



Foundation Investigation and Design Report

Rehabilitation/Replacement of 25 Non-Structural Culverts at various locations of Highway 9, Highway 12, Highway, 400, Highway 401, Hwy 404 in Simcoe County, York Region, Durham Region, and City of Toronto - **Highway 12 CSPA Culvert Replacement (CV-0204-0012-0001)**

GWP: 2111-19-00

Assignment No. 2020-E-0028

MTO Central Region

Latitude: 44.377620; Longitude: -79.104760

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Geotechnical Foundation and Investigation Report

Project Name:

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Highway 12 CSPA Culvert Replacement (CV-0204-0012-0001)
GWP 2111-19-00
Assignment No. 2020-E-0028
Date: May 17, 2023*

Part I: Foundation Investigation Report

Rehabilitation/Replacement of 25 Non-Structural Culverts at various locations of Highway 9, Highway 12, Highway, 400, Highway 401, Hwy 404 in Simcoe County, York Region, Durham Region, and City of Toronto - **Highway 12 CSPA Culvert Replacement (CV-0204-0012-0001)**

1.0 Introduction

EXP Services Inc. (EXP) was retained by CONSOR Engineers LLC (CONSOR) on behalf of The Ministry of Transportation (MTO) to provide detailed foundation investigation and engineering services and pavement engineering services for the proposed rehabilitation/replacement of 25 Non-Structural Culverts project at various locations of Highway 9, Highway 12, Highway 400, Highway 401, Hwy 404 in Simcoe County, York Region, Durham Region, and City of Toronto. The findings, analyses and recommendations related to foundation scope are presented in a Foundation Investigation Design Report created for each culvert location. The work was undertaken under GWP 2111-19-00, Assignment No. 2020-E-0028. The terms of reference (TOR) and the scope of work for the foundation investigation are outlined in Ministry of Transportation Ontario's (MTO) Request for Proposal, dated February 2022. The scope of this report is specifically limited to the proposed replacement of the Corrugated Steel Pipe Arch (CSPA) culvert on Highway 12 (CV-0204-0012-0001).

The general design drawings for the proposed culvert replacement were provided to EXP by CONSOR. The purpose of the investigation was to evaluate the subsurface conditions along the existing culvert, and based on this data, to permit detailed design for the culvert replacement and to examine the suitability of open-cut replacement under a full highway closure or open cut-staged replacement with and without temporary protection systems.

The site-specific geotechnical investigation consisted of borings, soil sampling, borehole logging, and field and laboratory testing. The field and laboratory work for this structure was performed by EXP. Based on collected geotechnical data, this report provides an assessment of the geotechnical issues, geotechnical design parameters, and geotechnical foundation design recommendations for the proposed structure. Geotechnical-related construction recommendations are also provided.

This foundation investigation report has been prepared specifically and solely for the project described herein. It contains the factual results of the investigation and the laboratory testing completed for this project.

2.0 Structure Description

The contract drawings titled CV-204-0012-0001, prepared by CONSOR, dated March 2023 shows the 30% design configuration of the proposed replacement of the Highway 12 culvert. A summary of the proposed structure is as follows:

- The existing 1260 mm by 620 mm CSPA culvert is proposed to be replaced with a 1200 mm diameter HDPE culvert along the same alignment. Based on the 30% contract drawing the invert level of the new culvert is proposed to be at approximately Elev. 251.8 m and 251.5 m at the inlet and outlet, respectively.
- The existing Highway 12 profile grade is planned to remain unchanged. It is understood that the half and half stage construction approach will be used to replace the existing culvert.

The 30% contract drawings were included as part of this report is used for initial context to address the nature and scope of the investigation. It is understood that some changes might occur as a result of normal refinement or the findings of the geotechnical report.

3.0 Site Description and Geological Setting

3.1 Site Description

The CSPA culvert is located on Highway 12, about 560 m north of the intersection of Highway 12 with Highway 48 in the Durham region, Ontario, in the Ministry of Transportation (MTO) Central Region. Highway 12 generally runs in the north-south direction, however, at the location of Culvert CV-0204-0012-0001, Highway 12 runs in a northeast-southwest direction. At the site, Highway 12 is a two lane roadway, with a speed limit of 80 km/h (unless otherwise posted). Based on the contract drawings, the roadway is about 7.7 m wide from edge of pavement to edge of pavement, with 3.0 m and 1.6 m paved and gravel shoulders at the west side and 0.4 m and 3.5 m paved and gravel shoulders at the east side. In total, the existing roadway with both shoulders included is about 16.2 m wide along the culvert footprint. The existing culvert is positioned approximately perpendicular to the highway central line. The elevation of highway pavement centerline at the site is about 254.4 m. The roadway embankment above the existing ground is about 2.5 m on the west (inlet) side and 2.9 m on the east (outlet) side. The sides of the embankment slope at approximately 3.2H:1V on the west side and 2.6H:1V on the east side.

Based on the information provided in the drawings, the existing culvert is approximately 28.7 m long with a height and width of 1250 mm and 620 mm, respectively, and with up to $2\pm$ m of cover. The invert of the culvert is at approximate Elev. 251.9 m, and 251.5 m on west (inlet) and east (outlet) sides, respectively. Selected photographs of the site and existing culvert are presented in Appendix A. The site plan and cross-section profiles for the proposed culvert alignment are shown on the drawings attached in Appendix B.

The general site conditions were assessed during a site reconnaissance on July 27, 2022, and during the field investigation works that took place between January 23 and March 16, 2023. At the time of the field investigation, the approximate top of water elevation at the outlet of the culvert was measured to be about 251.7 m. No riprap to protect against scour or erosion was observed on either side of the culvert. Vegetation at the site consists predominantly of deciduous trees with some coniferous trees, wild bushes and shrubs, and other various species of mature vegetative cover. At the time of investigation, the vegetation immediately adjacent to the culvert openings appears to be light, however the ground was covered in snow. Based on google earth images taken in the late autumn of 2022, the vegetation appears to be relatively heavier just outside the culvert area.

Photographs 1 and 2 (taken by MTO) and Photographs 3 to 9 (taken by EXP between July 2022 and October 2022) in Appendix A show the existing site, culvert, and road conditions. Photographs 1 and 2 show the condition of the inside of the culvert. It can be seen that the culvert barrels are corroded up to the springline; this also provides an indication of the high creek water levels expected through the culvert. It can be seen that the bottom of the culvert is almost completely deteriorated due to corrosion at the inlet side of the culvert. Photographs 3 and 4 shows the outside of the culvert inlet and outlet, respectively, and the side slopes of the embankment surrounding the culvert. Both ends of the culvert are surrounded by light vegetation immediately adjacent to the culvert opening. Photographs 5 and 6 show the existing condition of the NBL and SBL lane of Highway 12 at the culvert location, respectively. The existing pavement appears to be in good condition.

3.2 Geological Setting

Based on a review of geological maps of Southern Ontario (Chapman and Putnam, 1984; 2007), the site is situated within the Peterborough Drumlin Field physiographic region where the predominate landforms are Till Plains

(Drumlinized) and Drumlins. The Peterborough Drumlin Field extends from Hastings County in the east to Simcoe County in the west and includes the drumlins south of the moraine in Northumberland County.

According to the Ministry of Northern Development and Mines, Map 2556 (Quaternary Geology of Ontario, Southern Sheet, 1991) the surface conditions in the vicinity of the project area typically consists of sandy silt to silty sand-textured till, commonly rich in clasts, often high in total matrix carbonate content. In addition, Map 2544 (Bedrock Geology of Ontario, Southern Sheet, 1991), the bedrock geology at the site consists of limestone, dolostone, shale, arkose, and siltstone belonging to the Ottawa Group and Simcoe Group of the Shadow Lake Formation.

4.0 Previous Investigations

There are no available previous geotechnical reports directly at this site in the MTO GEOCREs library. However, one report was available pertaining to a geotechnical investigation for several culvert extensions within the vicinity of Culvert CV-0204-0012-0001. The report is listed below for reference:

Geocres No. 31D-399: "Foundation Investigation and Design Report, Proposed Culvert Extensions/Replacements, Hwy 12 Widening from South Junction of Hwy 48 to North Junction of Hwy 48, W.P. 611-89-00, District 7 – Durham, Central Region, Sites 22-411C and 22-412C", Project: SPT 1024C, Prepared by: Shaheen & Peaker Limited, March 2003.

5.0 Investigation Procedures

5.1 Site Investigation and Field Testing

A site-specific investigation was undertaken by EXP between January 2023 to March 2023, and it included the following:

1. A walkover site assessment was carried out by a Geotechnical Engineer from EXP;
2. Subsequent to the borehole layouts in the field, existing utilities were cleared by public utility companies;
3. Traffic control required to close the driving lanes of Highway 12 during the drilling of on-road boreholes was provided by Barricade Traffic Services.
4. At the time of this report, the program involved the drilling of six (6) boreholes for sampling, consisting of 3 pavement and 3 geotechnical boreholes, numbered PV012-001-01 to PV012-001-03 and BH012-001-01 to BH012-001-03, respectively. Two (2) boreholes were located at each end of the existing culverts, which were PV012-001-01 and BH012-001-03. Additionally, two (2) boreholes were drilled on the west and east shoulders, which were PV012-001-01 and BH012-001-03, respectively. Finally, two (2) boreholes were drilled on the south and north sides of the culvert, which were BH012-001-01 and BH012-001-02, respectively. BH012-001-01 was drilled approximately 13.0 m south of the culvert, and BH012-001-02 was drilled approximately 19.2 m north of the culvert. The locations of the boreholes drilled during this investigation are shown on Drawing 1 in Appendix C. Table 1.1 provides a summary of the boreholes completed by EXP.
5. The boreholes drilled during this fieldwork were advanced using a MARL M5T Rubber Track Drill owned and operated by Drilltech drilling Ltd. The machines are equipped with solid stem augers, and fitted with capability for Standard Penetration Testing (SPT).

6. Soil samples in the boreholes were taken at frequent intervals of depth by the Standard Penetration Test method (SPT), in general accordance with ASTM D1586. The test consists of freely dropping a 63.5 kg hammer a vertical distance of 0.76 m to drive a 51 mm O.D. split barrel (SS-split-spoon) sampler into the ground. The number of blows of the hammer required to drive the sampler into the relatively undisturbed ground by a vertical distance of 0.30 m is recorded as the Standard Penetration Resistance, or the N-value, of the soil which is indicative of the compactness of granular (or cohesionless) soils (gravels, sands and silts) or the consistency of cohesive soils (clays and clayey soils);
7. The fieldwork was supervised by a member of EXP's engineering staff who directed the drilling and sampling operation, logged borehole data in accordance with MTO and/or ASTM Standards for Soils Classification, and retrieved soil samples for subsequent laboratory testing and identification;
8. All spoon samples obtained in the Standard Penetration Tests (SPT, ASTM D-1586) were placed in moisture proof bags after field classification. Samples were allocated from the spoon samples for moisture content testing without delay. They were subsequently re-examined under controlled laboratory conditions prior to assigning other laboratory tests;
9. Selected soil samples for chemical analytical testing were sent to the Bureau Veritas Laboratories (formerly Maxxam Analytics), a CALA-certified and accredited laboratory in Mississauga, Ontario. The selected soil samples for the analytical testing were placed in a laboratory prepared glass jar, labelled, and stored in a secure cooler.
10. The borehole locations and their ground surface elevations were surveyed by EXP using a Trimble DA2 GNSS receiver with Trimble Catalyst GNSS positioning, having an accuracy of ± 0.10 m horizontal and vertical directions. MTM NAD83 Zone 10 coordinates and the geodetic elevation for the boreholes are listed in Table 1.1 below. It can also be found on the Record of Borehole Sheet (Appendix D); and
11. Upon completion of drilling and field testing, the boreholes were backfilled with a mixture of bentonite and auger cuttings. groundwater level measurements were carried out in boreholes in accordance with MTO guidelines. The recorded groundwater levels after completion of drilling boreholes were presented in the borehole log sheets in Appendix D.
12. The borehole decommissioning was in general accordance with the Ministry of the Environment Regulation 903, as amended by Regulation 128/03 (the well regulation under the Ontario Water Resources Act).

Table 1.1: Summary of boreholes completed

Borehole No.	Borehole Location	Location (MTM NAD83 Zone 10)		Latitude	Longitude	Borehole Elevation (m)	Borehole Depth (m)
		Northing	Easting				
PV012-001-01	Inlet, off-road	4915365.1	336293.8	44.377609	-79.104785	251.9	3.7
PV012-001-02	West shoulder	4915359.7	336302.4	44.377560	-79.104678	254.1	2.1
PV012-001-03	East shoulder	4915359.2	336314.7	44.377555	-79.104523	254.4	2.1
BH012-001-01	On-road – North bound (NB) direction	4915346.2	336307.5	44.377438	-79.104614	254.3	10.4

Borehole No.	Borehole Location	Location (MTM NAD83 Zone 10)		Latitude	Longitude	Borehole Elevation (m)	Borehole Depth (m)
		Northing	Easting				
BH012-001-02	On-road – North bound (NB) direction	4915376.5	336318.5	44.377710	-79.104475	254.6	9.1
BH012-001-03	Outlet, off-road (east ditch)	4915351.6	336322.6	44.377486	-79.104425	251.6	5.2

5.2 Laboratory Testing

All samples returned to the laboratory were subjected to visual examination and classification. The laboratory testing program included the determination of natural moisture content on all samples and particle size distribution for approximately 25% of the collected soil samples. In addition, unit weight, Atterberg limits and grain size analysis (sieve and hydrometer) tests were performed on selected soil samples (performed by EXP). Chemical analyses were also carried out on one soil samples selected by EXP. The samples were tested at the Bureau Veritas Laboratories (formerly Maxxam Analytics), a CALA-certified and accredited laboratory in Mississauga, Ontario. All of the laboratory tests were carried out according to MTO and/or ASTM Standards as appropriate. The performed laboratory testing program is listed in Table 1.2.

Table 1.2: List of Laboratory Test Completed by EXP

Borehole No.	Moisture Content	Atterberg Limits	Sieve	Hydrometer	Unit Weight	Corrosivity
PV012-001-01	4	1	1	1	---	---
PV012-001-02	3	---	1	---	---	---
PV012-001-03	3	---	---	---	---	---
BH012-001-01	11	1	3	2	---	---
BH012-001-02	10	1	2	2	---	1
BH012-001-03	4	2	2	2	---	---

The laboratory test results are provided on the attached borehole log sheets in Appendix D as well as graphically in Appendix E.

6.0 Subsurface Conditions

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the borehole log sheets in Appendix D. Laboratory test results of grain size analyses and Atterberg limit tests are provided in Appendix E. The “Explanation of Terms Used in Report” preceding the borehole logs in Appendix D forms an integral part of and should be read in conjunction with this report.

A borehole location plan and cross section subsurface profiles are provided in Appendix C. It should be noted that the stratigraphic boundaries indicated on the borehole log and cross section stratigraphic profiles are inferred from semi-continuous sampling, observations of drilling progress and results of Standard Penetration Tests. These boundaries typically represent transitions from one soil type to another and should not be regarded as exact planes of geological change. Furthermore, subsurface conditions may vary between and beyond the borehole locations.

In general, the subsoil condition below the roadway consists of non-cohesive fills underlain by native sandy silt till layers or a buried topsoil layer overlaying a layer of clayey silt till which is further underlain by a layer of non-cohesive silt and sand tills. At the inlet side, the subsurface conditions consist of topsoil overlying silt and sand till followed by clayey silt till underlain by sandy silt till. At the outlet side, topsoil overlays clayey silt followed by a layer of sandy silt till.

A detailed description of the subsurface conditions encountered is discussed further in subsequent sections. It should be noted that the following sections are based on the geotechnical investigation conducted by EXP. The lab test results available at the time of writing this draft report are included, while the other results will be added in the next submission of this report.

6.1 Subsoils

6.1.1 Asphalt

A pavement structure consisting of asphalt was encountered at the ground surface in boreholes BH012-001-01, BH012-001-02 and PV012-001-02. The thickness of asphalt ranged from approximately 50 mm to 230 mm.

6.1.2 Topsoil

A topsoil layer was encountered at the ground surface of boreholes PV012-001-01 and BH012-001-03. The thickness of this layer was approximately 100 mm. An additional topsoil layer ranging from 390 mm to 410 mm in thickness was encountered underlying the silty sand fill in boreholes BH012-001-01 and BH012-001-02. The layer contained rootlets and organics and was generally moist to wet ranging from dark grey to black in color.

6.1.3 Cohesionless Fill

Cohesionless fill layers with trace to some clays were encountered in boreholes BH012-001-01, BH012-001-02, PV012-001-02 and PV012-001-03. The approximate elevations of the surface and base of each fill layer, thickness, description and SPT (N Value) encountered in boreholes are summarized in Table 1.3 below:

Table 1.3: Summary of Cohesionless Fill Layers

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH012-001-01	254.2	253.6	0.2	0.6	Gravelly Sand	34
	252.8	252.3	1.5	0.5	Silty Sand	19
BH012-001-02	254.4	253.9	0.2	0.5	Gravelly Sand	-

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
	253.9	252.6	0.8	1.3	Silty Sand	13 – 20
PV012-001-02	254.0	252.5	0.1	1.5	Sand with Gravel	20
PV012-001-03	254.4	252.8	0.0	1.6	Sand with Gravel	17 – 50

The composition of the layers encountered is as presented in Table 1.3 above. The layer was moist with color ranging from grey to brown. The SPT "N" values within this layer ranged from 17 to 50 blows per 300 mm penetration, corresponding to compact to very dense but generally compact in compactness condition.

Moisture Content:

- 3% to 24.9%

Grain Size Distribution:

- 19% to 28% gravel;
- 36% to 63% sand;
- 27% to 29% silt;
- 10% to 18% clay;
- 9% to 21% silt and clay;

The results of the moisture content and grain size distribution tests are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution tests are also provided on Figure 1 and Figure 2 in Appendix E.

6.1.4 Cohesive Till

A cohesive till layer with traces of gravel was encountered below the topsoil in boreholes BH012-001-01 to BH012-001-03 and below the silt and sand till layer PV012-001-01. The approximate elevations of the surface and base of the till layer, thickness, description and SPT (N Value) encountered in boreholes are summarized in Table 1.4 below:

Table 1.4: Summary of Cohesive Till Layers

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH012-001-01	251.9	249.8	2.4	2.1	Clayey Silt Till	7 – 11
BH012-001-02	252.2	250.0	2.4	2.2	Clayey Silt Till	10 – 13

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH012-001-03	251.5	249.3	0.1	2.2	Clayey Silt Till	5 – 9
PV012-001-01	251.1	249.6	0.8	1.5	Clayey Silt Till	6 – 9

The cohesive till layer consisted of clayey silt which is sandy with trace to some gravel. Trace organics were encountered at the culvert outlet (BH012-001-03). The layer was moist to wet with color ranging from brown to grey. SPT "N" values ranged from 5 to 13 blows per 300 mm penetration corresponding to firm to stiff in consistency.

The results of moisture content, grain size distribution and Atterberg Limits tests are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution and Atterberg limit tests are also provided on Figures 3 to 6 in Appendix E.

Moisture Content:

- 7% to 26%

Grain Size Distribution:

- 5% to 13% gravel;
- 28% to 50% sand;
- 36% to 40% silt;
- 11% to 30% clay;

Atterberg Limits:

- Liquid Limit: 17% to 33%
- Plastic Limit: 12% to 16%
- Plasticity Index: 5% to 17%

6.1.5 Cohesionless Till

Cohesionless till layers were encountered in all boreholes. The approximate elevations of the surface and base of each till layer, thickness, description and SPT (N Value) encountered in the boreholes are summarized in Table 1.5 below:

Table 1.5: Summary of Cohesionless Till Layers

Borehole	Elevation (m)		Layer Surface Depth (m)	Layer Thickness (m)	Layer Description	SPT "N" Value Range
	Top	Bottom				
BH012-001-01	249.8	244.0	4.6	3.1	Silt and Sand Till	13 – 56
BH012-001-02	250.0	245.5	4.6	4.5	Silt and Sand Till	22 – 26
BH012-001-03	249.3	246.4	2.3	2.9	Sandy Silt Till	26 – 38
PV012-001-01	251.8	251.1	0.1	0.7	Silt and Sand Till	3
	249.6	248.2	2.3	1.4	Sandy Silt Till	36 – 40
PV012-001-02	252.5	251.9	1.5	0.6	Sandy Silt Till	10
PV012-001-03	252.8	252.2	1.5	0.6	Sandy Silt Till	11

The cohesionless till layers consisted predominantly of silt and sand with gravel content ranging from some gravel to gravelly, trace to some clay, and occasional cobbles and boulders which were inferred based on the SPT sampler being unable to advance. The layer was moist to wet with color ranging from brown to grey. The SPT "N" values within this layer ranged from 3 to 56 blows per 300 mm penetration corresponding to very loose to very dense but generally compact to dense in compactness condition.

The results of moisture content, grain size distribution and Atterberg Limits tests are provided on the record of borehole sheets in Appendix D. The results of the grain size distribution and Atterberg limits tests are also provided on Figure 7 and Figure 8 in Appendix E.

Moisture Content:

- 7% to 18%

Grain Size Distribution:

- 13% to 20% gravel;
- 34% to 41% sand;
- 35% to 36% silt;
- 10% to 11% clay;

Atterberg Limits:

- Liquid Limit: 16% to 18%
- Plastic Limit: 11% to 12%

- Plasticity Index: 5% to 6%

6.2 Groundwater and Surface Water Conditions

The groundwater levels in boreholes were observed during and upon completion of their drilling during EXP's investigation in April 2021. The groundwater levels encountered in the boreholes are shown on the borehole logs and presented below in Table 1.6.

Table 1.6: Summary of Observed Groundwater Levels

Borehole	Ground Surface Elevation (m)	Water Level Depth/ Elevation (m) ¹	Date Measured	Comments
BH012-001-01	254.3	-	Jan. 23, 2023	Cave-in at 2.60 m, retrieved samples were fully saturated from 4.6 m below ground surface to end of borehole
BH012-001-02	254.6	4.93 / 249.7	Jan. 24, 2023	Upon completion of drilling
BH012-001-03	251.6	-	Mar. 16, 2023	Cave-in at 0.46 m, <i>retrieved samples were fully saturated from 0.8 m below ground surface to end of borehole</i>
PV012-001-01	251.9	-	Mar. 16, 2023	Cave-in at 0.46 m, <i>retrieved samples were fully saturated from the ground surface to end of borehole</i>
PV012-001-02	254.1	Dry	Jan. 24, 2023	Upon completion of drilling
PV012-001-03	254.4	Dry	Jan. 24, 2023	Upon completion of drilling

Note:

1. Depths are relative to ground surface

The measured elevations of the top of creek water at the existing CSP culvert location on January 23, 2023, were approximately Elev. 251.7 m at the outlet and inlet sides.

Groundwater levels would be expected to reflect levels in the adjacent open water and to fluctuate seasonally. Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year and lower levels during drier periods.

6.3 Chemical Analysis

One soil sample was selected for chemical analysis during the current investigations performed by EXP. The soil sample collected by EXP was tested at a CALA-certified and accredited laboratory. The results of the corrosion potential chemical analysis testing including sulfide, chloride, sulfate, pH, electrical conductivity, resistivity and redox potential are included in Appendix E and summarized in Table 1.7.

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Table 1.7. Summary of chemical analysis results

Borehole ID	Sample	Depth (m)	Chloride (ppm)	Sulphate (ppm)	pH	Electrical Conductivity (umho/cm)	Resistivity (ohm-cm)	Redox Potential (mV)
BH012-001-02	SS5	2.64	1900	220	9.05	3880	260	380

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Part II: Foundation Design Report

Rehabilitation/Replacement of 25 Non-Structural Culverts at various locations of Highway 9, Highway 12, Highway, 400, Highway 401, Hwy 404 in Simcoe County, York Region, Durham Region, and City of Toronto - **Highway 12 CSPA Culvert Replacement (CV-0204-0012-0001)**

7.0 ENGINEERING DISCUSSION & RECOMMENDATIONS

7.1 General

This section of the report provides geotechnical design recommendations for the replacement of the Corrugate Steel Pipe Arch (CSPA) culvert on Highway 12 (Culvert ID: CV-0204-0012-0001), located approximately 560 m north of the intersection of Highway 12 with Highway 48 in the Durham region (Latitude: 44.377620; Longitude: -79.104760) in the Ministry of Transportation (MTO) Central Region. The recommendations are based on interpretation of the factual data obtained from the boreholes advanced during the current investigation at the site performed by EXP between January 23 and March 16, 2023. The compiled factual data is presented in **Part I-Foundation Investigation Report** of this report. The interpretation and recommendations provided are intended solely to permit designers to assess foundation alternatives and design the new culvert replacement. Comments on construction are only provided to highlight issues that could affect the design. Contractors bidding on the works should make their own assessments of the factual data and how it might affect construction means and methods, scheduling and the like.

Based on the AutoCAD drawings provided by MTO and information provided in the TOR and contract drawings, the existing culvert is approximately 28.7 m long with a height and width of 1250 mm and 620 mm, respectively. The culvert is approximately perpendicular to the highway centreline. The elevation of the highway central line at the culvert location is approximately Elev. 254.4 m. The flow through the culvert is from west to east, following the natural topographic conditions in the vicinity of the site.

It is also understood that half-and-half open cut and cover staged construction with unsupported cut temporary side slope of 1H:1V parallel and perpendicular to highway centerline or with the use of temporary protection systems are under consideration for the replacement of culvert. Shoulder strengthening will also be required on both the NBL and SBL to facilitate this option.

As proposed in the contract drawings, the existing CSPA culvert will be replaced with a 1200 mm high density polyethylene (HDPE) pipe. It is understood that the new culvert will be installed at the same location as the existing culvert with the proposed culvert invert at about Elev. 251.8 m to 251.5 m from inlet to outlet, respectively. No significant grade change nor widening are expected at the culvert location.

This part of the report addresses the geotechnical design of the foundation for the new culvert by providing geotechnical design parameters at the Ultimate Limit State (ULS) and Serviceability Limit States (SLS) as well as other geotechnical parameters that may be required in accordance with the latest edition of the *Canadian Highway Bridge Design Code (CHBDC) (CAN/CSA-S6-19)*, the *Canadian Foundation Engineering Manual (CFEM) (2006)*, *MTO Gravity Pipe Design Guidelines (May 2007)*, *Guideline for MTO Foundation Engineering Services, Version 02 (October 2020)* and generally accepted good practice. Pertinent construction issues from a geotechnical standpoint are examined in general accordance with the Terms of Reference provided to us in the (MTO) Request for Proposal, dated February 2022. The assessment involved review of options for replacement of the existing culvert along the proposed alignment using an open-cut replacement method with full highway closure or staged open-cut replacement methods using unsupported cut sides and/or with a properly designed temporary roadway protection system. The protection of construction site by cofferdams is also addressed.

7.2 Expected Ground Conditions

The following ground conditions along the proposed culvert alignment are evident from the current investigation:

- a) Highway 12 is a two-lane road (~ 7.7 m wide) with 3.0 m and 1.6 m paved and gravel shoulders at the west side and 0.4 m and 3.5 m paved and gravel shoulders at the east side at the culvert location. In total, the existing roadway with both shoulders included is about 16.2 m. Highway 12 is generally oriented in the north-south direction, but at the site location it is oriented in a northeast-southwest direction. The highway crosses the 1250 mm by 620 mm CSPA culvert with up to approximately 2.2 m of embankment fill above the crown. The current elevation of the highway centerline is about Elev. 254.4 m at the culvert location. The sides of the embankment slope at approximately 3.2H:1V on the west side and 2.6H on the east side. The roadway embankment above the existing ground is about 2.5 m high on the west (inlet) side and 2.9 m high on the east (outlet) side. The existing highway embankment side slopes near the existing culvert did not show any visible signs of distress at the time of the investigation. Additionally, the road surface at the culvert location appears to be in good condition. However, the culvert was found to be in deteriorated condition. The bottom of the existing culvert barrel is highly disintegrated due to the corrosion, and the bottom of the culvert barrel is corroded up to the springline in general.
- b) Below the pavement structure, the highway embankment consists of gravelly sand fill (~0.6 m to 1.5 m thick) followed by silty sand fill (~ 0.5 m to 1.2 m thick) which was encountered in borehole BH012-001-01 and BH012-001-02. In boreholes BH012-001-01 and BH012-001-02, the embankment fill is underlain by topsoil (~ 0.4 m) over firm to stiff clayey silt till (~2.2 m thick) followed by silt and sand till (~4.5 m to 5.8 m thick). In pavement boreholes PV012-001-02 and PV013-001-03, the embankment fill is underlain by sandy silt till (~0.6 m thick). Cobbles and/or boulders were inferred within the native soils based on the split spoon sampler being unable to advance. Bedrock was not encountered within the investigated depth.
- c) At the inlet, the topsoil (~0.1 m thick) is underlain by very loose silt and sand till (~0.7 m thick) followed by firm to stiff clayey silt till (~1.5 m thick) underlain by dense sandy silt till (~1.4 m thick) up to an investigated depth of 3.7 m (Elev. 248.2 m). At the outlet, the topsoil (~0.1 m thick) is underlain by firm to stiff clayey silt till (~2.2 m thick) followed by dense sandy silt till (~2.9 m thick) up to an investigated depth of 5.2 m (Elev. 246.4 m).
- d) As per the survey performed during the investigation, the inverts of the inlet (west side) and outlet (east side) are at about Elev. 251.9 m, and 251.5 m for the existing culvert, respectively.
- e) At the time of investigation (January 23, 2023), the top of the creek water was at Elev. 251.7 m. The groundwater table measured in the boreholes drilled at the site was at about Elev. 249.7 m. Groundwater levels would be expected to reflect levels in the adjacent open water. Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year (such as spring thaw and late fall) and lower levels during drier periods.

7.3 Construction Alternatives

Based on the contract drawings, it was understood that the preferred method of culvert replacement is to use half-and-half open cut and cover staged construction with 1H:1V unsupported cut sides (i.e. without the use of temporary protection systems). Additional methods that should be considered include open-cut staged replacement with temporary protection systems and open-cut replacement under a full highway closure. The existing CSPA culvert is proposed to be replaced with a 1200 mm diameter HDPE pipe. Shoulder strengthening will also be required on both the NBL and SBL to facilitate this option. No significant grade change nor widening are expected at the culvert location. It is planned that the new culvert will be placed at the same location as the existing culvert.

The following construction methods were considered as possible construction alternatives for the culvert replacement at this site:

1. Open-cut replacement under a full highway closure
2. Half-and-half construction maintaining signalized one-lane of traffic on the existing embankment during construction. The following three options of excavation and replacement using the half-and-half approach were considered:
 - A. Construction with unsupported cut side slope of 1H:1V parallel and perpendicular to highway centerline, including shoulder strengthening/ temporary widening on the NBL and SBL of the roadway.
 - B. Construction using roadway protection parallel to highway centerline and unsupported excavation of cut sides
 - C. Construction using roadway protection parallel to highway centerline and braced cut sides

All methods considered utilize a cut and cover approach for culvert replacement which allows complete removal of the existing culvert, but it requires disruption of traffic.

The following Table 2.1 summarize advantages and disadvantages of considered construction alternatives. The table also shows assessed risk/consequences and relative costs of the considered methods. Schematic diagrams of considered alternatives using temporary protection systems are attached in Appendix H.

Table 2.1: Construction alternatives for culvert replacement (see schematic sketches in Appendix H)

Installation Method	Advantages	Disadvantages	Relative Cost	Ranking
<i>Option 1: Open Cut Unsupported Excavation under a Full Highway Closure</i>	<ul style="list-style-type: none"> Assessment of the foundation soil No excavation support required Install entire new culvert at once No need to temporarily divert surface water flow since the existing SPCSP culvert can be used to maintain the surface water flow Removal of existing SPCSP culvert Straightforward construction Short mobilization time Existing embankment fill can be removed and replaced with free draining granular material, if necessary Adaptable to changing ground conditions Experienced contractors 	<ul style="list-style-type: none"> Traffic interruption Long detour around site using other existing roads required Large amount of soil to be excavated Existing fills and native soils require 2H:1V cut slopes to maintain stability Erosion control of temporary cuts required Potential claims to compensate vehicle occupants and local business for delays or time lost due to detour routes Risk of cost overrun and inability to finish job: low 	Less expensive than staged cut and cover approaches	1
<i>Option 2A: Half-and-half Construction with Unsupported Cut Side Slope of 1H:1V Parallel and Perpendicular to Highway Centerline</i>	<ul style="list-style-type: none"> Traffic flow maintained at the site during construction Short mobilization time Straight forward construction and construction procedures Existing embankment fill can be removed and replaced with free draining granular material, if necessary 	<ul style="list-style-type: none"> Traffic Interruption Large amount of soil to be excavated Larger disruption of embankment compared to other half-and-half methods Need to temporarily control existing creek water Shoulder strengthening and/or temporary widening of existing roadway may be required to facilitate this option Risk of cost overrun and inability to finish job: moderate 	More expensive than open cut unsupported excavation with full highway closure	2

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Installation Method	Advantages	Disadvantages	Relative Cost	Ranking
Option 2B: Half-and-half Construction with TPS Parallel to Highway Centerline and Unsupported Cut Sides (Figure H1.A, Appendix H)	<ul style="list-style-type: none"> Traffic flow maintained at the site during construction Short mobilization time Straight forward construction and construction procedures Existing embankment fill can be removed and replaced with free draining granular material, if necessary 	<ul style="list-style-type: none"> Traffic interruption Roadway protection in the middle of the road of up to ~3.3 m high required to maintain one lane of traffic Require dewatering to provide safe temporary cut slopes High cost of roadway protection system Large amount of soil to be excavated Need to temporarily control existing creek water Risk of cost overrun and inability to finish job: moderate to high 	More expensive than Option 2A due to high cost of shoring system	3
Option 2C: Half-and-half Construction with TPS Parallel to Highway Centerline Braced or Anchored Cut Sides (Figure H1.B, Appendix H)	<ul style="list-style-type: none"> One or possibly two lanes of traffic flow maintained on existing road (e.g. steel decking, but costly) Global stability of excavation enhanced by narrow geometry Less traffic interruption than with unsupported cut sides approach Temporary decking could be usable over braced cut to allow for excavation of both halves prior to diverting stream and backfilling Cost savings due to limited excavation and backfill Cost saving due to no need for temporary cut slopes and extensive dewatering 	<ul style="list-style-type: none"> Traffic interruption Roadway protection of up to ~3.3 m high (at C/L) required to maintain one lane of traffic if steel decking is not possible High cost of roadway protection system and/or decking Require side shoring and bracing Bracing (e.g., struts) may interfere with excavation Excavation of material and placement of bracing required in limited space Need to decommission the shoring system Need to temporarily control existing creek water Risk of cost overrun and instability to finish job: low to moderate 	More expensive than other cut and cover options due to high costs for shoring system and temporary decking	4

Based on the above list of advantages and disadvantages of the possible construction methods, we recommend the following ranking of the considered options:

1. OPTION 1: Open-cut replacement under a full highway closure
2. OPTION 2A: Half-and-half construction with unsupported cut side slope of 1H:1V parallel and perpendicular to highway centerline
3. OPTION 2B: Half-and-half construction with unsupported cut sides (Figure I1.A, Appendix H)
4. OPTION 2C: Half-and-half construction with braced or anchored cut sides (Figure I1.B, Appendix H)

The following sections discuss these options in more details.

7.4 Open Cut Installation

7.4.1 Installation Alternatives

7.4.1.1 Option 2: Open-cut Replacement under a Full Highway Closure

From geotechnical and economic considerations, open cut unsupported excavation appears to be one of the most viable culvert replacement methods if the local detour is available and a full highway closer is possible. With this approach, the existing culvert will be removed, and the existing foundation soil conditions will be assessed. The stability analyses show that the existing embankment fill could be excavated in open cut with the temporary slopes of not steeper than 1H:1V. The fill will be replaced with free draining granular material. Sections 7.4.4.1, 7.4.3.4 and 7.4.3.5 will address excavation, bedding and backfill considerations, respectively. However, with the flow of traffic and its use this option is unlikely to be considered.

7.4.1.2 Option 1: Half-and-Half Construction

The half-and-half construction method could be utilized to maintain the flow of the traffic on Highway 12 (see Figures H1.A and H1.B, Appendix H for Options 2B and 2C which use temporary protection systems). In this method, one lane of the existing highway will be used to maintain the local traffic while the other half of the existing highway will be excavated and the half of the existing culvert will be exposed. Then the excavated portion of the existing culvert will be removed and replaced with a new culvert, followed by rebuilding of that half of the embankment to grade. Upon completion of the new embankment, the traffic will be moved onto the new fill and the process will be repeated to complete the construction and culvert replacement.

For the options that require the use shoring systems, the temporary excavation at the site required to remove half of the existing embankment would be up to approximately 3.3 m deep. Therefore, temporary shoring such as a sheet pile system will be required as a roadway protection system to allow staging excavation/construction. It will be the Contractors responsibility to design a suitable temporary support system for the MTO review prior to installation. The Contractor is to follow OPSS 902 regarding excavations for structures, and OPSS.PROV 539 regarding temporary protection systems. Recommendations for a temporary roadway protection are given in Section 7.6. Using the half-and-half construction approach, two methods of culvert replacement were considered for this site suitable as discussed below:

- A. Construction with unsupported cut sides parallel and perpendicular to highway centerline
- B. Construction using roadway protection and unsupported excavation of cut sides
- C. Construction using roadway protection and braced or anchored cut sides

7.4.1.2.1 Option 2A: Half-and-Half Construction with Unsupported 1H:1V Cut Side Slopes

This method entails excavating approximately half the existing embankment at a time without the use of temporary protection systems. The side slopes of the temporary cut parallel and perpendicular to the highway centerline should be no steeper than 1H:1V (see Section 7.8.2 for discussion of open cut stability).

This option could be the most economical half-and-half staged construction option since a temporary shoring structure is not required, however it will be the more disruptive to the embankment compared to Options 1B and 1C. Additionally, shoulder strengthening and/or temporary widening on both lanes may be required to facilitate this option.

7.4.1.2.2 Option 2B: Half-and-Half Construction with Unsupported Cut Sides

This method provides roadway protection parallel to the highway between two lanes, and allows to divert traffic to the one side and undertake open cut with sloping sides at the other side (see Figure H1.A, Appendix H). The roadway protection can take the form of reversible shoring such as a sheet pile system or a soldier pile and lagging system for horizontal support. Once one-lane is completed the supports can be reversed and the other lane constructed in similar fashion. The shoring system would likely be decommissioned in place. Temporary surface water flow control must be developed by the Contractor.

This option could be more economical due to possible cost savings for reversible wall configuration, but it will be more disruptive to the highway embankment than the half-and-half construction with braced or anchored cut sides option (Option 2C) since it needs to excavate a larger amount of soil. However, it could be less economical than Option 1A since a temporary shoring system is required.

7.4.1.2.3 Option 2C: Half-and-Half Construction with Braced or Anchored Cut Sides

This method provides braced or anchored cut shoring system perpendicular to the highway for face protection and to allow culvert construction (see Figure H1.B, Appendix H). Excavation in this case would have to accommodate the necessary cross-bracing, such as struts, which in the relatively narrow working area could create difficulties for installation of the new culvert. Installation of tiebacks could be the alternative solution. Temporary decking could possibly be used over the supported cut to allow for excavation of both halves prior to backfilling. However, decking would be costly. Like Option 1.A, temporary surface water flow control must be performed/developed by the Contractor.

This option with braced or anchored cut sides will disrupt less of the embankment than the other half-and-half construction methods, but it might cost more due to the cost of an additional shoring system. However, the global stability of excavation will be enhanced with that shoring system. Both options require decommissioning of shoring system upon completion of the work.

7.4.2 Culvert Replacement

Based on the contract drawings, the existing CSPA culvert is proposed to be replaced with a 1200 mm diameter HDPE pipe. However, for completeness, different culvert types are considered in this report in the following section. The choice of culvert type and size depends on hydraulic performance, staging requirements, geotechnical resistance available in the foundation soils, initial cost, maintenance costs, ease of construction, water and soil corrosiveness, salvageability and local availability of materials and equipment. However, from a geotechnical perspective, the following culvert replacement options were considered at this site:

- High-density polyethylene (HDPE) pipe,
- Corrugated Steel Pipe (CSP) culvert,
- Precast rigid frame concrete box culvert,
- Cast-in-place rigid frame concrete box culvert, and
- Cast-in-place rigid frame open footing concrete culvert supported on shallow foundations.

Based on the subsurface information obtained from the site investigations, 0.5 m of engineered fill over firm to stiff clayey silt till and loose silt and sand till is considered suitable for supporting any suggested culvert, assuming that any underlying organic soils (peat) or soft or very loose materials are to be replaced with clean and compactable soils.

It is noted that regardless of the option selected, the existing CSPA culvert is to be removed. This will require excavation down to the existing founding elevation for all options (Elev. 251.9 m to Elev. 251.5 m from inlet to outlet). This suggests the need for surface/groundwater control as discussed in Section 7.7 below.

In general, any loose and/or soft soils encountered below the existing embankment should be excavated and replaced with engineered fill. If the depth of excavation to remove unstable soils is excessive, using a geotextile fabric in accordance with OPSS.PROV 1860, Class II Non-Woven (OPSS 1860 II-N), in conjunction with engineered fill can be considered to assist in providing a stable base for the new culvert. Based on previous experience, typically it should consist of Granular A or Granular B Type II (OPSS.PROV 1010) with a minimum thickness of 500 mm beneath the culvert and extend a minimum of 500 mm horizontally on either side of the culvert edge. If clear stones are used as bedding under the water, the fabric should be installed a manner to mitigate the migration of fines from adjacent material.

An evaluation of structure alternatives including advantages, disadvantages, risk/consequences and relative cost from a foundation perspective is provided in Table 2.2.

Table 2.2: Evaluation of culvert replacement alternatives

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/ Consequences
High-Density Poly-Ethylene (HDPE) Pipe	1	<ul style="list-style-type: none"> ▪ Straightforward construction, easy to install ▪ Reduced construction period, consequently, traffic management and water control period ▪ Reduced excavation depth ▪ Resistant to Corrosion ▪ Low cost, durable, has long design life 	<ul style="list-style-type: none"> ▪ Requires bedding material ▪ Disturbance of natural streambed ▪ Possible sediment accumulation in the upstream of the culvert ▪ Sensitivity to stress cracking 	Low	<ul style="list-style-type: none"> ▪ Risk of unacceptable differential settlements if the entire foundation is not supported on competent soil
Corrugated Steel Pipe (CSP) culvert	2	<ul style="list-style-type: none"> ▪ Straightforward construction ▪ Reduced construction period, consequently, traffic management and water control period ▪ Reduced excavation depth 	<ul style="list-style-type: none"> ▪ Requires bedding material ▪ Limited design life ▪ Potential for corrosion ▪ Disturbance of natural streambed ▪ Possible sediment accumulation in the upstream of the culvert 	Low	<ul style="list-style-type: none"> ▪ Risk of unacceptable differential settlements if the entire foundation is not supported on competent soil ▪ Risk of structure segment loss due to corrosion
Precast rigid frame concrete box culvert	3	<ul style="list-style-type: none"> ▪ Straightforward construction ▪ Reduced construction period; consequently, traffic management and water control period ▪ Reduced excavation depth ▪ Can be more readily installed during cold weather conditions 	<ul style="list-style-type: none"> ▪ If floor is thin and poorly reinforced, it may heave and crack ▪ During high flows, the concrete floor can be undermined ▪ Susceptible to defects/leakage at joints ▪ Requires bedding material ▪ Disturbance of natural streambed ▪ Possible sediments accumulation in the upstream of the culvert 	Low to medium	<ul style="list-style-type: none"> ▪ Risk of unacceptable differential settlements if the entire foundation is not supported on competent soil ▪ Risk of leaking from joints if not properly installed
Cast-in-place rigid frame concrete box culvert	4	<ul style="list-style-type: none"> ▪ Suitable if site is not appropriate for heavy equipment for installation of precast sections 	<ul style="list-style-type: none"> ▪ Slower construction process ▪ If floor is thin and poorly reinforced, it may heave and crack 	Likely more expensive than precast due to longer duration of installation	<ul style="list-style-type: none"> ▪ Risk of unacceptable differential settlements if the entire foundation is not supported on competent soil

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/ Consequences
		<ul style="list-style-type: none"> Reduced excavation depth Culvert design can be customized in the field for high stress or load conditions or other site-specific requirements 	<ul style="list-style-type: none"> During high flows, the concrete floor can be undermined Requires concrete curing Disturbance of natural streambed Possible sediments accumulation in the upstream of the culvert 		<ul style="list-style-type: none"> Risk of disturbance of base during construction
Cast-in-place rigid frame open footing concrete culvert	5	<ul style="list-style-type: none"> Wider span may be considered to maintain existing channel and so allows for natural streambed to remain intact Less accumulation of sediments in the upstream of culvert 	<ul style="list-style-type: none"> Deeper excavation and/or below water excavation required Dewatering system might be required Require placement of lean concrete 	Likely more expensive than other options due to need for dewatering and deeper excavation	<ul style="list-style-type: none"> Risk of unacceptable differential settlements if the entire footing is not supported on competent soil Risk of delay in construction due to deeper excavation below water if proper dewatering is not maintained Higher scour risk

The key findings and conclusions of the assessment for the culvert type are summarized as follows:

- HDPE, CSP and closed concrete box culverts, either precast or cast-in-place, installed with appropriate granular bedding over the subgrade were determined to be feasible. Among these options, the use of a HDPE Pipe culvert or CSP culvert is a more economical option than a concrete culvert. It should be noted that the proposed structure must meet the required flow capacity and hydraulic requirements.
- An open-footed concrete culvert on spread footings is feasible at this site, however, likely more expensive than other options due to deeper excavations required for casting the footings with dewatering.

7.4.3 Culvert Foundation Recommendations

7.4.3.1 Geotechnical Resistance

Based on the subsurface stratigraphy encountered at this site and the proposed replacement of the existing culvert, the following Table 2.3 summarizes the recommended resistances at founding elevations for different types of culverts. The geotechnical resistances provided are for vertical loading conditions only; load eccentricity and load inclination effects should be addressed in accordance with the CHBDC and its commentary. The geotechnical resistances provided in sections below were factored with typical consequence factors of 1.0 at ULS and SLS and high degree of understanding (factor of 0.5 at ULS and factor of 0.9 at SLS) in accordance with Table 6.1 and 6.2 of the CHBDC S6-19.

Table 2.3: Recommended spread footing design parameters

Culvert Type	Founding Elevation (m)	Footing Size (m)	Founding Soil Type	Factored Geotechnical Resistance at ULS (kPa)	Geotechnical Reaction at SLS ² (kPa)
HDPE Culvert, CSP culvert, precast or cast-in-place rigid frame concrete box culvert	251.8 to 251.5 (inlet to outlet)	~1.2	~ 0.5 m thick Granular 'A' or 'B' Type II ⁽³⁾ Pad underlain by firm to stiff clayey silt till and loose silt and sand silt till	225	135
Cast-in-place rigid frame open footing concrete culvert	250.2 to 249.9 (inlet to outlet)	~1.0	~ 0.5 m thick Granular 'A' or 'B' Type II ⁽³⁾ Pad underlain by firm to stiff clayey silt till and loose silt and sand till	225	135

Notes:

1. Below the frost line. Requires deeper groundwater control
2. For maximum settlement of 25 mm
3. The granular material used for the granular pad shall be Granular 'A' or Granular B Type II conforming to OPSS.PROV 1010 and compacted to 98 % SPMDD

It is assumed that, if any, underlying organic soils and any other soft or very loose materials are to be replaced with clean and compactable soil such as Granular A or Granular B Type II. Given that no significant grade raise and/or widening is planned, the anticipated maximum total settlements for the new proposed culvert are not expected to exceed 25 mm for construction done in accordance with these design parameters and assuming good construction practice including sound base preparation.

7.4.3.2 Resistance to Lateral Loads

Resistance to lateral forces/ sliding should be calculated in accordance with Section 6.10.5 of the CHBDC (CAN/CSA S6-19), using the following parameters provided in Table 2.4:

Table 2.4: Recommended parameters for calculation of unfactored horizontal resistance

Interface and Loading Conditions	Parameters
Between Granular A and pre-cast concrete	Coefficient of friction ($\tan \delta$)=0.55
Between Granular A and cast-in-place concrete	Coefficient of friction ($\tan \delta$)=0.6

The listed values are unfactored; in accordance with the CHBDC (CAN/CSA S6-19), a factor of 0.8 is to be applied in calculating the horizontal resistance.

7.4.3.3 Frost Protection

The frost depth in the area of the culvert is estimated to be approximately 1.6 m in accordance with OPSD 3090.101. Therefore, a minimum 1.6 m of soil cover or equivalent frost protection should be provided using thermal insulation only to the rigid frame open footing culvert option. For the box culvert, HDPE, and CSP culvert the frost protection is not required.

7.4.3.4 Culvert Bedding

OPSDs 802.010, 803.010 and MTOD 803.021 which are included in Appendix G provide the bedding, embedment, cover and backfill standards for the different culvert material. According to these standards the culvert bedding for the culvert should consist of Granular A or Granular B Type II (OPSS.PROV 1010) with a minimum thickness of 500 mm beneath the culvert and extend a minimum of 500 mm horizontally on either side of the culvert edge. The bedding material should be placed in layers not exceeding 200 mm in thickness, loose measurement, and compacted in accordance with OPSS.PROV 501, or according to OPSS.PROV 314 if Granular B Type II is used, before a subsequent layer is placed in accordance with OPSS. PROV 401. Based on the existing conditions at the site, Granular B Type II is preferred material for the culvert bedding below the water table.

Prior to placing any fill material, the exposed subgrade should be inspected by a qualified geotechnical engineer. A non-woven geotextile separator is to be placed between the approved subgrade and the compacted fill to assist in material placement and maintain the integrity of the founding soil along the entire length of the culvert. The geotextile separator is to be a Class II non-woven material with an equivalent opening size of 75-150 µm.

7.4.3.5 Culvert Backfill

The selection and placing of the backfill and cover should be in accordance with OPSS.PROV 421, OPSS 422 and OPSDs 802.034 (pipe culvert), 803.010 (concrete culvert), and 3101.150 for different culvert materials. The backfill adjacent to the culvert as per these standards should consist of free-draining, non-frost susceptible granular materials conforming to OPSS.PROV 1010.

All granular backfill materials should be placed in thin lifts (i.e. not exceeding 300 mm before compaction) and each lift should be compacted in accordance with OPSS. PROV 501, or according to OPSS.PROV 314 if Granular B Type II is used. The final lift of embankment fills prior to placing pavement sub-base should be compacted to 100 % SPMDD. The Granular A base and Granular B sub-base courses (for pavement) should be compacted to 100% of the material's SPMDD.

The use of heavy compaction equipment should be avoided immediately adjacent and above the culvert, as per MTO practice. The minimum height of fill cover above the crown of the culvert before power operated tractors or rolling equipment shall be 900 mm, unless otherwise noted by the Structural Engineer. During backfill placement, the height of the backfill should be maintained at approximately the same level on both sides of the structure, to avoid lateral displacement of the structure.

Where less than frost depth (1.6 m) of earth cover is provided above the top of the culvert, a frost taper should be included as per OPSD 803.030, 803.031, and MTOD 803.021, whichever is applicable. If the frost taper exists at the site it will be reinstalled within the zone of excavation with accordance to OPSD 803.031.

7.4.3.6 Lateral Earth Pressure

Culvert walls and temporary shoring (if any) should be designed to resist lateral earth pressure. The expression for calculating lateral earth pressure is given by:

$$P = K(\gamma h + q) \text{ for non-braced cut, or } K(0.65\gamma h + q) \text{ for braced cut}$$

where,

P = earth pressure intensity at depth h , kPa

K = earth pressure coefficient

γ = unit weight of retained soil, kN/m³

q = surcharge near wall, kPa

h = depth to point of interest, m

The above expression does not take into account hydrostatic pressure, which must be included for the groundwater levels measured on the site. Table 2.5 lists earth pressure parameters for given materials. These recommendations assume level backfill and ground surface behind the walls.

Table 2.5: Material types and earth pressure properties

Material	Unfactored Friction Angle ϕ' (°)	Coefficient of Active Earth Pressure (K_a)	Coefficient of Passive Earth Pressure (K_p)	Coefficient of Earth Pressure At- Rest (K_o)	Unit Weight γ (kN/m ³)
Granular A	35	0.27	3.69	0.43	22.8
Granular B Type II	35	0.27	3.69	0.43	22
Gravelly Sand Fill (compact to very dense)	33	0.29	3.39	0.46	21
Silty Sand Fill (compact)	30	0.33	3.00	0.5	20
Buried Topsoil	19	0.51	1.97	0.67	17
Clayey Silt Till (firm to stiff) ¹	30	0.33	3.00	0.5	19
Silt and Sand to Till (very loose portion)	27	0.38	2.66	0.55	19
Silt and Sand to Silty Sand Till (compact to very dense portion)	32	0.31	3.25	0.47	21

Note:

- 1) Assumes long term conditions. In short term conditions $K_o = K_p = 1$

The mobilization of full active or passive resistance requires a measurable and perhaps significant wall movement or rotation. Therefore, unless the structural element can tolerate these deflections, the at rest earth pressure should be used in design. This would normally be the case for concrete box culverts.

The effect of compaction surcharge should be taken into account in the calculations of active and at rest earth pressures. The lateral pressure due to compaction should be taken as at least 12 kPa at the surface, and its magnitude should be assumed to diminish linearly with depth to zero at the depth where the active (or at rest) pressure is equal to 12 kPa. This pressure distribution should be added to the calculated active (or at rest) pressure. Notwithstanding, lighter compaction equipment and smaller lifts should be used adjacent to culvert walls to prevent oversteering.

It is likely that bracing for the temporary support system (if any) will be required at a maximum interval of 5 m. For multiple support systems refer to Canadian Foundation Engineering Manual (CFEM) for apparent earth pressure distributions (CFEM, Section 26.10.3, Figure 26.8).

7.4.4 Construction Considerations

7.4.4.1 Excavation

All excavations at this site must be conducted in accordance with the Occupational Health and Safety Act (OHSA) and Regulations for Construction (O. Reg. 213/91). The gravelly sand and silty sand fill, silt and sand to sandy silt till, and clayey silt till may be classified as a Type 3 soil above the groundwater table and Type 4 soil below the groundwater table in conformance with the OHSA. It is expected that most of excavations will be above the groundwater levels except those at the invert level.

To avoid disturbance of the founding subgrade and to allow placement of backfill in dry conditions, groundwater must be controlled to below the proposed invert excavation levels prior to digging to final levels. The ingress of surface water must be controlled using a suitable system as well, as described in Section 7.7.

Temporary excavation side slopes for Type 3 soils should not exceed 1H:1V in accordance with OHSA, while temporary excavation side slopes for Type 4 soils should not exceed 3H:1V where applicable. There is a potential for sloughing to occur if the trench remains open for an extended period of time (i.e. > 24 hours) or during a rainfall event. In addition, some localized surficial sloughing may be experienced in areas of perched groundwater seepage (i.e. within the embankment fill).

7.4.4.2 Embankment Reconstruction

For fills immediately below any roadway, it is recommended that Granular A or B Type II materials be used. Below the pavement base/subbase and above the frost line (1.6 m), the roadway embankment above the culvert should be reconstructed using free-draining, non-frost susceptible granular materials conforming to OPSS.PROV 1010 (Granular A/Granular B Type I or Type II/Selected Subgrade Material (SSM)). As noted in Section 7.4.3.5, proper tapering as per standards should be provided if required. Below a depth of about 2.4 m from any finished road grade, approved compactable fill, such as select subgrade materials (OPSS.PROV 1010), or reused native fill can be used.

All granular backfill materials should be placed in thin lifts (i.e., not exceeding 300 mm before compaction) and each lift should be compacted in accordance with OPSS. PROV 501, or according to OPSS.PROV 314 if Granular B Type II is used.

The existing embankment fill and the new fill along the existing roadway embankment slopes should be integrated in accordance with OPSD 208.010. The final embankment side slopes should be protected against erosion by surface water runoff as soon as practical after completion of slope grading using a combination of materials in accordance with OPSS.MUNI 802, OPSS.PROV 803 and/or OPSS.PROV 804.

It is anticipated that the reconstructed embankment will have the the side slopes not steeper than 2H:1V at the location of the culverts (see Section 7.8 for discussion on global stability).

7.5 Seismic Potential Consideration

Seismic characterization of the site should be compliant with the Canadian Highway Bridge Design Code (CHBDC, CSA-S6-19). Table 4.1 in the CHBDC (see Clause 4.4.3.2) shows site classification for seismic site response based on average soil properties in the top 30 m. At the site, the subsoil beneath the embankment fill generally consists of firm to stiff clayey silt till and very loose to very dense sand and silt and sand to sandy silt till. Bedrock was not encountered within the investigated depth. The groundwater level is at about a 4.7 m depth below the existing Highway 12 road surface. The reported N-values for the native soils ranged from 3 to 56 blows for 300 mm of penetration, with an average value being between 15 and 50 blows per 300 mm of penetration within the drilled depth. Based on these soil characteristics, the site class for this site is estimated to be Class "D" according to Table 4.1. However, these parameters should be reviewed by the Structural Engineer.

From Natural Resources Canada website, 2020 NBC seismic hazard values are obtained using the site location coordinates (44.377620°N, 79.104760°W), where the damped spectral accelerations are $S_a(0.2)=0.282g$, $S_a(0.5)=0.289g$, $S_a(1.0)=0.176g$, $S_a(2.0)=0.0851g$ the peak ground acceleration (PGA) is 0.156 g (g = acceleration due to gravity -9.81 m/s²). These values are associated with an earthquake having 2 percent probability of exceedance in a 50-year period (1 in 2475-year event) for Site Class D as shown on the GSC seismic hazard calculation data sheet for this site attached in Appendix I.

7.6 Temporary Roadway Protection

Temporary roadway protection is anticipated to be a part of the half-and-half construction approach that will be required to maintain on-site traffic during the construction. Roadway protection systems shall be design in accordance with OPSS.PROV 539 and OPSS.PROV 903 as amended by SP109F57. The complete design, construction, monitoring and removal of the installed protection system should be a responsibility of the Contractor. Due to nature of this application it is expected that much of temporary shoring will be decommissioned in place noting the high cost for removal. Decommissioning must be consistent with good practice to avoid interference with highway systems and utilities, if any. The protection system should be designed to provide protection for excavations as required by the OHSA, at locations specified in the contract, and at any locations where the stability, safety or function of an existing structure and/or utility may be impaired by construction work.

Based on the geotechnical conditions at the site, a shoring system such as steel sheet piling can be considered for design. It should be designed based on the earth pressures coefficients and soil parameters provided in Table 2.5. If a cantilever system is used, an embedded depth of sheet piles should be determined by balancing moments about

the pile tip and it could be approximately 2.0 to 2.5 times its exposed height. Alternatively, a system of rakers can be used for support.

Cobbles and/or boulders were inferred within native soil deposits at the site during site investigation. Additionally, cobbles and boulders were encountered in the native soils in nearby sites in the region. Therefore, it is recommended that care has to be taken during installation of sheet piles.

The protection system shall be designed for Performance Level 2 (for small, less important sections). The minimum requirements for monitoring should include the survey measurements of 6 m apart scaled targets attached to the shoring wall at the elevations specified. If movement approaches the allowable limit of 25 mm (Performance level 2), suitable measures should be taken to ensure stability of the protection system and to ensure that the movement does not exceed the performance level specified.

After construction of the new culvert, the protection system could be removed. In that case the details of the procedures associated with the removal of the protection system indicating: method, sequence of work, and removal limits are required from the Contractor as per OPSS.PROV 539. However, if the protection system is decided to be left in place the top should be removed to at least 1.2 m below the finished grade or ground level or at least 0.6 m below the streambed. All disturbed areas should be restored to an equivalent or better condition than what existed prior to the commencement of construction.

7.7 Site Dewatering

7.7.1 Cofferdams

Temporary cofferdams will be required at both the upstream and downstream ends of the culvert to envelop the construction site and keep it free of water during replacement of the existing CSPA culvert. Two types of cofferdams, i) sheet pile wall, and ii) rockfill/earth dam, could be considered. During construction, creek flow should be maintained through the temporary flow passage system with a culvert in place. Design and construction specifications for the chosen temporary cofferdam system should be prepared in accordance with OPSS.PROV 539 (Construction Specification for Temporary Protection Systems) by the Contractor.

Based on the geotechnical conditions, suitably designed steel sheet pile walls can be used as cofferdams at this site. Sheet piles perpendicular to the highway at least 3 m into the embankment slopes should be considered to prevent water getting in through the sides. If a cantilever system is used, an embedded depth of sheet piles can be approximately 2.0 to 2.5 times its exposed height. The proposed sheet pile wall should be at least one meter above the designed HWL defined by the Hydraulic Engineer. The required minimum section modulus and embedment pile length should be designed based on the recommended design parameters. Cobbles and/or boulders were noted to be contained within the native soil deposits; therefore, care has to be taken during installation of sheet piles. It is recommended that a NSSP be included in the Contract Documents to warn the Contractor of the presence of cobbles and/or boulders at the site. An example of a NSSP for obstructions is provided in Appendix J.

Alternatively, a rockfill/earth cofferdam can be used. The rockfill/earth cofferdam will have to be constructed to accommodate all topographic constraints. The size of material suitable for use depends on the erosion potential, stream flow velocity, etc. The rockfill/earth cofferdam should be designed with a more impervious water barrier at the outside face to create a more watertight enclosure. Schemes involving 50.8 mm (2") minus crusher run with finer facing material upstream have been successfully used in similar settings. Any required permitting must be

determined. The proposed rockfill/earth cofferdam should be at least one meter above the designed high water level (HWL) defined by the Hydraulic Engineer.

As mentioned, which cofferdam system is best suited depends on many technical and economic factors. The advantages and disadvantages of both cofferdam systems are summarized in Table 2.6.

Table 2.6: Evaluation of foundation alternatives

Options	Rank	Advantages	Disadvantages	Relative Costs	Risks/ Consequences
Steel sheet piles	1	<ul style="list-style-type: none"> Provides more watertight base Structural elements and seals easier to positively construct Increased safety with appropriate design Easily removed Less seepage Reusable 	<ul style="list-style-type: none"> More costly More likely time consuming for installation May present issues for seepage and/or piping Larger machines required May require bracing May face difficulty driving through soil deposits if cobbles and/or boulders are present May require strengthening toe of sheet pile 	Medium to High	<ul style="list-style-type: none"> May take longer to install Environmental permits
Rock fill/ Earth	2	<ul style="list-style-type: none"> Less costly Relatively less time consuming for installation Native material can be usable Not affected by presence of cobbles and/or boulders 	<ul style="list-style-type: none"> Require more space for installation Less safe Subjected to wave erosion Less watertight Prone to land shifts, slides and collapse More likely time consuming to remove 	Low to Medium	<ul style="list-style-type: none"> Less stable and safe. May generate 'mud waves' May take longer to remove May require installing clay cut off More dewatering Environmental permits

Given the soil conditions, topography of the surrounding terrain, and available space, the use of a suitably designed steel sheet pile system of sufficiently robust cross-section is recommended at the inlet and outlet of the existing culvert. The design of these cofferdams, which are temporary retaining structures, is the responsibility of the Contractor. The cofferdam must be designed to withstand the anticipated design loads and to be watertight as practically as possible. The Contractor is also responsible for cofferdam's materials, construction, monitoring and removal.

Design and construction specifications for the chosen temporary cofferdam system should be prepared in accordance with OPSS.PROV 539 (Construction Specification for Temporary Protection Systems) by the Contractor. Piling should be in accordance with OPSS.PROV 903. Cantilevered walls should be designed for the earth pressures shown in Table 2.9 and earth pressure diagram shown in the CFEM Figure 26.3. As mentioned before, besides design

and construction of the temporary cofferdam system, the Contractor is also responsible for its removal. The temporary cofferdam shall be fully removed, unless it is specified in the Contract Documents that the cofferdam system may be partially left in place. The method and sequence of removal shall be so that there shall be no damage to the new work, existing work, and facility being protected.

7.7.1.1 Soil Parameters for Cofferdam Design

The temporary cofferdam system, which is a temporary retaining structure, should properly designed by a Professional Engineer experienced in this type of work and employed by the Contractor.

For unbraced design, the triangular pressure relationship outlined below is applicable, as follows:

$$P = K(\gamma h + q)$$

where,

P = earth pressure intensity at depth h, kPa

K = earth pressure coefficient

γ = unit weight of retained soil/ water, kN/m³

q = surcharge near wall, kPa

h = depth to point of interest, m

The above expression does not take into account hydrostatic pressure, which must be included for the groundwater within the existing ground and within the depth of the structure, and for water in the creek.

For design purposes, the following parameters given in Table 2.7 can be assumed after installation of retaining system.

Table 2.7: Soil parameters and lateral earth pressure coefficient information required for temporary cofferdam design

Unit	Relevant Boreholes	Approx. Elevation (m)	Materials	Unit Weight γ (kN/m ³)	GWL/ Creek Water Elevation (m)	Angle of Friction ϕ' (°)	Effective Stress Properties		
							Coefficient of Lateral Earth Pressure		
Inlet	PV012-001-01	251.9 – 249.7	Silt and Sand Till Very loose to loose	19	249.7 / 251.7	28	0.36	2.77	0.53
		249.7 – 248.3	Sandy Silt Till Dense	21		32	0.31	3.25	0.47
Outlet	BH012-001-03	251.9 – 249.7	Silt and Sand Till Loose	19		28	0.36	2.77	0.53
		249.7 – 246.8	Sandy Silt Till Dense	21		32	0.31	3.25	0.47

Notes:

K_a = active earth pressure coefficient

K_o = coefficient of earth pressure at rest

K_p = passive earth pressure coefficient

7.7.1.2 Piping

Given the groundwater conditions and soils present (pervious materials, sands and silts), piping of the soil is anticipated to be a potential issue at the site due to an unbalanced hydrostatic head causing large upward seepage pressures in the soil at the bottom of the inside cofferdam. Piping should be controlled by lowering the water table outside the cofferdam or driving the sheeting to sufficient depth to mitigate against piping. If a rock fill/earth cofferdam is used, piping can be controlled by installing a clay cutoff trench, slurry trench or impervious blanket upstream of the cofferdam.

7.7.2 Groundwater Control

The groundwater level at the site was encountered at about Elev. 249.7 m at the time of investigation. However, groundwater levels would be expected to reflect levels in the adjacent open water. At the time of the field investigation (January 2023), the approximate top of water elevation was at approximately Elev. 251.7 m, respectively. Construction for the replacement of the culvert is recommended during the low water level season.

The excavation to the foundation level for HDPE pipe, CSP and/or box culverts has to be carried out to approximately Elev. 251.3 m to 251.0 m from the inlet to outlet, respectively, or for the culvert on open footings it has to be carried out up to approximately Elev. 249.7 m to 249.4 m from the inlet to outlet. The soils encountered at the site and within potential excavation depths consist of gravelly sand/sand and gravel and silty sand fill, and clayey silt, silt and sand, and sandy silt till. Grain size distribution curves are presented in Appendix E. The estimated range of hydraulic conductivity (k) of these materials is 10^{-2} - 10^{-7} m/s.

The soils encountered below the groundwater table and within potential excavation depths consist of sandy/silty fills and native materials. Some of these materials are susceptible to disturbance from groundwater and mobilized equipment. The groundwater level needs to be controlled to 0.5 m below the excavation level to avoid disturbance, and any surface or groundwater seepage should be removed from the excavation prior to the placement of granular backfill in the dry. Granular B Type II or clear stone with geotextile wrapping can be used in the wet condition.

Considering that the soils within potential excavation depths consist of silty and sandy native/fill soils, it is assessed that these soils are susceptible to disturbance from groundwater and mobilized equipment. Therefore, the groundwater level needs to be controlled to at least 0.5 m below the excavation level to avoid disturbance, and any surface or groundwater seepage should be removed from the excavation prior to the culvert bedding material placement of granular backfill in the dry. In general, where the excavation base is within 0.5 m of the prevailing groundwater level at the time of construction, it is anticipated that control of seepage can be accomplished by using properly filtered sumps.

Dewatering shall be carried out in accordance with OPSS.PROV 517 and SP517F01. It is responsibility of the Contractor to propose a suitable dewatering system based on the time of construction, water levels and flow conditions. The method used should not undermine the adjacent existing footings. Alternatively, and in accordance with SP 5017F01, the dewatering systems may be completed by a design Engineer and design-checking Engineer with a minimum of 5 years' experience.

Dewatering requirements behind the cofferdams to keep the construction site dry will be impacted by water levels in the creek at the time of construction activities. Seasonal variations in the water table should be expected, with higher levels occurring during wetter periods of the year and lower levels during drier periods. Dewatering for cofferdams should be carried out in accordance with OPSS.PROV 902 as modified by NSSP FOUN0003 (Dewatering of Structure Excavation) which is included in Appendix J. It is the responsibility of the Contractor to propose a suitable dewatering system based on the time of construction, water levels and flow conditions in the creek. The method used should not undermine the existing highway embankment or adjacent side slopes.

Dewatering may require water taking permits (i.e. Permit to Take Water PTTW). A PTTW is required for any water taking if the volume exceeds 50,000 L/day. The rate and volume required for dewatering will be dependent on the construction methods and staging chosen by the Contractor.

Erosion and sediment control during culvert construction should be as per the MTO Drainage Manual, Volume 2. Silt fences and other sediment control measures should be included to protect the downstream environment from the construction activities.

7.8 Structures Stability Considerations

7.8.1 New Embankment

7.8.1.1 Stability Analyses of Side Slopes

Slope stability analyses were performed to assess the global stability of the reconstructed embankment to check if a minimum Factor of Safety of 1.4 for static and 1.1 for seismic conditions is achieved as per MTO criteria for typical degree of understanding (Provincial Engineering Memorandum, Material Engineering and Research Office #2020-01, March 23, 2020). The static and seismic slope stability analyses were performed using the Morgenstern-Price method developed on the basis of limit equilibrium. The SLOPE/W computer program developed by GeoSlope International was employed for computation.

The stratigraphy and groundwater condition at the site were developed based on the results of the geotechnical investigation presented in Part I - Foundation Investigation Report. The seismic properties given in Appendix I (Section 7.5) were obtained from the Natural Resources Canada website, 2020 NBC, using the site location coordinates. Tabulated below in Table 2.8 are the soil parameters used for the slope stability analyses.

Table 2.8: Soil properties used in slope stability analyses

Soil Type	Bulk Unit Weight γ (kN/m ³)	Undrained Shear Strength C_u (kPa)	Effective Stress Parameters	
			Friction Angle, ϕ' (°)	Cohesion c' (kPa)
Granular A/B Type II	22	-	35	0
Gravelly Sand Fill (compact)	21	-	33	0

Soil Type	Bulk Unit Weight γ (kN/m ³)	Undrained Shear Strength C_u (kPa)	Effective Stress Parameters	
			Friction Angle, ϕ' (°)	Cohesion c' (kPa)
Silty Sand Fill generally compact)	20	-	30	0/2 ¹
Clayey Silt Till (firm to stiff)	19	40	30	0/3 ¹
Silt and Sand Till (generally loose)	19	-	29	0
Silt and Sand to Sandy Silt Till (compact to very dense)	21	-	32	0/2 ¹

Notes:

- 1) Soil layer modelled with cohesion for temporary open cuts under effective stress (long term) conditions

Based on the borehole information, the subsoils encountered at the work area consist of cohesionless fill and native cohesionless and cohesive soils. Therefore, effective stress (drained/long-term conditions) and total stress (undrained/short-term) analyses of the slopes were performed taking into consideration the subsoil conditions encountered at the site. The analyses assumes that all organic material (if encountered) will be removed prior to construction. In addition, a traffic surcharge pressure of 16 kPa was adopted in the slope stability assessments. Table 2.9 summarizes the results of performed slope stability analyses. The SLOPE/W graphical printout for the analyses is included in Appendix F (Figures F1 – E6).

Table 2.9: Summary of results of new embankment slope stability analyses

Location	Max Height (m)	Conditions	Min FOS
West (Inlet) Side (2H:1V)	~3	Drained long-term conditions, static condition	1.8 (Figure F1)
		Undrained short-term conditions, static condition	1.8 (Figure F2)
		Drained long-term conditions, seismic condition	1.3 (Figure F3)
East (Outlet) Side (2H:1V)		Drained long-term conditions, static condition	1.6 (Figure F4)
		Undrained short-term conditions, static condition	1.8 (Figure F5)
		Drained long-term conditions, seismic condition	1.1 (Figure F6)

The results of the slope stability analyses for the new reconstructed embankment having side slopes of 2H:1V on both sides show that the slopes are stable for static and seismic conditions (i.e., calculated $FOS \geq 1.4$ for static and $FOS \geq 1.1$ for seismic), assuming that all loose soils below the culvert are excavated and replaced with properly compacted granular material.

7.8.1.2 Embankment Settlement

It is not planned to change the existing embankment grade nor significant permanent widening at the culvert location. It is anticipated that there should be negligible additional settlements under the new embankment. However, a settlement of about 25 mm should be allowed due to rebound during the construction.

7.8.2 Open Cut – Temporary Slopes for Half-and-Half Staged Construction

The results of the analysis for temporary open cut side slopes perpendicular to the highway centerline are shown in Figure F7 and F8 in Appendix F and summarized in Table 2.10. The results suggest that the temporary open cut is stable for static conditions ($FOS \geq 1.3$) with 1H:1V slopes.

Table 2.10: Summary of results of new embankment slope stability analyses

Location	Max Height (m)	Conditions	Min FOS
Excavation of NBL (1H:1V side slope perpendicular to highway CL)	~3	Drained long-term conditions, static condition	1.3 (Figure E7)
		Undrained short-term conditions, static condition	1.3 (Figure E8)

7.9 Scour/Erosion Protection

Scour/erosion protection should be provided at the culvert inlet and outlet (including the side slopes). The erosion/scour protection should be designed by a specialist Hydraulic Engineer (as erosion and scour largely depend on the velocity of water in the watercourse and its regime) who is familiar with the findings of this report. The following are some general suggestions, considering that the boreholes indicate that the main soil type consists of sand and silt.

The need for and nature of scour and erosion protection systems must be assessed and where required, must be designed, implemented and remain effective for the design life of the culvert. The potential for scour below foundations must be incorporated into the design.

Rip-rap protection should be provided where the culvert discharges into the open creek and where the open creek enters the culvert. The design should be finalized by the Hydraulics Engineer. For preliminary guidance, the rip-rap should extend approximately 5 m beyond the ends of the culvert and line the embankment slope to the spring line of the culvert. Such protection may involve 0.5 m thick rock (OPSS.PROV 511) extending from 1 m above the high water level to the toe of the slope and into the stream bed within the plan limits of the culvert. The rip-rap configuration at the creek bed should generally follow OPSD 810.010. The slope of the riprap shall follow the embankment fill slope.

The erosion protection should consider the possible installation of seepage protection measures at both upstream and downstream ends. For culverts, the following are typical options for seepage cutoff approaches: a typical clay seal, steel or wooden sheet pile cutoff at the upstream end of culvert, a cutoff wall incorporated in the apron slab

(if one is used) of the culvert, and a cut-off trench constructed with geotextile and rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert. The seepage protection is addressed in the following Section 7.11.

A clay seal should be placed at the inlet of the proposed culvert to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment. The installation procedures and the material used for the clay seal should conform to all the requirements stipulated in OPSS.PROV 1205, as detailed in Section 7.10.1.

The scour design, nature and extent of the required protection is the responsibility of a qualified Hydraulic Design Engineer experienced in this field. Geotechnical soil parameters necessary for the scour analyses are: SPT N-value, in-situ moisture content, percent passing the No. 200 sieve (%200), mean grain size diameter (D50), liquid limit (LL), plastic limit (PL), and plasticity index (PI). These parameters can be determined based on the soils encountered at the site during the investigation.

7.10 Seepage Cut-off Requirements

The seepage cut-off requirements should be reviewed in the following context. The native silty soils at the inlet side and outlet side and below the culvert bedding has a high potential for migration with high seepage gradients. For the culvert replacement and new culvert installation, it is prudent to examine possible methods to avoid piping of material resulting from seepage along the culvert. For culverts the following are typical methods: (i) clay seal, (ii) steel or wooden sheet pile cutoff at the upstream end of culvert, (iii) cut-off wall incorporated in the apron slab (if one is used) of the culvert, (iv) cut-off trench constructed with geotextile, and (v) rockfill at the upstream end of the culvert barrel to terminate below the granular bedding of the culvert. Only the clay seal and cut-off trench will be addressed since the sheet pile cut-off will require the understanding of the hydraulics of the stream. Piping related to temporary cofferdam is discussed in Section 7.7.1.

7.10.1 Clay Seal

Where readily available a clay seal should be placed at the inlet of the proposed culvert to prevent the migration of material along the face of the culvert, the formation of flow paths, and any potential internal erosion within the highway embankment. OPSS.PROV 1205 specifies that material used for clay seals shall be natural clay, clay mixture (1 part Bentonite powder and 3.5 parts Granular "A") or a Geosynthetic Clay Liner (GCL). The coefficient of permeability shall not exceed 1×10^{-6} cm/s.

The following outlines the installation procedures and minimum material requirement of the clay seal:

- The clay seal should be placed along the sides and top of the culvert a minimum of 1.0 m along the side of the culvert and extending out laterally 1.0 m from the culvert. However, it is the responsibility of the designer to select the dimensions of the clay seal.
- The clay seal should be placed from the top of the culvert footings and extend along the side and the top of the culvert. The clay must not be placed below the culvert.
- The clay should have a Liquid Limit greater than 40% and a Plasticity Index greater than $0.73 \times (\text{Liquid Limit} - 20\%)$.

- The clay seal is to be placed in maximum 150 mm thick lifts and compacted to 95% SPMDD within 2% of the optimum moisture content.

If a GCL is used as a clay seal its material specifications containing the physical, mechanical and hydraulic properties shall be obtained from the manufacturer. It is estimated that an approximately 12 mm thick GCL should be installed a minimum 1.0 m along the side of the culvert.

7.10.2 Cut-Off Trench/Wall

A cut-off trench/wall can be used at both the upstream and downstream ends of the culvert and can be incorporated when the rip-rap apron at both ends of the culvert are being installed (see Figure H2 in Appendix H). In general, a trench is dug across the stream alignment to well beyond the walls of the culvert and a geomembrane liner is laid on the side of the trench keyed into the culvert at the top and on the base of the trench. The trench is then backfilled with graded rip-rap.

7.11 Corrosion Potential and Cement Type

One (1) soil sample was selected for chemical analyses during this investigation. The testing was completed to determine the potential degradation of the concrete in the presence of soluble sulphates and the potential of corrosion of exposed steel used in foundations and buried infrastructure. The analyses results are summarized in Table 1.7 of this report.

The pH, resistivity and chloride concentration provide an indication of the degree of corrosiveness of the sub-surface environment. The soil pH value measured at the site was 9.05 which is higher than the normal range of soil pH of 5.5 to 8.5 but it is not considered to be detrimental to culvert durability (AASHTO, 2000/MTO Gravity Pipe Design Guidelines, April 2014). The chemical data indicates very low ($R < 2000$ ohm-cm) resistivity of the tested soil which suggests high potential for corrosion of buried metallic elements as per Table 3.2 of the MTO Gravity Pipe Design Guideline. The measured chloride content was 1900 ppm ($\mu\text{g/g}$) which also indicates a moderate potential for additional corrosion (Molinas and Mommandi, 2009).

These chemical test results may be used to aid in the selection of coatings and corrosion protection systems for buried steel culverts, if selected. If the concrete culvert option is selected, consideration should be given by the designer to designing for a « C » type of exposure class of concrete as defined by CSA A23.1:19 Table 1, since the culvert will be exposed to de-icing salt.

The maximum water-soluble sulphate content of the soils tested is 220 ppm ($\mu\text{g/g}$), i.e. 0.0022%, and being less than 0.10% (as per CSA A23.1:19, Table 3) does not require sulphate resistant cement. The data supports our local experience.

7.12 Obstructions during Installation of Temporary Protection Systems

Cobbles and/or boulders were noted to be contained within the native soil deposits at the site during site investigation. Therefore, care has to be taken since the presence of these obstructions may affect the excavation for culvert replacement and installation of protection system elements including the temporary roadway protection system and temporary dewatering/unwatering systems. It is recommended that a NSSP be included in the Contract

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Assignment No. 2020-E-0028
Date: May 17, 2023*

Documents to warn the Contractor of the presence of cobbles and/or boulders within the overburden soils. An example of NSSP for obstructions is provided in Appendix J.

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GWP 2111-19-00
Assignment No. 2020-E-0028
Date: May 17, 2023

8.0 CLOSURE

The recommendations made in this report are in accordance with our present understanding of the project and are provided solely for the team responsible for the design of the works described herein.

We recommend that we be retained to review our recommendations as the design nears completion to ensure that the final design is in agreement with the assumptions on which our recommendations are based and that our recommendations have been interpreted as intended. If not accorded this review, EXP will assume no responsibility for the interpretation and use of the recommendations in this report.

A subsurface investigation is a limited sampling of a site; the subsurface conditions have been established only at the test hole locations. Should conditions at the site be encountered which differ from those reported at the test locations, we require that we be notified immediately in order to assess this additional information and our recommendations, as appropriate. It may then be necessary to perform additional investigation and analysis.

Contractors bidding on or undertaking any proposed work at this site should, relative to the subsurface conditions, decide on their own investigations, if deemed necessary, as well as their own interpretations of the factual results provided herein, so they may draw their own conclusions as to how the subsurface conditions may affect them.

This Foundation Investigation and Design Report has been prepared by Daniel Mroz, M.E.Sc., EIT, Stephen Fredericks, M.Eng., P.Eng., and Nimesh Tamrakar, M.Eng., P.Eng. It was reviewed by TaeChul Kim, M.E.Sc., P.Eng. and by Stan E. Gonsalves, M.Eng., P.Eng., Designated MTO Foundation Contact. The field investigation was supervised by Stephen Fredericks, M.Eng., P.Eng.

EXP Services Inc.



Daniel Mroz, M.E.Sc., EIT
Technical Specialist



Nimesh Tamrakar, M.Eng., P.Eng.
Geotechnical Engineer
Project Manager



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Specialist



Stan E. Gonsalves, M.Eng., P.Eng.
Principal Engineer
Designated MTO Foundation Contact



9.0 REFERENCES

- Canadian Geotechnical Society, 2006. Canadian Foundation Engineering Manual, 4th Edition. The Canadian Geotechnical Society, BiTech Publisher Ltd., British Columbia.
- Canadian Standards Association (CSA), 2019. Canadian Highway Bridge Design Code and Commentary on CAN/CSA-S6-19. CSA Special Publication.
- Highway Standards Branch, Provincial Memorandum, Material Engineering and Research Office (MERO) #2020-01, March 23, 2020
- Ministry of Northern Development and Mines, Map 2556. Quaternary Geology of Ontario, Southern Sheet, 1991
- Ministry of Northern Development and Mines Map 2544. Bedrock Geology of Ontario, Southern Sheet, 1991
- Ministry of Transportation, April 2014. MTO Gravity Pipe Design Guidelines. Circular Culverts and Storm Sewers.
- Ministry of Transportation, October 2020. Guideline for MTO Foundation Engineering Services, Version 02
- Molinas, A., and Mommandi, A., 2009. Development of New Corrosion/Abrasion Guidelines for Selection of Culvert Pipe Materials, Report No. CDOT-2009-11. Colorado Department of Transportation, DTD Applied Research and Innovation Branch.

ASTM International:

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

Ontario Provincial Standard Specifications (OPSS):

- OPSS.PROV 314 Construction Specification for Untreated Subbase, Base, Surface, Shoulder, Selected Subgrade, and Stockpiling
- OPSS.PROV 401 Construction Specification for Trenching, Backfilling and Compacting
- OPSS.PROV 421 Construction Specification for Pipe Culvert Installation in Open Cut
- OPSS.MUNI 422 Construction Specification for Precast Reinforced Concrete Box Culverts in Open Cut
- OPSS.PROV 501 Construction Specification for Compacting
- OPSS.PROV 511 Rip Rap, Rock Protection and Granular Sheetting
- OPSS.PROV 517 Construction Specification for Dewatering
- OPSS.PROV 539 Construction Specification for Temporary Protection Systems
- OPSS.MUNI 802 Construction Specification for Topsoil
- OPSS.PROV 803 Construction Specification for Vegetative Cover
- OPSS.PROV 804 Temporary Erosion Control

OPSS.PROV 902 Construction Specification for Excavating and Backfilling – Structures
OPSS.PROV 903 Construction Specification for Deep Foundations
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

Ontario Provincial Standard Drawings (OPSD):

OPSD 208.010 Benching of Earth Slopes
OPSD 802.010 Flexible Pipe Embedment and Backfill Earth Excavation
OPSD 802.034 Rigid Pipe Bedding and Cover in Embankment, Original Ground, Earth or Rock
OPSD 803.010 Backfill and Cover for Concrete Culverts with Span Less Than or Equal to 3.0 m
MTOD 803.021 Bedding and Backfill for Precast Concrete Box Culverts
OPSD 803.030 Frost Treatment, Pipe Culverts, Frost Penetration Line Below Bedding Grade
OPSD 803.031 Frost Treatment – Pipe Culverts Frost Penetration Line Between Top of Pipe and Bedding Grade
OPSD 810.010 Rip-Rap Treatment for Sewer and Culvert Outlets
OPSD 3090.100 Foundation Frost Penetration Depths for Northern Ontario
OPSD 3101.150 Walls, Abutment, Backfill, Minimum Granular Requirement

Special Provisions (SP):

SP 109F57 Amendment to OPSS 903
SP 517F01 Amendment to OPSS 517
NSP FOUN0003 Amendment to OPSS.PROV 902

Ontario Water Resources Act:

R.R.O 1990, Regulation 903 Wells, under Ontario Water Resources Act, R.S.O. 1990, c. O.40

Ontario Occupational Health and Safety Act (OHSA):

Ontario Regulation 213/91 Construction Projects

10.0 LIMITATIONS AND USE OF REPORT

BASIS OF REPORT

This report ("Report") is based on site conditions known or inferred by the geotechnical investigation undertaken as of the date of the Report. Should changes occur which potentially impact the geotechnical condition of the site, or if construction is implemented more than one year following the date of the Report, the recommendations of EXP may require re-evaluation.

The Report is provided solely for the guidance of design engineers and on the assumption that the design will be in accordance with applicable codes and standards. Any changes in the design features which potentially impact the geotechnical analyses or issues concerning the geotechnical aspects of applicable codes and standards will necessitate a review of the design by EXP. Additional field work and reporting may also be required.

Where applicable, recommended field services are the minimum necessary to ascertain that construction is being carried out in general conformity with building code guidelines, generally accepted practices and EXP's recommendations. Any reduction in the level of services recommended will result in EXP providing qualified opinions regarding the adequacy of the work. EXP can assist design professionals or contractors retained by the Client to review applicable plans, drawings, and specifications as they relate to the Report or to conduct field reviews during construction.

Contractors contemplating work on the site are responsible for conducting an independent investigation and interpretation of the borehole results contained in the Report. The number of boreholes necessary to determine the localized underground conditions as they impact construction costs, techniques, sequencing, equipment and scheduling may be greater than those carried out for the purpose of the Report.

Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates are based on investigations performed in accordance with the standard of care set out below and require the exercise of judgment. As a result, even comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations or building envelope descriptions involve an inherent risk that some conditions will not be detected. All documents or records summarizing investigations are based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated. Some conditions are subject to change over time. The Report presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, these should be disclosed to EXP to allow for additional or special investigations to be undertaken not otherwise within the scope of investigation conducted for the purpose of the Report.

RELIANCE ON INFORMATION PROVIDED

The evaluation and conclusions contained in the Report are based on conditions in evidence at the time of site inspections and information provided to EXP by the Client and others. The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose as communicated by the Client.

EXP has relied in good faith upon such representations, information and instructions and accepts no responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of any misstatements, omissions, misrepresentation or fraudulent acts of persons providing information. Unless specifically stated otherwise, the applicability and reliability of the findings, recommendations, suggestions or opinions expressed in the Report are only valid to the extent that there has been no material alteration to or variation from any of the information provided to EXP.

STANDARD OF CARE

The Report has been prepared in a manner consistent with the degree of care and skill exercised by engineering consultants currently practicing under similar circumstances and locale. No other warranty, expressed or implied, is made. Unless specifically stated otherwise, the Report does not contain environmental consulting advice.

COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment form part of the Report. This material includes, but is not limited to, the terms of reference given to EXP by its client ("Client"), communications between EXP and the Client, other reports, proposals or documents prepared by EXP for the Client in connection with the site described in the Report. In order to properly understand the suggestions, recommendations and opinions expressed in the Report, reference must be made to the Report in its entirety. EXP is not responsible for use by any party of portions of the Report.

USE OF REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. No other party may use or rely upon the Report in whole or in part without the written consent of EXP. Any use of the Report, or any portion of the Report, by a third party are the sole responsibility of such third party. EXP is not responsible for damages suffered by any third party resulting from unauthorised use of the Report.

REPORT FORMAT

Where EXP has submitted both electronic file and a hard copy of the Report, or any document forming part of the Report, only the signed and sealed hard copy shall be the original documents for record and working purposes. In the event of a dispute or discrepancy, the hard copy shall govern. Electronic files transmitted by EXP have utilized specific software and hardware systems. EXP makes no representation about the compatibility of these files with the Client's current or future software and hardware systems. Regardless of format, the documents described herein are EXP's instruments of professional service and shall not be altered without the written consent of EXP.

Appendix A – Site Photographs



Photograph 1. Inside of existing CSPA culvert at inlet side (taken by MTO)



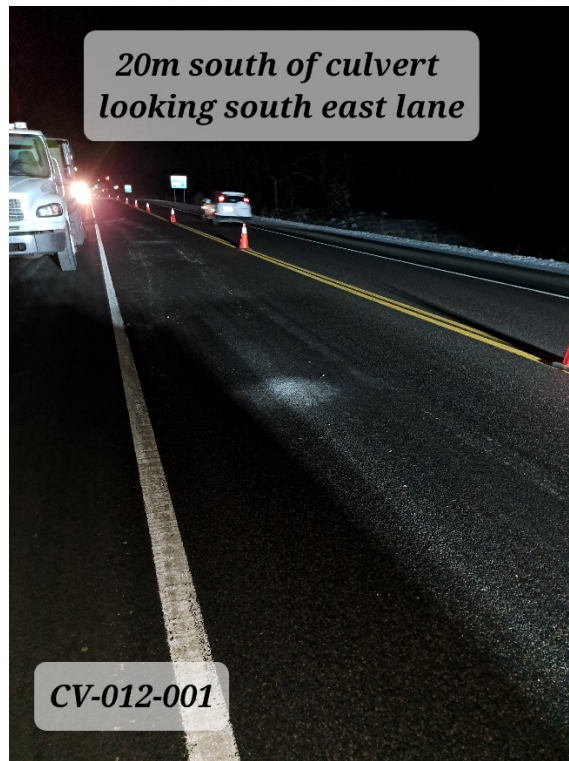
Photograph 2. Inside of existing CSPA culvert at outlet side (taken by MTO)



Photograph 3. Culvert inlet and embankment side slope area (facing east), January 2023 (taken by EXP)



Photograph 4. Culvert outlet and embankment side slope area (facing west), January 2023 (taken by EXP)



Photograph 5. Highway 12 roadway at culvert location, NB lane (facing south), January 2023 (taken by EXP)



Photograph 6. Highway 12 roadway at culvert location, SB lane (facing south), January 2023 (taken by EXP)

Appendix B – General Arrangement Drawings

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2016-10
ANSI-D
MINISTRY OF TRANSPORTATION, ONTARIO

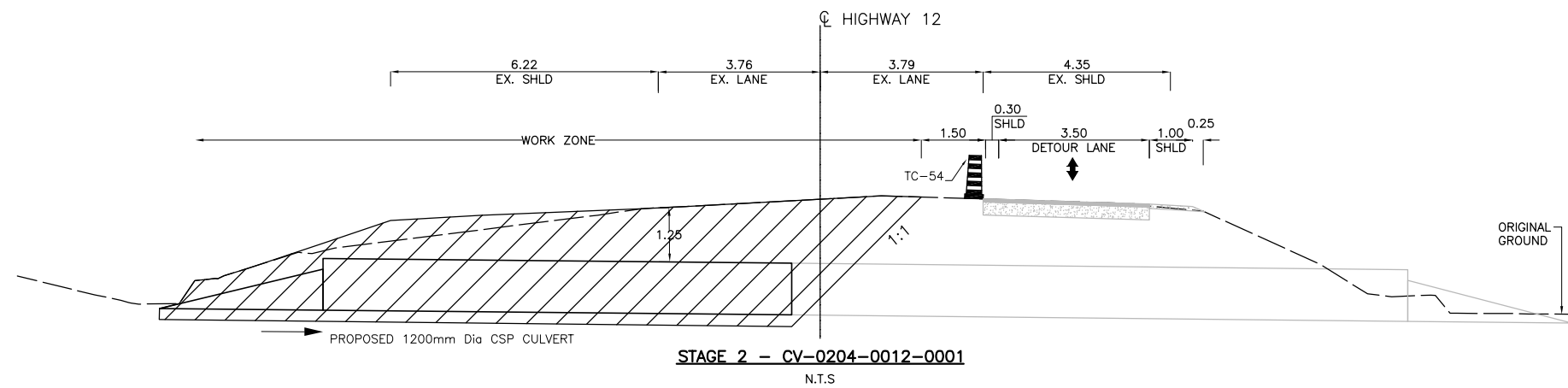
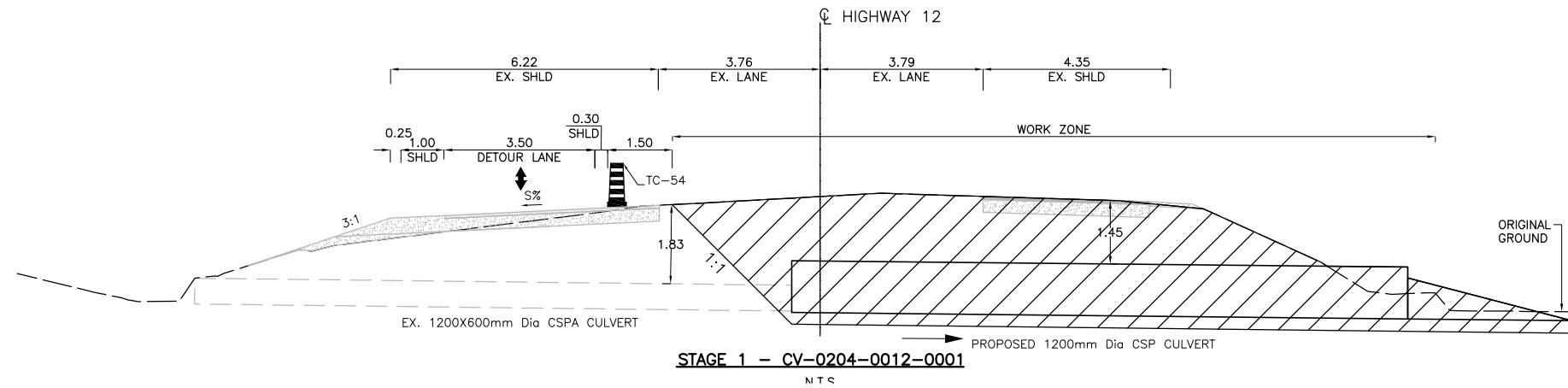
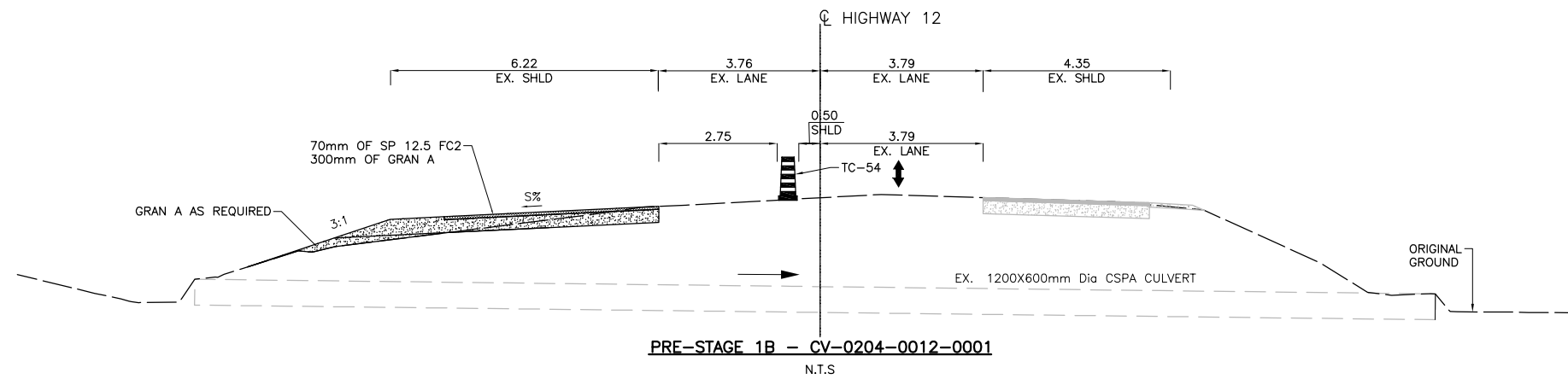
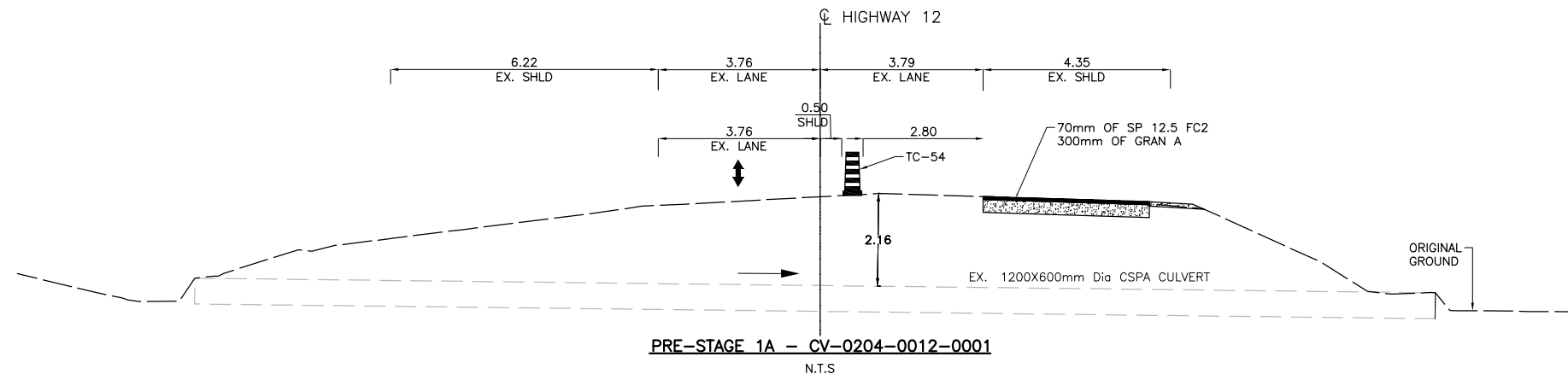


PLATE No	CONT 2023-2024
GWP 2111-19-00	
CV-0204-0012-0001	SHEET 10
STAGING TYPICAL	

- NOTES:
1. SINGLE LANE TRAFFIC TO BE CONTROLLED BY TRAFFIC CONTROL PERSON DURING THE PRE-STAGE AND MAIN STAGES.

CAD FILE LOCATION AND NAME: P:\V-TPD\Projects\CA\Projects\0220768CN_25 Culverts\Drafting\Sheets\Highways\0220768CN_S01.dwg
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DATE PLOTTED: 5/15/2023 5:05:00 PM BY: RMISTRY

2016-10
ANS-D
MINISTRY OF TRANSPORTATION, ONTARIO

LEGEND	
	PROPOSED WORK ZONE
	COMPLETED CONSTRUCTION
	SHOULDER STRENGTHENING DONE AT PRE-STAGE
	TEMPORARY WIDENING DONE AT PRE-STAGE
	TRAFFIC FLOW
	TC-54
	MTD RIGHT OF WAY

- GENERAL NOTES:
- CONSTRUCTION STAGING AND TRAFFIC MANAGEMENT SHALL BE IN ACCORDANCE WITH "OTM" BOOK 7 AND ROADSIDE DESIGN MANUAL.
 - TWO CRASH TRUCKS WITH TC-12 BAR SHALL BE PROVIDED TO PROTECT THE OPEN EXCAVATION DURING EACH STAGE.
 - TRAFFIC FROM ACCESSES SHALL BE MAINTAINED AT ALL TIMES.
 - CONSTRUCTION STAGING DRAWINGS ARE PROVIDED TO ILLUSTRATE THE SUGGESTED TRAFFIC MANAGEMENT APPROACH AND GENERAL CONSTRUCTION STAGING WITHIN THE LIMITS OF CONSTRUCTION. THE DETAILED SCHEDULING OF CONSTRUCTION WORK REQUIRED TO ACCOMMODATE THIS APPROACH (INCLUDING ANY PREPARATORY OR FINISHING WORK) SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR.
 - CONSTRUCTION STAGING DRAWINGS ILLUSTRATE TRAFFIC CONDITIONS TYPICALLY EXPECTED DURING EACH STAGE DURING PERMITTED WORKING HOURS AND HOURS PERMITTED FOR LANE CLOSURES (PER CONTRACT REQUIREMENTS).
 - WORK IN ALL STAGES TO BE COMPLETED AS PER THE GUIDELINES AND DATES SPECIFIED ELSEWHERE IN THE CONTRACT.
 - CONTRACTOR TO MAINTAIN POSITIVE DRAINAGE DURING ALL STAGES.
 - CONTRACTOR SHALL LOCATE AND PROTECT ALL EXISTING UTILITIES.
 - REINSTATE PAVEMENT MARKINGS.

CV-0204-0012-0001
(HWY 12 - DURHAM REGION)
STAGE 1

CV-0204-0012-0001 CULVERT REPLACEMENT STAGE 1	
TRAFFIC	CONSTRUCTION
PRE-STAGES	PRE-STAGES
1. NIGHTTIME LANE CLOSURE WITH TC-54.	1. STRENGTHEN THE EXISTING SHOULDER AND WIDEN ROADWAY AS REQUIRED.
STAGE 1	STAGE 1
1. DURING NIGHTTIME, CLOSE ONE LANE AND KEEP ONE LANE OPEN FOR BOTH DIRECTIONS CONTROLLED BY TCP. 2. DURING THE DAYTIME, REINSTATE TRAFFIC TO NORMAL CONFIGURATIONS.	1. REMOVE SBGR AND TCB WITHIN THE EXCAVATION LIMITS. 2. EXCAVATE AND REMOVE THE SOUTH PORTION OF THE EXISTING CSPS CULVERT. 3. PLACE NEW HDPE CULVERT, BACKFILL & PROVIDE ASPHALT PAVEMENT AS SPECIFIED IN THE CROSS SECTION DETAILS (SEE SHEET-XX). 4. REINSTATE SBGR AND TCB.

PVMS-1-R1		
PVMS-1-R1 (FRAME-1)	ANS	AWS
	MESSAGE DETAILS	
PHASE 1	HWY 12 SINGLE LANE FLAGGING	SINGLE LANE FLAGGING AHEAD
PHASE 2	MMM-DD TO MMM-DD	BE PREPARED TO STOP

PLACE PVMS AT HIGHWAY 12 SB AT APPROX. 600m NORTH OF THORAH CONCESSION RD 3.

PLATE No
CONT 2023-2024
GWP 2111-19-00

CV-0204-0012-0001
STAGE 1 AND 2



SHEET
11

PVMS-2-R2		
PVMS-2-R2 (FRAME-1)	ANS	AWS
	MESSAGE DETAILS	
PHASE 1	HWY 12 SINGLE LANE FLAGGING	SINGLE LANE FLAGGING AHEAD
PHASE 2	MMM-DD TO MMM-DD	BE PREPARED TO STOP

PLACE PVMS AT HIGHWAY 12 NB AT APPROX. 1000m SOUTH OF BROCK CONCESSION RD 14.

SCALE
5m 0 10m

CV-0204-0012-0001
(HWY 12 - DURHAM REGION)
STAGE 2

CV-0204-0012-0001 CULVERT REPLACEMENT STAGE 2	
TRAFFIC	CONSTRUCTION
1. DURING NIGHTTIME, CLOSE ONE LANE AND KEEP ONE LANE OPEN FOR BOTH DIRECTIONS CONTROLLED BY TCP. 2. DURING THE DAYTIME, REINSTATE TRAFFIC TO NORMAL CONFIGURATIONS.	1. EXCAVATE AND REMOVE THE NORTH PORTION OF THE EXISTING CSPS CULVERT. 2. PLACE NEW HDPE CULVERT, BACKFILL & PROVIDE ASPHALT PAVEMENT AS SPECIFIED IN THE CROSS SECTION DETAILS (SEE SHEET-XX).

PVMS-1-R1		
PVMS-1-R1 (FRAME-1)	ANS	AWS
	MESSAGE DETAILS	
PHASE 1	HWY 12 SINGLE LANE FLAGGING	SINGLE LANE FLAGGING AHEAD
PHASE 2	MMM-DD TO MMM-DD	BE PREPARED TO STOP

PLACE PVMS AT HIGHWAY 12 SB AT APPROX. 600m NORTH OF THORAH CONCESSION RD 3.

PVMS-2-R2		
PVMS-2-R2 (FRAME-1)	ANS	AWS
	MESSAGE DETAILS	
PHASE 1	HWY 12 SINGLE LANE FLAGGING	SINGLE LANE FLAGGING AHEAD
PHASE 2	MMM-DD TO MMM-DD	BE PREPARED TO STOP

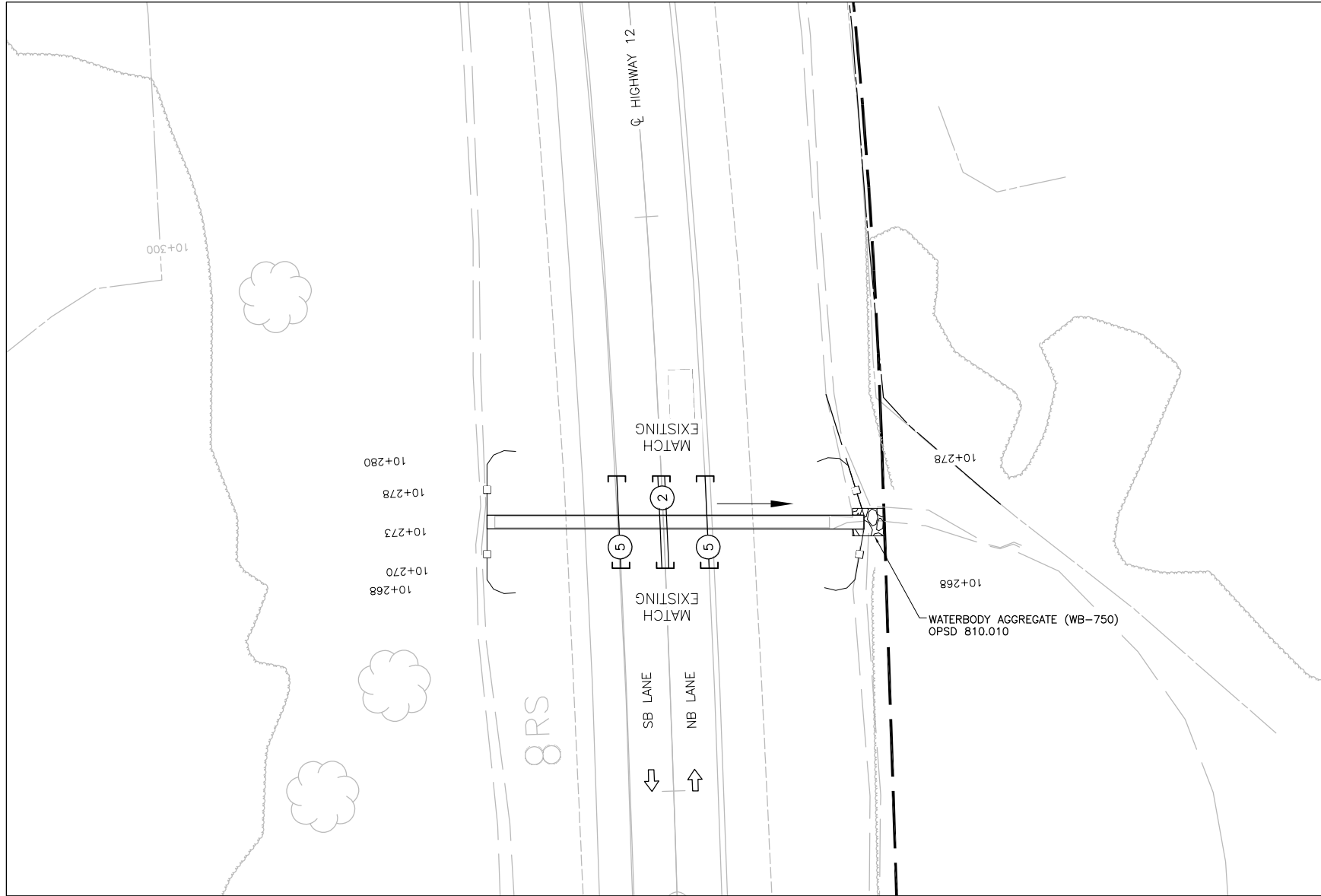
PLACE PVMS AT HIGHWAY 12 NB AT APPROX. 1000m SOUTH OF BROCK CONCESSION RD 14.

SCALE
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MINISTRY OF TRANSPORTATION, ONTARIO
ANS-D
2016-10

CV-0204-0012-0001
(HWY 12 - DURHAM REGION)



LEGEND

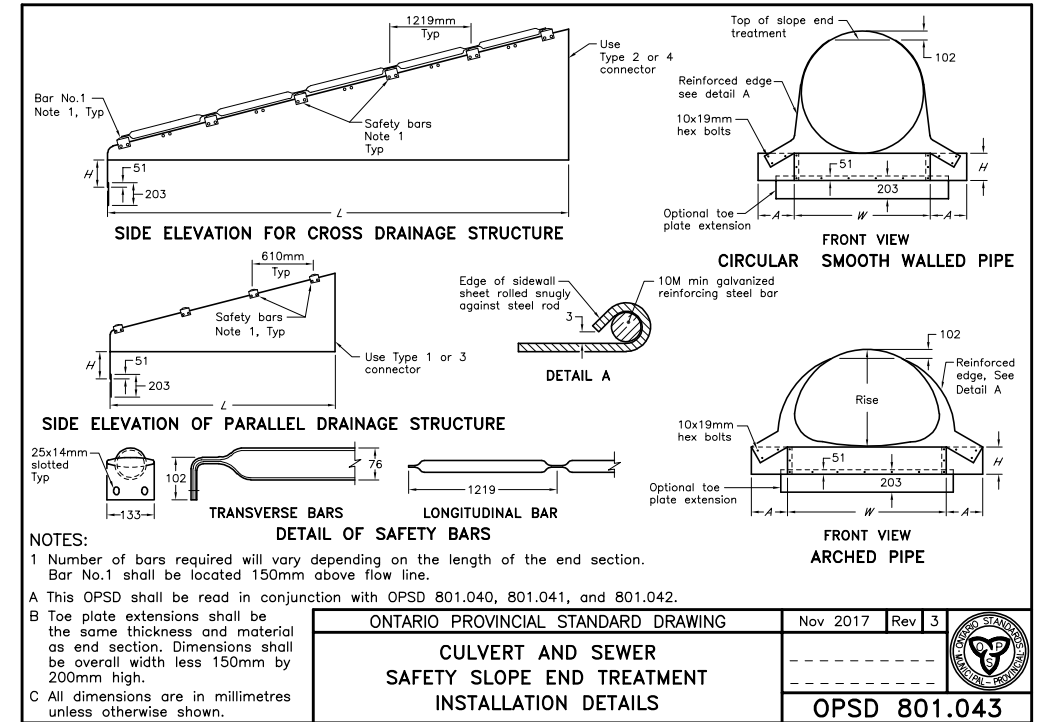
- RIP-RAP/WATERBODY AGGREGATE
- CULVERT REPLACEMENT
- CURB AND GUTTER
- GUIDERAIL
- LIGHT-DUTY SILT FENCE BARRIER
- FLOW DIRECTION

PLATE No
CONT 2023-2024
GWP 2111-19-00

NEW CONSTRUCTION
CV-0204-0012-0001

consor

SHEET
22



1	SOLID YELLOW,10cm
2	SOLID DOUBLE YELLOW,10cm
3	363 BROKEN YELLOW,10cm
4	SOLID YELLOW,20cm
5	SOLID WHITE,10cm
6	333 BROKEN WHITE,10cm
7	363 BROKEN WHITE,10cm
8	393 BROKEN WHITE,10cm
9	SOLID WHITE,20cm
10	111 BROKEN WHITE,20cm
11	333 BROKEN WHITE,20cm
12	333 BROKEN WHITE ,30cm
13	SOLID WHITE,30cm
14	SOLID WHITE,45cm
15	SOLID WHITE,60cm
20	SYMBOLS
] [LIMITS OF MARKINGS	

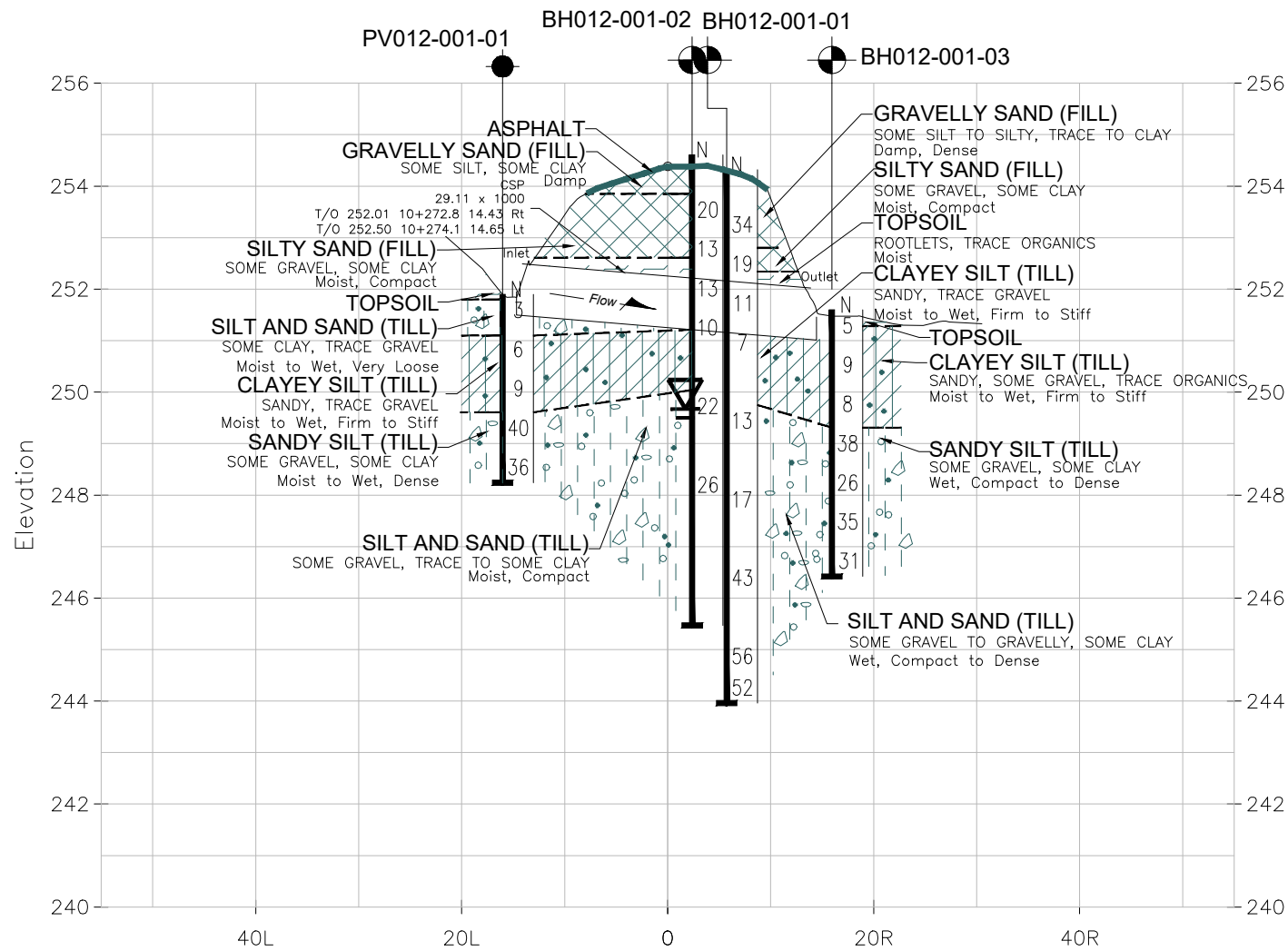
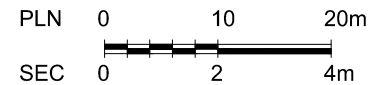
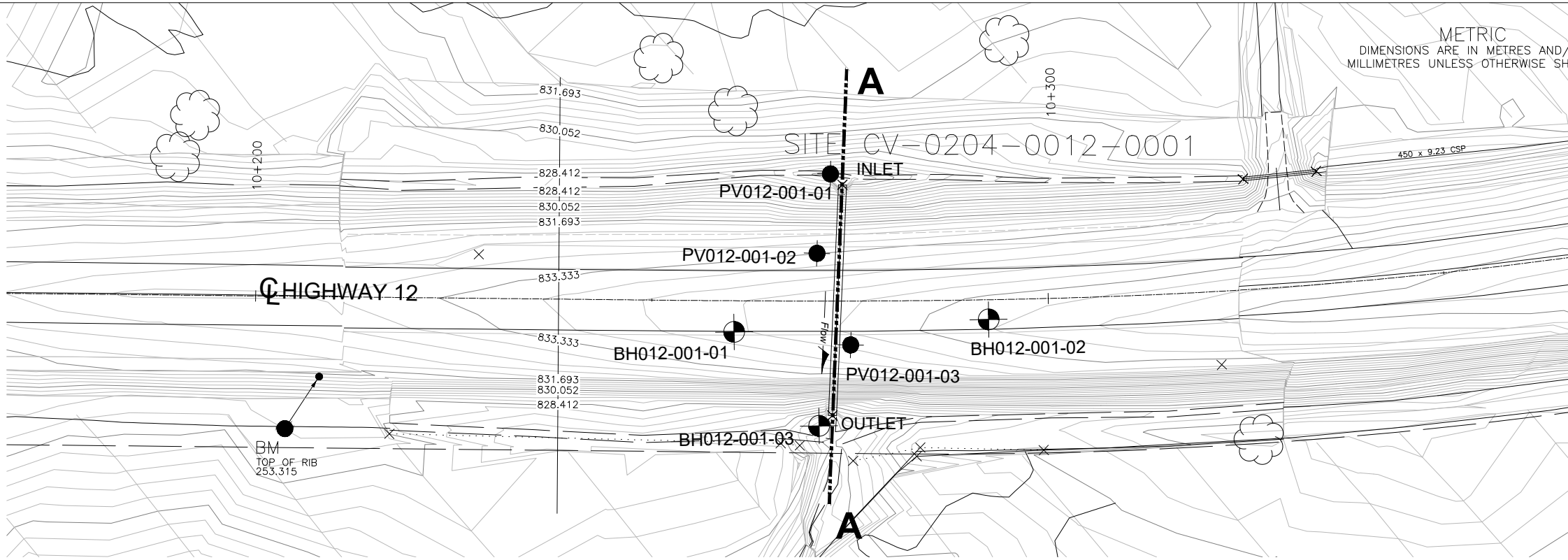
NOTES:

- 333, 363, 393, DENOTES PAVEMENT MARKING SPACING (ie., 3 m line, 3 m gap, 3 m line)
- Use ① to Denote PAVEMENT MARKING
- Use ① to Denote PAVEMENT MARKING, TEMPORARY
- Use △ to Denote PAVEMENT MARKING, TEMPORARY- REMOVABLE
- Use ① to Denote PAVEMENT MARKING, DURABLE
- FROST TAPERS are based on OPD 803.030, 803.031

SCALE
5m 0 10m

Appendix C – Borehole Location Plan and Stratigraphic Strata

FILE NAME: I:\2003-Brampton\Proposals\Projects\International\MTD Projects\MTD 2020-E-0028 25 culverts\working drawings\CAD drafting\CV-0204-0012-0001 - borehole location plan & soil strata.dwg
MODIFIED: 2023-05-16 11:03



SECTION A-A ALONG & CV-0204-0012-0001 CULVERT

ASSIG No. 2020-E-0028

GWP No. 2111-19-00

HIGHWAY 12 CULVERT REPLACEMENT, DURHAM, ON

CV-0204-0012-0001

Latitude: 44.377620° Longitude: -79.104760°

BOREHOLE LOCATION PLAN & SOIL STRATA



EXP SERVICES INC.



KEY PLAN
N.T.S.

LEGEND

- Borehole Location
- Pavement Borehole
- Water Level Upon Completion of Drilling
(W. L. NOT STABILIZED)
- Blows/0.3m (Std. Pen. Test, 475 J/blow)

SOIL STRATA SYMBOLS

- ASPHALT
- FILL
- TOPSOIL
- CLAYEY SILT (TILL)
- SILT AND SAND (TILL)

BOREHOLE CO-ORDINATES/ NAD 83/ MTM ON-10

BH No.	ELEV.	NORTHING	EASTING
BH012-001-01	254.3	4915346.2	336307.5
BH012-001-02	254.6	4915376.5	336318.4
BH012-001-03	251.6	4915351.6	336322.6
PV012-001-01	251.9	4915365.1	336293.8
PV012-001-02	254.1	4915359.7	336302.4
PV012-001-03	254.4	4915359.2	336314.7

NOTES

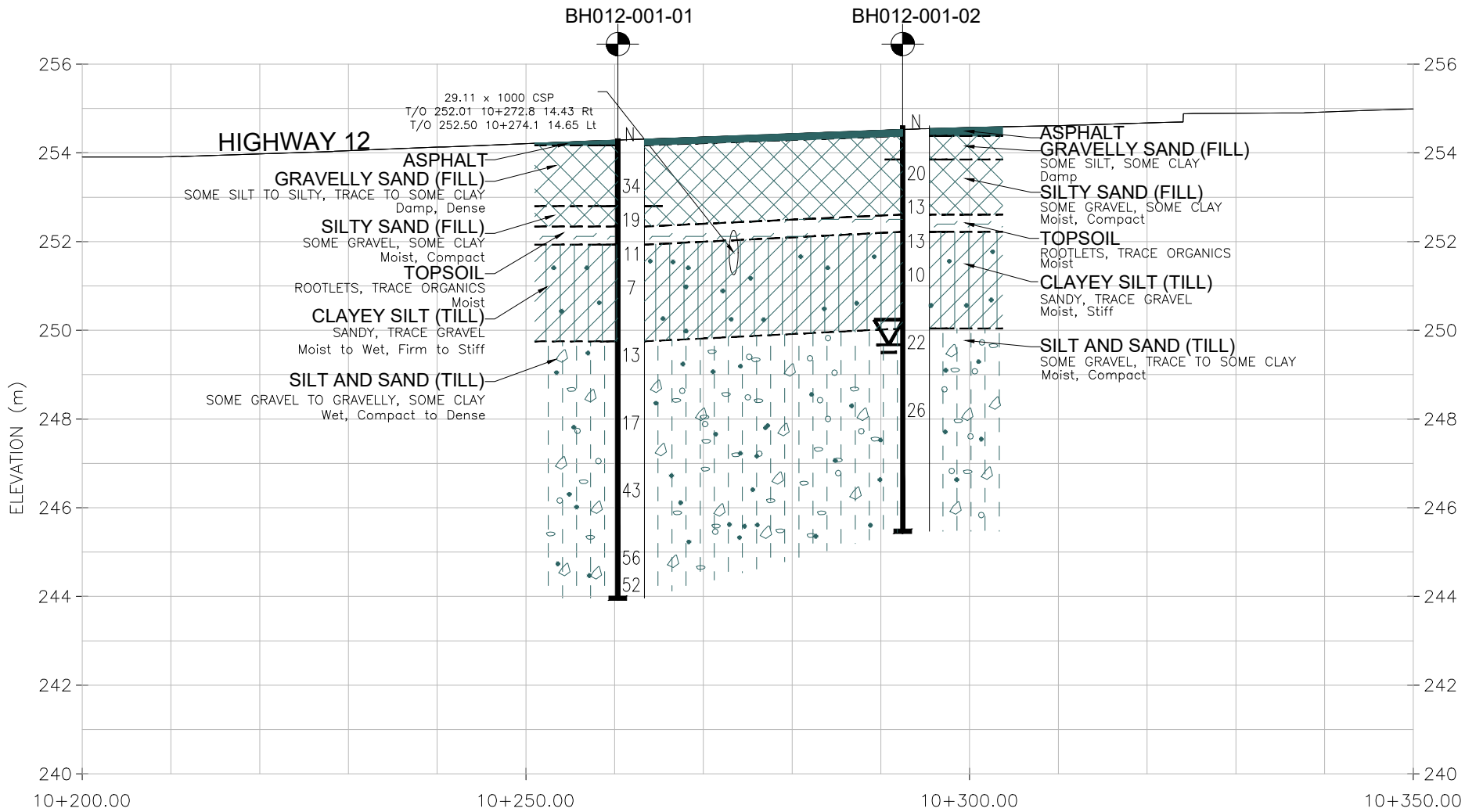
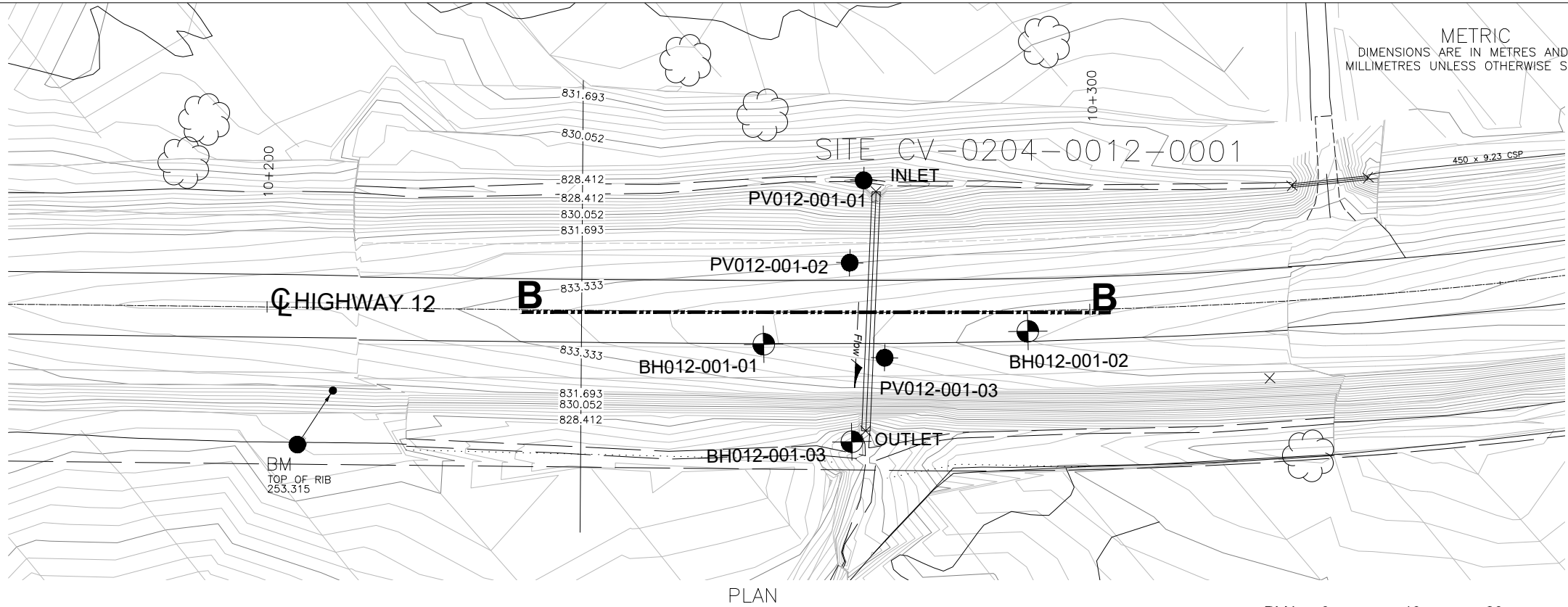
This drawing is for subsurface information only. The proposed structure details/works are shown for illustration purposes only and may not be consistent with the final design configuration as shown elsewhere in the Contracts Documents.

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

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

SUBMISSION FOR MTO REVIEW			
NO	DATE	BY	DESCRIPTION
PROJECT No.	ADM-22007871-A0	GEOCRES No.	31D-821
SUBM'D SH	CHKD. SM	DATE	MAY 17, 2023 SITE-
DRAWN SH	CHKD. TC	APPRD SG	DWG 01

FILE NAME: I:\2003-Brampton\Proposals\Projects\International\MTD Projects\MTD 2020-E-0028 25 culverts\working drawings\CAD drafting\CV-0204-0012-0001 - borehole location plan & soil strata.dwg
MODIFIED: 2023-05-16 11:03



ASSIG No. 2020-E-0028

GWP No. 2111-19-00

HIGHWAY 12 CULVERT REPLACEMENT, DURHAM, ON

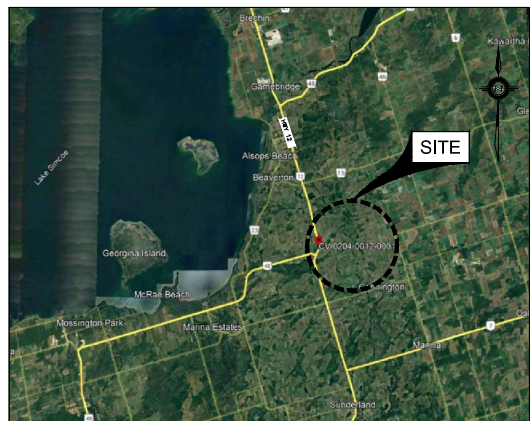
CV-0204-0012-0001

Latitude: 44.377620° Longitude: -79.104760°

BOREHOLE LOCATION PLAN & SOIL STRATA



EXP SERVICES INC.



KEY PLAN
N.T.S.

LEGEND

- Borehole Location
- Pavement Borehole
- Water Level Upon Completion of Drilling
(W. L. NOT STABILIZED)
- Blows/0.3m (Std. Pen. Test, 475 J/blow)

SOIL STRATA SYMBOLS

- ASPHALT
- FILL
- TOPSOIL
- CLAYEY SILT (TILL)
- SILT AND SAND (TILL)

BOREHOLE CO-ORDINATES/ NAD 83/ MTM ON-10

BH No.	ELEV.	NORTHING	EASTING
BH012-001-01	254.3	4915346.2	336307.5
BH012-001-02	254.6	4915376.5	336318.4
BH012-001-03	251.6	4915351.6	336322.6
PV012-001-01	251.9	4915365.1	336293.8
PV012-001-02	254.1	4915359.7	336302.4
PV012-001-03	254.4	4915359.2	336314.7

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.

The complete foundation investigation and design report for this project and other related documents may be examined at the Materials Engineering and Research Office, Downsview. Information contained in the report and related documents are specifically excluded in accordance with the conditions of Section GC 2.01 of OPS Gen. Cond.

SUBMISSION FOR MTO REVIEW			
NO	DATE	BY	DESCRIPTION
PROJECT No.	ADM-22007871-A0	GEOCRES No.	31D-821
SUBM'D SH	CHKD. SM	DATE	MAY 17, 2023 SITE-
DRAWN SH	CHKD. TC	APPRD SG	DWG 02

Appendix D – Borehole Logs

Explanation of Terms Used on Borehole Records

SOIL DESCRIPTION

Terminology describing common soil genesis:

Topsoil: mixture of soil and humus capable of supporting good vegetative growth.

Peat: fibrous fragments of visible and invisible decayed organic matter.

Fill: where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc.; none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.

Till: the term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

Terminology describing soil structure:

Desiccated: having visible signs of weathering by oxidization of clay minerals, shrinkage cracks, etc.

Stratified: alternating layers of varying material or color with the layers greater than 6 mm thick.

Laminated: alternating layers of varying material or color with the layers less than 6 mm thick.

Fissured: material breaks along plane of fracture.

Varved: composed of regular alternating layers of silt and clay.

Slickensided: fracture planes appear polished or glossy, sometimes striated.

Blocky: cohesive soil that can be broken down into small angular lumps which resist further breakdown.

Lensed: inclusion of small pockets of different soil, such as small lenses of sand scattered through a mass of clay; not thickness.

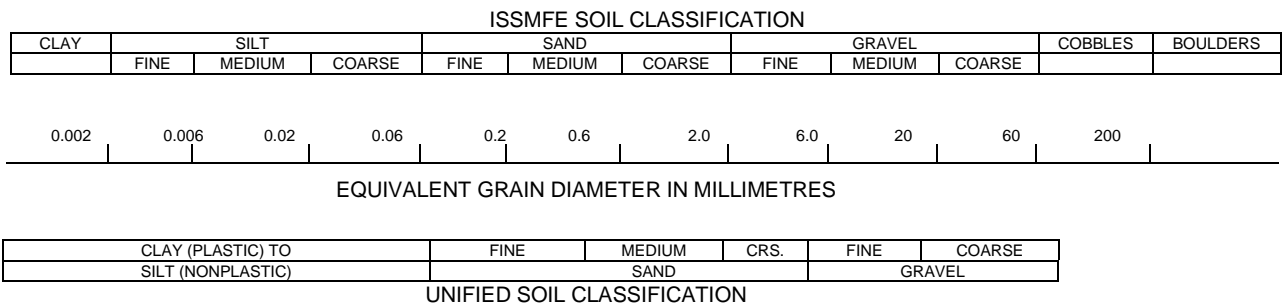
Seam: a thin, confined layer of soil having different particle size, texture, or color from materials above and below.

Homogeneous: same color and appearance throughout.

Well Graded: having wide range in grain sized and substantial amounts of all predominantly on grain size.

Uniformly Graded: predominantly on grain size.

All soil sample descriptions included in this report follow generally the ASTM D2487-11 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System) with some modification to reflect current MTO practices. The system divides soils into three major categories: (1) coarse grained, (2) fine-grained, and (3) highly organic. The soil is then subdivided based on either gradation or plasticity characteristics. The system provides a group symbol (e.g. SM) and group name (e.g. silty sand) for identification. The classification excludes particles larger than 76 mm. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually in accordance with ASTM D2488-09a Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems. Others may use different classification systems; one such system is the ISSMFE Soil Classification.



Terminology describing materials outside the USCS, (e.g. particles larger than 76 mm, visible organic matter, construction debris) is based upon the proportion of these materials present and as described below in accordance with Canadian Foundation Engineering Manual (CFEM):

Table a: Percent or Proportion of Soil

Term	Description	Criteria
"trace"	trace gravel, trace sand, etc.	1% - 10%
"some"	some gravel, some sand, etc.	10% - 20%
Adjective	gravelly, sandy, silty and clayey	20% - 35%
"and"	and gravel, and sand, etc.	>35%
Noun	gravel, sand, silt, clay	>35% and main fraction

The standard terminology to describe cohesionless soils includes the compactness as determined by the Standard Penetration Test 'N' value:

Table b: Apparent Density of Cohesionless Soil

	'N' Value (blows/0.3 m)
Very Loose	N<5
Loose	5≤N<10
Compact	10≤N<30
Dense	30≤N<50
Very Dense	50≤N

The standard terminology to describe cohesive soils includes consistency, which is based on undrained shear strength as measured by insitu vane tests, penetrometer tests, unconfined compression tests or similar field and laboratory analysis, Standard Penetration Test 'N' values can also be used to provide an approximate indication of the consistency and shear strength of fine grained, cohesive soils:

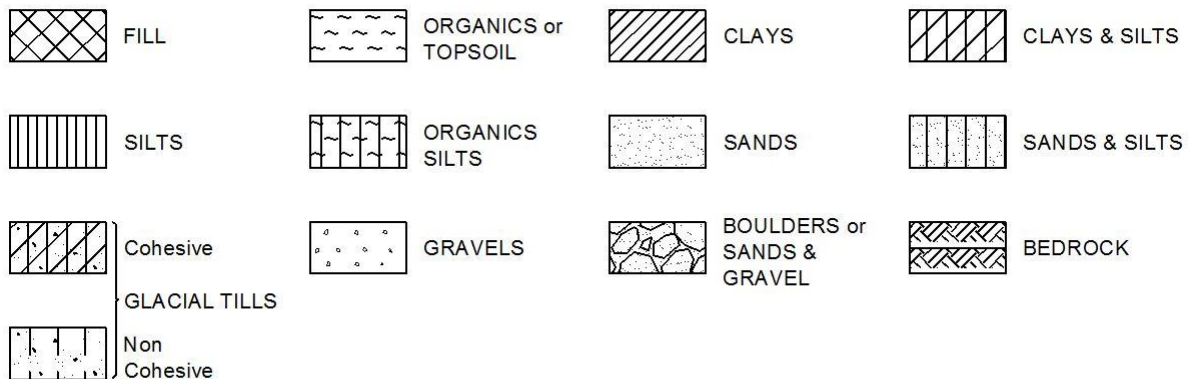
Table c: Consistency of Cohesive Soil

Consistency	Vane Shear Measurement (kPa)	'N' Value
Very Soft	<12.5	<2
Soft	12.5-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very Stiff	100-200	15-30
Hard	>200	>30

Note: 'N' Value - The Standard Penetration Test records the number of blows of a 140 pound (64kg) hammer falling 30 inches (760mm), required to drive a 2 inch (50.8mm) O.D. split spoon sampler 1 foot (305mm). For split spoon samples where full penetration is not achieved, the number of blows is reported over the sampler penetration in meters (e.g. 50/0.15).

STRATA PLOT

Strata plots symbolize the soil or bedrock description. They are combinations of the following basic symbols:



WATER LEVEL MEASUREMENT



Open Borehole or Test Pit



Monitoring Well, Piezometer or Standpipe

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

SS	Split spoon sample (obtained from the Standard Penetration Test)
WS	Wash sample
BS	Bulk sample
TW	Thin wall sample or Shelby tube
PS	Piston sample
AS	Auger sample
VT	Vane test
GS	Grab sample
HQ, NQ, etc.	Rock core samples obtained with the use of standard size diamond drilling bits

STRESS AND STRAIN

u_w	kPa	Pore water pressure
r_u	1	Pore pressure ratio
σ	kPa	Total normal stress
σ'	kPa	Effective normal stress
τ	kPa	Shear stress
$\sigma_1, \sigma_2, \sigma_3$	kPa	Principal stresses
ε	%	Linear strain
$\varepsilon_1, \varepsilon_2, \varepsilon_3$	%	Principal strains
E	kPa	Modulus of linear deformation
G	kPa	Modulus of shear deformation
μ	1	Coefficient of friction

MECHANICAL PROPERTIES OF SOIL

m_v	kPa ⁻¹	Coefficient of volume change
c_c	1	Compression index
c_s	1	Swelling index
c_r	1	Recompression index
c_v	m ² /s	Coefficient of consolidation
H	m	Drainage path
T_v	1	Time factor
U	%	Degree of consolidation
σ'_{v0}	kPa	Effective overburden pressure
σ'_p	kPa	Preconsolidation pressure
τ_f	kPa	Shear strength
c'	kPa	Effective cohesion intercept
ϕ'	—°	Effective angle of internal friction
c_u	kPa	Apparent cohesion intercept
ϕ_u	—°	Apparent angle of internal friction
τ_R	kPa	Residual shear strength
τ_r	kPa	Remoulded shear strength
S_t	1	Sensitivity = c_u/τ_r

PHYSICAL PROPERTIES OF SOIL

P_s	kg/m ³	Density of solid particles
γ_s	kN/m ³	Unit weight of solid particles
ρ_w	kg/m ³	Density of water
γ_w	kN/m ³	Unit weight of water
ρ	kg/m ³	Density of soil
γ	kN/m ³	Unit weight of soil
ρ_d	kg/m ³	Density of dry soil
γ_d	kN/m ³	Unit weight of dry soil
ρ_{sat}	kg/m ³	Density of saturated soil
γ_{sat}	kN/m ³	Unit weight of saturated soil
ρ'	kg/m ³	Density of submerged soil
γ'	kN/m ³	Unit weight of submerged soil
e	1, %	Void ratio
n	1, %	Porosity
w	1, %	Water content
S_r	%	Degree of saturation
W_L	%	Liquid limit
W_P	%	Plastic limit
W_s	%	Shrinkage limit
I_p	%	Plasticity index = $(W_L - W_P)$
I_L	%	Liquidity index = $(W - W_P)/I_p$
I_C	%	Consistency index = $(W_L - W)/I_p$
e_{max}	1, %	Void ratio in loosest state
e_{min}	1, %	Void ratio in densest state
I_D	1	Density index = $(e_{max} - e)/(e_{max} - e_{min})$
D	mm	Grain diameter
D_n	mm	N percent - diameter
C_u	1	Uniformity coefficient
h	m	Hydraulic head or potential
q	m ³ /s	Rate of discharge
v	m/s	Discharge velocity
i	1	Hydraulic gradient
k	m/s	Hydraulic conductivity
j	kN/m ³	Seepage force

Brampton, Ontario

RECORD OF BOREHOLE No BH012-001-01


























































1 OF 1

METRIC

W.P. CV-0204-0012-0001 LOCATION CV-0204-0012-0001, Durham, ON, MTM ON-10 336307.5E 4915346.2N, 3.90 Rt ORIGINATED BY SF

DIST Durham HWY 12 BOREHOLE TYPE Rubber Track Drill - MARL M5T / SSA COMPILED BY SF

DATUM Geodetic DATE 2023.01.23 - 2023.01.23 LATITUDE 44.377438 LONGITUDE -79.104614 CHECKED BY NT/AA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER								
254.3							20	40	60	80	100					
250.0	ASPHALT - (150 mm)		AS1	AS												
0.2	GRAVELLY SAND (FILL) - some silt, trace to some clay, brown, damp, dense		AS2	AS												22 57 (21)
	- becoming silty at depth of 0.8 m		SS3	SS	34											25 36 29 10
252.8																
1.5	SILTY SAND (FILL) - some gravel, some clay, brown with grey inclusions, moist, compact		SS4	SS	19											
252.3																
2.0	TOPSOIL - (410 mm) contains rootlets, trace organics, black, moist															
251.9																
2.4	CLAYEY SILT (TILL) - sandy, trace gravel, grey to brown, moist to wet, firm to stiff		SS5	SS	11											5 28 37 30
																
			SS6	SS	7											
																
																
249.8																
4.6	SILT AND SAND (TILL) - some gravel, some clay, grey to brown, wet, compact to dense		SS7	SS	13											
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
																
244.0	END OF BOREHOLE															
10.4	NOTE: 1) Groundwater level could not be measured due to cave-in at 2.60 m in borehole.															

ONTARIO MTO CV-0204-0012-0001_BH.GPJ ONTARIO MTO.GDT 5/4/23

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

Brampton, Ontario

RECORD OF BOREHOLE No BH012-001-02

1 OF 1

METRIC

W.P. CV-0204-0012-0001 LOCATION CV-0204-0012-0001, Durham, ON, MTM ON-10 336318.4E 4915376.5N, 2.59 Rt ORIGINATED BY SF

DIST Durham HWY 12 BOREHOLE TYPE Rubber Track Drill - MARL M5T / SSA COMPILED BY SF

DATUM Geodetic DATE 2023.01.24 - 2023.01.24 LATITUDE 44.37771 LONGITUDE -79.104475 CHECKED BY NT/AA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)						
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa											
								UNCONFINED + FIELD VANE											
254.6	ASPHALT - (230 mm)		AS1	AS															
254.4	GRAVELLY SAND (FILL) - some silt, some clay, brown, damp		AS2	AS															
253.9	SILTY SAND (FILL) - some gravel, some clay, grey to brown, moist, compact		SS3	SS	20														
252.6			SS4	SS	13														
252.0	TOPSOIL - (390 mm), contains rootlets, trace organics, dark grey to black, moist																		
252.2	CLAYEY SILT (TILL) - sandy, trace gravel, grey to brown, moist, stiff		SS5	SS	13														
250.0			SS6	SS	10														
4.6	SILT AND SAND (TILL) - some gravel, trace to some clay, grey to brown, moist, compact		SS7	SS	22														
			SS8	SS	26														
	- inferred cobble/boulder at 7.6 m		AS9	AS															
245.5	- inferred cobble/boulder at 9.1 m																		
9.1	END OF BOREHOLE																		
	NOTE: 1) Sample AS9 was terminated after application of 50 consecutive blows from start and no advancement of split spoon sampler (possibly cobbles). Sample was obtained from auger after drilling for subsequent sample. 2) Borehole terminated at 9.14 m after application of 50 consecutive blows from start and no advancement of split spoon sampler (possibly cobbles). 3) Groundwater level was encountered at a depth of 4.93 m upon completion of drilling.																		

+ 3, X 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

ONTARIO MTO CV-0204-0012-0001_BH.GPJ ONTARIO MTO.GDT 5/4/23

Brampton, Ontario

RECORD OF BOREHOLE No BH012-001-03

1 OF 1

METRIC

W.P. CV-0204-0012-0001 LOCATION CV-0204-0012-0001, Durham, ON, MTM ON-10 336322.6E 4915351.6N, 15.71 Rt ORIGINATED BY SF
 DIST Durham HWY 12 BOREHOLE TYPE Rubber Track Drill - MARL M5T / SSA COMPILED BY SF
 DATUM Geodetic DATE 2023.03.16 - 2023.03.16 LATITUDE 44.377486 LONGITUDE -79.104425 CHECKED BY NT/AA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER							WATER CONTENT (%)			
251.6								20	40	60	80	100						
250.6	TOPSOIL - (100 mm)																	
0.1	CLAYEY SILT (TILL) - sandy, some gravel, trace organics, brown, moist to wet, firm to stiff		SS1	SS	5		251											
			SS2	SS	9													13 39 36 12
			SS3	SS	8		250											
249.3	SANDY SILT (TILL) - some gravel, some clay, brown, wet, compact to dense		SS4	SS	38		249											20 34 35 11
2.3			SS5	SS	26		248											
			SS6	SS	35													
			SS7	SS	31		247											
246.4	END OF BOREHOLE																	
5.2	NOTE: 1) Groundwater level could not be measured due to cave-in at 0.46 m in borehole.																	

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

ONTARIO MTO CV-0204-0012-0001_BH.GPJ ONTARIO MTO.GDT 5/4/23

Brampton, Ontario

RECORD OF BOREHOLE No PV012-001-01

1 OF 1

METRIC

W.P. CV-0204-0012-0001 LOCATION CV-0204-0012-0001, Durham, ON, MTM ON-10 336293.8E 4915365.1N, 16.1 Lt ORIGINATED BY SF
 DIST Durham HWY 12 BOREHOLE TYPE Rubber Track Drill - MARL M5T / SSA COMPILED BY SF
 DATUM Geodetic DATE 2023.03.16 - 2023.03.16 LATITUDE 44.377609 LONGITUDE -79.104785 CHECKED BY NT/AA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _P	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa									
○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER																	
251.9							20	40	60	80	100						
250.8	TOPSOIL - (100 mm)																
0.1	SILT AND SAND (TILL) - some clay, trace gravel, brown, moist to wet, very loose		SS1	SS	3								○				
251.1																	
0.8	CLAYEY SILT (TILL) - sandy, trace gravel, brown to grey, moist to wet, firm to stiff		SS2	SS	6												
			SS3	SS	9								○				
249.6																	
2.3	SANDY SILT (TILL) - some gravel, some clay, brown to grey, moist to wet, dense		SS4	SS	40												
			SS5	SS	36								○				
248.2													○				
3.7	END OF BOREHOLE																
	NOTE: 1) Groundwater level could not be measured due to cave-in at 0.46 m in borehole.																

+ 3, X 3: Numbers refer to Sensitivity O 3% STRAIN AT FAILURE

ONTARIO MTO CV-0204-0012-0001_PV.GPJ ONTARIO MTO.GDT 5/4/23

Brampton, Ontario

RECORD OF BOREHOLE No PV012-001-02

1 OF 1

METRIC

W.P. CV-0204-0012-0001 LOCATION CV-0204-0012-0001, Durham, ON, MTM ON-10 336302.4E 4915359.7N, 6.02 Lt ORIGINATED BY SF
 DIST Durham HWY 12 BOREHOLE TYPE Rubber Track Drill - MARL M5T / SSA COMPILED BY SF
 DATUM Geodetic DATE 2023.01.24 - 2023.01.24 LATITUDE 44.37756 LONGITUDE -79.104678 CHECKED BY NT/AA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL P. PENETROMETER								
254.1							20	40	60	80	100					
253.7	ASPHALT - (50 mm)															
253.7	SAND WITH GRAVEL (BASE COURSE) - (300 mm), trace silt, brown, damp		AS1	AS												28 63 (9)
253.3	SAND WITH GRAVEL (SUB-BASE) - (410 mm), trace silt, brown, damp															
253.3	SAND WITH GRAVEL (FILL) - some silt, some clay, grey to brown, moist, compact		SS2	SS	20											
252.5																
251.9	SANDY SILT (TILL) - some gravel, some clay, grey to black, moist, compact		SS3	SS	10											
251.9	END OF BOREHOLE															
2.1	NOTE: 1) Groundwater was not encountered in open borehole upon completion of drilling.															

Brampton, Ontario

RECORD OF BOREHOLE No PV012-001-03

1 OF 1

METRIC

W.P. CV-0204-0012-0001 LOCATION CV-0204-0012-0001, Durham, ON, MTM ON-10 336314.7E 4915359.2N, 5.54 Rt ORIGINATED BY SF
 DIST Durham HWY 12 BOREHOLE TYPE Rubber Track Drill - MARL M5T / SSA COMPILED BY SF
 DATUM Geodetic DATE 2023.01.24 - 2023.01.24 LATITUDE 44.377555 LONGITUDE -79.104523 CHECKED BY NT/AA

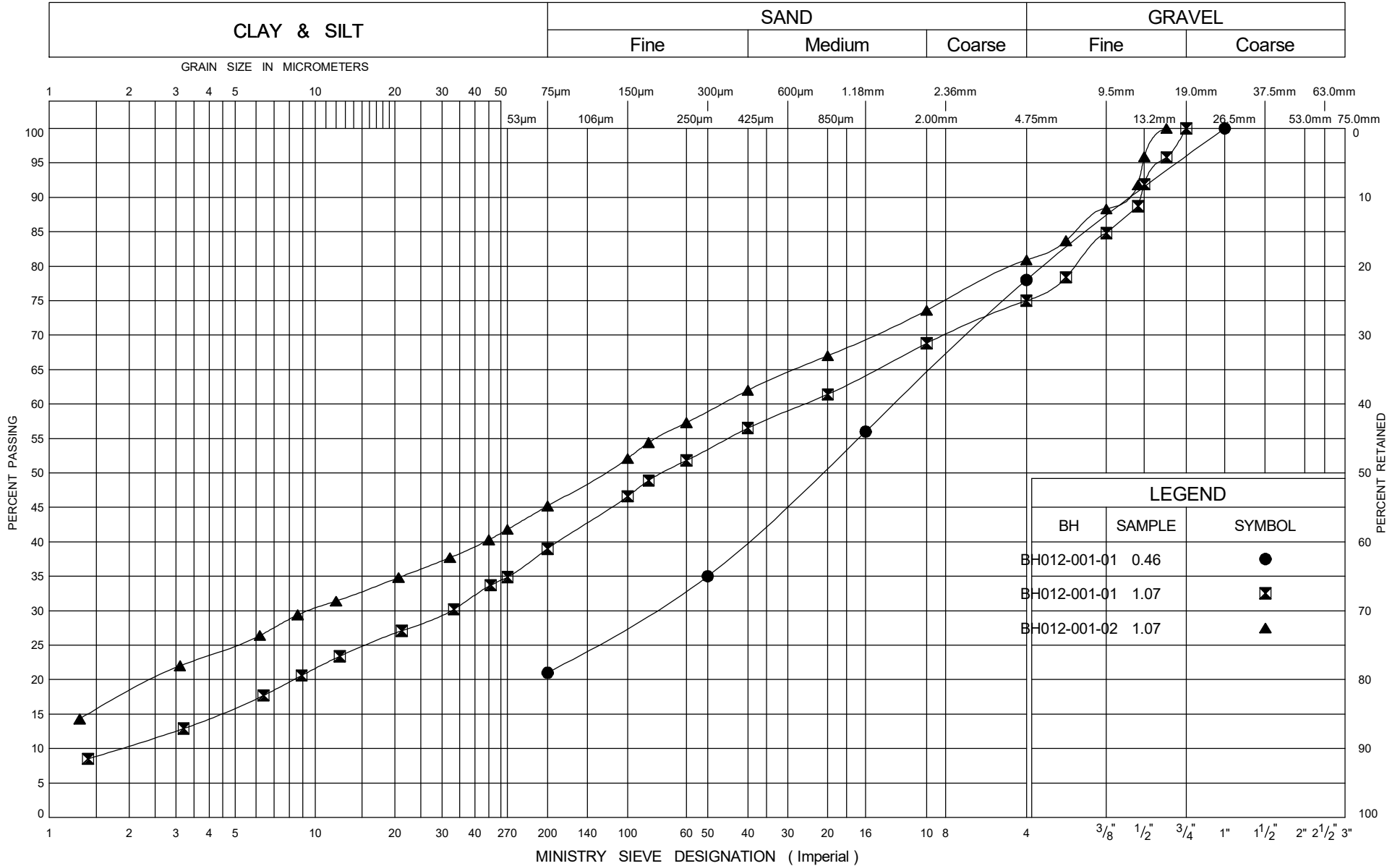
SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			SHEAR STRENGTH kPa					W _p	W	W _L		
254.4							20	40	60	80	100					
0.0	SAND WITH GRAVEL (FILL) - some silt, some clay, brown to grey, moist, compact to very dense		SS1	SS	50	254										
			SS2	SS	17											
252.8						253										
1.5	SANDY SILT (TILL) - some gravel, some clay, brown to grey, moist, compact		SS3	SS	11											
252.2																
2.1	END OF BOREHOLE NOTE: 1) Groundwater was not encountered in open borehole upon completion of drilling.															

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

ONTARIO MTO CV-0204-0012-0001_PV.GPJ ONTARIO MTO.GDT 5/4/23

Appendix E – Laboratory Data

UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION

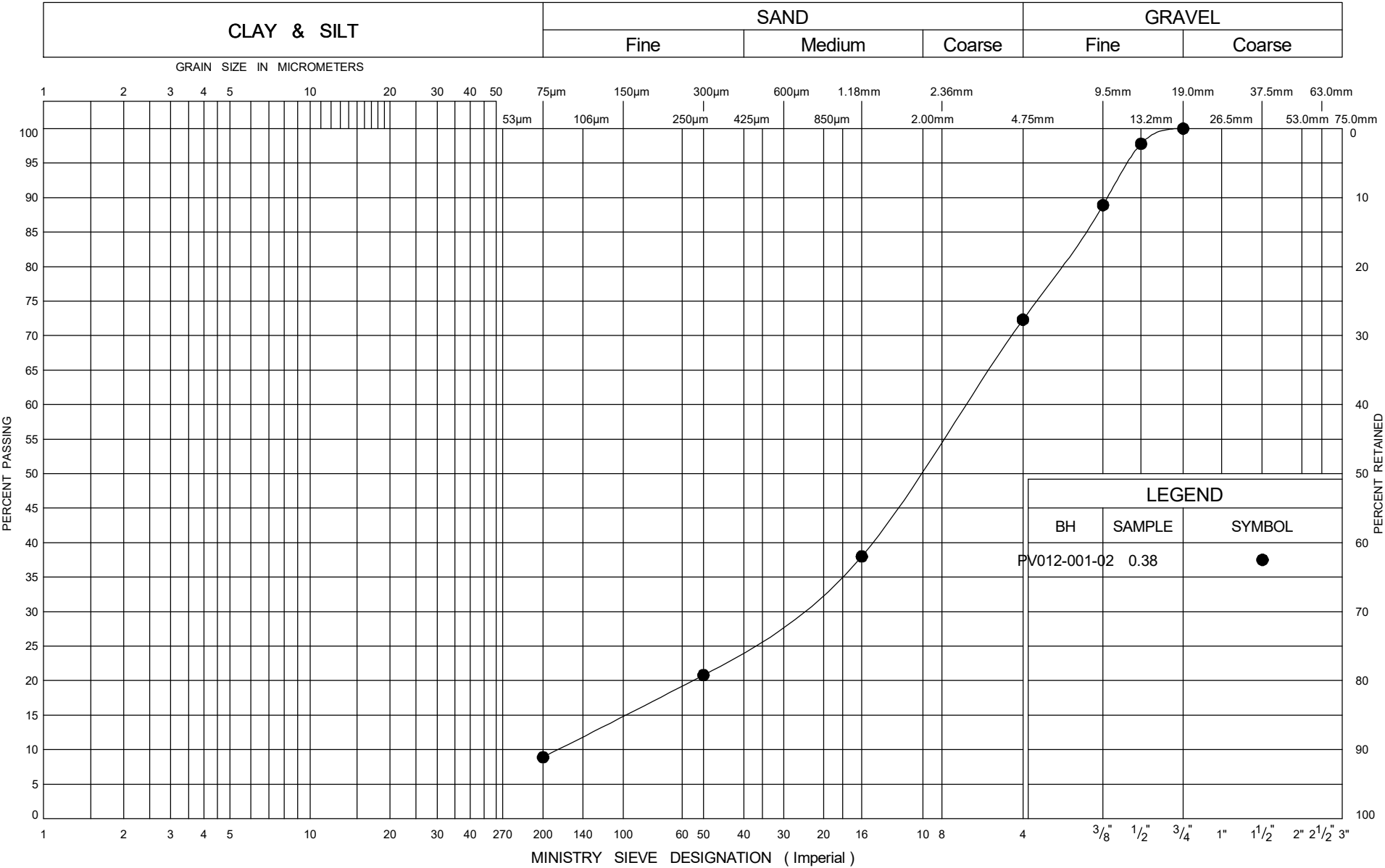
Cohesionless Fill

FIG No 1

GWP 2111-19-00

Culvert ID CV-0204-0012-0001

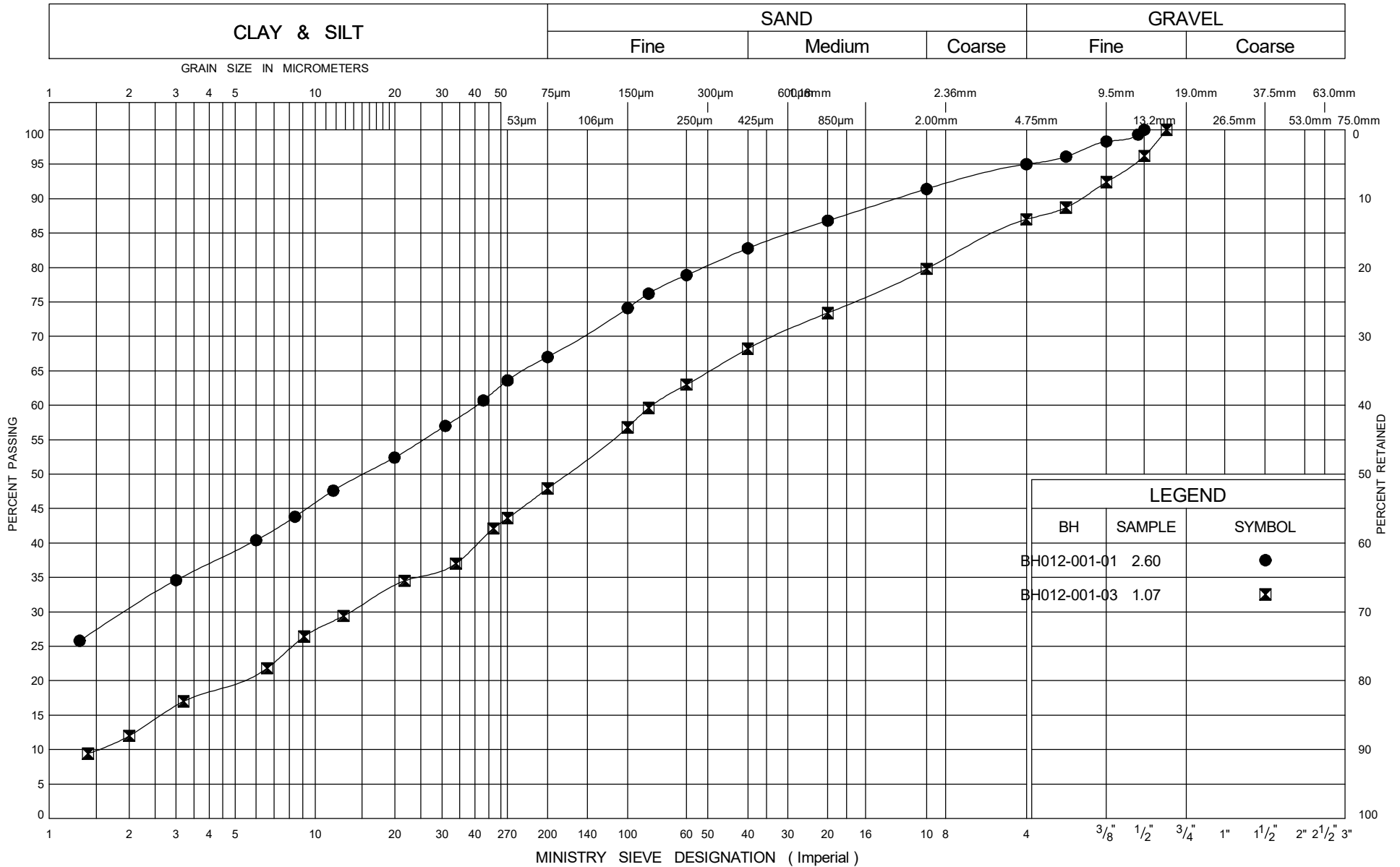
UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION
Cohesionless Fill

FIG No 2
GWP 2111-19-00
Culvert ID CV-0204-0012-0001

UNIFIED SOIL CLASSIFICATION SYSTEM



GRAIN SIZE DISTRIBUTION

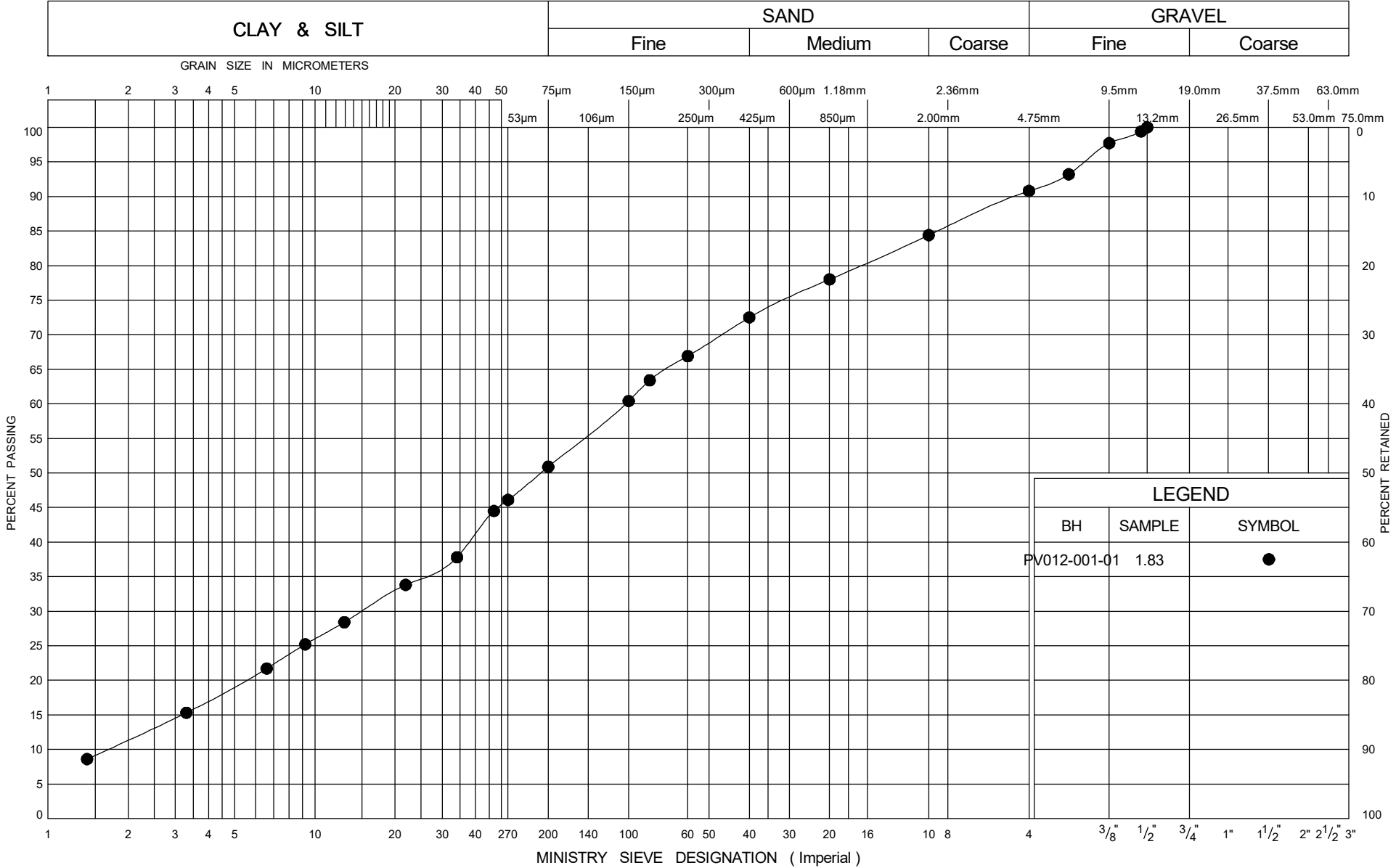
Clayey Silt Till

FIG No 3

GWP 2111-19-00

Culvert ID CV-0204-0012-0001

UNIFIED SOIL CLASSIFICATION SYSTEM



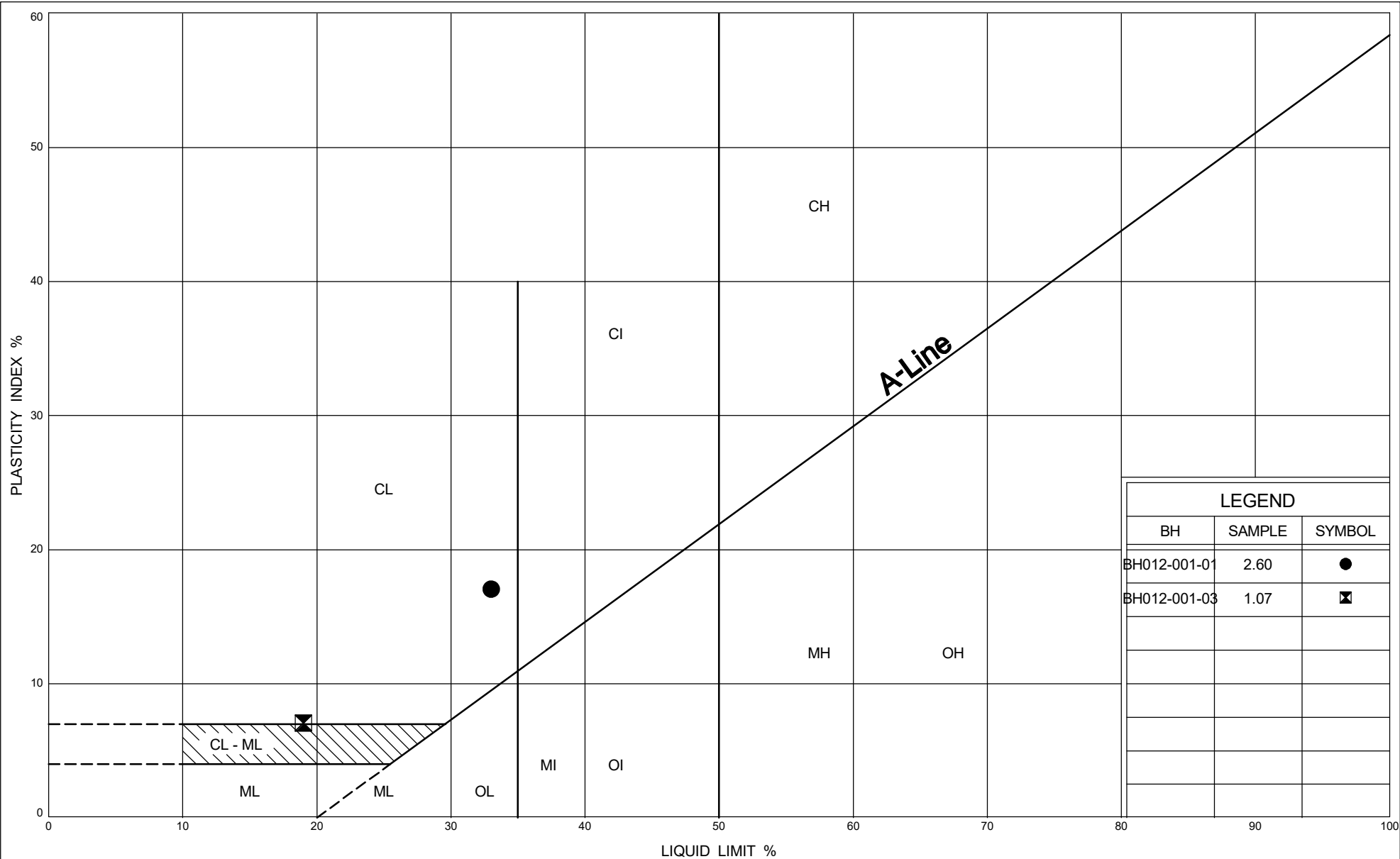
GRAIN SIZE DISTRIBUTION

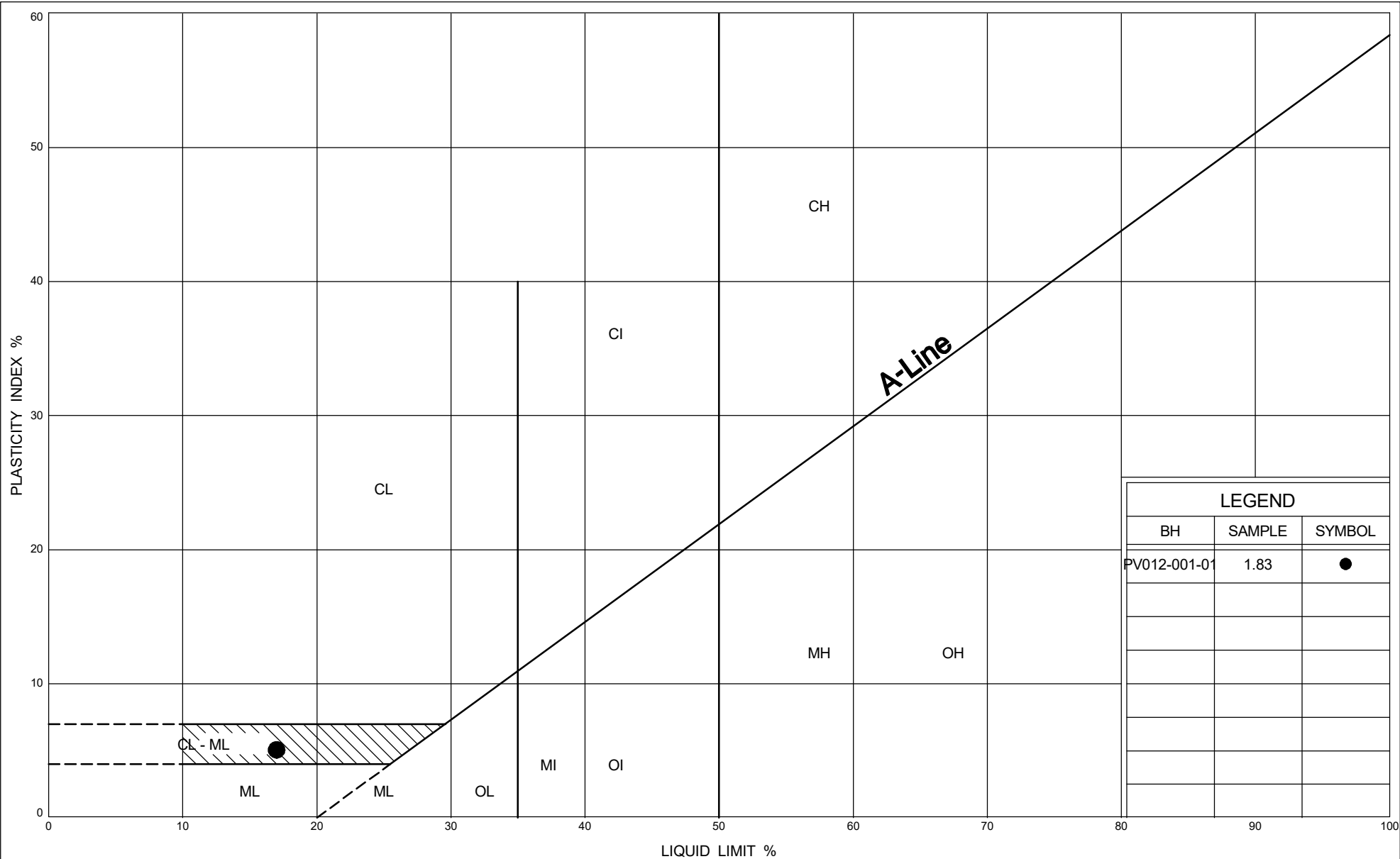
Clayey Silt Till

FIG No 4

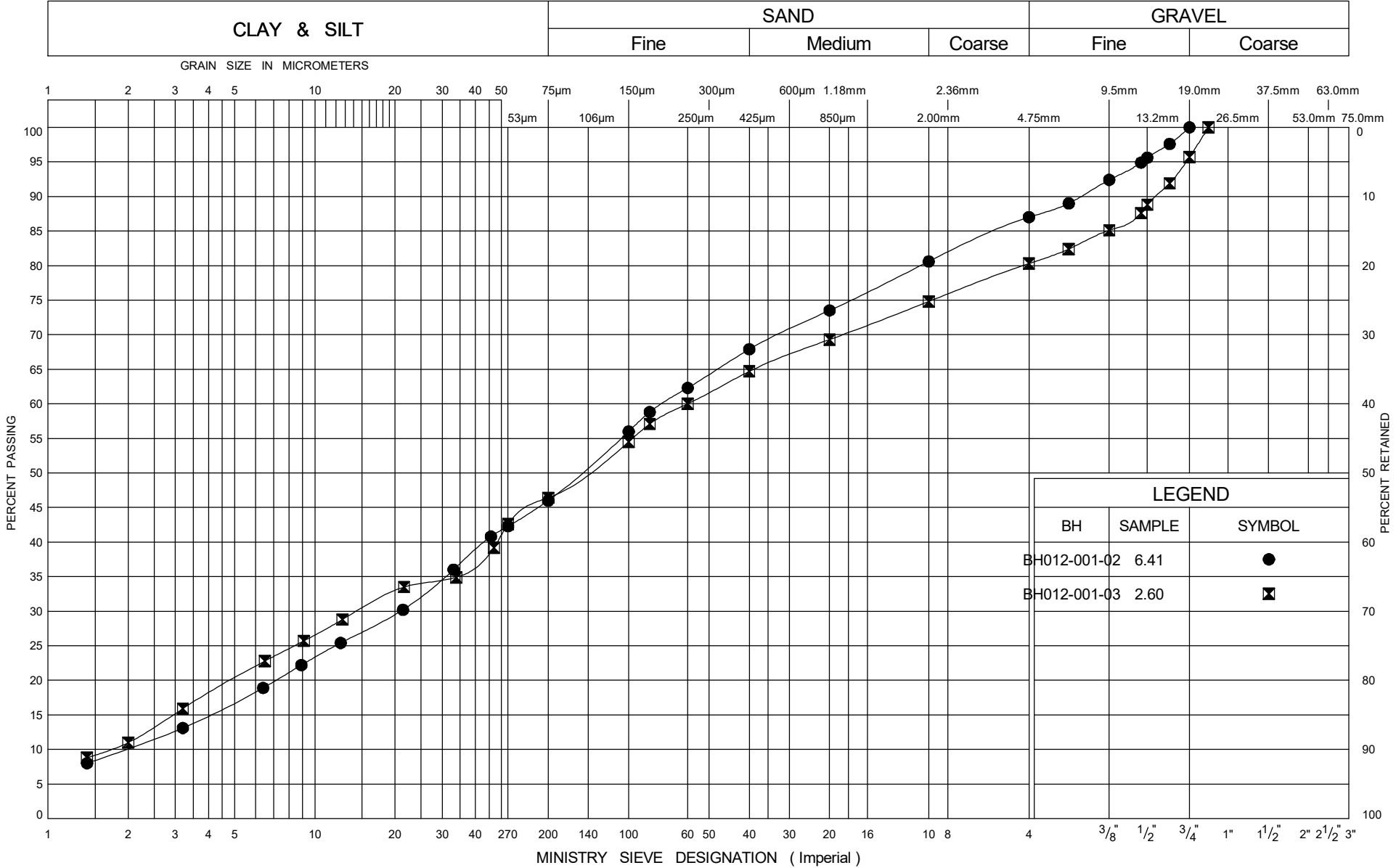
GWP 2111-19-00

Culvert ID CV-0204-0012-0001





UNIFIED SOIL CLASSIFICATION SYSTEM



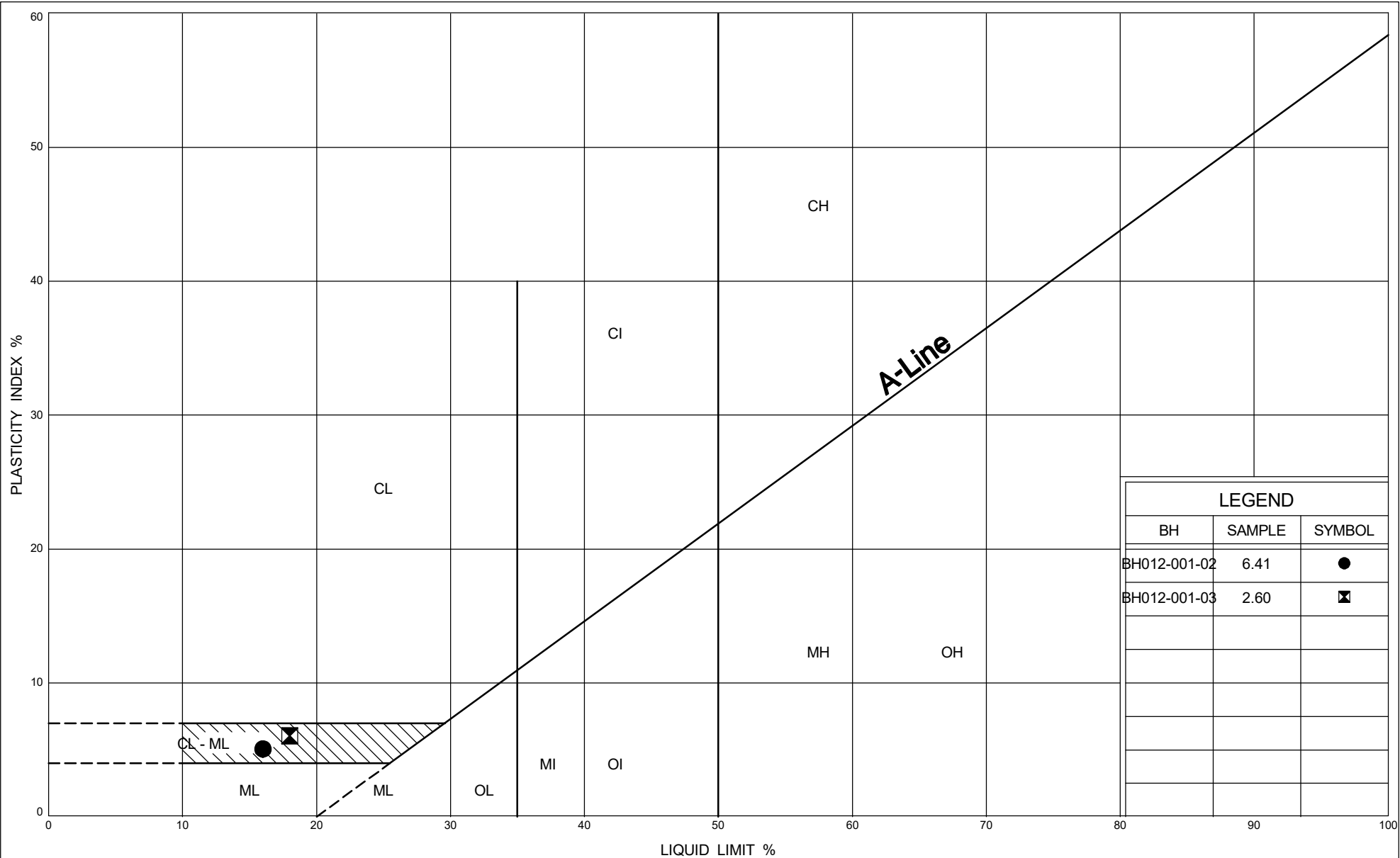
GRAIN SIZE DISTRIBUTION

Cohesionless Till

FIG No 7

GWP 2111-19-00

Culvert ID CV-0204-0012-0001





SOIL CORROSIVITY PACKAGE (SOIL)

Bureau Veritas ID		UYF676			UYF676			UYF677		
Sampling Date		2023/01/25 12:18			2023/01/25 12:18			2023/01/27 10:30		
COC Number		903374-07-01			903374-07-01			903374-07-01		
	UNITS	BH 12-001-02 SS5	RDL	QC Batch	BH 12-001-02 SS5 Lab-Dup	RDL	QC Batch	BH 400-50-04 SS5	RDL	QC Batch

Calculated Parameters										
Resistivity	ohm-cm	260		8481161				1100		8481161

CONVENTIONALS										
Redox Potential	mV	380	N/A	8485160				330	N/A	8485160

Inorganics										
Soluble (20:1) Chloride (Cl-)	ug/g	1900	40	8485316				530	20	8485316
Conductivity	umho/cm	3880	2	8485730				938	2	8485730
Available (CaCl2) pH	pH	9.05		8484048				7.57		8484048
Soluble (20:1) Sulphate (SO4)	ug/g	220	20	8485330				37	20	8485330
Sulphide	mg/kg	4.6 (1)	0.5	8489070	4.0	0.5	8489070	2.4 (1)	0.5	8489070

Physical Testing										
Moisture-Subcontracted	%	9.9	0.30	8489069				20	0.30	8489069

RDL = Reportable Detection Limit





QC Batch = Quality Control Batch

Lab-Dup = Laboratory Initiated Duplicate

N/A = Not Applicable

(1) Sample contained greater than 10% headspace at time of extraction.

Appendix F – Slope Stability Analyses

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clayey Silt Till (firm to stiff)	19	0	30
	Gran. A/B Type II	22	0	35
	Silt and Sand Till (generally loose)	19	0	29
	Silt and Sand to Sandy Silt Till (compact to very dense)	21	0	32

2020-E-0028 MTO Central Region
GWP 2111-19-00 - Replacement/Rehabilitation of 25 Non-Str Culverts
Culvert CV-0204-0012-0001
New Embankment - Inlet Side
Drained - Static Conditions

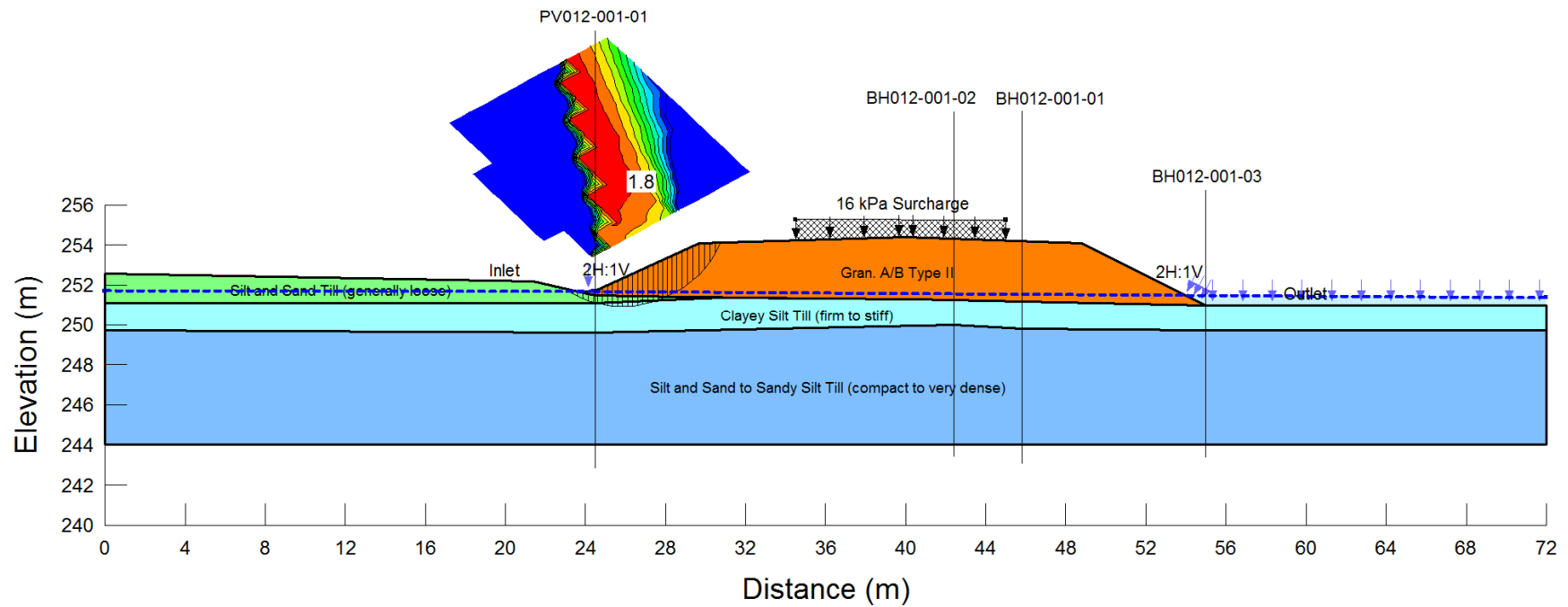






Figure F1: Slope stability analysis for inlet side of new embankment reconstructed w/ Granular A/B Type II (2H:1V) – drained static condition

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Cohesion (kPa)
	Clayey Silt Till (firm to stiff)	19			40
	Gran. A/B Type II	22	0	35	
	Silt and Sand Till (generally loose)	19	0	29	
	Silt and Sand to Sandy Silt Till (compact to very dense)	21	0	32	

2020-E-0028 MTO Central Region
GWP 2111-19-00 - Replacement/Rehabilitation of 25 Non-Str Culverts
Culvert CV-0204-0012-0001
New Embankment - Inlet Side
Undrained - Static Conditions

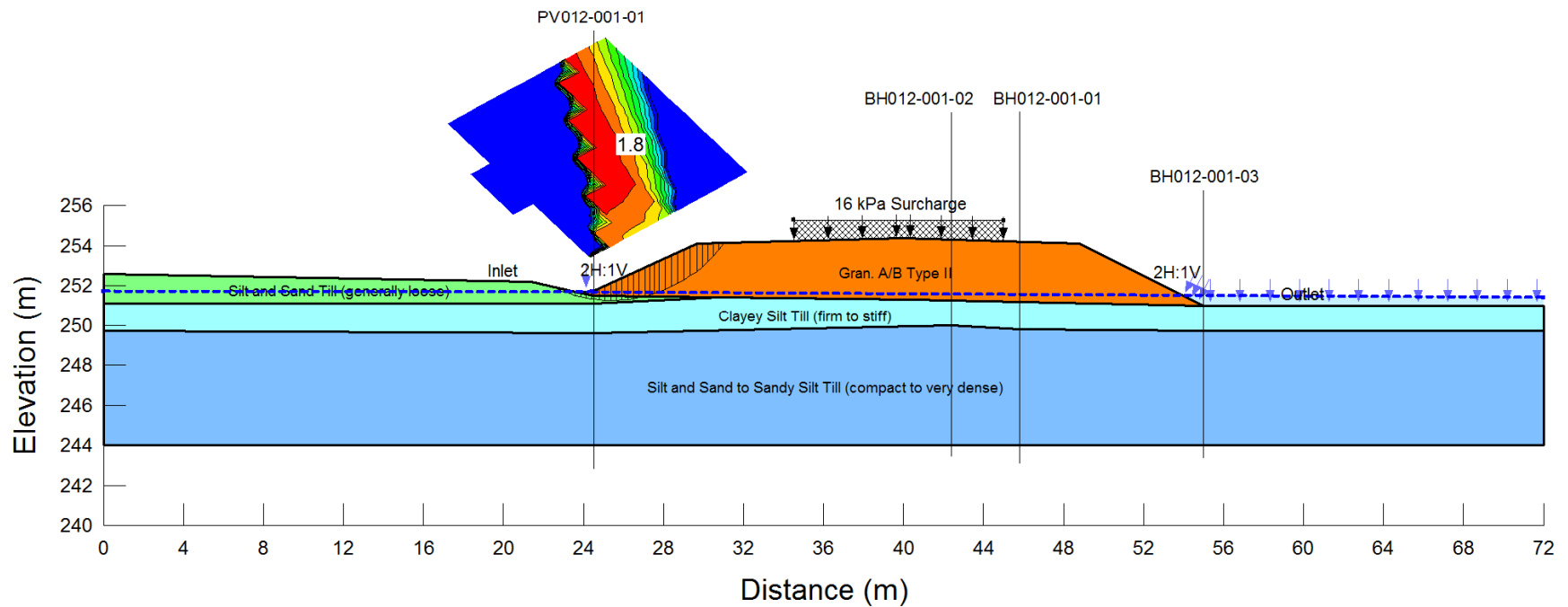






Figure F2: Slope stability analysis for inlet side of new embankment reconstructed w/ Granular A/B Type II (2H:1V) – undrained static condition

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clayey Silt Till (firm to stiff)	19	0	30
	Gran. A/B Type II	22	0	35
	Silt and Sand Till (generally loose)	19	0	29
	Silt and Sand to Sandy Silt Till (compact to very dense)	21	0	32

2020-E-0028 MTO Central Region
GWP 2111-19-00 - Replacement/Rehabilitation of 25 Non-Str Culverts
Culvert CV-0204-0012-0001
New Embankment - Inlet Side
Drained - Seismic Conditions

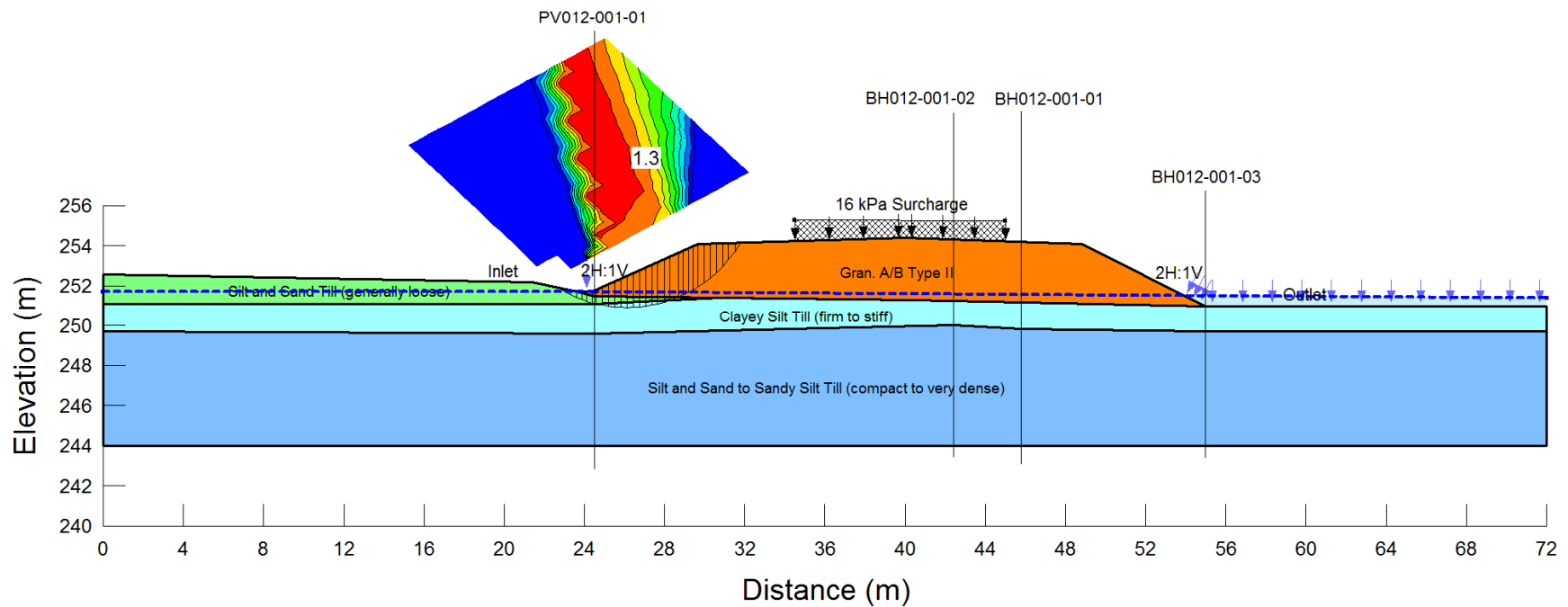






Figure F3: Slope stability analysis for inlet side of new embankment reconstructed w/ Granular A/B Type II (2H:1V) – drained seismic condition

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clayey Silt Till (firm to stiff)	19	0	30
	Gran. A/B Type II	22	0	35
	Silt and Sand Till (generally loose)	19	0	29
	Silt and Sand to Sandy Silt Till (compact to very dense)	21	0	32

2020-E-0028 MTO Central Region
GWP 2111-19-00 - Replacement/Rehabilitation of 25 Non-Str Culverts
Culvert CV-0204-0012-0001
New Embankment - Outlet Side
Drained - Static Conditions

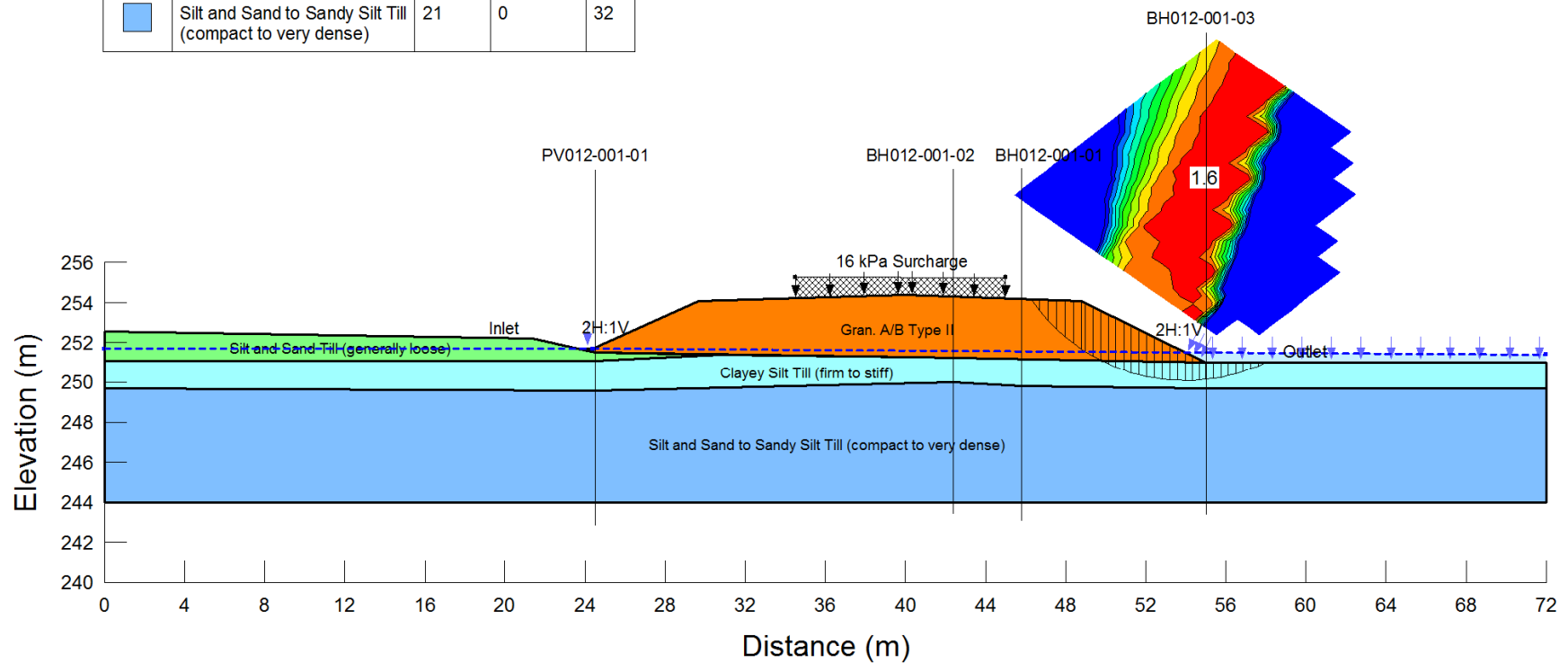






Figure F4: Slope stability analysis for outlet side of new embankment reconstructed w/ Granular A/B Type II (2H:1V) – drained static condition

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Cohesion (kPa)
	Clayey Silt Till (firm to stiff)	19			40
	Gran. A/B Type II	22	0	35	
	Silt and Sand Till (generally loose)	19	0	29	
	Silt and Sand to Sandy Silt Till (compact to very dense)	21	0	32	

2020-E-0028 MTO Central Region
GWP 2111-19-00 - Replacement/Rehabilitation of 25 Non-Str Culverts
Culvert CV-0204-0012-0001
New Embankment - Outlet Side
Undrained - Static Conditions

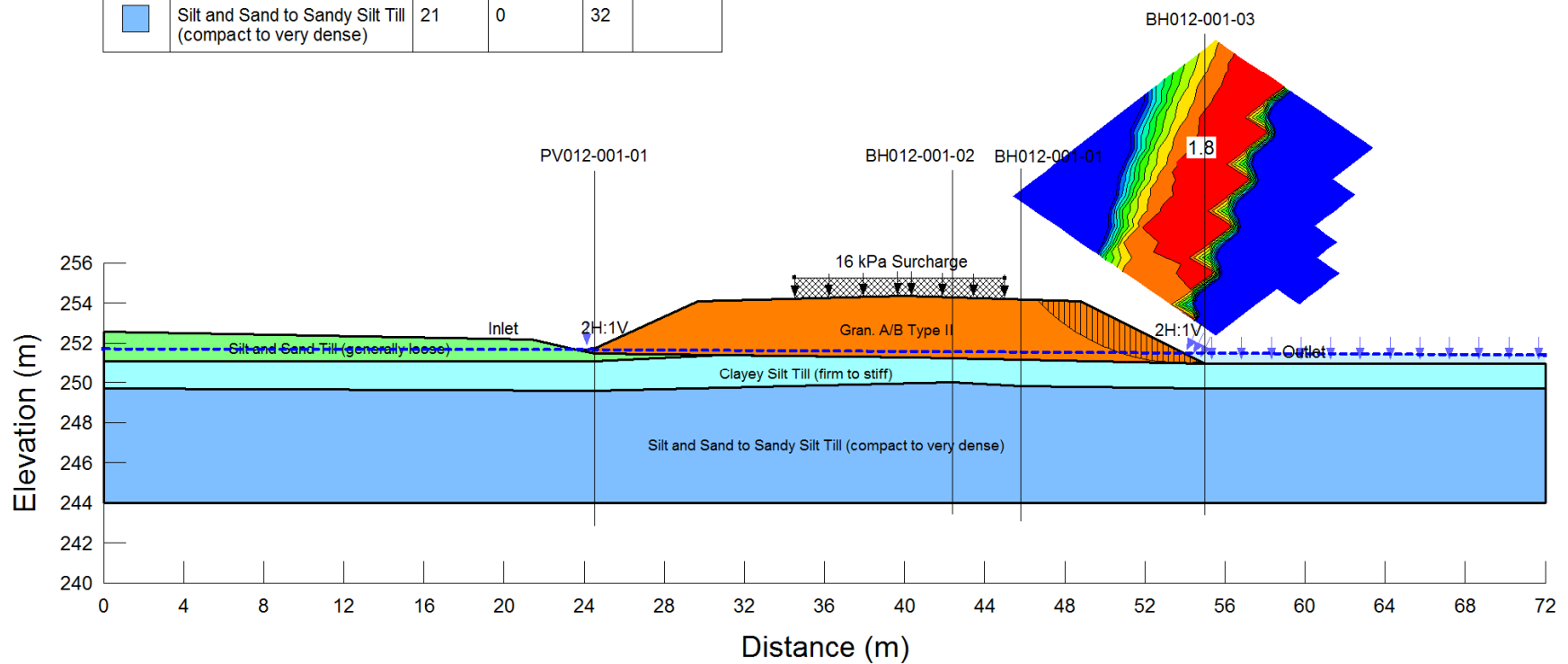






Figure F5: Slope stability analysis for outlet side of new embankment reconstructed w/ Granular A/B Type II (2H:1V) – undrained static condition

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clayey Silt Till (firm to stiff)	19	0	30
	Gran. A/B Type II	22	0	35
	Silt and Sand Till (generally loose)	19	0	29
	Silt and Sand to Sandy Silt Till (compact to very dense)	21	0	32

2020-E-0028 MTO Central Region
GWP 2111-19-00 - Replacement/Rehabilitation of 25 Non-Str Culverts
Culvert CV-0204-0012-0001
New Embankment - Outlet Side
Drained - Seismic Conditions

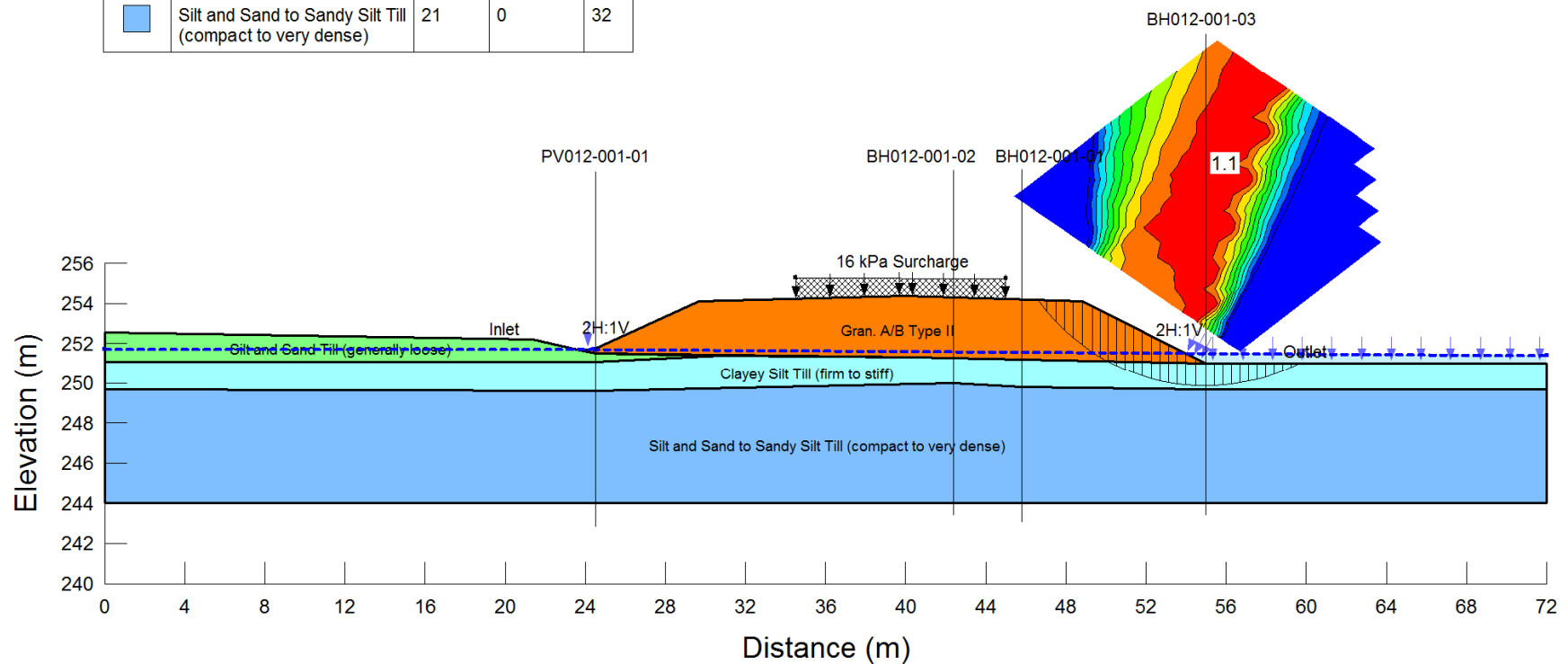







Figure F6: Slope stability analysis for outlet side of new embankment reconstructed w/ Granular A/B Type II (2H:1V) – drained seismic condition

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clayey Silt Till (firm to stiff)	19	3	30
	Gravelly Sand Fill (compact)	21	0	33
	Silt and Sand Till (generally loose)	19	0	29
	Silt and Sand to Sandy Silt Till (compact to very dense)	21	2	32
	Silty Sand Fill (generally compact)	20	2	30

2020-E-0028 MTO Central Region
GWP 2111-19-00 - Replacement/Rehabilitation of 25 Non-Str Culverts
Culvert CV-0204-0012-0001
Temporary Open Cut - NBL Excavation
Drained - Static Conditions

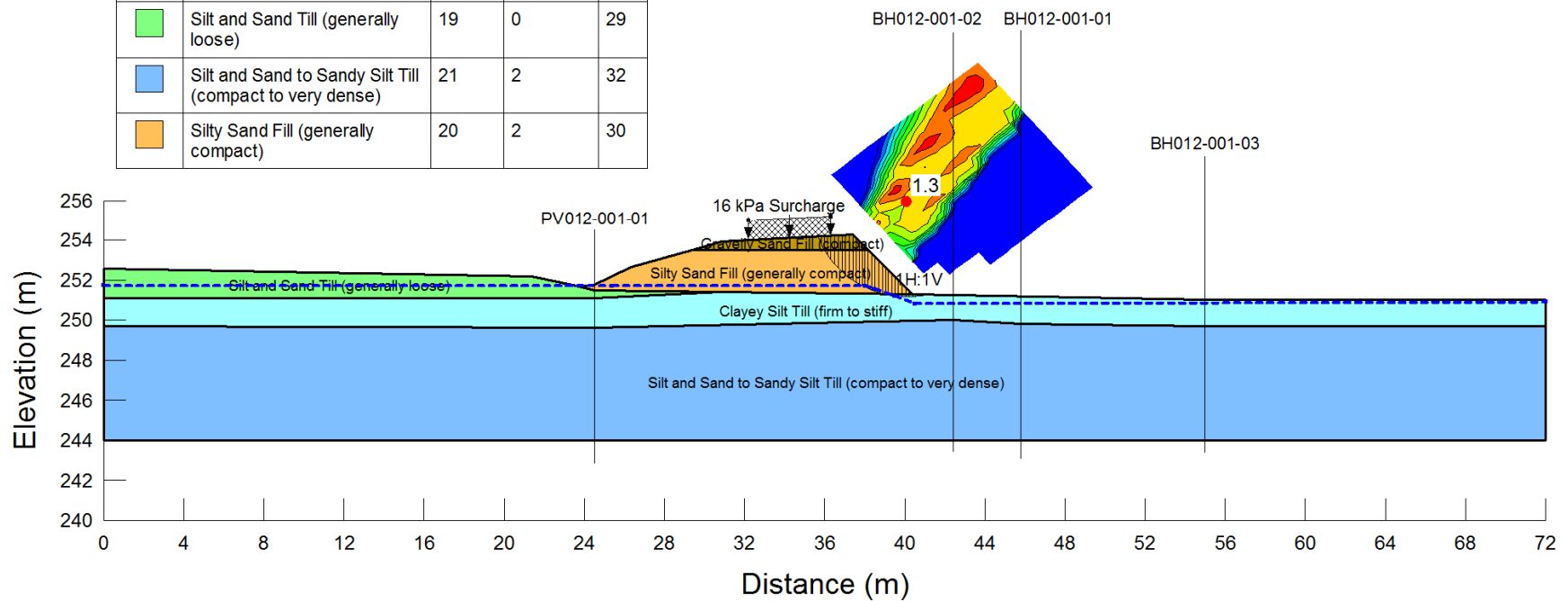







Figure F7: Slope stability analysis for temporary slopes, open cut (1H:1V) – drained static condition

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Cohesion (kPa)
	Clayey Silt Till (firm to stiff)	19			40
	Gravelly Sand Fill (compact)	21	0	33	
	Silt and Sand Till (generally loose)	19	0	29	
	Silt and Sand to Sandy Silt Till (compact to very dense)	21	2	32	
	Silty Sand Fill (generally compact)	20	2	30	

2020-E-0028 MTO Central Region
GWP 2111-19-00 - Replacement/Rehabilitation of 25 Non-Str Culverts
Culvert CV-0204-0012-0001
Temporary Open Cut - NBL Excavation
Undrained - Static Conditions

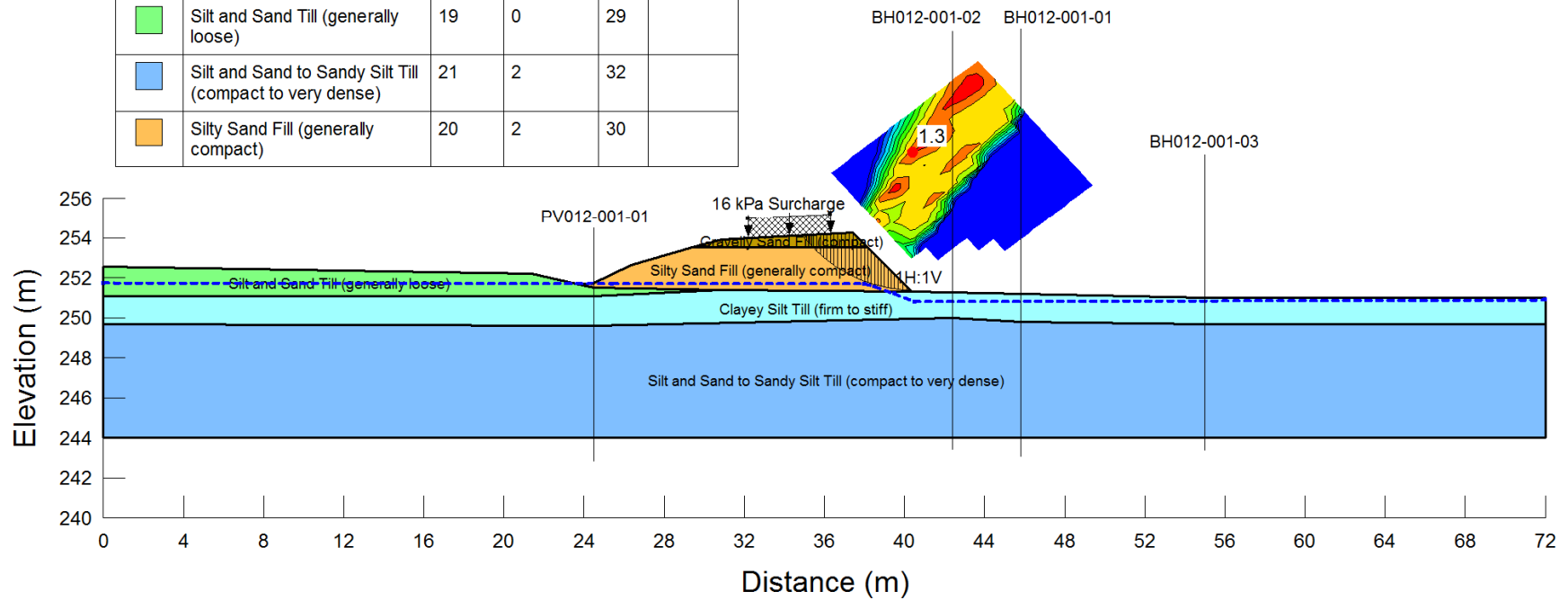
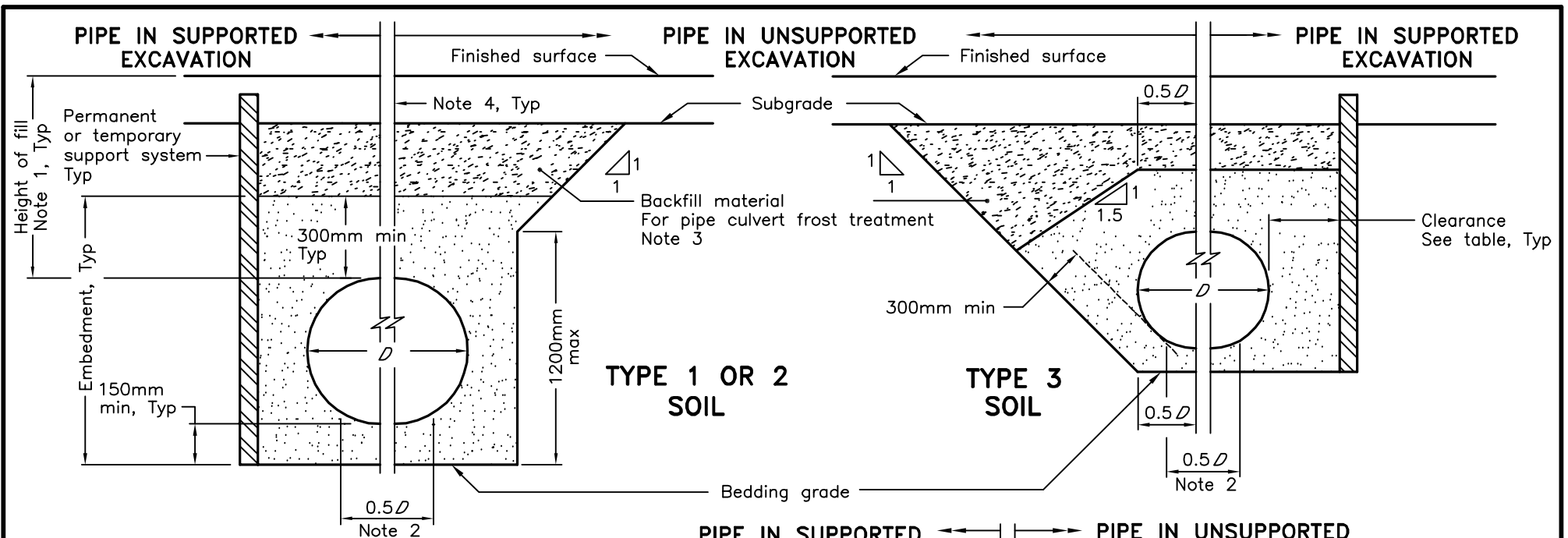


Figure F8: Slope stability analysis for temporary slopes, open cut (1H:1V) – undrained static condition

Appendix G – OPSDs

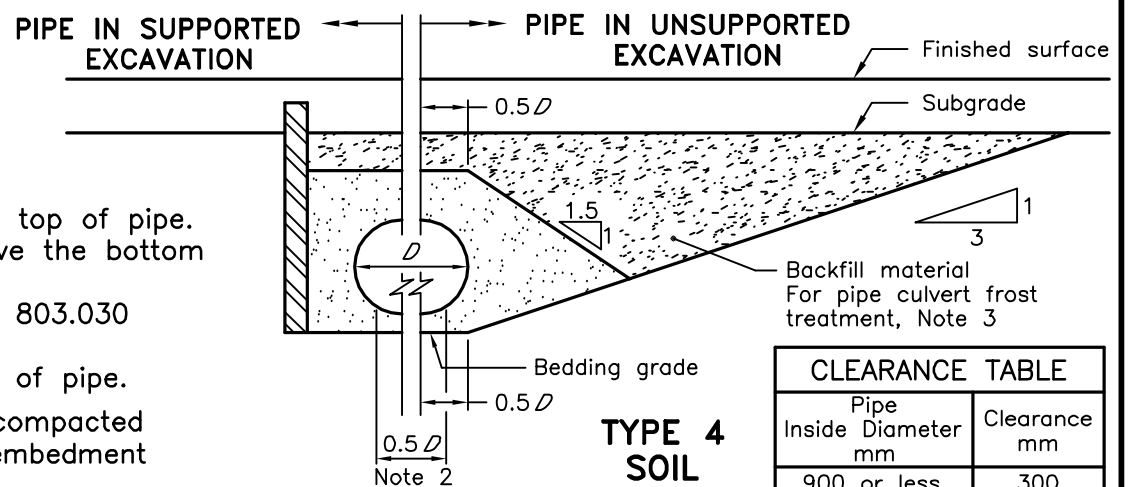


LEGEND:

D - Inside diameter

NOTES:

- 1 Height of fill is measured from the finished surface to top of pipe.
 - 2 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.
 - 3 Pipe culvert frost treatment shall be according to OPSD 803.030 and 803.031.
 - 4 Condition of excavation is symmetrical about centreline of pipe.
- A Granular material placed in the haunch area shall be compacted prior to placing and compacting the remainder of the embedment material.
- B Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.
- C All dimensions are in metres unless otherwise shown.



CLEARANCE TABLE	
Pipe Inside Diameter mm	Clearance mm
900 or less	300
Over 900	500

ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2014

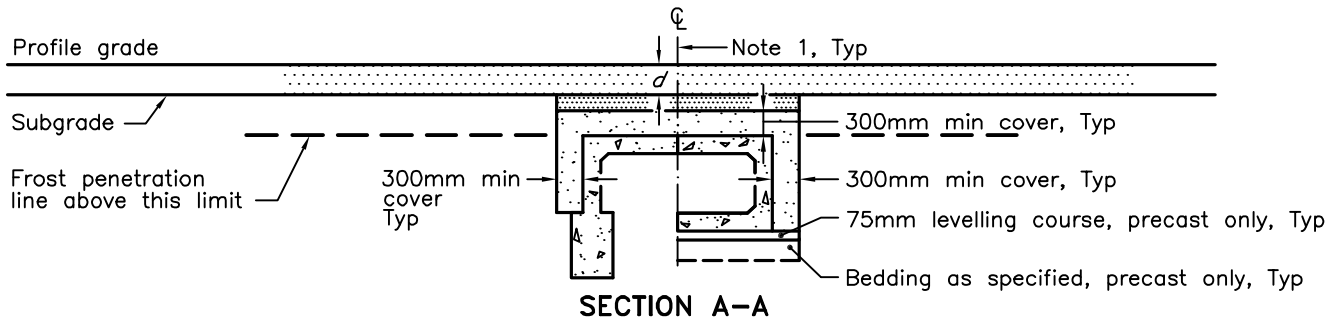
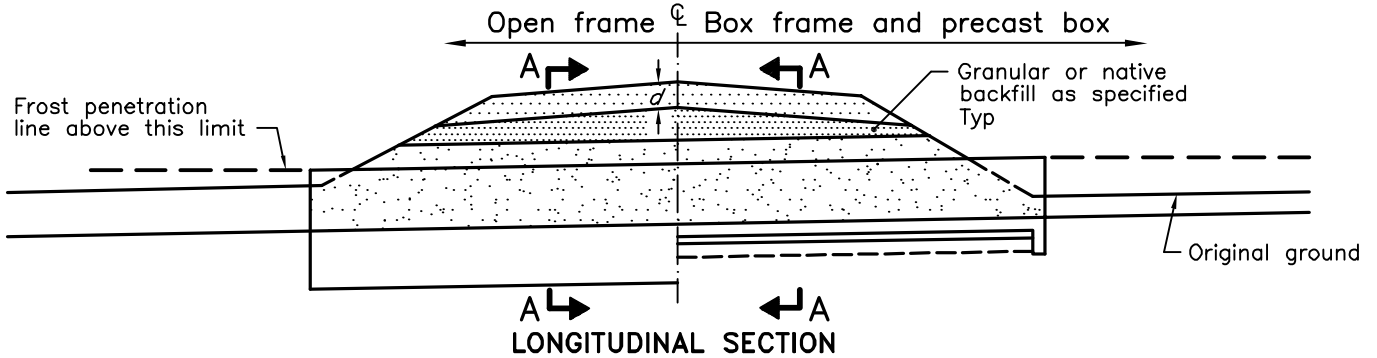
Rev 3

FLEXIBLE PIPE
EMBEDMENT AND BACKFILL
EARTH EXCAVATION

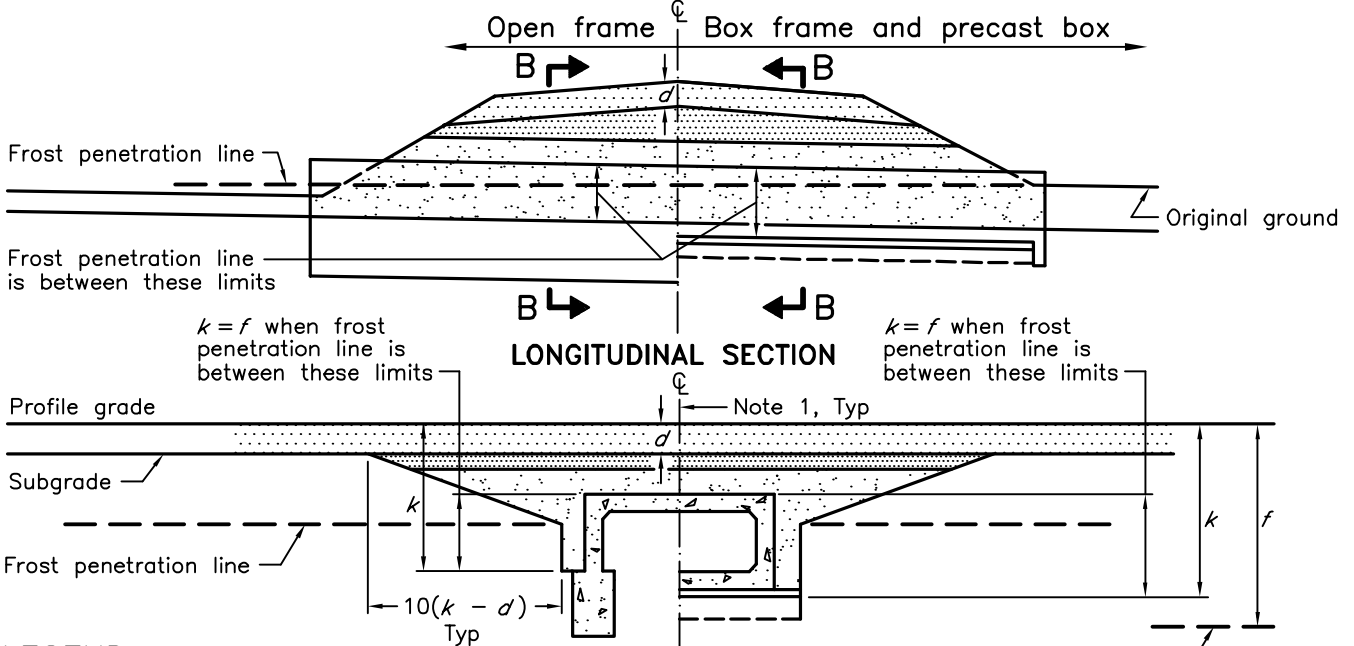
OPSD 802.010



FROST PENETRATION LINE AT OR ABOVE TOP OF CULVERT



FROST PENETRATION LINE BELOW TOP OF CULVERT



LEGEND:

- d = depth of roadbed granular
- k = depth of frost treatment below profile grade
- f = depth of frost penetration below profile grade

NOTES:

- 1 Condition of frost treatment symmetrical about centreline of culvert.
- A Bedding, levelling, and cover material shall be granular as specified.
- B The depth of roadbed granular shall be 600mm minimum.
- C The maximum depth of frost treatment shall be bottom of box frame or top of footing.
- D All dimensions are in millimetres unless otherwise shown.

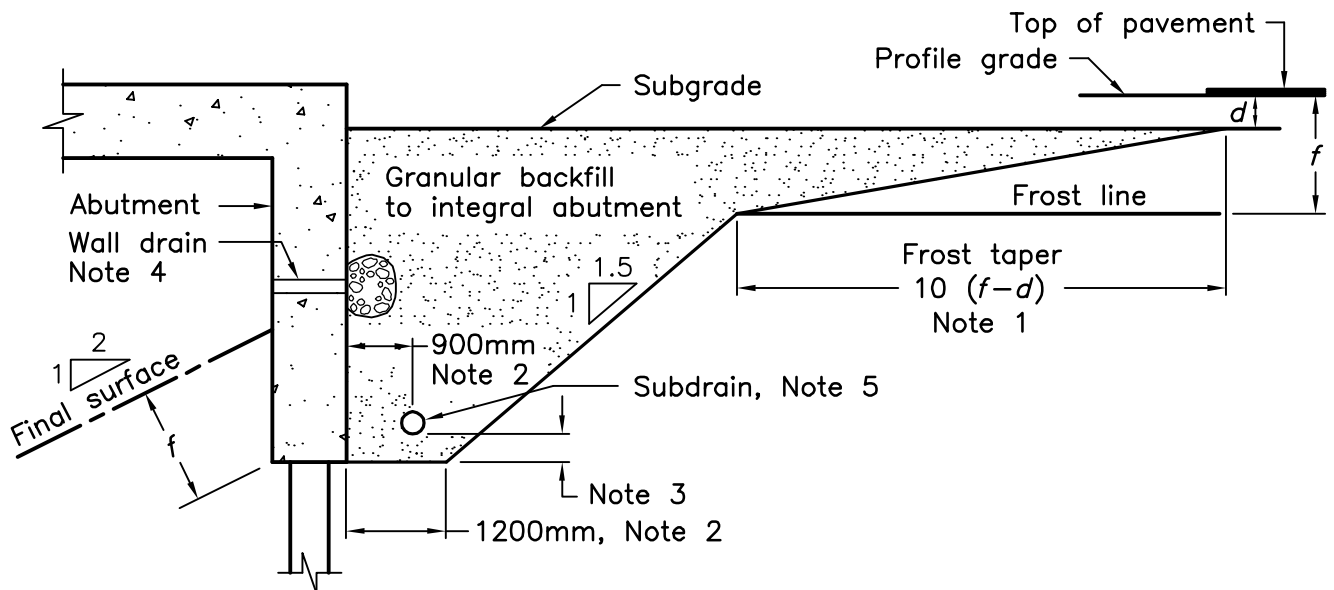
ONTARIO PROVINCIAL STANDARD DRAWING

Nov 2010 Rev 2

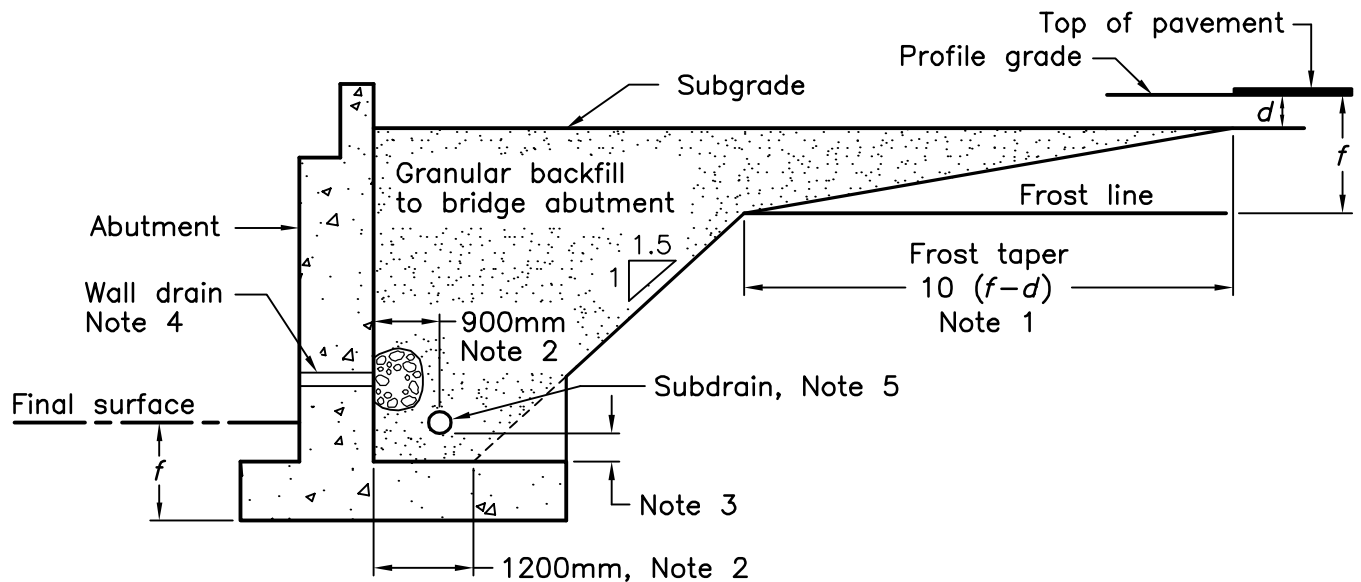
**BACKFILL AND COVER FOR
CONCRETE CULVERTS WITH SPANS
LESS THAN OR EQUAL TO 3.0M**

OPSD 803.010





INTEGRAL ABUTMENT



ABUTMENT

NOTES:

- 1 d = depth of combined base and subbase courses
 f = frost penetration depth as specified
- 2 Dimensions perpendicular to back face of abutment.
- 3 Height to be consistent with positive drainage of subdrain as specified.
- 4 Where specified, wall drains shall be installed according to OPSD 3190.100.
- 5 150mm dia perforated pipe subdrain wrapped with geotextile.
- A Lateral limits of granular backfill to bridge abutment to be inside face to inside face of retaining wall or wingwall. Frost taper shall extend the full width of the backfill unless interrupted by the retaining wall or wingwall.
- B Sections shown are parallel to centreline of roadway.
- C Subdrain shall be installed with a 2% gradient behind wall.
- D All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING

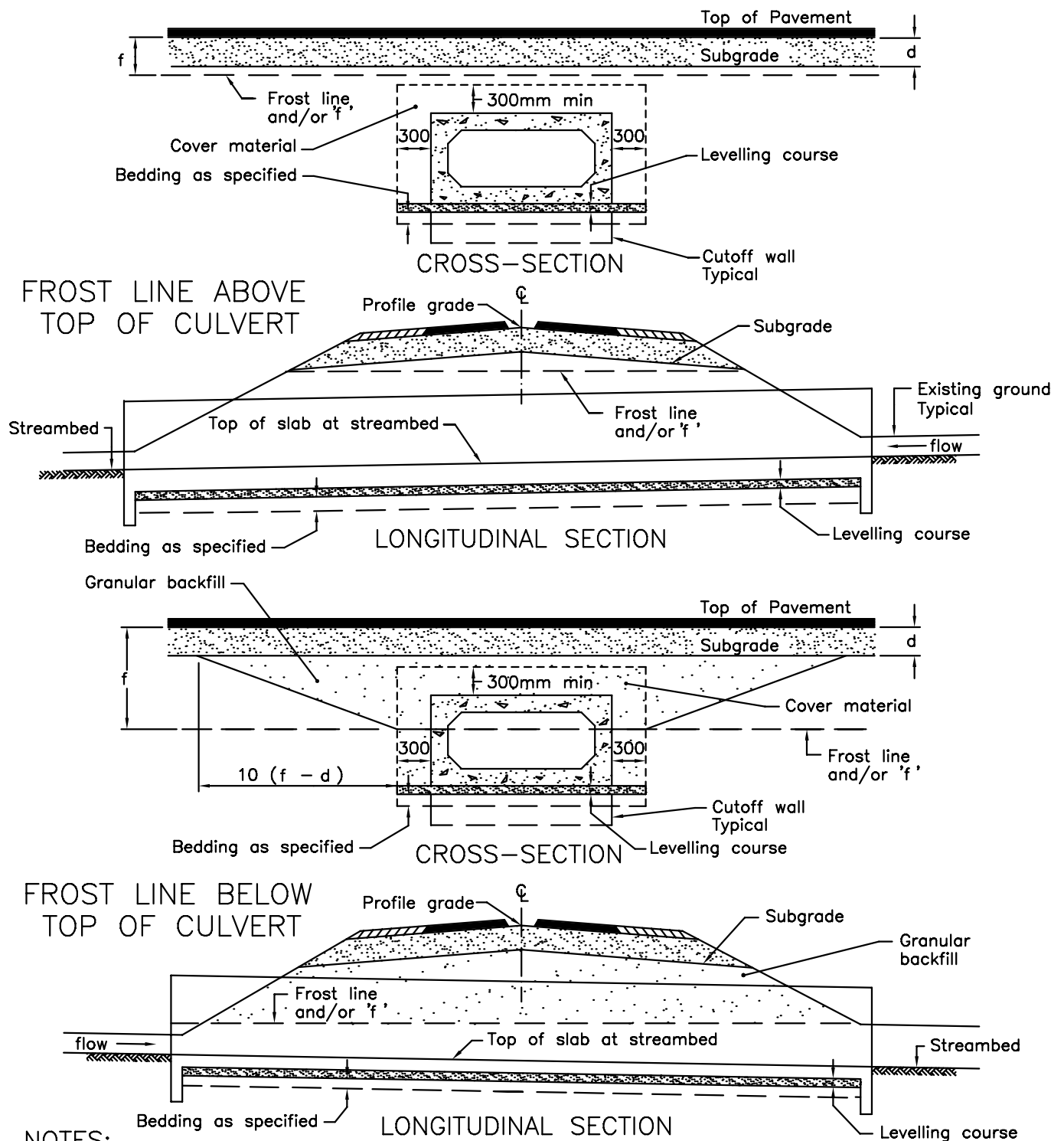
Nov 2010

Rev 1



WALLS
ABUTMENT, BACKFILL
MINIMUM GRANULAR REQUIREMENT

OPSD 3101.150



NOTES:

- A Bedding, levelling, cover and backfill material to be granular as specified.
- B Where frost line is below bottom of levelling course, frost tapers start at the bottom of levelling course.
- C All dimensions are in millimetres unless otherwise shown.

LEGEND:

d = Denotes depth of granular (roadbed)
 f = Depth of frost treatment=____
 (measured from profile grade)

MINISTRY OF TRANSPORTATION ONTARIO DRAWING

Date | 1994 05 25 | Rev |

BEDDING AND BACKFILL
 FOR PRECAST CONCRETE BOX CULVERTS

Issue Date
 WP
 Issued by

MTOD - 803.021

- A drainage system behind a retaining structure should ensure that a groundwater table does not exist above the footing level. Preferably, the ground water level is controlled by the use of free-draining granular backfill and a collection system such as weep holes or perforated drains at the footing level. These weep holes and drains should be inspected and maintained to ensure that they do not become blocked. If free-draining, granular backfill is not employed, the permeability of the backfill and the hydrostatic head will control the extent to which the groundwater table can be depressed locally by seepage towards a footing drain. In practice, design for frost protection is best done using free-draining backfill.

The design should also consider the risk of unusually large inflows of water creating a temporary hydrostatic head of water behind the wall. An example is the overtopping of a retaining wall, adjoining a large body of water, by storm waves. Measures such as the use of quarried rock backfill, design for full hydrostatic pressure, or provision of a sloped impermeable surface layer should be considered.

Measurements have shown that earth pressures can vary seasonally, but the effects have normally been neglected in design, except for winter frost pressures. These latter can be very large if the backfill is frost susceptible and for this reason free-draining granular backfill is recommended.
- Figure C6.20 shows examples of minimum backfill requirements.

The distance, x , should be equal to or greater than the estimated vertical frost penetration. This distance may be reduced if the wall abuts a vertical face of bedrock that is not susceptible to frost. The frost penetration may be reduced by the use of suitable insulation, in which case a thermal analysis should be performed by a Geotechnical Engineer.

If rock fill is used as a backfill material, consideration should be given to the possible deterioration of the rockfill with time, which could result in the reduction or even the total loss of free-draining properties and, hence, increased frost susceptibility.

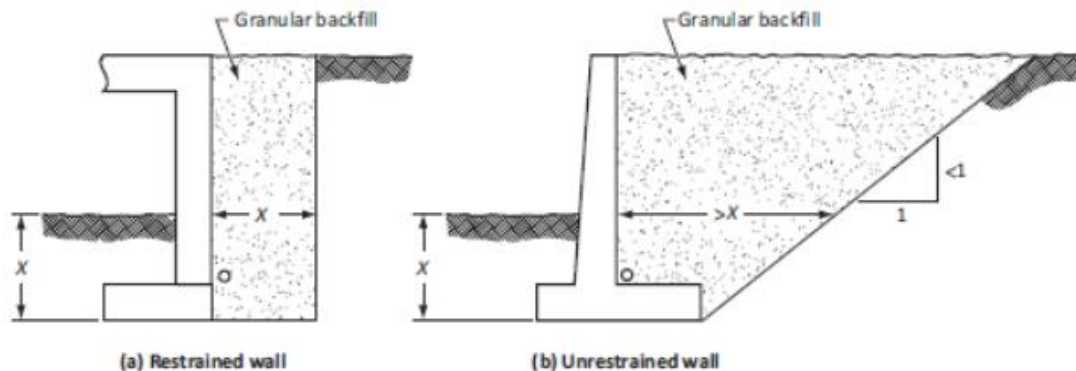
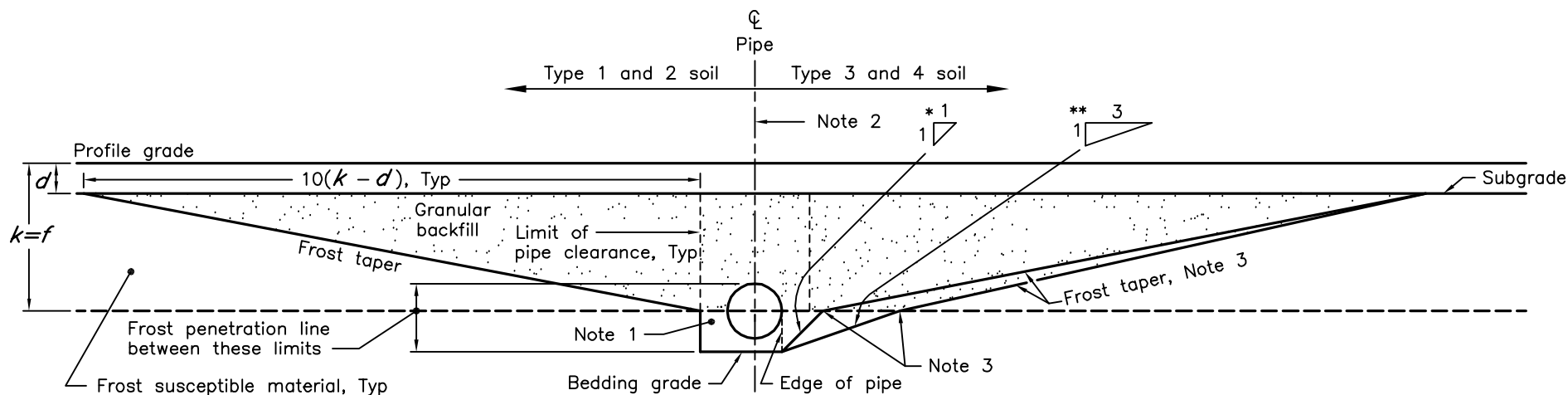


Figure C6.20
Backfill for frost protection
 (See Clause C6.12.1.)

C6.12.2 Lateral ground pressures

C6.12.2.1 General

Earth pressure acting on a structure depends on the relative movement of the structure, the backfill, the type of soil adjacent to the backfill, and the soil below the footing or supporting piles. Appropriate geotechnical parameters should be chosen for the calculation of lateral pressures based on recognized geotechnical theories as specified in Clause 6.12.2.2 for the backfill behind the wall. Geotechnical parameters frequently used in allowable stress design methods are applicable in limit states design pressure calculation. Where the possibility exists, hydrostatic pressure needs to be considered, e.g., in situations where walls are partially submerged or where non-free-draining backfill is used.



FROST TREATMENT RIGID AND FLEXIBLE PIPE

NOTES:

- 1 Pipe embedment or bedding, cover, and backfill shall be according to:
 - a) Flexible OPSD 802.010, 802.013, 802.014, 802.020, 802.023, and 802.024.
 - b) Rigid – OPSD 802.030, 802.031, 802.032, 802.033, 802.034, 802.050, 802.051, 802.052, 802.053, and 802.054.
- 2 Condition of frost treatment symmetrical about centreline of pipe.
- 3 Frost tapers shall start at the intersection of the 1H:1V or 3H:1V slope and the frost penetration line.
- A Soil types as defined in the Occupational Health and Safety Act and Regulations for Construction Projects.

LEGEND:

- d – depth of roadbed granular
 k – depth of frost treatment below profile grade
 f – depth of frost penetration below profile grade
 $*$ – Type 3 soil
 $**$ – Type 4 soil

ONTARIO PROVINCIAL STANDARD DRAWING

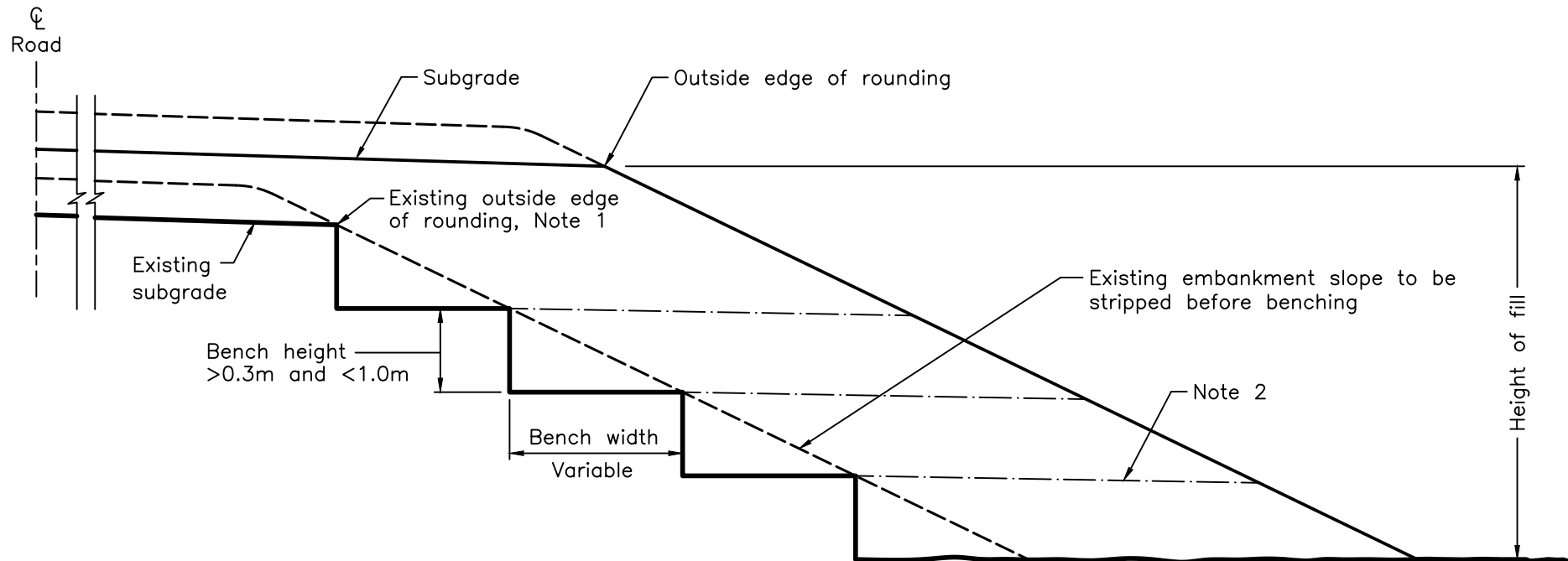
**FROST TREATMENT – PIPE CULVERTS
FROST PENETRATION LINE BETWEEN
TOP OF PIPE AND BEDDING GRADE**

Nov 2015

Rev 4



OPSD 803.031



NOTES:

- 1 When the subgrade is below the existing outside edge of rounding, benching shall be carried out below the point where the subgrade intersects the existing slope.
 - 2 Benches shall be excavated one level at a time and the fill placed and compacted before the next bench is excavated.
- A Benching is not required on existing slopes flatter than 3H:1V.

ONTARIO PROVINCIAL STANDARD DRAWING

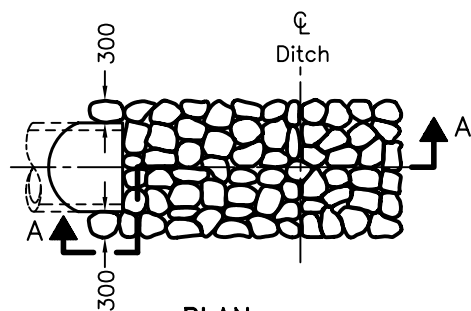
Apr 2019

Rev 4

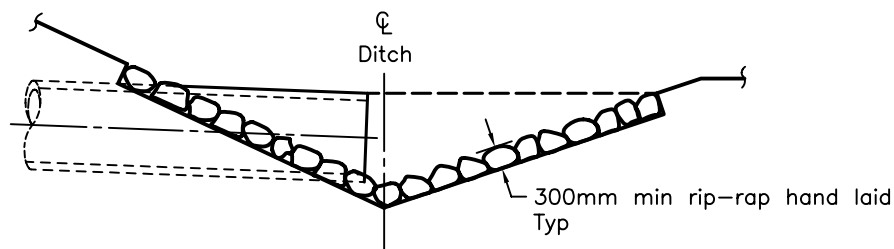
BENCHING OF EARTH SLOPES

OPSD 208.010

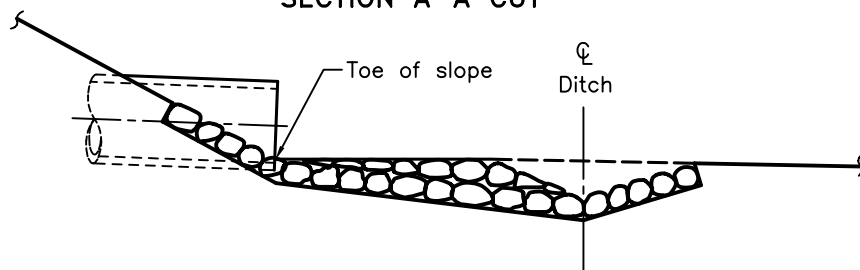




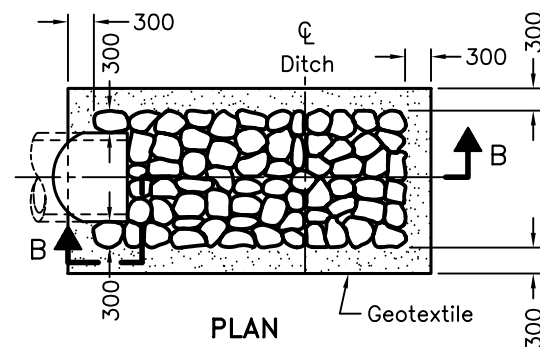
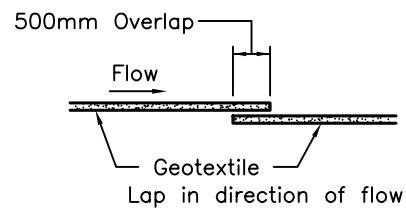
PLAN
CUT OR FILL



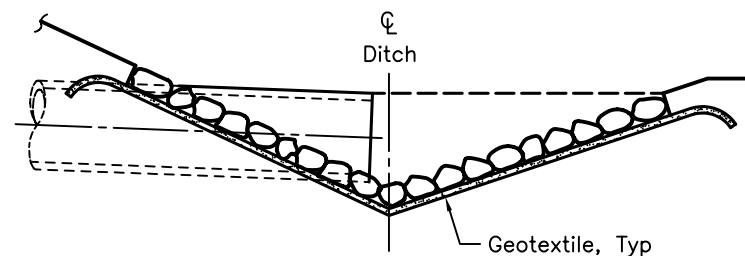
SECTION A-A CUT



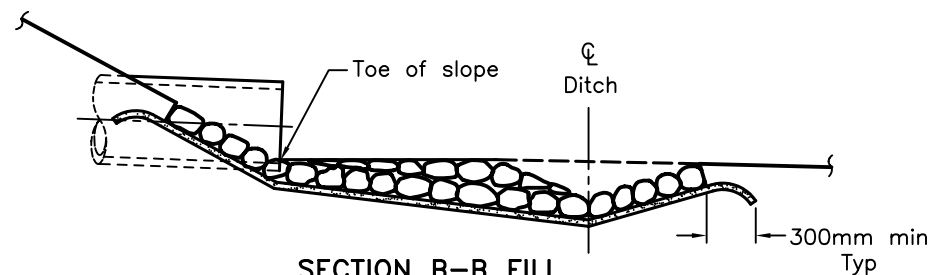
SECTION A-A FILL
TYPE A – WITHOUT GEOTEXTILE



PLAN
CUT OR FILL



SECTION B-B CUT



SECTION B-B FILL
TYPE B – WITH GEOTEXTILE

NOTES:

A All dimensions are in millimetres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING

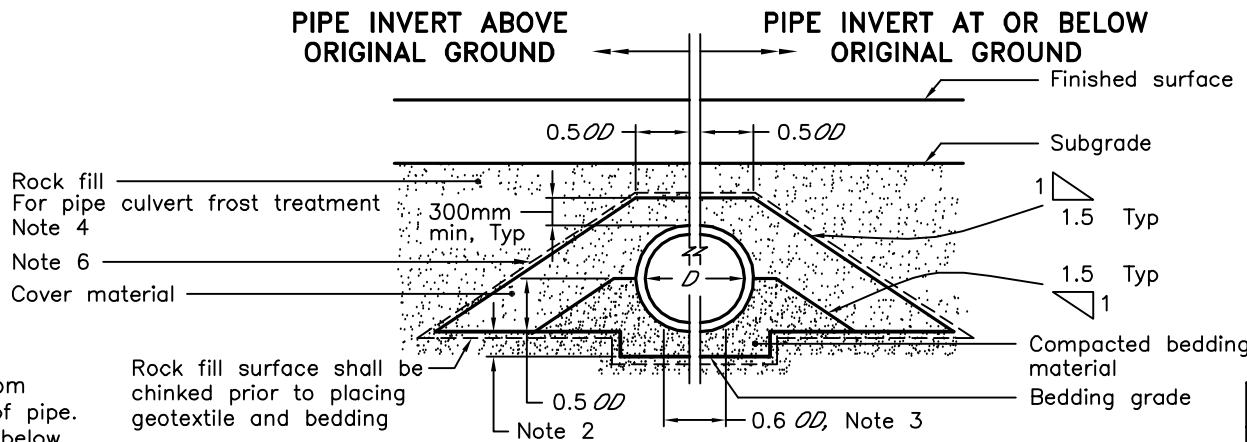
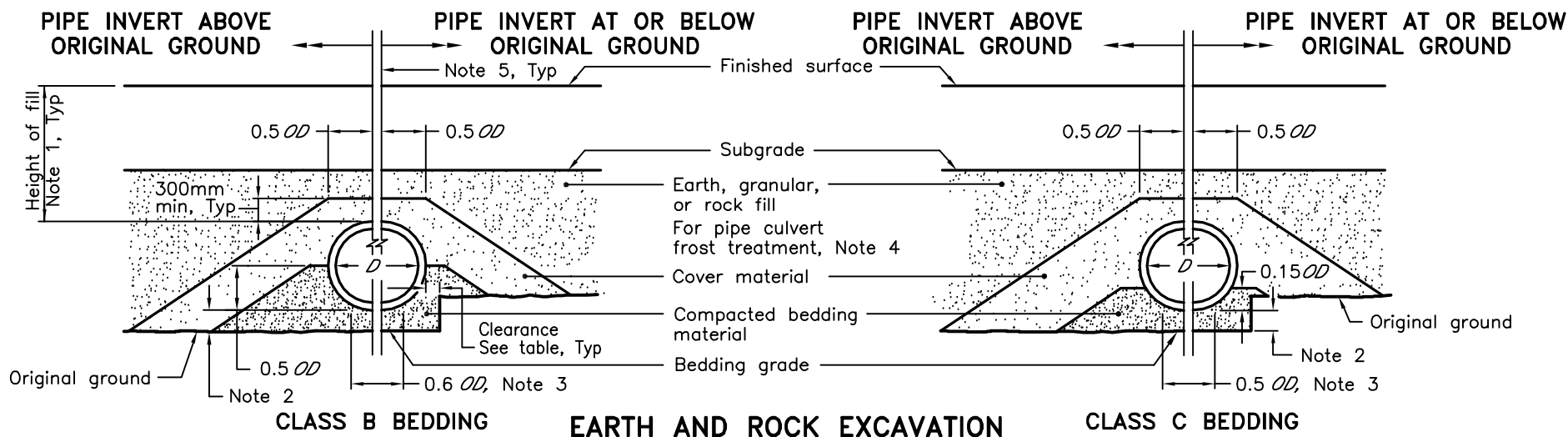
Nov 2001

Rev 0

RIP-RAP TREATMENT
FOR SEWER AND CULVERT OUTLETS



OPSD – 810.010



NOTES:

- 1 Height of fill is measured from the finished surface to top of pipe.
 - 2 The minimum bedding depth below the pipe shall be $0.15D$, except on a rock foundation where the minimum bedding depth shall be $0.25D$. In no case shall the minimum dimension be less than 150mm or greater than 300mm.
 - 3 The pipe bed shall be compacted and shaped to receive the bottom of the pipe.
 - 4 Pipe culvert frost treatment shall be according to OPSD 803.030 and 803.031.
 - 5 Condition of excavation is symmetrical about centreline of pipe.
 - 6 Bedding and cover material shall be wrapped in non-woven geotextile when specified.
- A All dimensions are in metres unless otherwise shown.

LEGEND:
 D – Inside diameter
 OD – Outside diameter

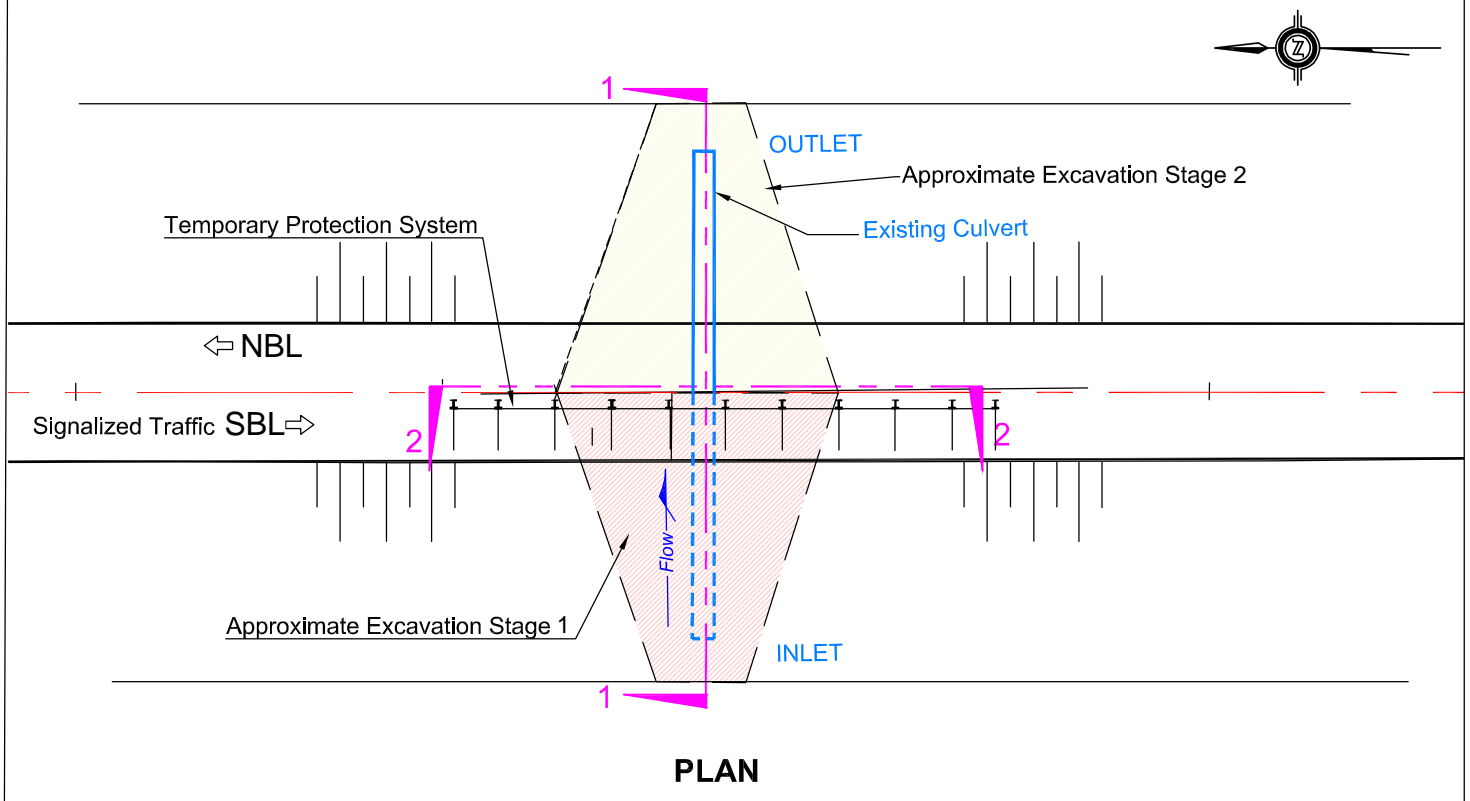
CLEARANCE TABLE	
Pipe Inside Diameter mm	Clearance mm
900 or less	300
Over 900	500

ONTARIO PROVINCIAL STANDARD DRAWING RIGID PIPE BEDDING AND COVER IN EMBANKMENT ORIGINAL GROUND: EARTH OR ROCK	Nov 2015 Rev 3 <div style="border: 1px solid black; width: 100px; height: 100px; margin: 0 auto; display: flex; align-items: center; justify-content: center;"> </div>
	<div style="font-size: 24px; font-weight: bold; margin: 0;">OPSD 802.034</div>

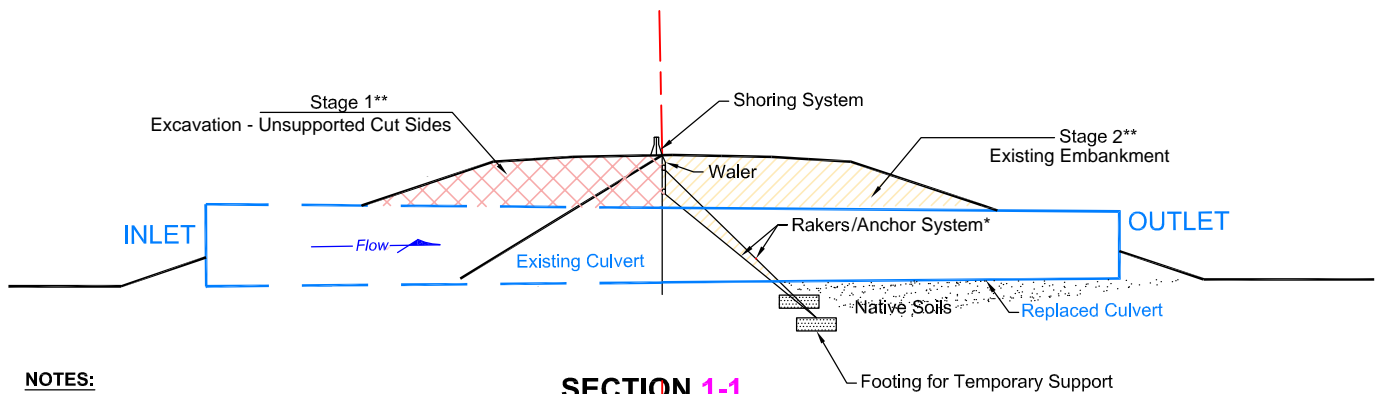
Appendix H – Schematic Sketches

FIGURE H1A: HALF AND HALF CONSTRUCTION WITH UNSUPPORTED CUT SIDES

SCHEMATIC DIAGRAMS (NST)



Half and Half Construction, Shoring System with either Cut or Anchor System - Unsupported Cut



NOTES:

* Rakers or Anchor System

** Stage 2 Following Stage 1 in Opposite Way

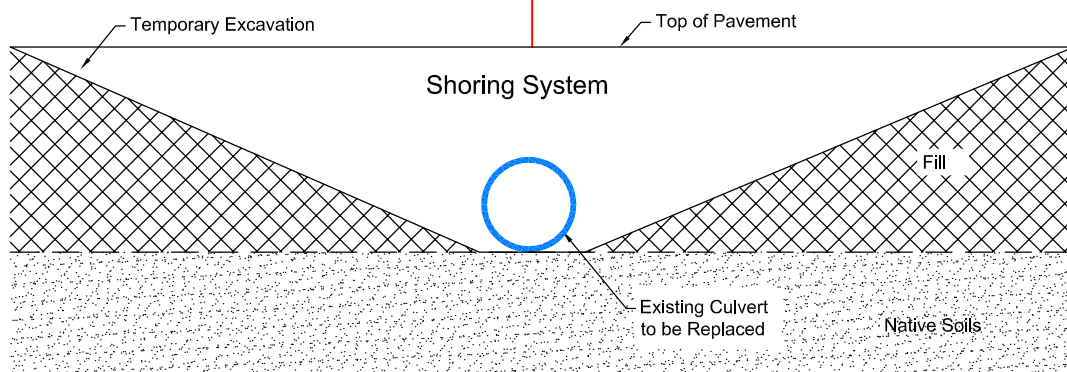
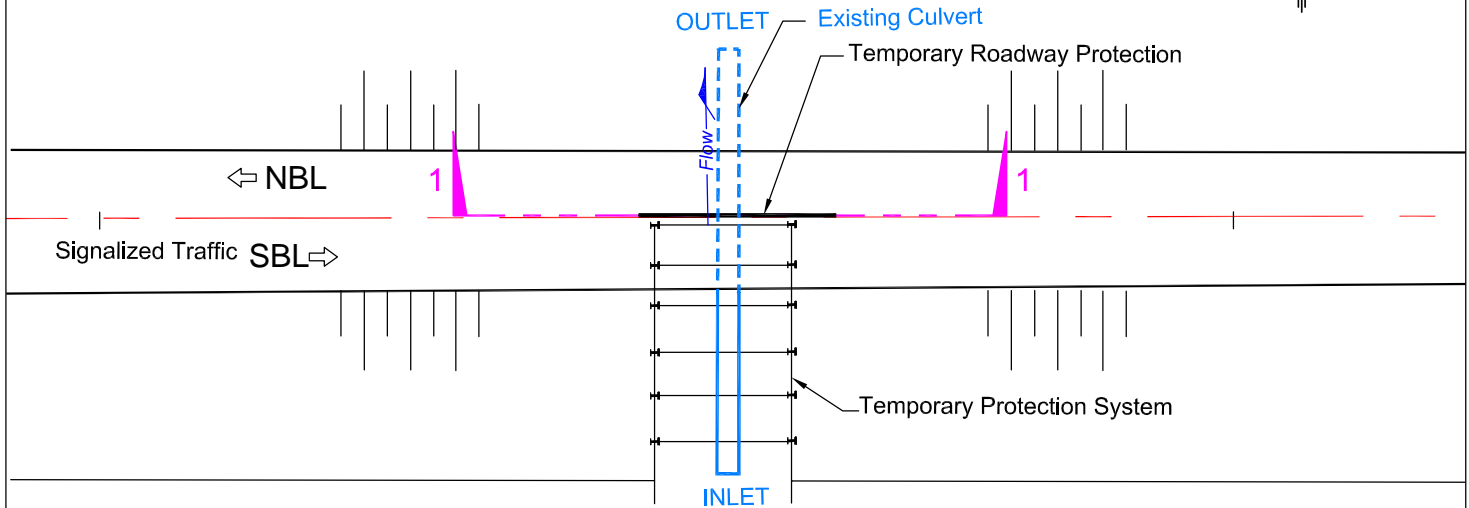
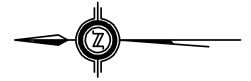


FIGURE H1B: HALF AND HALF CONSTRUCTION WITH BRACED CUT SIDES OR ANCHOR SYSTEM
SCHEMATIC DIAGRAMS (NST)

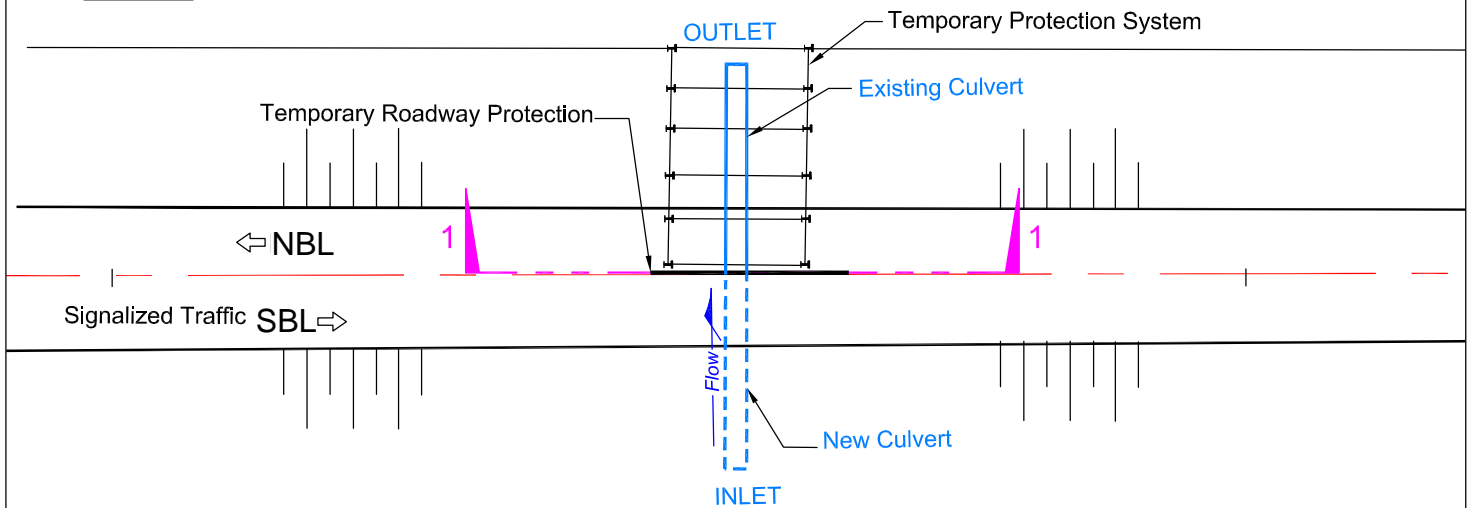


Stage 1



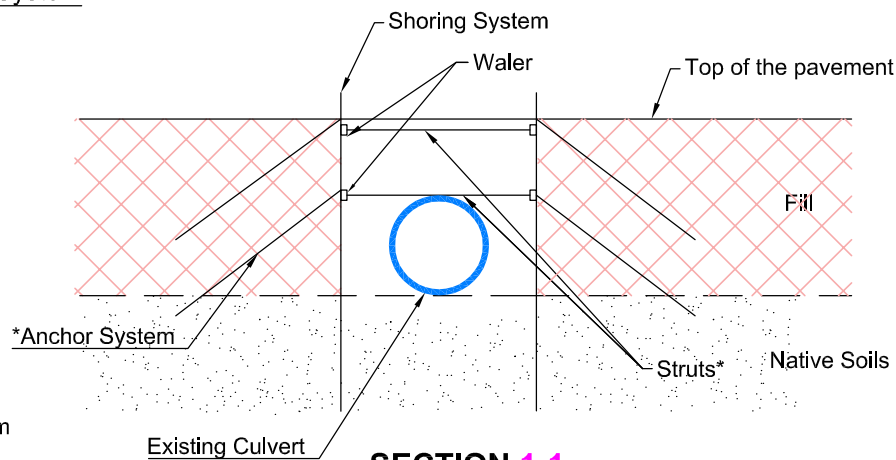
PLAN

Stage 2



PLAN

Half and half Construction, Shoring System- Braced Cut Struts or Anchor System

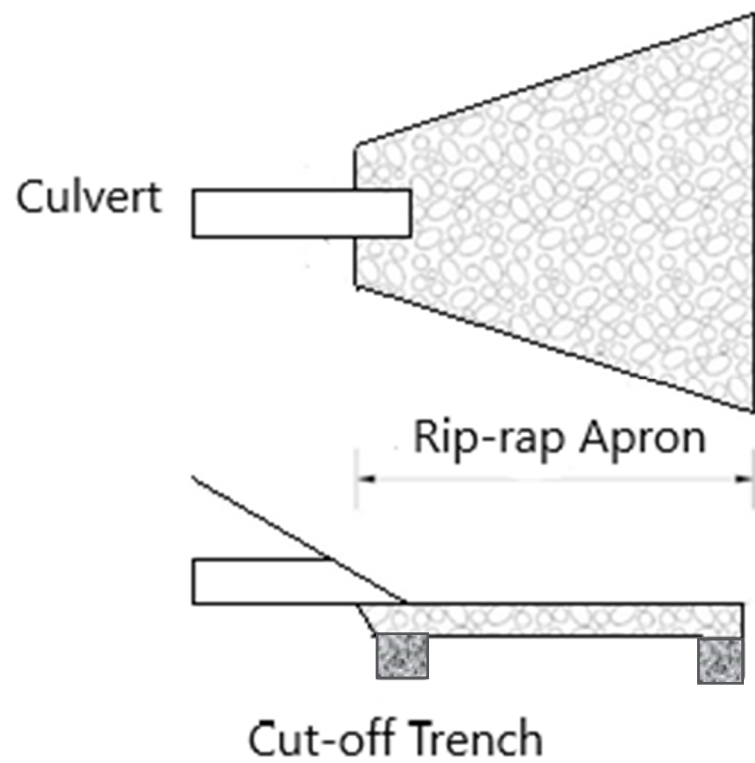


SECTION 1-1

NOTE:

* Struts or Anchor System

FIGURE H2: SCHEMATIC SKETCH OF EROSION PROTECTION AT OUTLET



Appendix I – Seismic Hazard Calculation



Government
of Canada

Gouvernement
du Canada

[Canada.ca](#) > [Natural Resources Canada](#) > [Earthquakes Canada](#)

2020 National Building Code of Canada Seismic Hazard Tool

i This application provides seismic values for the design of buildings in Canada under Part 4 of the National Building Code of Canada (NBC) 2020 as prescribed in Article 1.1.3.1. of Division B of the NBC 2020.

Seismic Hazard Values

User requested values

Code edition	NBC 2020
Site designation X_S	X_D
Latitude (°)	44.378
Longitude (°)	-79.105

Please select one of the tabs below.

NBC 2020

Additional Values

Plots

API

Background Information

The 5%-damped spectral acceleration ($S_a(T, X)$, where T is the period, in s, and X is the site designation) and peak ground acceleration ($PGA(X)$) values are given in units of acceleration due to gravity (g , 9.81 m/s^2). Peak

ground velocity. (PGV(X)) values are given in m/s. Probability is expressed in terms of percent exceedance in 50 years. Further information on the calculation of seismic hazard is provided under the *Background Information* tab.

The 2%-in-50-year seismic hazard values are provided in accordance with Article 4.1.8.4. of the NBC 2020. The 5%- and 10%-in-50-year values are provided for additional performance checks in accordance with Article 4.1.8.23. of the NBC 2020.

See the *Additional Values* tab for additional seismic hazard values, including values for other site designations, periods, and probabilities not defined in the NBC 2020.

NBC 2020 - 2%/50 years (0.000404 per annum) probability

$S_a(0.2, X_D)$	$S_a(0.5, X_D)$	$S_a(1.0, X_D)$	$S_a(2.0, X_D)$	$S_a(5.0, X_D)$	$S_a(10.0, X_D)$	PGA(X_D)	PGV(X_D)
0.282	0.289	0.176	0.0851	0.0227	0.00715	0.156	0.184

The log-log interpolated 2%/50 year $S_a(4.0, X_D)$ value is : **0.0313**

▼ Tables for 5% and 10% in 50 year values

NBC 2020 - 5%/50 years (0.001 per annum) probability

$S_a(0.2, X_D)$	$S_a(0.5, X_D)$	$S_a(1.0, X_D)$	$S_a(2.0, X_D)$	$S_a(5.0, X_D)$	$S_a(10.0, X_D)$	PGA(X_D)	PGV(X_D)
0.176	0.18	0.106	0.0494	0.0123	0.0039	0.0974	0.106

The log-log interpolated 5%/50 year $S_a(4.0, X_D)$ value is : **0.0173**

NBC 2020 - 10%/50 years (0.0021 per annum) probability

$S_a(0.2, X_D)$	$S_a(0.5, X_D)$	$S_a(1.0, X_D)$	$S_a(2.0, X_D)$	$S_a(5.0, X_D)$	$S_a(10.0, X_D)$	PGA(X_D)	PGV(X_D)
-----------------	-----------------	-----------------	-----------------	-----------------	------------------	--------------	--------------

$S_a(0.2, X_D)$	$S_a(0.5, X_D)$	$S_a(1.0, X_D)$	$S_a(2.0, X_D)$	$S_a(5.0, X_D)$	$S_a(10.0, X_D)$	PGA(X_D)	PGV(X_D)
0.115	0.116	0.0666	0.03	0.00694	0.00221	0.063	0.0648

The log-log interpolated 10%/50 year $S_a(4.0, X_D)$ value is : **0.0099**

Download CSV

← Go back to the [seismic hazard calculator form](#)

Date modified: 2021-04-06

Appendix J – NSSPs

NSSP FOR OBSTRUCTIONS

Scope of Work

The Contractor shall be alerted to the potential presence of cobbles and boulders in the fill and native soils encountered in few boreholes advanced at the site. Therefore, appropriate equipment and procedures will be required for open cut excavation and installation of roadway protection systems and temporary dewatering/unwatering systems.

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.

DEWATERING STRUCTURE EXCAVATIONS - Item No.

Special Provision No. FOUN0003

Amendment to OPSS 902, November 2019

902.02 REFERENCES

Section 902.02 of OPSS 902 is amended by the addition of the following:

Ontario Provincial Standard Specifications, Construction

OPSS 517 Dewatering
OPSS 805 Temporary Erosion and Sediment Control Measures

902.03 DEFINITIONS

Section 902.03 of OPSS 902 is amended by the addition of the following:

Automatic Transfer Switch means as defined in OPSS 517.

Cofferdam means as defined in OPSS 539.

Cut-Off Wall means as defined in OPSS 517.

Design Storm Return Period means as defined in OPSS 517.

Groundwater Control System means as defined in OPSS 517.

Plug means as defined in OPSS 517.

Sediment means as defined in OPSS 517.

Sediment Control Measure means as defined in OPSS 517.

Temporary Flow Passage System means as defined in OPSS 517.

Unwatering means as defined in OPSS 517.

Vegetated Discharge Area means as defined in OPSS 517.

Waterbody means as defined in OPSS 517.

Watercourse means as defined in OPSS 517.

902.04 DESIGN AND SUBMISSION REQUIREMENTS

902.04.01 Design Requirements

902.04.01.01 Dewatering

Clause 902.04.01.01 of OPSS 902 is deleted in its entirety and replaced with the following:

A dewatering system shall be designed to control water and the flow of water into the excavation, prevent disturbance of the foundation, permit the placing of concrete in the dry, and complete the excavating and backfilling for structures work.

When the system includes temporary flow passage system, the system shall be designed, as a minimum, for a [* Designer Fill-In, See Notes to Designer] year design storm return period, and groundwater discharge. A longer return period shall be used when determined appropriate for the work.

The dewatering system shall be according to the design requirements specified in OPSS 517.

902.04.02 Submission Requirements

Subsection 902.04.02 of OPSS 902 is deleted in its entirety and replaced with the following:

902.04.02.01 Preconstruction Survey

When a groundwater control system by wells or a well point system will be used, a condition survey of property and structures that may be affected by the work shall be carried out. The condition survey shall include the location and condition of adjacent properties, buildings, underground structures, water wells, Utilities, and structures, within a distance of [** Designer Fill-In, See Notes to Designer] metres from the groundwater control system. In addition, all water wells used as a supply of drinking water and located within this distance shall be tested for compliance with Ontario Drinking Water Quality Standards.

Water wells within the preconstruction survey distance can be located using the website <https://www.ontario.ca/environment-and-energy/map-well-records> or its successor site.

Copies of the condition survey and water quality test results shall be submitted to the Contract Administrator prior to the operation of the groundwater control system.

902.04.02.02 Working Drawings

Working Drawings for the dewatering system shall be according to OPSS 517.

902.07 CONSTRUCTION

902.07.04 Dewatering Structure Excavation

Subsection 902.07.04 of OPSS 902 is amended by the addition of the following clauses:

902.07.04.01 General

The dewatering systems shall be constructed and operated according to the Working Drawings.

Activation and deactivation of a temporary flow passage system, if applicable, shall be according to OPSS 517.

The dewatering system shall be continuously operational to control buoyancy forces until such forces can be resisted by backfill and structure self-weight, to keep excavations stable, to avoid erosion impacts from the release of accumulated water, and to keep the work area in the condition required to complete the associated work as specified in the Contract Documents.

When a temporary flow passage system is to remain operational through a seasonal shutdown period, the Contractor shall be responsible for any maintenance or repair costs due to the system during the seasonal shutdown period.

Temporary erosion and sediment control measures, including controlling the discharge of water, shall be according to OPSS 805. Measures not specified in OPSS 805 shall be according to the Working Drawings. Temporary erosion and sediment control measures and cover material to protect exposed soils, as required by the Working Drawings, shall be installed as soon as is practical.

Stranded fish shall be managed as specified in the Contract Documents.

Unwatering shall be carried out as necessary.

Water suspected of being contaminated as indicated by visual or olfactory observations shall be reported to the Contract Administrator.

Dewatering and temporary flow passage systems shall be discontinued in a manner that does not disturb any structure, pipeline, or flow channel. Operation of the dewatering system shall be shut down according to the procedures specified in the Working Drawings, where applicable.

902.07.04.02 Discharge of Water

The discharge of water shall be according to OPSS 517.

902.07.04.03 Monitoring

Monitoring shall be according to OPSS 517.

902.07.04.04 System Amendments

Amendments to stop any displacement, damage, soil loss or erosion due to the operation of the dewatering system shall be according to OPSS 517.

902.07.04.05 Removal

Removal of dewatering system and temporary flow passage system components shall be according to OPSS 517.

NOTES TO DESIGNER:

- * Fill in the design storm return period according to MTO Drainage Design Standard TW-1.
- ** Fill in the preconstruction survey distance as recommended by the foundation engineer.

WARRANT: Include with this standard tender item only on the recommendation of a foundation engineer.

CUSTODIAN: Tony Sangiuliano, MERO - Foundation Group.