PROCUREMENT-READY DESIGN

Foundation Design Report

Replacement of Structural Culvert 11X-0422/C0
Highway 401/Wallbridge-Loyalist Interchange, Belleville, Ontario
MTO GWP 4053-18-00, WP 4097-20-01, Agreement 4021-E-0032

Submitted to:

Ministry of Transportation Ontario

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1.0 INTRODUCTION

WSP Canada Inc. (WSP, formerly Golder Associates Ltd., amalgamated with WSP in 2023) is working as part of the WSP Total Project Management team on behalf of the Ministry of Transportation, Ontario (MTO) to support the development of the procurement-ready design for replacement of bridges, culverts and interchange improvements associated with the widening of Highway 401 from four to six lanes (with provision for eight lanes in the future), in the City of Belleville, Ontario, as part of MTO GWP 4053-18-00, under MTO Agreement No. 4021-E-0032.

This report addresses the foundation design for the replacement of Culvert 11X-0422/C0 carrying the Potter Creek tributary under both the eastbound and westbound lanes of Highway 401, approximately 150 m west of Wallbridge-Loyalist Road in Belleville, Ontario.

Foundation investigation services were completed under a separate MTO retainer assignment (MTO Agreement No. 4020-E-0012-03) and are documented in the following Foundation Investigation Report:

- **GEOCRES No. 31C-317:** Foundation Investigation Report, Replacement of Potter Creek Culvert (Site No. 11X-0422/C0), Highway 401 from 1 km West of Wallbridge-Loyalist Road to 4.3 km East of Highway 37, Belleville, Ontario, GWP 4053-18-00, WP 4096-20-01, Agreement 4020-E-0012-3, prepared by WSP, dated August 2024.

2.0 SITE DESCRIPTION AND PROJECT UNDERSTANDING

2.1 Site Description

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 the magnetic north shown on the foundations drawing. For the purposes of this report, Highway 401 is taken as oriented in a west-east direction, and Culvert 11X-0422/C0 is oriented in a north-south orientation. The site location is shown in Drawing 1.

The existing structure is an open footing concrete culvert with an approximate span and internal height of 1.2 m and 1.5 m, respectively. The culvert extends below the existing eastbound (EBL) and westbound (WBL) lanes of Highway 401 at Station 21+846 over a total length of approximately 57 m, with the Potter Creek tributary flowing from north to south. Based on the results of the latest visual inspection detailed in the Structural Design Report (SDR), the culvert is noted to be in good to fair condition.

At the culvert location, Highway 401 has a four-lane cross-section with two eastbound and two westbound lanes with paved shoulders separated by a concrete median wall; the existing culvert also crosses the N/S-W Ramp on the north side of Highway 401. The existing Highway 401 grade is at approximately Elevation 102.5 m while the existing natural ground surface outside of the highway is at approximately Elevation 99.5 m to 100.5 m, such that the Highway 401 embankment is up to approximately 3 m high relative to the surrounding grade. Based on WSP's site observations at the time of the field investigation, the existing highway embankment in the culvert area appears to be performing satisfactorily. There was no visual evidence of instability (i.e., soil movement) on the embankment side slopes, nor tension cracks near the embankment crest that would be indicative of instability.

The area surrounding the proposed culvert location is grass- and tree-covered, with cattails present along the creek alignment at the culvert inlet.

2.2 Project Understanding

It is understood that in the vicinity of Culvert 11X-0422/C0, Highway 401 is to be rehabilitated and widened from the existing four-lane configuration (i.e., two lanes in each direction) to a six-lane configuration (i.e., three lanes in each direction), with provision for eight lanes in the future. The existing grade on Highway 401 will be raised in the vicinity of the culvert by approximately 400 mm. The existing Highway 401 centreline will be maintained, with approximately 7 m of embankment widening to the north and south with placement of up to about 3 m of fill.

Based on the design information in WSP's Preliminary General Arrangement (GA) drawing dated July 2024, Culvert 11X-0422/C0 is to be replaced on a new alignment at Station 21+884, approximately 38 m east of the existing culvert (as measured midpoint-to-midpoint along the Highway 401 centreline), with a skew of approximately 1.5°. The replacement culvert will be approximately 61.2 m long to accommodate the ultimate Highway 401 widening. Based on the Highway 401 right-of-way limits and topography, concrete headwalls and retaining walls are not required at the ends of the culvert to retain the embankment fill.

As the culvert will be replaced on a new alignment, watercourse flows can be maintained through the existing culvert throughout construction. It is understood that the culvert is planned to be replaced via open-cut excavations in two stages while maintaining highway traffic. Following construction of the new culvert, the existing culvert can be decommissioned by removal or by abandoning in place via grouting.

3.0 DISCUSSION AND ENGINEERING RECOMMENDATIONS

3.1 General

This section of the report provides foundation engineering recommendations for the detailed design of the replacement of Culvert 11X-0422/C0. The guidance provided herein is based on an interpretation of the factual data provided in WSP's Foundation Investigation Report (GEOCRES No. 31C-317), dated August 2024, and the design information in the Preliminary GA drawing dated July 2024.

The Foundation Design Report including the discussion and recommendations are intended for the use of the MTO and their detail designers and shall not be used or relied upon for any other purpose or by any other parties, including the future construction contractor. Contractors undertaking this work must make their own interpretation based on the factual data in the Foundation Investigation Report. Where comments are made on construction, they are provided to highlight those aspects that could affect the 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.

3.2 Culvert Replacement and Foundation Options

From a geotechnical/foundation perspective, a pipe culvert, a closed-bottom pre-cast concrete box culvert, or an open-footing cast-in-place culvert are considered feasible alternatives for this culvert replacement. The culvert types are briefly summarized below, and a comparison of advantages, disadvantages, and risks is provided in Table 6 following the text of this report.

- Multiple pipe culverts would likely be required to provide a similar flow-through capacity compared to an open-footing or closed-bottom box culvert option. Further, if constructed from steel, pipe culverts will likely have a shorter design life compared to concrete structures.

- A closed-bottom, segmental pre-cast concrete box culvert can be placed more expeditiously compared to a cast-in-place option, offering schedule advantages with respect to construction/traffic staging dewatering and in-water restrictions (although this culvert will be constructed offline on a new alignment, and in-water restrictions are not directly applicable). Concrete box culverts can typically be founded at a shallower depth compared to open footing culverts, reducing excavation and dewatering requirements. Soil and aggregate materials can be incorporated above the base slab to create a more natural channel substrate for fisheries.
- A cast-in-place concrete open-footing culvert typically requires deeper foundation excavations as compared to a box culvert and would generally extend the construction schedule and increase the excavation, dewatering, and shoring requirements compared to a pre-cast concrete box culvert. There can also be a slightly higher risk of erosion/scour and undermining of foundations along the length of an open footing culvert, compared to a box culvert in which erosion and scour protection is required only at the inlet and outlet.

Based on the above considerations, a closed-bottom segmental, pre-cast concrete box culvert is preferred from a geotechnical/foundation perspective. However, other culvert types may be preferred due to construction staging or other considerations, such as fisheries requirements related to natural channel substrate or alignment.

Based on the Preliminary GA dated July 2024, it is understood that a precast reinforced concrete box culvert has been selected as the preferred structure replacement type. The culvert will have an internal span and height of 3.6 m and 2.4, respectively. Based on hydraulic requirements, the invert varies from approximately Elevation 99.35 m at the inlet (north end) to Elevation 99.0 m at the outlet (south end). Waterbody aggregate substrate materials will be provided inside the culvert to form a natural channel base.

3.3 General Foundation Design Context

3.3.1 Consequence and Site Understanding Classification

As the proposed replacement culvert crosses Highway 401 which carries large traffic volumes with the potential to impact alternative transportation corridors, a “typical consequence level” is considered appropriate for this project, as outlined in Section 6.5 of the Canadian Highway Bridge Design Code (CHBDC 2019) and its Commentary. Further, given the level of geotechnical investigation and laboratory testing completed to date as presented in WSP’s Foundation Investigation Report for this culvert site, a “typical degree of site and prediction model understanding” has been used. Accordingly, the appropriate corresponding ULS and SLS consequence factor, $\Psi = 1.0$, and geotechnical resistance factors, ϕ_{gu} and ϕ_{gs}, from Tables 6.1 and 6.2 of the CHBDC have been used for design. Specifically, the factored geotechnical resistances provided in Section 3.4 are based on geotechnical resistance factors for shallow foundations of $\phi_{gu} = 0.50$ for bearing, $\phi_{gu} = 0.80$ for sliding, and $\phi_{gs} = 0.80$ for settlement.

For seismic design, the consequence factor, ψ, and resistance factor, ϕ_{gu}, should be taken as 1, and the geotechnical resistance factor shall be as specified in Table 6.3 per Section 6.14.4 of CHBDC (2019).

3.3.2 Seismic Design

The seismic hazard values associated with the design earthquakes are those established for the National Building Code of Canada (NBCC 2020) by the Geological Survey of Canada (GSC). The current seismic hazard maps (referred to as the 6th generation seismic hazard maps) were developed by the GSC and were made available for public use in December 2020.

The subsurface conditions for seismic site characterization were assessed based on the results of the field investigation. Based on the energy-corrected average standard penetration resistance, $\overline{N}_{60}$, below the founding level, the site may be classified as Site Class C in accordance with Clause 4.4.3.2 and Table 4.1 of CHBDC (2019).

In accordance with Section 4.4.3.1 of the CHDBC and based on the location of the proposed structure, the Class C peak seismic hazard values based on data obtained from Earthquakes Canada (www.earthquakescanada.nrcan.gc.ca) are provided in Table 1.

Table 1: Class C Peak Seismic Hazard Values

Parameter	2% Probability of Exceedance in 50 Years (2,475-year return period) (g)
PGA	0.143
Sa (0.2)	0.304
Sa (0.5)	0.203
Sa (1.0)	0.113
Sa (2.0)	0.0544
Sa (5.0)	0.0147
Sa (10.0)	0.00504
PGV [m/s]	0.133

3.3.3 Soil Liquefaction

Liquefaction is a phenomenon whereby seismically induced shaking generates shear stresses within the soil under undrained conditions. These stresses tend to densify the soil which may lead to potentially large surface deformations, and under undrained conditions generate excess pore water pressures that can lead to sudden temporary losses in strength. Where existing static shear stresses are present, the loss of strength can lead to significant lateral movements (analogous to slope failure) often referred to as “lateral spreading” or under certain conditions even catastrophic failure of slopes often referred to as “flow slides”.

In general, the fill materials and native soils at this culvert site consist of stiff to hard clay to silty clay with varying amounts of sand, gravel, cobbles, and boulders. Based on the consistency of the soils and the site-specific PGA, the soils at this site are considered to have a low potential for liquefaction during a seismic event.

3.3.4 Frost Protection

The frost penetration depth in this area is approximately 1.4 m as interpreted from Ontario Provincial Standard Drawing (OPSD) 3090.101. Footings constructed at this site would require a minimum embedment depth of 1.4 m below the final finished grade for frost protection purposes. However, it is not necessary to ensure that the full length is found below this frost depth for frost protection purposes, if a box culvert is constructed as they are tolerant of small magnitudes of movement related to freeze-thaw cycles, should these occur.

3.4 Culvert Foundation Design Recommendations

3.4.1 Box Culvert Bedding and Levelling Layer Requirements

Excavation and backfilling for installation of the new concrete culvert should be carried out in accordance OPSS.PROV 902 (*Construction Specification for Excavating and Backfilling – Structures*) and MTO Special Provision (SP) No. 109S61, Amendment to OPSS 902, November 2019 - Dewatering and Protection Systems; dated February 2024.

Provided adequate dewatering is in place, a minimum 150 mm thick layer of OPSS.PROV 1010 (Aggregates) and SP No. 110S06 Granular A material is recommended for bedding purposes. The bedding should be placed in accordance with OPSS.PROV 501 (Compacting) and compacted to at least 98% of the material's Standard Proctor maximum dry density (SPMDD).

In addition, a 75 mm thick uncompacted leveling pad consisting of OPSS.PROV 1010 (Aggregates) Granular 'A' or fine concrete aggregate that meets the grading requirements specified in OPSS.PROV 1002 (Aggregates – Concrete) should be placed on top of the bedding layer to facilitate placement and adjustment of the precast concrete box segments.

3.4.2 Box Culvert Founding Level and Factored Axial Geotechnical Resistances

Based on a 250 mm thick concrete bottom slab and the minimum bedding and leveling layer thicknesses recommended above, the highest founding subgrade level for the replacement culvert will range from approximately Elevation 98.9 m to 98.5 m at the inlet and outlet respectively. For the proposed box culvert within an overall footprint width of 4.1 m (exterior dimension) founded on the properly prepared granular bedding/leveling course overlying the native soils at the above-noted elevations, the following factored geotechnical resistances may be used for the design:

- Factored ultimate geotechnical resistance: 500 kPa
- Factored serviceability geotechnical resistance (for 25 mm of settlement): 350 kPa

The factored serviceability geotechnical resistance considers the embankment unloading associated with a replacement culvert installed along the proposed new alignment.

3.4.3 Open Footing Culvert Founding Level and Factored Axial Geotechnical Resistances

If an open footing culvert option is selected, based on the low flow channel elevations and the frost penetration depth of 1.4 m, it is estimated that the highest founding level for the strip footings would range from Elevation 98.4 m to 98.1 m at the culvert inlet and outlet, respectively.

Cast-in-place strip footings should be placed on the properly prepared native subgrade soils, or on a minimum 100 mm thick concrete working mat to protect the subgrade during forming and pouring of the cast-in-place footings. If precast footings are utilized, a 75 mm thick uncompacted leveling layer should be placed on the prepared silty clay subgrade, or on a minimum 100 mm thick concrete working mat if the footing placement cannot be completed on the same shift as inspection and approval of the subgrade to protect it from degradation.

For 0.76 m wide footings founded on the properly prepared native soils at or below the above-noted elevations, the following factored geotechnical resistances may be used for the design:

- Factored ultimate geotechnical resistance: 200 kPa

- Factored serviceability geotechnical resistance (for 25 mm of settlement): >200 kPa

The factored geotechnical resistances provided are based on the loading applied perpendicular to the base of the footing; where applicable, the inclination of the load should be considered in accordance with Section 6.10.2 and Section C6.10.5 of CHBDC (2019) and its Commentary.

The factored geotechnical resistances are dependent on the footing width and founding elevation and as such, the geotechnical resistances should be reviewed if the footing width or founding elevations differ from those given above.

3.4.4 Resistance to Lateral Loads/Sliding Resistance

Resistance to lateral forces/sliding resistance should be calculated in accordance with Section 6.10.4 of CHBDC (2019), applying the appropriate consequence and degree of site understanding factors (Ψ = 1.0 and ϕ_{gu} = 0.80) noted above in Section 3.3.1. The interface friction angle(s) and interface shear strengths provided in Table 2 may be used to assess the critical conditions for sliding resistance.

Table 2: Interface Friction Angles and Shear Strengths

Culvert Type	Interface	Unfactored Coefficient of Friction
Box Culvert	Between cast-in-place (CIP) concrete working slab and underlying very stiff clay (if CIP working slab is adopted)	c' = 0 kPa, tan ϕ' = 0.58
	Between Granular A bedding and underlying CIP concrete working slab (if CIP working slab is adopted)	c' = 0 kPa, tan δ = 0.45
	Between pre-cast concrete and underlying Granular A bedding/leveling layer	c' = 0 kPa, tan δ = 0.45
Open Footing Culvert	Between CIP footing and very stiff clay subgrade, or between CIP working slab and clay subgrade	c' = 0 kPa, tan ϕ' = 0.67
	Between CIP footing and cured concrete working slab	c' = 0 kPa, tan δ = 0.65

3.4.5 Culvert Subgrade Preparation

Prior to placing the bedding/leveling course for pre-cast concrete box culvert sections, it is recommended that any organic material (i.e., topsoil, peat, and/or mixed organic soils), existing fill, and any soft, loose, or otherwise disturbed materials encountered below the foundation footprint be sub-excavated and replaced with OPSS.PROV 1010 Granular A or Granular B Type II fill.

3.4.6 Culvert Backfill

Backfill above/behind the culvert walls, headwalls, and retaining walls should consist of granular fill meeting the specifications for OPSS.PROV 1010 (Aggregates) Granular A or Granular B Type I or II. The backfill should be placed in a maximum 300 mm thick loose lifts and compacted to not less than 98% of the material's SPMDD 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 per OPSS.PROV 902 (Excavating and Backfilling – Structures). Embankment restoration after completion of the culvert replacement should be carried out in accordance with OPSS.PROV 206 (Grading).

3.4.7 Culvert Erosion and Scour Protection

To prevent surface water from flowing either beneath the 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 which could lead to the formation of sinkholes), a concrete cut-off wall and/or a clay seal is recommended at the upstream and downstream ends; retaining walls can also assist in such cut-off but are not required at this culvert site based on the culvert length relative to the embankment. Based on the Preliminary GA drawing, it is understood that concrete apron cut-off walls are to be constructed at both the inlet and outlet ends of the replacement culvert.

If a clay seal is included in the design, in lieu of or in addition to cut-off walls, the clay material should meet the requirements of OPSS.PROV 1205 (Clay Seal), and the seal should be a minimum of 1 m thick, whether constructed of natural clay or soil-bentonite mix.

Alternatively, a geosynthetic clay liner (GCL) may be incorporated, and this is generally considered the preferred alternative as it is much thinner than the standard natural clay or soil-bentonite layer, thus requiring a shallower excavation into the slope, it does not require sourcing or mixing of natural clay soils and bentonite, and the GCL is easier to install. The clay seal or GCL should extend a minimum horizontal distance of 2 m on either side of the culvert inlet opening, and from a depth of 1 m below the scour level up to a minimum vertical height on the embankment side slopes equivalent to the high-water level. If a GCL is used, the GCL should be constructed within the embankment slope to allow for a minimum 0.3 m thick granular cover layer to be placed over the GCL to provide protection from the requisite overlying erosion protection material. Rip-rap/rock fill slope protection material should be placed on the granular cover layer and not directly on the GCL. A Non-Standard Special Provision (NSSP) for a GCL has been provided in Appendix A.

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 could also follow the standard presented in OPSD 810.010 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.

The requirements for and design of erosion protection measures for the culvert and re-constructed embankment side slopes should be assessed by the Drainage and Hydrology engineers. If additional erosion protection is required, consideration could be given to the use of rip-rap, rock protection, or granular sheeting meeting the requirements of OPSS.PROV 1004 (Aggregates – Miscellaneous), placed and constructed in accordance with OPSS.PROV 511 (Rip-Rap, Rock Protection, and Granular Sheeting).

3.4.8 Lateral Earth Pressures

The lateral earth pressures acting on culvert side walls 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:

- Select, free draining, non-frost susceptible granular fill meeting the requirements of OPSS.PROV 1010 (Aggregates) Granular ‘A’ or Granular ‘B’ Type II should be used as backfill behind the culvert walls, as well as on top of the culvert for a minimum thickness of 300 mm in a similar configuration to that shown in OPSD 803.010 (Backfill and Cover for Concrete Culverts).

- A minimum compaction surcharge of 12 kPa should be included in the lateral earth pressures for the structural design of the walls, in accordance with Section 6.12.3 and Figure 6.8 of CHBDC (2019). Hand-operated compaction equipment should be used to compact the backfill soils immediately behind the walls as per OPSS.PROV 501. Other surcharge loadings should be accounted for in the design, as required.
- For restrained walls, the granular fill should be placed in a zone with a width equal to at least 1.4 m behind the back of the wall (see Figure C6.31(a) of the Commentary to CHBDC). For unrestrained walls, the fill should be placed within the wedge-shaped zone defined by a line drawn flatter than 1H:1V extending up and back from the rear face of the footing (see Figure C6.31(b) of the Commentary to CHBDC).

The lateral earth pressure coefficients provided in Table 3 have been developed for flat (i.e., non-sloping) ground above/behind the culvert walls, as well as for a 2H:1V slope condition if unrestrained retaining walls are incorporated at the ends of the replacement culvert. If the inclination of the slope above the wall differs, revised lateral earth pressure parameters will need to be calculated in accordance with CHBDC Clause C6.12.1, Figures C6.28 (active earth pressure) and C6.29 (passive earth pressure), and Clause C6.12.2.2 (at-rest earth pressure).

If the wall does not allow lateral yielding (i.e., a restrained structure where the rotational or horizontal movement is not sufficient to mobilize an active earth pressure condition), at-rest earth pressures (plus any compaction surcharge) should be assumed for geotechnical design. If the wall allows lateral yielding (i.e., unrestrained structure), active earth pressures should be used in the geotechnical design of the structure. The movement required to allow active pressures to develop within the backfill, and thereby assume an unrestrained structure for design, should be calculated in accordance with Section C6.12.1 and Table C6.12 of the Commentary to CHBDC (2019).

Table 3: Lateral Earth Pressure Coefficients

Wall Movement Condition	Restrained Wall	Unrestrained Wall			
Fill Material	Existing Embankment Fill Behind Granular Backfill Zone $\phi'=32°$	Granular A and B Type II $\phi'=35°$		Granular B Type I $\phi'=32°$	
Unit Weight (kN/m^3)	19	22	22	21	21
Ground Surface Above Top of Wall	Horizontal	Horizontal	2H:1V	Horizontal	2H:1V
Active Earth Pressure (K_a)	-	0.27	0.39	0.31	0.47
At-Rest Earth Pressure (K_o)	0.47	-	-	-	-
Passive Earth Pressure (K_p)[1]	3.25	3.69	10.78	3.25	8.58

Notes:

1 The total passive resistance may be calculated based on the values of K_p indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.27 of the CHBDC (2019) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

3.5 Embankment Widening, Stability and Settlement

3.5.1 Embankment Subgrade Preparation and Construction

Prior to the widening of the Highway 401 embankment approximately 7 m to the north and south, it is recommended that all topsoil/peat and loose or disturbed soil be removed from the widening footprint.

Fill for construction of the widened embankments may consist of OPSS.PROV 1010 Granular A or Granular B Type I or Type II, or alternatively earth fill or select subgrade material (SSM). Fill should be placed and compacted in accordance with OPSS.PROV 206 (Grading) and OPSS.PROV 501 (Compacting). Where new embankment fill is placed against existing embankment slopes, the existing slope must be benched in accordance with OPSD 208.010.

Where earth fill or SSM is used for embankment construction, the exposed materials will be susceptible to erosion and shallow ravelling. To reduce surface water erosion and ravelling on the embankment side slopes or cut slopes, treatment per OPSS.PROV 804 (Temporary Erosion Control) and OPSS.PROV 803 (Vegetative Cover) must be provided. If slope protection is not in place prior to winter or periods of excessive precipitation, alternate protection measures such as gravel sheeting per OPSS 511 (Rip-Rap, Rock Protection, and Granular Sheeting) and OPSS.PROV 1004 (Aggregates – Miscellaneous) is recommended to reduce the potential for erosion and associated requirements for remedial works on the slope faces prior to topsoil dressing and seeding.

3.5.2 Global Stability of Widened Embankment Side Slopes

Based on the Preliminary GA drawing, it is understood that the existing embankment heights at the replacement culvert location will be raised by approximately 400 mm over the existing Highway 401 grade.

For the stability analyses, and in the context of the CHBDC (2019), the target Factor of Safety is defined as being equal to the inverse of the product of the consequence factor, Ψ and the geotechnical resistance factor, ϕ_{gu}, (i.e., FoS = 1 / (Ψ * ϕ_{gu})). Accordingly, for a ‘typical’ consequence level and a ‘typical’ degree of site and prediction model understanding, target minimum Factors of Safety of 1.33 and 1.54 have been used for the design of the widened embankment, considering global stability for temporary (short-term) and permanent (long-term) conditions, respectively, per Table 6.2 of CHBDC (2019).

Provided the side slopes are oriented no steeper than 2H:1V, the approximately 3 m high embankment widening will have a Factor of Safety of greater than 1.5 for a deep-seated slip surface that could affect the stability of the highway embankment. Under the design earthquake loading, the approach embankments have a factor of safety of greater than 1.1.

3.5.3 Embankment Settlement

3.5.3.1 Methods and Parameters

As detailed on the Preliminary GA drawing and outlined in Section 2.2, the Highway 401 embankment will be raised by approximately 400 mm and widened by approximately 7 m to the north and south, with a maximum of approximately 3 m of fill placed above the existing embankment side slopes at the culvert location.

The settlement analysis discussed below assumes that any topsoil/organics within the footprint of the widened embankments will be stripped or sub-excavated prior to the placement of any new embankment fill material for the widening.

The compression of the native soils was modelled based on typically accepted correlations with the SPT ‘N’ values as presented in Bowles (1984) and by Kulhawy and Mayne (1990) together with engineering judgment based on experience in similar subsurface conditions. The unit weight and associated stiffness (moduli) geotechnical design parameters used for the settlement analysis are summarized in Table 4.

Table 4: Geotechnical Design Parameters for Settlement Analysis

Material	Unit Weight (kN/m^3)	Elastic Modulus (MPa)
Stiff to very stiff clay (weathered crust)	18	50
Compact to dense gravelly sand and silt till	21	50

3.5.3.2 Results of Analyses

The estimated total settlement of the existing site soils under the loading imposed by the widened and raised embankment is estimated to be less than 10 mm. This settlement is expected to be elastic and to occur during and immediately following the construction of the embankment widening, with no long-term settlement anticipated.

The above estimate does not include compression of the fill itself, which would occur during the construction of the embankment depending on the type of material used. The magnitude of granular fill compression may range from 0.5% to 1% of the height of the embankment, assuming a compaction level of 98% of the material's SPMDD is achieved during construction. In this case, settlement of granular fill itself is expected to occur essentially during embankment construction.

3.5.3.3 Comparison to MTO's Settlement Criteria

The estimated settlements meet MTO's Embankment Settlement Criteria (July 2010), and no settlement mitigation will be required for the existing culvert or proposed replacement culvert structure.

3.6 Corrosion Assessment and Protection

The analytical results for the site soil samples submitted for testing are summarized in the Foundation Investigation Report (FIR) for this culvert site, referenced in Section 1.0 of this report.

The potential for sulphate attack and corrosion are discussed in the following sub-sections; however, it is ultimately up to the designer to determine the appropriate construction materials, including the exposure class, and ensure that all aspects of CSA A23.1:19 Section 4.1.1 "Durability Requirements" are followed when designing concrete elements, as applicable.

3.6.1 Potential for Sulphate Attack

The sulphate test results were compared with Table 3 of the CSA Standard A23.1-19 and Table 7.2 of MTO's Gravity Pipe Design Guidelines (2014), and generally indicate a low degree of sulphate attack potential on concrete structures at this site. Accordingly, GU cement in accordance with Table 6 of the CSA Standard A23.1-19 could be specified for concrete in below-grade applications.

3.6.2 Potential for Corrosion

The soil has a pH of 8.5 and according to the MTO Gravity Pipe Design Guidelines (2014), pH levels between 5.5 and 8.5 are not considered detrimental to culvert durability. The measured resistivity of 3,330 ohm-cm is classified as moderately corrosive (4,500>R>2,000), as per Table 3.2 of the MTO Gravity Pipe Design Guidelines (2014). Given that the culvert location will be exposed to de-icing salts, it is recommended that a C-1 (reinforced concrete) or C-2 (non-structurally reinforced concrete) class exposure concrete be considered, as appropriate as defined by CSA A23.1 Table 1.

3.7 Construction Considerations

3.7.1 Excavation and Temporary Protection Systems

All excavations must be carried out in accordance with Ontario Regulation 213, Ontario Occupational Health and Safety Act for Construction Projects (OHSA), as amended. The temporary excavations for the culvert replacement will extend through the existing embankment fill and into the stiff to very stiff clay, potentially reaching the till deposit. The fill and clay at this site are considered Type 3 soils according to OHSA. Temporary open-cut excavations in Type 3 soils should be excavated no steeper than 1H:1V. If and where water-bearing non-cohesive soils are encountered, they would be classified as Type 4 soils in the OHSA, and the side slopes would be required to be no steeper than 3H:1V unless appropriate groundwater control is implemented.

Construction staging will need to be confirmed by the future design-builder. Given the relatively low embankment and considering that this culvert is being constructed on a new alignment such that flow may be maintained in the existing culvert, it is expected that the replacement culvert will be constructed in two stages with temporary protection systems along (parallel to) Highway 401.

The selection of the type, extents, and method of installation of temporary protection system must consider the potential presence of cobbles and boulders in the existing fill and till soils, the irregularly sloping and relatively shallow depth to bedrock, and the high groundwater table associated with the underlying till and bedrock at the site. Driven steel sheet piles may not be able to penetrate the hard/dense portions of the till deposit or zones of cobbles or boulders and would not be able to penetrate the strong limestone bedrock so may not achieve sufficient toe length. Soldier piles (for a soldier pile and lagging system) would likely have to be socketed into pre-drilled holes in the bedrock to achieve sufficient toe resistance to support the excavation. Additional lateral support to the shoring system could be in the form of struts, walers, rakers, or anchors and the amount of lateral support required will depend on the type, stiffness, and toe fixity of the selected shoring wall.

The design of the shoring will be the responsibility of the Contractor; the geotechnical parameters in Table 5 are provided for information purposes. Temporary protection systems should be designed and constructed in accordance with OPSS.PROV 539 (Temporary Protection Systems), amended by SP 105S09. The lateral movement of the temporary protection systems should meet Performance Level 2 per OPSS.PROV 539. Traffic loading should be included as a surcharge. Traffic loading does not account for construction equipment loadings which may be higher; the Contractor's shoring designer should confirm the load requirements. The design of the temporary support system should include an evaluation of base stability and hydraulic uplift stability associated with the underlying till deposit, as defined in the Canadian Foundation Engineering Manual 5th Edition (CFEM 2023).

Table 5: Geotechnical Parameters for Temporary Protection Systems

Soil Type	Bulk Unit Weight, γ (kN/m^3)	Internal Angle of Friction, ϕ (°)	Lateral Earth Pressure Coefficients (1)		
			Active, K_a	At Rest, K_o	Passive, K_p (2)
New Granular A or B Type I or II fill	22	35	0.27	0.43	3.69
Existing loose to dense embankment fill	20	32	0.31	0.47	3.25
Stiff to very clay (weathered crust)	18	28	0.41	0.53	2.77
Compact to dense gravelly sand and silt till	21	32	0.31	0.47	3.25

Notes:

1. The lateral earth pressure coefficients presented above are based on a horizontal surface behind the excavation. If sloped surfaces are present, the coefficients should be corrected accordingly.
2. The total passive resistance below the base of the excavation adjacent to the temporary protection system may be calculated based on the values of Kp indicated above but reduced by an appropriate factor that considers the allowable wall movement in accordance with Figure C6.27 of the CHBDC (2019) to account for the fact that a large strain would be required for mobilization of the full passive resistance.

3.7.2 Control of Groundwater and Surface Water

It is anticipated that the creek flow will be maintained within the existing culvert while the replacement culvert is being constructed, and that no temporary flow bypass is required at the replacement culvert during construction.

Some perched groundwater is expected at the base of the fill atop the clay deposit, and seepage may also occur from seams or layers of non-cohesive soil within the clay crust and predominantly cohesive glacial till deposit. It is expected that such seepage will be able to be controlled with the use of pumps placed in filtered sumps within the excavation. The extent/depth of groundwater control requirements must be reviewed by the contractor, based on their proposed construction methods.

While a relatively low groundwater control rate will apply for this individual culvert site, the requirement for an Environmental Activity Section Registry (EASR, for pumping volumes greater than 50 m^3/day) or Permit to Take Water (PTTW, for pumping volumes greater than 400 m^3/day) must be assessed for the overall construction contract depending on the estimated pumping volumes for the number of sites requiring excavation and dewatering at one time.

Dewatering of all excavations should be carried out in accordance with OPSS.PROV 517 (Dewatering), as modified by SP 517F01, a copy of which is included in Appendix A. The risk of dewatering-induced settlement is low for this type of system given the site soil conditions and distance to any settlement-sensitive receptors; as such, the fill-in in SP 517F01 should indicate that a preconstruction survey is not applicable, and there is no special requirement for dewatering specialist qualifications.

3.7.3 Subgrade Preparation

Prior to placing the bedding and leveling layer for a precast box culvert, all existing fill, topsoil/organic materials and any disturbed/loosened native soils should be sub-excavated from below the plan limits of the culvert. The subgrade should be inspected to ensure that all organics and other unsuitable materials have been removed, in accordance with OPSS.PROV 902. It is recommended that any subexcavation be backfilled with OPSS.PROV 1010 Granular ‘A’ or Granular ‘B’ Type II that is placed and compacted in accordance with OPSS.PROV 501 (Compacting).

If a cast-in-place open footing culvert is selected, it is recommended that a minimum 100 mm thick concrete working slab be placed on the subgrade following its inspection and approval, to prevent degradation of the subgrade. A concrete working slab is not required below the bedding and levelling layers for a precast concrete box culvert as the bedding layer will protect the subgrade provided that any groundwater seepage is addressed; however, such a slab may be incorporated by the contractor as part of their excavation and groundwater control scheme.

3.7.4 Obstructions

The contractor should be alerted to the potential presence of cobble and boulder obstructions within the native till deposit above the bedrock at this site. The extent and depth of the obstructions may vary between and beyond the borehole locations. A sample Notice to the Contractor is included in Appendix A.

3.7.5 Methane Gas

A methane pocket was encountered during bedrock coring at Borehole C-06 at an approximate depth of 5.0 m (Elevation 94.5 m). Methane concentrations above the lower explosive level (LEL) were measured at the top of the borehole casing using an RKI Model GX-2012 4-Gas Monitor.

The contractor should be alerted to the potential presence of methane gas exceeding the lower explosive level (LEL) at elevations near or within the bedrock, throughout the project limits. It should be expected that methane could be encountered within the bedrock if any protection system installation, excavation or other /construction activities extend to this level. A sample Notice to the Contractor alerting the Contractor to existing subsurface conditions is included in Appendix A.

4.0 CLOSURE

This Foundation Design Report was prepared and reviewed by Lisa Coyne, P.Eng., Senior Technical Director and David Staseff, P.Eng., MTO Principal Foundations Contact.

WSP Canada Inc.

Lisa Coyne, P.Eng.
Senior Technical Director

David Staseff, P.Eng.
MTO Principal Foundations Contact

LCC/DS/al

https://wsponline.sharepoint.com/sites/ca-221-08798-00/14tech_profservices/14.18 foundations/deliverables/culvert 11x-0422/gwp 4053-18-00_fdr_rev0_culvert_11x-0422c0_(221-08798-00).docx

REFERENCES

Bowles, Joseph, E., 1997. *Foundation Analysis and Design*, Fifth Edition. McGraw-Hill International Editions, Civil Engineering Series, Singapore.

Canadian Geotechnical Society, 2023. *Canadian Foundation Engineering Manual,* 5th Edition

Canadian Standards Association (CSA), 2019. *Canadian Highway Bridge Design Code* and *Commentary on CSA S6:19.*

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

Kulhawy, F.H. and Mayne, P.W. 1990. *Manual on Estimating Soil Properties for Foundation Design*. Electric Power Research Institute EL-6800s.

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

Occupational Health and Safety Act and Regulation for Construction Projects (as amended)

Ontario Provincial Standard Specifications (OPSS)

OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheeting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 803	Construction Specification for Vegetative Cover
OPSS.PROV 804	Construction Specification for Temporary Erosion Control
OPSS.PROV 902	Construction Specification for Excavating and Backfilling - Structures
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
OPSS.PROV 1860	Material Specification for Geotextiles

MTO Special Provisions (SP)

SP 105S22	Amendment to OPSS 501
SP 517F01	Special Provision for Temporary Flow Bypass and Dewatering
SP 105S09	Amendment to OPSS 539 – Temporary Protection Systems
SP 109S61	Amendment to OPSS 902, November 2019 - Dewatering and Protection Systems; dated February 2024
SP 110S06	Amendment to OPSS 1010 – Aggregates

Ontario Provincial Standard Drawings (OPSD)

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 3090.101	Foundation, Frost Penetration Depths for Southern Ontario

Ontario Water Resource Act

Regulation 903	Wells (as amended)

Table 6: Comparison of Alternative Culvert Types

Option	Feasibility	Advantages	Disadvantages	Risks/Consequences
Precast Concrete, Box Culvert	▪ Feasible – preferred option from a foundation perspective.	▪ Minimizes depth of excavation, extent of protection systems, and dewatering requirements compared to cast-in-place, open-footing culvert option. ▪ Allows faster construction resulting in shorter duration for dewatering and surface water diversion pumping. ▪ More tolerant of total and differential settlements.	▪ May not satisfy fisheries requirements related to natural channel substrate, if applicable, although waterbody aggregate can be incorporated on top of the base slab. ▪ Cut-off wall (or clay seal) likely required at inlet to mitigate potential scour under or around the culvert.	▪ Lower risk of disturbance of the native subgrade soils during construction; can be mitigated with the use of a granular working pad/bedding layer or concrete working slab. ▪ Low risk related to settlement performance as precast box segments can accommodate some total and differential settlements.
Cast-in-Place Concrete, Open Footing Culvert	▪ Feasible from a foundation perspective.	▪ May be feasible to construct the culvert on precast footing sections to accelerate construction schedule and reduce time for groundwater control. ▪ Would likely satisfy fisheries requirements related to natural channel substrate, if applicable.	▪ Excavation depths are greater than for a pre-cast box culvert option, resulting in increased excavation support, cofferdam and dewatering requirements, and additional spoil material to be disposed off-site. ▪ Constructing footings and culvert will take longer. ▪ Generally less tolerant of total and differential settlements, although this is not an issue for this culvert site.	▪ Higher risk of disturbance of the native subgrade soils during construction; can be mitigated with use of a granular working pad/bedding layer or concrete working slab. ▪ May require greater depth of dewatering for footing construction.
SPCSP Pipe Culvert(s)	▪ Feasible from a foundation's perspective.	▪ Allows for faster construction resulting in shorter duration for unwatering and surface water diversion pumping compared to open-footing and box culverts. ▪ More tolerant of total and differential settlement, although this is not an issue for this site.	▪ Generally reduced flow-through capacity compared to box culvert and open-footing culvert options with a similar span – additional flow through capacity may have to be provided by multiple pipes. ▪ Cut-off wall or clay seal may be required at inlet to mitigate potential scour under the culvert(s). ▪ SPCSP culvert does not have as long of a design life compared to concrete options.	▪ Lower risk of disturbance of the native subgrade soils during construction; can be mitigated with the use of a granular working pad/bedding layer or concrete working slab.

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

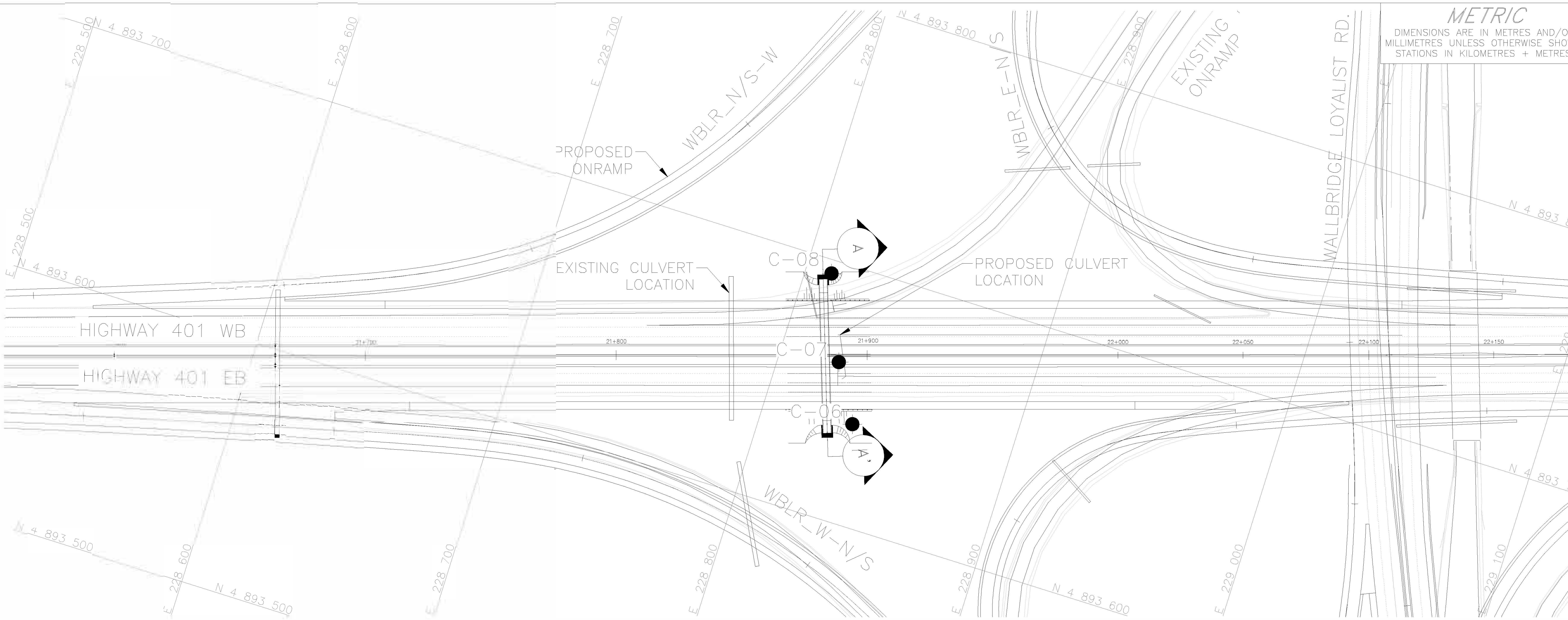
CONT No.
WP No. 4053-18-00

SHEET

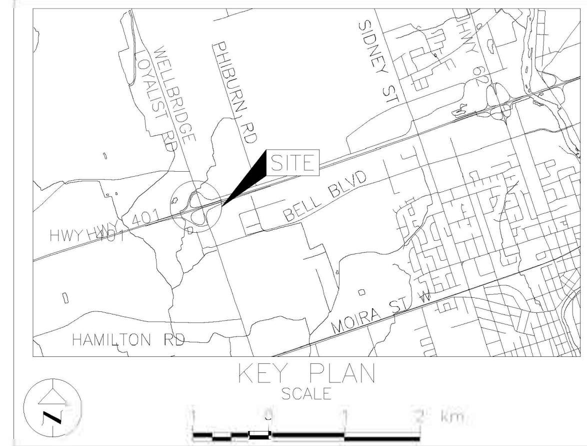
HIGHWAY 401 WIDENING
REPLACEMENT OF CULVERT 11X-0422/C0

BOREHOLE LOCATIONS AND SOIL STRATA

WSP



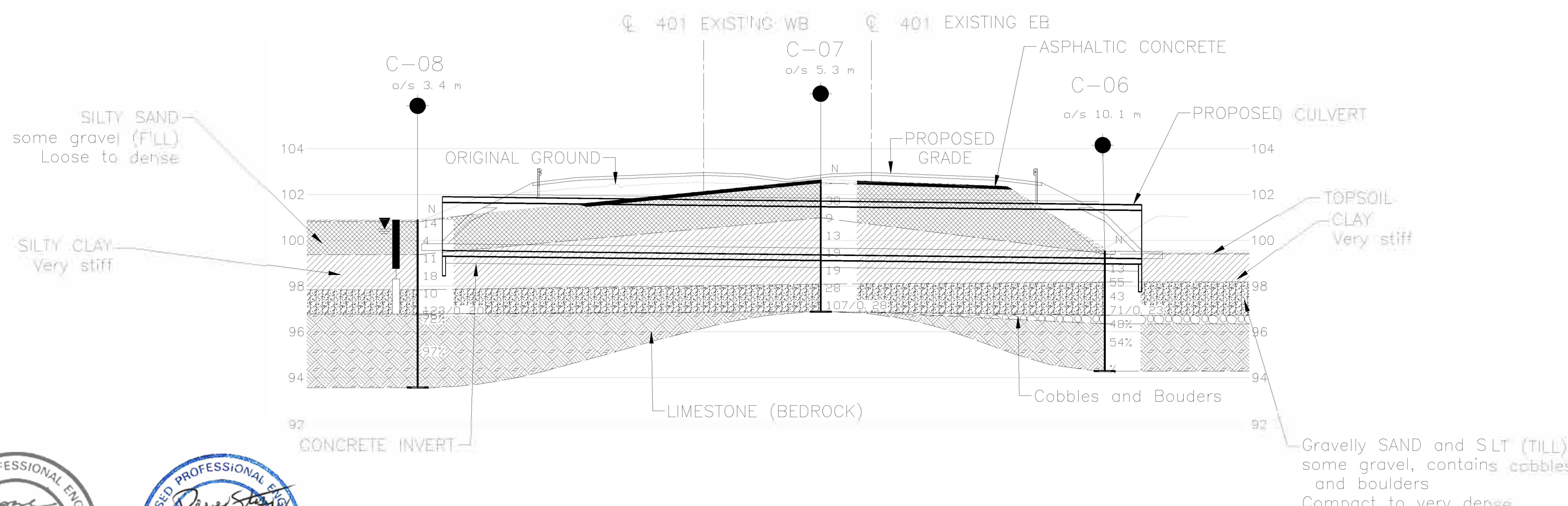
PLAN
SCALE
20 0 20 40 m



KEY PLAN
SCALE
1 0 1 2 km

LEGEND

- ● Borehole – Current Investigation
- Seal
- Piezometer
- N Standard Penetration Test Value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 j/blow)
- 100% Rock Quality Designation (RQD)
- ▼ WL in piezometer, measured on February 27, 2024



SECTION
SCALE
5 0 5 10 m

BOREHOLE CO-ORDINATES NAD83 (CSRS) MTM ZONE 9			
No.	ELEVATION	NORTHING	EASTING
C-06	99.5	4893640.0	228836.2
C-07	102.4	4893661.9	228823.7
C-08	100.9	4893694.6	228810.4

Structural Site Location: Latitude: 44.179013 Longitude: -77.45022

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 Procurement-Ready Design Documents.

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

REFERENCE

Base plans provided in digital format by MTO, drawing file nos 3216057_EP.dwg and 3216057_Hwy 401 _8 Lanes Design_ACAD.dwg, received Oct. 13 2022.
General arrangement provided in digital format by WSP, drawing file no. S16M-01435-01-354-001GA.dwg, received April 11, 2024.

NO.	DATE	BY	REVISION

Geocres No. 31C00-317

HWY.	PROJECT NO. 221-08798-00		DIST. EASTERN
SUBM'D. BW	CHKD. KCP	DATE: 9/15/2025	SITE: 11X-0422/C0
DRAWN: SA	CHKD. KCP	APPD. LCC/DS	DWG. 1

LICENSED PROFESSIONAL ENGINEER L. C. COYNE 21Nov2025 PROVINCE OF ONTARIO

LICENSED PROFESSIONAL ENGINEER D. STASEFF 21Nov2025 PROVINCE OF ONTARIO

APPENDIX A

Special Provisions

Special Provision No. 517F01 February 2024

Amendment to OPSS 517, November 2023

Return Period Flow and Preconstruction Survey Distance

517.04 DESIGN AND SUBMISSION REQUIREMENTS

517.04.01 Design Requirements

Clause 517.04.01.01 of OPSS 517 is amended by deleting the second last paragraph in its entirety and replacing it with the following:

The temporary flow passage system shall allow the work to be conducted as specified in the Contract Documents. Design flow shall include groundwater discharge and flow resulting from a minimum 2 year return period design storm, except for the work specified in Table 1. For the work specified in Table 1, design flow shall include groundwater discharge and flow resulting from a design storm of the minimum return period specified in Table 1. A longer return period shall be used when determined appropriate for the work.

The flow estimates as specified in Table 1 do not include flow volumes from groundwater discharge.

The Owner specifically excludes flow estimates from the warranty in the Reliance on Contract Documents subsection of OPSS 100, MTO General Conditions of Contract.

TABLE 1
Site Location and Reference Information

<table>
<tr><th colspan="8">TEMPORARY FLOW PASSAGE SYSTEMS</th></tr>
<tr><th colspan="8">Source of Return Period Flow Estimates:</th></tr>
<tr><th rowspan="2">Site Name / Station Reference</th><th rowspan="2">Minimum Return Period (Years)</th><th colspan="4">Return Period Flow Estimates (m^3/s) (Note 1)</th><th rowspan="2">Design Engineer Requirements (Note 2)</th><th rowspan="2">Fish Passage Required (Note 3)</th></tr>
<tr><th>2 Year</th><th>5 Year</th><th>10 Year</th><th>25 Year</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

DEWATERING SYSTEMS			
Site Name / Station Reference	**Preconstruction Survey Distance (m)** (Note 4)	**Minimum Lowered Groundwater Depth Below Base of Excavation or Work Area (m)** (Note 5)	**Design Engineer Requirements** (Note 2)
Culvert 11X-0422/C0	N/A	1 m	Yes

Notes:

1. a) The Design Engineer is to satisfy themselves to the accuracy and applicability of the provided flows.
   b) The intensity-duration-frequency (IDF) information can be accessed through MTO's IDF Curve Lookup web-based application tool at https://idfcurves.mto.gov.on.ca/
   c) The design, operation and maintenance of the temporary flow passage system is the sole responsibility of the Contractor.
2. "Yes" means the design Engineer and design-checking Engineer shall have a minimum of 5 years of experience in designing systems of similar nature and scope to the required work. "No" means a minimum experience level is not required for the design Engineer and design-checking Engineer.
3. "Yes" means that the design Engineer must design the temporary flow passage system to meet the fish passage requirements. "No" means fish passage is not required.
4. "N/A" means a preconstruction survey is not required.
5. Groundwater shall be lowered within the excavation or work area to below this minimum depth.

[* Designer Fill-Ins for Table 1, See Notes to Designer]

Existing Subsurface Conditions

Notice to Contractor

The Contactor is alerted to the possibility of encountering abandoned underground structures, construction debris, refuse, and other obstructions, in addition to cobbles and boulders, during excavation. The extent and depth of obstructions may vary beyond and between the borehole locations.

The Contractor is also alerted to the potential for encountering methane gas above the lower explosive level (LEL) as observed during bedrock coring at Borehole C-06. Based on the methane encountered in this borehole and in other boreholes near this site, it should be expected that methane could be encountered during excavation/construction activities at elevations near or within the bedrock, throughout the project limits.

Consideration of the presence of these obstructions and methane gas must be made in selection of appropriate equipment and procedures for temporary works and/or construction/installation of the culvert foundation, as may be required.

<u>GEOSYNTHETIC CLAY LINER</u>

Special Provision October 2024

<u>1.0</u> SCOPE

This specification describes the requirements for the manufacturing, supply and installation of a reinforced Geosynthetic Clay Liner (GCL) in conjunction with the required excavation and fill placement as detailed in the Contract Documents.

2.0 REFERENCES

American Society for Testing and Materials (ASTM)

- ASTM D 4632, Standard Test Method for Grab breaking Load and Elongation of Geotextiles
- ASTM D 4643, Determination of Moisture Content of Soil by the Microwave Oven Method
- ASTM D 5261, Test Method for Measuring Mass per Unit Area of Geotextiles
- ASTM D 5887, Measurement of Index Flux through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter
- ASTM D 5890, Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners
- ASTM D 5891, Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners
- ASTM D 5993, Standard Test Method for Measuring Bentonite Mass per Unit Area of Geosynthetic Clay Liners
- ASTM D 6768, Standard Test Method for Tensile Strength of Geosynthetic Clay Liners

3.0 DEFINITIONS – N/A

4.0 DESIGN AND SUBMISSION REQUIREMENTS

4.01 Submission Requirements

4.01.01 Working Drawings

At least three (3) weeks prior to the use of the geosynthetic clay liner, the Contractor shall submit to the Contract Administrator six (6) copies of the Working Drawings and a method statement signed and sealed by the design Engineer and design-check Engineer.

4.01.02 Quality Test Certificates

Prior to installation of the geosynthetic clay liner, the Contractor shall submit quality test certification for each production lot supplied from a laboratory accredited by the Standards Council of Canada. The quality test certificates shall demonstrate compliance with all requirements of this special provision (see Tables 1 and 2)

4.01.03 Delivery, Storage, Handling, and Protection Procedure

At least 3 weeks before the commencement of work, the Contractor shall submit to the Contract Administrator the method of delivery, storage, handling and protection from damage by weather, traffic, construction staging and other causes as per the geosynthetic clay liner manufacturer's requirement.

A Manufacturer's Certificate of Conformance and a separate report shall be submitted to the Contract Administrator at least three (3) weeks prior to the delivery of each geosynthetic clay liner.

This report shall include the following information:

1. Name of the manufacturer
2. Product name
3. Roll numbers and identification
4. Mill test data
5. Sampling procedures and frequency
6. Results of quality control tests including description of test methods

Upon request, documentation describing the manufacturer's Quality Control program shall be made available to the Contract Administrator.

The delivery of each geosynthetic clay liner, shall not proceed until a Notice to Proceed has been received from the Contract Administrator.

4.02 As-Built Drawings

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

The as-built drawings shall be dated and bear the seal and signature of the design check Engineer and design Engineer

5.0 MATERIALS

The geosynthetic clay liner shall meet the requirements of Table 1

*** Design Fill – In – see Notes to Designer**

The geotextile components shall be non-woven, needle punched and woven polypropylene or polyester material with Typical and Minimum Average Roll Values (MARV) meeting or exceeding the criteria specified Table 1.

The bentonite shall consist of montmorillonite (sodium bentonite).

The geosynthetic clay liner product shall retain their structure during handling, placement and long-term service.

The geosynthetic clay liner shall be resistant to acid and alkali action, micro-organisms and insects and ultra violet degradation.

During shipping and on-site storage, the geosynthetic clay liner shall be protected at all times against exposure from sun; moisture, contamination by mud, dust, dirt; puncture; tearing and any other damaging or deleterious conditions.

Each geosynthetic clay liner roll shall have waterproof labels in two separate locations, which contains the following information:

- Manufacturer's name,
- Production Identification,
- Lot Number,
- Roll Number,
- Roll Weight, and
- Roll Dimensions.

6.0 EQUIPMENT - Not Used

7.0 CONSTRUCTION

7.01 General

The geosynthetic clay liner shall be installed and covered as specified in the Contract Documents.

7.01.01 Placement of the Geosynthetic Clay Liner

The placement of the geosynthetic clay liner shall be undertaken under the supervision of the Contractor's Engineer.

The manufacturer's representative shall be on site to oversee installation of the geosynthetic clay liner at the commencement of the installation.

7.02 Delivery, Storage and Handling

The product shall be suitably marked to identify its type, number and the manufacturer's name or trademark.

The Contractor shall handle the geosynthetic clay liner in such a manner as to avoid damage.

The Contractor shall protect the geosynthetic clay liner from exposure to sunlight to avoid ultraviolet degradation as per manufacturer's recommendation.

Protection of materials and works from damage by weather, traffic, construction staging, fire or vandalism and other causes shall be the responsibility of the Contractor.

7.02 Foundation Excavation

Foundation excavation shall be carried out to the design elevations shown on the drawings. Any softened, loosened or deleterious materials at the foundation footing elevation shall be sub-excavated and replaced with Granular A or Granular B material meeting the requirements of OPSS 1010.

The Contractor shall maintain the subgrade surface in suitable condition in accordance with OPSS 206 throughout the installation period

7.03 Installation of Geosynthetic Clay Liner Blocks

The Contractor shall:

1. Install the geosynthetic clay liner as indicated by the manufacturer and as detailed on the Contract Documents.
2. Place panels from the lowest elevation towards the highest elevation.
3. Overlap all geosynthetic clay liner panels. Along the width of the mat, the overlap of side joints shall be a minimum of 300 mm, or as specified by the manufacturer. The edges of the geosynthetic clay liner panels should be adjusted to smooth out any wrinkles or creases, in order to maximize contact with the underlying panel.
4. Remove any soil or other deleterious material present in the overlap zone
5. Place or pour a fillet of bentonite or other sealing material recommended by the manufacturer and acceptable to the Contract Administrator, in a continuous manner along the overlap zone at a rate of at least 1800 grams per lineal metre (0.25 pounds per lineal foot) to seal the overlaps. The bentonite used in the overlap areas shall meet the specifications for the bentonite used in manufacture of the geosynthetic clay liner as specified.
6. Cut the geosynthetic clay liner using a utility blade in a manner recommended by the manufacturer and exercise due care to prevent damage to any underlying or adjacent liner system components during cutting.
7. Replace or properly repair any geosynthetic clay liner damaged by stones or other foreign objects, or installation activities.
8. Repair any holes or tears in the geosynthetic clay liner by placing a geosynthetic clay liner patch over the hole, overlapping the edges of the hole or tear by at least 600 mm in all directions. Bentonite shall be applied between the geosynthetic clay liner and the patch in the overlap area, as per the manufacturer's specifications. Patches shall NOT be nailed or stapled.
9. Remove any soil or other material which may have penetrated the torn geosynthetic clay liner.
10. Place only the amount of geosynthetic clay liner which can be covered with earth material within the same day.
11. Install the geosynthetic clay liner in a way that reduces the potential for hydration of the mat prior to completion of construction of the overlying cover soil.
12. Remove the geosynthetic clay liner and replace with new material if it becomes hydrated before the overlying earth material is placed.
13. In the presence of wind, sufficiently weight all geosynthetic clay liner with sandbags or the equivalent. Install such sandbags during placement and maintain in place until replaced with cover material.
14. Provide temporary ballast as necessary to prevent movement of the geosynthetic clay liner both in storage and as placed due to windy conditions
15. Geosynthetic clay liner shall not be installed in standing water, snow or ice.
16. Geosynthetic clay liner shall not be installed during precipitation, high winds or other conditions that may cause rapid hydration of or damage to the geosynthetic clay liner.
17. Cover material shall be installed in such a manner that equipment does not drive directly on the liner material

7.04 Permanent Cover Materials

A Request to Proceed shall be submitted to the Contract Administrator prior to the placement of any permanent cover materials.

No permanent cover materials shall proceed until a Notice to Proceed has been received from the Contract Administrator.

8.0 QUALITY ASSURANCE - Not Used

8.0 MEASUREMENT FOR PAYMENT

Measurement is by Plan Quantity, as may be revised by Adjusted Plan Quantity, in square metres following the contours of the subgrade.

9.0 BASIS OF PAYMENT

Payment at the contract price for the above tender item shall be full compensation for all labour, equipment and material to do the work.

NOTES TO DESIGNER

Designer Fill-in:

* In consultation with the Regional Geotechnical Section and Foundations Office, insert the recommended specifications for the geogrid application.

TABLE 1 MINIMUM REQUIRED PROPERTIES		
Property	**ASTM Test Method**	**Specified Value**
Geotextiles		
Upper Non-Woven Cover:		
Mass/Unit Area	D 5261	200 g/m^2 MARV
Lower Woven Carrier:		
Mass/Unit Area	D 5261	105 g/m^2 MARV
Bentonite		
Swell Index	D 5890	Minimum 20 ml/2 g
Moisture Content	D 4643	Maximum 12 %
Fluid Loss	D 5891	Maximum 20 ml
Material (sodium bentonite)	XRD	90% montmorillonite

GCL Product		
Bentonite Mass/Unit Area	D 5993	Minimum 3,600 g/m^2
Tensile Strength	D 6768	Minimum 5kN/m MARV
Peel Strength *	D 4632	Minimum 93N
Index Flux	D 5887	Maximum 1x10^{-8} m^3/m^2/s
Permeability	D 5887	Maximum 5x10^{-9} cm/s

*Modified ASTM D 4632 to use a 100 mm wide grip.

TABLE 2
REQUIRED PRE-SHIPPING TESTING OF GCL

Property	ASTM Test Method	Specified Frequency
Geotextile Mass/Unit Area	D 5261	1 per 4,000 m^2
Swell Index; Fluid Loss	D 5890, D 5891	1 per shipment or per 50,000 kg max.
Moisture Content	D 4643	1 per 4,000 m^2
Bentonite Mass/Unit Area	D 5993	1 per 4,000 m^2
GCL Tensile	D 6768	1 per 10,000 m^2
GCL Grab Tensile for Peel Strength	D 4632	1 per 10,000 m^2
GCL Index Flux	D 5887	1 per 10,000 m^2
Permeability	D 5887	1 per 10,000 m^2

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