



THURBER ENGINEERING LTD.

**PRELIMINARY
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 TWINNING, RENFREW AREA
CULVERTS 26 AND 26N
STA. 13+227, MCNAB TOWNSHIP
WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009**

Geocres No.: 31F07-007

Report to:

Ministry of Transportation Ontario

Latitude: 45.447032°
Longitude: -76.565280°

December 2024
Thurber File No.: 24726



TABLE OF CONTENTS

PART 1. FACTUAL INFORMATION

1	INTRODUCTION	1
2	SITE DESCRIPTION.....	1
2.1	General	1
2.2	Site Geology.....	2
3	SITE INVESTIGATION AND FIELD TESTING.....	3
4	LABORATORY TESTING	4
5	GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS	5
5.1	Embankment Fill.....	5
5.1.1	Asphalt.....	5
5.1.2	Sand to Sandy Silt Fill	5
5.1.3	Gravel to Cobbles and Boulders Rockfill	6
5.2	Topsoil.....	6
5.3	Peat.....	6
5.4	Silty Sand to Sandy Silt	6
5.5	Sand to Sandy Silt to Gravel with Sand & Silt (Glacial Till)	7
5.6	Bedrock	8
5.7	Groundwater.....	9
5.8	Analytical Testing	10
6	MISCELLANEOUS	11

PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7	INTRODUCTION	13
7.1	Background Information	13
7.2	Proposed Structures.....	14
7.3	Applicable Codes and Design Considerations	15
8	SEISMIC CONSIDERATIONS	15
8.1	Spectral and Peak Acceleration Hazard Values.....	15

8.2	Seismic Liquefaction Potential	16
8.3	CHBDC Seismic Site Classification and Performance Category	16
9	DESIGN OPTIONS	16
9.1	Culvert Type and Foundation Alternatives	16
9.2	Construction Methodology Alternatives.....	17
9.3	Recommended Approach	18
10	PRELIMINARY FOUNDATION DESIGN RECOMMENDATIONS	18
10.1	Concrete Pipe Culvert Foundation.....	18
10.2	Closed Box Concrete Culvert	18
10.3	Subgrade Preparation, Bedding and Backfilling.....	19
10.4	Backfill and Lateral Earth Pressures.....	20
10.4.1	Static Lateral Earth Pressure	21
10.4.2	Combined Static and Seismic Lateral Earth Pressure	22
10.5	Frost Penetration Depth	23
10.6	Cement Type and Corrosion Potential.....	24
10.7	Embankments	24
10.7.1	Eastbound Embankment Reinstatement	24
10.7.2	Embankment Stability	25
10.7.3	Embankment Settlement.....	26
11	CONSTRUCTION CONSIDERATIONS	28
11.1	Temporary Excavations.....	28
11.2	Temporary Protection Systems.....	29
11.3	Surface and Groundwater Control	30
11.4	Erosion and Scour Control.....	31
12	DESIGN AND CONSTRUCTION CONCERNS	32
13	CLOSURE	33



APPENDICES

Appendix A.	Borehole Location Plan and Stratigraphic Drawings
Appendix B.	Record of Borehole Sheets
Appendix C.	Laboratory Testing
Appendix D.	Site Photographs
Appendix E.	GSC Seismic Hazard Calculation
Appendix F.	Foundation Comparison
Appendix G.	Slope Stability Analysis Figures
Appendix H.	List of Referenced Specifications Non-Standard Special Provisions



**PRELIMINARY
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 TWINNING, RENFREW AREA
CULVERTS 26 AND 26N
STA. 13+227, MCNAB TOWNSHIP
WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009**

Geocres No.: 31F07-007

PART 1. FACTUAL INFORMATION

1 INTRODUCTION

Thurber Engineering Ltd. (Thurber) has been engaged by the Ministry of Transportation Ontario (MTO) to carry out Foundation Investigations to support the design of the Highway 17 Twinning Project which extends from Scheel Drive westerly to 3 km west of Bruce Street within the County of Renfrew, Ontario. Thurber carried out the investigation under Ministry of Transportation (MTO) Assignment No. 4018-E-0009.

This report addresses the Highway 17 culvert crossing located near Station 13+227 in McNab-Braeside Township (McNab) within Renfrew County, Ontario. The existing Highway 17 alignment at this site will become the future Highway 17 eastbound lanes and new westbound lanes will be constructed to the north of the existing alignment at this location. The existing culvert (Culvert 26) will be replaced, and a new culvert (Culvert 26N) is required to convey Liffey Creek below the embankment supporting the proposed Highway 17 westbound lanes.

This section of the report presents the factual findings obtained from the foundation investigation conducted by Thurber as part of the current study.

The purpose of this investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide a borehole location plan, records of boreholes, stratigraphic profile, laboratory test results and a written description of the subsurface conditions.

It should be noted that the use of and reliance on Part 1 of the Report is governed by and limited to the terms and conditions set out in the Report and a reliance letter. The Preferred Proponent remains responsible to assess the need for additional investigations and to complete that work.

2 SITE DESCRIPTION

2.1 General

For project purposes, Highway 17 is herein described as oriented east-west, and the culvert is described as oriented north-south. The culvert crosses Highway 17 at Sta. 13+227 McNab, which is approximately 260 m west of McCallum Drive.



In the area of the culvert, the existing Highway 17 is a three-lane highway including a westbound passing lane and has a posted speed limit of 90 km/h. The highway profile is inclined at about 3% down to the east towards McCallum Drive. To the west, the highway profile continues to rise at the same incline to approximately 800 m west of the culvert site. The shoulders have a total width of approximately 3.5 m and 1.5 m in the east- and westbound directions, respectively. Approximately 0.5 m of the shoulders are paved. Galvanized W beam guiderails on metal posts are present along both shoulders. The traffic volume for this section of Highway 17 is understood to have been 13,900 AADT in 2016.

The culvert under the existing Highway 17 was not visible during the field investigation. The existing culvert was assumed flooded. Water was ponding near the inlet and outlet with surface of the ponded water at approximate elevation 152.5 m on July 26, 2024. The existing culvert is reported to be a 1,000 mm diameter, corrugated steel pipe (CSP) culvert oriented approximately perpendicular to the highway alignment. At the time of the field investigation, no discernible creek flow was present, but it is assumed based on the site topography that the creek water flows under the highway embankment from south to north. Drawings provided by MTO indicate the existence of natural springs near Station 13+400 by the eastbound embankment toe.

Embankment side slopes, in the vicinity of the site, are inclined at approximately 1.9H:1V on the north side and 2.3H:1V on the south side. The existing embankment side slopes at the culvert site did not show any visible signs of global instability at the time of the investigation.

The site is in a rural setting and the area directly adjacent to the highway is undeveloped and densely vegetated with coniferous and deciduous trees. The terrain along the ditch line is relatively rugged in the vicinity of the culvert site. A low-lying marshy area with grasses and ponded water is located on both sides of the highway. Rockfill material is present immediately north of the highway westbound embankment toe. Rock outcrops are visible approximately 150 m east and west of the culvert site. Overhead utility lines are not present.

Photographs of the project area are included in Appendix D. These photographs show the existing condition of the highway embankment at the time of the field investigation.

2.2 Site Geology

Under the same MTO Assignment a Foundation investigation was conducted by Thurber in several high fill locations within the Highway 17 twinning project boundaries. The available information was reviewed prior to this investigation and can be found in the Geocres Library under Geocres Number 31F00-235. Borehole N-HF-02 from that investigation is relevant to the present report and has been included in Appendix B.

According to Crins et al. 2009¹ the project area is described as Ecoregion 6E (Lake Simcoe-Rideau Ecoregion) within the Mixedwood Plains Ecozone. According to Wester et al. 2018² the

¹ <https://files.ontario.ca/mnrf-ecosystemspart1-accessible-july2018-en-2020-01-16.pdf>

² <https://files.ontario.ca/ecosystems-ontario-part2-03262019.pdf>



ecoregion is subdivided into Ecodistrict 6E-16 (Pembroke Ecodistrict). The area is characterized by glaciolacustrine dominated landscape overlying a mix of Paleozoic to Precambrian bedrock.

Based on published geological information in *The Physiography of Southern Ontario* by Chapman and Putnam (1984), the site lies within the physiographic region known as the Ottawa Valley Clay Plains. The Ottawa Valley Clay Plains are characterized primarily by clay plains deposited by the Champlain Sea (Leda Clay) interrupted by ridges of rock or sand.

Ontario Geological Survey Map P.3784³ suggests the bedrock in the project area comprises felsic intrusive rocks, such as monzogranites to syenogranites.

3 SITE INVESTIGATION AND FIELD TESTING

Borehole N-HF-02 was drilled off-road on November 17, 2020, using a CME 850 track mounted drill rig equipped with hollow stem augers.

The foundation investigation and field-testing program was augmented between February 20 and March 22, 2024, and consisted of one on-road borehole identified as SC26-2 and four off-road boreholes identified as SC26-1, SC26-3, SC-26-4, and SC26-5. The on-road borehole was advanced with a CME 75 truck mounted drill rig utilizing hollow stem augers, NW casing, and coring techniques in the cobbles and boulders and bedrock. The off-road Boreholes SC26-3, SC26-4, and SC26-5 were advanced with a CME 55 track mounted drill rig utilizing hollow stem augers, NW casing, and coring techniques in bedrock. Borehole SC26-1 was advanced with portable drilling equipment. Prior to commencement of drilling, utility clearances were obtained in the vicinity of the borehole locations.

A summary of the borehole coordinates, elevations, and termination depths is provided in Table 3-1. The locations and elevations of the boreholes were surveyed by Thurber with a Trimble Catalyst DA1 antenna with centimeter accuracy and were measured relative to BM HCP 102 (Elevation 129.023 m) and BM HCP 118 (Elevation 139.303 m). Horizontal locations were measured by Thurber relative to existing site features. The elevations and borehole coordinates were reviewed and referenced to the survey data provided by the MTO. The borehole coordinates and elevations are shown on the Borehole Location and Soil Strata drawing included in Appendix A and on the individual Record of Borehole sheets included in Appendix B. The borehole coordinates are referenced to MTM Zone 9.

Table 3-1: Borehole Summary

Borehole No.	Drilled Location	Northing (Latitude)	Easting (Longitude)	Ground Surface Elevation (m)	Termination Depth (m)
SC26-1	Near Culvert 26 Inlet	5 034 061.8 (45.446469)	299 720.0 (-76.564941)	152.7	4.1

³ <http://www.geologyontario.mndm.gov.on.ca/mines/data/google/mrd126/doc.kml>

Borehole No.	Drilled Location	Northing (Latitude)	Easting (Longitude)	Ground Surface Elevation (m)	Termination Depth (m)
SC26-2	Existing Westbound Shoulder	5 034 094.3 (45.446761)	299 701.4 (-76.565181)	160.2	15.8
SC26-3	Near Culvert 26 Outlet	5 034 121.9 (45.447009)	299 715.5 (-76.565001)	154.0	13.8
SC26-4	Near Culvert 26N Inlet	5 034 124.4 (45.447032)	299 693.5 (-76.565281)	153.6	9.8
SC26-5	Near Culvert 26N Outlet	5 034 160.6 (45.447358)	299 676.1 (-76.565504)	151.0	8.5
N-HF-02	Near Proposed Eastbound Lanes	5 034 144.4 (45.447212)	299 663.0 (-76.565671)	151.6	7.2

Soil samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in general accordance with ASTM D 1586. The portable drill used for Borehole SC26-1 was equipped with a full weight hammer, thus no adjustments were necessary for the SPT N values.

A 25 mm diameter piezometer was installed in each of Borehole SC26-1 and N-HF-02, and 50 mm diameter monitoring wells were installed in Boreholes SC26-3 and SC26-5 to allow for measurements of the groundwater level after drilling. The details for the piezometer and well installations are illustrated on the respective Record of Borehole sheets provided in Appendix B. The piezometers and monitoring wells installed as part of the current investigation will be decommissioned by Thurber, as outlined in the Hydrogeological Investigation and Design Report.

Boreholes SC26-2 and SC26-4 were backfilled in accordance with MOE requirements (O.Reg 903, as amended). Borehole SC26-2 was capped with cold patch asphalt to reinstate the pavement surface.

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

4 LABORATORY TESTING

Laboratory testing was selected in accordance with the current MTO Guideline for Foundation Engineering Services, Section 5. Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. At least 25% of the recovered soil samples were subjected to testing for grain size distribution analysis and, where



appropriate, Atterberg Limits in accordance with MTO and ASTM standards. Chemical analysis for determination of pH, conductivity, resistivity, sulphide, sulphate, and chloride was carried out on two soil samples.

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

5 GENERAL DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole Location and Soil Strata Drawing included in Appendix A. A general description of the stratigraphy based on the conditions encountered in the boreholes is given in the following sections. However, the factual data presented on the Borehole Records takes precedence over the Soil Strata Drawing and the general description. It must be recognized that the soil and groundwater conditions may vary between and beyond borehole locations. Soil descriptions are in accordance with the MTO Guideline for Foundation Engineering Services (GFES) Manual (April 2022) and the 4th Edition of the Canadian Foundation Engineering Manual.

In general, the encountered stratigraphy below the existing fills and surficial peat and topsoil consists of a native deposit silty sand to sandy silt underlain by glacial till over bedrock.

5.1 Embankment Fill

5.1.1 Asphalt

A 115 mm thick layer asphalt was encountered at the ground surface in Borehole SC26-2.

5.1.2 Sand to Sandy Silt Fill

A fill layer consisting of sand to silty sand to sandy silt with varying amounts of gravel and organics was encountered below the asphalt in Borehole SC26-2 and at the ground surface in Boreholes SC26-3 and SC26-4. The thickness of the layer ranged from 0.7 to 2.9 m (base elev. at 159.4 to 151.1 m). The SPT N values ranged from 4 to 53 blows, indicating a loose to very dense condition.

The moisture content of the samples tested ranged from 2 to 46%. The results of grain size analyses conducted on a sample of this fill material are summarized in the table below and are illustrated on Figure C1 in Appendix C.

Summary of Grain Size Distribution Testing – Sand to Sandy Silt Fill

Soil Particle	Percentage (%)
Gravel	38
Sand	53
Silt & Clay	9

5.1.3 Gravel to Cobbles and Boulders Rockfill

A rockfill layer consisting of gravel to cobbles and boulder sized particles was encountered below the silty sand to sandy silt fill in Boreholes SC26-2 and SC26-4. The thickness of the layer ranged from 2.2 to 7.6 m (base elev. at 151.8 and 150.6 m). The cobbles and boulders rockfill was interbedded with sand; voids were noted between boulders. Varying amounts of sand and silt were encountered throughout the layer. The SPT N values ranged from 5 to 41 blows but were typically greater than 11 blows, indicating a compact to dense condition. SPT refusal was encountered at several depths in Borehole SC26-2; coring techniques were required to advance the borehole. Rock particle sizes of 200 mm and 300 mm were noted in the recovered cores.

The moisture content of the samples tested ranged from 1 to 21% but were typically less than 10%. The results of grain size analyses conducted on a sample of the gravel with silt and sand fill material are summarized in the table below and are illustrated on Figure C2 in Appendix C. It is noted that the gradation test results may be biased to smaller particle sizes due to the physical limitations of the split spoon sampler.

Summary of Grain Size Distribution Testing – Gravel with Silt and Sand Fill

Soil Particle	Percentage (%)
Gravel	64
Sand	28
Silt & Clay	8

5.2 Topsoil

A 200 mm thick layer of topsoil was encountered at the ground surface in Borehole N-HF-02.

5.3 Peat

A native deposit of coarse fibrous peat was encountered at the ground surface in Borehole SC26-5. The thickness of the layer was 0.8 m (base elev. 150.2 m). The layer is described as very soft based on tactile evaluations of strength. The moisture content of a sample tested was 536%.

5.4 Silty Sand to Sandy Silt

A native deposit of silty sand to sandy silt was encountered at the ground surface in Borehole SC26-1, below the sand to silty sand fill in Borehole SC26-3, below the gravel rockfill in Borehole SC26-4, below the peat in Borehole SC26-5, and below the topsoil in Borehole N-HF-02. Varying amounts of organics were noted within the layer. The thickness of the layer ranged from 1.2 to 6.1 m (base elev. 151.5 to 144.1 m). The SPT N-values recorded were between 2 and 38 blows indicating a very loose to dense relative density.

The moisture content of the samples tested ranged from 11 to 35%. The results of grain size analyses conducted in seven samples of this layer are summarized in the table below and are illustrated on Figure C3 and C4 in Appendix C.

Summary of Grain Size Distribution Testing – Silty Sand to Sandy Silt

Soil Particle	Percentage (%)
Gravel	0 – 1
Sand	8 – 59
Silt	34 – 73
Clay	6 – 19

The results of Atterberg Limits testing carried out in the fines portion of one sample of this material are summarized below and are illustrated on Figure C5 in Appendix C. The laboratory results indicate that the fines are of low plasticity (ML). The results of Atterberg Limit testing conducted on the fines portion of five other samples of the deposit indicate a non-plastic material.

Summary of Atterberg Limit Testing – Silty Sand to Sandy Silt

Parameter	Value
Liquid Limit	21
Plastic Limit	17
Plasticity Index	4

5.5 Sand to Sandy Silt to Gravel with Sand & Silt (Glacial Till)

A layer of sand to sandy silt to gravel with sand and silt till was encountered below the cobbles and boulders rockfill in Borehole SC26-2 and below the silty sand to sandy silt in all the other boreholes. Varying amounts of gravel, cobbles, and boulders were encountered throughout the layer. Where fully penetrated, the thickness of the layer ranged from 0.3 to 2.7 m (base elev. 151.2 to 146.9 m). The layer was not fully penetrated in Boreholes SC26-3, SC26-5 and N-HF-02 but was proven to extend to a depth of as much as 13.8 m below ground surface (elev. 140.2 m). SPT N-values ranged from 5 blows to refusal but were typically greater than 11 blows, indicating a compact to very dense relative density.

The moisture content of the samples tested ranged from 3 to 27%. The results of gradation analyses completed on seven samples of the layer are illustrated in Figures C6 and C7 of Appendix C. The results of the tests are summarized below and on the Record of Borehole sheets in Appendix B.

Summary of Grain Size Distribution Testing – Sand to Silty Sand (Glacial Till)

Soil Particle	Percentage (%)	
Gravel	4 – 23	
Sand	65 – 72	
Silt	22 – 28	11 – 14
Clay	1 – 7	

The results of Atterberg Limit testing conducted on the fines portion of four samples of the deposit indicate a non-plastic material.

The base of the glacial till in Borehole SC26-5 was observed to be coarser gravel with silt and sand. Cobbles were also noted. The results of gradation analyses completed on a sample of the coarse till are illustrated in Figure C8 of Appendix C. The results of the tests are summarized below and on the Record of Borehole sheets in Appendix B.

Summary of Grain Size Distribution Testing – Gravel with Silt and Sand Till

Soil Particle	Percentage (%)
Gravel	74
Sand	19
Silt & Clay	7

5.6 Bedrock

Boreholes SC26-3, SC26-5 and N-HF-02 were terminated on auger refusal at elevations ranging from 140.2 to 144.4. Refusal could be due to the presence of bedrock or cobbles and boulders.

Bedrock was proven by coring in Boreholes SC26-1, SC26-2, and SC26-4. The bedrock surface sloped downwards from south to north with depths ranging from 1.5 to 11.1 m (elevation 151.2 to 146.9 m).

The bedrock encountered consisted of slightly weathered to fresh jointed, coarse grained, reddish pink to grey monzogranite. Photographs of the bedrock cores are provided in Appendix C. The rock core quality measurements are summarized in the Table 5-1.

Table 5-1: Bedrock Details

Parameter	Range
Total Core Recovery (TCR), %	79 – 100
Solid Core Recovery (SCR), %	22 – 90
Rock Quality Designation (RQD), %	30 – 85
Fracture Index (fractures per 0.3 m) ⁽¹⁾	0 – >10
Unconfined Compressive Strength (MPa)	71 – 126

Note: (1) Indicated as “FI” on Borehole Logs

The RQD values ranged from 30 to 85% indicating a bedrock of poor to good quality (CFEM, 2023). The results of unconfined compressive strength tests (UCS) ranged from 71 to 126 MPa, indicating that the tested samples of the bedrock are strong to very strong (CFEM, 2023). The UCS test results are included in Appendix C.

5.7 Groundwater

Piezometers with a 25 mm diameter were installed in Boreholes SC26-1 and N-HF-02, and monitoring wells with a 50 mm diameter were installed in Boreholes SC26-3 and SC26-5. The recorded groundwater levels are presented in Table 5-2.

Table 5-2: Summary of Groundwater Levels

Borehole No.	Bottom of Screen Elevation (m)	Groundwater Depth ^(a) (m)	Groundwater Elevation (m)	Date of Measurement
SC26-1	148.6	-0.4	153.1	April 09, 2024
		-0.4	153.1	May 01, 2024
		-0.1	152.8	June 10, 2024
		-0.3	153.0	June 28, 2024
		0.0	152.7	August 28, 2024
SC26-3	144.9	2.1	151.9	March 12, 2024
		2.1	151.9	March 22, 2024
		2.1	151.9	April 09, 2024
		2.1	151.9	May 01, 2024
		2.2	151.8	June 07, 2024
		2.2	151.8	June 26, 2024
		2.2	151.8	June 28, 2024
		2.3	151.7	July 15, 2024
		2.4	151.6	August 28, 2024

Borehole No.	Bottom of Screen Elevation (m)	Groundwater Depth ^(a) (m)	Groundwater Elevation (m)	Date of Measurement
SC26-5	144.9	-0.1	151.1	March 12, 2024
		-0.2	151.2	March 22, 2024
		-0.2	151.2	April 09, 2024
		-0.2	151.2	May 01, 2024
		0.0	151.0	June 10, 2024
		-0.2	151.2	June 26, 2024
		0.1	150.9	August 28, 2024
N-HF-02	144.9	0.0 ^(b)	151.6	December 12, 2020
		0.5	151.1	September 23, 2021
		0.5	151.1	November 11, 2021
		-0.1 ^(b)	151.7	January 24, 2022
		-0.1 ^(c)	151.7	May 01, 2024
		0.4 ^(c)	151.2	August 28, 2024

Notes: (a) negative ground water depths indicate artesian conditions
(b) piezometer water was frozen at the time of measurements
(c) water level taken after borehole log was finalized

The surface of the ponded water in the creek was at approximately elevation 152.5 m near the north and south embankment toes on July 26, 2024.

These observations are considered short term as they were recorded at discrete times, and it should be noted that the groundwater level at the time of construction may be different and seasonal fluctuations of the groundwater level are to be expected. In particular, the creek water and groundwater levels may be at a higher elevation after periods of significant and/or prolonged precipitation.

5.8 Analytical Testing

Two samples of the native silty sand to sandy silt were submitted to Paracel Laboratories in Ottawa, Ontario for analysis of pH, water soluble sulphate, sulphide and chloride concentrations, resistivity, and conductivity. The analysis results are summarized in Table 5-3. Copies of the test results are provided in Appendix C.

Table 5-3: Results of Chemical Analysis

Borehole	Sample	Depth (m)	Chloride (µg/g)	Sulphate (µg/g)	Sulphide (%)	pH (-)	Resistivity (Ohm-cm)
SC26-3	SS5	3.0 – 3.6	82	16	< 0.01	6.79	3,870
SC26-5	SS4	2.3 – 2.9	92	45	0.02	7.17	3,270



6 MISCELLANEOUS

The borehole locations reflect existing site features and access constraints. The as-drilled locations and ground surface elevation were measured by Thurber following completion of the field program. Limitless Drilling Ltd. Renfrew, Ontario, supplied and operated the portable equipment and George Downing Estate Drilling Ltd. of Hawkesbury, Ontario, supplied and operated the drill rigs used to drill, test, sample, and decommission the boreholes. Traffic control was performed in accordance with Ontario Book 7 and was provided by T.G. Carroll Cartage Ltd. of Carp, Ontario. The field investigation was supervised on a full-time basis by Mr. I. Khan, EIT, and Mr. D. Amorim Pereira, Geotechnical Technician, and Mr. R. Howarth, Geotechnical Technician. Overall supervision of the field investigation program was provided by Mr. J. Gray, P.Eng.

Routine geotechnical laboratory testing were completed by Thurber's laboratory in Ottawa. UCS testing were completed by Thurber's laboratory in Oakville. Analytical testing was completed by Paracel Laboratories Ltd. in Ottawa.



Interpretation of the factual data and preparation of this report was completed by I. Khan, EIT, and A. de Oliveira, P.Eng. The report was reviewed by Dr. F. Griffiths, P.Eng., and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:

Ibrahim Khan, EIT
Engineering Intern



Anderson de Oliveira, M.A.Sc., P.Eng.
Geotechnical Engineer



Dr. Fred Griffiths, P.Eng.
Principal, Senior Geotechnical Engineer



Dr. P.K. Chatterji, P.Eng.
Designated Principal Contact,
Principal, Senior Geotechnical Engineer



**PRELIMINARY
FOUNDATION INVESTIGATION AND DESIGN REPORT
HIGHWAY 17 TWINNING, RENFREW AREA
CULVERTS 26 AND 26N
STA. 13+227, MCNAB TOWNSHIP
WP 4068-09-00 / ASSIGNMENT NO. 4018-E-0009**

Geocres No.: 31F07-007

PART 2. ENGINEERING DISCUSSION AND RECOMMENDATIONS

7 INTRODUCTION

Part 2 of the report provides an interpretation of the factual data from Part 1 and presents preliminary geotechnical recommendations to assist the project team in designing the foundations for a culvert replacement to be located at approximate Station 13+227 on existing Highway 17 McNab Township, Renfrew County and a new culvert crossing located at approximate Station 13+190 on the proposed new westbound lanes of Highway 17. Thurber carried out the investigation under Ministry of Transportation (MTO) Assignment No. 4018-E-0009.

This preliminary foundation investigation and design report with the interpretation and recommendations are intended for the use of the Ministry of Transportation and shall not be used or relied upon for any other purposes or by any other parties including design-build contractors. It should be noted that the use of and reliance on Part 1 of the Report is governed by and limited to the terms and conditions set out in the Report and a reliance letter. The Preferred Proponent remains responsible to assess the need for additional investigations and to complete that work. The Preferred Proponent must make their own interpretation based on the factual data in Part 1 of the report. The information included in Part 2 is not to be relied upon for design purposes and foundation design is the sole responsibility of the Preferred Proponent. No use shall be made of Part 2 or any part thereof. The Preferred Proponent must make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction methods and scheduling.

The following sections provide preliminary geotechnical recommendations for the construction of foundation elements for the proposed works. The discussion and preliminary recommendations presented in this report are based on information provided by the MTO and the factual data obtained during the current field investigation.

7.1 Background Information

The site is located on Highway 17 approximately 260 m west of McCallum Drive in McNab Township, Renfrew County. For project purposes, Highway 17 is herein described as oriented east-west and the creek flows from south to north.



The existing highway near the culvert site is sloped upwards to the west and has an elevation of approximately 160.2 m near the existing culvert (Culvert 26). The existing culvert is reported to be 1,000 mm diameter, corrugated steel pipe (CSP) culvert oriented approximately perpendicular to the highway alignment. However, the culvert was not visible as ponded water was present on both sides of the existing highway on July 26, 2024. The surface of the water was at approximately elevation 152.5. It is assumed that the existing culvert invert is approximately at elevation 151.5 to 150.8 at the inlet and outlet respectively.

The encountered stratigraphy below the existing fills and surficial peat and topsoil consists of a native deposit of silty sand to sandy silt underlain by glacial till over bedrock. It is noted that the groundwater elevation in the three monitoring wells and piezometers ranged from 151.2 m to 153.1 m on April 9, 2024. Slight artesian conditions were noted in the boreholes.

It is noted that a Foundation Investigation and Design Report was previously prepared for several proposed high fill embankments for the overall Highway 17 twinning assignment as documented in Geocres Number 31F-235. The current site is located within High Fill Area N which encompasses the new westbound alignment from 13+100 to 13+275, McNab Township.

7.2 Proposed Structures

The existing Highway 17 alignment at this site will become the future Highway 17 eastbound lanes and new westbound lanes will be constructed approximately 52.5 m north (rounding to rounding) of the existing alignment at this location. Culvert 26 currently present under the existing Highway 17 lanes will require replacement, and a new culvert (Culvert 26N) will be required under the proposed westbound lanes. These culverts will convey Liffey Creek under the existing and proposed highway embankments.

The Structure and Culvert List of February 23, 2022, for this project indicated that the proposed culvert replacement (Culvert 26) beneath the new eastbound lanes is to be a structural, pre-cast, closed-bottom concrete box culvert (CBC) with a length of 48.7 m, a span of 3.0 m, a rise of 2.4 m, and a 1.35% slope. It is assumed that the invert of the replacement culvert will be near elevation 151.5 and 150.8 m at the inlet and outlet, respectively.

Proposed Culvert 26N is to be constructed for the west bound lanes at approximate Sta. 13+190. It will also be a structural, pre-cast, closed-bottom concrete box culvert (CBC) and will have a length of 57.3 m, a span of 3.0 m, a rise of 2.4 m, and a 4.06% slope. It is assumed that the invert of the new westbound embankment culvert will be near elevations 150.6 and 148.3 m at the inlet and outlet. As per the preliminary MTO drawings, the proposed final grade at Station 13+190 of the new westbound embankment is approximate elevation 161.4 m. The proposed embankment has a height of approximately 10.4 m above the original ground surface.

Based on preliminary information provided by MTO, no retaining walls or headwalls are proposed at the culverts.



It is noted that preliminary GA drawings are not available at the time of writing. The preliminary recommendations presented herein must be reassessed once the type, configuration, location, elevation, and orientation of the proposed works are established.

7.3 Applicable Codes and Design Considerations

The geotechnical assessment presented herein has been prepared based on the available data regarding the proposed work, existing ground conditions document in Part 1 of this report, and in accordance with the Canadian Highway Bridge Design Code (CHBDC), version CSA S6-19.

In accordance with the CHBDC, the analysis and design of the structure takes into consideration the importance of the structure and the consequence associated with exceeding limit states. The importance category and consequence classification are defined by the Regulatory Authority which, in this case, is the Ministry of Transportation, Ontario (MTO).

It is understood that the new culvert structures are being designated as a “Major Route” importance category. As per Section 6.14.2.1.b and 6.14.2.3.b of the CHBDC, a Major-Route geotechnical system is required to have a seismic performance criterion that meets a return period of 475-years.

It is understood that the culverts have been assigned a Typical Consequence Classification, in accordance with Section 6.5.1 of the CHBDC. Accordingly, a consequence factor (Ψ) of 1.0, as per Table 6.1 of the CHBDC, has been used in assessing factored geotechnical resistances. If the consequence classification changes, the geotechnical assessment and recommendations provided within this report may need to be reviewed and revised.

The degree of site and prediction model understanding for this site has been assessed to be typical understanding (Section 6.5.3 of CHBDC).

The frost penetration depth and associated recommendations are provided in Section 10.5.

8 SEISMIC CONSIDERATIONS

8.1 Spectral and Peak Acceleration Hazard Values

The seismic hazard data for the CHBDC is based on the fifth-generation seismic model developed by the Geological Survey of Canada (GSC)⁴. The GSC seismic hazard calculation data sheet for this site for the *reference* ground condition (Site Class C) is presented in Appendix E. The site coefficients used to determine the design spectral acceleration values are a function of the Site Class, PGA, and S_a (0.2). The PGA value at this site provided by GSC for a *reference* Site Class C with a 2% probability of exceedance in 50 years (2475-year event) is 0.228 g. This value is to be scaled by the $F(PGA)$ based on the *site-specific* Site Class, as discussed in Section 8.3.

⁴ <https://earthquakescanada.nrcan.gc.ca/hazard-alea/interpolat/calc-en.php>

8.2 Seismic Liquefaction Potential

Based on the assessment using the SPT data following the simplified method for cohesionless soil as outlined in Boulanger and Idriss (2014)⁵, the soils at this site are generally considered not susceptible to liquefaction during a 1 in 2475yr design earthquake. Discrete sections in Borehole SC26-3 of the existing embankment fills are considered potentially susceptible to liquefaction during a 1 in 2475yr design earthquake. However, these materials will be excavated and replaced during culvert installation. Furthermore, these soils are not susceptible to liquefaction during a 1 in 475 year design earthquake.

8.3 CHBDC Seismic Site Classification and Performance Category

In accordance with Section 4.4.3.2 of the CHBDC, the selection of the seismic site classification is based on the nature of the soil deposits within the upper 30 m of the stratigraphy. As per Table 4.1 within Section 4.4.3.2 of the CHBDC, the site has been classified as a Seismic Site Class D.

The $F(PGA)$, as per Table 4.8 within Section 4.4.3.3 of the CHBDC, is equal to 1.13 for this site yielding a scaled *site-specific* Site Class D PGA of 0.258 g for a seismic event with a 2% probability of exceedance in 50 years (2475 year event). Similarly, the $F(PGA)$ is 1.29 and the Site Class D PGA is 0.098 g for a seismic event with a 10% probability of exceedance in 50 years (475 year event).

As per Section 4.4.4 of the CHBDC, the Seismic Performance Category is assigned based on the fundamental period, the importance category, and the spectral accelerations scaled to the site class. The $F(0.2)$ and $F(1.0)$, as per Tables 4.2 and 4.4 within Section 4.4.3.3 of the CHBDC, is equal to 1.12 and 1.42 for this site, yielding a scaled *site-specific* $S_a(0.2)$ of 0.396 and $S_a(1.0)$ of 0.139. A Seismic Performance Category of 3 is applicable to this site based on Table 4.10 of the CHBDC. The seismic performance category should be confirmed by the structural engineer.

9 DESIGN OPTIONS

9.1 Culvert Type and Foundation Alternatives

Selection of the culvert type must consider the proposed construction procedures, staging requirements, geotechnical resistance available in the foundation soils, depth to suitable bearing stratum and post-construction settlement criteria. From a geotechnical perspective, the following culvert types were considered:

⁵ Boulanger, R. W., and Idriss, I. M. (2014). *CPT and SPT based liquefaction triggering procedures*, Report No. UCD/CGM-14/01, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, University of California, Davis, CA, 134 pp.

- Circular Pipes (Concrete, HDPE, Steel)

Although, from a foundation engineering perspective, a pipe culvert is a technically feasible alternative, the proposed pipe must meet the required flow capacity, navigation and hydraulic requirements.

- Open-Bottom Culvert (Box, Arch)

The construction of open-bottom culverts will have greater construction concerns due to the shallow water table and requirement for greater excavation depths to construct the culvert footings to satisfy frost depth requirements. It is anticipated that the underside of the footings for Culvert 26N would be as deep as approximate elevation 146.4 m which is more than 4 m below the observed groundwater level on April 9, 2024, and approximately 15 m below the proposed road surface. The use of open bottom culverts would require greater dewatering efforts compared to other culvert options and is not recommended at this site.

- Closed-Bottom Culvert (Box)

A pre-cast, segmental, closed-bottom, box culvert is considered a feasible option from a foundation engineering perspective. Precast sections, rather than cast-in-place construction, can be installed expediently with less potential for disturbance of the subgrade during installation, require less excavation depth than open bottom culverts, and allow for more manageable dewatering efforts.

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

9.2 Construction Methodology Alternatives

At the time of the field investigation, the creek flowed from south to north with ponded water surface elevations near the existing culvert inlet and outlet at approximately 152.5 m. Groundwater elevation ranged from 151.2 m to 153.1 m on April 9, 2024. Slight artesian conditions were noted in the boreholes. Excavations will likely extend below the water level of the creek. An adequate and effective dewatering plan including surface water management, cofferdams, creek diversion, and excavation dewatering will be required to enable excavation to the required founding elevation and construction of the foundations in the dry (see Section 11.3).

At the time of preparation of this report, a construction staging plan has not yet been developed. The foundation recommendations presented herein have been prepared based on the assumption that construction of the new culvert and the new westbound embankment will be carried out while traffic remains on the existing alignment. Upon completion of the construction of the new lanes, all traffic would be temporarily directed onto those new lanes to allow culvert replacement for the eastbound lanes under a road closure of the existing alignment.



9.3 Recommended Approach

From a geotechnical perspective, closed-bottom, box culverts are recommended at this site. It is anticipated that construction for the westbound lanes would be carried out while traffic remains on the existing alignment. Once the new lanes are open, all traffic would be rerouted onto the new lanes, while the culvert under the existing lanes is replaced.

Pipe culverts would also be considered a feasible alternative. Construction staging would be similar to that for the closed bottom box culvert option.

10 PRELIMINARY FOUNDATION DESIGN RECOMMENDATIONS

From a foundation engineering perspective, concrete box culverts are recommended. The following bullets summarize the relevant elevations near each culvert:

Existing Highway 17 / Eastbound Lanes (Culvert 26)

- | | |
|---------------------------------------|------------------|
| • Existing top of pavement | 160.2 m |
| • Culvert invert at outlet | 150.8 m |
| • Groundwater elevation April 9, 2024 | 153.1 m |
| • Bedrock surface elevation | 151.2 to 140.2 m |

Proposed Highway 17 Westbound Lanes (Culvert 26N)

- | | |
|---------------------------------------|------------------|
| • Top of pavement | 161.4 m |
| • Culvert invert at outlet | 148.3 m |
| • Groundwater elevation April 9, 2024 | 151.2 m |
| • Bedrock surface elevation | 146.9 to 142.5 m |

10.1 Concrete Pipe Culvert Foundation

It is anticipated that the inverts of the culverts will be within the silty sand and glacial till layers. Bearing resistance values are not required for pipe culverts. The culvert should be founded on a granular bedding layer (see Section 10.3). Subgrade preparation should follow the recommendations provided in Section 10.3 to provide a suitable subgrade for the bedding. Surface water diversion and dewatering will be required to place the bedding material and install the culvert in the dry (see Section 11.3).

If a concrete pipe is selected, resistance to lateral forces/sliding resistance between concrete and the underlying Granular 'A' bedding (see Section 10.3) should be evaluated based on the recommendations in Section 10.3.

10.2 Closed Box Concrete Culvert

It is anticipated that the subgrade soils beneath the culvert footprint on the westbound lanes will be subjected to the additional loads from the proposed embankment with a height of

approximately 10.4 m above existing grades. Further discussion on the potential settlement of the underlying soils is provided in Section 10.7.3. The subgrade should be prepared as described in Section 10.3.

The recommended geotechnical resistances for a 3.6 m wide (outside) pre-cast, closed-bottom, box culvert with the culvert base at or below approximate elevation 151.0 m for Culvert 26 and 150.0 m for Culvert 26N, installed on bedding layers with a minimum thickness of 0.3 m placed on an undisturbed native silty sand to sandy silt subgrade are as follows:

- Factored Geotechnical Resistance at ULS of 300 kPa
- Factored Geotechnical Resistance at SLS of 200 kPa (provided settlement mitigation is included in the design for Culverts 26 and 26N – see Section 10.7.3)

The factored geotechnical resistances include the following factors:

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

The bearing resistance values are for vertical, concentric loading. In the case of eccentric or inclined loading, the bearing resistance must be reduced in accordance with CHBDC Clause 6.10.2. Foundation settlement, based on the supplied SLS resistance, is expected to be greater than 25 mm for Culverts 26 and 26N, see further discussion in Section 10.7.3.

Resistance to lateral forces/sliding resistance between the precast concrete and underlying granular a bedding (Section 10.3) should be evaluated in accordance with the CHBDC assuming an unfactored coefficient of friction of 0.45. A resistance factor of 0.8 (as per CHBDC Table 6.2) should be used to estimate the sliding resistance between the culvert and Granular A.

Surface water diversion and dewatering will be required to place the bedding material and install the culvert in the dry (Section 11.3).

10.3 Subgrade Preparation, Bedding and Backfilling

“Granular A” in this section refer to OPSS Granular A meeting the specifications of OPSS.PROV 1010 and SP 110S06. “Granular A” is further defined as “Quarry-Source Granular A” unless specifically described as “Pit-Source Granular A”. Fills should be placed and compacted as per OPSS.PROV 501 and OPSS.PROV 206.

The culvert should be constructed following OPSS.PROV 401 and either OPSS.PROV 421 (pipe culvert) or OPSS.PROV 422 (box culvert).

Subgrade preparation for the replacement of Culvert 26 should include excavation and removal of the existing culvert if replaced along the same alignment. If the replacement culvert is placed



on a new alignment, the existing culvert may be decommissioned in place (see Section 10.7.3 for further details).

Topsoil and peat with a thickness of approximately 0.2 to 0.8 m were encountered in the area of the proposed Culvert 26N during the drilling investigation and must be removed from beneath the culverts and embankment footprints.

At the founding level, existing fill, soft/loose soils, disturbed soils, or otherwise deleterious materials encountered will need to be removed down to competent inorganic soils. Construction traffic should not travel on the exposed subgrade. As soon as practical, the excavation should be backfilled to the underside of the bedding elevation to protect the subgrade from disturbance from both construction traffic and weather. Granular A should be used in dewatered excavations to backfill any sub-excavations required for subgrade improvement, see further comments below for excavations in the wet.

Foundation preparation for a pipe culvert should be as per OPSS.PROV 421 and OPSD 802.010 (flexible pipe), OPSD 802.031 (rigid pipe), and OPSD 803.031 with bedding extending to 300 mm below the pipe in both cases. It is recommended that culvert cover, embedment, and bedding materials consist of OPSS.PROV 1010 Granular A.

In order to provide a more uniform foundation subgrade condition for a closed box culvert, bedding and cover material conforming to OPSS.PROV 1010 Granular A requirements must be provided under the base of the culvert as per OPSS.PROV 422 and OPSD 803.010. The Granular bedding layer should be a minimum of 300 mm thick and covered with a 75 mm levelling course of Granular A. Backfill and cover for concrete box culverts should be as per OPSD 803.010 with cover material consisting of OPSS.PROV 1010 Granular A.

Backfill above the granular cover material for a closed box or rigid pipe culvert should be in accordance with OPSS.PROV 902 and consist of materials meeting the requirements of OPSS Select Subgrade Material (SSM) or better.

Heavy compaction equipment, used adjacent to or directly above the culvert, must be restricted in accordance with OPSS.PROV 501 to protect the culvert from damage.

It is noted that construction will extend below the observed water level. Dewatering will be required to place the granular bedding in the dry. Please review Section 11.3 for additional comments on groundwater and surface water control.

10.4 Backfill and Lateral Earth Pressures

Structural backfill material should consist of Granular A or Granular B Type II meeting the OPSS.PROV 1010 and SP 110S06 specifications. Large scale direct shear box testing on samples of Granular A and Granular B Type II from several nearby aggregate sources was completed for this project. The results indicate that for design of structural backfill for this project,



an internal angle of friction of 40 degrees and 42 degrees can be used for quarry-sourced Granular A and Granular B Type II, respectively, generated within this area provided the effective vertical pressure on the material is less than 150 kPa (Geocres Memorandum 31F-213). An Operational Constraint will be required in the contract restricting the source of Granular A to quarries. Throughout this report, the term “Granular A” is defined as “Quarry-Source Granular A” unless specifically described as “Pit-Source Granular A”.

The backfill must be in accordance with OPSS.PROV 902 and placed to the extents as generally shown on OPSD 3101.150. Structural backfill should consist of Granular A or Granular B Type II placed and compacted in accordance with OPSS.PROV 501. Heavy compaction equipment used adjacent to the walls must be restricted in accordance with OPSS.PROV 501.07.02a).

Lateral earth pressure parameters provided in Table 10-1 and Table 10-2 in the sections below are based on the assumptions that the wall is vertical and the backfill is fully drained so that there are no unbalanced hydrostatic pressures above the permanent groundwater level. If adequate drainage cannot be confirmed, the potential for buildup of hydrostatic pressures should be considered in design.

Where back slopes are horizontal, the corresponding coefficients provided in Table 10-1 and Table 10-2 should be used. For other backfill and wall geometries, Thurber will need to calculate the appropriate earth pressure coefficients once the final geometry is confirmed.

10.4.1 Static Lateral Earth Pressure

Lateral earth pressures should be computed in accordance with the CHBDC. Under drained conditions the lateral earth pressure is generally given by the following expression:

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

where:

σ_h	=	horizontal pressure on the wall at depth h (kPa)
K	=	earth pressure coefficient (see table below) (K_A for unrestrained walls, K_0 for restrained walls)
γ	=	unit weight of retained soil (see table below), use submerged unit weight below groundwater level
h	=	depth below top of fill where pressure is computed (m)
q	=	value of any surcharge (kPa)

A lateral earth pressure due to backfill compaction should be added to the calculated lateral earth pressure in accordance with Clause 6.12.3 of the CHBDC. Typical earth pressure coefficients for OPSS Granular A and OPSS Granular B Type II backfill are shown in Table 10-1.

Table 10-1: Static Earth Pressure Coefficients

Condition	Pit Sourced OPSS Granular A	Quarry Sourced OPSS Granular A	Quarry Sourced OPSS Granular B Type II
	$\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	$\phi = 40^\circ, \gamma = 22.8 \text{ kN/m}^3$	$\phi = 42^\circ, \gamma = 22.8 \text{ kN/m}^3$
Coefficient of at Rest Earth Pressure, K_0 (Restrained Wall)	0.43	0.36	0.33
Coefficient of Active Earth Pressure, K_A (Unrestrained Wall)	0.27	0.22	0.20
Coefficient of Passive Earth Pressure, K_P (Movement toward soil)	3.7	4.6	5.0

The parameters in Table 10-1 correspond to full mobilization of active and passive earth pressures and require certain relative movements between the wall and adjacent soil to produce these conditions. The movement required can be assessed from Table C6.12 of the Commentary to the CHBDC. Active earth pressures should be used for unrestrained walls. For rigid structures, at-rest horizontal earth pressures would apply for design.

10.4.2 Combined Static and Seismic Lateral Earth Pressure

In accordance with Clause 6.14 of the CHBDC, retaining structures should be designed using dynamic earth pressure coefficients that incorporate the effects of earthquake loading. The following recommendations are per Section C6.14 of the Commentary of the CHBDC which states that seismically induced lateral soil pressures may be calculated using Mononobe Okabe Method with:

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

The coefficients of horizontal earth pressure for seismic loading presented in Table 10-2 may be used for vertical walls. The provided earth pressure coefficients are based on a Seismic Site Class D. Please see Section 8.3 for the respective PGA and F(PGA) values.

Table 10-2: Combined Static and Seismic Earth Pressure Coefficients – Site Class D (2,475-year)

Condition	Pit Sourced OPSS Granular A $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$	Quarry Sourced OPSS Granular A $\phi = 40^\circ, \gamma = 22.8 \text{ kN/m}^3$	Quarry Sourced OPSS Granular B Type II $\phi = 42^\circ, \gamma = 22.8 \text{ kN/m}^3$
Coefficient of Active Earth Pressure, K_{AE} (Restrained Wall)	0.44	0.37	0.34
Coefficient of Active Earth Pressure, K_{AE} (Unrestrained Wall)	0.35	0.28	0.26

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

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

where:

σ_{hAE}	=	combined static and seismic lateral earth pressure on wall at depth d (kPa)
d	=	depth below the top of the wall where pressure is computed (m)
K	=	static earth pressure coefficient (K_A for unrestrained walls, K_o for restrained walls)
γ	=	unit weight of retained soil, adjusted below water level
K_{AE}	=	combined static and seismic earth pressure coefficient
H	=	total height of the wall (m)

10.5 Frost Penetration Depth

The depth of frost penetration at this site is estimated to be 1.9 m (as per OPSD 3090.101); shallow foundations, if any, should be founded at or below this depth or provided with equivalent insulation. Closed-bottom box culverts are not typically provided with frost protection. The earth cover should be measured perpendicular to the ground surface. Thermally equivalent frost protection could be in the form of insulation provided it is placed *above* the high-water level. It should be noted that open graded materials, such as rock protection, do not have the same thermal protection as soils.

Please also refer to the pavement design report for frost taper recommendations for the pavement.



10.6 Cement Type and Corrosion Potential

Chemical analysis for determination of pH, water soluble sulphate, sulphides, chloride concentrations, resistivity and electrical conductivity was carried out on samples of the native materials. The analysis results are summarized in Section 5.8 and a copy of the test results is provided in Appendix C.

The pH, resistivity, and chloride concentration provide a preliminary indication of the degree of corrosiveness of the sub-surface environment. The test results provided in Section 5.8 were compared with Table 3.2 of the MTO Gravity Pipe Design Guideline and generally indicate a moderate corrosive environment. The test results provided in Section 5.8 may be used to aid in the selection of coatings and corrosion protection systems for buried steel objects.

The concentration of soluble sulphate provides an indication of the degree of sulphate attack that is expected for concrete in contact with the soil and groundwater at the site. The sulphate results provided in Section 5.8 were compared with Table 3 of Canadian Standards Association Standards A23.1-19 (CSA A23.1) and indicate a less than moderate degree of sulphate attack potential on concrete structures at this site.

The corrosive effects of road de-icing salts should also be considered.

10.7 Embankments

Embankments shall be constructed in accordance with OPSS.PROV 206. It is recommended that local marine clay not be used as embankment fill.

10.7.1 Eastbound Embankment Reinstatement

The existing highway embankment side slopes are inclined at approximately 1.9H:1V on the north side and 2.3H:1V on the south side. The existing slopes did not show any visible signs of global instability at the time of the investigation.

It is understood that no grade raise or embankment widening is anticipated along the Highway 17 alignment.

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

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

10.7.2 Embankment Stability

Eastbound – Culvert 26

As part of the current report, embankment stability has been assessed perpendicular to the highway alignment for the reinstatement of the eastbound embankment near Station 13+227. The slope stability analyses were carried out using GeoStudio 2024 Slope/W software for limit equilibrium analysis. Input parameters, soil model and groundwater conditions for the analysis are based on the in situ testing and the results of laboratory testing and are shown on the stability analyses outputs provided in Appendix G. The following additional parameters and assumptions were used in the analysis:

- The soil stratigraphy is based on the nearest boreholes.
- Maximum fill heights of 8.8 m for the eastbound embankment.
- Mid-height benches 2 m wide are included in the cross-section for earth/granular embankments 8 m or more in height.
- Eastbound embankment reinstatement with slopes of 2H:1V and Select Subgrade Material (SSM)/Granular B Type I fill.
- A site adjusted PGA value for ground motions with a return period of at least 475 years of 0.049 g, equal to ½ of the site adjusted PGA value (0.098 g), was used for seismic analysis, as per Sections 4.4.3.3 and 6.14.2.3 of the CHBDC and outlined in Section 8.3.
- A traffic surcharge of 17 kPa has been applied as a temporary load.

Copies of the output from the stability analyses are provided in Appendix G. Each output figure shows the slope geometry, groundwater conditions, soil stratigraphy and soil strength parameters utilized in the analysis. The stability analyses generated the following factor of safety values for the eastbound embankment design:

Table 10-3: Slope Stability Analysis Results for Eastbound Embankment, Sta. 13+227

Condition	Case	Factor of Safety
		2H:1V [SSM/Granular B I]
Temporary (traffic loading)	Short Term (Undrained)	1.5 (Fig G1-1)
Permanent (no traffic loading)	Long Term (Drained)	1.5 (Fig G2-2)
Temporary (includes seismic)	Pseudo-Static Seismic (Undrained)	1.3 (Fig G3-3)

The geotechnical resistance factors provided in Table 6.2 of the CHBDC for embankment fills with a typical degree of understanding and a consequence factor (Ψ) of 1.0 generates minimum target Factors of Safety of 1.5 and 1.3 for permanent and temporary conditions, respectively. All the static results presented in Table 10-3 meet or exceed the target Factors of Safety.

Table 6.3 in Section 6.14.4.1 of the CHBDC indicates a minimum seismic resistance factor of 0.95 for force-based design and 1.0 for performance-based design. Based on these values and consequence factor (Ψ) of 1.0, a target Factor of Safety of 1.1 is considered appropriate for the pseudo-static seismic analysis. However, it is noted that some displacement of the embankment can occur where the pseudo-static Factor of Safety is less than 1.3. The pseudo-static results, presented in Table 10-3 above, meet the target Factors of Safety for seismic design.

Westbound - Culvert 26N

As noted in Section 7.1 above, a Foundation Investigation and Design Report was previously prepared for several proposed high embankment fills for the overall Highway 17 twinning assignment as documented in Geocres Report 31F-235. The current site is located within High Fill Area N which encompasses the new westbound alignment from 13+100 to 13+275, McNab Township. Stability analyses were completed for the new westbound embankment and presented in that report. The analyses assessed a maximum embankment height of 9.8 m which will occur at Station 13+175. All the static and pseudo-static cases generated acceptable factors of safety.

It was recommended that the new embankment should be constructed with side slopes of 2H:1V (or flatter) if constructed using Granular B Type I or Select Subgrade Material (SSM) meeting the requirement of OPSS.PROV 1010. Alternatively, the embankments could be constructed of rock fill with slopes at 1.25H:1V. Further, mid-height berms comprising 2 m wide benches should be incorporated along the length of embankments with heights at or exceeding 8 m of granular fill. Similarly for rock fill embankments, mid-height berms comprising 2 m wide benches should be incorporated along the length of embankments with heights at or exceeding 10 m.

10.7.3 Embankment Settlement

Embankments must be overbuilt to compensate for the estimated settlements.

It is noted that the addition of a widened platform to accommodate future grade raises has not been included in the design assumptions. Similarly, the placement of slope flattening material on rock fill slopes has not been included in the analyses. Inclusion of these modifications to the cross-sections will affect the settlement magnitude presented herein.

Eastbound – Culvert 26

The reinstated eastbound embankment will have a similar height to the existing. The proposed culvert opening is greater than the existing, thus, the construction represents a net unloading. No additional settlement is expected along the existing alignment. However, as the underlying soils are anticipated to behave elastically, rebound should be anticipated as the existing fill is removed to install the replacement culvert. The rebound will subsequently resettle once the excavation is backfilled which would affect the Culvert 26 replacement. The estimated settlement of soils underlying the eastbound embankment reinstatement will likely exceed the typical SLS limit of 25 mm for a structural foundation. It is recommended that Culvert 26 be designed to accommodate the anticipated movement either by oversizing the opening or by including a camber. The amount of rebound and settlement should be determined during detailed design based on the excavation



plans selected by the contractor as well as the ultimate cross-section of the backfilled embankment (current cross-section includes three lanes which could be reduced to two). It is also noted that shallow bedrock was encountered in a couple of boreholes at this site; therefore, it is anticipated that differential settlement may occur. This must also be considered during detailed design of the culvert camber.

If the existing culvert is to be decommissioned by filling with grout or removed and backfilled, it is estimated that this would induce further settlement of less than 10 mm beneath the existing culvert alignment as a result of the increased load imposed by the grout/fill. Settlement should be reviewed if the embankment is widened or reinstated to design grades greater than the existing grades.

Self-settlement of the 8.8 m high embankment required to reinstate the eastbound lanes after installation of Culvert 26 will also occur. For an embankment constructed of compacted SSM material, approximately 45 mm of self settlement will occur with the majority of that complete during construction. It is recommended that final grading of the pavement base layer and placement of asphalt be delayed for six months for the eastbound embankment reinstatement.

Settlement of the eastbound embankment due to the construction of the new westbound embankment is expected to range from approximately 15 mm at the existing north toe of slope of the eastbound embankment to less than 5 mm below the existing north edge of pavement.

Westbound - Culvert 26N

Settlement of the proposed embankment to support the new westbound lanes was assessed as part of Geocres Report 31F-235. The current site is located within High Fill Area N which encompasses the new westbound alignment from 13+100 to 13+275, McNab Township. It is anticipated that approximately 1.0 m of peat and otherwise unacceptable materials will need to be removed from beneath the new westbound embankment and that this will be achieved working in the wet. The 1.0 m deep excavation would then be backfilled by end-dumping rock fill to above the water level. Above the water level the embankment would be constructed with compacted rock fill or compacted granular fill. Please refer to the previous report for details on the soil parameters used in the settlement analyses. The calculated settlements for High Fill Area N are presented in the tables below.

Table 10-4: Predicted Settlement of Underlying Soil

Site	Height of Embankment (m)	Thickness of Compressible Clay (m)	Cumulative Settlement (Rock Fill/SSM Fill, mm)				
			3 Months	6 Months	12 Months	24 Months	20 Years
N	9.8	0	110/130	110/130	110/130	110/130	110/130

The estimated settlement of soils underlying the new westbound embankment exceeds the typical SLS limit of 25 mm for a structural foundation. In this case the settlement is elastic and will occur as the embankment is constructed. It is recommended that Culvert 26N be designed to accommodate this additional movement either by oversizing the opening or by including a camber. It is noted that shallow bedrock was encountered in a couple of boreholes at this site;

therefore, it is anticipated that differential settlement may occur. This must be considered during detailed design of the culvert camber.

Table 10-5: Predicted Embankment Fill Compression

Site	Fill Height (m)	Compression (mm)	
		Compacted Granular Fill Embankment	Compacted Rock Fill Embankment
N	9.4 + 1.0 ^(a)	65 ^(b)	160 ^(b)

Notes: (a) Estimated depth of end-dumped rock fill required.

(b) Includes compression of end-dumped rock fill below water level.

The magnitude of the self-compression in an embankment constructed with granular materials is in the order of 0.5% of the embankment height and is expected to occur within 1 year following fill placement with 90% occurring in the first six months. The magnitude of the embankment compression in an embankment constructed with rock fill is in the order of 1.5% of the embankment height where compacted during placement or 2.0% of the embankment height where end dumped and is expected to occur within 1 year following fill placement (with 90% of this value occurring in the first six months).

The total embankment settlement at Site N exceeds MTO guidelines for post construction settlement. It is recommended that final grading of the pavement base layer and placement of asphalt be delayed for six months for the westbound embankment construction. Note that a settlement monitoring program should be carried out to confirm the duration of the delay.

11 CONSTRUCTION CONSIDERATIONS

11.1 Temporary Excavations

All temporary excavation must be conducted in accordance with the requirements of the Occupational Health & Safety Act & Regulations (OHSA) for Construction Projects. The peat may be classified as a Type 4 soil. The native silt sand and sandy silt may be classified as Type 3 soils and the glacial till materials as Type 2 soil. **Side slopes for excavations through more than one soil type must be entirely based on the highest soil type number.**

Excavation should occur in a dewatered environment (see Section 11.3). Excavations must be planned and carried out in a manner that does not impact on the stability of existing roadway. The temporary cut slopes may have to be protected from precipitation and runoff to avoid surficial instabilities. The duration of temporary open excavations and cut slopes should be minimized to reduce the likelihood of causing instability concerns. Embankment and cut slope stability is the responsibility of the Contractor.

Excavation should be carried out in accordance OPSS.PROV 902, OPSS.PROV 421, and OPSS.PROV 422. The management and disposal of excess material shall be in accordance with



OPSS.PROV 180. Excavations will extend through existing fills and into the underlying native soil deposits.

Selection of the equipment and methodology to excavate and prepare the founding surface is the responsibility of the Contractor. Material stockpiling is a temporary construction measure, and the associated stability implications are the responsibility of the Contractor. The selection and placement of construction equipment (such as cranes) and construction of temporary construction access roads are also the Contractor's responsibility. Placement of the crane or temporary stockpiling must not destabilize the embankment.

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

11.2 Temporary Protection Systems

Temporary Protection Systems (TPS) could be used for excavation support or groundwater control. They must be implemented in accordance with OPSS.PROV 539. Performance Level 2 (maximum 25 mm horizontal deflection) is considered appropriate where the protection supports an existing roadway. More stringent performance levels may be required if the protection system is intended to support existing structures or utilities. The pressure distribution acting on the shoring system is a function of the construction sequence and the relative flexibility of the wall, and these factors must be considered when designing the shoring system.

It will be difficult to drive sheet piles at this site due to the presence of rockfill, cobbles and boulders in the till and shallow sloping bedrock. In Boreholes SC26-1 and SC26-4 the bedrock elevation was 151.2 m and 146.9; the bedrock surface appears to slope down from the eastbound culvert inlet to the westbound culvert outlet. Suggested wording for Contract Provisions concerning obstructions and sloping bedrock are provided in Appendix H. Drilled in soldier piles with lagging is considered suitable at this site; however, the selection and design of roadway protection is the responsibility of the Contractor. All protection systems should be designed by a licensed Professional Engineer experienced in such designs and retained by the Contractor. The design of the roadway protection system must incorporate traffic loading and surcharge loading due to construction equipment and operations. An anchoring and/or internal bracing system may need to be incorporated into the temporary protection design to resist lateral earth pressure loadings.

The lateral earth pressure coefficients and undrained strengths for the existing soils are given in Table 11-1 for a vertical wall and a horizontal backslope. Unit weights provided herein are to be adjusted for applications below the groundwater level. Unbalanced hydrostatic pressures should be considered in the design of the protection systems.

Table 11-1: Static Earth Pressure Coefficients for Existing Soils

Material	Unit Weight ^(*) (kN/m ³)	K _A	K _P	K ₀
Existing Granular Fills	20	0.33	3.0	0.50
Existing Rockfill	20	0.20	5.0	0.33
Native Silty Sand to Sandy Silt	19	0.33	3.0	0.50
Native Sand to Silty Sand to Gravel (Glacial Till)	21	0.27	3.7	0.43

Note: () to be adjusted when below water level*

It is recommended that the protection systems installed within 3 m from the edges of the culvert should be left in place and cut off in accordance with OPSS.PROV 539.

11.3 Surface and Groundwater Control

Culvert subgrade preparation and placement and compaction of granular bedding/pads and culvert placement must be carried out in the dry. The Contractor must control groundwater, perched groundwater and surface water flow at the site with a flow passage system and a dewatering system to permit construction in a dry and stable excavation.

The temporary flow diversion pipe should be placed outside the construction area. If the replacement culvert is installed on a new alignment the existing culvert could be used for flow diversion until the new culvert is completed. The design of flow passage systems is the responsibility of the Contractor. Given the site conditions and anticipated works, the Designer Fill-In (Note 2) in SP 517F01 Table 1 for flow passage systems should be “No; the design Engineer and design-checking Engineer do not need a minimum of 5 years of experience in designing similar flow passage systems.

The design of dewatering systems is the responsibility of the Contractor. The Contract Documents must alert the Contractor to this responsibility and to design the system in accordance with SP 517F01 which amends OPSS.PROV 517. The contractor's design should include an assessment of any adverse effects the dewatering method, construction layout and staging may have on adjacent structures, utilities and facilities. Given the site conditions (potential for base disturbance with groundwater flow through silty sand/sandy silt) and anticipated works (excavating to approximately 2 m below groundwater level), the Designer Fill-In (Note 2) in SP 517F01 Table 1 should be “Yes” for dewatering systems; the design Engineer and design-checking Engineer need a minimum of 5 years of experience in designing similar dewatering systems. A preconstruction survey is not recommended; thus, Designer Fill-In Note 4 in this SP should be “N/A”. Based on the groundwater elevation at the time of the investigation, it is anticipated that the site will require dewatering to lower the groundwater to below the final excavation or footing level; Note 5 of SP 517F01 Table 1 should be a minimum of 0.5 m below the underside of the planned excavation base prior to each stage of excavation.



The water level will fluctuate and the minimum design groundwater elevation for the site at the time of the excavation should be no lower than the highwater level in the creek generated by the return period flow estimates defined in SP 517F01.

The dewatering plan should be coordinated with the TPS design. It is anticipated that sump pumps will likely be sufficient to extract water from the excavation for the culverts. Pumping from within a sandbag cofferdam system is one option. Pumping will be needed to control inflow such that the granular bedding and culverts can be placed and backfilled in a dry stable environment. More than one pump may be required.

Further assessment of dewatering requirements and the need for registration on the Environmental Activity and Sector Registry (EASR) or a Permit to take Water (PTTW) should be carried out by specialists experienced in this field.

Please refer to Hydrogeological Investigation and Design Report for additional discussion on dewatering with respect to this assignment.

11.4 Erosion and Scour Control

The Contractor should provide silt fences and erosion control blankets as per OPSS.PROV 805 and OPSD 219.110 throughout the duration of construction to prevent transport of silt/sediment.

Particle size analysis on samples of the existing native materials indicate that the soils have a low to medium potential for soil erodibility (Wischmeier Nomograph factor, K).

Slope protection and drainage measures will be required to ensure the long-term surficial stability of the new embankment slopes. A vegetation cover should be established on exposed earth surfaces to protect against surficial erosion in general accordance with OPSS.PROV 803 and OPSS.PROV 804. Slope vegetation should be established as soon as possible after completion of construction in order to limit surficial erosion and water should be prevented from running down an unprotected earth and granular slope.

Scour and erosion protection must be provided for the culvert inlet and outlet areas. Effective scour and erosion protection should be provided along the waterline and ditches. Design of the erosion protection measures must consider hydrologic and hydraulic factors and shall be carried out by specialists experienced in this field. Typically, rock protection should be provided over all earth surfaces subjected to flowing water in accordance with OPSS.PROV 511. Treatment at the outlet should be in accordance with OPSD 810.010.

Given the slope proposed for Culvert 26N and to minimize the potential for piping and erosion around the inlet of the new culvert, a clay seal is recommended. The clay seal must extend to approximately 300 mm above the high water level and laterally for the width of the granular material, and have a minimum thickness of 500 mm. The material requirements should be in



accordance with OPSS.PROV 1205. A geosynthetic clay liner could be considered for use as a clay seal.

Liaison between the Foundations Consultant, Structural Engineer and Hydraulic/Drainage Engineer will be required in design to ensure that scour protection, if required, is adequately addressed.

12 DESIGN AND CONSTRUCTION CONCERNS

The preliminary recommendations presented herein must be reassessed once the type, location, elevation and orientation of the works are established.

The seismic hazard data considered for the preliminary design recommendations provided in this report were obtained from the fifth-generation seismic model developed by the Geological Survey of Canada (GSC). Additional seismic analyses will be required to reflect the reference seismic hazard available at the time of detailed design.

The DB Contractor must review the existing factual information and determine the extent of additional field investigations and laboratory testing required to support the foundation design of the proposed works. It is noted that preliminary drawings for the culverts are not available at the time of writing. The preliminary recommendations provided herein will need to be re-evaluated once the culvert invert elevations are confirmed.

The planned construction methodology includes open cut excavations for the installation of foundation elements of new culverts. Potential construction concerns may include, but are not necessarily limited to:

- Construction will extend below the water level in the creek. An adequate and effective surface water management and dewatering plan must be implemented to construct the foundations in the dry.
- Control of groundwater seepage during excavation.
- The Contractor's selection of construction equipment and methodology must include assessment of the capability of the existing soils to support the proposed construction equipment and supplies.
- The bedrock elevation is variable across the site. Sloping bedrock may be encountered, and bedrock excavation may be required. A Notice to Contractor has been included in Appendix H.
- Buried obstructions may be encountered during construction and will interfere with excavations and installation of temporary protection/dewatering systems. A Notice to Contractor has been included in Appendix H.
- Mitigation of the settlement induced by the new westbound embankment and reinstatement of the eastbound embankment will require culvert structures designed to accommodate the settlements.

The successful performance of the structure installations will depend largely upon good workmanship and quality control during construction. Observation of the excavation and backfilling operations will be required as per OPSS.PROV 902 during construction to confirm that the foundation recommendations are correctly implemented, and material specifications are met.

13 CLOSURE

Engineering analysis and preparation of this report was carried out by A. de Oliveira, P.Eng. The report was reviewed by Dr. F. Griffiths, P.Eng. and Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundation Projects.

Thurber Engineering Ltd.
Report Prepared By:



Anderson de Oliveira, M.A.Sc., P.Eng.
Geotechnical Engineer



Dr. Fred Griffiths, P.Eng.
Principal, Senior Geotechnical Engineer

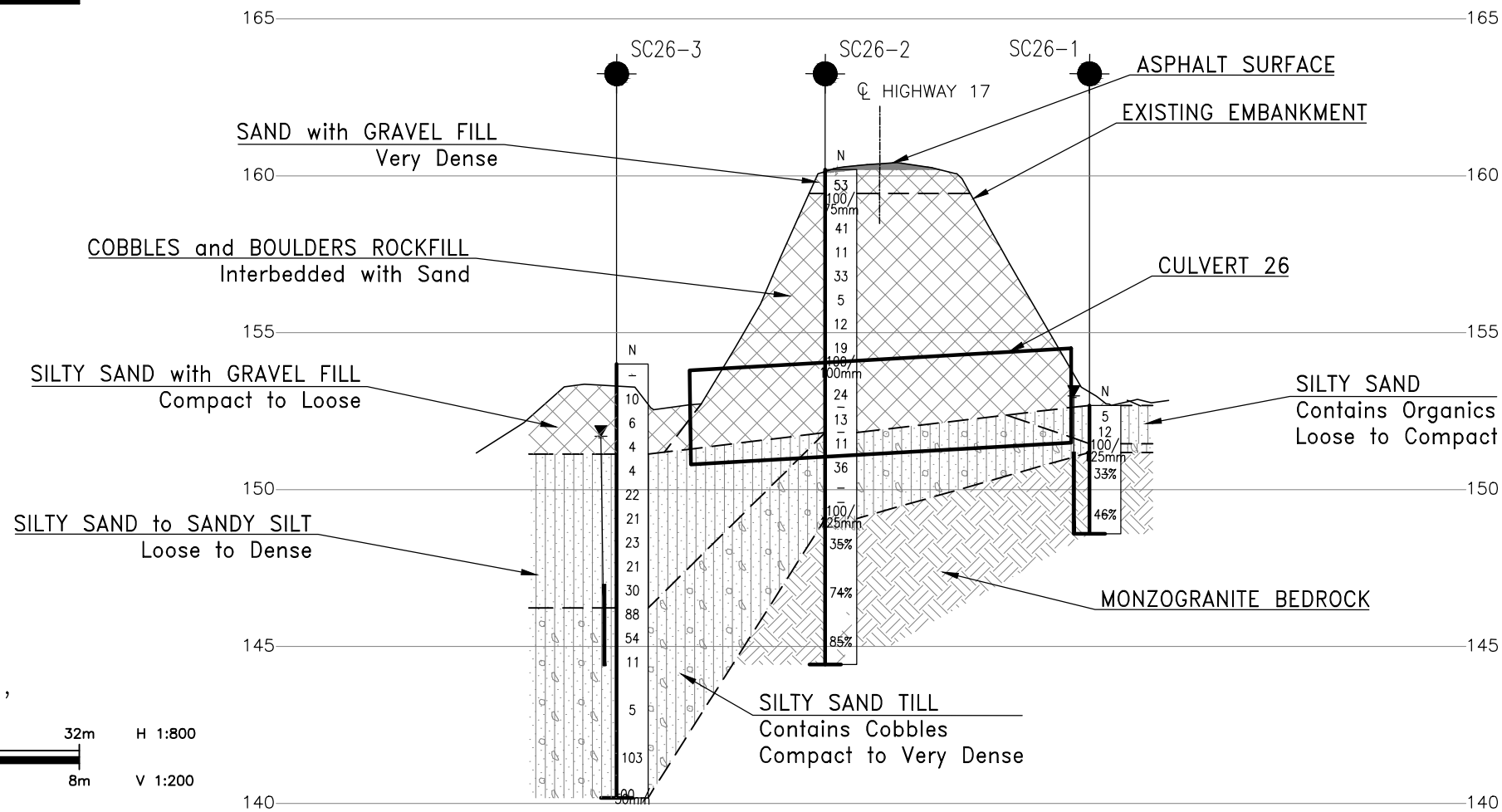
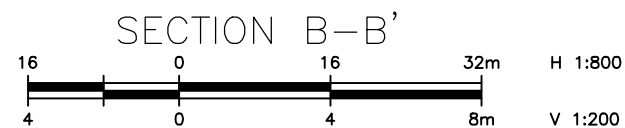
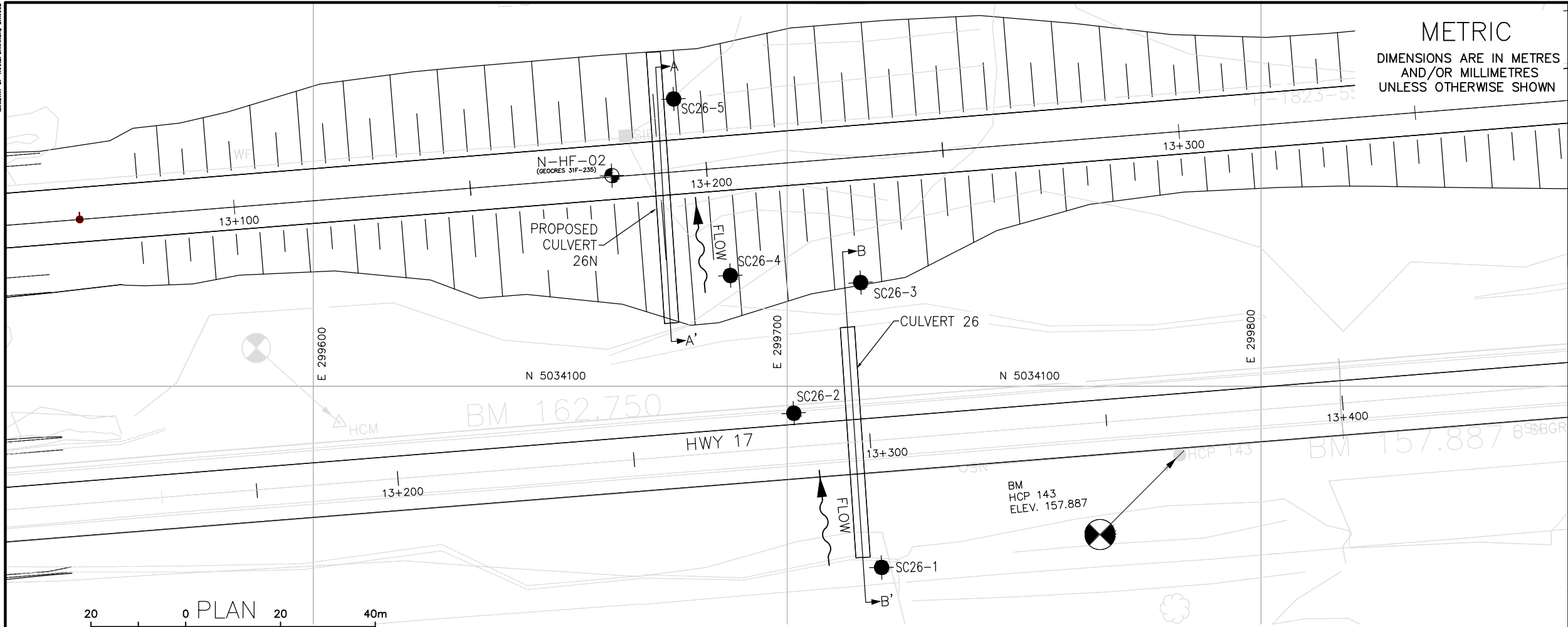


Dr. P.K. Chatterji, P.Eng.
Designated Principal Contact,
Principal, Senior Geotechnical Engineer



Appendix A.

Borehole Location Plan and Stratigraphic Drawings



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

CONT No
GWP No 4068-09-00
HIGHWAY 17 TWINNING
STATION 13+227, MCNAB TWP.
CULVERT 26/26N
BOREHOLE LOCATION PLAN AND SOIL STRATA








SHEET
1



KEYPLAN

LEGEND

	Borehole
	Historic Borehole
N	Blows /0.3m (Std Pen Test, 475J/blow)
CONE	Blows /0.3m (60° Cone, 475J/blow)
PH	Pressure, Hydraulic
	Water Level Upon Completion of Drilling
	Water Level in Monitoring Well/Piezometer
	Monitoring Well/Piezometer Screen
90%	Rock Quality Designation (RQD)
A/R	Auger Refusal

NO	ELEVATION	NORTHING	EASTING
SC26-1	152.7	5 034 061.8	299 720.0
SC26-2	160.2	5 034 094.3	299 701.4
SC26-3	154.0	5 034 121.9	299 715.5
SC26-4	153.6	5 034 124.4	299 693.5
SC26-5	151.0	5 034 160.6	299 676.1
N-HF-02	151.6	5 034 144.4	299 663.0

-NOTES-

- The boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
- This drawing is for subsurface information only. Surface details and features are for conceptual illustration.
- Coordinate system is MTM NAD 83 Zone 9.

GEOCRES No. 31F07-007

REVISIONS	DATE	BY	DESCRIPTION
DESIGN	AO	CHK	—
DRAWN	RH	CHK	FG
CODE	SITE	LOAD	DATE
STRUCT	DWG	1	NOV 2024



Appendix B.
Record of Borehole Sheets



SYMBOLS, ABBREVIATIONS AND TERMS USED ON TEST HOLE RECORDS

TERMINOLOGY DESCRIBING COMMON SOIL GENESIS

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

TERMINOLOGY DESCRIBING SOIL STRUCTURE:

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

RECOVERY:

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

N-VALUE:

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

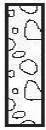
DYNAMIC CONE PENETRATION TEST (DCPT):

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



STRATA PLOT:

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



Boulders
Cobbles
Gravel



Sand



Silt



Clay



Organics



Asphalt



Concrete



Fill



Bedrock

TEXTURING CLASSIFICATION OF SOILS

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

TERMS DESCRIBING CONSISTENCY (COHESIVE SOILS ONLY)

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

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

SAMPLE TYPES

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

TERMS DESCRIBING CONSISTENCY (COHESIONLESS SOILS ONLY)

Descriptive Term	SPT "N" Value
Very Loose	Less than 4
Loose	4 – 10
Compact	10 – 30
Dense	30 – 50
Very Dense	Greater than 50

MODIFIED UNIFIED SOIL CLASSIFICATION

Major Divisions		Group Symbol	Typical Description
COARSE GRAINED SOIL	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly-graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly-graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILT AND CLAY SOILS $W_L < 35\%$	ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		OL	Organic silts and organic silty-clays of low plasticity.
	SILT AND CLAY SOILS $35\% < W_L < 50\%$	MI	Inorganic compressible fine sandy silt with clay of medium plasticity, clayey silts.
		CI	Inorganic clays of medium plasticity, silty clays.
		OI	Organic silty clays of medium plasticity.
	SILT AND CLAY SOILS $W_L > 50\%$	MH	Inorganic silts, micaceous or diatomaceous fine sandy of silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
		OH	Organic clays of high plasticity, organic silts.
HIGHLY ORGANIC SOILS		Pt	Peat and other organic soils.

Note - W_L = Liquid Limit



EXPLANATION OF ROCK LOGGING TERMS

ROCK WEATHERING CLASSIFICATION

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

TERMS

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

DISCONTINUITY SPACING

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

STRENGTH CLASSIFICATION

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

RECORD OF BOREHOLE No SC26-1

1 OF 1

METRIC

WP# 4068-09-00 LOCATION Lat: 45.446469°, Long: -76.564941° Culvert 26/26N; McNab Township; MTM z9: N 5 034 061.8 E 299 720.0 ORIGINATED BY IK
HWY 17 BOREHOLE TYPE Portable / Tricone / NW Casing / NQ Coring COMPILED BY AO
DATUM Geodetic DATE 2024.03.22 - 2024.03.22 CHECKED BY JG

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																														
152.7	Ground Surface							20	40	60	80	100																										
0.0	SILTY SAND contains organics loose to compact dark brown to brown		1	SS	5		152																															
			2	SS	12																																	
151.5			3	SS	100/																																	
1.2			4	NQ	125mm																																	
151.2	SILTY SAND (SM) , trace gravel contains cobbles and boulders very dense brown GLACIAL TILL MONZOGRAHITE BEDROCK slightly weathered to fresh jointed reddish pink to grey coarse grained strong to very strong						151																															
1.5			1	RUN	-																																	
								150																														
			2	RUN	-																																	
148.6							149																															
4.1	End of Borehole Piezometer installed: Schedule 40 PVC standpipe with 25-mm diameter and 1.5-m slotted screen. Stick-up cover installed at ground surface. Water Level Readings: <table><tr><th>DATE</th><th>DEPTH (m)</th><th>ELEV. (m)</th></tr><tr><td>2024/04/09</td><td>-0.4</td><td>153.1</td></tr><tr><td>2024/05/01</td><td>-0.4</td><td>153.1</td></tr><tr><td>2024/06/10</td><td>-0.1</td><td>152.8</td></tr><tr><td>2024/06/28</td><td>-0.3</td><td>153.0</td></tr><tr><td>2024/08/28</td><td>0.0</td><td>152.7</td></tr></table> Note: Full-weight hammer was used to advance the split-spoons.	DATE	DEPTH (m)	ELEV. (m)	2024/04/09	-0.4	153.1	2024/05/01	-0.4	153.1	2024/06/10	-0.1	152.8	2024/06/28	-0.3	153.0	2024/08/28	0.0	152.7																			
DATE	DEPTH (m)	ELEV. (m)																																				
2024/04/09	-0.4	153.1																																				
2024/05/01	-0.4	153.1																																				
2024/06/10	-0.1	152.8																																				
2024/06/28	-0.3	153.0																																				
2024/08/28	0.0	152.7																																				

DOUBLE LINE CULVERT 26 GINT LOGS.GPJ 2012TEMPLATE(MTO).GDT 12-17-24

RECORD OF BOREHOLE No SC26-2

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.446761°, Long: -76.565181° Culvert 26/26N; McNab Township; MTM z9: N 5 034 094.3 E 299 701.4 ORIGINATED BY DAP
 HWY 17 BOREHOLE TYPE CME 75 Truckmount / HSA / NW Casing / NQ Coring COMPILED BY AO
 DATUM Geodetic DATE 2024.03.12 - 2024.03.12 CHECKED BY JG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT 7 kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)				
160.2	Ground Surface							20 40 60 80 100	W P	W	W L			
0.0	ASPHALT (115 mm)							20 40 60 80 100						
0.1	SAND with gravel very dense grey FILL		1	SS	53		160						38 53 9 (SI+CL)	
159.4	COBBLES and BOULDERS interbedded with brown sand voids between larger boulders noted ROCKFILL		2	SS	100/ 75mm		159							
0.8			3	SS	41		158							
			4	SS	11		157							
			5	SS	33		156							
			6	SS	5		155							
			7	SS	12		154							
			8	SS	19		153							
			9	SS	100/ 100mm		152							
	- 200 mm boulder at a depth of 6.2 m (elev. 154.0 m)		1	NQ			151							
			10	SS	24									
			2	NQ	-									
			11	SS	13									
	- 300 mm boulder at a depth of 8.0 m (elev. 152.2 m)		3	NQ	-									
151.8	SILTY SAND (SM), trace gravel contains cobbles compact to dense grey GLACIAL TILL		12	SS	11								4 67 22 7 Non-plastic	
8.4			13	SS	36									

DOUBLE LINE CULVERT 26 GINT LOGS.GPJ 2012TEMPLATE(MTO).GDT 12-17-24

Continued Next Page

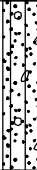

+³, ×³: Numbers refer to Sensitivity 20 15 10 5 0 5 10 15 20 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No SC26-2

2 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.446761°, Long: -76.565181°
Culvert 26/26N; McNab Township; MTM z9: N 5 034 094.3 E 299 701.4 ORIGINATED BY DAP
HWY 17 BOREHOLE TYPE CME 75 Truckmount / HSA / NW Casing / NQ Coring COMPILED BY AO
DATUM Geodetic DATE 2024.03.12 - 2024.03.12 CHECKED BY JG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							
								WATER CONTENT (%)							
	Continued From Previous Page		1	GS	-		20	40	60	80	100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	
149.1	SILTY SAND (SM) , trace gravel contains cobbles compact to dense grey GLACIAL TILL		4	NQ	-										
			14	SS	100/ 125mm										
11.1	MONZOGRANITE BEDROCK slightly weathered to fresh jointed reddish pink to grey coarse grained strong to very strong		1	RUN	-										
			2	RUN	-										
			3	RUN	-										
144.4															
15.8	End of Borehole														

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

RECORD OF BOREHOLE No SC26-3

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.447009°, Long: -76.565001° Culvert 26/26N; McNab Township; MTM z9: N 5 034 121.9 E 299 715.5 ORIGINATED BY RH
HWY 17 BOREHOLE TYPE CME 55 Trackmount / HSA / NW Casing / NQ Coring COMPILED BY AO
DATUM Geodetic DATE 2024.02.22 - 2024.02.22 CHECKED BY JG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
							WATER CONTENT (%)							
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W P W W L							
154.0	Ground Surface													
0.0	SILTY SAND with gravel compact to loose brown FILL		1	GS	-									
			2	SS	10		153							
			3	SS	6		152							
			4	SS	4									
151.1														
2.9	SILTY SAND to SANDY SILT loose to dense grey						151							
			5	SS	4									
			6	SS	22		150							
			7	SS	21		149							
			8	SS	23									
							148							
			9	SS	21									
			10	SS	30		147							
146.2														
7.8	SILTY SAND (SM), trace gravel very dense to compact grey GLACIAL TILL		11	SS	88		146							
			12	SS	54									
							145							
			13	SS	11									

Continued Next Page

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

METRIC

[illegible]

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No SC26-4

1 OF 1

METRIC

WP# 4068-09-00 LOCATION Lat: 45.447032°, Long: -76.565281° Culvert 26/26N; McNab Township; MTM z9: N 5 034 124.4 E 299 693.5 ORIGINATED BY RH
HWY 17 BOREHOLE TYPE CME 55 Trackmount / HSA / NW Casing / NQ Coring COMPILED BY AO
DATUM Geodetic DATE 2024.02.21 - 2024.02.21 CHECKED BY JG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)				
								○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT W _P W W _L				
153.6	Ground Surface						20	40	60	80	100	20	40	60					
0.0	SANDY SILT contains organics loose brown FILL		1	GS	-														
152.8																			
0.8	GRAVEL with sand and silt compact to dense brown ROCKFILL		2	SS	18														
			3	GS	-														
			4	GS	-														
150.6																			
3.0	SILTY SAND to SANDY SILT loose to dense brown to grey		5	SS	9														
			6	SS	38														
149.0																			
4.6	SILTY SAND (SM), trace gravel compact to very dense grey GLACIAL TILL		7	SS	43														
			8	SS	21														
			9	SS	66														
146.9																			
6.7	MONZOGRANITE BEDROCK slightly weathered to fresh jointed reddish pink to grey coarse grained strong to very strong		10	SS	100/ 0mm														
			1	RUN	-														
			2	RUN	-														
143.8																			
9.8	End of Borehole																		

DOUBLE LINE CULVERT 26 GINT LOGS.GPJ 2012TEMPLATE(MTO).GDT 12-17-24

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

RECORD OF BOREHOLE No SC26-5

1 OF 2

METRIC

WP# 4068-09-00 LOCATION Lat: 45.447358°, Long: -76.565504° Culvert 26/26N; McNab Township; MTM z9: N 5 034 160.6 E 299 676.1 ORIGINATED BY RH
 HWY 17 BOREHOLE TYPE CME 55 Trackmount / HSA / NW Casing / NQ Coring COMPILED BY AO
 DATUM Geodetic DATE 2024.02.20 - 2024.02.20 CHECKED BY JG

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										
151.0	Ground Surface							20	40	60	80	100						
0.0	COARSE FIBROUS PEAT very soft brown to black		1	GS	-													
150.2																		
0.8	SILTY SAND to SANDY SILT very loose to compact brown to grey		2	SS	3		150											
			3	SS	23		149											0 59 34 7 Non-plastic
			4	SS	12		148											
			5	SS	4		147											
			6	SS	4		146											0 8 73 19
			7	SS	6		145											
			8	SS	5		144											
			9	SS	6		143											1 55 38 6 Non-plastic
144.1																		
6.9	SILTY SAND to GRAVEL with sand and silt contains cobbles very dense grey GLACIAL TILL		10	SS	68		144											
			11	SS	67		143											74 19 7 (SI+CL)
142.5																		
8.5	End of Borehole Borehole terminated upon Auger Refusal Monitoring Well installed: Schedule 40 PVC standpipe with 50-mm diameter and 3.0-m slotted screen. Stick-up cover installed at ground surface.		12	SS	100/ 0mm													

Continued Next Page

+³, ×³: Numbers refer to
Sensitivity

20
15
10
5
0
(%) STRAIN AT FAILURE

DOUBLE LINE CULVERT 26 GINT LOGS.GPJ 2012TEMPLATE(MTO).GDT 12-17-24

2 OF 2

WP#	4068-09-00	LOCATION	Lat: 45.447358°, Long: -76.565504° Culvert 26/26N; McNab Township; MTM z9: N 5 034 160.6 E 299 676.1	ORIGINATED BY	RH
HWY	17	BOREHOLE TYPE	CME 55 Trackmount / HSA / NW Casing / NQ Coring	COMPILED BY	AO
DATUM	Geodetic	DATE	2024.02.20 - 2024.02.20	CHECKED BY	JG

SOIL PROFILE				SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL																													
ELEV DEPTH	DESCRIPTION		STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa					WATER CONTENT (%)																																	
									○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE					W P W W L																																	
Continued From Previous Page									20 40 60 80 100					20 40 60			kN/m ³																														
<div>Water Level Readings:</div> <table><tr><th>DATE</th><th>DEPTH (m)</th><th>ELEV. (m)</th></tr><tr><td>2024/03/12</td><td>-0.1</td><td>151.1</td></tr><tr><td>2024/03/22</td><td>-0.2</td><td>151.2</td></tr><tr><td>2024/04/09</td><td>-0.2</td><td>151.2</td></tr><tr><td>2024/05/01</td><td>-0.2</td><td>151.2</td></tr><tr><td>2024/06/10</td><td>0</td><td>151.0</td></tr><tr><td>2024/06/26</td><td>-0.2</td><td>151.2</td></tr><tr><td>2024/08/28</td><td>0.1</td><td>150.9</td></tr></table>									DATE	DEPTH (m)	ELEV. (m)	2024/03/12	-0.1	151.1	2024/03/22	-0.2	151.2	2024/04/09	-0.2	151.2	2024/05/01	-0.2	151.2	2024/06/10	0	151.0	2024/06/26	-0.2	151.2	2024/08/28	0.1	150.9															
DATE	DEPTH (m)	ELEV. (m)																																													
2024/03/12	-0.1	151.1																																													
2024/03/22	-0.2	151.2																																													
2024/04/09	-0.2	151.2																																													
2024/05/01	-0.2	151.2																																													
2024/06/10	0	151.0																																													
2024/06/26	-0.2	151.2																																													
2024/08/28	0.1	150.9																																													

DOUBLE LINE CULVERT 26 GINT LOGS.GPJ 2012TEMPLATE(MTO).GDT 12-17-24

+³, ×³: Numbers refer to Sensitivity

RECORD OF BOREHOLE No N-HF-02

1 OF 1

METRIC

WP# 4068-09-00 LOCATION Lat: 45.447212°, Long: -76.565671°
High Fills; MTM Zone 9: N 5 034 144.4 E 299 663.0 ORIGINATED BY AO
HWY 17 BOREHOLE TYPE CME 850 Trackmount / HSA COMPILED BY AO
DATUM Geodetic DATE 2020.11.17 - 2020.11.17 CHECKED BY JG

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											
151.6	Ground Surface							20	40	60	80	100							
0.0	TOPSOIL (200 mm)							20	40	60	80	100							
0.2	SANDY SILT (ML) trace organics very loose to compact yellow-brown to grey-brown		1	SS	2		151												
			2	SS	3														
			3	SS	12														
149.3																			
2.3	SAND (SW-SM) with silt and gravel compact to very dense grey to black-brown TILL		4	SS	42		149												
			5	SS	100/ 150mm														
			6	SS	20														
			7	SS	49														
			8	SS	100/ 25mm														
			9	SS	100/ 75mm														
			144.4																
			7.2	End of Borehole Spoon and auger refusal on inferred bedrock. Piezometer installation consists of 25-mm diameter Schedule 40 PVC pipe with a 1.5-m slotted screen Water Level Readings: DATE DEPTH (m) ELEV. (m) 2020/12/16 0.0 (Frozen) 151.6 2021/09/23 0.5 151.1 2021/11/11 0.5 151.1 2022/01/24 -0.1 (Frozen) 151.7															

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



Appendix C.

Laboratory Testing



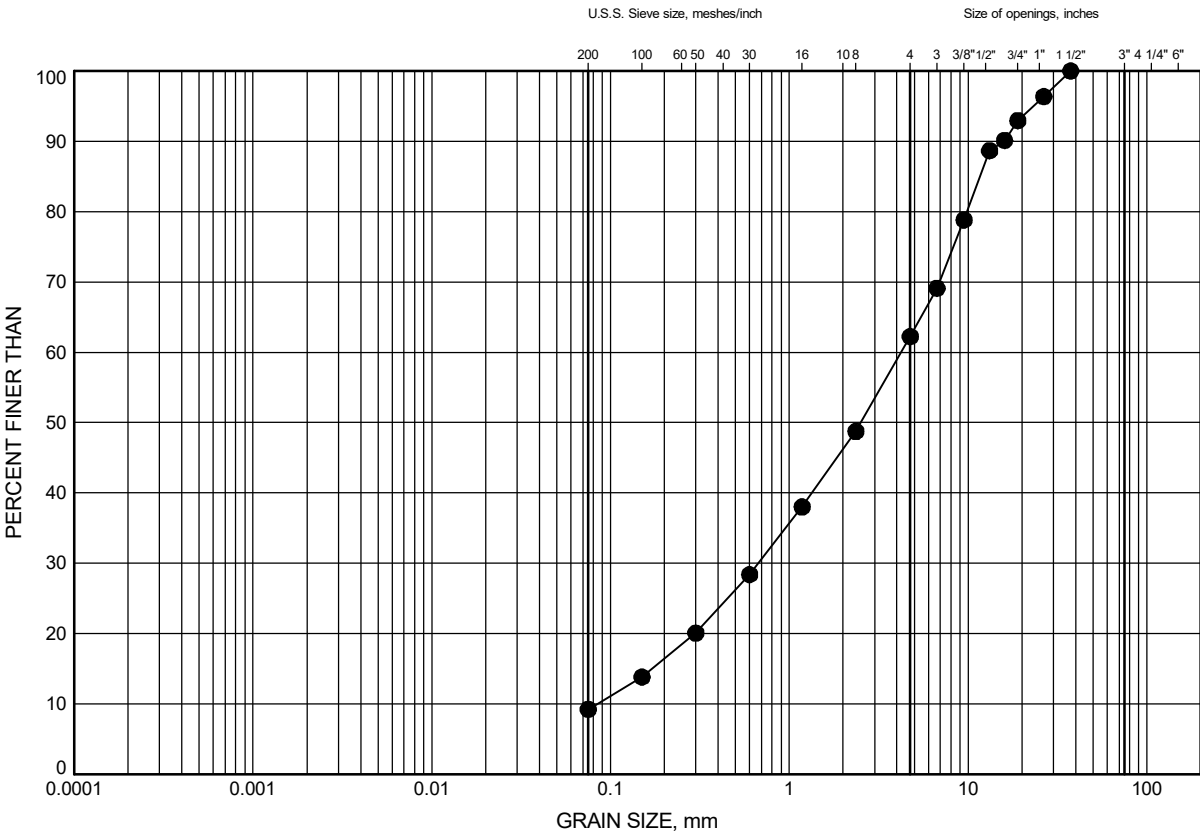
Appendix C.1
Particle Size Analysis Figures
Atterberg Limit Test Results
Unconfined Compressive Strength Testing Results
Rock Core Photos

Highway 17 Twinning, Culverts 26 and 26N

GRAIN SIZE DISTRIBUTION

FIGURE C1

FILL: Sand to Sandy Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC26-2	0.5	159.7

GRAIN SIZE DISTRIBUTION - THURBER CULVERT 26 GINT LOGS.GPJ 9-5-24

Date September 2024
GWP# 4018-E-0009



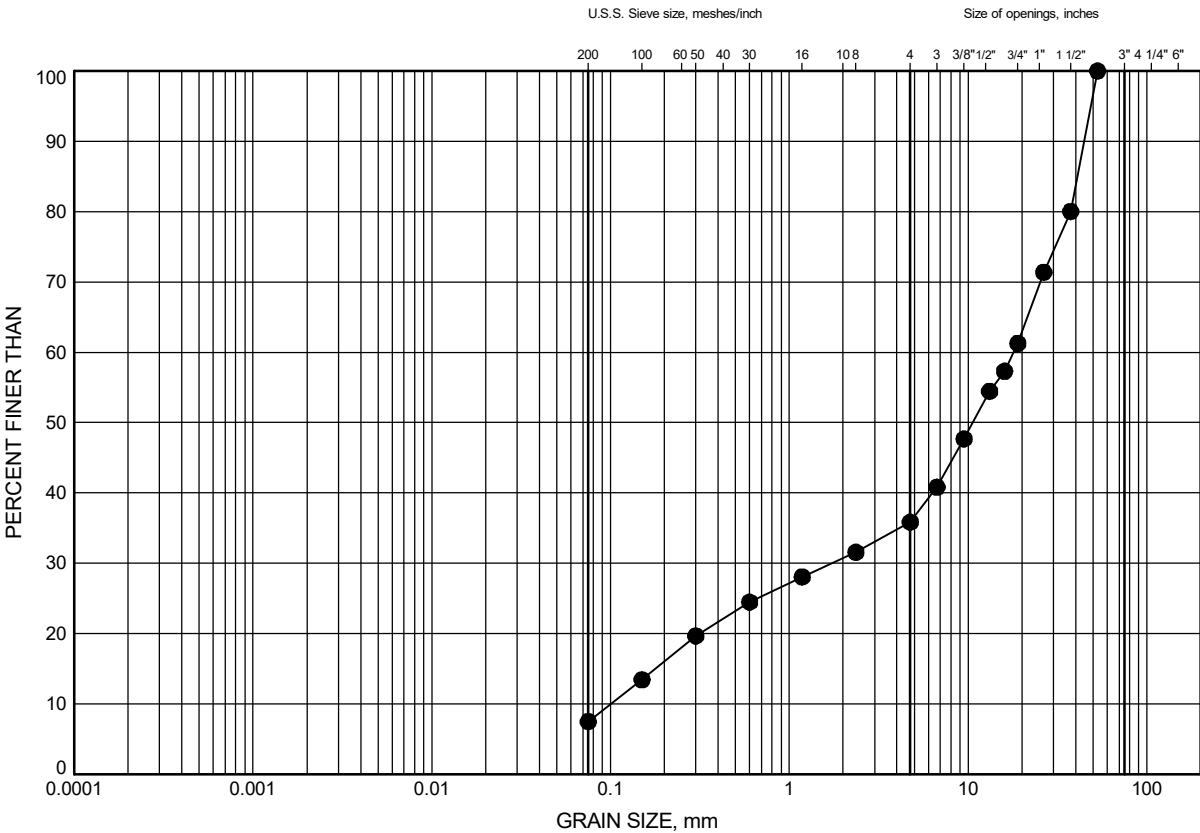
Prep'd RH
Chkd. AO

Highway 17 Twinning, Culverts 26 and 26N

GRAIN SIZE DISTRIBUTION

FIGURE C2

FILL: Gravel with Silt and Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC26-4	2.6	151.0

GRAIN SIZE DISTRIBUTION - THURBER CULVERT 26 GINT LOGS.GPJ 9-5-24

Date September 2024
GWP# 4018-E-0009



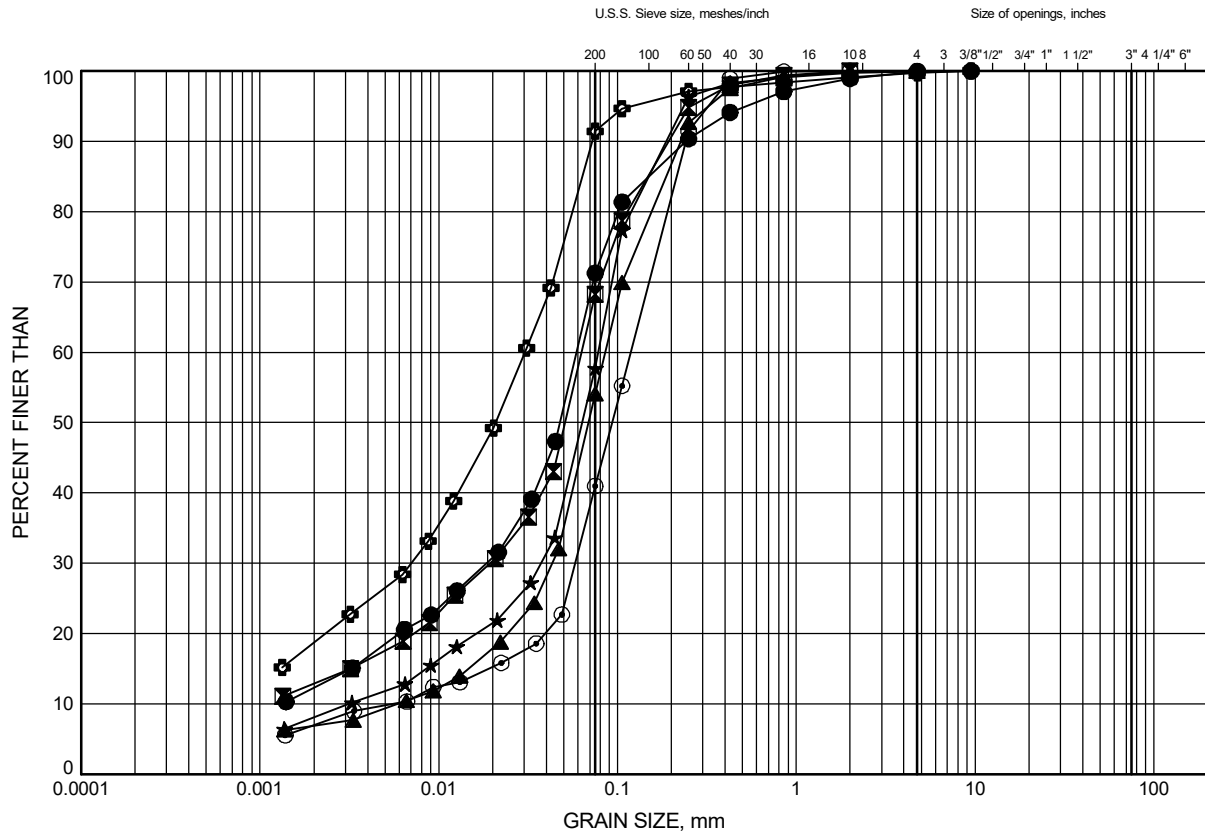
Prep'd RH
Chkd. AO

Highway 17 Twinning, Culverts 26 and 26N

GRAIN SIZE DISTRIBUTION

FIGURE C3

Silty Sand to Sandy Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	N-HF-02	1.8	149.8
⊠	SC26-3	4.1	149.9
▲	SC26-3	6.4	147.6
★	SC26-4	4.1	149.5
⊙	SC26-5	1.8	149.2
⊕	SC26-5	4.1	146.9

Date September 2024

GWP# 4018-E-0009



Prep'd RH

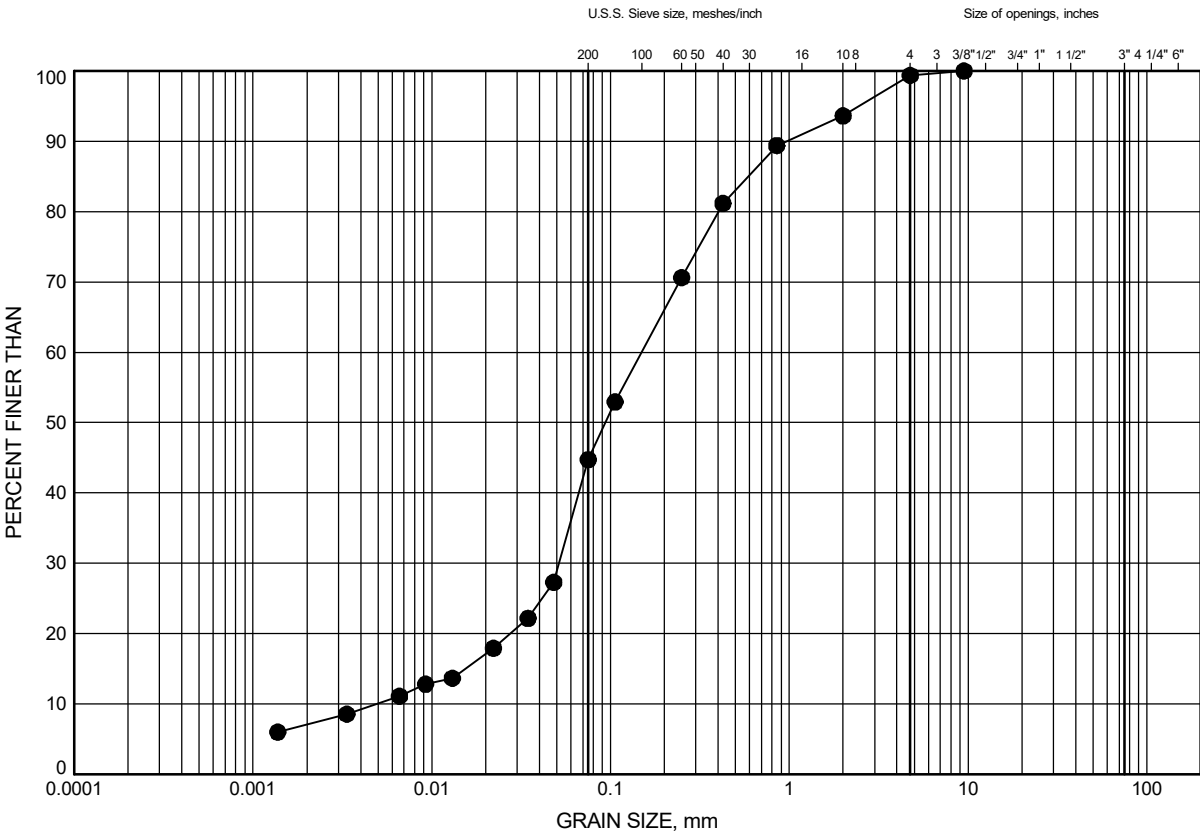
Chkd. AO

Highway 17 Twinning, Culverts 26 and 26N

GRAIN SIZE DISTRIBUTION

FIGURE C4

Silty Sand to Sandy Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC26-5	6.4	144.6

GRAIN SIZE DISTRIBUTION - THURBER CULVERT 26 GINT LOGS.GPJ 9-5-24

Date September 2024
GWP# 4018-E-0009



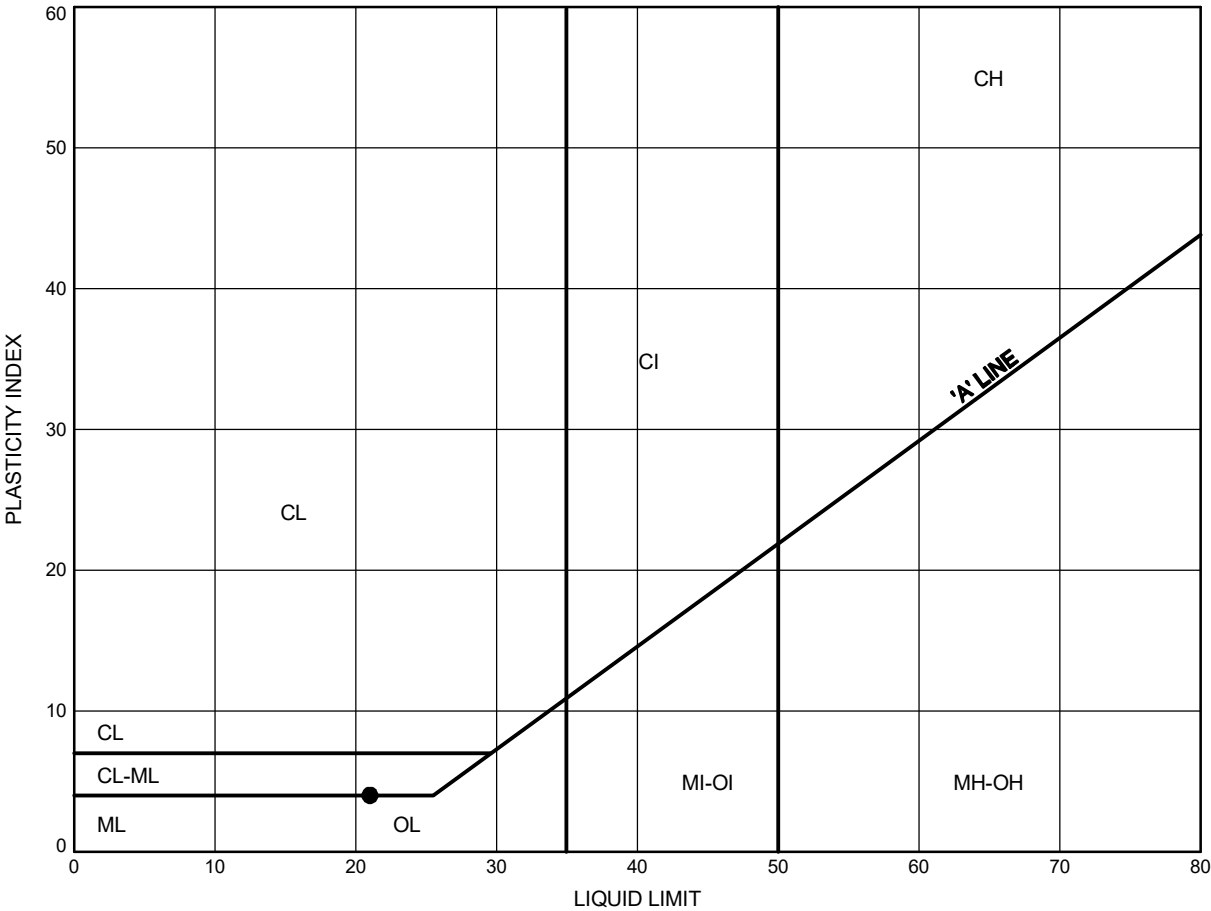
Prep'd RH
Chkd. AO

Highway 17 Twinning, Culverts 26 and 26N

ATTERBERG LIMITS TEST RESULTS

FIGURE C5

Silty Sand to Sandy Silt



LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC26-5	4.1	146.9

THURBALT CULVERT 26 GINT LOGS.GPJ 9-5-24

Date September 2024
GWP# 4018-E-0009



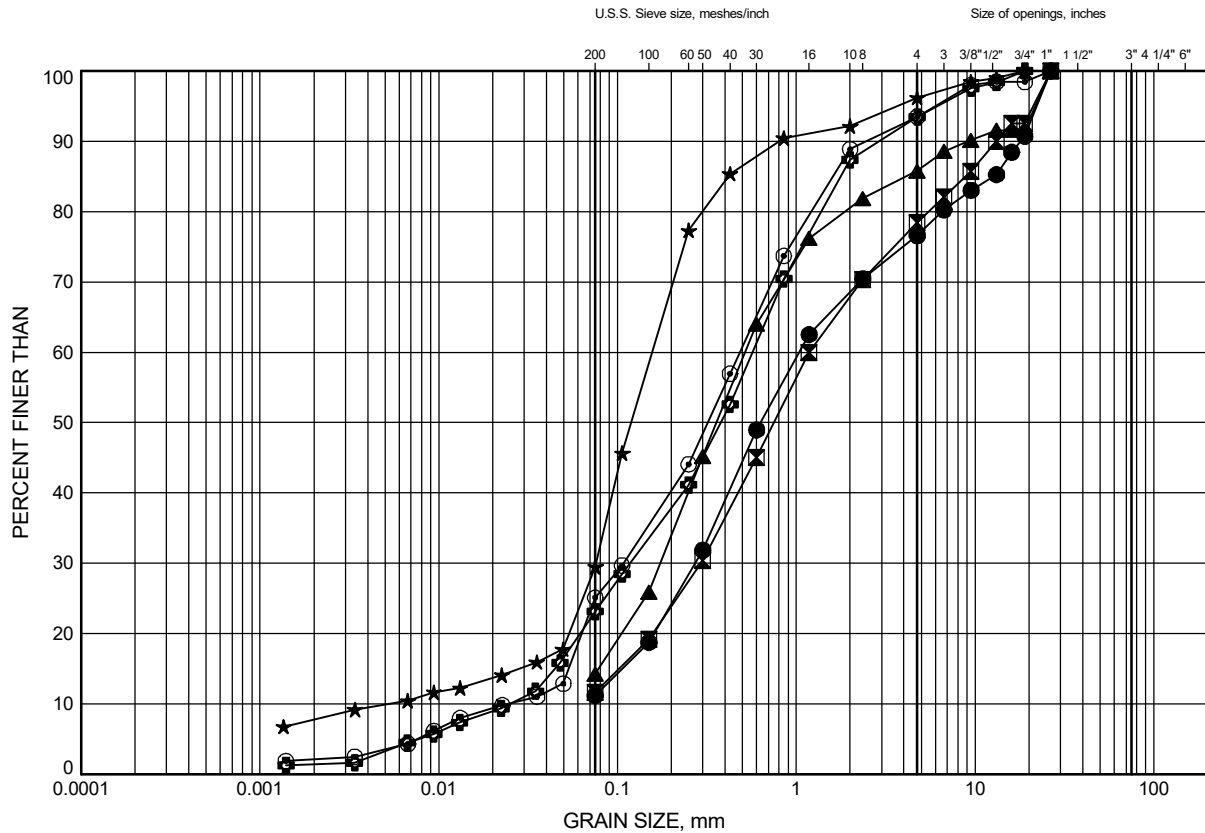
Prep'd RH
Chkd. AO

Highway 17 Twinning, Culverts 26 and 26N

GRAIN SIZE DISTRIBUTION

FIGURE C6

Sand to Silty Sand (Glacial Till)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	N-HF-02	2.6	149.0
⊠	N-HF-02	4.9	146.7
▲	SC26-1	1.3	151.4
★	SC26-2	8.7	151.5
⊙	SC26-3	8.7	145.3
⊕	SC26-3	12.5	141.5

Date September 2024

GWP# 4018-E-0009



Prep'd RH

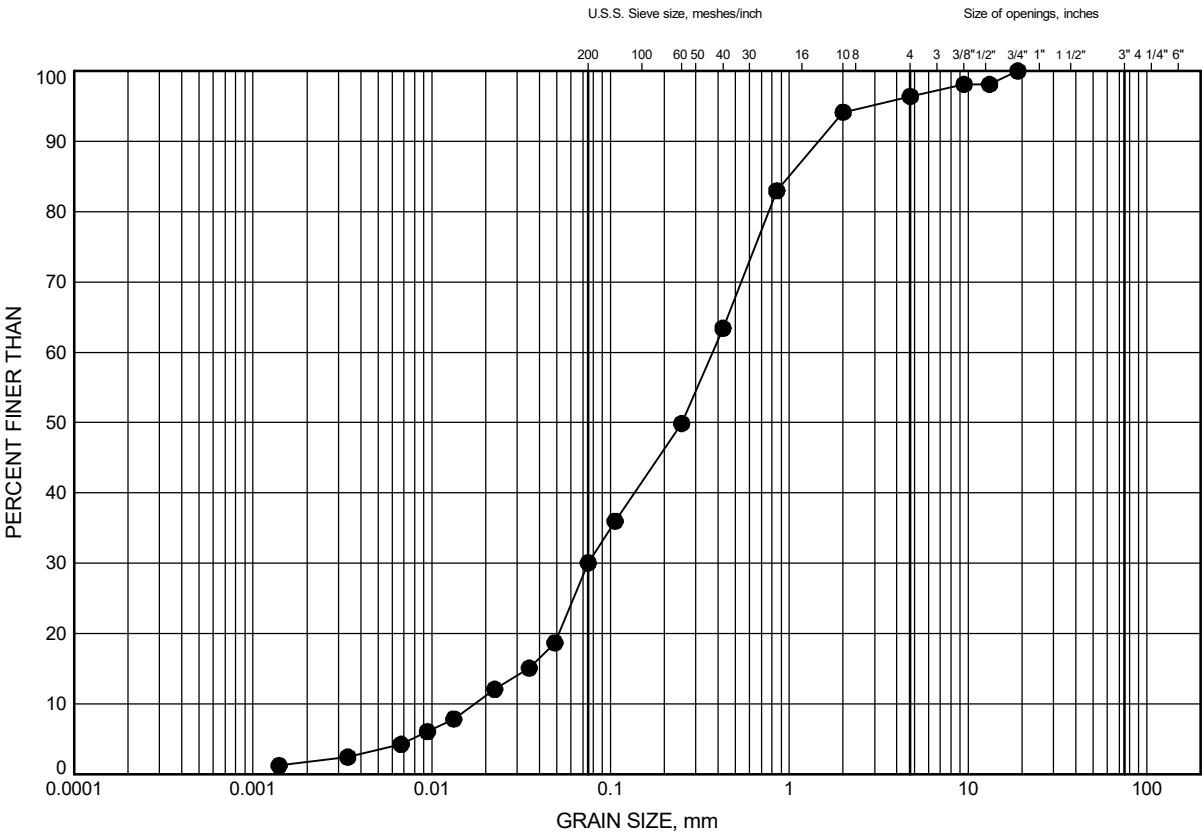
Chkd. AO

Highway 17 Twinning, Culverts 26 and 26N

GRAIN SIZE DISTRIBUTION

FIGURE C7

Sand to Silty Sand (Glacial Till)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC26-4	6.3	147.3

GRAIN SIZE DISTRIBUTION - THURBER CULVERT 26 GINT LOGS.GPJ 9-5-24

Date September 2024
GWP# 4018-E-0009



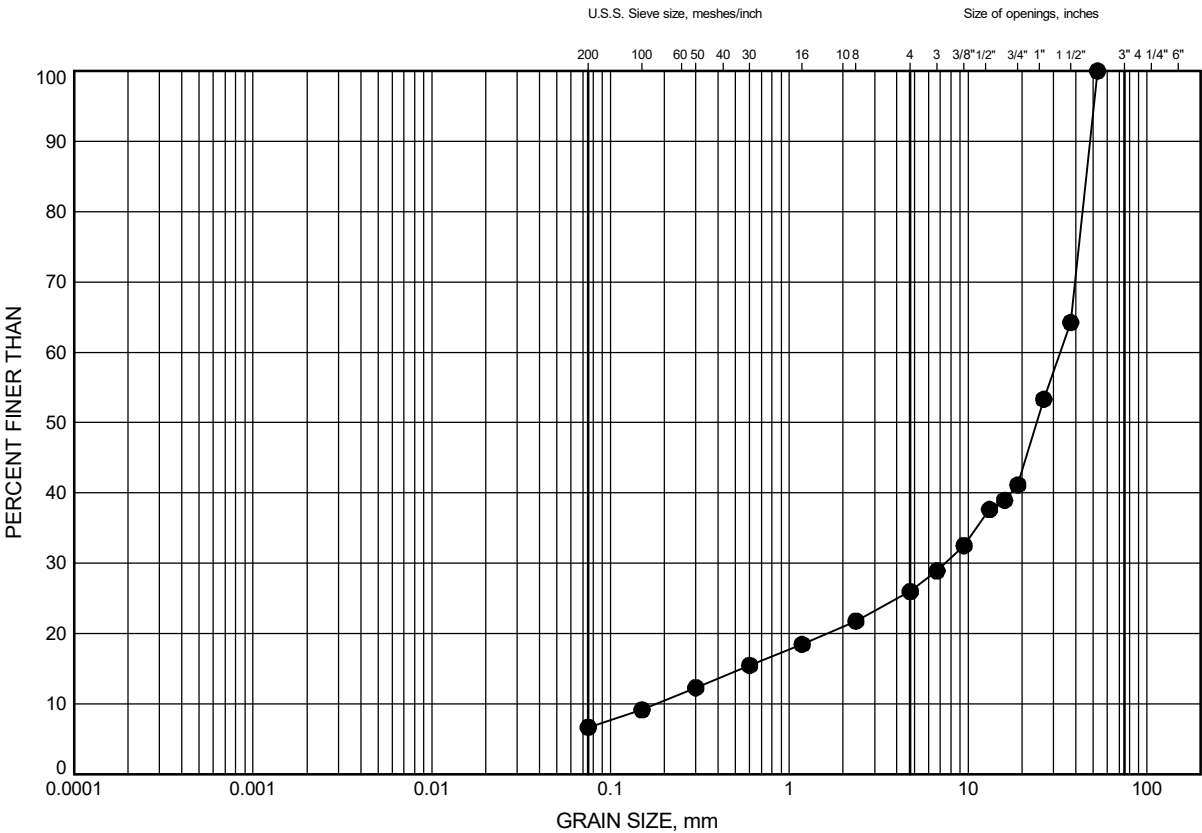
Prep'd RH
Chkd. AO

Highway 17 Twinning, Culverts 26 and 26N

GRAIN SIZE DISTRIBUTION

FIGURE C8

Gravel with Silt and Sand (Glacial Till)



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	SC26-5	7.9	143.1

GRAIN SIZE DISTRIBUTION - THURBER CULVERT 26 GINT LOGS.GPJ 9-5-24

Date September 2024
GWP# 4018-E-0009



Prep'd RH
Chkd. AO

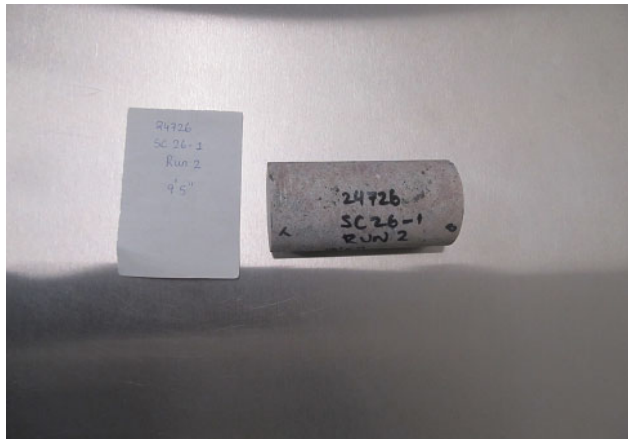
UNCONFINED COMPRESSION TEST REPORT

ASTM D7012-14

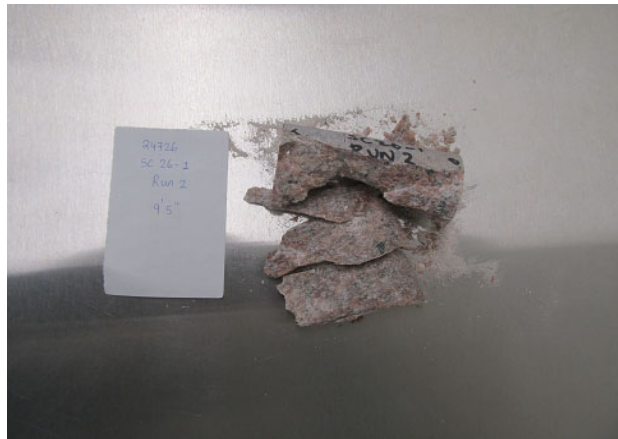
CLIENT:	Thurber Engineering (Ottawa)	FILE NUMBER:	24726
PROJECT NAME:	Highway 17 Twinning - Renfrew	REPORT DATE:	2-Aug-24
BOREHOLE No.:	SC26-1	TEST DATE:	9-May-24
SAMPLE No.:	Run 2		
SAMPLE DEPTH:	2.87 m		
DESCRIPTION:	Granite		

Avg. Height (cm):	10.0	Weight (g):	525.0
Avg. Diameter (cm):	5.0	Wet Density (kg/m ³):	2,674
H. to Dia. Ratio**:	2:1	Dry Density (kg/m ³):	2,674
Cross Sectional Area (cm ²):	19.63	Moisture Content* (%):	N/A
Sample Volume (cm ³):	196.35		

ORIGINAL SPECIMEN



FRACTURED SPECIMEN



AVG. RATE OF STRAIN TO FAILURE:	0.250 MPa/s
MAXIMUM COMPRESSIVE LOAD:	248.3 kN
UNCONFINED COMPRESSIVE STRENGTH:	126.5 MPa

Note: * The moisture content was obtained before the test.
 ** Dimensions of Specimen conform to ASTM D 4543-04.

TEST DONE BY: GF
 REVIEWED BY: WM

UCS SC26-1 Run 2

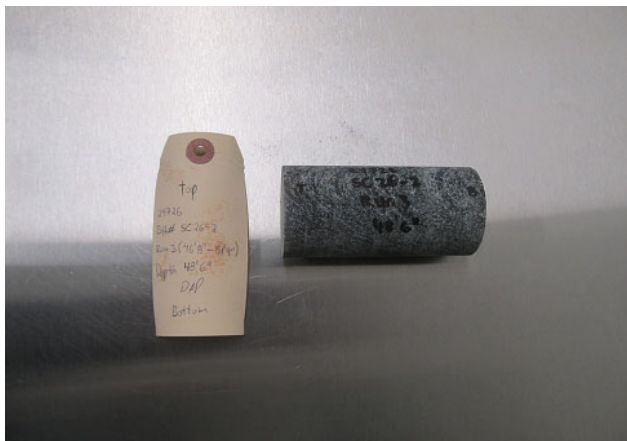
UNCONFINED COMPRESSION TEST REPORT

ASTM D7012-14

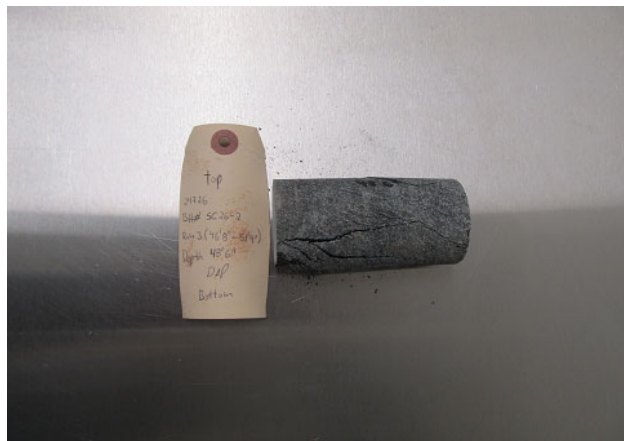
CLIENT:	Thurber Engineering (Ottawa)	FILE NUMBER:	24726
PROJECT NAME:	Highway 17 Twinning - Renfrew	REPORT DATE:	2-Aug-24
BOREHOLE No.:	SC26-2	TEST DATE:	9-May-24
SAMPLE No.:	Run 3		
SAMPLE DEPTH:	14.78 m		
DESCRIPTION:	Granite		

Avg. Height (cm):	9.5	Weight (g):	476.6
Avg. Diameter (cm):	4.7	Wet Density (kg/m ³):	2,892
H. to Dia. Ratio**:	2:1	Dry Density (kg/m ³):	2,892
Cross Sectional Area (cm ²):	17.35	Moisture Content* (%):	N/A
Sample Volume (cm ³):	164.82		

ORIGINAL SPECIMEN



FRACTURED SPECIMEN



AVG. RATE OF STRAIN TO FAILURE:	0.250 MPa/s
MAXIMUM COMPRESSIVE LOAD:	126.6 kN
UNCONFINED COMPRESSIVE STRENGTH:	73.0 MPa

Note: * The moisture content was obtained before the test.
 ** Dimensions of Specimen conform to ASTM D 4543-04.

TEST DONE BY: GF
 REVIEWED BY: WM

UCS SC26-2 Run 3

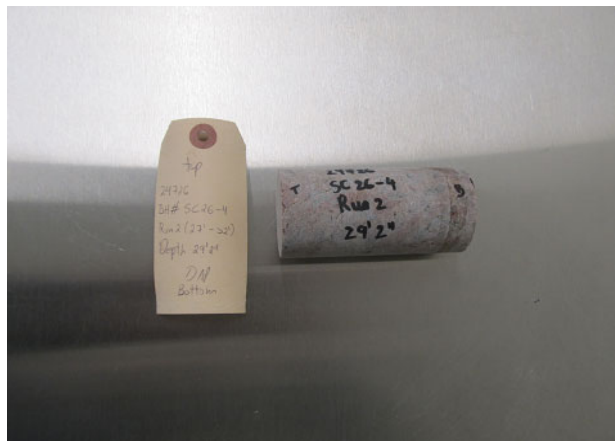
UNCONFINED COMPRESSION TEST REPORT

ASTM D7012-14

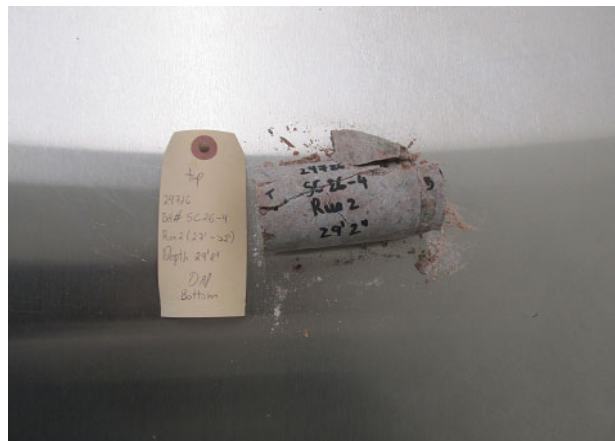
CLIENT:	Thurber Engineering (Ottawa)	FILE NUMBER:	24726
PROJECT NAME:	Highway 17 Twinning - Renfrew	REPORT DATE:	2-Aug-24
BOREHOLE No.:	SC26-4	TEST DATE:	9-May-24
SAMPLE No.:	Run 2		
SAMPLE DEPTH:	8.89 m		
DESCRIPTION:	Granite		

Avg. Height (cm):	9.6	Weight (g):	435.0
Avg. Diameter (cm):	4.7	Wet Density (kg/m ³):	2,612
H. to Dia. Ratio**:	2:1	Dry Density (kg/m ³):	2,612
Cross Sectional Area (cm ²):	17.35	Moisture Content* (%):	N/A
Sample Volume (cm ³):	166.55		

ORIGINAL SPECIMEN



FRACTURED SPECIMEN



AVG. RATE OF STRAIN TO FAILURE:	0.250 MPa/s
MAXIMUM COMPRESSIVE LOAD:	123.3 kN
UNCONFINED COMPRESSIVE STRENGTH:	71.1 MPa

Note: * The moisture content was obtained before the test.
 ** Dimensions of Specimen conform to ASTM D 4543-04.

TEST DONE BY: GF
 REVIEWED BY: WM

UCS SC26-4 Run 2

Borehole SC26-1
Runs 1 and 2
Depth 1.5 to 4.1 m
Elevation 151.2 to 148.6 m
Dry Sample



Borehole SC26-1
Runs 1 and 2
Depth 1.5 to 4.1 m
Elevation 151.2 to 148.6 m
Wet Sample



Borehole SC26-2

Run 1

Depth 11.1 to 12.6 m

Elevation 149.1 to 147.6 m

Dry Sample

Cobbles and Boulders (NQ 1, 2, 3, and 4)



Run 1 Start
elev. 149.1 m



Run 1 End
elev. 147.6 m

Borehole SC26-2

Run 1

Depth 11.1 to 12.6 m

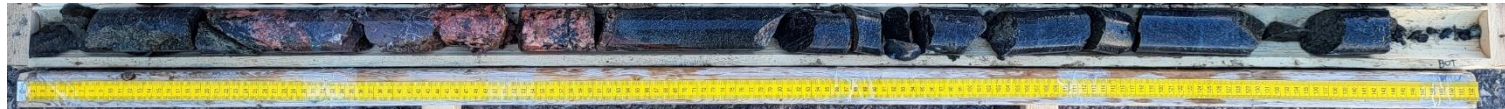
Elevation 149.1 to 147.6 m

Wet Sample

Cobbles and Boulders (NQ 1, 2, 3, and 4)



Run 1 Start
elev. 149.1 m



Run 1 End
elev. 147.6 m

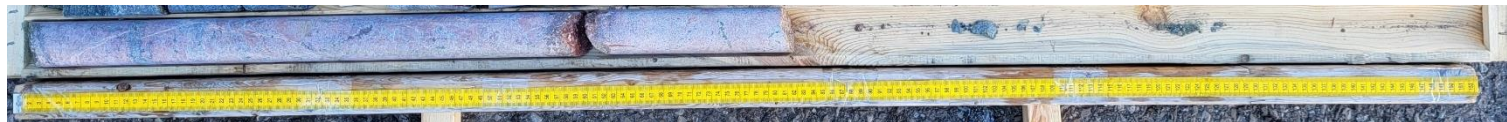
Borehole SC26-2
Runs 2 and 3
Depth 12.6 to 15.8 m
Elevation 147.6 to 144.4 m
Dry Sample

Run 2 Start
elev. 147.6 m



Run 2 End
elev. 146.0 m

Run 3 Start
elev. 146.0 m



Run 3 End
elev. 144.4 m

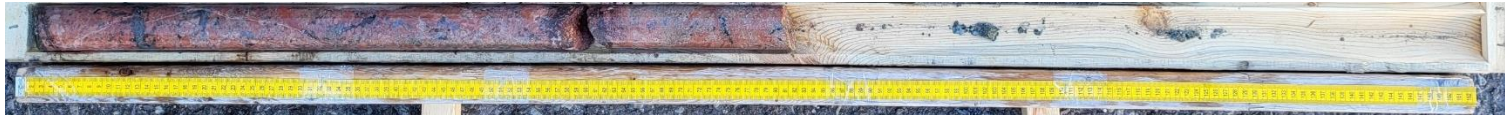
Borehole SC26-2
Runs 2 and 3
Depth 12.6 to 15.8 m
Elevation 147.6 to 144.4 m
Wet Sample

Run 2 Start
elev. 147.6 m



Run 2 End
elev. 146.0 m

Run 3 Start
elev. 146.0 m

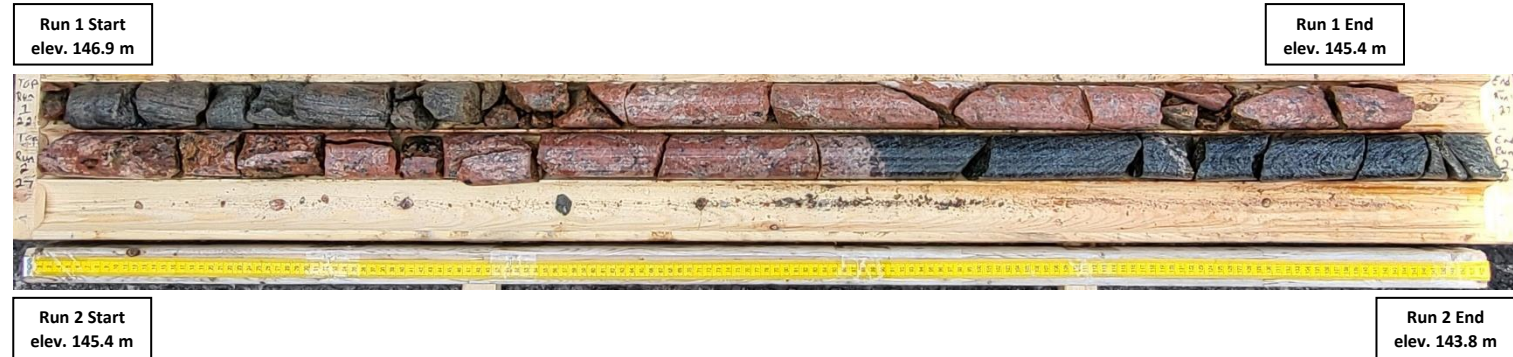


Run 3 End
elev. 144.4 m

Borehole SC26-4
Runs 1 and 2
Depth 6.7 to 9.8 m
Elevation 146.9 to 143.8 m
Dry Sample



Borehole SC26-4
Runs 1 and 2
Depth 6.7 to 9.8 m
Elevation 146.9 to 143.8 m
Wet Sample





Appendix C.2

Analytical Testing Results

Certificate of Analysis

Report Date: 29-Feb-2024

Client: Thurber Engineering Ltd.

Order Date: 26-Feb-2024

Client PO: Culvert 26

Project Description: 24726 Task 700.706a

Client ID:	SC26-3 SS#5 10'-12'	SC26-5 SS#4 7'6"-9'6"	-	-	
Sample Date:	22-Feb-24 13:00	20-Feb-24 10:30	-	-	-
Sample ID:	2409075-01	2409075-02	-	-	-
Matrix:	Soil	Soil	-	-	-
MDL/Units					

Physical Characteristics

% Solids	0.1 % by Wt.	78.7	84.8	-	-	-	-
----------	--------------	------	------	---	---	---	---

General Inorganics

Conductivity	5 uS/cm	259	306	-	-	-	-
pH	0.05 pH Units	6.79	7.17	-	-	-	-
Resistivity	0.1 Ohm.m	38.7	32.7	-	-	-	-

Anions

Chloride	10 ug/g	82	92	-	-	-	-
Sulphate	10 ug/g	16	45	-	-	-	-

**SGS Canada Inc.**

P.O. Box 4300 - 185 Concession St.
Lakefield - Ontario - K0L 2H0
Phone: 705-652-2000 FAX: 705-652-6365

Paracel Laboratories

Attn : Dale Robertson

300-2319 St.Laurent Blvd.
Ottawa, ON
K1G 4K6, Canada

Phone: 613-731-9577
Fax:613-731-9064

07-March-2024

Date Rec. : 28 February 2024

LR Report: CA12795-FEB24

Reference: Project#: 2409075

Copy: #2

CERTIFICATE OF ANALYSIS

Final Report - Revised

Sample ID	Sample Date & Time	Sulphide (Na ₂ CO ₃) %
1: Analysis Start Date		06-Mar-24
2: Analysis Start Time		06:37
3: Analysis Completed Date		06-Mar-24
4: Analysis Completed Time		09:27
5: RL		0.01
6: SC26-3 SS#5 10'-12'	22-Feb-24 13:00	< 0.01
7: SC26-5 SS#4 7'6"-9'6"	20-Feb-24 10:30	0.02

RL - SGS Reporting Limit

Revised March 7, 2024 - Sample collection date for SC26-5 SS#4 7'6"-9'6" corrected.

Kimberley Didsbury
Project Specialist,
Environment, Health & Safety



Appendix D.

Site Photographs



Photo 1. Looking east along existing eastbound embankment (March 22, 2024)



Photo 2. Looking east at ponded water near the EB embankment toe (April 9, 2024)



Photo 3. Looking southwest along eastbound embankment (July 26, 2024)



Photo 4. Looking west along Highway 17 (July 26, 2024)



Photo 5. Looking west along Highway 17 (July 26, 2024)



Photo 6. Looking east along Highway 17 and existing WB embankment (July 26, 2024)



Appendix E.

GSC Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

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

Site: 45.447N 76.565W

User File Reference: Culvert 26, Highway 17, Sta 13+275

2024-08-02 20:02 UT

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.358	0.183	0.105	0.032
Sa (0.1)	0.424	0.228	0.138	0.045
Sa (0.2)	0.354	0.198	0.123	0.043
Sa (0.3)	0.269	0.155	0.098	0.036
Sa (0.5)	0.192	0.113	0.073	0.026
Sa (1.0)	0.098	0.059	0.038	0.013
Sa (2.0)	0.048	0.028	0.018	0.005
Sa (5.0)	0.013	0.007	0.004	0.001
Sa (10.0)	0.005	0.003	0.002	0.001
PGA (g)	0.228	0.125	0.076	0.025
PGV (m/s)	0.161	0.091	0.056	0.018

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

References

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

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

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

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



Natural Resources
Canada

Ressources naturelles
Canada

Canada



Appendix F.

Foundation Comparison



COMPARISON OF ALTERNATIVE FOUNDATION TYPES

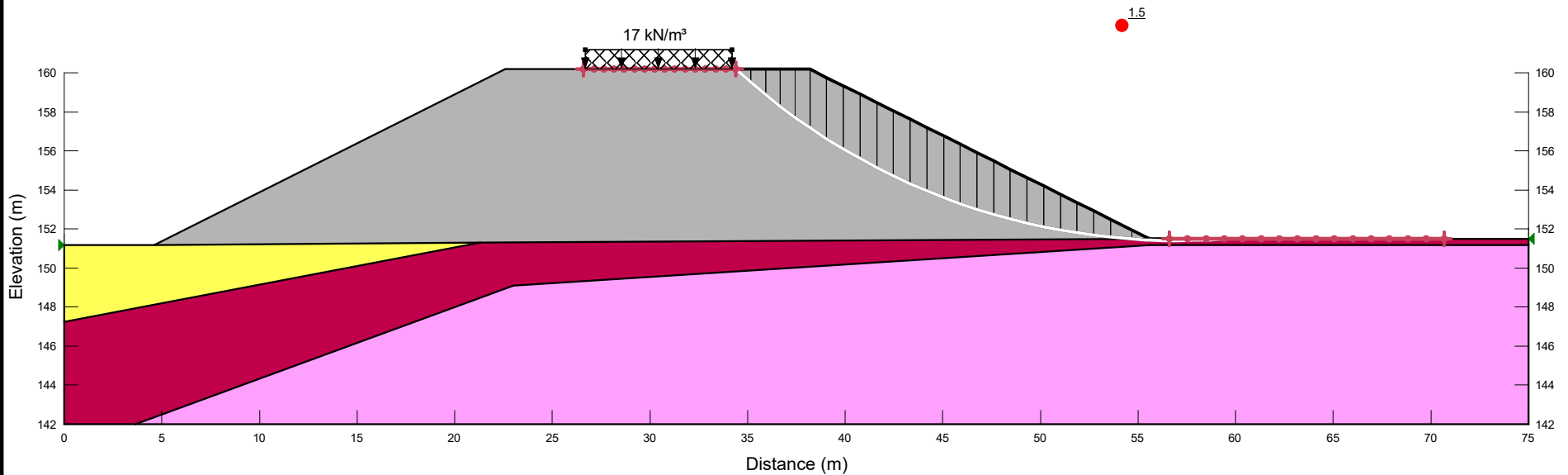
	Pipe Culverts	Open-Bottom Box Culverts	Closed-Bottom Box Culverts
Advantages	Relatively expedient installation if precast units are used.	Readily encompasses natural substrate. Preferrable from environmental perspective Possibility to maintain work zone to span the existing culvert; however, the replacement would need to be significantly wider than existing to allow for foundation excavation without conflict with existing pipe.	Relatively expedient installation if precast units are used Smaller magnitude of settlement than open footing culvert due to lower bearing stress on subgrade. Closed box culvert mitigates risk of structural damage to liquefaction of underlying soils.
Disadvantages	Requires a temporary by-pass to maintain waterflow Several parallel pipes may be required to provide hydraulic opening equivalent to box culvert Protection system may require bracing, anchors and/or rakers Difficult to include natural substrate.	Requires protection system for construction of foundations Protection system may require bracing, anchors and/or rakers Deepest excavation increases quantities and dewatering concerns. Less expedient installation as cast-in-place footings needed prior to placement of precast units	Requires a temporary by-pass to maintain waterflow Requires deeper concrete box with increased rise to include natural substrate. Protection system may require bracing, anchors and/or rakers
Risks/Consequences	Some risk of basal disturbance during excavation due to depth of excavation below water table.	Increased risk of basal disturbance during footing excavation due to depth of excavation below water table. Potential liquefaction of underlying soils/increased risk of structural damage.	Some risk of basal disturbance during excavation due to depth of excavation below water table.
Relative Cost	Low to Moderate	Moderate	Moderate
Recommendation	Feasible	Not Recommended	Recommended



Appendix G.

Slope Stability Analysis Figures

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
■	a) Silty Sand	Mohr-Coulomb	19	0	30	1
■	b) Silty Sand (Till)	Mohr-Coulomb	21	0	35	1
■	c) Bedrock	Bedrock (Impenetrable)				1
■	d) SSM	Mohr-Coulomb	21	0	32	1

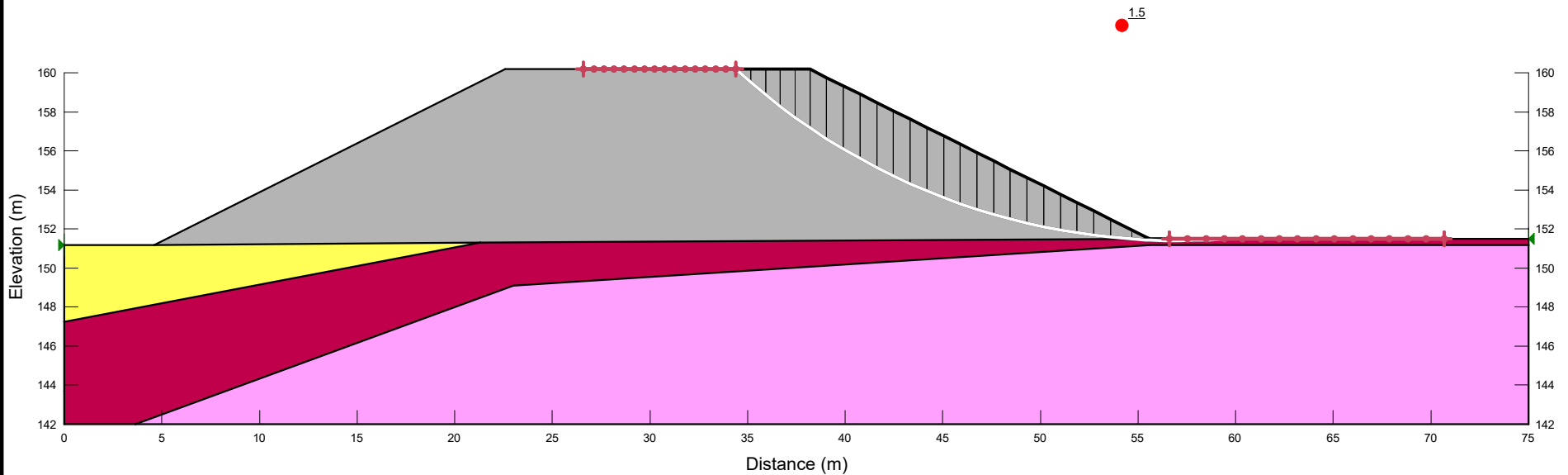


Project 24726 - Hwy 17, Sta 13+227, Culvert 26		
Analysis a1) Temporary (traffic), short term, static		
Seismic Coefficient H: g, V: g	Last Run 2024-11-28, 03:40:12 PM	Scale 1:320

Additional Details
 Name: a) 2.0H:1V SSM embankment
 Comments:
 Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1.5 m
 Entry: (34.4, 160.2) m, Exit: (59.42, 151.5) m
 Center: (57.009924, 184.89599) m, Radius: 33.48284 m

Figure G1-1

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
■	a) Silty Sand	Mohr-Coulomb	19	0	30	1
■	b) Silty Sand (Till)	Mohr-Coulomb	21	0	35	1
■	c) Bedrock	Bedrock (Impenetrable)				1
■	d) SSM	Mohr-Coulomb	21	0	32	1

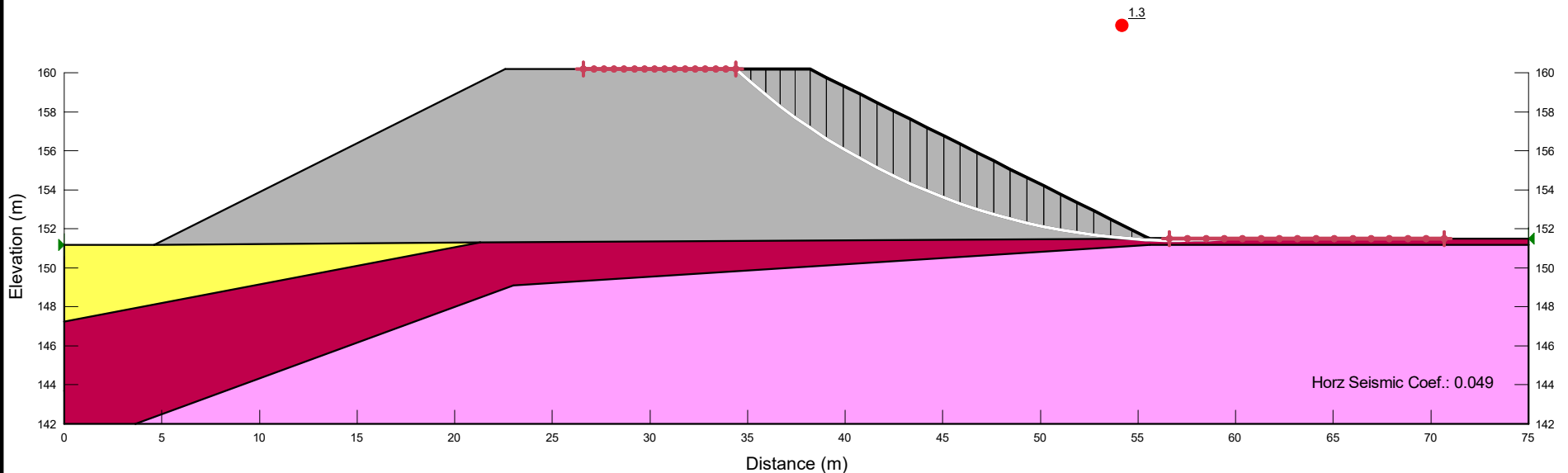


Project 24726 - Hwy 17, Sta 13+227, Culvert 26		
Analysis a2) Permanent, long term, static, drained		
Seismic Coefficient H: g, V: g	Last Run 2024-11-28, 03:40:12 PM	Scale 1:320

Additional Details
 Name: a) 2.0H:1V SSM embankment
 Comments:
 Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1.5 m
 Entry: (34.4, 160.2) m, Exit: (59.42, 151.5) m
 Center: (57.009924, 184.89599) m, Radius: 33.48284 m

Figure G1-2

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Effective Cohesion (kPa)	Effective Friction Angle (°)	Piezometric Surface
■	a) Silty Sand	Mohr-Coulomb	19	0	30	1
■	b) Silty Sand (Till)	Mohr-Coulomb	21	0	35	1
■	c) Bedrock	Bedrock (Impenetrable)				1
■	d) SSM	Mohr-Coulomb	21	0	32	1



Project 24726 - Hwy 17, Sta 13+227, Culvert 26		
Analysis a3) Temporary (seismic), pseudo-static, undrained		
Seismic Coefficient H: 0.049g, V: g	Last Run 2024-11-28, 03:40:10 PM	Scale 1:320

Additional Details
 Name: a) 2.0H:1V SSM embankment
 Comments:
 Method: Morgenstern-Price, Half-Sine
 Minimum Slip Surface Depth: 1.5 m
 Entry: (34.4, 160.2) m, Exit: (59.42, 151.5) m
 Center: (57.009924, 184.89599) m, Radius: 33.48284 m

Figure G1-3



Appendix H.

List of Referenced Specifications Non-Standard Special Provisions



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

OPSS.PROV 180	Management of Excess Materials
OPSS.PROV 206	Construction Specification for Grading
OPSS.PROV 401	Trenching, Backfilling, and Compacting
OPSS.PROV 421	Pipe Culvert Installation in Open Cut
OPSS.PROV 422	Precast Reinforced Concrete Box Culverts and Box Sewers in Open Cut
OPSS.PROV 501	Construction Specification for Compacting
OPSS.PROV 511	Construction Specification for Rip-Rap, Rock Protection, and Granular Sheetting
OPSS.PROV 517	Construction Specification for Dewatering
OPSS.PROV 539	Construction Specification for Temporary Protection Systems
OPSS.PROV 803	Vegetative Cover
OPSS.PROV 804	Construction Specification for Seed and Cover
OPSS.PROV 805	Construction Specification for Temporary Erosion and Sediment Control Measures
OPSS.PROV 902	Construction Specification for Excavating and Backfilling Structures
OPSS.PROV 1010	Material Specification for Aggregates Base, Subbase, Select Subgrade, and Backfill Material
OPSS.PROV 1205	Clay Seal
OPSD 208.010	Benching of Earth Slopes
OPSD 219.110	Light-Duty Silt Fence Barrier
OPSD 802.010	Flexible Pipe Embedment and Backfill, Earth Excavation
OPSD 802.031	Rigid Pipe Bedding, Cover and Backfill, Type 3 Soil, Earth Excavation
OPSD 803.010	Backfill and Cover for Concrete Culverts with Spans Less Than or Equal To 3.0 m
OPSD 803.031	Frost Treatment - Pipe Culverts, Frost Penetration Line Between Top of Pipe and Bedding Grade
OPSD 810.010	General Rip-Rap Layout for Sewer and Culvert Outlets
OPSD 3090.101	Foundation Frost Depths for Southern Ontario
OPSD 3101.150	Walls Abutment, Backfill Minimum Granular Requirement
SP 110S06	Amendment to OPSS 1010, April 2013
SP 517F01	Amendment to OPSS 517 - Construction Specification for Dewatering



2. Suggested wording for NSSPs

“Structural Backfill”

Structural backfill for the culvert and retaining walls shall consist of OPSS Granular B Type II or Quarry Sourced OPSS Granular A material.

“Notice to Contractor: Obstructions”

Buried obstructions may be encountered during construction and interfere with excavations and installation of temporary protection/dewatering systems. Cobbles and boulders may be encountered within the existing fill and the glacial till layer. The Contractor must be prepared to dislodge or penetrate obstructions. Where obstructions are encountered near the surface, the Contractor may choose to remove such obstructions, provided it does not destabilize the existing embankment or temporary works.

“Shallow and Sloping Bedrock”

The contractor is hereby notified that bedrock was encountered at variable elevation in the boreholes drilled at the site. The presence of shallow bedrock may affect the installation of Temporary Protection Systems. The Contractor’s Temporary Protection System design shall include consideration of shallow bedrock.

“Dewatering and Temporary Flow Passage”

It will be necessary to divert the ditch flow around the excavation to place the bedding and construct each culvert in the dry. Excavations and placement of bedding material must be completed in the dry. The presence of cohesionless native soils may increase seepage rates. Suitable diversion and dewatering systems must be employed. The diversion and dewatering systems will be critical for culvert construction at this site. The Contractor should be prepared to take appropriate measures to construct the bedding layer and place the culverts in dry and stable environments.