or box sewers, payment for the swamp excavation shall be under the tender item covering the swamp excavation for earth embankment construction.



**TABLE 1**  
**Defects and Deficiencies Repairable by Standard Methods**

<b>Repairable Defects and Deficiencies</b>	<b>Condition</b>	<b>Repair Method</b>
Honeycombing, Voids, Cavities, Spalls, and Delaminations	Any area less than an equivalent area of 300 mm x 300 mm with no steel reinforcement l exposed.	<ul style="list-style-type: none"> <li>a) Square all sides of the repair area.</li> <li>b) Sawcut perimeter of removal area to a depth of 10 mm or to the depth of steel reinforcement, whichever is less.</li> <li>c) Remove all loose concrete using a chipping hammer or hand tools.</li> <li>d) Insert corrosion resistant wires and anchors.</li> <li>e) Abrasive blast clean all concrete surfaces to be patched according to OPSS 929.</li> <li>f) Remove all dust and loose material from the prepared surface by using compressed air.</li> <li>g) Moisten area to be repaired.</li> <li>h) Fill repair area with concrete or a proprietary product patching material.</li> <li>i) Cure concrete according to this Special Provision. Cure proprietary patching material according to the manufacturer's recommendations.</li> </ul>
Low Cover	Any cover readings outside the minimum tolerance by less than 5 mm.	The entire surface of the element shall be sealed with a two-component sealer. Areas against which concrete is to be placed shall not be sealed.
Rapid Chloride Permeability (RCP)	<ul style="list-style-type: none"> <li>a) RCP value for the lot exceeding 2500 and less than or equal to 3500 Coulombs.</li> <li>b) RCP value for the lot of concrete containing silica fume exceeding 1000 and less than or equal to 2000 Coulombs.</li> </ul>	The entire surface of all the elements of the lot shall be sealed with a sealer acceptable to the Owner. Areas against which concrete is to be placed, or waterproofed and paved shall not be sealed.
Cracks	> 0.3 mm	<ul style="list-style-type: none"> <li>a) Repair cracks in the areas where the total linear measurement of crack per m<sup>2</sup> is &lt; 5m. Repair shall be according to OPSS 932.</li> <li>b) Remove and replace the cracked areas where the total linear measurement of crack per m<sup>2</sup> is ≥ 5m. Removals and preparation of concrete shall be according to OPSS 930.</li> </ul>
	≤ 0.3 mm	Apply sealer acceptable to the ministry to the cracked areas. Where the total linear measurement of crack per m <sup>2</sup> is ≥ 5m the entire element shall be sealed.
Air Void System	Spacing factor value for the lot exceeding 0.200 mm and less than 0.250 mm.	The entire surface of all the elements of the lot, except areas against which new concrete is to be placed, or waterproofed and paved, shall be sealed with a sealer acceptable to the Owner.



**NOTES TO DESIGNER:**

This NSSP was reviewed by BO and MERO and the Precast Fabrication is consistent and current with SP 999F31, Precast Concrete Bridge Elements, February 2013.

If this NSSP is modified in any manner it shall be marked as "M".

Rolled waterproofing shall be as MERO's NSSP Culvert Waterproofing, March 2014 or most current version. This NSSP can be obtained from NER QA.

**WARRANT:**

- \* All Precast Culvert(s) and/or appurtenance(s) within NER that is designed and fabricated for that particular location and is outside the scope of OPSS 422 and OPSS 1821.

- \* Always with this item

**CUSTODIAN:** Operations - Quality Assurance Section

**DATE:** June 19, 2015



## **OBSTRUCTIONS**

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### Non-Standard Special Provision

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As part of the work for the culvert installation at the Kenetogami Creek culvert, the contractor should be alerted to the presence of wood fragments within the embankment fill as encountered in Borehole KC-3 as well as the potential for cobbles as inferred by to be present based on instances of auger grinding in Boreholes KC-2, KC-3 and KC-4 and split-spoon refusal in Borehole KC-2. The contractor should also be alerted to the presence of cobbles within the native soils as encountered (cored) in Borehole KC-4 and as inferred from auger grinding in Boreholes KC-1 to KC-4 and split-spoon refusal in Borehole KC-4.



**DEWATERING OF STRUCTURE EXCAVATION - Item No.**

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Non-Standard Special Provision

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Construction of the Kenetogami Creek culvert will require excavations to extend below the groundwater level. The gravelly sand fill and the native sand to sand and gravel stratum that is present below the groundwater level at about the culvert founding level will slough, run, boil or cave into the excavation unless appropriate groundwater controls are in place. The Contractor is to design and install an appropriate excavation protection and dewatering system and carry out unwatering of the excavation to enable construction and to prevent disturbance to the founding soils.

**Basis of Payment**

Payment at the lump sum contract price for this tender item shall be full compensation for all labour, equipment and materials for completion of the work.



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