



THURBER ENGINEERING LTD.

**PRELIMINARY FOUNDATION INVESTIGATION REPORT
HIGHWAY 401 WIDENING, HIGHWAY 16 TO MAITLAND ROAD
BLUE CHURCH ROAD UNDERPASS, SITE NO. 16X-0165/B0
GWP 4024-20-00 / ASSIGNMENT NO. 4019-E-0010.2**

SITE NO. 16X-0165/B0

Geocres No.: 31B12-002

Report to:

MTO c/o AECOM Canada Ltd.

Latitude: 44.696810°
Longitude: -75.573677°

March 2024
Thurber File No.: 29381



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PART 1. FACTUAL INFORMATION

1 INTRODUCTION

Thurber Engineering Ltd. (Thurber) has been retained by AECOM Canada Ltd. (AECOM) on behalf of the Ministry of Transportation Ontario (MTO) under Assignment No. 4019-E-0010, Work Item No. 2, to carry out Foundation Investigations to support the Preliminary Design and Environmental Assessment for the widening of Highway 401 from Highway 16 to Maitland Road. The overall scope of work comprises replacement or rehabilitation of 14 existing structures, including 10 bridges and four structural culverts.

This report addresses the Highway 401 Underpass at Blue Church Road (Site 16X-0165/B0), located approximately 9.5 km west of Highway 416 in the Township of Augusta within the Leeds and Grenville County, Ontario.

This section of the report presents the factual findings obtained from a foundation investigation completed at the site, as well as data from existing subsurface information pertinent to the site, obtained from the MTO's Foundation Library (Geocres No. 31B00-003).

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, a stratigraphic profile, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions influencing design and replacement of the structure was developed during the current investigation.

It is a condition of this report that Thurber's performance of its professional services is subject to the attached Statement of Limitations and Conditions.

2 BACKGROUND AND SITE DESCRIPTION

2.1 General

The Blue Church Road Underpass is located on Highway 401 approximately 9.5 km west of Highway 416. The location of the structure is shown on the inset Key Plan on Drawing No. 1 in Appendix A. For project orientation purposes, Blue Church Road will be described as oriented north-south and Highway 401 as oriented east-west.



The existing structure carries two lanes of Blue Church Road traffic over Highway 401. The Ontario Structure Inspection Manual (OSIM) report prepared by MTO on March 7, 2018, indicates that the existing structure is a four-span, post-tensioned, cast-in-place concrete structure, constructed in 1965. The inspection report indicates that the bridge deck is approximately 64.3 m long and 9.3 m wide, with an approximate 13-degree skew to the highway. The existing structure is located about 60 m west of the original (pre-Highway 401) alignment of Blue Church Road and, as such, is on a curved alignment with horizontal curve radius of approximately 580 m.

At the site, Highway 401 has two through lanes in each direction with paved shoulders. The eastbound and westbound lanes are separated by a paved median with concrete barrier. In the area of the structure the Highway 401 median is more than 18 m wide from shoulder to shoulder. Beyond the site, approximately 80 m north and south of Blue Church Road, the eastbound and westbound lanes of Highway 401 are separated by a grass median.

Within the project limits, Blue Church Road has one lane in each direction. On the approaches, concrete curb and gutter and steel beam guiderails are present in both directions. The existing approach embankments are up to approximately 7 m high above the lowland areas adjacent to Highway 401 with slopes inclined between about 2H:1V and 2.3H:1V (Horizontal:Vertical). The embankment slopes are vegetated with long grasses, shrubs, and occasional trees. At the time of the field investigation, the embankments did not show any visible signs of distress or other performance issues.

The land north and south of the site generally consists of open or treed, undeveloped lands, some farmlands with few residential dwellings. Concession Road 2 runs parallel to Highway 401 approximately 30 m north. The terrain surrounding the site is relatively flat. Storm water drainage in the area is a combination of median storm sewers on Highway 401 and roadside ditches along Blue Church Road and the outsides of Highway 401.

Photographs showing the existing conditions at the site at the time of the field investigation are included in Appendix D for reference.

2.2 Site Geology

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 Edwardsburg Sand Plain. The Edwardsburg Sand Plain is characterized by glaciofluvial (deposited by glacial meltwater) sand deposits overlying bedrock, till or clay. Terrain is relatively flat, with sand ridges and moraines providing some relief. The area is known to be underlain by dolostone and dolomitic sandstone bedrock of the Beekmantown Group.

3 SITE INVESTIGATION AND FIELD TESTING

3.1 Previous Investigations

A foundation investigation report for the existing Highway 401 Blue Church Road Underpass (31B00-003, 1964) was obtained from the online Geocres library. The investigation included ten



boreholes and seven dynamic cone penetration tests (DCPT). The Geocres file includes correspondence subsequent to the completion of the field investigation that clarifies the locations of the completed boreholes. The correspondence suggests that the boreholes were put down along the centreline of the then-existing Blue Church Road (approximately 60 m east of the current bridge alignment at Highway 401).

A summary of the interpreted locations of the two boreholes relevant to the current study, put down within the current Highway 401 median, east of the proposed pier location is provided in the table below. The borehole coordinates and elevations are shown on the Borehole Location and Soil Strata Drawing 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 (1964 Investigation)

Borehole No.	Drilled Location	Northing ¹ (Latitude)	Easting ¹ (Longitude)	Ground Surface Elevation ² (m)	Termination Depth (m)
BH 4	Highway 401 Median	4 951 219.7 (44.697222°)	378 246.5 (75.573267°)	108.5	5.2
BH 9	Highway 401 Median	4 951 203.7 (44.697080°)	378 233.4 (75.573434°)	108.5	4.0

Notes: (1) Borehole were interpolated from historical drawings and are approximately only
 (2) Ground surface at the time of the 1964 investigation

3.2 Current Field Investigation

The current field investigation for this site included advancing two boreholes within the proposed abutment footprints on April 18, 2023. The boreholes were advanced using a track mounted CME 55 drill rig equipped with hollow stem augers, NW casing, and NQ coring equipment. Thurber contacted Ontario One Call in advance of the field investigation to obtain utility locates/clearances in the vicinity of the borehole locations. In addition, MTO was contacted to obtain the location of electrical and fibre optic utilities within the project limits.

The approximate locations in MTM NAD83, Zone 9 coordinates, elevations, and termination depths of the boreholes are provided in the table below. The as-drilled elevations of the boreholes were surveyed by Thurber with a Trimble Catalyst DA1 antenna with centimeter accuracy. The elevations were surveyed relative to available MTO benchmarks and existing site features and were cross-referenced with elevations on the original design drawings. The borehole coordinates and elevations are shown on the Borehole Location and Soil Strata Drawing in Appendix A and on the individual Record of Borehole sheets included in Appendix B.

Soil samples were collected at regular depth intervals in the boreholes during the completion of Standard Penetration Tests (SPT), following the methods described in ASTM Standard D1586. The drilling and sampling operations were supervised on a full-time basis by a member of Thurber’s geotechnical staff. The drilling supervisor logged the boreholes and processed the recovered soil and bedrock samples for transport to Thurber’s Ottawa geotechnical laboratory for further examination and testing.



Table 3-2: Borehole Summary (Current Investigation)

Borehole No.	Drilled Location	Northing ¹ (Latitude)	Easting ¹ (Longitude)	Ground Surface Elevation ² (m)	Termination Depth (m)
165-23-01	Proposed South Abutment	4 951 161.7 (44.696701°)	378 233.1 (-75.573444°)	109.0	3.9
165-23-02	Proposed North Abutment	4 951 210.5 (44.697145°)	378 199.1 (-75.573866°)	108.0	6.1

A piezometer consisting of a 32 mm PVC pipe was installed in Borehole 165-23-02 to allow for measurement of the groundwater level at the site. The piezometer construction details are illustrated on the corresponding Record of Borehole sheet provided in Appendix B. The standpipe piezometer at Borehole 165-23-02 was decommissioned in accordance with MOE requirements on June 16, 2023.

Following completion of the field investigation, the borehole without a piezometer was decommissioned in general accordance with O.Reg. 903, as amended and capped with granular material and cold patch asphalt to reinstate the pavement surface.

4 LABORATORY TESTING

Geotechnical laboratory testing consisted of natural moisture content determination and visual identification of all retained soil samples. Recovered soil samples were selected for grain size distribution and Atterberg Limit testing in accordance with MTO and ASTM standards. All rock cores were photographed and their total core recovery (TCR), solid core recovery (SCR) and rock quality designation (RQD) were measured. One sample of intact rock core from Borehole 165-23-02 was submitted for Unconfined Compressive Strength (UCS) testing.

The results of the geotechnical tests are summarized on the Record of Borehole sheets included in Appendix B and all laboratory test results from the investigation are provided in Appendix C.

5 DESCRIPTION OF SUBSURFACE CONDITIONS

Details of the encountered soil stratigraphy are presented on the Record of Borehole sheets included in Appendix B and the Borehole 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 this general description for interpretation of site conditions. It must be recognized that the soil and groundwater conditions will vary between and beyond borehole locations. Soil classification is in accordance with ASTM D2487. Description of cohesive soils and secondary components are described as outlined in the MTO Guideline for Foundation Engineering Services Manual (April 2022).

In general terms, the encountered stratigraphy consisted of topsoil and gravelly silty sand fill, overlying a deposit of native silt which is, in turn, underlain by limestone bedrock.



5.1 Surficial Deposits

Topsoil, with a thickness of about 75 mm, was encountered at the ground surface in both 2023 boreholes.

Beneath the topsoil, a fill layer consisting of gravelly silty sand was encountered. The gravelly silty sand fill ranged in thickness from 0.7 m to 2.2 m (base Elev. 108.2 m to 105.7 m). Standard Penetration Test (SPT) N-values ranging from 5 to 14 blows per 0.3 m of penetration were recorded within this layer indicating a loose to compact relative density.

The recorded moisture content of samples of the gravelly silty sand ranged from 4 to 18 %. The results of gradation analyses completed on two samples of the fill are illustrated on Figure C1 of Appendix C. The results of the tests are summarized below and on the Record of Boreholes sheets in Appendix B.

Soil Particle	Percentage (%)
Gravel	33 – 34
Sand	35 – 49
Silt	18 – 31
Clay	

5.2 Silt

A layer of silt was encountered beneath the silty sand with gravel fill in Borehole 165-23-02 and near the then-existing ground surface (now Highway 401) at Borehole BH 9. The thickness of this layer ranged from 0.8 m (base Elev. 104.9 m) north of Highway 401 at Borehole 165-23-02 to 2.4 m (base Elev. 106.1 m) near the Highway 401 median at Borehole BH 9. No silt was encountered at Borehole 165-23-01 put down south of Highway 401. SPT N-values in the silt ranged from 6 to 15 blows per 0.3 m of penetration, indicating a loose to compact relative density.

Recorded moisture contents ranged from 13 to 24 %. The results of gradation analyses completed on one sample of silt are illustrated on Figure C2 of Appendix C. The results of the tests are summarized below and on the Record of Boreholes sheet in Appendix B.

Soil Particle	Percentage (%)
Gravel	0
Sand	5
Silt	88
Clay	7

The result of Atterberg limit test completed on one sample of the silt indicates it as non plastic fine grain material.



5.3 Bedrock

Bedrock was proven in all boreholes. The depth to bedrock at the two 2023 boreholes was 0.8 m and 3.1 m (elev. 108.2 m to 104.9 m). Bedrock was encountered at about Elevation 106.1 m within the highway 401 median (BH 9). Bedrock logs are provided Appendix B and photographs of the bedrock cores are provided in Appendix C. The rock core quality and strength are summarized in Table 5-1.

Table 5-1: Bedrock Details

Parameter	Range
Total Core Recovery (TCR), %	98 – 100
Solid Core Recovery (SCR), %	78 – 100
Rock Quality Designation (RQD), %	21 – 93
Fracture Index (fractures per 0.3 m) ⁽¹⁾	1 – 6
Unconfined Compressive Strength (UCS) ⁽²⁾ , MPa	154

Notes: (1) Indicated as "FI" on Borehole Logs

(2) Samples tested from Boreholes 165-23-02

Unconfined compressive strength (UCS) testing was carried out on a sample of the limestone bedrock from Borehole 165-23-02. The results of this test indicated a UCS strength of 154.2 MPa indicating a very strong bedrock. The results of the UCS testing are included in Appendix C.

5.4 Groundwater

A standpipe piezometer consisting of a 32 mm diameter PVC pipe was installed in Borehole 165-23-02 to monitor the groundwater level after completion of drilling. The measured groundwater levels are summarized in the table below.

Borehole No.	Bottom of Screen Elev. (m)	Screened Unit	Depth (mbgs)	Groundwater Elevation (m)	Date of Measurement
165-23-02	101.8	Bedrock	0.8	107.2	April 26, 2023
			0.7	107.3	June 16, 2023

It should be noted that the values shown above are considered short-term readings and may not reflect groundwater levels at the time of construction, and seasonal fluctuations of the groundwater level are to be expected. In particular, the groundwater level may be at a higher elevation after periods of significant and/or prolonged precipitation events.



6 MISCELLANEOUS

The borehole locations were selected by Thurber relative to existing site features. The as-drilled locations and ground surface elevations of the boreholes were surveyed by Thurber following completion of the field program. The elevation survey of the boreholes was carried out with reference to geodetic elevation benchmarks provided by the MTO or relative to structure feature elevations provided on as-built drawings. Eastern Ontario Diamond Drilling of Hawkesbury, Ontario supplied and operated the drilling equipment and carried out the drilling, soil sampling, in-situ testing, and borehole decommissioning. Traffic control and water supply were provided by T.G. Carroll Cartage Limited of Carp, Ontario.

The field investigation was supervised on a full-time basis by Richard Howarth, C.Tech. under the direction of Katya Walker, P.Eng. Routine geotechnical laboratory testing was completed by Thurber's laboratory in Ottawa, Ontario. Unconfined Compressive Strength Testing of the bedrock was carried out by Stantec's laboratory in Ottawa, Ontario.

Overall project management and direction of the field investigation was provided by Matt Kennedy, P.Eng. Interpretation of the factual data and preparation of this report was completed out by Ibrahim Khan, EIT and Matt Kennedy, P.Eng. The report was reviewed by Fred Griffiths, P.Eng., a Designated Principal Contact for MTO Foundations Projects.

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STATEMENT OF LIMITATIONS AND CONDITIONS

1. STANDARD OF CARE

This Report has been prepared in accordance with generally accepted engineering or environmental consulting practices in the applicable jurisdiction. No other warranty, expressed or implied, is intended or made.

2. COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment are a part of the Report, which is of a summary nature and is not intended to stand alone without reference to the instructions given to Thurber by the Client, communications between Thurber and the Client, and any other reports, proposals or documents prepared by Thurber for the Client relative to the specific site described herein, all of which together constitute the Report.

IN ORDER TO PROPERLY UNDERSTAND THE SUGGESTIONS, RECOMMENDATIONS AND OPINIONS EXPRESSED HEREIN, REFERENCE MUST BE MADE TO THE WHOLE OF THE REPORT. THURBER IS NOT RESPONSIBLE FOR USE BY ANY PARTY OF PORTIONS OF THE REPORT WITHOUT REFERENCE TO THE WHOLE REPORT.

3. BASIS OF REPORT

The Report has been prepared for the specific site, development, design objectives and purposes that were described to Thurber by the Client. The applicability and reliability of any of the findings, recommendations, suggestions, or opinions expressed in the Report, subject to the limitations provided herein, are only valid to the extent that the Report expressly addresses proposed development, design objectives and purposes, and then only to the extent that there has been no material alteration to or variation from any of the said descriptions provided to Thurber, unless Thurber is specifically requested by the Client to review and revise the Report in light of such alteration or variation.

4. USE OF THE REPORT

The information and opinions expressed in the Report, or any document forming part of the Report, are for the sole benefit of the Client. NO OTHER PARTY MAY USE OR RELY UPON THE REPORT OR ANY PORTION THEREOF WITHOUT THURBER'S WRITTEN CONSENT AND SUCH USE SHALL BE ON SUCH TERMS AND CONDITIONS AS THURBER MAY EXPRESSLY APPROVE. Ownership in and copyright for the contents of the Report belong to Thurber. Any use which a third party makes of the Report, is the sole responsibility of such third party. Thurber accepts no responsibility whatsoever for damages suffered by any third party resulting from use of the Report without Thurber's express written permission.

5. INTERPRETATION OF THE REPORT

- a) Nature and Exactness of Soil and Contaminant Description: Classification and identification of soils, rocks, geological units, contaminant materials and quantities have been based on investigations performed in accordance with the standards set out in Paragraph 1. Classification and identification of these factors are judgmental in nature. Comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations utilizing the standards of Paragraph 1 will involve an inherent risk that some conditions will not be detected and all documents or records summarizing such investigations will be based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated and the Client and all other persons making use of such documents or records with our express written consent should be aware of this risk and the Report is delivered subject to the express condition that such risk is accepted by the Client and such other persons. Some conditions are subject to change over time and those making use of the Report should be aware of this possibility and understand that the Report only presents the conditions at the sampled points at the time of sampling. If special concerns exist, or the Client has special considerations or requirements, the Client should disclose them so that additional or special investigations may be undertaken which would not otherwise be within the scope of investigations made for the purposes of the Report.
- b) Reliance on Provided Information: The evaluation and conclusions contained in the Report have been prepared on the basis of conditions in evidence at the time of site inspections and on the basis of information provided to Thurber. Thurber has relied in good faith upon representations, information and instructions provided by the Client and others concerning the site. Accordingly, Thurber does not accept responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of misstatements, omissions, misrepresentations, or fraudulent acts of the Client or other persons providing information relied on by Thurber. Thurber is entitled to rely on such representations, information and instructions and is not required to carry out investigations to determine the truth or accuracy of such representations, information and instructions.
- c) Design Services: The Report may form part of design and construction documents for information purposes even though it may have been issued prior to final design being completed. Thurber should be retained to review final design, project plans and related documents prior to construction to confirm that they are consistent with the intent of the Report. Any differences that may exist between the Report's recommendations and the final design detailed in the contract documents should be reported to Thurber immediately so that Thurber can address potential conflicts.
- d) Construction Services: During construction Thurber should be retained to provide field reviews. Field reviews consist of performing sufficient and timely observations of encountered conditions in order to confirm and document that the site conditions do not materially differ from those interpreted conditions considered in the preparation of the report. Adequate field reviews are necessary for Thurber to provide letters of assurance, in accordance with the requirements of many regulatory authorities.

6. RELEASE OF POLLUTANTS OR HAZARDOUS SUBSTANCES

Geotechnical engineering and environmental consulting projects often have the potential to encounter pollutants or hazardous substances and the potential to cause the escape, release or dispersal of those substances. Thurber shall have no liability to the Client under any circumstances, for the escape, release or dispersal of pollutants or hazardous substances, unless such pollutants or hazardous substances have been specifically and accurately identified to Thurber by the Client prior to the commencement of Thurber's professional services.

7. INDEPENDENT JUDGEMENTS OF CLIENT

The information, interpretations and conclusions in the Report are based on Thurber's interpretation of conditions revealed through limited investigation conducted within a defined scope of services. Thurber does not accept responsibility for independent conclusions, interpretations, interpolations and/or decisions of the Client, or others who may come into possession of the Report, or any part thereof, which may be based on information contained in the Report. This restriction of liability includes but is not limited to decisions made to develop, purchase or sell land.



Appendix A.

Borehole Location Plan and Stratigraphic Drawing

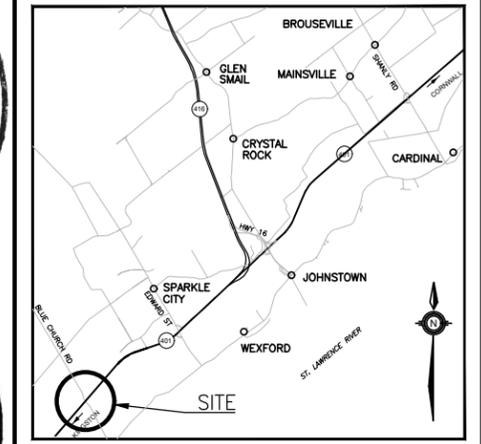
METRIC
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES
UNLESS OTHERWISE SHOWN

CONT No
GWP No 4024-20-00



HIGHWAY 401
BLUE CHURCH ROAD
BRIDGE REPLACEMENT
BOREHOLE LOCATIONS AND SOIL STRATA

SHEET



KEYPLAN

LEGEND

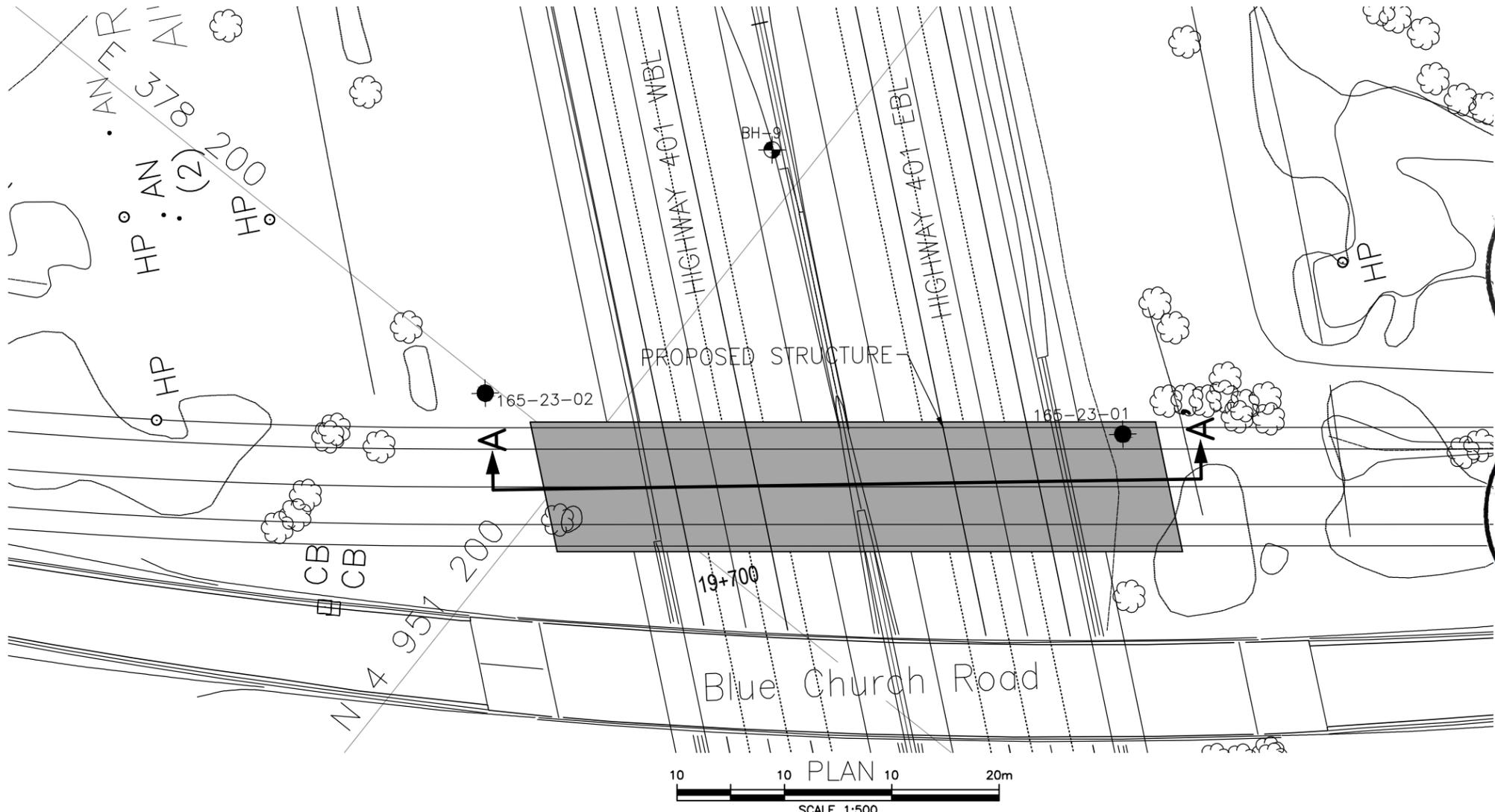
- Borehole (Current Investigation)
- ⊕ Borehole (Previous Investigation)
- N Blows /0.3m (Std Pen Test, 475J/blow)
- CONE Blows /0.3m (60' Cone, 475J/blow)
- PH Pressure, Hydraulic
- ▽ Water Level
- ⊖ Head Artesian Water
- ⊥ Piezometer
- 90% Rock Quality Designation (RQD)

NO	ELEVATION	NORTHING	EASTING
165-23-01	109.0	4 951 161.7	378 233.1
165-23-02	108.0	4 951 210.5	378 199.1
BH-04	109.0	4 951 219.7	378 246.5
BH-09	109.0	4 951 203.7	378 233.4

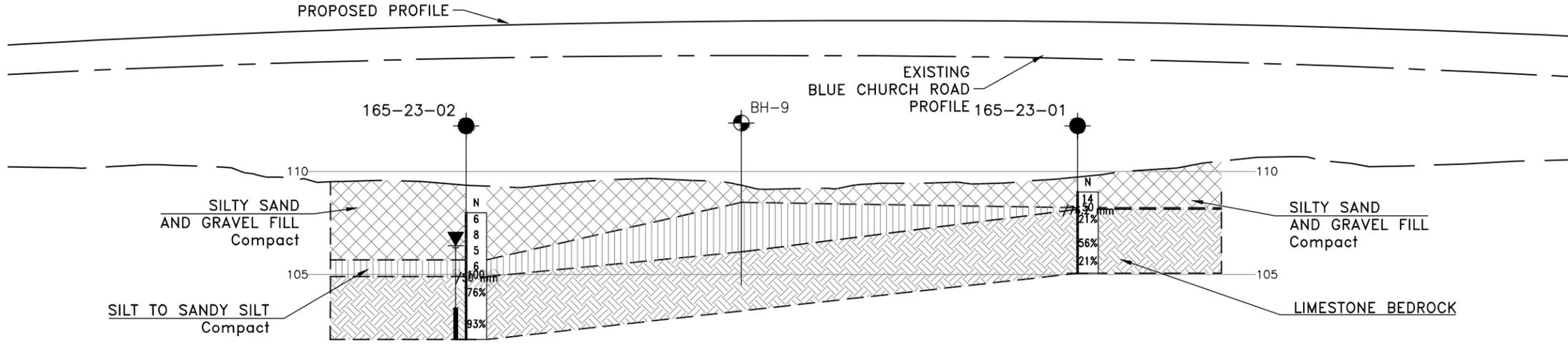
-NOTES-

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

GEOCRES No. 31B12-002



PLAN
SCALE 1:500



PROFILE ALONG BLUE CHURCH ROAD

SCALE 1:500
SCALE 1:300

REVISIONS	DATE	BY	DESCRIPTION

DESIGN	AO	CHK	MJK	CODE	LOAD	DATE	MARCH 2024
DRAWN	JW	CHK	AO	SITE	16X-0166STRUCT	DWG	1



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).

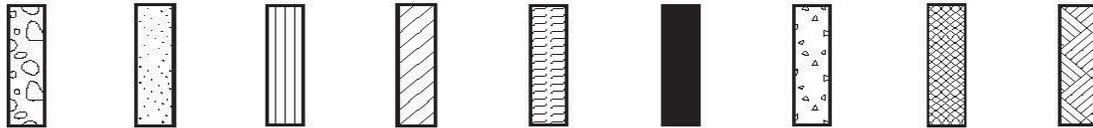
DYNAMIC CONE PENETRATION TEST (DCPT):

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 or 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 165-23-01

1 OF 1

METRIC

GWP# 4024-20-00 LOCATION Lat: 44.696701°, Long: -75.573444°
Hwy 401 BOREHOLE TYPE CME 55 Track / HSA / NW Casing / NQ Coring ORIGINATED BY RH
DATUM Geodetic DATE 2023.04.18 - 2023.04.18 CHECKED BY KW

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT w _p	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa								
						20	40	60	80	100	20	40	60	kn/m ³	GR SA SI CL	
109.0	Ground Surface															
0.0	TOPSOIL (75 mm)															
0.1	Gravelly SILTY SAND to SAND, some fines		1A/B	SS	14										33	49 18 (SI+CL)
	Compact Grey-brown Moist FILL		2	SS	50											
108.2	LIMESTONE BEDROCK															
0.8	Grey Slightly weathered Thinly bedded		1	RUN												RUN #1 TCR=100% SCR=87% RQD=21%
			2	RUN												RUN #2 TCR=100% SCR=78% RQD=56%
			3	RUN												RUN #3 TCR=100% SCR=82% RQD=21%
105.1	End of Borehole															
3.9	A representative open-hole groundwater level measurement was not obtained due to the introduction of water during drilling.															

DOUBLE LINE 29381 BOREHOLE LOGS REPLACEMENT SITES.GPJ_2012TEMPLATE(MTO).GDT_3-19-24

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

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & RESEARCH DIVISION

RECORD OF BOREHOLE NO. 4

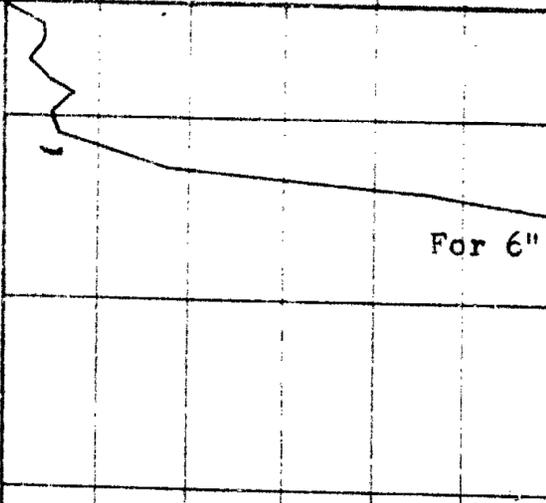
FOUNDATION SECTION

JOB 64-F-59 LOCATION Hwy. #401 & Blue Church Rd. Line 'C',
Ch. 15+79 - 31'-0" Rt. ORIGINATED BY W.W.K.
W.P. 25-59 BORING DATE July 22, 1964 SAMPLED BY W.W.K.
DATUM 356.0 BOREHOLE TYPE Wash Boring BX Casing

ELEV. DEPTH	SOIL NAME / DESCRIPTION	STRAT. PL. OF	SAMPLE		ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT - W			BULK DENSITY	REMARKS
			NUMBER	TYPE		BLOWS / FOOT	20	40	60	80	100	PLASTIC LIMIT - WP	WATER CONTENT - W		
356.0	Groundlevel														
0.5	Black Org. Topsoil														
	Clayey Sandy Silt		1	SS	15										
	Stiff to Hard		2	SS	14										
344.4			3	SS	74										
11.6	Limestone Bedrock														
339.1															
16.9	End of Borehole														

DYNAMIC PENETRATION RESISTANCE
BLOWS / FOOT
20 40 60 80 100
SHEAR STRENGTH P.S.F.

LIQUID LIMIT - W
PLASTIC LIMIT - WP
WATER CONTENT - W
WATER CONTENT %
10 20 30





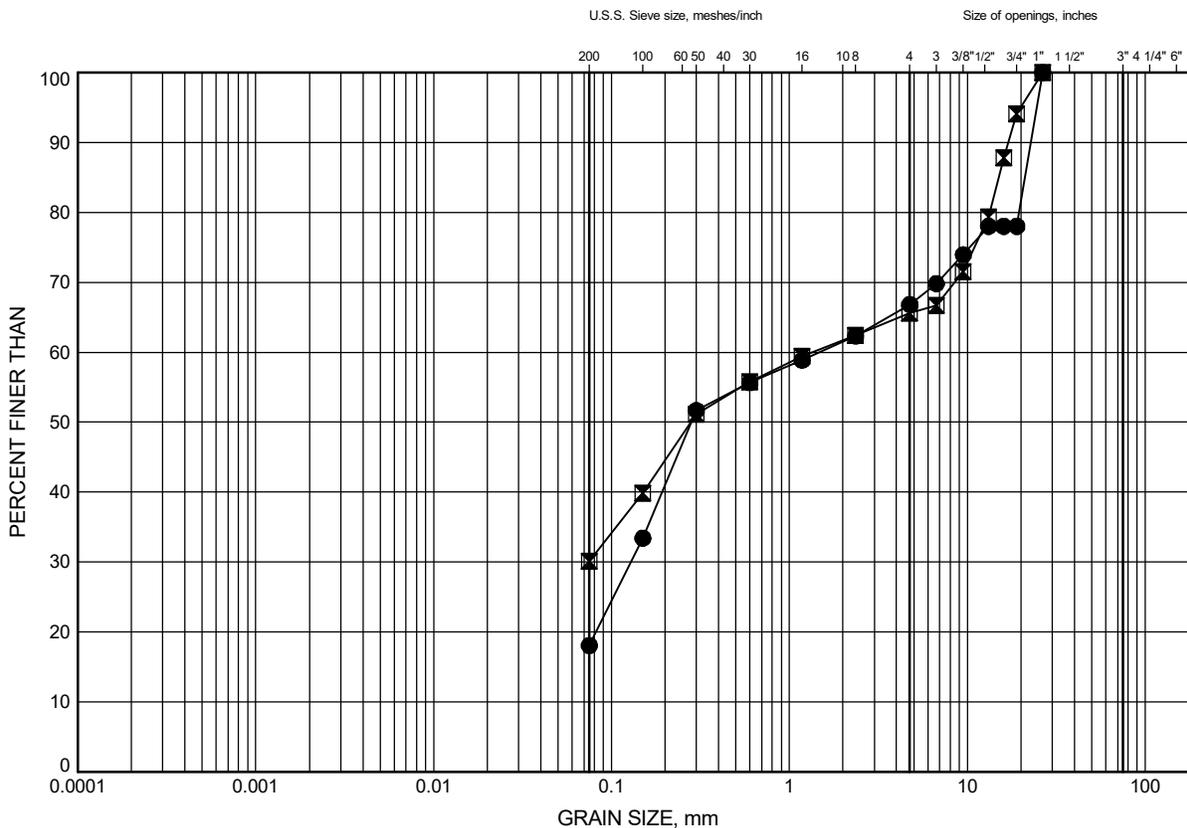
Appendix C.
Laboratory Testing



Appendix C.1
Particle Size Analysis Figures
Atterberg Limit Test Results

GRAIN SIZE DISTRIBUTION

FILL: Gravelly Silty Sand



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	165-23-01	0.3	108.7
◻	165-23-02	1.8	106.2

GRAIN SIZE DISTRIBUTION - THURBER 165-BLUE CHURCH.GPJ 8-23-23

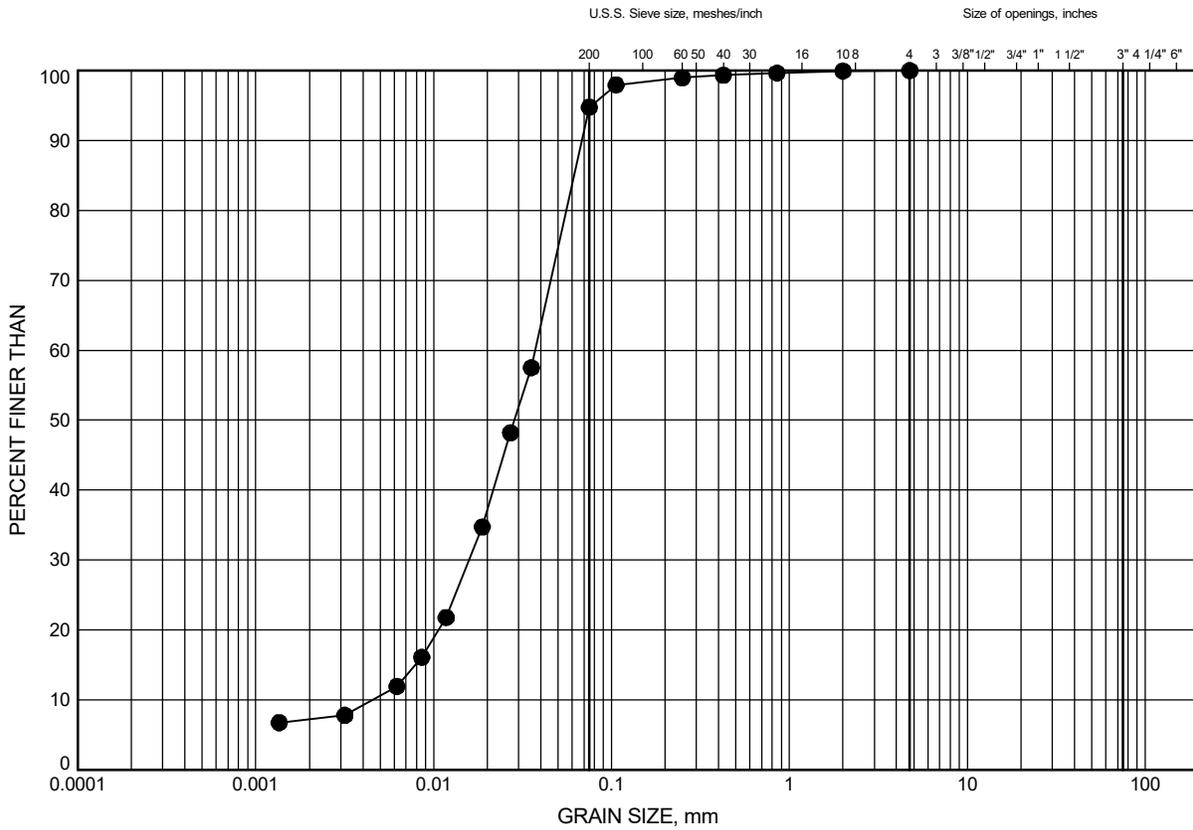
Date .. August 2023 ..
 GWP# .. 4024-20-00 ..



Prep'd .. RH ..
 Chkd. .. MJK ..

GRAIN SIZE DISTRIBUTION

Silt



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

LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	165-23-02	2.6	105.4

GRAIN SIZE DISTRIBUTION - THURBER 165-BLUE CHURCH.GPJ 8-23-23

Date .. August 2023 ..
 GWP# .. 4024-20-00 ..



Prep'd .. RH ..
 Chkd. .. MJK ..



Appendix C.2

UCS Test Results



May 3, 2023
File: 122410864

Client: Thurber Engineering, File #29381

Reference: ASTM D7012, Method C, Unconfined Compressive Strength of Intact Rock Core Hwy 401

The following table summarizes unconfined compressive strength results for three intact rock cores.

Location	Sample Depth	Compressive Strength (MPa)	Description of Break
239-23-01 Run-3	15'11"-16'6"	203.8	Vertical crack no cone
126-23-01 Run-2	15'2"-16'1"	148.7	Cones on both ends
165-23-02 Run-2	19'2"-20'2"	154.2	Cones on both ends

Sincerely,

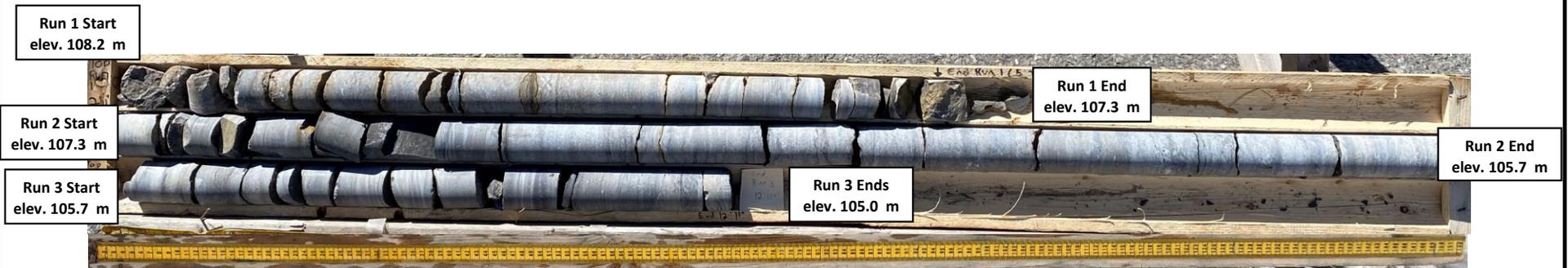
Stantec Consulting Ltd.

Brian Prevost
Laboratory Supervisor
Tel: 613-738-6075
Fax: 613-722-2799
brian.prevost@stantec.com



Appendix C.3
Bedrock Core Photographs

Borehole 165-23-01
Runs 1 to 3
Depth 0.8 to 3.9 m
Elevation 108.2 to 105.0 m
Dry Sample

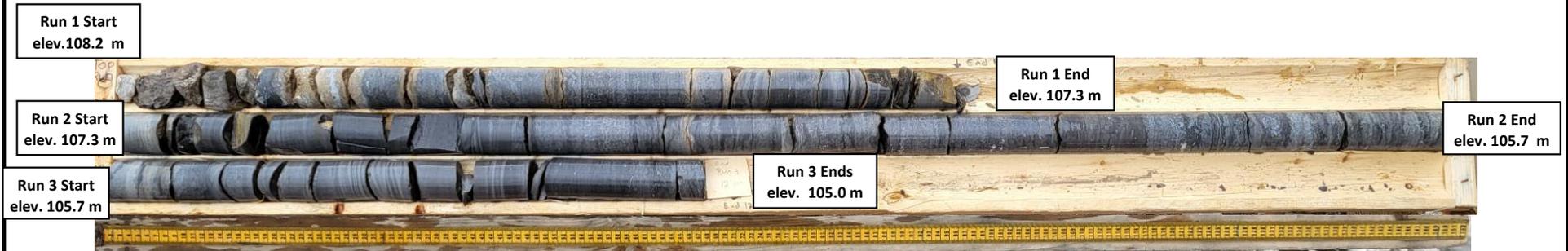


THURBER ENGINEERING LTD.

Highway 401 Underpass at Blue Church Road
(Site No. 16X-0165)
Assignment No. 4019-E-0010.2, GWP 4024-20-00

BH 165-23-01
Project No.: 29381

Borehole 165-23-01
Runs 1 to 3
Depth 0.8 to 3.9 m
Elevation 108.2 to 105.0 m
Wet Sample

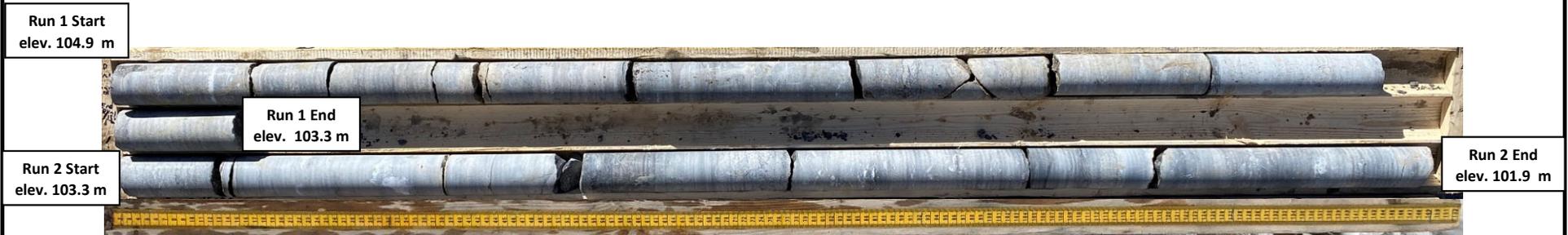


THURBER ENGINEERING LTD.

Highway 401 Underpass at Blue Church Road
(Site No. 16X-0165)
Assignment No. 4019-E-0010.2, GWP 4024-20-00

BH 165-23-01
Project No.: 29381

Borehole 165-23-02
Runs 1 to 2
Depth 3.1 to 6.1 m
Elevation 104.9 to 101.9 m
Dry Sample



THURBER ENGINEERING LTD.

Highway 401 Underpass at Blue Church Road
(Site No. 16X-0165)
Assignment No. 4019-E-0010.2, GWP 4024-20-00

BH 165-23-02
Project No.: 29381

Borehole 165-23-02
Runs 1 to 2
Depth 3.1 to 6.1 m
Elevation 104.9 to 101.9 m
Wet Sample



Highway 401 Underpass at Blue Church Road
(Site No. 16X-0165)
Assignment No. 4019-E-0010.2, GWP 4024-20-00

BH 165-23-02
Project No.: 29381



Appendix D.
Selected Site Photographs



Photo 1: Looking northwest toward existing bridge (2023/04/18)



Photo 2: Looking south along east side of existing bridge (2023/04/18)



Photo 3: Looking east along westbound Highway 401 (2023/04/18)



Photo 4: Looking south along north embankment (2023/04/18)