REGIONAL MUNICIPALITY OF NIAGARA
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS

V3.9 – Geotechnical Investigations

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LIST OF APPENDICES

V3.9.1

REGIONAL MUNICIPALITY OF NIAGARA
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS

Geotechnical Investigation

Geotechnical Baseline – Study Area

REPORT

Geotechnical Desktop Study Report

South Niagara Falls Wastewater Solutions Schedule C Class Environmental Assessment

Submitted to:

GM BluePlan Engineering Ltd.
3300 Highway 7
Vaughan, ON
L4K 4M3
Attn: Chris Campbell

Submitted by:

Golder Associates Ltd.
6925 Century Avenue, Suite #100, Mississauga, Ontario,
L5N 7K2, Canada

+1 905 567 4444

18104462

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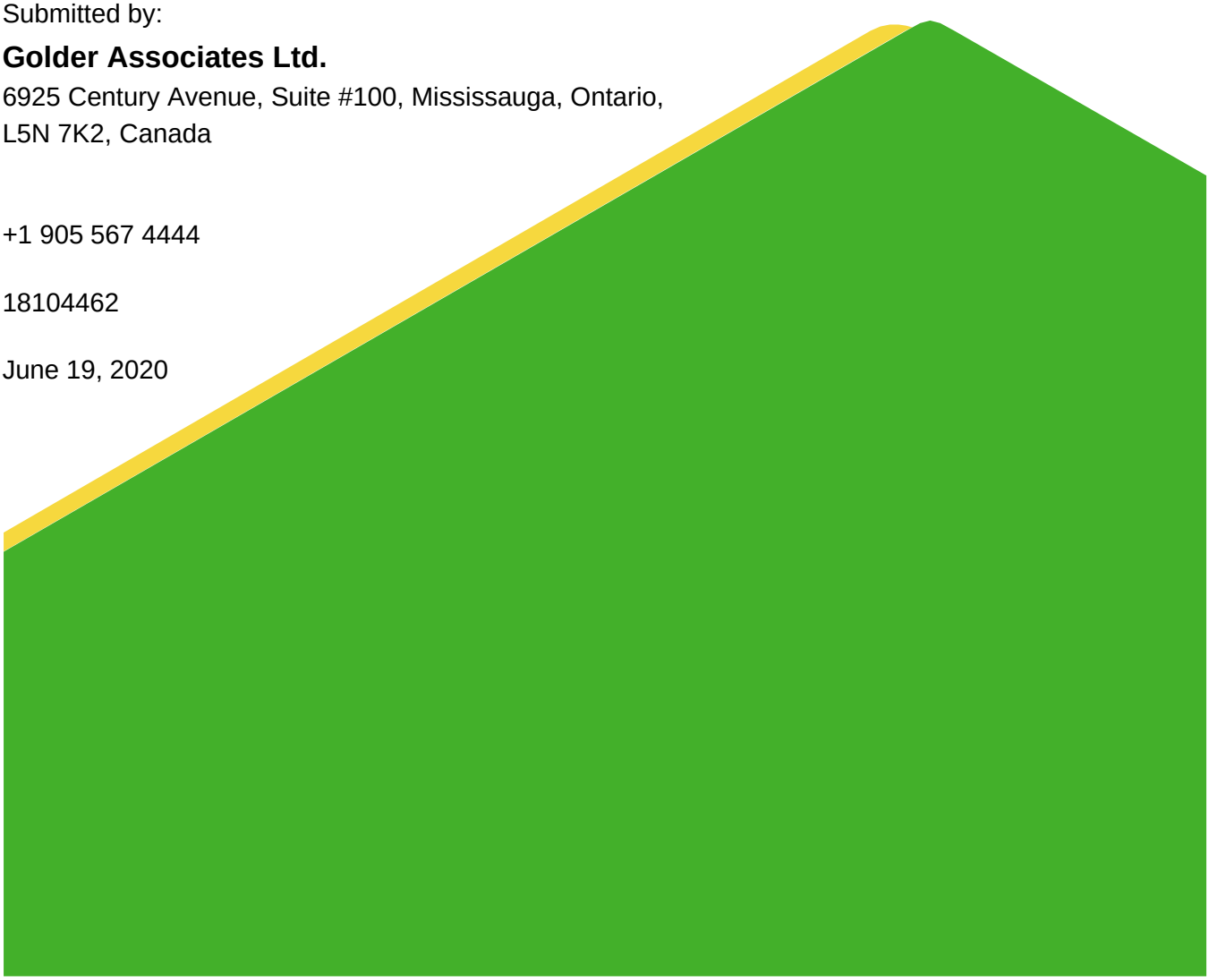

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APPENDIX A

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by GM BluePlan Engineering Ltd. (GMBP) to prepare a geotechnical desktop study report in support of the South Niagara Falls Wastewater Solutions Schedule 'C' Municipal Class Environmental Assessment (EA) Project (the Project).

This report was prepared for the exclusive use of GMBP and The Regional Municipality of Niagara (the Region) and is only intended to be used for planning and early stage design purposes as well as recommendations for aspects of future geotechnical investigations. Any use that a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of the third party. The report is based solely on the review of historical and publicly available information and data obtained by Golder and/or provided by GMBP/the Region as described in this report. Additional explorations of subsurface conditions will need to be carried out to better define the local geologic stratigraphy, groundwater levels, and the engineering properties of the subsurface materials for any further design activities.

The factual data, conceptual interpretations, considerations, and recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. In addition, this report should be read in conjunction with the "Important Information and Limitations of This Report" contained following the text of this report. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report.

2.0 PROJECT AND SITE DESCRIPTION

The Region recently completed their 2041 Growth Plan, which identified significant growth in residents and employment within the Municipality by 2041. In 2017, the Region updated their Water and Wastewater Master Servicing Plan Update (MSP), which evaluated the ability of existing and planned water and wastewater infrastructure to efficiently and effectively service the Region's existing users, service anticipated growth and evaluate and develop recommended strategies. The Region is to select a new Wastewater Treatment Plant (WWTP) within South Niagara Falls as the preferred South Niagara Falls servicing strategy to service the anticipated growth for Niagara Region. It is currently anticipated that the proposed new WWTP would be located on one of the Sites of Interest while associated infrastructure upgrades may take place within the wider Regional Study Area.

A key map of the Regional Study Area is shown on Figure 1. The approximate eastern and western extents of Regional Study Area reach from the Welland Canal area to the Niagara River, and extends to Church's Lane to the north and to Marshall Road in the south.

The Sites of Interest are located in the southern part of the Regional Study Area as shown on Figure 2. There are ten Sites of Interest (Sites 1 to 10), encompassing numerous lots and concessions for a total area of approximately 400.8 hectare (ha). Sites of Interest occupy the following lots and concessions:

- Sites 1, 3 to 7, and 9 occupy portions or the entirety of Lots 187, 197, 205, and 209-216, Geographic Township of Stamford, former County of Welland, now the City of Niagara Falls, Regional Municipality of Niagara.

- Sites 8 and 10 occupy portions of Lots 5-8, Broken Front on Chippawa Creek, Geographic Township of Willoughby, former County of Welland, now the City of Niagara Falls, Regional Municipality of Niagara.
- Site 2 occupies portions of Lot 5-6, Broken Front Concession, Geographic Township of Crowland, former County of Welland, now the City of Niagara Falls, Regional Municipality of Niagara.

The land use in the Sites of Interest is primarily agricultural with some industrial or residential developments throughout the Regional Study Area.

3.0 SOURCES OF INFORMATION

Databases of publicly available documents which were not subjected to non-disclosure agreements (NDAs) or containing any sensitive environmental (contamination) issues were reviewed in development of this desktop study. Water well records provided by the Ministry of the Environment, Conservation and Parks (MECP) and boreholes from the Ministry of Transportation of Ontario (MTO) database were used for this study. MTO boreholes are generally available along the Queen Elizabeth Way (QEW) and in some cases are far from the proposed alignment. Near the Welland Canal, available boreholes are about 50 m away from the proposed alignment. Where available, the overburden information from the MECP boreholes could not be relied upon since the MECP water wells were drilled primarily for measuring groundwater levels and the information related to the geotechnical conditions were not included during drilling.

The following documents, provided to Golder by GMBP, were also reviewed in preparation of this desktop geotechnical study report.

- Palmer Environmental Consulting Group Inc., “Geotechnical Memo in support of the Environmental Assessment Amendment – Niagara Falls WTP Water Intake, Niagara Falls, Ontario”, dated, July 8, 2011.
- Trow Associates Inc., “Preliminary Geotechnical Investigation Niagara Falls Water Treatment Plant, Intake Relocation, City of Niagara Falls, Ontario”, dated, August 8, 2007.
- Peto Associates Limited, “Soil Investigation Report High Lift Pumping Station, Niagara Falls, Ontario for Regional Municipality of Niagara Public Works Department”, dated January 1972.
- The Hydro-Electric Power Commission of Ontario “Canal Rehabilitation Plan and Geological Section Ch. 97+100 to Ch. 328+000, Sir Adam Back-Niagara G.S. No. 1, Drawing No. 7-3-1798-e”, dated May 1964.
- The Hydro-Electric Power Commission of Ontario “Canal Rehabilitation Cut-off Grout Curtain Closure Gates at Sta. 412+25, Sir Adam Back-Niagara G.S. No. 1, Drawing No. 7-3-1825”, dated September 1964.
- MTO Geocres No. 30M03-307, Thurber Engineering Ltd. titled “Foundation Investigation and Design Report Replacement of Welland River Twin Bridge Structures Queen Elizabeth Way (QEW) City of Niagara Falls, Ontario”, dated October 2, 2018.
- MTO Geocres No. 30M03-280, Golder Associates Ltd. titled “Preliminary Foundation Investigation and Design Report Tee Creek Bridges, QEW Structure Replacements at Black Creek, Lyons Creek, Seventh Street and Tee Creek, Regional Municipality of Niagara, G.W.P. 2177-08-00”, dated December 15, 2014.

- MTO Geocres No. 30M03-279, Golder Associates Ltd. titled “Preliminary Foundation Investigation and Design Report Lyons Creek Bridges (Site Nos. 36-66/1 and 36-66/2), QEW Structure Replacements at Black Creek, Lyons Creek, Seventh Street and Tee Creek, Regional Municipality of Niagara, G.W.P. 2177-08-00”, dated February 11, 2015.
- MTO Geocres No. 30M03-289, Terraprobe titled “Foundation Investigation and Design Report Tee, Lyons and Black Creeks Bridge Structures, Tee Creek North Bound Bridge Replacement Queen Elizabeth Way (QEW), MTO, Ontario “, dated July 15, 2016.
- MTO Geocres No. 30M03-288, Terraprobe titled “Foundation Investigation and Design Report Tee, Lyons and Black Creeks Bridge Structures, Lyons Creek North Bound and South Bound Bridge Replacements Queen Elizabeth Way (QEW), MTO, Ontario”, dated July 15, 2016.
- MTO Geocres No. 30M03-212, Ministry of Transportation Technical Memorandum Subject titled “South Approach Embankment, QEW SBL Structure Over Welland River and NYC Railway WO 93-11022, dated December 19, 1994.
- MTO Geocres No. 30M03-111, Ministry of Transportation Technical Memorandum Subject titled “Foundation Investigation Report for Proposed S-E.W. Ramp Crossing at Lyons Creek QEW and Lyons Creek Interchange District No. 4 (Hamilton), dated March 20, 1968.
- Chapman, L.J., and Putnam, D.F., “The Physiography of Southern Ontario, Ontario Geological Survey Special Volume 2, Third Edition, Ministry of Natural Resources, Ontario”, 1984.
- Karrow, P.F. and O.L. White. Urban Geology of Canadian Cities – Geological Association of Canada (GAC) Special Paper 42 (1998). Chapter on Urban Geology od St. Cathartines - Niagara Falls, Regional Niagara by J. Menzies and E.M. Taylor, pages 287 to 321.
- Ministry of Northern Development and Mines (MNDM). Bedrock Geology – Ontario Geological Survey 2011. 1:25000 Scale, Bedrock Geology of Ontario.
- MNDM. Surficial Geology – Ontario Geological Survey 2011. 1:250 000 Scale, Surficial Geology of Ontario.
- MECP Water Well Records.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 Regional Geology

The Regional Study Area is generally located within the Haldimand Clay Plain physiographic region with the northwest corner of the Regional Study Area extending to the Niagara Escarpment physiographic region to Lake Erie, as delineated in The Physiography of Southern Ontario (Chapman and Putnam 1984).

The Haldimand Clay Plain was submerged by glacial Lake Warren and much of it is covered by lacustrine clay deposits. The general topography of this region is generally flat, gentle sloping landscape dominated by clayey soils. At its highest ground where the Haldimand Clay Plain meets the Niagara Escarpment, recessional moraines were built by ice globe that occupies the Lake Ontario basin. Aside from the gravel hills of Fonthill, the moraines

consist of heavy boulder clay and have a much-subdued relief due to having been formed under water (Chapman and Putnam 1984). These clayey soils are presented by the fine-textured glaciolacustrine deposits that are mapped across the majority of the Haldimand Clay physiographic region. Coarser-textured soils were mapped beneath the central part of the Niagara Falls built up area while minor areas of alluvial deposits were mapped along the Region's creeks and rivers. The surficial geology mapping shows several areas of man-made deposits within the physiographic region as shown on Figure 3. These are interpreted to be areas of fill soils resulting from large scale construction works and industrial sites. Fill soils should also be expected near roadways. Most of the Sites of Interest are underlain by the fine-textured glaciolacustrine deposits with smaller area of alluvial deposits along the Welland River/Chippawa Creek.

The Niagara peninsula of the Niagara Escarpment consists of Palaeozoic sedimentary strata bedrock of the Silurian and Devonian age. The bed dips to the south under Lake Erie with a shallow inclination of approximately 5.7 m/km. The massive dolomitic limestone is from the Salina Formation within the Welland area and Salina Formation contains siltstone and calcareous shaly interbeds with occasional limestone layers and inclusions of gypsum within the dolomite. The lower Welland River subwatershed are predominantly underlain with bedrock from the middle to upper Silurian period; Eramosa Formation (dolostone), Guelph Formation (dolostone), and the Salina Formation (dolostone, shale and gypsum) as described in the Urban Geology of Canadian Cities (Menzies and Taylor 1984). These bedrock units are generally oriented horizontally with a slight dip towards the south as shown on Figure 4.

During the middle Silurian period, the tropical sea that covered the Niagara Peninsula deepened and the Guelph formation was deposited. The Guelph formation consists of reef and inter-reef deposits, characterized by tan, sugary, fossiliferous dolostone (Ministry of Northern Development 2011). During the upper Silurian period, the seas become shallower resulting in land surfaces becoming more arid, and deposition of shale and fine grained dolostone occurred. Restricted circulation and increased evaporation of the sea resulted in deposition of evaporites (halite, gypsum, and anhydrite), evaporitic carbonates and shales of the Salina Formation (Ministry of Northern Development 2011).

The bedrock predominately at the Sites of Interest is Guelph formation and Salina Formation composing of dolomite and shale.

4.2 Subsurface Conditions

A desktop review of the available subsurface information near the proposed trunk sewer alignment has been carried out, obtained from publicly available sources listed in Section 3.0. The available borehole records are contained in Appendix A. The detailed subsurface soil, bedrock and groundwater conditions encountered in the boreholes and the results of in situ and laboratory test results are provided on the borehole records. The borehole locations are shown on Figures 6 to 10 and projected on a profile line along the proposed trunk sewer alignment. Consideration should be given to the distance between the proposed alignment and WWTP and the borehole locations when interpreting the borehole information.

Based on available borehole information, the subsurface conditions along the proposed sewer alignment beneath any at/near surface layers of topsoil, organics and fill consist of up to about 30 m thick glaciolacustrine cohesive soils overlying a dense to very dense non-cohesive soils comprised of sandy silt to silty sand, with varying amount of gravel. Generally, the glaciolacustrine cohesive deposit has a consistency of very soft to very stiff.

The depth to bedrock (thickness of overburden soils) varies from approximately 12 m to deeper than 30 m along the proposed trunk sewer alignment.

A summary of subsurface conditions encountered in the available boreholes are provided below.

4.2.1 Fill

An approximately 2 m to 10 m thick layer of fill was encountered in boreholes advanced near the Welland Canal. The fill consists of cohesive and non-cohesive layers.

The Standard Penetration Test (SPT) “N”-values measured within the fill layer range from 2 blows to 63 blows per 0.3 m of penetration, suggesting loose to dense state of compactness.

4.2.2 Cohesive Layer

An approximately 9 m to 25 m thick layer of cohesive soils comprised of clayey silt to silty clay was encountered below the fill in the boreholes advanced near the Welland Canal. The deposit in places contain non-cohesive pockets of silt to sand.

The SPT “N”-values measured within the cohesive layer range from 1 blow to 26 blows per 0.3 m of penetration, suggesting a very soft to very stiff consistency. In situ shear vane tests were carried out within the cohesive layer and measured undrained shear strengths of 25 kPa to 96 kPa, indicating soft to stiff consistency.

4.2.3 Non-cohesive Layer

Below the cohesive layer, boreholes penetrated a layer of non-cohesive soils. The non-cohesive soils grades from silt to sandy silt to silt and sand to silty sand to sand and contain variable amount of gravel. The layer is up to about 10 m thick and overlies the bedrock at this site.

The SPT “N”-values measured within the non-cohesive layer range from 12 blows per 0.3 m of penetration to 100 blows per 0.02 m of penetration, indicating a compact to very dense compactness.

4.2.4 Bedrock Conditions

The overburden soils are underlain by bedrock of the Upper Silurian with sedimentary limestone, shale, sandstone, and dolostone.

Bedrock typically consists of completely weathered to fresh, grey, fine to very fine grained, medium strong to very strong limestone and dolomite layers and very weak to medium strong shale of Salina Formation. The bedrock generally transitions with depth from completely weathered at bedrock surface to fresh bedrock. Completely to highly weathered dolostone/residual soil/till and dolostone mixture zone should be expected at the overburden and bedrock interface.

Based on the available information, the depth of bedrock in the vicinity of the proposed sewer alignment generally ranges from 12 m (north) to deeper than 30 m (south) below ground surface. The depths to bedrock as encountered in the existing boreholes are shown on Figures 8 and 9.

It is possible that the upper few meters of bedrock may be more weathered and fractured. Below the more weathered/fractured zone, the bedrock is expected to be of moderately weathered to fresh.

Shale is expected to have strength grades of very weak (R1) to Medium Strong (R3) and limestone/siltstone is expected to have strength grades of Medium Strong (R3) to Very Strong (R5).

4.2.5 Groundwater Conditions

Based on the limited available information, the prevalent groundwater level at the Sites of Interest can be assumed to be approximately 1 m to 3 m below ground surface. The MECP water well record locations are provided in Figure 5. The groundwater level should be expected to fluctuate seasonally in response to changes in precipitation and snow melt and is expected to be higher during the spring and periods of precipitation. Perched groundwater conditions are expected within the till soils.

5.0 CONCEPTUAL DESIGN CONSIDERATIONS

It is understood that the Region proposes a new WWTP and associated infrastructure within one of the Sites of Interest. At the time of preparing this report, the final location of the WWTP is not confirmed.

5.1 Wastewater Treatment Facility Foundations

The details of the proposed wastewater facilities and associated structures are not available at the time of preparing this report. Considering the shallow soil conditions within the Regional Study Area, comprised of soft to stiff cohesive soils, it is expected that settlement sensitive structures would have to be supported on a system of deep foundations. Lightly loaded structures with more tolerance for settlements may be supported on conventional spread footings or deep foundations.

The final foundation types should be selected based on the subsurface conditions at the actual locations, structural loads, and settlement tolerance.

5.2 Trunk Sewer System

The conceptual sketches indicate that a trunk sewer system will be installed from Sta 0+00 to Sta 4+554 with the invert of the trunk sewer ranges from about 8 m to 17 m as shown on Figures 6 to 10. It is expected that the trunk sewer will be installed by means of tunnelling (i.e., trenchless method). This section of the report provides conceptual geotechnical recommendations and considerations as part of the Municipal Class EA for the installation of the sewer pipes.

5.2.1 Tunnelling Installations

Based on the proposed invert elevations and limited subsurface information, the trenchless installations will likely be excavated mostly through overburden soils with a possibility of installation in bedrock.

The project planning should consider the cost, schedule, space for entry and exit points, and availability of local contractors and equipment. The appropriateness of the trenchless installation methods will depend greatly on the subsurface conditions at the site and size of the installation (diameter and length). A detailed subsurface exploration should be carried out for trenchless installations.

The advantages, disadvantages, and risks/consequences associated with various trenchless construction methods, are compared in Table 1 on the basis of anticipated ground conditions, depth of cover, vertical and horizontal alignment, length of pipe installation, availability of equipment, and levels of risk of successfully completing the installation.

Table 1: Evaluation of Trenchless Installation Methods

Installation Method	Advantages	Disadvantages	Risk / Consequences
Micro-tunnelling Boring Machine (MTBM) with Slurry	■ Slurry-type MTBM is able to counterbalance earth (soil and/or rock) and groundwater pressures in a controlled manner, providing continuous face support and eliminating need for dewatering at the tunnel face along the alignment. ■ Can be steered continuously, providing good control over line and grade. ■ Tunnel is fully lined as excavation progresses (i.e., casing pipe is installed behind the MTBM during forward advancement). ■ No personnel entry is required. ■ Potential effects on structures and underground utilities next to the tunnel alignment can be better controlled than most other methods. ■ Machines can include rock-cutting face tools and internal crushers.	■ For some systems, slurry processing systems / separation plants are required along with additional working areas at shaft locations.	■ Relatively low risk of ground loss during tunnelling when a counterbalancing and appropriately viscous slurry and pressure is used. ■ Greater risk of fluid losses to the surface compared to other methods that do not utilize slurries, but the potential of fluid losses to the surface depends on slurry composition, viscosity, pressure and the existence of available pathways (old boreholes or wells, utility bedding, etc.). ■ Subsurface conditions at interface of fill and native ground may include risks of encountering wood debris or other materials that obstruct tunnelling.

Table 1: Evaluation of Trenchless Installation Methods

Installation Method	Advantages	Disadvantages	Risk / Consequences
Tunnelling with Earth-pressure balance tunnel boring machine (EPB TBM)	■ EPB TBM is able to counterbalance earth (soil and/or rock) and groundwater pressures in a controlled manner, providing continuous face support and eliminating the need for dewatering at the tunnel face along the alignment. ■ Can be steered continuously, providing good control over line and grade. ■ Tunnel is fully lined as excavation progresses (i.e., precast segmental liner is installed behind the EPB TBM during forward advancement). ■ Potential effects on structures and underground utilities next to the tunnel alignment can be better controlled than most other methods. ■ Machines can include rock-cutting face tools and older systems that use load or pressure-controlled gates for spoil discharge from forward chamber can pass some larger potential obstructions depending on face opening and relieving gate sizes.	■ Susceptible to ground losses depending on operator control of face pressures, relieving gate or screw conveyor operations. ■ Addition of appropriate conditioning agents (e.g., bentonite) may be required to modify spoil for appropriate consistency and face pressure control.	■ Relatively low risk of ground loss during tunnelling when a counterbalancing face pressure is used, and conditioning agents may be required.

Table 1: Evaluation of Trenchless Installation Methods

Installation Method	Advantages	Disadvantages	Risk / Consequences
Rock Tunnel Boring Machine (TBM)	■ Man-entry and access to the tunnel face is possible.	■ Rock TBM is not suitable for high groundwater level and gases present in the shale bedrock. This method is not suitable for tunnelling on overburden soils.	■ The tunnel face is not pressurized. Not suitable for mixed face conditions. Groundwater need to be controlled.
Traditional Jack and Bore	■ Tunnel is fully lined as excavation progresses (i.e., casing pipe is installed behind the boring head during forward advancement).	■ Traditional jack and bore is considered not suitable for granular material below water levels, or in granular soils above water levels if a plug of soil cannot be maintained in lead end of casing. ■ Traditional jack and bore is considered not suitable for squeezing soils (soft cohesive soils). ■ Difficult to control line and grade using jack and bore, potentially requiring installation of a larger culvert/casing pipe than that specified to accommodate variation during installation.	■ Significant potential for loss of ground into casing/pipe without dewatering of bore alignment, especially in wet/flowing conditions and even with plug of soil ahead of augers. ■ Obstructions can result in deflection of the casing/pipe resulting in misalignment of the sewer. Cutter head can be specified to have capability for cutting through boulders.

Table 1: Evaluation of Trenchless Installation Methods

Installation Method	Advantages	Disadvantages	Risk / Consequences
Pipe Ramming	■ Less risk of subsidence above sewer alignment when compared to jack and bore installation methods. ■ Better suited for penetrating through potential obstructions such as cobbles and boulders when compared to jack and bore methods. ■ Better suited to site soils below the groundwater level when compared to jack and bore methods. ■ Potentially slightly smaller footprint for entry/exit shafts than that required for jack and bore and MTBM.	■ Limited drive length. ■ Difficult to control line and grade using pipe ramming. ■ Potential for heaving at ground surface (where cover is thin) as a long plug of soil is maintained inside pipe – may require periodic removal of soil plug which is not recommended in saturated ground. ■ Ramming vibration could affect adjacent service lines (if any). ■ Noise can be a public nuisance.	■ Less risk of ground loss during tunnelling when compared to jack and bore methods. ■ Obstructions can result in deflection of the casing/pipe resulting in misalignment of the sewer. ■ Vibration from pipe ramming may impact adjacent buried service lines.

Table 1: Evaluation of Trenchless Installation Methods

Installation Method	Advantages	Disadvantages	Risk / Consequences
Jack and Bore with Guided Boring Machine (Pilot Tube Boring)	■ Tunnel is fully lined as excavation progresses (i.e., sewer pipe is installed behind the boring head during forward advancement). ■ Pilot tube is steered, providing better line and grade control for final installation as compared to traditional jack and bore.	■ Jack and bore with guided boring machine (GBM) are no more suitable to penetrate through granular material above and below the water table when compared to traditional jack and bore. ■ Dewatering likely required along tunnel alignment to be used successfully. ■ Very stiff/hard or very dense subsurface material may limit penetration of the pilot tube, depending on equipment used for advancement of pilot tube.	■ Significant potential for loss of ground into casing/pipe without dewatering of bore alignment, especially in wet/flowing conditions and even with plug of soil ahead of auger. ■ Obstructions can result in deflection of the pilot tube resulting in misalignment of the sewer, although this can be better managed than for traditional jack and bore. ■ Unexpectedly hard/dense ground conditions can halt penetration of the pilot tube, depending on equipment details.

Table 1: Evaluation of Trenchless Installation Methods

Installation Method	Advantages	Disadvantages	Risk / Consequences
Mechanically Assisted and Hand Mining (Shield Tunnelling)	■ Obstructions can be easily removed by personnel at the tunnel face.	■ Typically, shield mining is not considered suitable for "flowing" conditions unless dewatering and special provisions are used to manage groundwater issues or squeezing conditions. ■ Dewatering likely required along alignment to be used successfully, particularly if the tunnel is to be advanced through both existing and new embankments given water levels at north end. ■ "Hooded" or angled-face shield required, and poling plates or spilling needed to control ravelling of ground near crown and above spring-line of tunnel.	■ Significant potential for loss of ground into the tunnel without proactive control of saturated conditions.

5.2.2 SHAFT DESIGN and CONSTRUCTION CONSIDERATIONS

Trenchless installation requires shafts as entry and exit points. The construction of shafts should consider subsurface soil and groundwater conditions. At this stage, it is recommended to assume that the support of excavations for the shafts should be constructed using a relatively watertight structure to minimize groundwater seepage into the excavation and ground movements adjacent to the shafts.

6.0 RECOMMENDED GEOTECHNICAL INVESTIGATIONS DURING DESIGN PHASES

6.1 Data Gap

The available geotechnical and hydrogeological information is limited along the proposed tunnel alignment. Most of the publicly available boreholes along the alignment were drilled to the north and south of Welland Canal, located approximately 50 m away from the proposed alignment. The location of MTO boreholes are provided in Figures 6 to 11 and borehole logs are provided in Appendix A. The database search provided very limited background geotechnical information within the study areas and very limited borehole information was available near the exit location of the sewer alignment, as shown on Figures 9 and 10, which present boreholes located approximately 700 m away from the sewer alignment.

6.2 Geotechnical and Hydrogeological Program

Due to insufficient information available for the design development, the following section provides information for the proposed geotechnical and hydrogeological investigations within the boundaries of the Site. During the design phases, site-specific geotechnical investigations and in-situ and laboratory testing will be required to assist with subsurface risk management and construction cost objectives. Consideration should be given to conducting the following tests during the geotechnical field surveys:

1) Conventional boreholes including SPT to obtained SPT and undisturbed soil samples from subsurface strata and Cone Penetration Tests (CPT) through very soft to firm/very loose to compact layers.

2) Continuous PQ or Sonic boreholes at shaft locations.

3) Monitoring well installations and in-situ hydrogeological testing of soil and rock including pumping tests.

4) Laboratory classification testing including water content determination; Atterberg limits tests; and grain size distributions.

5) Laboratory and in-situ strength testing in soil and bedrock.

7.0 CLOSURE

We trust this report these meets your current needs. If you have any questions, please contact the undersigned.

Signature Page

Golder Associates Ltd.

Manisha Ahuja, P.Eng., P.E.
Geotechnical Engineer

Dave Walters, Ph.D., P.Eng.
Senior Geotechnical Engineer, Principal

MA/AV/DW/ml/wlm

https://golderassociates.sharepoint.com/sites/29902g/technical work/02_environmental/06_geotechnical/final/18104462-r-revd-19june2020-geotechstudy-snf wwf.docx

IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

Standard of Care: Golder Associates Ltd. (Golder) has prepared this report in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering and science professions currently practising under similar conditions in the jurisdiction in which the services are provided, subject to the time limits and physical constraints applicable to this report. No other warranty, expressed or implied is made.

Basis and Use of the Report: This report has been prepared for the specific site, design objective, development and purpose described to Golder by the Client. The factual data, interpretations and recommendations pertain to a specific project as described in this report and are not applicable to any other project or site location. Any change of site conditions, purpose, development plans or if the project is not initiated within eighteen months of the date of the report may alter the validity of the report. Golder cannot be responsible for use of this report, or portions thereof, unless Golder is requested to review and, if necessary, revise the report.

The information, recommendations and opinions expressed in this report are for the sole benefit of the Client. No other party may use or rely on this report or any portion thereof without Golder's express written consent. If the report was prepared to be included for a specific permit application process, then upon the reasonable request of the client, Golder may authorize in writing the use of this report by the regulatory agency as an Approved User for the specific and identified purpose of the applicable permit review process. Any other use of this report by others is prohibited and is without responsibility to Golder. The report, all plans, data, drawings and other documents as well as all electronic media prepared by Golder are considered its professional work product and shall remain the copyright property of Golder, who authorizes only the Client and Approved Users to make copies of the report, but only in such quantities as are reasonably necessary for the use of the report by those parties. The Client and Approved Users may not give, lend, sell, or otherwise make available the report or any portion thereof to any other party without the express written permission of Golder. The Client acknowledges that electronic media is susceptible to unauthorized modification, deterioration and incompatibility and therefore the Client can not rely upon the electronic media versions of Golder's report or other work products.

The report is of a summary nature and is not intended to stand alone without reference to the instructions given to Golder by the Client, communications between Golder and the Client, and to any other reports prepared by Golder for the Client relative to the specific site described in the report. In order to properly understand the suggestions, recommendations and opinions expressed in this report, reference must be made to the whole of the report. Golder can not be responsible for use of portions of the report without reference to the entire report.

Unless otherwise stated, the suggestions, recommendations and opinions given in this report are intended only for the guidance of the Client in the design of the specific project. The extent and detail of investigations, including the number of test holes, necessary to determine all of the relevant conditions which may affect construction costs would normally be greater than has been carried out for design purposes. Contractors bidding on, or undertaking the work, should rely on their own investigations, as well as their own interpretations of the factual data presented in the report, as to how subsurface conditions may affect their work, including but not limited to proposed construction techniques, schedule, safety and equipment capabilities.

Soil, Rock and Ground Water Conditions: Classification and identification of soils, rocks, and geologic units have been based on commonly accepted methods employed in the practice of geotechnical engineering and related disciplines. Classification and identification of the type and condition of these materials or units involves judgment, and boundaries between different soil, rock or geologic types or units may be transitional rather than abrupt. Accordingly, Golder does not warrant or guarantee the exactness of the descriptions.

Special risks occur whenever engineering or related disciplines are applied to identify subsurface conditions and even a comprehensive investigation, sampling and testing program may fail to detect all or certain subsurface conditions. The environmental, geologic, geotechnical, geochemical and hydrogeologic conditions that Golder interprets to exist between and beyond sampling points may differ from those that actually exist. In addition to soil variability, fill of variable physical and chemical composition can be present over portions of the site or on adjacent properties. The professional services retained for this project include only the geotechnical aspects of the subsurface conditions at the site, unless otherwise specifically stated and identified in the report. The presence or implication(s) of possible surface and/or subsurface contamination resulting from previous activities or uses of the site and/or resulting from the introduction onto the site of materials from off-site sources are outside the terms of reference for this project and have not been investigated or addressed.

Soil and groundwater conditions shown in the factual data and described in the report are the observed conditions at the time of their determination or measurement. Unless otherwise noted, those conditions form the basis of the recommendations in the report. Groundwater conditions may vary between and beyond reported locations and can be affected by annual, seasonal and meteorological conditions. The condition of the soil, rock and groundwater may be significantly altered by construction activities (traffic, excavation, groundwater level lowering, pile driving, blasting, etc.) on the site or on adjacent sites. Excavation may expose the soils to changes due to wetting, drying or frost. Unless otherwise indicated the soil must be protected from these changes during construction.

Sample Disposal: Golder will dispose of all uncontaminated soil and/or rock samples 90 days following issue of this report or, upon written request of the Client, will store uncontaminated samples and materials at the Client's expense. In the event that actual contaminated soils, fills or groundwater are encountered or are inferred to be present, all contaminated samples shall remain the property and responsibility of the Client for proper disposal.

Follow-Up and Construction Services: All details of the design were not known at the time of submission of Golder's report. Golder should be retained to review the final design, project plans and documents prior to construction, to confirm that they are consistent with the intent of Golder's report.

During construction, Golder should be retained to perform sufficient and timely observations of encountered conditions to confirm and document that the subsurface conditions do not materially differ from those interpreted conditions considered in the preparation of Golder's report and to confirm and document that construction activities do not adversely affect the suggestions, recommendations and opinions contained in Golder's report. Adequate field review, observation and testing during construction are necessary for Golder to be able to provide letters of assurance, in accordance with the requirements of many regulatory authorities. In cases where this recommendation is not followed, Golder's responsibility is limited to interpreting accurately the information encountered at the borehole locations, at the time of their initial determination or measurement during the preparation of the Report.

Changed Conditions and Drainage: Where conditions encountered at the site differ significantly from those anticipated in this report, either due to natural variability of subsurface conditions or construction activities, it is a condition of this report that Golder be notified of any changes and be provided with an opportunity to review or revise the recommendations within this report. Recognition of changed soil and rock conditions requires experience and it is recommended that Golder be employed to visit the site with sufficient frequency to detect if conditions have changed significantly.

Drainage of subsurface water is commonly required either for temporary or permanent installations for the project. Improper design or construction of drainage or dewatering can have serious consequences. Golder takes no responsibility for the effects of drainage unless specifically involved in the detailed design and construction monitoring of the system.

FIGURES

650000

660000

4710000

TOWN OF NIAGARA-ON-THE-LAKE

CITY OF ST. CATHARINES

CITY OF THOROLD

CITY OF NIAGARA FALLS

CITY OF WELLAND

UNITED STATES

CANADA

GLENDALE AVENUE
MERRITT STREET
HIGHWAY 406
SAINT DAVIDS ROAD
TAYLOR ROAD
MEWBURN ROAD
MOUNTAIN ROAD
ST PAUL AVENUE
CHURCHS LANE
SWAYZE DRIVE
SINNICKS AVENUE
PORTAGE ROAD
STANLEY AVENUE
WHIRLPOOL ROAD
NIAGARA RIVER PARKWAY
COLLIER ROAD SOUTH
RICHMOND STREET
HIGHWAY 58
MOUNT CARMEL BOULEVARD
DORCHESTER ROAD
THOROLD STONE ROAD
KALAR ROAD
GARNER ROAD
MONTROSE ROAD
BRIDGE STREET
VICTORIA AVENUE
RIVER ROAD
BEAVERDAMS ROAD
NIAGARA FALLS ROAD
MORRISON STREET
VALLEY WAY
FALLS AVENUE
ALLANBURG ROAD
HIGHWAY 59
HIGHWAY 420
DRUMMOND ROAD
MAIN STREET
LUNDYS LANE
BEECHWOOD ROAD
HIGHWAY 20
THOROLD TOWNLINE ROAD
DUNN STREET
BARRON ROAD
MCLEOD ROAD
QUEEN ELIZABETH WAY
ALLANPORT ROAD
BROWN ROAD
MAIN STREET CHIPPAWA
CHIPPAWA PARKWAY
CHIPPAWA CREEK ROAD
LYONS CREEK ROAD
WILLOUGHBY DRIVE
RIVER STREET
BIGGAR ROAD
SODOM ROAD
MOYER ROAD
HIGHWAY 406
MARSHALL ROAD
SCHISLER ROAD

0 1 2 3

1:60,000 KILOMETRES

LEGEND

- SITES OF INTEREST
- REGIONAL STUDY AREA
- MUNICIPAL BOUNDARY

REFERENCE(S)

1. BASE DATA - MNRF LIO, OBTAINED 2019
2. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2019
3. IMAGERY: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
REGIONAL STUDY AREA LOCATION PLAN

CONSULTANT
GOLDER

YYYY-MM-DD	2020-04-27
DESIGNED	PR
PREPARED	PR
REVIEWED	MA
APPROVED	-

PROJECT NO.	CONTROL	REV.	FIGURE
18104462	0008	0.0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ANSI B

0 25mm

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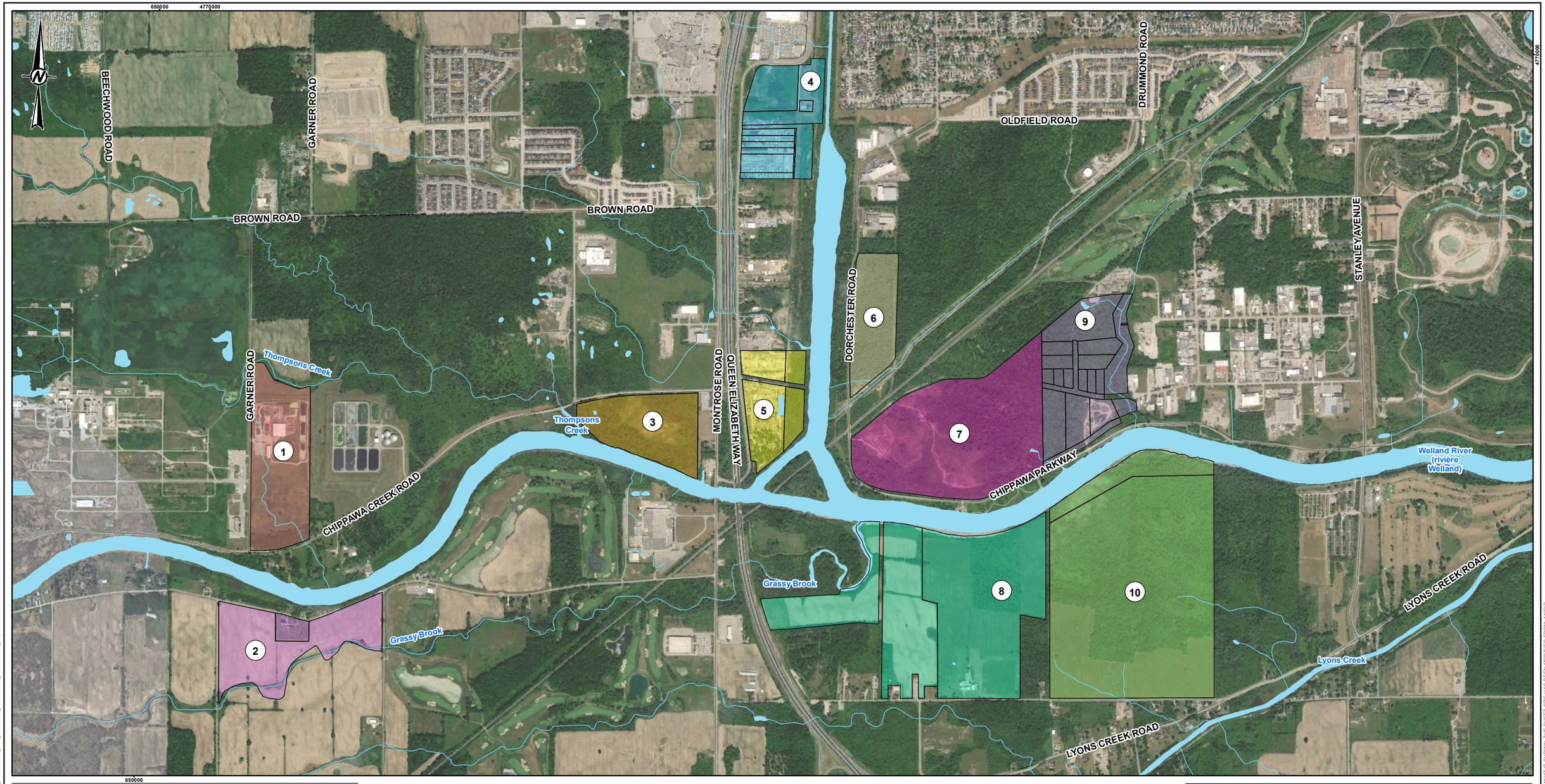

LEGEND

- WATERCOURSE
- WATERBODY
- (1) SITES OF INTEREST ID
- SITES OF INTEREST
- SITE 1
- SITE 2
- SITE 3
- SITE 4
- SITE 5
- SITE 6
- SITE 7
- SITE 8
- SITE 9
- SITE 10

REFERENCE(S)

1. BASE DATA - MNRF LIO, OBTAINED 2019
2. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2019
3. IMAGERY: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

0 500 1,000
1:19,000 METRES

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

CONSULTANT
GOLDER

YYYY-MM-DD	2020-04-27
DESIGNED	PR
PREPARED	PR
REVIEWED	AM
APPROVED	-

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
SITES OF INTEREST

PROJECT NO.	CONTROL	REV.	FIGURE
18104462	0001	0.0	2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

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650000 4770000

BEECHWOOD ROAD
GARNER ROAD
BROWN ROAD
BROWN ROAD
GARNER ROAD
Thompsons Creek
CHIPPAWA CREEK ROAD
Thompsons Creek
MONTROSE ROAD
QUEEN ELIZABETH WAY
DORCHESTER ROAD
OLDFIELD ROAD
DRUMMOND ROAD
STANLEY AVENUE
CHIPPAWA PARKWAY
Welland River (rivière Welland)
Grassy Brook
Grassy Brook
LYONS CREEK ROAD
Lyons Creek
LYONS CREEK ROAD

8a
8a
8a
8a
21
21
21
21
19
19
19

1
2
3
4
5
6
7
8
9
10

650000

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

LEGEND

- ROAD
- WATERCOURSE
- WATERBODY
- (1) SITES OF INTEREST ID
- SITES OF INTEREST

SURFICIAL GEOLOGY

- 8A MASSIVE TO WELL LAMINATED - FINE-TEXTURED GLACIOLACUSTRINE DEPOSITS: SILT AND CLAY, MINOR SAND AND GRAVEL
- 19: MODERN ALLUVIAL DEPOSITS
- 21: MAN-MADE DEPOSITS

REFERENCE(S)

1. BASE DATA - MNRF LIO, OBTAINED 2019
2. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2019
3. SURFICIAL GEOLOGY - MINISTRY OF NORTHERN DEVELOPMENT AND MINES, 1:250 000 SCALE SURFICIAL GEOLOGY OF ONTARIO; ONTARIO GEOLOGICAL SURVEY
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

0 500 1,000
1:19,000 METRES

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

CONSULTANT
GOLDER

YYYY-MM-DD	2020-04-27
DESIGNED	PR
PREPARED	PR
REVIEWED	AM
APPROVED	-

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
SURFICIAL GEOLOGY

PROJECT NO.	CONTROL	REV.	FIGURE
18104462	0001	0.0	3

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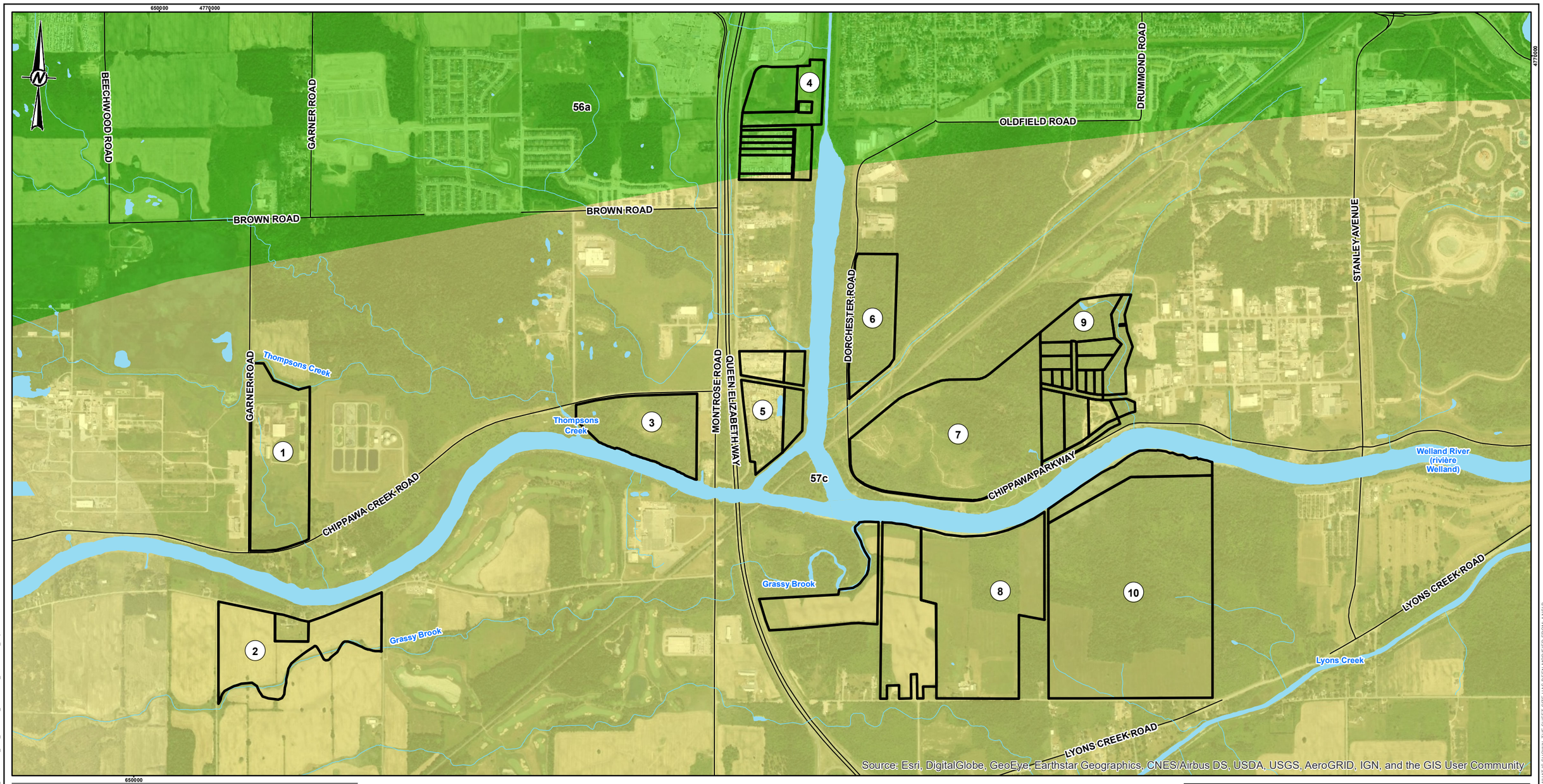

LEGEND

- ROAD
- WATERCOURSE
- WATERBODY
- (1) SITES OF INTEREST ID
- SITES OF INTEREST

BEDROCK GEOLOGY

- 57C SALINA FM.
- 56A GUELPH FM.

REFERENCE(S)

1. BASE DATA - MNRF LIO, OBTAINED 2019
2. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2019
3. BEDROCK GEOLOGY - ONTARIO GEOLOGICAL SURVEY 2011. 1:250 000 SCALE BEDROCK GEOLOGY OF ONTARIO; ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE---DATA 126-REVISION 1.
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

0 500 1,000
1:19,000 METRES

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

CONSULTANT
GOLDER

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PREPARED	PR
REVIEWED	AM
APPROVED	-

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
BEDROCK GEOLOGY

PROJECT NO.	CONTROL	REV.	FIGURE
18104462	0001	0.0	4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

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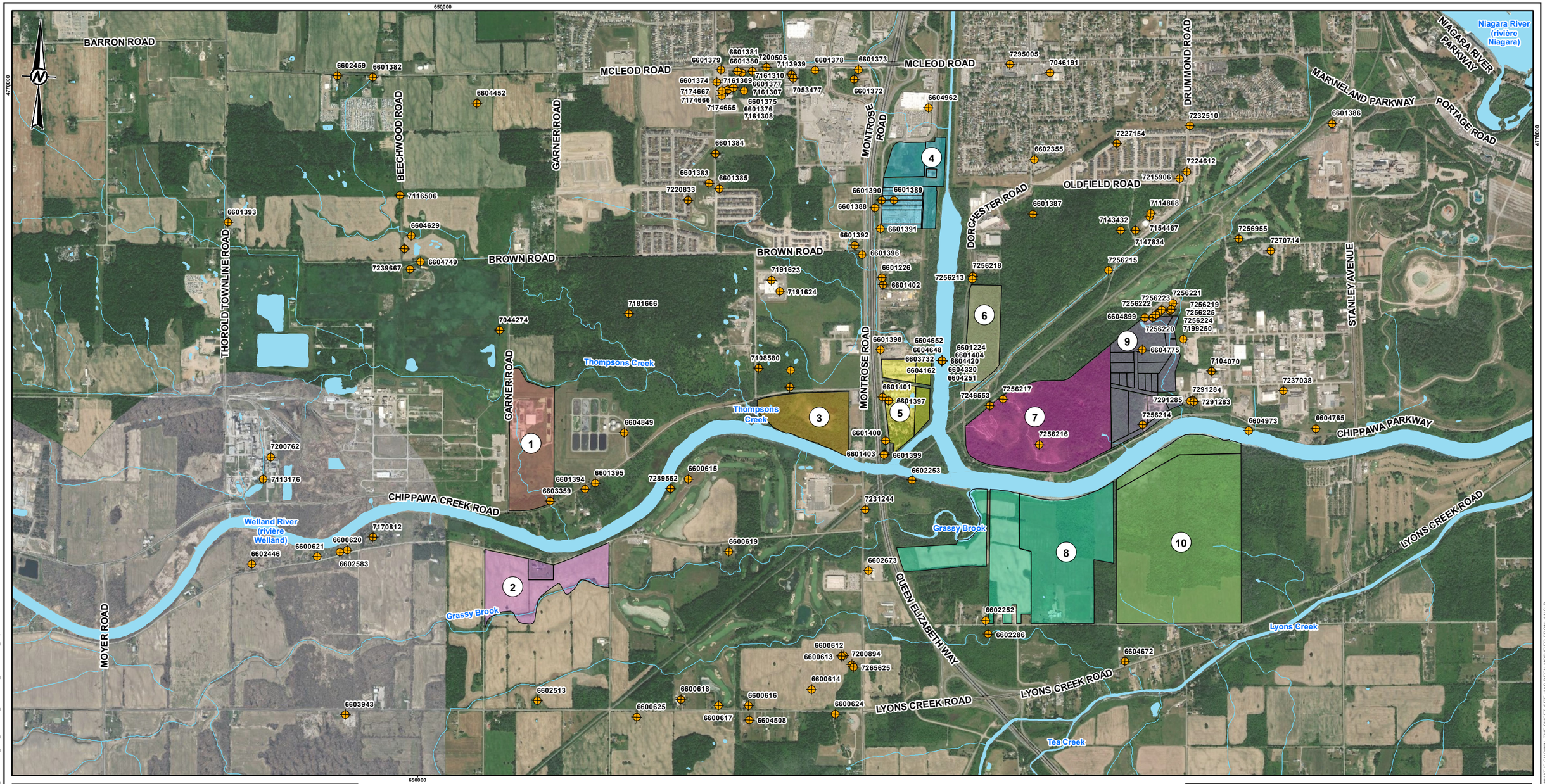

LEGEND

- MECP WATER WELL RECORD LOCATION
- WATERCOURSE
- WATERBODY
- (1) SITES OF INTEREST ID
- SITES OF INTEREST
- SITE 1
- SITE 2
- SITE 3
- SITE 4
- SITE 5
- SITE 6
- SITE 7
- SITE 8
- SITE 9
- SITE 10

REFERENCE(S)

1. BASE DATA - MNRF LIO, OBTAINED 2019
2. PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY, © QUEENS PRINTER 2019
3. IMAGERY: SOURCE: ESRI, DIGITALGLOBE, GEOEYE, EARTHSTAR GEOGRAPHICS, CNES/AIRBUS DS, USDA, USGS, AEROGRID, IGN, AND THE GIS USER COMMUNITY
4. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

0 500 1,000
1:25,000 METRES

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

CONSULTANT
GOLDER

YYYY-MM-DD	2020-04-27
DESIGNED	PR
PREPARED	PR
REVIEWED	AM
APPROVED	-

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
MECP WATER WELL RECORD LOCATION

PROJECT NO.	CONTROL	REV.	FIGURE
18104462	0001	0.0	5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

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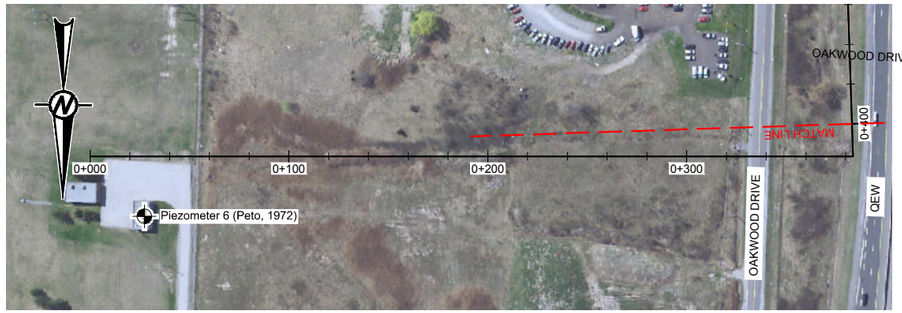
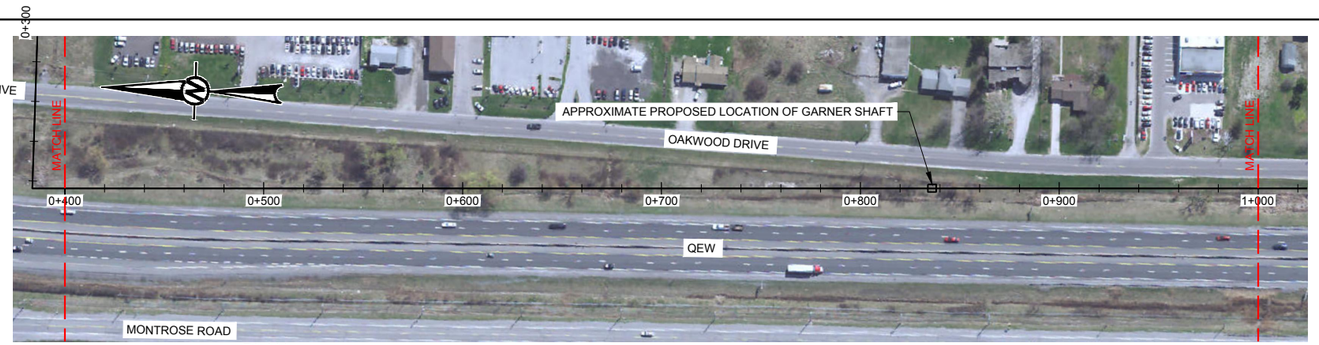
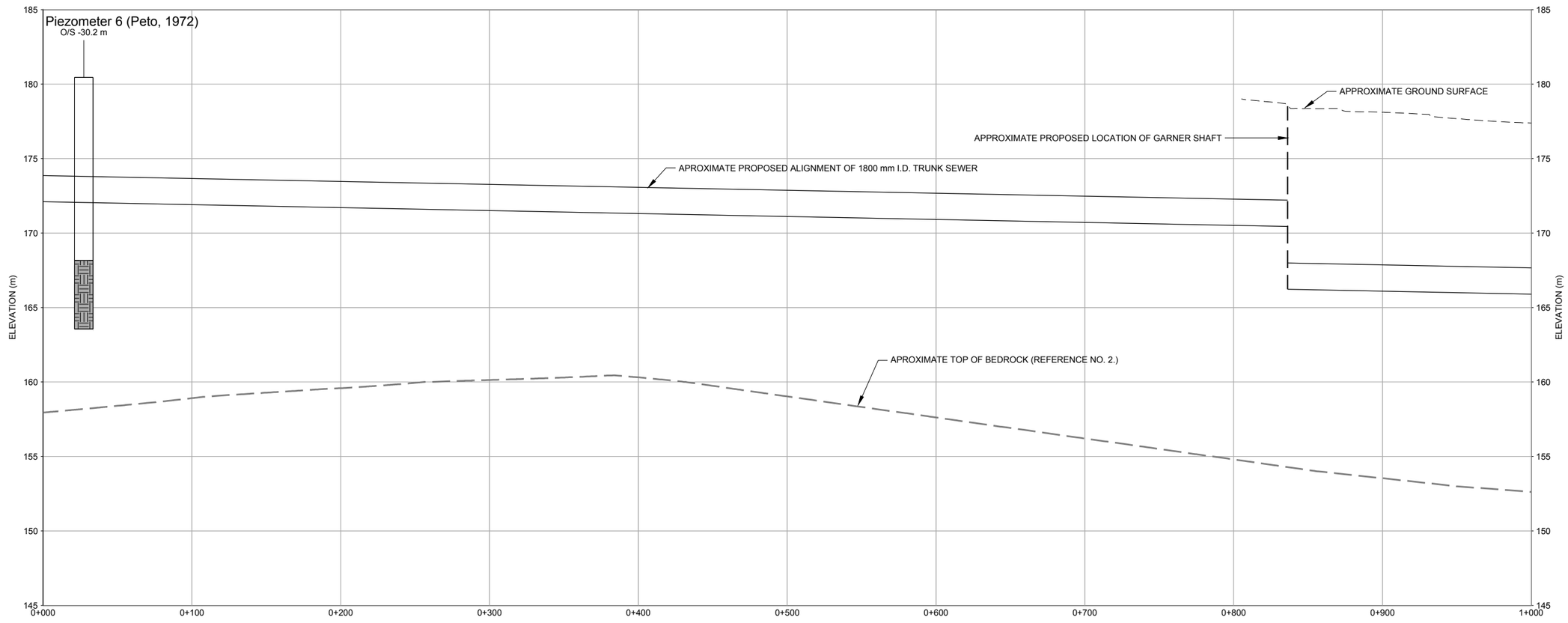




PLAN



PROFILE A-A'

LEGEND

- ASPHALT
- CONCRETE
- OVERBURDEN
- FILL
- TOPSOIL
- GRAVEL
- SAND AND GRAVEL
- (ML/SM) SILT AND SAND TO (SM) SILTY SAND TO (SP) SAND
- (ML) SILT
- ORGANIC SILT
- SILT TILL
- ORGANIC CLAYEY SILT
- (CL) CLAYEY SILT TO (CI) SILTY CLAY
- CLAYEY SILT TILL
- BEDROCK

0 5 10
1:300 VERTICAL METRES

0 50 100
1:3,000 HORIZONTAL METRES

REFERENCE(S)

1. EXISTING GROUND CONTOURS AND APPROXIMATE 1800 mm I.D. TRUNK SEWER PROVIDED BY GM BLUEPLAN ENGINEERING LIMITED, RECEIVED FEBRUARY 13, 2020. EXISTIN GROUND SURFACE WAS NOT AVAILABLE BETWEEN STA. 0+000 AND STA. 0+800.
2. BEDROCK TOPOGRAPHY AND OVERBURDEN THICKNESS MAPPING, SOUTHERN ONTARIO; ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE-DATA 207 (MRD 207), 2006.
3. REGION OF NIAGARA, SOUTHWESTERN ONTARIO ORTHOPHOTOGRAPHY PROJECT (SWOOP), 2015.

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

CONSULTANT
GOLDER

YYYY-MM-DD	2020-06-16
DESIGNED	
PREPARED	DD
REVIEWED	MA
APPROVED	

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
PROFILE A-A' - STA. 0+000 TO STA. 1+000

PROJECT NO.	PHASE	REV.	FIGURE
18104462	(3000)	A	6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

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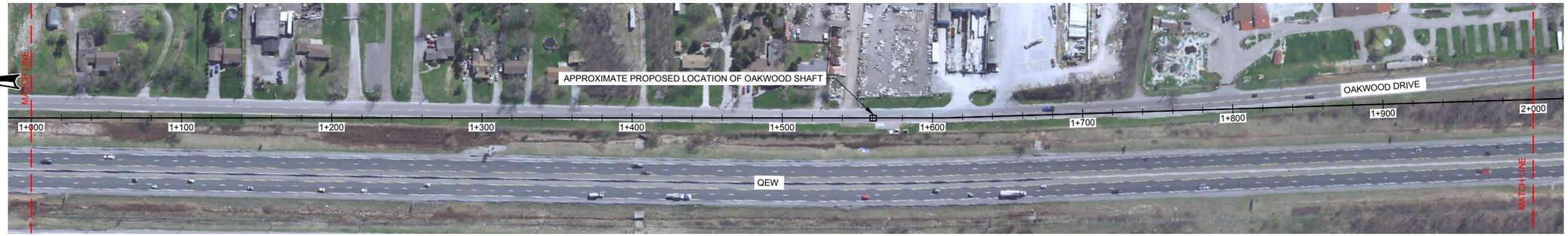

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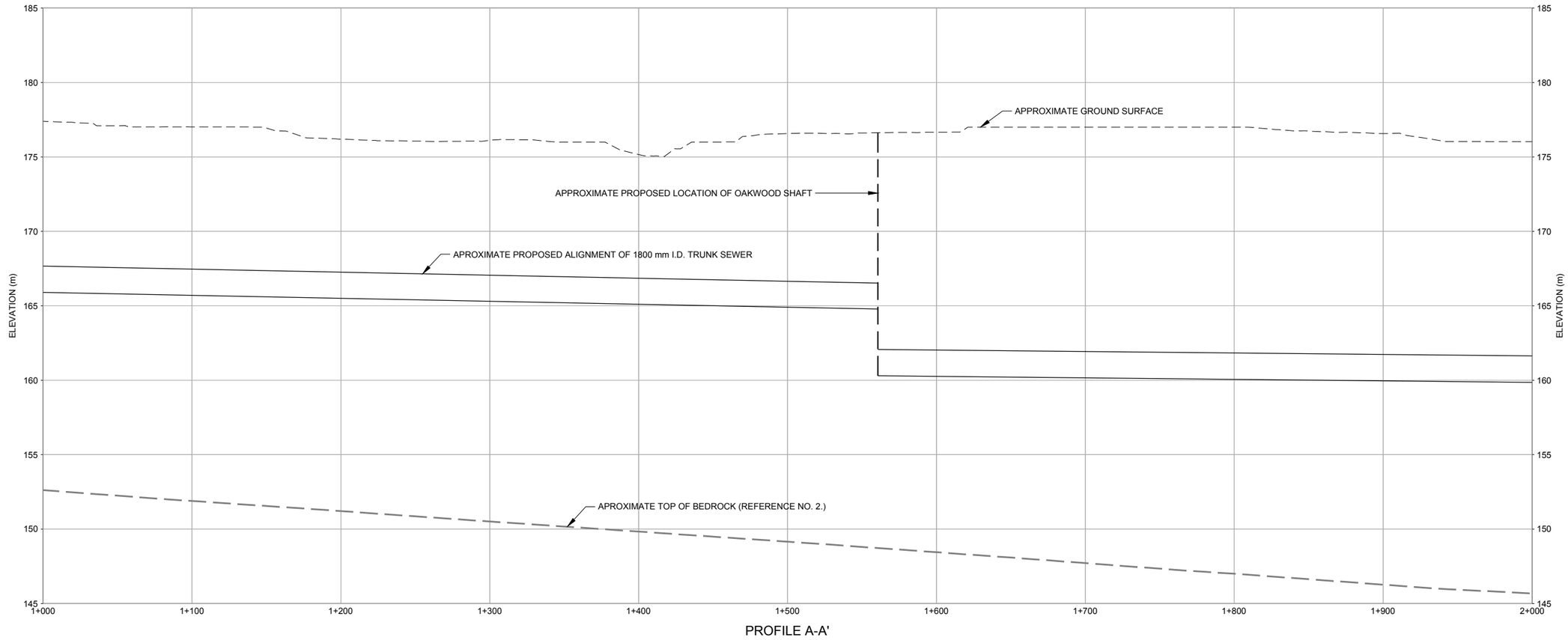

PROFILE A-A'

LEGEND

- ASPHALT
- CONCRETE
- OVERBURDEN
- FILL
- TOPSOIL
- GRAVEL
- SAND AND GRAVEL
- (ML/SM) SILT AND SAND TO (SM) SILTY SAND TO (SP) SAND
- (ML) SILT
- ORGANIC SILT
- SILT TILL
- ORGANIC CLAYEY SILT
- (CL) CLAYEY SILT TO (CI) SILTY CLAY
- CLAYEY SILT TILL
- BEDROCK

0 5 10
1:300 VERTICAL METRES

0 50 100
1:3,000 HORIZONTAL METRES

REFERENCE(S)

1. EXISTING GROUND CONTOURS AND APPROXIMATE 1800 mm I.D. TRUNK SEWER PROVIDED BY GM BLUEPLAN ENGINEERING LIMITED, RECEIVED FEBRUARY 13, 2020.
2. BEDROCK TOPOGRAPHY AND OVERBURDEN THICKNESS MAPPING, SOUTHERN ONTARIO; ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE-DATA 207 (MRD 207), 2006.
3. REGION OF NIAGARA, SOUTHWESTERN ONTARIO ORTHOPHOTOGRAPHY PROJECT (SWOOP), 2015.

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

CONSULTANT
GOLDER

YYYY-MM-DD	2020-06-16
DESIGNED	
PREPARED	DD
REVIEWED	MA
APPROVED	

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
PROFILE A-A' - STA. 1+000 TO STA. 2+000

PROJECT NO.	PHASE	REV.	FIGURE
18104462	(3000)	A	7

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

0 25 mm

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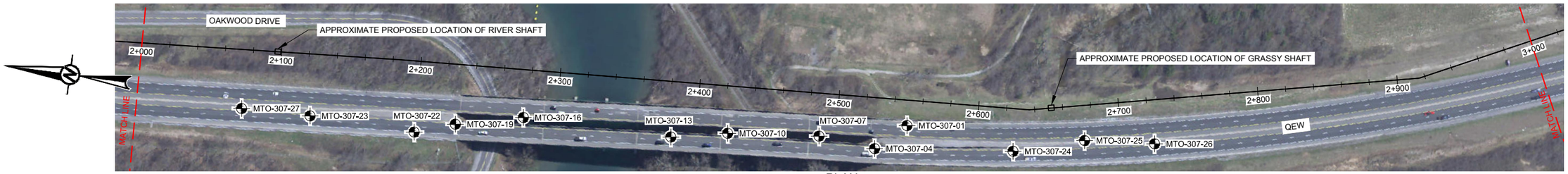

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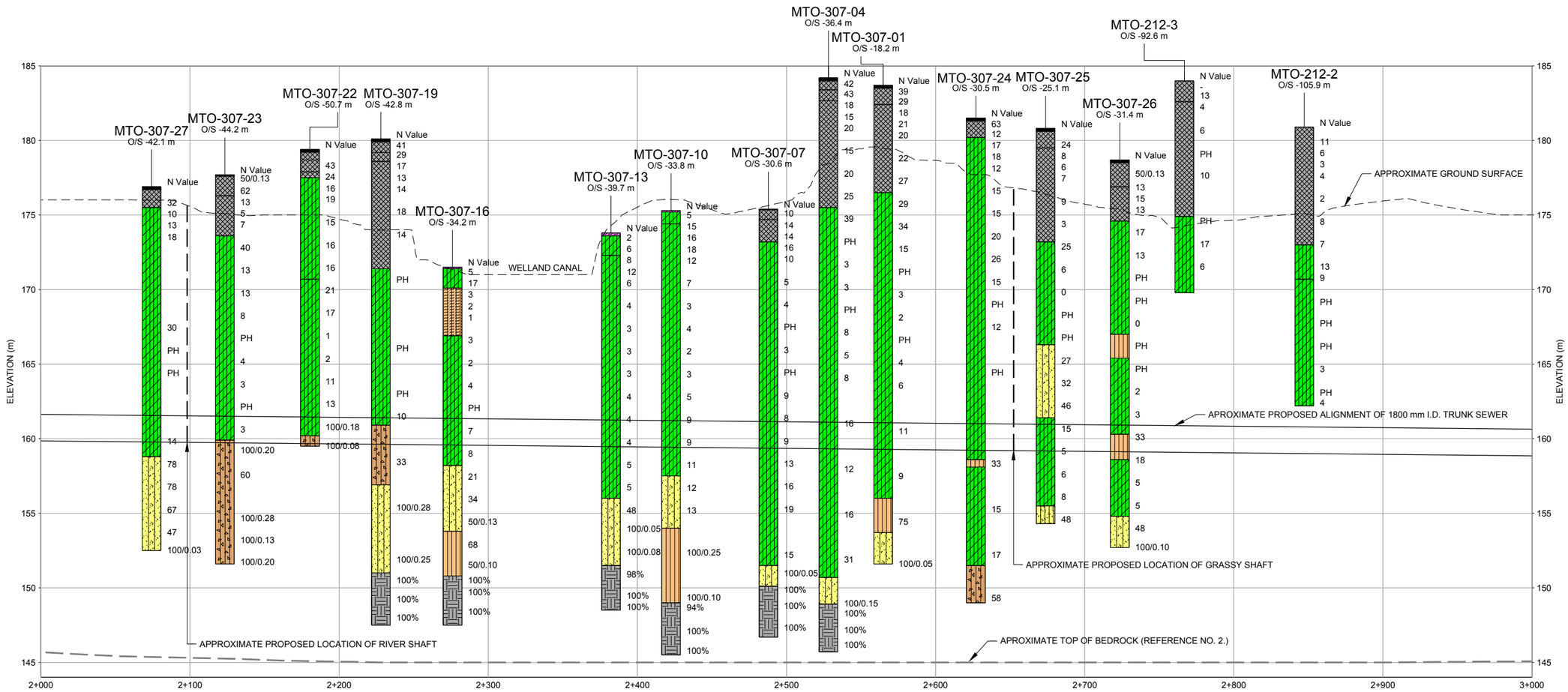

PROFILE A-A'

LEGEND

- ASPHALT
- CONCRETE
- OVERBURDEN
- FILL
- TOPSOIL
- GRAVEL
- SAND AND GRAVEL
- (ML/SM) SILT AND SAND TO (SM) SILTY SAND TO (SP) SAND
- (ML) SILT
- ORGANIC SILT
- SILT TILL
- ORGANIC CLAYEY SILT
- (CL) CLAYEY SILT TO (CI) SILTY CLAY
- CLAYEY SILT TILL
- BEDROCK

0 5 10
1:300 VERTICAL METRES

0 50 100
1:3,000 HORIZONTAL METRES

REFERENCE(S)

1. EXISTING GROUND CONTOURS AND APPROXIMATE 1800 mm I.D. TRUNK SEWER PROVIDED BY GM BLUEPLAN ENGINEERING LIMITED, RECEIVED FEBRUARY 13, 2020.
2. BEDROCK TOPOGRAPHY AND OVERBURDEN THICKNESS MAPPING, SOUTHERN ONTARIO; ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE-DATA 207 (MRD 207), 2006.
3. REGION OF NIAGARA, SOUTHWESTERN ONTARIO ORTHOPHOTOGRAPHY PROJECT (SWOOP), 2015.

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

CONSULTANT
GOLDER

YYYY-MM-DD	2020-06-16
DESIGNED	
PREPARED	DD
REVIEWED	MA
APPROVED	

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
PROFILE A-A' - STA. 2+000 TO STA. 3+000

PROJECT NO.	PHASE	REV.	FIGURE
18104462	(3000)	A	8

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

0 25 mm

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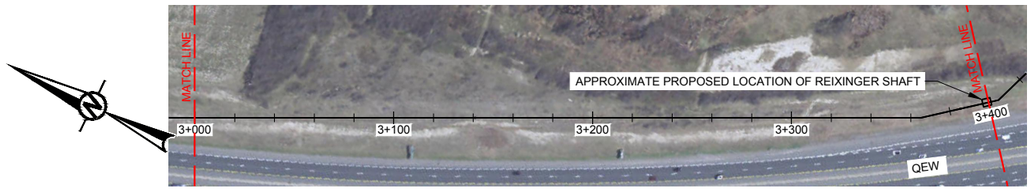
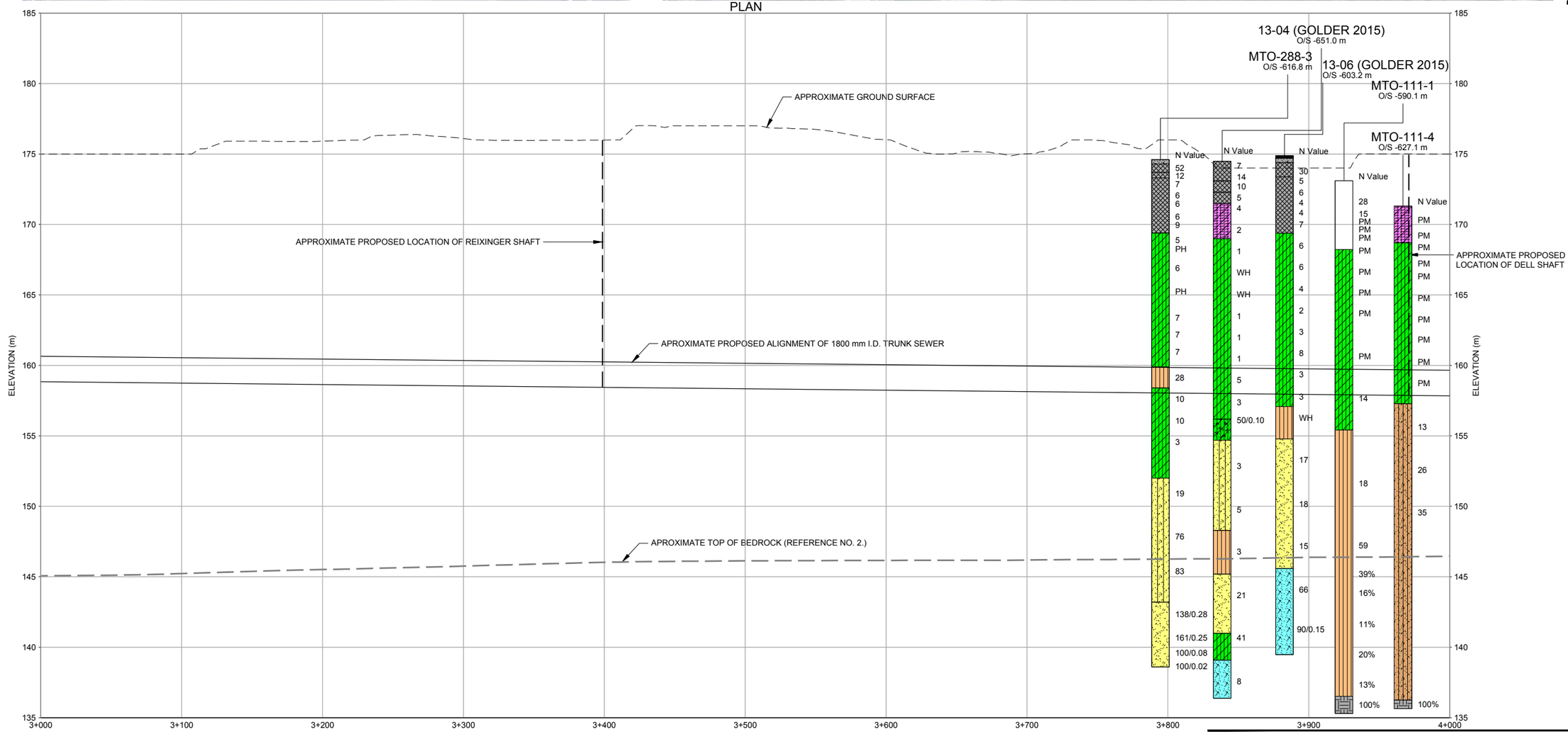


PLAN



PROFILE A-A'

LEGEND

- ASPHALT
- CONCRETE
- OVERBURDEN
- FILL
- TOPSOIL
- GRAVEL
- SAND AND GRAVEL
- (ML/SM) SILT AND SAND TO (SM) SILTY SAND TO (SP) SAND
- (ML) SILT
- ORGANIC SILT
- SILT TILL
- ORGANIC CLAYEY SILT
- (CL) CLAYEY SILT TO (CI) SILTY CLAY
- CLAYEY SILT TILL
- BEDROCK

0 5 10
1:300 VERTICAL METRES

0 50 100
1:3,000 HORIZONTAL METRES

REFERENCE(S)

1. EXISTING GROUND CONTOURS AND APPROXIMATE 1800 mm I.D. TRUNK SEWER PROVIDED BY GM BLUEPLAN ENGINEERING LIMITED, RECEIVED FEBRUARY 13, 2020.
2. BEDROCK TOPOGRAPHY AND OVERBURDEN THICKNESS MAPPING, SOUTHERN ONTARIO; ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE-DATA 207 (MRD 207), 2006.
3. REGION OF NIAGARA, SOUTHWESTERN ONTARIO ORTHOPHOTOGRAPHY PROJECT (SWOOP), 2015.

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

CONSULTANT
GOLDER

YYYY-MM-DD	2020-06-16
DESIGNED	
PREPARED	DD
REVIEWED	MA
APPROVED	

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

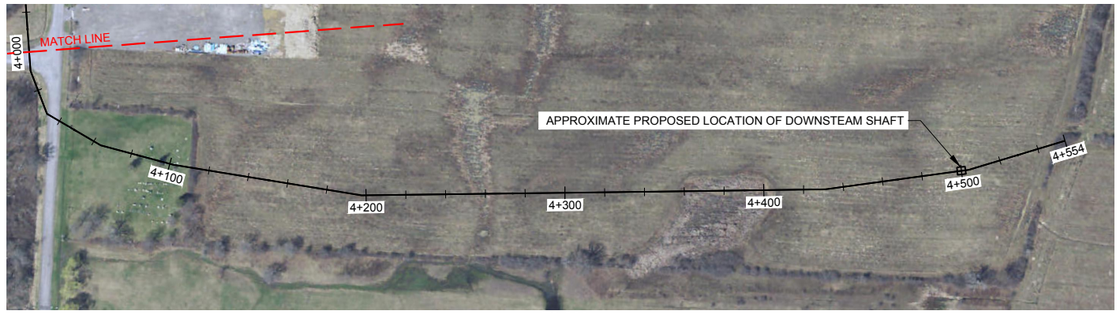
TITLE
PROFILE A-A' - STA. 3+000 TO STA. 4+000

PROJECT NO.	PHASE	REV.	FIGURE
18104462	(3000)	A	9

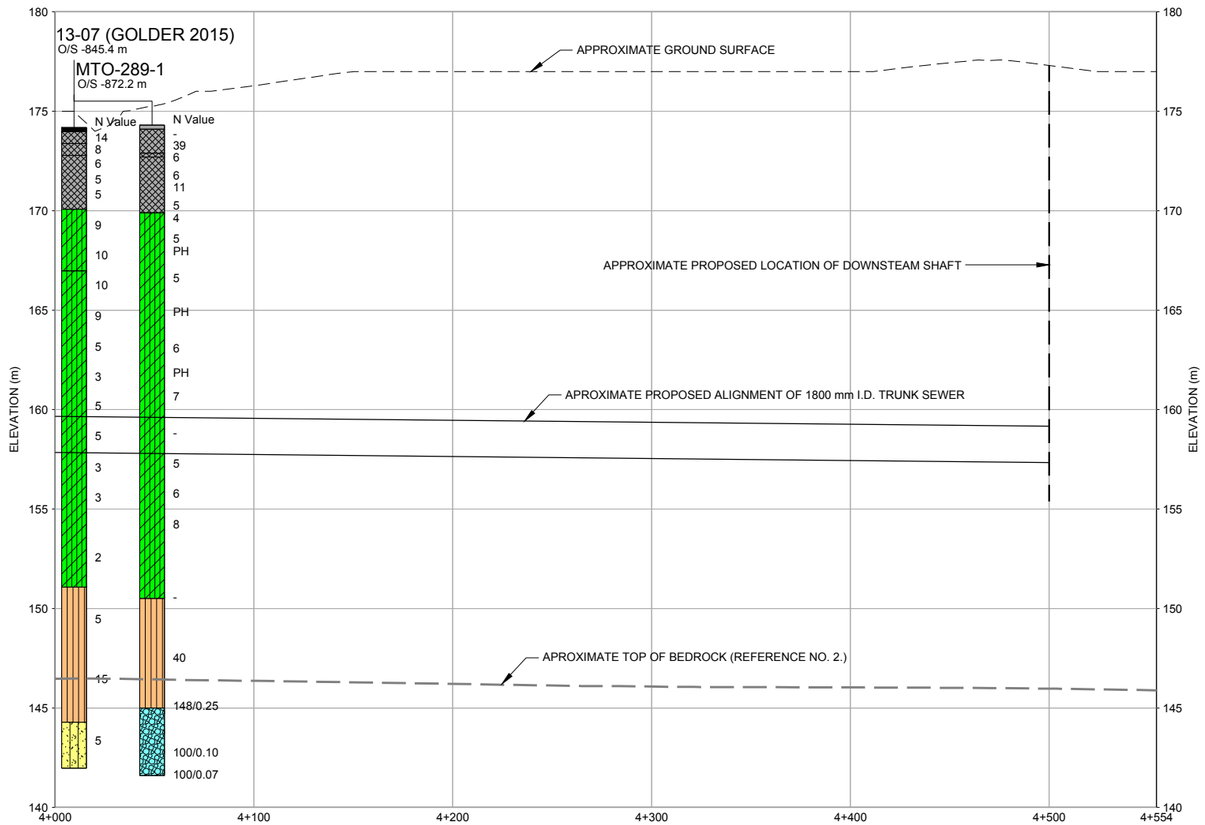
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

0 5 10 15 20 25 mm

Path: \\golder.gds\corp\ekata\toffice\mississauga\SIM\Clients\Region_of_Niagara\New_WasteWaterTreatmentPlant\99_PROJ\18104462_GMBluePlan_SNF_WWTP40_PROD\0008_Geotechnical_Report\ | File Name: 18104462-0008-BG-0009.dwg | Last Edited By: ddojcinovic Date: 2020-06-10 Time:11:20:35 AM | Printed By: ddojcinovic Date: 2020-06-16 Time:11:59:26 AM



PLAN



PROFILE A-A'
(STA. m)

LEGEND

- ASPHALT
- CONCRETE
- OVERBURDEN
- FILL
- TOPSOIL
- GRAVEL
- SAND AND GRAVEL
- (ML/SM) SILT AND SAND TO (SM) SILTY SAND TO (SP) SAND
- (ML) SILT
- ORGANIC SILT
- SILT TILL
- ORGANIC CLAYEY SILT
- (CL) CLAYEY SILT TO (CI) SILTY CLAY
- CLAYEY SILT TILL
- BEDROCK

0 5 10
1:300 VERTICAL METRES

0 50 100
1:3,000 HORIZONTAL METRES

REFERENCE(S)

1. EXISTING GROUND CONTOURS AND APPROXIMATE 1800 mm I.D. TRUNK SEWER PROVIDED BY GM BLUEPLAN ENGINEERING LIMITED, RECEIVED FEBRUARY 13, 2020.
2. BEDROCK TOPOGRAPHY AND OVERBURDEN THICKNESS MAPPING, SOUTHERN ONTARIO; ONTARIO GEOLOGICAL SURVEY, MISCELLANEOUS RELEASE-DATA 207 (MRD 207), 2006.
3. REGION OF NIAGARA, SOUTHWESTERN ONTARIO ORTHOPHOTOGRAPHY PROJECT (SWOOP), 2015.

CLIENT
REGIONAL MUNICIPALITY OF NIAGARA

CONSULTANT
GOLDER

YYYY-MM-DD	2020-06-16
DESIGNED	
PREPARED	DD
REVIEWED	MA
APPROVED	

PROJECT
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS
SCHEDULE C CLASS ENVIRONMENTAL ASSESSMENT

TITLE
PROFILE A-A' - STA. 4+000 TO STA. 4+554

PROJECT NO.	PHASE	REV.	FIGURE
18104462	(3000)	A	10

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 mm

APPENDIX A

MTO Boreholes

RECORD OF BOREHOLE No 18-01 1 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 217.4 E 335 654.1 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.04.11 - 2018.04.11 LATITUDE 43.044147 LONGITUDE -79.121259 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS
183.7	GROUND SURFACE					
0.0	**ASPHALT**					
0.2	**SAND** and **GRAVEL** Dense to Compact Grey Moist (FILL)		1	SS	39	
			2	SS	29	
182.4						
1.3	Silty **CLAY**, some sand, trace gravel Very Stiff Reddish Brown Moist (FILL)		3	SS	18	
			4	SS	21	
			5	SS	20	
			6	SS	22	
			7	SS	27	
176.5						
7.2	Silty **CLAY**, trace to some sand Very Stiff to Hard Reddish Brown Moist		8	SS	29	
			9	SS	34	

ELEVATION SCALE: 183, 182, 181, 180, 179, 178, 177, 176, 175, 174

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)	GR	SA	SI	CL
	0	0	33	67
	0	0	35	65

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 / 10 / 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-01 2 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 217.4 E 335 654.1 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.04.11 - 2018.04.11 LATITUDE 43.044147 LONGITUDE -79.121259 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace to some sand Very Stiff Reddish Brown Moist						173				
			10	SS	15				○		
							172				
			1	TW	PH				○		
	Firm Wet						171				
								+ 2.9			
			11	SS	3		170		○		
							169	+ 3.2			
			12	SS	2				⊢○⊣		0 10 51 39
							168				
								+ 8.0			
			2	TW	PH		167		○		
								+			
							166				
			13	SS	4				○		
							165				
								+ 3.1			
							164				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-01 3 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 217.4 E 335 654.1 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.04.11 - 2018.04.11 LATITUDE 43.044147 LONGITUDE -79.121259 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace to some sand, trace gravel Firm to Stiff Reddish Brown Wet		14	SS	6		163	+ 4.3	○		0 11 50 39
							162				
			15	SS	11		161		○		
							160	+ 2.9			
							159				
							158				
			16	SS	9		157	+ 4.7	○		2 9 47 42
155.9							156				
27.7	Sandy **SILT**, trace clay Very Dense Reddish Brown Wet						155				
			17	SS	75				○		0 24 71 5
153.7							154				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-01 4 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 217.4 E 335 654.1 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.04.11 - 2018.04.11 LATITUDE 43.044147 LONGITUDE -79.121259 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
30.0	Continued From Previous Page										
	SILT and **SAND**, trace clay, trace gravel Very Dense Grey Moist (TILL)						153 152				
151.6			18	SS	100/ 0.050				○		
32.1	END OF BOREHOLE AT 32.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 1.2m, SAND TO 0.3m, CEMENT TO 0.1m THEN ASPHALT TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\overset{20}{15\text{-}\oplus\text{-}5}$ $\overset{}{10}$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

MTO 307-4

THURBER

RECORD OF BOREHOLE No 18-04 1 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 238.2 E 335 634.7 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.20 - 2018.04.20 LATITUDE 43.044343 LONGITUDE -79.121488 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
184.2	GROUND SURFACE										
0.0	**ASPHALT**										
0.2	**SAND** and **GRAVEL** Dense Grey Moist (FILL)		1	SS	42				○		
183.4											
0.8	Sandy **GRAVEL**, trace silt Dense Brown Wet (FILL)		2	SS	43				○		64 30 6 (SI+CL)
182.7											
1.5	Silty **CLAY**, some sand, trace gravel Very Stiff Brown Moist (FILL)		3	SS	18				○		
			4	SS	15				○		
			5	SS	20				○		
			6	SS	15				○		0 0 40 60
			7	SS	20				○		
			8	SS	25				○		
175.5											
8.7	Silty **CLAY**, trace sand Hard Reddish Brown Moist		9	SS	39				○		

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-04 2 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 238.2 E 335 634.7 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.20 - 2018.04.20 LATITUDE 43.044343 LONGITUDE -79.121488 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand Stiff Reddish Brown Wet						174				
			1	TW	PH				○		
							173	+ 3.6			
			10	SS	3		172		○		
	Firm										
							171	+ 3.0			
			11	SS	3				○		
							170	+ 5.8			
			2	TW	PH		169		○		
							168	+ 3.4			
			12	SS	8				○		
							167	+ 3.3			
			13	SS	5		166		○		
							165	+ 3.3			

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

20
15 5
10 (%) STRAIN AT FAILURE

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

RECORD OF BOREHOLE No 18-04 3 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 238.2 E 335 634.7 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.20 - 2018.04.20 LATITUDE 43.044343 LONGITUDE -79.121488 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand Stiff Reddish Brown Wet		14	SS	8		164	4.0	○		0 0 64 36
							163				
							162				
	Very Stiff		15	SS	16		161		○		
							160				
							159				
			16	SS	12		158		○		
							157				
							156				
			17	SS	16		155		○		
154.2											

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-04 4 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 238.2 E 335 634.7 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.20 - 2018.04.20 LATITUDE 43.044343 LONGITUDE -79.121488 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page							20 40 60 80 100	20 40 60		
30.0	Silty **CLAY**, some sand, trace gravel, containing cobbles Hard Reddish Brown Wet (TILL)						154				
							153				
			18	SS	31		152		○		
	casing refusal, switch to coring gravel and cobbles (max. 150mm) from 32.6m to 35.1m										
150.7							151				
33.5	**SILT** and **SAND**, some clay, some gravel, containing cobbles Very Dense Reddish Brown Moist (TILL)						150				
148.9			19	SS	100/		149		○		11 33 37 19
35.3	**DOLOSTONE BEDROCK** slightly weathered, very strong, grey horizontal fracture at 35.4m, 35.5m, 35.8m, 36.1m, 36.4m, 36.6m and 36.7m sub vertical fracture at 35.5m and 35.6m		1	RUN	0.225		148				RUN #1 TCR=100% SCR=95% RQD=92% UCS=147.8MPa (average)
	horizontal fracture at 36.9m, 37.0m, 37.1m and 37.2m sub vertical fracture at 37.1m, (50mm) at 37.2m, 37.4m, (100mm) at 37.4m and (75mm) at 37.7m		2	RUN			147				RUN #2 TCR=100% SCR=100% RQD=34% UCS=123.6MPa (average)
			3	RUN			146				RUN #3 TCR=100% SCR=100% RQD=100% UCS=180MPa (average)
145.7											
38.5	END OF BOREHOLE AT 38.5m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.8m, SAND TO 0.2m, CEMENT TO 0.1m THEN ASPHALT TO SURAFCE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-07 1 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 278.7 E 335 638.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.28 - 2018.03.28 LATITUDE 43.044702 LONGITUDE -79.121495 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
175.4	GROUND SURFACE										
0.0	**TOPSOIL** (50mm)										
0.0	Silty **SAND**, some clay, trace gravel, trace roots Compact Dark Brown Moist (FILL)		1	SS	10		175				
174.7											
0.7	Clayey **SILT**, some sand, trace gravel, trace organics Stiff to Very Stiff Reddish Brown Moist (FILL)		2	SS	14		174				
			3	SS	14						
173.2							173				
2.2	Silty **CLAY**, trace sand Very Stiff to Stiff Reddish Brown Moist		4	SS	16						
			5	SS	10		172				0 0 61 39
	Wet		6	SS	5		171				
							170	2.7			
	Firm		7	SS	4		169				
								2.9			
			1	TW	PH		168				
							167	3.2			
			8	SS	3		166				0 0 57 43

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-07 2 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 278.7 E 335 638.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.28 - 2018.03.28 LATITUDE 43.044702 LONGITUDE -79.121495 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand Firm Grey Wet						165	4.0			
			2	TW	PH				○		
							164				
			9	SS	9		163		○		
								7.0			
			10	SS	8		162		○		0 4 50 46
							161				
			11	SS	9		160		○		
								3.6			
	stiff to very stiff		12	SS	13		159		○		
							158				
			13	SS	16		157		○		
							156				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-07 3 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 278.7 E 335 638.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.28 - 2018.03.28 LATITUDE 43.044702 LONGITUDE -79.121495 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand Very Stiff Grey Wet		14	SS	19		155				0 0 53 47
							154				
							153				
			16	SS	15		152				
151.5											
23.9	**SILT** and **SAND**, trace clay, trace gravel, containing cobbles Very Dense Reddish Brown Wet (TILL) gravel and cobbles (max. 75mm) from 24.4m to 25.3m		17	SS	100/ 0.050		151				
150.1											
25.3	**DOLOSTONE BEDROCK** slightly weathered, very strong, grey horizontal fracture at 25.4m and 25.6m		1	RUN			150			FI 4 0 0	RUN #1 TCR=100% SCR=79% RQD=79% UCS=171.5MPa (average)
	horizontal fracture at 26.9m and 27.1m sub vertical fracture (25mm) at 27.3m		2	RUN			149			0 0 0	RUN #2 TCR=100% SCR=100% RQD=100% UCS=168.8MPa (average)
	horizontal fracture at 27.5m		3	RUN			148			2 1 0	RUN #3 TCR=100% SCR=100% RQD=100% UCS=158.8MPa (average)
146.7	horizontal fracture at 28.4m						147			0 1	
28.7	END OF BOREHOLE AT 28.7m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-10 1 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 343.7 E 335 631.3 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.16 - 2018.03.17 LATITUDE 43.045286 LONGITUDE -79.121577 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
175.3	GROUND SURFACE										
0.0 / 0.1	**TOPSOIL** (75mm)										
	Silty **CLAY**, some sand, trace gravel, trace rootlets, occasional wood fibres Firm Dark Brown Moist		1	SS	5		175				
174.4 / 0.9	Silty **CLAY**, trace to some sand, trace gravel Very Stiff to Stiff Reddish Brown Moist		2	SS	15		174				0 0 67 33
			3	SS	16		173				
			4	SS	18		173				
			5	SS	12		172				
			6	SS	7		171				0 0 31 69
							170	3.1			
	Firm Wet		7	SS	3		169				
							168	2.8			
			8	SS	4		167				0 0 56 44
							167	2.7			
			9	SS	2		166				

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

15 20 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-10 2 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 343.7 E 335 631.3 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.16 - 2018.03.17 LATITUDE 43.045286 LONGITUDE -79.121577 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand Firm Reddish Brown Wet						165	3.5			
			10	SS	3		164				
			11	SS	5		163				0 0 57 43
	switch to casing cobbles from 13.0m to 13.9m		12	SS	9		162				
	Stiff		13	SS	9		161				
			14	SS	11		160				
157.5							159				
17.8	**SILT** and **SAND**, gravelly, trace clay Compact Reddish Brown Wet (TILL)		15	SS	12		158				
							157				
							156				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

20
15 10 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-10 3 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 343.7 E 335 631.3 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.16 - 2018.03.17 LATITUDE 43.045286 LONGITUDE -79.121577 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page								
	SILT and **SAND**, gravelly, trace clay Compact Reddish Brown Wet (TILL)		16	SS	13		155 154		30 34 27 9
154.0 21.3	**SILT**, clayey, trace sand, containing cobbles Very Dense Reddish Brown Moist		17	SS	100/ 0.250		153 152 151 150		0 5 69 26
	casing refusal, switch to coring gravel and cobbles (max. 75mm) from 23.1m to 25.9m		18	SS	100/ 0.175		149	FI	
149.0 26.3	**DOLOSTONE BEDROCK**, slightly weathered, very strong, grey horizontal fracture at 26.5m, 26.6m, 26.8m, 26.9m, 27.0m and 27.4m		1	RUN			148	>10 4 3 2 1	RUN #1 TCR=94% SCR=83% RQD=75% UCS=153.8MPa (average)
	sub horizontal fracture (25mm) at 27.3m horizontal fracture at 27.9m, 28.0m, 28.4m and 28.5m		2	RUN			147	1 1 2 0	RUN #2 TCR=100% SCR=100% RQD=100% UCS=148.1MPa (average)
	sub vertical fracture (50mm) at 29.3m		3	RUN			146	1 1	RUN #3 TCR=100% SCR=100% RQD=93% UCS=113.0MPa (average)
145.5 29.8	END OF BOREHOLE AT 29.8m.							0	

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa 20 40 60 80 100
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE

PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L
WATER CONTENT (%) 20 40 60

+ ³, × ³: Numbers refer to Sensitivity

20 15 5 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-10 4 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 343.7 E 335 631.3 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.16 - 2018.03.17 LATITUDE 43.045286 LONGITUDE -79.121577 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
	Continued From Previous Page										
	BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

15-20-10-5 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-13 1 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 383.6 E 335 623.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.18 - 2018.03.19 LATITUDE 43.045788 LONGITUDE -79.121632 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
173.8	GROUND SURFACE										
0.0	**TOPSOIL** (175mm)										
0.2	Silty **CLAY**, trace rootlets Soft to Firm Brown to Reddish Brown Wet		1	SS	2						
	occasional wood fibres		2	SS	6		173				0 0 32 68
172.3											
1.5	Silty **CLAY**, trace sand Stiff to Firm Reddish Brown Moist		3	SS	8		172				
			4	SS	12		171				
			5	SS	6		170	3.1			
			6	SS	4		169				0 0 28 72
							168	2.7			
			7	SS	3		167				
								2.6			
			8	SS	3		166				
							165	2.6			
			9	SS	3						0 4 53 43
							164				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-13 2 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 383.6 E 335 623.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.18 - 2018.03.19 LATITUDE 43.045788 LONGITUDE -79.121632 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand Stiff Reddish Brown to Grey Wet							3.2			
			10	SS	4		163				0 0 51 49
								4.0			
			11	SS	4		162				
							161	3.3			
			12	SS	4		160				
								3.5			
			13	SS	5		159				0 4 51 45
							158	4.0			
	gravelly at 17.7m switch to casing		14	SS	5		157				
156.0							156				
17.8	**SILT** and **SAND**, gravelly, some clay, containing cobbles Dense to Very Dense Grey Wet (TILL)		15	SS	48						22 35 30 13
							155				
			16	SS	100/		154				

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-13 3 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 383.6 E 335 623.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.18 - 2018.03.19 LATITUDE 43.045788 LONGITUDE -79.121632 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page				0.050						
	casing refusal, switch to coring gravel and cobbles (max. 150mm) from 21.4m to 22.1m		17	SS	100/ 0.075		153		○		
151.5	rubble zone from 22.1m to 22.3m						152			FI	
22.3	**DOLOSTONE BEDROCK** slightly weathered, very strong, grey horizontal fracture at 22.4m, 22.5m, 22.6m, 23.0m, 23.1m and 23.3m		1	RUN			151			>25 4 1 4 1	RUN #1 TCR=98% SCR=87% RQD=87% UCS=169.2MPa (average)
	horizontal fracture (50mm) at 23.9m and 24.7m		2	RUN			150			2 1 0	RUN #2 TCR=100% SCR=100% RQD=100% UCS=197.7MPa (average)
148.5			3	RUN			149			1 0 0	RUN #3 TCR=100% SCR=100% RQD=100% UCS=193.0MPa (average)
25.3	END OF BOREHOLE AT 25.3m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-16 1 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 490.0 E 335 622.7 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.23 - 2018.03.24 LATITUDE 43.046605 LONGITUDE -79.121673 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS
171.5	GROUND SURFACE					
0.0 / 0.1	**TOPSOIL** (75mm)					
	Silty **CLAY**, with sand, trace roots, occasional wood fibres Firm to Soft Brown Moist (FILL)		1	SS	5	
			2	SS	17	
170.1 / 1.4	Organic **SILT**, trace roots Very Soft Dark Brown Wet		3	SS	3	
			4	SS	2	
			5	SS	1	
166.9 / 4.6	Silty **CLAY**, trace sand Firm Reddish Brown Wet		6	SS	3	
			7	SS	2	
			8	SS	4	
			1	TW	PH	

ELEVATION SCALE: 171, 170, 169, 168, 167, 166, 165, 164, 163, 162

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)

GR	SA	SI	CL
0	38	35	27
0	6	48	46

6.0
4.0
3.3
123
127

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 / 10 / 5 (%) STRAIN AT FAILURE

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-16 2 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 490.0 E 335 622.7 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.23 - 2018.03.24 LATITUDE 43.046605 LONGITUDE -79.121673 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page							20 40 60 80 100	20 40 60		
	Silty **CLAY**, trace sand Firm to Stiff Reddish Brown Wet							3.0			
			9	SS	7		161		○		
							160	3.5			
			10	SS	8		159		○		
158.2											
13.3	**SILT** and **SAND**, clayey, trace gravel, containing cobbles Comapct to Very Dense Reddish Brown Moist (TILL)						158				
			11	SS	21		157		○		10 40 28 22
			12	SS	34		156		○		
	gravelly zone with cobbles casing refusal, switch to coring		13	SS	50/ 0.125		155		○		
153.8							154				
17.7	Sandy **SILT**, trace clay, trace gravel Very Dense Reddish Brown Wet										
			14	SS	68		153		○		
			15	SS	50/		152		○		

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 / 10 / 5 (%) STRAIN AT FAILURE

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

RECORD OF BOREHOLE No 18-16 3 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 490.0 E 335 622.7 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.03.23 - 2018.03.24 LATITUDE 43.046605 LONGITUDE -79.121673 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (20 40 60 80 100): ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page				0.100						
150.9							151			FI	
20.7	**DOLOSTONE BEDROCK** slightly weathered, very strong, grey horizontal fracture at 21.0m sub vertical fracture (100mm) at 21.1m		1	RUN						>5 1 2	RUN #1 TCR=100% SCR=88% RQD=70% UCS=149.2MPa (average)
			2	RUN			150			0 0 0	RUN #2 TCR=100% SCR=100% RQD=100% UCS=176.1MPa (average)
			3	RUN			149			0 0 0	RUN #3 TCR=100% SCR=100% RQD=100% UCS=191.9MPa (average)
	quartz interbed at 23.3m horizontal fracture at 23.4m						148			1 0	
147.5											
24.0	END OF BOREHOLE AT 24.0m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO SURFACE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

20
15 10 5 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

MTO 307-19

THURBER

RECORD OF BOREHOLE No 18-19 1 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 537.5 E 335 611.4 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.18 - 2018.04.18 LATITUDE 43.047036 LONGITUDE -79.121755 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
180.1	GROUND SURFACE						180				
0.0	**ASPHALT**										
0.2	**SAND** and **GRAVEL** Dense Grey Moist (FILL)		1	SS	41				○		
179.2							179				
0.9	Silty **SAND**, trace clay Compact Reddish Brown Moist (FILL)		2	SS	29				○		
178.6							178				
1.5	Silty **CLAY**, trace sand, trace gravel Very Stiff to Stiff Reddish Brown Moist (FILL)		3	SS	17				○		
			4	SS	13				○		
			5	SS	14		177		○		
							176				
			6	SS	18				○		
							175				
			7	SS	14		174		○		
							173				
	Wet		8	SS	8				○		0 0 46 54
171.4							172	+ 3.5			
8.7	Silty **CLAY**, trace sand, trace rootlets Firm Reddish Brown Wet		1	TW	PH		171		○		

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

20 / 15 / 10 / 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-19 2 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 537.5 E 335 611.4 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.18 - 2018.04.18 LATITUDE 43.047036 LONGITUDE -79.121755 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand, trace rootlets Firm Reddish Brown Wet						170	4.7			
			9	SS	5		169		○		
								3.2			
			10	SS	3		168		○		
							167				
			2	TW	PH			4.5	○		
							166				
								2.7			
			11	SS	8		165		○		
	trace silt seams										
							164				
	Stiff							2.8			
			12	TW	PH		163		○		
							162				
			13	SS	10				○		
160.9							161				
19.2	**SILT** and **SAND**, some clay, some gravel, containing cobbles Dense Reddish Brown Wet										

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-19 3 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 537.5 E 335 611.4 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.18 - 2018.04.18 LATITUDE 43.047036 LONGITUDE -79.121755 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	(TILL) casing refusal, switch to coring boulder (350mm) at 19.6m						160				
							159				
			14	SS	33				○		11 36 34 19
156.9							158				
23.2	Silty **SAND**, trace clay Very Dense Reddish Brown Wet						157				
							156				
			15	SS	100/ 0.275				○		0 70 25 5
							155				
							154				
							153				
			16	SS	100/ 0.250				○		
	gravel and cobbles (max. 125mm) from 27.7m to 29.1m						152				
151.0											
29.1	**DOLOSTONE BEDROCK** slightly weathered, very strong, grey horizontal fracture at 29.2m, 29.4m, 29.6m, 29.8m, 30.0m and 30.1m		1	RUN			151			FI 2 1 2	RUN #1 TCR=100% SCR=100% RQD=83% UCS=153.1MPa (average)

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-19 4 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 537.5 E 335 611.4 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.18 - 2018.04.18 LATITUDE 43.047036 LONGITUDE -79.121755 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page						150			1	
	horizontal fracture at 30.4m, 30.5m, 30.7m, 30.9m, 31.4m and 31.6m sub vertical fracture at 30.7m		2	RUN			149			3 6 1 0	RUN #2 TCR=100% SCR=100% RQD=88% UCS=211.5MPa (average)
	horizontal fracture at 31.8m		3	RUN			148			1 1 0	RUN #3 TCR=100% SCR=100% RQD=100% UCS=172.4MPa (average)
147.5											
32.6	END OF BOREHOLE AT 32.6m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG, CEMENT AND ASPHALT TO SURFACE.									0	

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \quad 5}$ (%) STRAIN AT FAILURE
$\frac{}{10}$

Ministry of Transportation
Ontario

MTO 307-22

THURBER

RECORD OF BOREHOLE No 18-22 1 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 565.9 E 335 601.8 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.04.06 - 2018.04.06 LATITUDE 43.047284 LONGITUDE -79.121990 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS
179.4	GROUND SURFACE					
0.0	**ASPHALT**					
0.2	**SAND**, trace gravel Brown Moist			GS		
178.7	(FILL)					
0.7	**SAND** and **GRAVEL** Dense Brown Moist		1	SS	43	
177.9	(FILL)					
1.5	**SAND**, trace gravel Compact		2	SS	24	
177.5	Brown					
1.9	Moist (FILL)					
	Silty **CLAY**, trace sand, trace gravel Very Stiff Grey Moist		3	SS	16	
			4	SS	19	
	trace rootlets		5	SS	15	▽
	Wet occasional wood fibre		6	SS	16	
			7	SS	16	
170.7						
8.7	Silty **CLAY**, trace sand Very Stiff Reddish Brown to Grey Wet		8	SS	21	

ELEVATION SCALE: 179, 178, 177, 176, 175, 174, 173, 172, 171, 170

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%) 20 40 60

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)				
GR	SA	SI	CL	
0	0	49	51	
0	0	53	47	

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

RECORD OF BOREHOLE No 18-22 2 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 565.9 E 335 601.8 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.04.06 - 2018.04.06 LATITUDE 43.047284 LONGITUDE -79.121990 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand Very Stiff to Stiff Reddish Brown to Grey Wet						169				
			9	SS	17		168				
	Firm		10	SS	1		167				
			11	SS	2		166	2.8			0 0 62 38
			12	SS	11		165	3.0			0 0 50 50
			13	SS	13		164				
	Hard		14	SS	100/ 0.175		163				
160.2							162				
19.2	**SILT** and **SAND**, some clay, trace gravel, occasional cobbels Very Dense Reddish Brown						161				
159.5	Moist		15	SS	50/		160				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \cdot 10 \cdot 5}$ (%) STRAIN AT FAILURE

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

RECORD OF BOREHOLE No 18-22 3 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 565.9 E 335 601.8 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.04.06 - 2018.04.06 LATITUDE 43.047284 LONGITUDE -79.121990 CHECKED BY GRL

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES						GR SA SI CL
	Continued From Previous Page										
19.9	(TILL) END OF BOREHOLE AT 19.9m. WATER LEVEL AT 5.2m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.3m, CEMENT TO 0.07m THEN ASPHALT TO SURFACE.				0.075						

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

THURBER

RECORD OF BOREHOLE No 18-23 1 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 641.2 E 335 603.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.19 - 2018.04.19 LATITUDE 43.047968 LONGITUDE -79.121829 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L / WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
177.7	GROUND SURFACE										
0.0	**ASPHALT**										
0.1	**SAND** and **GRAVEL**, some silt Very Dense Grey Moist (FILL)		1	SS	50/ 0.125		177		○		
			2	SS	62				○		35 48 17 (SI+CL)
176.3							176				
1.4	Silty **CLAY**, some sand, trace rootlets Stiff to Firm Dark Brown/Grey Moist (FILL)		3	SS	13				○		
			4	SS	5		175		○		
			5	SS	7				○		
173.6							174				
4.1	Silty **CLAY**, trace sand, trace gravel Hard to Stiff Reddish Brown Moist		6	SS	40		173		○		
			7	SS	13		172		○		0 0 40 60
			8	SS	13		171		○		
	Wet		9	SS	8		170		○		0 4 48 48
							169				
							168				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-23 2 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 641.2 E 335 603.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.19 - 2018.04.19 LATITUDE 43.047968 LONGITUDE -79.121829 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand Firm Reddish Brown Wet							2.9			
			1	TW	PH		167		○		
								2.8			
			10	SS	4		166		○		
							165	3.0			
			11	SS	3		164		⊢○		0 0 62 38
							163	2.7			
			2	TW	PH		162		○		
								2.9			
159.8			12	SS	3		161		○		
17.8	**SILT** and **SAND**, some clay, some gravel, occasional cobbles Very Dense Grey Wet (TILL)						160				
			13	SS	100/ 0.200		159		○		
							158				

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-23 3 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 641.2 E 335 603.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.19 - 2018.04.19 LATITUDE 43.047968 LONGITUDE -79.121829 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE) (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Casing refusal, switch to coring gravel and cobbles (max. 100mm) from 20.4m to 22.9m		14	SS	60		157		○		
							156				
			15	SS	100/ 0.275		155		○		
							154				
	gravel and cobbles from 24.5m to 25.9m		16	SS	100/ 0.125		153		○		
151.6							152				
26.1	END OF BOREHOLE AT 26.1m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.8m, SAND TO 0.2m THEN CEMENT TO SURAFCE.		17	SS	100/ 0.200				○		

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

RECORD OF BOREHOLE No 18-24 1 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 139.8 E 335 646.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.21 - 2018.04.21 LATITUDE 43.043458 LONGITUDE -79.121369 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
181.5	GROUND SURFACE										
0.0	**ASPHALT**										
0.2	**SAND** and **GRAVEL** Very Dense to Compact Grey Moist (FILL)		1	SS	63		181		○		
180.2			2	SS	12				○		
1.3	Silty **CLAY**, some sand, trace gravel Very Stiff Reddish Brown Moist (FILL)		3	SS	17		180		○		
178.5			4	SS	18		179		○		0 0 44 56
3.0	Stiff		5	SS	12		178		○		
177.4			6	SS	15		177		○		
4.1			7	SS	15		176		○		
			8	SS	20		175		○		
			9	SS	26		174		○		0 0 34 66
							173				
							172		○		

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-24 2 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 139.8 E 335 646.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.21 - 2018.04.21 LATITUDE 43.043458 LONGITUDE -79.121369 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page									
171.3										
10.2	Silty **CLAY**, trace sand Very Stiff to Stiff Reddish Brown Moist		10	SS	15		171			
			1	TW	PH		170			
							169	4.2		
	Wet		11	SS	12		168			
166.7							167	3.7		
14.8	Firm		12	SS	7		166			0 0 42 58
							165	3.7		
			2	TW	PH		164	3.2		
			13	SS	4		163			
							162	3.2		

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

20 / 15 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-24 3 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 139.8 E 335 646.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.21 - 2018.04.21 LATITUDE 43.043458 LONGITUDE -79.121369 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand, trace gravel Firm Reddish Brown Wet		14	SS	6		161	2.6	○		
158.6							160				
22.9	**SILT**, trace clay Dense Reddish Brown		15	SS	33		159		○		0 0 91 9
158.1	Wet						158				
23.4	Silty **CLAY**, trace sand, trace gravel Very Stiff Reddish Brown Wet						157				
							156				
			16	SS	15				⊣○		0 0 49 51
	possible cobbles						155				
							154				
							153				
			17	SS	17				○		
151.5							152				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

15 (20/10) 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-24 4 OF 4 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 139.8 E 335 646.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE NW Casing/NQ Coring COMPILED BY MP

DATUM Geodetic DATE 2018.04.21 - 2018.04.21 LATITUDE 43.043458 LONGITUDE -79.121369 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
30.0	**SILT** and **SAND**, some clay, trace gravel, containing cobbles Very Dense Reddish Brown Moist (TILL) casing refusal, switch to coring gravel and cobbles (max. 75mm) from 29.6m to 32.0m						151 150				
149.1			18	SS	58				○		5 31 44 20
32.5	END OF BOREHOLE AT 32.5m. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG TO 0.9m, SAND TO 0.3m, CEMENT TO 0.1m, THEN ASPHALT TO SURAFCE.										

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \quad 5}$ (%) STRAIN AT FAILURE
$\frac{10}{}$

Ministry of Transportation
Ontario

MTO 307-25

THURBER

RECORD OF BOREHOLE No 18-25 1 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 090.2 E 335 660.7 ORIGINATED BY ES/ISP

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.07.10 - 2018.07.10 LATITUDE 43.043004 LONGITUDE -79.121229 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
180.8	GROUND SURFACE										
0.0	**ASPHALT** (225mm)										
0.2	Gravelly **SAND**, trace silt Compact Brown Moist (FILL)		1	GS							
179.5			1	SS	24		180				
1.3	Silty **CLAY**, trace sand, trace gravel Firm to Very Stiff Brown Moist (FILL)		2	SS	8	▽	179				
			3	SS	6		178				No recovery
			4	SS	7		177				
			5	SS	9		176				
175.2											
5.6	Soft occasional oxide staining		6	SS	3		175				0 0 33 67
173.2							174	20.0 +			
7.6	Silty **CLAY**, trace sand Very Stiff to Firm Reddish Brown Moist		7	SS	25		173				0 0 46 54
	Wet		8	SS	6		172				
							171				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15}\oplus\frac{5}{10}$ (%) STRAIN AT FAILURE

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

RECORD OF BOREHOLE No 18-25 2 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 090.2 E 335 660.7 ORIGINATED BY ES/ISP

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.07.10 - 2018.07.10 LATITUDE 43.043004 LONGITUDE -79.121229 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand Stiff to Firm Reddish Brown Wet							20.0			
			9	SS	0		170		○		
								5.0			
			1	TW	PH		169		○		
							168	2.5			
			2	TW	PH		167				No recovery
166.3											
14.5	**SILT** and **SAND**, trace clay Compact to Dense Reddish Brown Wet						166		○		
			10	SS	27		165				
			11	SS	32		164		○		0 40 56 4
							163				
			12	SS	46		162		○		
161.4											
19.4	Silty **CLAY**, trace sand Stiff to Firm Reddish Brown to Brown Wet						161				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15}$ $\frac{5}{10}$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-25 3 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 090.2 E 335 660.7 ORIGINATED BY ES/ISP

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.07.10 - 2018.07.10 LATITUDE 43.043004 LONGITUDE -79.121229 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page							20 40 60 80 100	20 40 60		
	Silty **CLAY**, trace sand Stiff to Firm Reddish Brown to Brown Wet		13	SS	15		160				
			14	SS	5		159				
			15	SS	6		158				
							157	2.8			
155.5			16	SS	8		156				No recovery
25.3	**SILT** and **SAND**, some clay, trace gravel Dense Brown Moist (TILL)		17	SS	48		155				
154.3											
26.5	END OF BOREHOLE AT 26.5m. WATER LEVEL AT 1.8m UPON COMPELTION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.1m, THEN ASPHALT TO SURAFCE.										

+ ³, × ³: Numbers refer to Sensitivity

15 (20/10) 5 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

MTO 307-26

THURBER

RECORD OF BOREHOLE No 18-26 1 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 040.3 E 335 665.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.07.11 - 2018.07.11 LATITUDE 43.042555 LONGITUDE -79.121177 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
178.7	GROUND SURFACE										
0.0	**ASPHALT** (200mm)										
0.2	Gravelly **SAND**, trace silt Very Dense Brown Moist (FILL)		1	GS							
			1	SS	50/ 0.125						
176.9			2	SS	13						
1.8	Silty **CLAY**, trace sand, trace gravel Stiff to Very Stiff Brown to Dark Brown Moist (FILL)		3	SS	15	▽					0 0 28 72
			4	SS	13						
174.6											
4.1	Silty **CLAY**, trace sand, trace organics, trace rootlets Stiff to Very Stiff Dark Brown Moist		5	SS	17						
			6	SS	13						
	Firm		1	TW	PH						
			2	TW	PH						

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

RECORD OF BOREHOLE No 18-26 2 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 040.3 E 335 665.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.07.11 - 2018.07.11 LATITUDE 43.042555 LONGITUDE -79.121177 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand Soft Reddish Brown Wet										
			7	SS	0		168				
167.0											
11.7	**SILT**, some sand Reddish Brown Moist						167	3.0			
			3	TW	PH		166				
165.4								3.2			
13.3	Silty **CLAY**, trace sand Firm Reddish Brown Wet						165				
			4	TW	PH		164	6.0			
	Stiff		8	SS	2		163				
								10.0			
			9	SS	3		162				
							161	8.0			
160.3											
18.4	**SILT**, some sand, some clay, trace gravel Dense to Compact Reddish Brown Wet		10	SS	33		160				6 11 72 11
							159				

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

20 / 15 ⊕ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-26 3 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 040.3 E 335 665.2 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.07.11 - 2018.07.11 LATITUDE 43.042555 LONGITUDE -79.121177 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
158.6	Continued From Previous Page										
20.1	Silty **CLAY**, trace sand, trace gravel Firm to Stiff Reddish Brown Wet		11	SS	18		158				
			12	SS	5		157				
			13	SS	5		156				
154.8							155				
23.9	**SILT** and **SAND**, gravelly Dense to Very Dense Brown Moist (TILL)		14	SS	48		154				
	occasional cobble						153				
152.7			15	SS	100/ 0.100						
26.0	END OF BOREHOLE AT 26.0m. WATER LEVEL AT 2.1m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND CUTTINGS TO 0.1m, THEN ASPHALT TO SURAFCE.										

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

15 20 10 5 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

MTO 307-27

THURBER

RECORD OF BOREHOLE No 18-27 1 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 690.4 E 335 601.8 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.07.12 - 2018.07.12 LATITUDE 43.048409 LONGITUDE -79.121919 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
176.9	GROUND SURFACE										
0.0	**ASPHALT** (200mm)										
0.2	Gravelly **SAND**, trace silt Dense Brown Moist (FILL)		1	GS							
175.5			1	SS	32		176				
1.4	Silty **CLAY**, trace sand, trace gravel, trace organics Stiff to Very Stiff Brown Moist		2	SS	10		175				
			3	SS	13		174				
			4	SS	18		173				
			5	SS	6		172				
			6	SS	9		171				0 0 37 63
			7	SS	6		170				
			8	SS	30		169	2.7			
							168				
							167				

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

20 / 15 / 10 / 5 (%) STRAIN AT FAILURE

ONTMT4S2 MTO-18426.GPJ 2017TEMPLATE(MTO).GDT 10/2/18

RECORD OF BOREHOLE No 18-27 2 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 690.4 E 335 601.8 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.07.12 - 2018.07.12 LATITUDE 43.048409 LONGITUDE -79.121919 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page										
	Silty **CLAY**, trace sand Stiff to Firm Brown Moist										
			1	TW	PH		166				
			2	TW	PH		165				
							164				
			9	SS	0		163				0 5 52 43
							162				
			10	SS	4						
							161				
			11	SS	14		160				
158.8							159				
18.1	**SILT** and **SAND**, trace clay, trace gravel, occasional cobbles Very Dense Brown Moist (TILL)		12	SS	78		158				
							157				

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 18-27 3 OF 3 METRIC

GWP# 2430-15-00 LOCATION Welland River Bridge Replacement, MTM NAD83-10: N 4 767 690.4 E 335 601.8 ORIGINATED BY ES

DIST HWY QEW BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY MP

DATUM Geodetic DATE 2018.07.12 - 2018.07.12 LATITUDE 43.048409 LONGITUDE -79.121919 CHECKED BY GRL

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued From Previous Page		13	SS	78						
							156				
			14	SS	67						
							155				
							154				
	Dense		15	SS	47						
							153				
152.5	possible cobbles and boulders		~~16~~	~~SS~~	~~100/~~ 0.025						No recovery
24.4	END OF BOREHOLE AT 24.4m. BOREHOLE BACKFILLED WITH CUTTINGS TO 0.1m, THEN ASPHALT TO SURAFCE.										

○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\frac{20}{15 \oplus 5}$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 2 1 OF 1 METRIC

W.O. 93-11022 LOCATION N 4 766903.4 E 335619.1 ORIGINATED BY DK

DIST 6 HWY QEW BOREHOLE TYPE H.S. Auger COMPILED BY DK

DATUM Geodetic DATE 93 09 01 CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
180.9	Ground Surface							
0.0			1	CS	–			
			2	SS	11			
	Trace Organics		3	SS	6			0 1 52 47
			4	SS	3			
	Silty Clay		5	SS	4			
	Grey and Brown							
	(Fill)		6	SS	2			
			7	SS	8			
173.0			8	SS	7			
7.9	Silty Clay							
	with Organic Inclusions		9	SS	13			
170.7	Dark Grey, Firm to Stiff		10	SS	9			
10.2			11	TW	PH			
	Silty Clay to Clayey Silt		12	TW	PH		19.5	
	Firm to Stiff		13	TW	PH		20.6	
	Grey and Reddish Brown		14	SS	3			
			15	TW	PH	P1		
162.2			16	SS	4			
18.7	End of Borehole							

ELEVATION SCALE: 180, 178, 176, 174, 172, 170, 168, 166, 164

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE; 20 40 60 80 100

PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

+100 +3 +2 +3 +2

organic content = 2.8%

94 10 25
* GROUND WATER CONDITIONS

PIEZO. NO.	GROUND WATER ELEVATION (Metres)
1	173.1

+3, ×5 : Numbers refer to Sensitivity

20 / 15 ◇ 5 / 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 3 1 OF 1 METRIC

W.O. 93-11022 LOCATION N 4 767011.1 E 335609.0 ORIGINATED BY DK

DIST 6 HWY QEW BOREHOLE TYPE H.S. Auger COMPILED BY DK

DATUM Geodetic DATE 93 09 02 CHECKED BY PP

SOIL PROFILE ELEV/DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (o UNCONFINED, + FIELD VANE, • QUICK TRIAXIAL, × LAB VANE)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
184.0	Ground Surface							20 40 60 80 100	20 40 60		
0.0	Granular Fill	FILL	1	CS	–	DRY *	182				
182.6	Grey, Compact		2	SS	13						
1.4	Silty Clay		3	SS	4			>100 +			
	Trace Gravel and Organics		4	SS	6		180				
	Greyish Brown		5	TW	PH					20.4	
	Very Stiff		6	SS	10		178				
	(Fill)							>120kPa +			
174.9							176				
9.1	Silty Clay		7	TW	PH						
	Firm to Very Stiff		8	SS	17		174				
	Reddish Brown and Grey		9	SS	6		172				
169.8								>120kPa +			
14.2	End of Borehole						170				

* 93 09 02
Hole dry upon completion

+3, ×5 ; Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 3

1 of 3

METRIC

G.W.P. _____ LOCATION Coords: E:336485.8 N:4765782.8 ORIGINATED BY AF

DIST _____ HWY QEW BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY SD

DATUM GEODETIC DATE 2015-12-7 - 2015-12-9 CHECKED BY RA

ELEV / DEPTH (m)	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SPT 'N' VALUE	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
174.9	**GROUND SURFACE**										
174.6	295mm **ASPHALTIC CONCRETE**										
0.3 / 174.0	**FILL**, sand and gravel, trace silt, very dense, brown, dry		1	SS	52						
0.9 / 173.6	**FILL**, sand, trace gravel, compact, reddish brown, moist		2	SS	12						
1.3	**FILL**, silty clay, trace sand, trace gravel, trace organics, firm to stiff, brown, moist		3	SS	7						
			4	SS	6						
			5	SS	6				LL=48		4 4 36 56
			6	SS	6						
			7	SS	9						
169.7 / 5.2	containing organics, black										
	SILTY CLAY, trace sand, trace gravel, firm to very stiff, brown, moist		8	SS	5						0 1 67 32
			9	TW	PH						
			10	SS	6						0 7 54 39
			11	TW	PH					20.0	0 7 55 38
			12	SS	7						
			13	SS	7						1 7 53 39
			14	SS	7						
160.2 / 14.7											

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

Ministry of Transportation
Ontario

Terraprobe

RECORD OF BOREHOLE No 3

2 of 3

METRIC

G.W.P. _____ LOCATION Coords: E:336485.8 N:4765782.8 ORIGINATED BY AF

DIST _____ HWY QEW BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY SD

DATUM GEODETIC DATE 2015-12-7 - 2015-12-9 CHECKED BY RA

ELEV / DEPTH (m)	DESCRIPTION (continued)	STRAT PLOT	SAMPLES NUMBER	TYPE	SPT 'N' VALUE	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILT, trace clay, trace sand, compact, grey, wet		15	SS	28		159		○		0 3 89 8
158.7											
16.2	**SILTY CLAY**, trace to some sand, trace sand, trace gravel, stiff to very stiff, brown to grey, wet		16	SS	10		158				
							157	>+			
			17	SS	10		156		⊢○⊣		4 14 49 33
			18	SS	3		155			○	1 2 56 41
							154	>+			
152.3							153				
22.6	**SILTY SAND**, trace clay, compact to very dense, brown, wet		19	SS	19		152				
							151				Dec. 07, 2015
							150				Dec. 08, 2015
			20	SS	76		149		○		0 62 34 4
							148				
							147				
	some clay		21	SS	83		146				
							145				

Continued Next Page

+ ^{3}, × ^{3}: Numbers refer to Sensitivity ○ $^{3\%}$ STRAIN AT FAILURE

Ministry of Transportation
Ontario

Terraprobe

RECORD OF BOREHOLE No 3

3 of 3 **METRIC**

G.W.P. _____ LOCATION Coords: E:336485.8 N:4765782.8 ORIGINATED BY AF

DIST _____ HWY QEW BOREHOLE TYPE HOLLOW STEM AUGERS COMPILED BY SD

DATUM GEODETIC DATE 2015-12-7 - 2015-12-9 CHECKED BY RA

ELEV / DEPTH (m)	DESCRIPTION (continued)	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) (20 40 60 80 100) O UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
143.5	**SILTY SAND**, trace clay, compact to very dense, brown, wet						144				
31.4	**GRAVELLY SAND**, trace clay, some silt, very dense, grey, wet		22	SS	138 / 275mm		143				
							142				
			23	SS	161 / 250mm		141	O			29 49 17 5
			24	SS	100 / 75mm		140				
138.9							139				Dec. 08, 2015
36.0	**END OF BOREHOLE**		25	SS	100 / 15mm						Dec. 09, 2015

Borehole filled with drill water upon completion of drilling.

Borehole extended with a Tricone bit below 29.0m.

Consolidation test performed on TW11

+ ^{3}, × ^{3}: Numbers refer to Sensitivity O $^{3\%}$ STRAIN AT FAILURE

file: 1-15-0689 lyon creek rd -- bh logs .gpj

Golder Associates

RECORD OF BOREHOLE No 13-04

SHEET 1 OF 3

METRIC

PROJECT 12-1111-0088
W.P. 2177-08-00
DIST Central HWY QEW
DATUM Geodetic

LOCATION N 4765750.7 ;E 336512.4
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
DATE July 9 to 11, 2013

ORIGINATED BY SB
COMPILED BY AV
CHECKED BY MM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × REMOULDED)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
174.5	GROUND SURFACE										
0.0	Sand and gravel, some silt, trace clay (FILL) Loose to compact Brown Moist		1	SS	7		174				
			2	SS	14						40 44 13 3
173.1							173				
1.4	Sand (FILL) Compact Brown Wet		3	SS	10						
172.3							172				
2.2	Silty clay, trace organics (FILL) Firm Grey Wet		4	SS	5						
171.5							171				
3.0	Clayey ORGANIC SILT, trace sand, trace rootlets Soft to stiff Dark grey to black Wet		5	SS	4					OC = 9.2%	0 4 41 55
			6	SS	2		170				
169.0							169				
5.5	CLAYEY SILT, trace sand, trace gravel Soft to stiff Grey Wet		7	SS	1		168				
			8	SS	WH		167				
			9	SS	WH		166				
			10	SS	1		165				
			11	SS	1		164				
			12	SS	1		163				3 4 56 37
							162				
							161				
							160				

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No 13-04

SHEET 2 OF 3

METRIC

PROJECT 12-1111-0088
W.P. 2177-08-00
DIST Central HWY QEW
DATUM Geodetic

LOCATION N 4765750.7 ;E 336512.4
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
DATE July 9 to 11, 2013

ORIGINATED BY SB
COMPILED BY AV
CHECKED BY MM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × REMOULDED)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---							20 40 60 80 100	20 40 60		
	CLAYEY SILT, trace sand, trace gravel Soft to stiff Grey Wet		13	SS	5		159				
	Trace silt seams below a depth of 16.8 m.		14	SS	3		158				
156.2							157	2 1			
18.3	Sandy CLAYEY SILT, some gravel (TILL) Hard Grey Wet		15	SS	50/0.10		156				13 21 41 25
154.7							155				
19.8	SILT and SAND, trace clay Very loose to loose Brown Wet		16	SS	3		154				0 45 52 3
			17	SS	5		153				
148.3							152				
26.2	Silt, some clay, trace sand Very loose Brown Wet		18	SS	3		151				0 3 79 18
145.2							150				
29.3	SAND, some gravel Compact Grey Wet						149				
							148				
							147				
							146				
							145				

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No 13-04

SHEET 3 OF 3

METRIC

PROJECT 12-1111-0088

W.P. 2177-08-00 LOCATION N 4765750.7 ;E 336512.4 ORIGINATED BY SB

DIST Central HWY QEW BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers COMPILED BY AV

DATUM Geodetic DATE July 9 to 11, 2013 CHECKED BY MM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SAND, some gravel Compact Grey Wet						144				
			19	SS	21						
							143				
							142				
141.0							141				
33.5	CLAYEY SILT, trace to some sand Hard Grey Wet		20	SS	41				⊢○⊣		0 8 53 39
139.1							140				
35.4	SAND and GRAVEL, trace to some silt, trace clay Loose Brown Wet						139				
			21	SS	8		138		○		34 57 6 3
136.4							137				
38.1	END OF BOREHOLE AUGER REFUSAL NOTE: 1. Depth to groundwater level was not measured upon completion of drilling.										

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No 13-06

SHEET 1 OF 3

METRIC

PROJECT 12-1111-0088
W.P. 2177-08-00
DIST Central HWY QEW
DATUM Geodetic

LOCATION N 4765798.4 ;E 336509.5
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
DATE June 18 and 19, 2013

ORIGINATED BY SB
COMPILED BY AV
CHECKED BY MM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
174.9	GROUND SURFACE										
0.0	ASPHALT (200 mm)										
174.4	CONCRETE (300 mm)										
0.5	Sand and gravel (FILL) Dense Brown Moist		1	SS	30		174		○		
173.4											
1.5	Silty clay, trace sand, trace organics (FILL) Firm Mottled grey and brown Wet		2	SS	5		173		○		
			3	SS	6		172		○		
			4	SS	4				○		
	Black staining below a depth of 3.8 m.		5	SS	4		171		○		0 2 33 65
			6	SS	7		170		○		
169.4								>96 +			
5.5	CLAYEY SILT, trace to some sand, trace to some gravel Stiff Brown becoming grey below a depth of 10.7 m Wet		7	SS	6		169		○		
							168	>96 +			
			8	SS	6		167		○		
								>96 +			
			9	SS	4		166		○		
							165	2 +			
								2 +			
			10	SS	2		164		○		
						▽		2 +			
							163	2 +			
			11	SS	3				○		
							162	2 +			
	Silt seams at a depth of 13.7 m.							>96 +			
			12	SS	8		161		○		
							160	3 +			

Continued Next Page

+ 3, × 3: Numbers refer to Sensitivity

○ 3% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No 13-06

SHEET 2 OF 3

METRIC

PROJECT 12-1111-0088
W.P. 2177-08-00
DIST Central HWY QEW
DATUM Geodetic

LOCATION N 4765798.4 ;E 336509.5
BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers
DATE June 18 and 19, 2013

ORIGINATED BY SB
COMPILED BY AV
CHECKED BY MM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × REMOULDED)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	CLAYEY SILT, trace to some sand, trace to some gravel Stiff Brown becoming grey below a depth of 10.7 m Wet		13	SS	3		159	+ 2	○		9 6 45 40
								+ 2			
			14	SS	3		158		○		
157.1											
17.8	SILT, some sand, trace to some clay Very loose Brown Wet		15	SS	WH		157	>96 +	○		0 13 80 7
154.8							156				
							155				
20.1	SAND, some silt, trace to some clay Compact Brown Wet						154				
			16	SS	17		153		○		
							152				
							151				
			17	SS	18		150		○		0 78 14 8
							149				
							148				
			18	SS	15		147		○		
145.6							146				
29.3							145				

Continued Next Page

$+^3$, $\times^3$: Numbers refer to Sensitivity

$\circ^{3\%}$ STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No 13-06

SHEET 3 OF 3

METRIC

PROJECT 12-1111-0088

W.P. 2177-08-00 LOCATION N 4765798.4 ;E 336509.5 ORIGINATED BY SB

DIST Central HWY QEW BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers COMPILED BY AV

DATUM Geodetic DATE June 18 and 19, 2013 CHECKED BY MM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	SAND and GRAVEL, some silt, trace to some clay Very dense Brown Wet		19	SS	66		144		○		
							143				
							142				
			20	SS	90/0.15				○		42 37 15 6
	Split-spoon sampler bouncing.						141				
139.5							140				
35.4	AUGER REFUSAL END OF BOREHOLE NOTES: 1. Sand blown up inside auger to a depth of 12.2 m (Elev. 162.7 m) during drilling at a depth of 18.9 m (Elev. 156.0 m). 2. Water level inside auger at a depth of 9.1 m below ground surface (Elev. 165.8 m) during drilling.										

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

FORM MB-MT-126
66-4846

OFFICE REPORT ON SOIL EXPLORATION

MTO 111-1

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO. 1

FOUNDATION SECTION

JOB 68-F-8 LOCATION Q.E.W. & Lyons Creek (Ramp S-EW) Sta. 5 + 47 10.5' Lt. ORIGINATED BY VK
W.P 158-64-3 BORING DATE Feb. 1, 1968 COMPILED BY VK
DATUM Geodetic BOREHOLE TYPE Diamond Drill - NX, AX Casing, AXT Core CHECKED BY

SOIL PROFILE ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	BLOWS/FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS/FOOT 20 40 60 80 100 / SHEAR STRENGTH PSF ○ Unconfined + Field Vane 400 800 1200 1600 2000	LIQUID LIMIT w_L / PLASTIC LIMIT w_P / WATER CONTENT w — WATER CONTENT % 20 40 60	BULK DENSITY ϒ PCF	REMARKS Gr.Sa.Si.Cl
568.0	Ground Level									
0.0	Desiccated (mottled brown to grey-brown) Very stiff		1	SS	28					0 1 27 72
			2	SS	15	560				0 4 61 35
			3	TW	PM		3345		124	▽556.5
			4	TW	PM					
			5	TW	PM					
552.0			6	TW	PM				121	
16.0	Silty clay to clayey silt, trace of sand & occasional gravel (occasional seams of silt up to 2" thick throughout) (grey-brown) Firm to stiff		7	TW	PM	550	+S.2			
			8	TW	PM	540	+S.2		126	
			9	TW	PM		+S.2			
			10	TW	PM	530			126	
510.0			11	SS	14	520				
58.0	Sandy silt to silty fine sand occasional boulders up to 6 to 12" in size below about elev. 477 Compact to very dense		12	SS	18	510				0 31 63 6
			13	SS	59	500				
			14	AXT	39%	490				
			15	AXT	16%	480				
			16	AXT	11%	470				
			17	AXT	20%	460				
			18	AXT	13%	450	0 + 15 — 9 — 10 % Strain to failure			
448.0										
120.0	Dolomitic Limestone		19	AXT	100%					
444.0	Bedrock (sound)									
124.0	End of Borehole									

MTO 111-4

DEPARTMENT OF HIGHWAYS - ONTARIO
MATERIALS & TESTING DIVISION

RECORD OF BOREHOLE NO 4

FOUNDATION SECTION

JOB 68-F-8 LOCATION (Ramp S-EW) Sta. 4 + 01 22.5' Rt. ORIGINATED BY VK
W P 158-64-3 BORING DATE Feb. 19, 1968 COMPILED BY VK
DATUM Geodetic BOREHOLE TYPE Diamond Drill - NX, BX Casing - AXT Core CHECKED BY

SOIL PROFILE ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	BLOWS / FOOT	ELEV SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT 20 40 60 80 100; SHEAR STRENGTH psf ○ Unconfined + Field Vane 400 800 1200 1600 2000	LIQUID LIMIT w_L, PLASTIC LIMIT w_P, WATER CONTENT w; w_P w w_L; WATER CONTENT % 20 40 60	BULK DENSITY γ PCF	REMARKS ▼ W.L.
562.0	Ground Level									
0.0	Organic clayey silt. (Black) Very soft to soft		1	TW	PM	560	+S.4 6.4		172 140	Org. 13.3%
553.5			2	TW	PM					
			3	TW	PM					
8.5	Silty clay to clayey silt, trace of sand and occasional gravel (grey-brown) Firm to stiff		4	TW	PM	550	+S.3		124	
			5	TW	PM		+S.3			
			6	TW	PM	540	+S.2		122	
			7	TW	PM		+S.2			
			8	TW	PM	530	+S.3		125	
			9	TW	PM		+S.2			
			10	TW	PM	520	S.2			
516.0										
46.0	Sandy silt to silty fine sand, occasional boulders up to 6-12" in size below about elev. 482. Compact to dense.		11	SS	13	510				Gr.0,Sa.19 Si.76,Cl.5
			12	SS	26	500				
			13	SS	15	490				
						480				
						470				
						460				
447.0						450				
445.0	Dolomitic Limestone Bedrock (sound)		14	AXT	100%					
117.0	End of Borehole					440	0 5 10 % Strain to failure			

Golder Associates

RECORD OF BOREHOLE No 13-07

SHEET 1 OF 3

METRIC

PROJECT 12-1111-0088

G.W.P. 2177-08-00 LOCATION N 4765574.3 ;E 336686.4 ORIGINATED BY SB

DIST Central HWY QEW BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers COMPILED BY AV

DATUM Geodetic DATE July 4 and 5, 2013 CHECKED BY MM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS
174.2	GROUND SURFACE					
0.0	ASPHALT (225 mm)					
0.2	Sand and gravel (FILL) Compact Grey Moist		1	SS	14	
173.4						
0.8	Silty sand (FILL) Loose Brown Wet		2	SS	8	
172.8						
1.4	Silty clay, some sand, trace gravel, trace organics, trace rootlets to a depth of 2.1 m (FILL) Firm Grey Wet		3	SS	6	
			4	SS	5	
			5	SS	5	
170.1						
4.1	SILTY CLAY to CLAY, trace sand, silt seams throughout Stiff Brown and grey Wet		6	SS	9	▽
			7	SS	10	
167.0						
7.2	CLAYEY SILT, trace sand, trace gravel Stiff Brown becoming grey below a depth of 10.7 m Wet		8	SS	10	
			9	SS	9	
			10	SS	5	
			11	SS	3	
			12	SS	5	

ELEVATION SCALE: 174, 173, 172, 171, 170, 169, 168, 167, 166, 165, 164, 163, 162, 161, 160

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × REMOULDED
20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%): 20 40 60

UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)	GR	SA	SI	CL
	3	73	24	0
	0	2	27	71

Continued Next Page

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

Golder Associates

RECORD OF BOREHOLE No 13-07

SHEET 2 OF 3

METRIC

PROJECT 12-1111-0088

G.W.P. 2177-08-00 LOCATION N 4765574.3 ;E 336686.4 ORIGINATED BY SB

DIST Central HWY QEW BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers COMPILED BY AV

DATUM Geodetic DATE July 4 and 5, 2013 CHECKED BY MM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa (○ UNCONFINED, ● QUICK TRIAXIAL, + FIELD VANE, × REMOULDED)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
	CLAYEY SILT, trace sand, trace gravel Stiff Brown becoming grey below a depth of 10.7 m Wet		13	SS	5		159				
							158				
			14	SS	3		157				
							156				
			15	SS	3		155				
							154				
			16	SS	2		153				
151.1							152				
23.1	SILT, trace to some clay, trace sand Loose to compact Brown Wet		17	SS	5		151				0 3 85 12
							150				
							149				
							148				
			18	SS	15		147				
							146				
							145				
144.3											

Continued Next Page

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

Golder Associates

RECORD OF BOREHOLE No 13-07

SHEET 3 OF 3

METRIC

PROJECT 12-1111-0088

G.W.P. 2177-08-00 LOCATION N 4765574.3 ;E 336686.4 ORIGINATED BY SB

DIST Central HWY QEW BOREHOLE TYPE 108 mm I.D. Continuous Flight Hollow Stem Augers COMPILED BY AV

DATUM Geodetic DATE July 4 and 5, 2013 CHECKED BY MM

ELEV / DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (20 40 60)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	--- CONTINUED FROM PREVIOUS PAGE ---										
29.9	Silty SAND, trace to some gravel, trace clay Loose Grey Wet		19	SS	5		144 143		○		6 71 22 1
142.0							142				
32.2	END OF BOREHOLE AUGER REFUSAL NOTE: 1. Water level inside auger at a depth of 5.1 m below ground surface (Elev. 169.1 m) upon completion of drilling.										

$+^3, \times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

RECORD OF BOREHOLE No 1

1 of 3

METRIC

G.W.P. _____ LOCATION Coords: E:336743.2 N:4765557.5 ORIGINATED BY SD

DIST _____ HWY QEW BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING COMPILED BY HA

DATUM GEODETIC DATE 2015-11-23 - 2015-11-25 CHECKED BY RA

ELEV / DEPTH (m)	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	SPT 'N' VALUE	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) (10 20 30)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
174.3	**GROUND SURFACE**						174				
174.1 / 0.2	165mm **ASPHALTIC CONCRETE**										
	FILL, gravelly sand, trace to some silt, trace clay, dense, brown, dry		1	AS	-						
			2	SS	39				○		43 42 12 3
172.9 / 1.4							173				
172.7 / 1.6	**FILL**, sand, trace silt, loose, brown, moist		3	SS	6						
	FILL, silty clay, trace sand, trace gravel, firm to stiff, brown, moist to wet						172				sampler wet at 2.3m
			4	SS	6						
			5	SS	11		171		○ LL=46		0 2 38 60
	some organics, grey		6	SS	5						
169.9 / 4.4	**SILTY CLAY**, trace sand, firm to stiff, grey, moist to wet		7	SS	4		170				
			8	SS	5		169				0 1 47 52
			9	TW	PH		168				
								+ 3.9			
							167	+ 2.4			
			10	SS	5				○		
							166	+ 2.4			
								+ 2.1			
			11	TW	PH		165			20.0	0 3 59 38
								+ 2.7			
							164	+ 2.2			
			12	SS	6						0 3 58 39
							163	+ 2.2			
								+ 1.8			
			13	TW	PH		162				
								+ 1.4			
							161	+ 2.1			
			14	SS	7						1 4 50 45
							160	+ 2.8			

Continued Next Page

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

Ministry of Transportation
Ontario

Terraprobe

RECORD OF BOREHOLE No 1

2 of 3

METRIC

G.W.P. _____ LOCATION Coords: E:336743.2 N:4765557.5 ORIGINATED BY SD

DIST _____ HWY QEW BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING COMPILED BY HA

DATUM GEODETIC DATE 2015-11-23 - 2015-11-25 CHECKED BY RA

ELEV / DEPTH (m)	DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: SPT 'N' VALUE	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT / WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	(continued)										
	SILTY CLAY, trace sand, firm to stiff, grey, moist to wet		15	SS	-*		159	1.8			Nov. 23, 2015
											Nov. 24, 2015
							158	1.9			
			16	SS	5						
							157	1.9			
								1.9			
			17	SS	6		156				2 4 55 39
								1.9			
							155	1.5			
			18	SS	8						
							154	1.9			
								1.6			
							153				
							152				
			19	SS	-*						
150.5							151	>+			
23.8	**SILT**, trace clay, trace to some sand, dense, brown, wet						150				
							149				
			20	SS	40		148				0 3 90 7
							147				
							146				
			21	SS	148 / 250mm						Nov. 24, 2015
145.0							145				Nov. 25, 2015
29.3	**SANDY GRAVEL**, containing cobbles and boulders, very dense, grey, moist to wet										

Continued Next Page

+ ³, × ³: Numbers refer to Sensitivity

○ ³% STRAIN AT FAILURE

Ministry of Transportation
Ontario

Terraprobe

RECORD OF BOREHOLE No 1

3 of 3 **METRIC**

G.W.P. _____ LOCATION Coords: E:336743.2 N:4765557.5 ORIGINATED BY SD

DIST _____ HWY QEW BOREHOLE TYPE HOLLOW STEM AUGERS/CASING AND WASH BORING COMPILED BY HA

DATUM GEODETIC DATE 2015-11-23 - 2015-11-25 CHECKED BY RA

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV / DEPTH (m)	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	SPT 'N' VALUE			SHEAR STRENGTH (kPa)	WATER CONTENT (%)	γ kN/m^3	GR SA SI CL
	(continued)							20 40 60 80 100	10 20 30		
	SANDY GRAVEL, containing cobbles and boulders, very dense, grey, moist to wet		22	RC			144				
			23	RC							
			24	RC			143				
			25	SS	100/ 100mm						
141.6 / 32.7			26	SS	100/ 75mm		142				

END OF BOREHOLE

Borehole filled with drill water upon completion of drilling.

*Rods slipped while attempting SPT Test.

Consolidation test performed on TW11.

Borehole extended with a Tricone bit from 31.3m to 32.6m.

○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE × LAB VANE

$+^3$, $\times^3$: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

file: 1-15-0689 tee creek rd – bh logs.gpj

Borehole 6

Ground Surface elevation 592.04
Top of bedrock depth 40'-4"
" " " elevation 551.71
B X L core was recovered from 40'-4" to 55"-5" and is described as follows.

40"-4"-42"4" Grey Dolomite, Genereally sound with some slight weathering.
42"-4"-46"-4" Grey Dolomite, sound. At 43"-4" lost some drilling water, no evidence in the core.
46"-4"-55"5" Grey Dolomite, Generally sound with vuggy texture, porous rock with water worn cavities up to 1"X¼"X½". some brown and white crystals in cavities probably calcite.

Piezometer 7

Ground surface elevation - 593.00
Continuous 3" diatmeter shelby tube samples were taken within the upper reddish silt stratuen from 15'-17', 17'-19' and 19'-21'. A piezometer was installed at 19 feet and sealed within the upper silty clay stratum.

The water level within the supper silt stratum has been establised at 6ft. 6 in.

Piezometer 8

Ground surface elevation - 592.34
Continuous 3" diatmeter shelby tube samples were taken within the lower reddish silt stratum from 30'-32', 32'-34' and 34'-36'. A piezometer was installed at 34ft 6in. and sealed within the lower sily clay stratum. The water level within the lower silt stratum has been established at 11ft 6in. A gradation curve of this stratum is attached.

golder.com

V3.9.2

REGIONAL MUNICIPALITY OF NIAGARA
SOUTH NIAGARA FALLS WASTEWATER SOLUTIONS

Geotechnical Investigation

Preliminary Geotechnical Investigations – Preferred WWTP Site and Trunk Sewer

REPORT ON PRELIMINARY GEOTECHNICAL INVESTIGATION FOR PROPOSED SOUTH NIAGARA FALLS WASTEWATER TREATMENT PLANT (WWTP) AND ASSOCIATED TRUNK SEWER, TOWNSHIP OF WILLOUGHBY, REGION OF NIAGARA

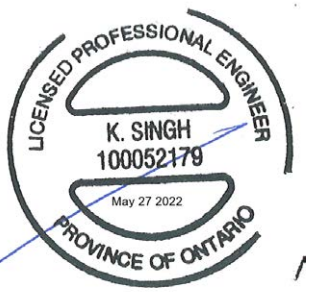
REGION OF NIAGARA

PROJECT NO.: 201-11602-00
MAY 27, 2022

WSP CANADA INC.
2 INTERNATIONAL BLVD., SUITE 201
TORONTO, ON M9W 1A2

T: +1 416 798-0518
WSP.COM

SIGNATURES



Kulbir Singh, M.Eng., P.Eng.
Senior Engineer,
Geotechnical

Laifa Cao, Ph.D., P.Eng. Principal
Engineer, Geotechnical

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APPENDICES

1 Introduction

WSP Canada Inc. (WSP) was retained by the Region of Niagara to undertake a preliminary geotechnical investigation for the proposed trunk sewer installation from the existing High Lift Sewage Pumping Station (SPS), along Montrose, Brown and Reixinger Roads, to the proposed location of a new Wastewater Treatment Plant (WWTP) at 6811 Reixinger Road.

The purpose of the investigation was to determine the subsurface conditions at the borehole locations and from the findings in the boreholes to make geotechnical engineering recommendations for the proposed watermain.

It is understood the proposed 1500 mm and 1800 mm concrete trunk sewer will be installed as part of South Niagara Falls Wastewater Solution project. It is further understood the invert of the proposed pipe will be at about 9.8m to 22.0m below existing ground.

This report is provided on the basis of the terms of reference presented above and, on the assumption, that the design will be in accordance with the applicable codes and standards. If there are any changes in the design features relevant to the geotechnical analyses, or if any questions arise concerning the geotechnical aspects of the codes and standards, this office should be contacted to review the design. It may then be necessary to carry out additional borings and reporting before the recommendations of this office can be relied upon.

The site investigation and recommendations follow generally accepted practice for geotechnical consultants in Ontario. The format and contents are guided by client specific needs and economics and do not conform to generalized standards for services. Laboratory testing for most part follows ASTM or CSA Standards or modifications of these standards that have become standard practice.

This report has been prepared for the Region of Niagara. Use of this report by third party without WSP consent is prohibited.

2 Field and Laboratory Works

2.1 Geotechnical Boreholes and Field Testing

The field investigation consisted of drilling a total of seventeen (17) exploratory boreholes (BH20-1 through BH20-12S/D and BH-P01 to BH-P03, see **Drawings 2** to **10** for borehole locations) to depths ranging from 4.6 of 39.6 m below ground surface.

A summary of the borehole data is presented in **Table 2.1**.

Table 2.1 Summary of Borehole Information

Location	Borehole	Easting	Northing	Approximate Ground Elevation (m)	Depth of Borehole (m)	Note
		NAD83, UTM Zone 17				
High Lift	BH20-01	653265.4	4769584.2	180.5	16.8	Monitoring
Montrose	BH20-02	652816.7	4769568.12	181.2	16.8	-
Brown	BH20-03	652136.1	4769057.2	178.1	20.1	Monitoring
Montrose	BH20-04	652847.8	4769091.2	178.9	19.9	-
Montrose	BH20-05	652873.2	4768160.9	177.8	25.0	-
Montrose	BH20-	652872.7	4767709.7	175.8	30.5	Monitoring
Montrose	BH20-	652872.6	4767710.5	175.8	15.2	Monitoringg
Montrose	BH20-	652880.1	4767374.6	177.1	30.7	Monitoring
Montrose	BH20-	652880.3	4767373.8	177.0	19.8	Monitoring
Reixinger	BH20-08	654312.3	4766690.0	176.9	39.6	Monitoring
Montrose	BH20-09	652916.4	4766605.9	176.0	29.3	-
Future	BH20-10	654268.2	4766859.2	176.7	9.8	Monitoring
Future	BH20-11	654318.8	4766986.7	176.5	9.8	Monitoring
Future	BH20-	654078.5	4767290.4	174. 9	9.8	Monitoring
Future	BH20-	654080.1	4767289.9	174.9	4.6	Monitoring
Montrose	BH-P01	653228.0	4769629.8	180.5	7.6	Monitoring
Brown	BH-P03	4769057.188	652135.2	178.1	5.2	Monitoring

Borehole locations for this investigation were established by WSP personnel in accordance with the Region of Niagara requirements. Prior to drilling operations, all underground utilities were cleared at the borehole locations.

The field investigation work of drilling the boreholes were undertaken on December 2 to 23, 2020 by a drilling sub-contractor under the direction and supervision of WSP personnel. Borehole logging services were provided by the engineering staff of WSP. The boreholes were advanced with power auger drilling machines equipped with hollow stem augers. The soil stratigraphy was recorded by observing the quality and changes of augered materials which were retrieved from the boreholes, and by sampling the soils at regular intervals of depth using a 50 mm O.D. split spoon sampler, in accordance with the Standard Penetration Test (ASTM D 1586) method. This sampling method recovers samples from the soil strata, and the number of blows (SPT 'N'-values) required to drive the sampler 0.3 m depth into the undisturbed soil gives an indication of the compactness condition or consistency of the sampled soil material. The SPT 'N' values are indicated on the borehole log sheets (Refer to **Appendix A**). Soil samples were visually classified in the field and later re-evaluated in our laboratory.

Upon encountering bedrock in BH20-01, BH20-03 to BH20-05, BH20-07D, BH20-08 and BH20-09, coring of the rock was affected with HQ-2 size double tube wireline equipment, allowing recovery of 63mm diameter rock cores. The monitoring technician recorded the standard penetration test resistances and visually described the soil and rock samples. The Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) values and Fracture Indices (FI) were recorded for the rock cores in accordance with the conventions used by the International Society for Rock Mechanics (ISRM). An explanation of these terms is presented in the fly sheet at the beginning of **Appendix A**. Photographs of the recovered cores are provided in **Appendix D**.

The ground surface elevations at the borehole locations were surveyed by WSP and referenced to a geodetic datum.

Groundwater monitoring wells were installed in thirteen (13) boreholes and the groundwater level measured from the monitoring wells are provided in Section 3.7.

2.2 Geotechnical Laboratory Testing

The soil samples were taken to our laboratory where they were re-examined. Representative samples were selected for geotechnical index testing. The testing program consisted of the measurement of the natural moisture content of all available soil samples, grain size analyses on twenty-one (21) selected samples and consistency (Atterberg) limits for nine (7) soil samples and two (2) soil unit weight. A one-dimensional consolidation test performed on undisturbed sample collected from soft clay and the results are attached in **Appendix E**. Test results are

shown on the individual borehole logs presented in **Appendix A**. The grain size analysis curves and results of the consistency (Atterberg) limit tests are plotted on **Figures 1 to 9** attached to this report in **Appendix B**.

Testing of the rock cores consisted of point load index strength tests on six (6) samples, unconfined compressive strength (UCS) tests on six (6) rock samples with measurement of unit weight (γ). These test results are provided in **Appendix D**. Results of point load tests and unconfined compressive strength are also presented on the borehole log sheets of **Appendix A**.

3 Subsurface Conditions

The borehole location plan and profiles are shown in **Drawings 1** to **10** and explanation of terms used in the record of borehole are presented in **Appendix A**. The subsurface conditions in the boreholes are presented on individual borehole logs (Refer to **Appendix A**). The subsurface conditions in the boreholes are summarized in the following paragraphs.

3.1 Pavement/Topsoil/Fill Material

The boreholes BH20-10 to BH20-12 were drilled on agricultural land and encountered about 150mm to 230mm of topsoil at the surface.

Five boreholes (BH20-02, BH20-03, BH20-05, BH20-06D, and BH20-09) were encountered 100mm to 150mm thick asphalt at the surface. 50mm and 700mm granular base material encountered in borehole BH20-05 and BH20-09, respectively. Below asphalt, 6.4 m thick crushed run limestone was encountered in BH20-02; 1.3 m thick granular fill was encountered in BH20-03; 50 mm granular fill and 0.9m crusher run limestone were encountered in BH20-05; 1.7 m thick crushed run limestone was encountered in BH20-06D; and 0.7 m thick granular fill was encountered in BH20-09. 0.8 m thick crushed run limestone was also encountered within the silty clay fill in BH20-06D

0.1 to 0.8 m thick crushed run limestone was encountered at ground surface in BH20-04 and BH20-07D.

Silty clay fill was encountered in some boreholes to depths varying from 1.1 to 5.7 m below ground surface (mbgs). Trace to some inclusions of organics were noted in the fill material. Fill was present in soft to very stiff consistency, with measured SPT ‘N’ values varying from 3 to 27 blows per 300 mm of penetration.

One (1) selected silty clay fill samples (BH20-3/SS6) were subjected to grain size analysis. Gradation curve is presented in **Figure 1** of **Appendix B** and summarized below:

Gravel:	0 %
Sand:	1 %
Silt and clay:	99 %

Atterberg limit testing was performed on the same sample (BH20-3/SS6) and the results is provided on **Figure 2** in **Appendix B**. The results of this testing indicated liquid limits of 54, plastic limits of 25, and plasticity indexes of 29. Based on this, the soil is classified as silty clay to clay of high plasticity (CH) according to the Unified Soil Classification System.

3.2 Silty Clay

Below the fill material in all boreholes a deposit of silty clay was encountered at depths of 1.1 to 6.6 mbgs and extended to depths of 4.6 to 23.2 mbgs. The borehole BH20-10 to BH20-12 were terminated within this cohesive deposit.

The cohesive deposit was found to be in a very soft to hard consistency with measured SPT 'N' value of nil blows to 30 blows per 300 mm of penetration. The water content obtained from the samples revealed from this deposit were 6 to 40%.

A layer of organic clay was embedded within the silty clay deposit in borehole BH20-06 at depths of 7.2 to 9.3 mbgs with measured SPT 'N' value of 0 to 4 blows per 300 mm of penetration and natural moisture content of 102 to 117%. The SPT 'N' value of 0 blow per 300 mm means the sampler settles more than 300 under the weight of 63.5 kg hammer.

Shear vane in-situ test was carried out within the silty clay deposit at regular intervals where the SPT 'N' values below 10 blows for 300 mm penetration. Shear vane testing within the silty clay deposit yielded shear strengths 28 to 59 kPa, indicating a firm to stiff consistency. The sensitivity ranged from 1.0 to 3.3.

One oedometer test was conducted on the silty clay sample at a depth of 6.6 mbgs. The test shows a compression index of 0.72, recompression index of 0.06, void ratio of 1.0, unit weight of 18.3 kN/m^3 and preconsolidation pressure of 180 kPa.

A layer of silt was interbedded within the silty clay deposit in borehole BH20-03, BH20-08 and BH20-09 at depths of 4.6 to 13.3 mbgs and extended to depths of 5.3 to 14.8 mbgs. The silt deposit was found to be in loose to compact state of compactness with measured SPT 'N' value of 8 to 24 blows per 300 mm penetration. The natural moisture content obtained from the sample reveled from silt layer was 24 to 27%.

Seventeen (17) selected silty clay samples were subjected to grain size analysis and Atterberg limit testing was performed on eight (8) samples and the results are provided on **Figure 3** in **Appendix B**. Gradation curves are presented in **Figure 4** of **Appendix B** and the result of gradation and Atterberg limit test are summarized in table below:

Borehole No.	Sample No.	Gravel %	Sand %	Silt and Clay %	Plastic Limit	Liquid Limit	Plastic Index
BH20-01	SS5	0	1	99	23	51	28
BH20-01	SS9	0	1	99	20	37	17
BH20-02	SS11	0	0	100	-	-	-

BH20-03	SS5	0	0	100	17	31	14
BH20-04	SS9	0	4	96	16	31	15
BH20-04	SS12	0	0	100	-	-	-
BH20-04	SS14	0	0	100	-	-	-
BH20-05	SS9	0	2	98	19	37	18
BH20-05	SS14	0	5	95	17	26	9
BH20-06	SS16	4	3	93	-	-	-
BH20-07	SS18	0	15	85	-	-	-
BH20-09	SS12	0	5	95	17	27	10
BH20-09	SS15	5	8	87	18	34	16
BH20-09	SS17	0	4	96	-	-	-
BH20-10	SS11	1	5	94	-	-	-
BH20-11	SS11	0	4	96	-	-	-
BH20-12	SS11	1	6	93	-	-	-

Based on this, the soil is classified as low to high plasticity silty clay or clay (CL or CH) according to the Unified Soil Classification System.

3.3 Clayey Silt Till

A deposit of clayey silt till deposit was encountered below the silty clay layer in borehole BH20-1 and below silt layer in boreholes BH20-2 and BH20-7 locations at depths of 10.2 to 24.7 mbgs. The clayey silt deposit was extended to the borehole depths of 11.7 to 26.4 mbgs.

Boulders/cobbles within the till deposit were interfered during the borehole drilling due to high SPT ‘N’ value and nature of deposit. The current investigation method could not determine the size and frequency of boulder and cobbles.

In general, SPT ‘N’ values in this deposit ranged from 7 to more than 50 blows per 300mm penetration, corresponding to firm to hard consistency. The moisture content of samples recovered from cohesionless deposit ranged between 8% to 24%.

A selected clayey silt till sample (BH20-1/SS12) was subjected to grain size analyses. Gradation curve is presented on **Figures 5** of **Appendix B** and summarized below:

Gravel:	11%
Sand:	32%
Silt:	45%
clay:	12%

3.4 Sandy Gravel/ Sand/ Silt and Sand/ Silt

Below the silty clay layer or below clayey silt till deposit in all boreholes, a deposit of cohesionless soils comprised of silt, silt and sand & sandy gravel was encountered at depths of 11.7 to 23.2 mbgs and extended to depths of 14.3 to 27.4 mbgs. The cohesionless deposit was found in very loose to very dense state of compactness with measured SPT 'N' value of 2 to over 50 blows per 300 mm penetration. Water contents ranged from 9% to 27%.

Boulders/cobbles should be expected within the cohesionless deposit due to their nature of deposit.

Three (3) selected silt to silty sand samples (BH20-1/SS13, BH20-3/SS17 and BH20-4/SS15) were subjected to grain size analyses. Gradation curves are presented on **Figures 6** of **Appendix B** and summarized below:

Gravel:	3 to 26%
Sand:	5 to 40%
Silt And Clay:	34 To 92%

3.5 Clayey Silt (Residual Soil)

Localized clayey silt (residual soil) clay deposit in borehole BH20-09. The residual soil deposit extended to a depth of 19.9 mbgs. The deposit hard clayey silt matrix containing extensive broken bedrock slabs and fragments. This stratum was difficult to auger due to the fragmented dolostone content and given its hard condition. The natural moisture content measured in the test sample from these materials was 13%.

This complex is a transitional deposit between bedrock and the overlying soil or may be the completely to highly weathered bedrock. This deposit has characteristics of both the bedrock and soil. The rock slabs found within the soil matrix can be quite large in size (0.5m to 1m or more).

3.6 Bedrock

Dolostone of Salina Formation was cored and inferred due to auger/spoon refusal in boreholes BH20-01, BH20-03, BH20-04, BH20-05, BH20-06D, BH20-07D, BH20-08 and BH20-09 at depths ranging from 14.3 to 29.3 m below the existing ground surface, corresponding to Elevation 147.6 to 166.1 m, as listed in **Table 3.1**. Bedrock was proven by bedrock coring in boreholes BH20-01, BH20-03, BH20-04, BH20-05, BH20-07, BH20-08 and BH20-09. Rock core logs are provided on borehole logs appended in **Appendix A** and the photographs of the rock cores are provided in **Appendix D** of this report. The rock core mainly consists of dolostone.

Table 3.1 Approximate Depth and Elevation of Bedrock Surface

Borehole No.	Existing Ground Surface Elevation (M)	Depth Of Bedrock Surface Below Existing Ground (M)	Approximate Elevation of Bedrock Surface (M)	Notes
BH20-01	180.5	14.3	166.1	Bedrock coring
BH20-03	178.1	15.2	162.9	Bedrock coring
BH20-04	178.9	16.5	162.5	Bedrock coring
BH20-05	177.8	23.8	154.1	Bedrock coring
BH20-	175.8	27.4	148.4	Augering
BH20-	177.1	26.4	150.7	Bedrock coring
BH20-08	176.9	29.3	147.6	Bedrock coring
BH20-09	176.0	20.9	155.1	Bedrock coring

Because of the method of drilling and sampling, the surface elevations of the bedrock may be different than indicated on the borehole logs. With augering, the auger may penetrate some of the more weathered dolostone and the coring may therefore begin below the bedrock surface. As such, the interred bedrock surface level should not be considered accurate to better than +/-1.5m.

The descriptive terms used on the record of rock cores and throughout this report are explained on the “Explanation of Terms Used in the Bedrock Core Log” sheet in **Appendix A**. In general, the conventions of the International Society for Rock Mechanics (ISRM) are

adopted herein. Detailed descriptions of the index properties and results of laboratory testing are presented in the following paragraphs.

Six-point load index strength tests were performed on dolostone rock samples. The test results are presented in individual borehole logs. The equivalent unconfined compressive strength of rock samples was inferred to range from 40.0 to 189.0 MPa in axial direction with average strength of 92.8 MPa and from 24.0 to 96.0 MPa in the diametral direction with average strength of 56.8 MPa. The values are indicative “weak” to “very Strong”, but generally “medium strong” to “very strong” rock under ISRM strength convention.

The UCS of the tested samples of bedrock ranged from 100 to 223.5 MPa. The test results indicated that the dolostone samples are “strong” to “very strong” rock under the ISRM strength convention. Results of point load tests and unconfined compressive strength are also presented on the borehole log sheets and appended in **Appendix C**.

3.6.1 Total Core Recovery (Tcr)

The total core recovery indicates the total length of rock core recovered, expressed as a percentage of the actual length of the core run. The total core recovery ranged from 58% to 100%. Generally, low core recovery was experienced only near the surface of the rock, where the formation is more weathered.

3.6.2 Solid Core Recovery (Scr)

The solid core recovery is the total length of solid, full diameter rock core that was recovered, expressed as a percentage of the length of the core run. Solid core recovery ranged from 23% to 100% but generally was found to be in the range of 70% to 100% generally improving with depth. The SCR index is influenced by the orientations of the fractures.

3.6.3 Rock Quality Designation (Rqd)

The rock quality designation index is obtained by measuring the total length of recovered rock core pieces which are longer than 100 mm and expressing the sum total length as a percentage of the length of the core run. RQD is a function of the frequency of joints, bedding plane partings and fractures in the rock cores. On the basis of the recorded RQD values which range from nil to 100%, the rock quality is estimated to be “very poor” to “excellent”, and the average value of 64.3% suggests a rock of generally “fair” quality.

3.6.4 Fracture Index

When logging the rock cores, the fracture Index (i.e. the number of fractures for each 0.3 m length of core) was also recorded. It was observed that the planes of weaknesses along which the cores tended to break, included planes of fissility and bedding, and some oblique and subvertical joints.

3.7 Groundwater Conditions

The groundwater levels measured in the monitoring wells installed along proposed trunk sewer and WWTP investigation are summarized in **Table 3.2**.

Table 3.2 Summary of Groundwater Observations in Monitoring Wells

Borehole No.	Date Of Drilling	Existing Ground Elevation (m)	Date Of Water Measurement	Screen Depth (m)		Groundwater Level Depth (m)	Groundwater Level Elevation (m)
				From	To		
BH20-01	Dec. 9, 2020	180.5	Dec. 18, 2020 Dec. 23, 2020	15.3	16.8	9.9 9.8	170.5 170.7
BH20-03	Dec. 2, 2020	178.1	Jan. 13, 2021	4.6	7.6	3.5	174.6
BH20-06D	Dec. 15, 2020	175.8	Jan. 13, 2021	28.4	30.5	3.5	172.3
BH20-06S	Dec. 15, 2020	175.8	Jan. 13, 2021	12.2	15.2	3.9	171.9
BH20-07D	DEC. 21, 2020	177.1	Jan. 13, 2021	27.4	30.5	5.3	171.8
BH20-07S	DEC. 23, 2020	177.0	Jan. 13, 2021	16.8	19.8	4.6	172.4
BH20-08	DEC. 18, 2020	176.9	Dec. 23, 2020 Jan. 13, 2020 Jan. 26, 2021	36.6	39.6	6.5 4.6 4.7	170.4 172.3 172.2

Borehole No.	Date Of Drilling	Existing Ground Elevation (m)	Date Of Water Measurement	Screen Depth (m)		Groundwater Level Depth (m)	Groundwater Level Elevation (m)
				From	To		
BH20-10	DEC. 11, 2020	176.7	Dec. 18, 2020 Dec. 23, 2020	6.7	9.7	6.2 5.2	170.6 171.5
BH20-11	DEC. 11, 2020	176.5	Dec. 18, 2020 Dec. 23, 2020	6.7	9.7	7.1 6.7	169.3 169.8
BH20-12D	DEC. 10, 2020	174.9	Dec. 18, 2020 Dec. 23, 2020	6.7	9.7	7.0 6.9	167.9 168.0
BH20-12S	DEC. 10, 2020	174.9	Dec. 18, 2020 Dec. 23, 2020	1.5	4.5	4.0 3.7	170.9 171.2
BH-P01	DEC. 9, 2020	180.5	DEC. 18, 2020 DEC. 23, 2020	4.6	7.6	3.5 2.3	177.0 178.2
BH-P03	DEC. 3, 2020	178.1	JAN. 13, 2020	2.2	5.2	3.3	174.8

It should be noted that the groundwater levels can vary and are subject to seasonal fluctuations in response to major weather events. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

Refer to WSP's report entitled "Preliminary Hydrogeological Investigation – South Niagara Falls WW Solutions EA, Niagara Region, ON", dated May 27, 2022 for detailed discussions on the groundwater.

4 Geotechnical Interpretation and Recommendations

In this section, the subsurface conditions are interpreted as relevant to the design and construction of the proposed sewer trunk installation in Section 4.4, shaft installation in Section 4.5, and construction of wastewater treatment plant in Section 4.6 at the aforementioned sites. Comments relating to construction are intended for the guidance of Region of Niagara and its designers to establish the construction method.

The construction methods described in this report must not be considered as being specifications or direct recommendations to contractors, or as being the only suitable methods. Prospective contractors should evaluate all of the factual information, obtain additional subsurface information as they might deem necessary and should select their construction methods, sequencing and equipment based on their own experience in similar ground conditions. The readers of this report are also reminded that the conditions are known only at the borehole locations and in view of the generally wide spacing of the boreholes, conditions may vary significantly between boreholes.

4.1 Overview Of Subsurface Conditions and Recommended Geotechnical Parameters

4.1.1 Overview Of Subsurface Conditions

In simplified terms, the subsurface profile consists of pavement structure, topsoil or surficial fill material underlain by a native very soft to very stiff (occasional hard spot) cohesive silty clay textures, the cohesive deposit followed by sand to gravelly sand deposit or clayey silt till deposit. The bedrock underlaying the site at depths of 14.3 to 29.3 mbgs (Elev. 147.6 to 166.1 m). At the monitoring well locations, the groundwater table lies between 2.3 and 11.0 mbgs (between Elev. 167.9 m and 178.2 m). Perched water should be expected in the shallow granular fill and in any granular fill in the existing nearby utility trenches.

Borehole locations and subsurface profiles of the trenchless and open cut sections are presented in **Drawing Nos. 1** through **10**.

4.1.2 Recommended Design Parameters For Soil And Groundwater

Suggested soil parameters (unfactored) for the design of pumping station, chambers/manholes and ground support systems are summarized in **Table 4.1**. The suggested soil parameters are based on SPT 'N'-values, soil laboratory test results and supplemented by the judgement based on local and regional experience with these soil types.

Table 4.1 Recommended Unfactored Soil Parameters

Soil Type Spt 'N'	New Granular Fill		Existing Fill	Cohesive Native Soils - Silty Clay/Clayey Silt				Non-Cohesive Native Soils –Sand, Sandt Gravel, Silty Sand Gravely nd Silt			
	'A'	'B'	2-18	1-7	8-14	15-29	≥30	1-9	10-19	20-49	≥50
UNIT WEIGHT (kN/m^3)	22	21	20.5	19	20.5	21	21.5	19	20	21.5	22.5
EFFECTIVE ANGLE OF INTERNAL FRICTION (^{O}), ø'	35	32	28	26	28	30	32	28	30	32	37
EFFECTIVE COHESION, C' (kPa)	-	-	1	0	5	10	15	-	-	-	-
UNDRAINED SHEAR STRENGTH (kPa) (**)	-	-	50	30	75	100	200	-	-	-	-
COEFFICIENT OF LATERAL EARTH PRESSURE											
ACTIVE, K_a	0.27	0.31	0.36	0.39	0.36	0.33	0.31	0.36	0.33	0.31	0.25
AT REST, K_O	0.43	0.47	0.53	0.56	0.53	0.50	0.60	0.53	0.50	0.55	0.80
PASSIVE, K_p	3.69	3.25	2.77	2.56	2.77	3.00	3.25	2.77	3.0	3.25	4.03
ELASTIC MODULUS (MPa)	-	-	4	4	8	15	30	4	5	30	50
POISSION'S RATIO	-	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Soil Type Spt 'N'	New Granular Fill		Existing Fill	Cohesive Native Soils - Silty Clay/Clayey Silt				Non-Cohesive Native Soils –Sand, Sandt Gravel, Silty Sand Gravely nd Silt			
	'A'	'B'	2-18	1-7	8-14	15-29	≥30	1-9	10-19	20-49	≥50
MODULUS OF SUBGRADE REACTION, K (MN/m³) (*)	-	-	4/B	4/B	8/B	15/B	30/B	4/B	5/B	30/B	50/B
LATERAL MODULUS OF SUBGRADE REACTION, Ks (MN/m³) (*)	-	-	4/B	4/B	8/B	15/B	30/B	4/B	5/B	30/B	50/B

(*) B is the width of footing/Pipe in metres.

(**) The recommended undrained shear strength is used for the structural design, not for the selection of the excavation machine for which an undrained shear strength of up to 1000 kPa should be considered.

For the design purpose the groundwater level must be taken as the higher of 1m higher than the measured groundwater level in the nearest monitoring wells and the regional flood level.

4.1.3 Cobbles and Boulders

Boulders/cobbles were inferred based on auger grindings and high SPT 'N' value in the cohesionless and till deposit as well as residual soils. A very slow rate of drilling advancement was experienced during augering of these deposits given their heavily overconsolidated nature and presence of cobbles/boulders. The current investigation method of borehole drilling could not determine the size and frequency of the cobbles and boulder.

Cobbles are defined as rock fragments that cannot pass through a screen with 75 mm square openings and are less than 300 mm in maximum dimension. Boulders are defined as rock fragments with their maximum dimension being equal to or greater than 300 mm. Removal of cobbles during open cut excavations is considered part of routine construction and these materials will not be considered as obstructions for this project.

Boulders and other obstructions including but not limited to construction debris will be randomly distributed within the fill. Considering that the fill materials extend from the ground

surface to relatively shallow depths, it is not considered necessary, and it is not feasible, to estimate the frequency of obstruction within the fill.

The majority of boulders within the cohesionless deposit are expected to be generally less than 1 m in diameter; however, boulders with maximum dimensions of between 2 and 3 m have been encountered in excavations in the soil deposits of Southern Ontario. Cobbles and boulders shall be assumed to be comprised of Canadian Shield derived igneous or metamorphic rock of “extremely high” Cerchar abrasiveness and “very strong to extremely strong” unconfined strength (100 MPa to 250 MPa), as defined by ISRM (International Society for Rock Mechanics).

For preliminary geotechnical design, boulders (maximum dimension > 300mm) will comprise the following percentages by total volume of excavated soils based on local and regional experience:

- Cohesionless deposit – 0.5%
- Glacial till deposit – 0.5%
- Residual soil – 2.5%

4.2 Frost Depth

All pipes and footings must have at least 1.1 m of earth cover for frost protection.

4.3 Seismic Site Classification

Based on the borehole information and according to Table 4.1.8.4.A of OBC 2012, the subject site for the proposed structures founded on native soils and bedrock can be classified as ‘Class D’ and “Class C’ for seismic site response, respectively.

4.4 Trunk Sewer Installation with Trenchless Method

Based on information provided in the preliminary design drawing the majority of the proposed sewer trunk will be installed using trenchless techniques. The information provided by borehole BH20-1 to BH20-5 and BH20-9 as shown in **Drawing Nos. 2** to **10** indicate that within the proposed trunk sewer alignment, the soils mainly consist of soft to firm silty clay and compact to very dense silty sand to sand and gravel, and the soil will be very stiff to hard silty clay or loose to very dense cohesionless deposit at alignment with the location of boreholes BH20-06D/S to BH20-07D/S . Obstructions such as boulders/cobbles in the dense to very dense

cohesionless deposit should be expected. The groundwater level was varying from 2.3 m to 11.0 m below existing ground surface corresponding to elevation 167.9 to 178.2 m.

The soft to firm silty clay for the purpose of tunnelling can be categorized as “squeezing” and the cohesionless deposit below groundwater table should be consider as “flowing”, “fast ravelling” and “bouldery” ground in accordance with the behaviouristic ground classification system established by Terzaghi in 1950. (Refer to **Appendix F** for definitions of ground performance in tunnelling). The silty clay should be considered as “sticky” clay for tunnelling. In general, trenchless condition is considered to be challenging due to presence of the soil deposits ranged from soft cohesive soil to very dense cohesionless soils as well as cobbles/boulders within the cohesionless soils and high groundwater table.

It is understood that microtunnel boring machine (MTBM) will be used for the installation of trunk sewer. In this case, following should be considered:

The MTBM is capable to operate within the soft to firm clay with lowest SPT N-value of 2. Alternatively, consideration should be given to improve the soft to firm soils using soil improvement methods such as jet grout or other methods; and

Additional geotechnical investigation with borehole drilling, piezocone penetration tests and laboratory tests for the design of concrete pipe and soil improvement.

Alternatively, consideration should be given to lower the proposed trunk sewer alignment into the bedrock or dense to very cohesionless soil from Sta. 1+020 to approximately 3+080. Additional deep borehole drilling, rock coring and testing are required to conform the bedrock surface and properties.

4.5 Sealed Shafts

It is proposed to construct seven (7) sealed shafts (six shafts will be of diameter 3 m and one will be of 1.8 m diameter) that will be used to launch and receive the tunneling equipment, including the sanitary sewers. On completion of the tunneling work, all the seven shafts will be converted to sanitary sewer manholes. The excavation for the shafts will penetrate through fill, cohesive soils (till and non-till silty clay) and cohesionless soils (silt, sand, sand and gravel, gravelly sand). The shafts can consist of cast-in-place concrete circular shafts constructed top-down, excavated in–the-wet progressively as the concrete ring segments are cast and pushed down. Mass concrete plug is recommended to be placed at the shaft bottom to form a working base.

Alternatively contiguous caisson walls or Continuous interlocked steel sheet piles toed into the bedrock can be considered to minimize the need of dewatering for the construction of shafts.

The groundwater inflow during construction within a sealed shaft can be removed using sump pumps.

The design and construction of the permanent shaft support will be the responsibility of the contractor who must retain a specialist shoring design engineer. All shoring designs shall be in accordance with the 4th Edition of the Canadian Foundation Engineering Manual and must be reviewed by a Geotechnical Consultant. For cast-in-place concrete circular shafts, the coefficient of earth pressure at rest (K_o) as recommended in Table 4.1 should be used.

4.5.1 Lateral Earth Pressure

The lateral earth pressure can be evaluated from the following equation.

$$P = K_0 (\gamma h + q) + \gamma_W h$$

where p = lateral earth pressure in kPa acting at depth h

K_0 = coefficient of lateral earth pressure, taken the value from Table 4.1

γ = unit weight of backfill, taken the value from Table 4.1

h = depth below ground surface, m

q = surcharge load at ground surface kN/m^2

γ_W = unit weight of water = 10 kN/m^3

For design purpose, the groundwater level must be taken as the higher of 1m higher than the measured groundwater level in the nearest monitoring wells and the regional flood level.

If the ground surface is not horizontal due to excavation for the open cut section or because of the natural ground, then the uneven portion can be treated as an equivalent surcharge.

During freezing conditions, the shored walls must be protected against frost penetration and the build-up of frost pressure behind the wall.

4.5.2 Uplift Pressure

The sealed shafts and the permanent structures (the MHs) should be designed as water-tight structure, and uplift forces on the shaft structure should assume buoyancy forces corresponding to the high design ground water level shall be taken as the higher of 1m higher than the measured groundwater level in the nearest monitoring wells and the regional flood level.

If the combination of the weight of the structure and the mobilized frictional resistance between the buried portion of the exterior walls and the backfill materials is insufficient to resist the uplift

forces during any stage of the construction and/or during the operation of the structure, then a fail-safe system of grouted ground anchors is needed.

Post tensioned pressure-grouted soil anchors bonded into firm to stiff silty clay and compact gravelly sand can be designed using an allowable bond resistance of 30 kPa, but in no case should the bonded length be less than 4m. The group ground anchor capacity should be the minimum of (a) the sum of the individual anchor capacity or (b) the sum of the shear (bond) resistance mobilised on the surface perimeter area of the group and the effective weight of anchor/soil enclosed by this perimeter.

Pressure-grouted rock anchors can be designed using an allowable bond resistance of 300 kPa, but in no case should the bonded length be less than 4m.

The actual capacity (bond resistance) of the anchors should be established by at least two (2) full scale pull-out tests ("performance test") in accordance with Canadian Foundation Manual (4th edition), testing to 200% of working load. Each installed anchor must be proof loaded to 1.33 times the design working load, in accordance with Post-Tensioning Institute (PTI) guidelines.

Permanent ground anchors should be double-corrosion protected (i.e. PTI Class I).

Friction between the exterior walls and the granular backfill materials should only be taken into account if it is absolutely certain that no excavations will be undertaken around the exterior walls any time in the future. In this case, an ultimate friction factor of 0.4 applied to the horizontal earth pressure on the wall could be used, the average coefficient of earth pressure of 0.53, and unit weight of 10.7 kN/m^3 below groundwater table can be used in the calculation of horizontal earth pressure. When checking the overall stability of the structure, the design should incorporate a minimum safety factor of 1.1 when using only the dead weight of the structures. The safety factor to be used for the frictional resistance should not be less than 2.0.

4.6 Wastewater Treatment Plant

We understand that buildings, chambers, tanks, pumping station, roadways and yard piping will be constructed at the proposed wastewater treatment plant (WWTP).

4.6.1 Foundations

Boreholes BH20-8 and BH20-10 to BH20-12 were drilled in the area of WWTP. Boreholes BH20-10 to BH20-12 were drilled to a depth of 9.8 m and were terminated within the overburden. However, Borehole BH20-8 was drilled and cored to a depth of 39.6 m below existing grade. As per borehole BH20-8, the subsurface conditions in general consisted of firm to stiff clayey fill extending to a depth of 1.5m below the existing grade, which in-turn was

followed by very soft to stiff silty clay extending to a depth of 13.3 m, further underlain by a compact dilatant silt extending to a depth of 14.8 m, further underlain by very soft to stiff silty clay extending to a depth of 23.2 m, further underlain by compact dilatant silt extending to a depth of 29.3 m below the existing ground surface. Bedrock of Salina Formation was encountered at a depth of 29.3 m below existing grades. The highest groundwater level measured in monitoring wells installed at BH20-8, BH20-10, BH20-11 and BH20-12 (shallow and deep) range from 3.7 m (Elev. 171.2 m) to 6.7 m (Elev. 169.8 m) below existing ground surface.

The geotechnical conditions at the site are suitable to support the buildings and chambers on steel H-piles.

Based on the borehole, it is likely that steel H-piles (HP310x110) extended approximate depth of 32 m long, driven at least 1 m into the bedrock can support a geotechnical reaction of 1000 kN/pile at the Serviceability Limit States (SLS) and a factored geotechnical bearing resistance of 1300 kN/pile at the Ultimate Limit States (ULS) in compression, provided the factored geotechnical resistance at ULS and geotechnical reaction at SLS are confirmed by dynamic testing procedures, ASTM D4945, using the Pile Driving Analyzer (PDA). Piles shall be driven about 1 m above the design elevation and then PDA testing must be carried out. Piles will need to be driven until the required ultimate capacity is achieved. A factor of safety of minimum 2.0 should be adopted to derive the factored geotechnical resistance of pile at ULS from the unfactored ultimate bearing capacity of pile. A minimum factor of safety equal to three (3) will be required to derive the geotechnical reaction at SLS from the ultimate bearing capacity of pile. Higher geotechnical reaction at SLS and factored geotechnical resistance at ULS could be used, provided it is confirmed by the field-testing using PDA.

The pile-driving hammer must be capable of driving the piles to the required capacity without damaging it. To achieve this, the hammer should have a rated energy of about 100 kilojoules per blow. An energy transfer of at least 40 percent of the pile driven rating is assumed. The cap-block may be modified to minimize over stressing of the pile.

Pile driving should be observed, on a full-time basis, by an experienced soil technician, who will record penetration resistance, pile toe elevation, etc. The technician must be supervised by a professional engineer experienced in this type of work.

If the piles encounter refusal before sufficiently penetrating into the recommended bearing zone, then pile capacities may need to be revisited and alternative measures sought. Therefore, pile driving records should be kept particularly, if refusal is met above the recommended bearing zone.

It should be noted that the pile tip elevation provided above is for initial guidance and estimating purposes only. Due to potentially variable soil conditions, the actual pile tip

elevation will vary. The contract should allow for some variation in pile lengths and this aspect should be taken into consideration when ordering the piles. The possibility of piles encountering potential cobbles and boulders or any other obstruction during angering or driving should be anticipated. In view of this, the tips of the piles should be stiffened to minimize damage to the piles while penetrating in recommended bearing zone. Care must be taken to avoid overdriving and damaging the pile tip (i.e., the structural capacity of the piles should not be exceeded). Stiffening of the tops of the piles may also be required.

During the driving process, piles that have already been driven will need to be monitored to assess if heaving occurred due to the effects of driving of adjacent piles. If this phenomenon occurs, the affected piles will need to be re-driven. Re-tapping, to check that relaxation has not occurred, will be necessary. Furthermore, it may be necessary to stagger the driving of the piles. The piles should be provided with reinforced tips, as per OPSD 3000.100.

The passive resistance and horizontal sub-grade coefficient of the soil (ks) are likely required to evaluate the lateral capacity of piles.

The soil parameters generally required to assess the passive earth pressure on the pile are presented in **Table 4.2**.

Table 4.2 Soil Parameters for Ultimate Lateral Earth Resistance on Piles

Soil	Passive Earth Pressure Coefficient, K_p	Effective unit weight, □□ (kN/m^3)
Well compacted 'Granular B' or equivalent Fill: adjacent to pile cap, extending at least 3 times its size vertically and laterally	3.3	12.0
Existing Fill (sandy or clayey), assuming angle of internal friction (22 degrees)	2.2	10.7
Native: very soft to stiff silty clay, assuming angle of internal friction 26 degrees	2.6	9.2
Native: compact Silt, assuming angle of internal friction (30 degrees)	3.0	10.2
Notes: i. To err on the conservative side, for the pile analyses, the groundwater table was assumed at the existing ground surface. The effective or		

submerged unit weight must be used below the groundwater level for long term passive resistance.

ii. The contribution of passive resistance within 1.1m below the finished grade (frost depth) must be ignored, unless it is approved by WSP.

The horizontal sub-grade coefficient of the soil (k_s) can be required to evaluate the lateral deflection of piles.

Where the soil is primarily cohesive, the undrained shear strength of the soil is given in Table 4.3.

In this case,

$k_s=67\ c_u/d$

Where k_s = coefficient of horizontal subgrade reaction
c_u = undrained shear strength
d = pile width or diameter

In cohesionless soils, the coefficient of horizontal sub-grade reaction can be estimated from:

$k_s=n_hz/d$

Where ks = coefficient of horizontal sub-grade reaction
z = depth
d = pile width
n_h = coefficient related to soil density as given in Table 4.3

Table 4.3 Recommended Unfactored Soil Parameters for Calculation of ks

Soil Type	Clayey Soil and Shale Bedrock, C_u (kPa)	Granular Soils, n_h (kN/m^3)
Well compacted 'Granular B' or equivalent Fill: adjacent to pile cap, extending at least 3 times its size vertically and laterally	--	4,400
Existing Fill (sandy or clayey)	--	1300
Native: very soft to stiff silty clay	12	--
Native: compact Silt	--	4400
Note: The contribution of lateral resistance within 1.1 m below the finished grade (frost depth) must be ignored, unless it is approved by WSP.		

The lateral resistance of the piles can be supplemented, if desired, by horizontal components of battered piles. In this instance, it is recommended that the batter be limited to no more than 4:1 as in practice greater batter may be difficult to install.

If the centre-to-centre distance between adjacent piles is less than three (3) times the pile size, group effect on the vertical bearing resistance should be considered. If the centre-to-centre distance between adjacent piles is equal to or greater than three (3) times the pile size, the group effect for the vertical bearing resistance can be ignored.

4.6.2 Yard Piping

The anticipated behaviour of the soils as related to the support of the pipe and the stability of open cut excavations are summarized on **Table 4.4** and are also briefly discussed in the following sections.

Table 4.4 Soil Behaviour in Open Cut

Soil Type	Pipe Support	Stability During Construction in Open Excavation	Possible Means of Groundwater Control Below Groundwater Table
Firm Fill and very soft to firm Silty clay	Not suitable	Stable at 1.5H:1V to 3H:1V	Pumping from filtered sumps established inside the base of trench
Stiff to very stiff silty clay fill and native silty clay;	Satisfactory	Stable at 1.5H:1V to 1H:1V	
Compact sandy fill and native silt	Satisfactory if properly dewatered or stabilized	Stable at 1.5H:1V (unstable below water table for silt to sand)	Closely spaced well points/eductors for trenches

4.6.3 Excavation and Dewatering

Excavations of overburden can be carried out with heavy hydraulic backhoe. The stabilized groundwater table in the overburden in the WWTP area is anticipated to be lying at Elev. 169.8 to 172.3 m. As the majority of soils is cohesive based on borehole information, no major problems with groundwater are anticipated for the excavation of proposed yard piping. The groundwater seepage can be handled generally by pumping from filtered sumps in the bottom of the excavation. Increasing dewatering will be locally required when excavation reaches the saturated silt within the cohesive soils at a depth of 13.3m (or below) below the ground surface at the borehole location of BH20-08.

More comments regarding the type and extent of groundwater control required is provided in the WSP's report entitled "Preliminary Hydrogeological Investigation – South Niagara Falls WW Solutions EA, Niagara Region, ON", dated May 27, 2022.

The excavation for yard piping is expected through the fill followed by silty clay locally interbedded with silt layer. Possible large obstructions such as buried concrete / bricks are also anticipated in the fill material. Provisions must be made in the excavation contract for the removal of possible obstructions in the fill material.

All excavations must be carried out in accordance with the most recent Occupational Health and Safety Act (OHSA). In accordance with OHSA, the fill material can be classified as Type 3 Soil above the groundwater table. The firm to stiff cohesive deposit can be classified as Type 3 Soil above the groundwater table and Type 4 Soil below the groundwater table. The very soft to soft cohesive deposit classified as Type 4 soil.

4.6.3.1 Trench Boxes

Where permissible under the OHSA and where its use is considered to be a safe alternative for shoring and bracing, contractors may decide to utilize trench boxes for temporary trench wall support for trenches less than 6 m deep in Type 2 and Type 3 Soils. Where trench depths exceed 6 m, Engineered Support Systems are required under the OHSA as defined in the Regulation. In such cases, the use of prefabricated support systems (trench boxes) is not permitted.

While the use of trench boxes is an effective and economical trench-support method, its use can cause increased loss of ground relative to properly braced shoring, especially when working close to granular base courses below the existing pavements or along existing utility trenches backfilled with granular materials. Trench boxes also reduce the contractor's ability to compact backfill materials placed between the trench wall and the outer trench box shell, thereby increasing the likelihood of post-construction settlements along the trench walls.

It is important that the trench not be over-excavated to ensure a tight fit between the box and the trench walls. Trench boxes need to be installed expediently. When moving the box, the void space between its outer walls and the trench must be backfilled and compacted. This may require raising the box sequentially prior to sliding it laterally.

When trench boxes are used along existing roadways, settlements frequently occur along the trench wall, which may manifest months after completion of backfilling. In such cases, following the backfilling of the trench, road reconstruction should include a provision for saw-cutting the asphalt at least 1.5 m back from the trench walls, recompacting the upper trench backfill, and then repaving.

All excavated spoils should be placed at least the depth of the trench away from the trench's edge to mitigate the risk of excavation instability.

It is recommended that the excavations for service trenches below the groundwater table be carried out in short sections using a suitable 'geofabric' below the bedding (fine migration prevention) and backfilling the trench section immediately after pipe placement.

4.6.3.2 Pipe Support and Bedding

The borehole records indicate that shallow compact fill and stiff to very stiff silty clay are capable of providing adequate pipe support using the OPSD 802.031. The subgrade condition must be inspected and verified by geotechnical personnel. If very soft to firm clayey soil or fill (SPT 'N' value < 8) are present at the proposed pipe invert or trench invert elevation, the unsuitable soil should be sub-excavated and replaced using conventional Class "B" bedding. The replacement fill should be placed in loose lifts not exceeding 150 mm in thickness and then compacted to 100% of Standard Proctor Maximum Dry Density (SPMDD) at a placement water content of ±2% of optimum. Each loose layer shall be compacted to 100% SPMDD prior to the placement of the next upper layer.

If the very soft to firm clayey soil (encountered at depths of 3.1 to 5.3 m below the existing ground surface in BH20-08, BH20-10, BH20-11, and BH20-12S) could not be removed, consideration should be given to use flexible pipe to allow big long-tern differential settlements. Consideration can be also given to soil improvement method (such as geopiers, soil/cement mixed columns) or deep foundation (such as helical piles) to support the yard piping.

The compacted granular base and the cover material for all pipes should consist of Granular "A" material in accordance to OPSS.MUNI 1010 for concrete pipes. Granular D (Limestone Screenings) is recommended for the bedding material of PVC pipes. All granular materials should be placed in maximum 200mm thickness. The granular bedding and cover materials should be compacted to 100% Standard Proctor Maximum Dry Density (SPMDD). Care should be exercised when compacting the cover material on top of the pipes to avoid damaging them. The use of light, hand operated compaction equipment is recommended in these areas.

4.6.3.3 Backfilling

Based on visual and tactile examination, the on-site excavated granular fill and native cohesionless soils are considered to be suitable for re-use as backfill in the service trenches provided their moisture contents at the time of construction are at or near (±2%) optimum.

The very soft to firm silty clay deposit is considered as not suitable for backfill due to its high-water content and compressibility.

The backfill should be placed in maximum 200 mm thick layers at or near (±2%) their optimum moisture content and each layer should be compacted to at last 95% SPMDD. The degree of compaction should be increased to 100% within the top 2.0 m of the subgrade. Unsuitable materials such as organic soils, boulders, cobbles, frozen soils, etc. should not be used for backfilling. The existing road pavement structure should be reinstated. The granular pavement sub-base and base materials should be compacted to at least 100% of their respective

SPMDD. New granular material must match into the undersides of existing to ensure unimpeded cross drainage.

4.7 Issues and Data Gaps

The following issues and data gaps were identified in the geotechnical data with warrant further investigation:

- Large zones of insufficient geological and geotechnical data;
- Specific data at river, creek and road crossings;
- Precise definition of the transition from overburden to bedrock;
- Definition of the bedrock channels/valleys;
- Depth of fill material;
- Depth of highly weathered bedrock and/or bedrock surface;
- Strength of overburden and bedrock;
- Zone of very soft to firm silty clay;
- Definition of the qualities of cobbles and boulders;
- Presence of naturally occurring gases including Methane gas within the bedrock;
- Data on till and bedrock potential for abrasiveness during tunnelling;
- Groundwater table; and
- Soil and bedrock environmental quality

The recommendations for further geotechnical investigation are as follows:

- Additional boreholes with spacing of approximately 150m along the proposal alignment of trunk sewer;
- Additional boreholes with monitoring wells at both sides of watercourses;
- Additional boreholes with monitoring well at both sides of QWE and CN Rail;
- Additional boreholes within the footing of proposed structure and access road in the WWTP site;
- Additional boreholes with soil coring to determine the quantity of cobbles/boulders;
- Geophysical survey along the proposal alignment of trunk sewer to determine the bedrock surface;
- Laboratory tests including consolidation tests and triaxial tests on the soft soils;

- Laboratory tests including unconfined compression tests, triaxial compression tests, tensile tests, punch penetration tests, and CERCHAR abrasivity tests, and slake durability on the bedrock if tunneling in bedrock is selected; and
- Geotechnical baseline report (GBR) for tunnelling

5 General Comments and Limitations of Report

WSP should be retained for a general review of the final design and specifications to verify that this report has been properly interpreted and implemented. If not accorded the privilege of making this review, WSP will assume no responsibility for interpretation of the recommendations in the report.

The comments given in this report are intended only for the guidance of design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc., would be much greater than has been carried out for design purposes. Contractors bidding on or undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual borehole and test pit results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

This report is intended solely for the Client named. The material in it reflects our best judgment in light of the information available to WSP at the time of preparation. Unless otherwise agreed in writing by WSP, it shall not be used to express or imply warranty as to the fitness of the property for a particular purpose. No portion of this report may be used as a separate entity, it is written to be read in its entirety.

The conclusions and recommendations given in this report are based on information determined at the test hole locations. The information contained herein in no way reflects on the environment aspects of the project, unless otherwise stated. Subsurface and groundwater conditions between and beyond the test holes may differ from those encountered at the test hole locations, and conditions may become apparent during construction, which could not be detected or anticipated at the time of the site investigation. The benchmark and elevations used in this report are primarily to establish relative elevation differences between the test hole locations and should not be used for other purposes, such as grading, excavating, planning, development, etc.

The design recommendations given in this report are applicable only to the project described in the text and then only if constructed substantially in accordance with the details stated in this report.

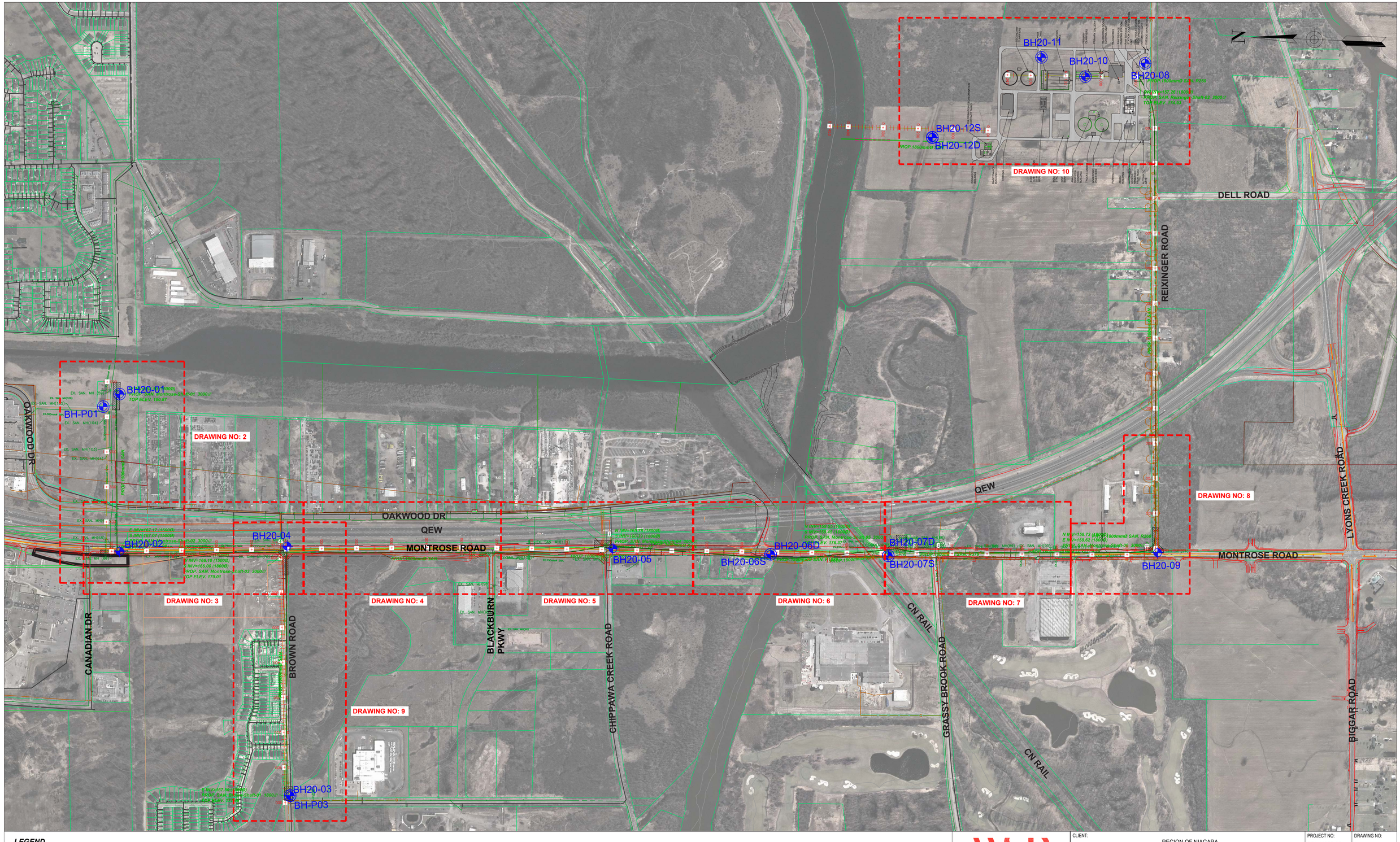
Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. WSP accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We accept no responsibility for any decisions made or actions taken as a result of this report unless we are specifically advised of and participate in such action, in which case our responsibility will be as agreed to at that time.

We trust that the information contained in this report is satisfactory. Should you have any questions, please do not hesitate to contact this office.

Drawings

Borehole Location Plan (Drawing No. 1 To 10)
Earth Pressure Distribution on Braced Excavations (Drawing No. 11)
Risk Zone (Drawing No. 12)



LEGEND

- ***BOREHOLE LOCATION***
- ***BOREHOLE WITH MONITORING WELL LOCATION***

100 0 100 200 400 (m)

2 INTERNATIONAL BLVD
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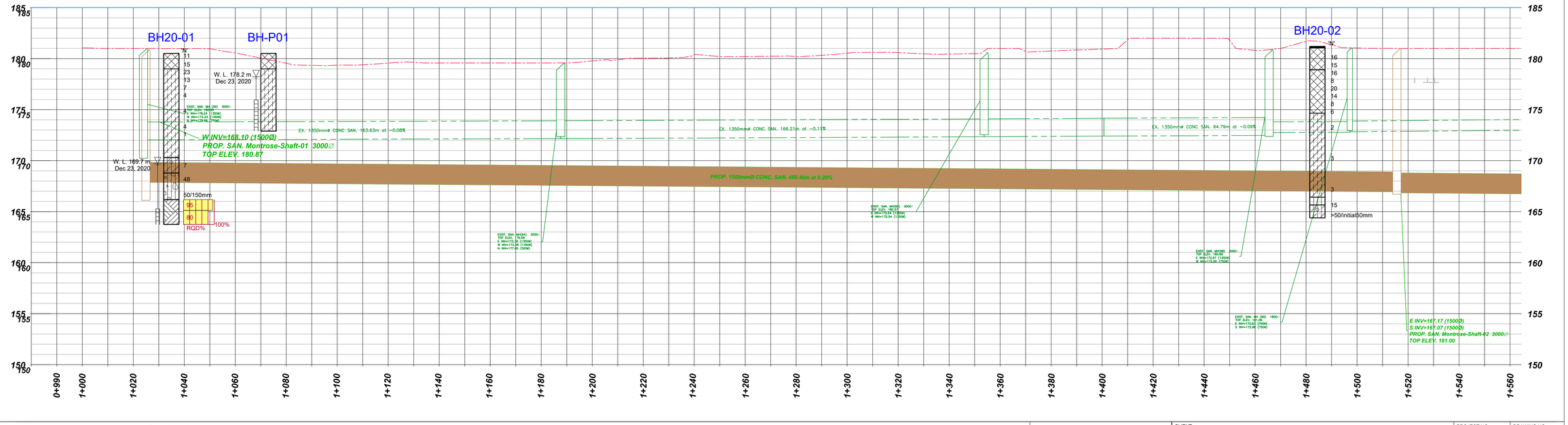
CLIENT: REGION OF NIAGARA		PROJECT NO: 201-11602-00	DRAWING NO: 1
TITLE: SITE PLAN		DRAWN BY: WSL	CHECKED BY: MK
PROJECT: PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT FOR PROPOSED SOUTH NIAGARA FALLS WASTEWATER TREATMENT PLANT (WWTP) AND ASSOCIATED TRUNK SEWER, TOWNSHIP OF WILLOUGHBY, REGION OF NIAGARA		DATE: OCT. 28, 2021	SCALE: AS SHOWN
		ORIGINAL SIZE: ARCH D	REV. # N/A



LEGEND

- Fill
- Topsoil
- Sand and Gravel + Boulders
- Asphalt
- Silty Clay
- Silt
- Gravelly Sand and Silt
- Organic Clayey Silt
- Clayey Silt Till
- Sand
- Clayey Silt Till/Shale Complex
- Bedrock

BOREHOLE LOCATION

BOREHOLE WITH MONITORING WELL LOCATION

10 0 10 20 40 (m)

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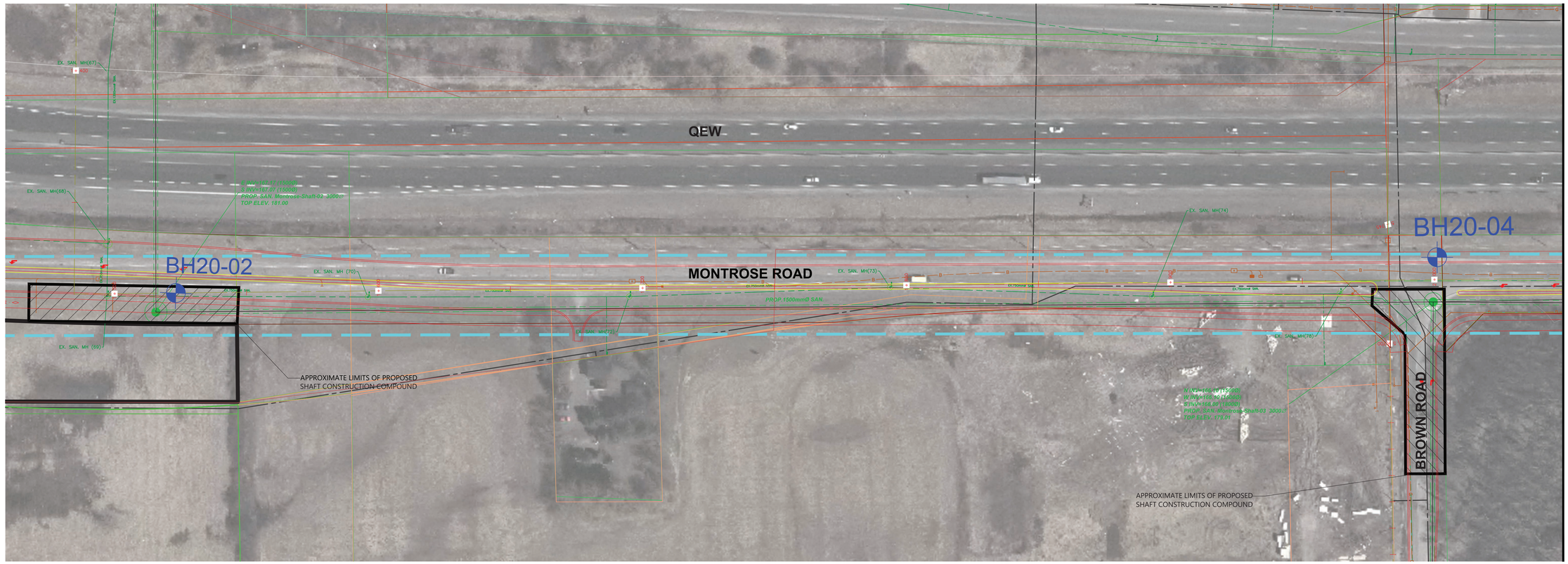
CLIENT: THE REGIONAL MUNICIPALITY OF NIAGARA		PROJECT NO: 201-11602-00	DRAWING NO: 2
TITLE: BOREHOLE LOCATION PLAN AND PROFILE STA 0+990 TO STA 1+560		DRAWN BY: WSL	CHECKED BY: MK
PROJECT: GEOTECHNICAL INVESTIGATION - NIAGARA REGION SANITARY SEWER		DATE: OCT 28, 2021	SCALE: AS SHOWN
		ORIGINAL SIZE: ARCH D	REV. # N/A



LEGEND

- Fill
- Topsoil
- Sand and Gravel + Boulders
- Asphalt
- Silty Clay
- Silt
- Gravelly Sand and Silt
- Organic Clayey Silt
- Clayey Silt Till
- Sand
- Clayey Silt Till/Shale Complex
- Bedrock
- BOREHOLE LOCATION
- BOREHOLE WITH MONITORING WELL LOCATION

10 0 10 20 40 (m)

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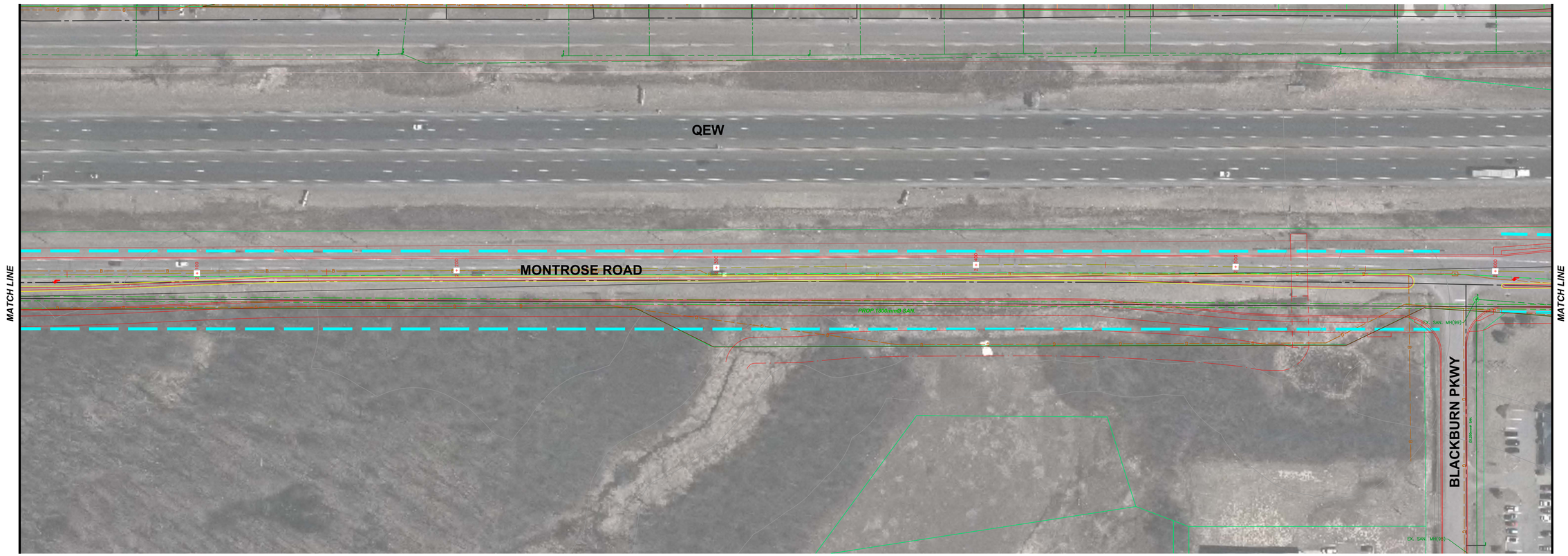
CLIENT: REGION OF NIAGARA		PROJECT NO: 201-11602-00	DRAWING NO: 3
TITLE: BOREHOLE LOCATION PLAN AND PROFILE STA 1+480 TO STA 2+040		DRAWN BY: WSL	CHECKED BY: MK
PROJECT: PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT FOR PROPOSED SOUTH NIAGARA FALLS WASTEWATER TREATMENT PLANT (WWTP) AND ASSOCIATED TRUNK SEWER, TOWNSHIP OF WILLOUGHBY, REGION OF NIAGARA		DATE: OCT. 28, 2021	SCALE: AS SHOWN
		ORIGINAL SIZE: ARCH D	REV. # N/A



10 0 10 20 40 (m)

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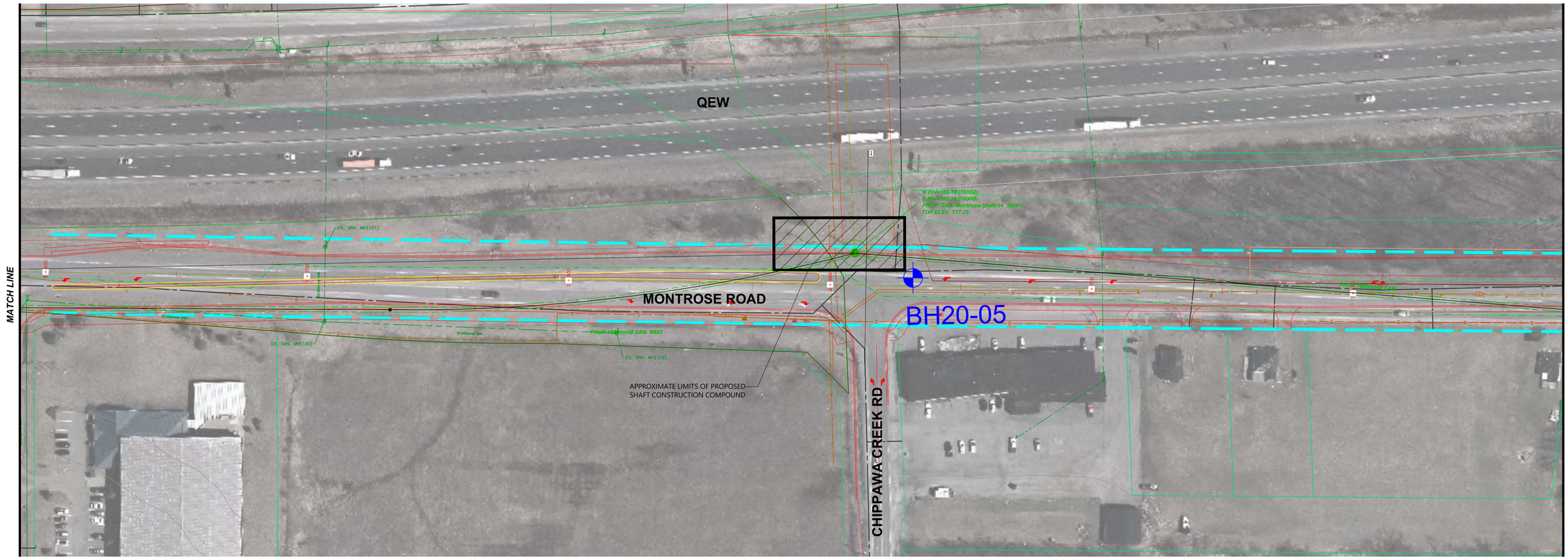
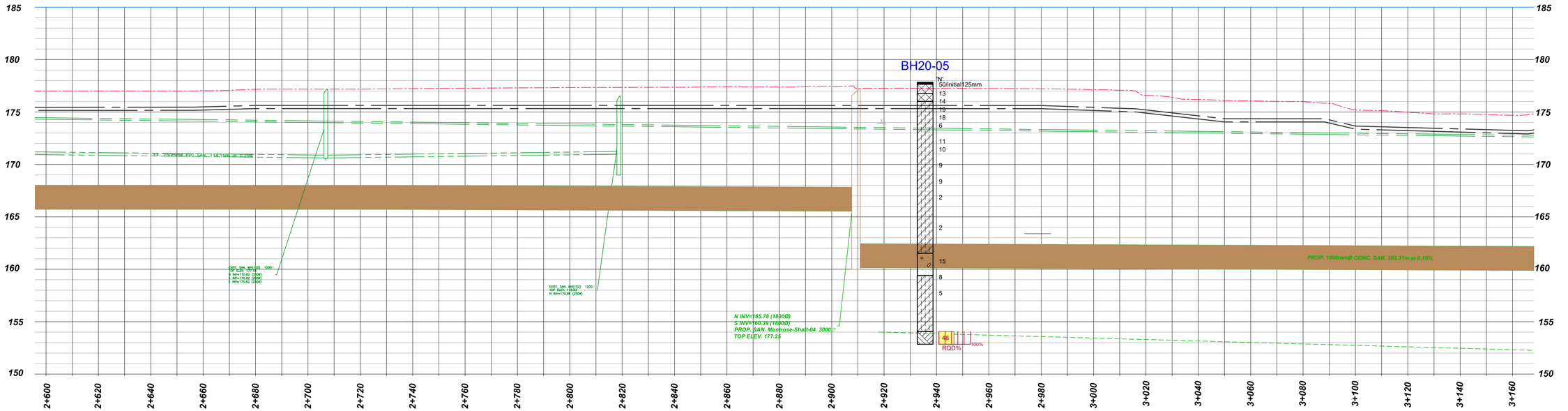
CLIENT: REGION OF NIAGARA		PROJECT NO: 201-11602-00	DRAWING NO: 4
TITLE: BOREHOLE LOCATION PLAN AND PROFILE STA 2+040 TO STA 2+600		DRAWN BY: WSL	CHECKED BY: MK
PROJECT: PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT FOR PROPOSED SOUTH NIAGARA FALLS WASTEWATER TREATMENT PLANT (WWTP) AND ASSOCIATED TRUNK SEWER, TOWNSHIP OF WILLOUGHBY, REGION OF NIAGARA		DATE: OCT. 28, 2021	SCALE: AS SHOWN
		ORIGINAL SIZE: ARCH D	REV. # N/A





LEGEND

- Fill
- Topsoil
- Sand and Gravel + Boulders
- Asphalt
- Silty Clay
- Silt
- Gravelly Sand and Silt
- Organic Clayey Silt
- Clayey Silt Till
- Sand
- Clayey Silt Till/Shale Complex
- Bedrock
- BOREHOLE LOCATION
- BOREHOLE WITH MONITORING WELL LOCATION

10 0 10 20 40 (m)

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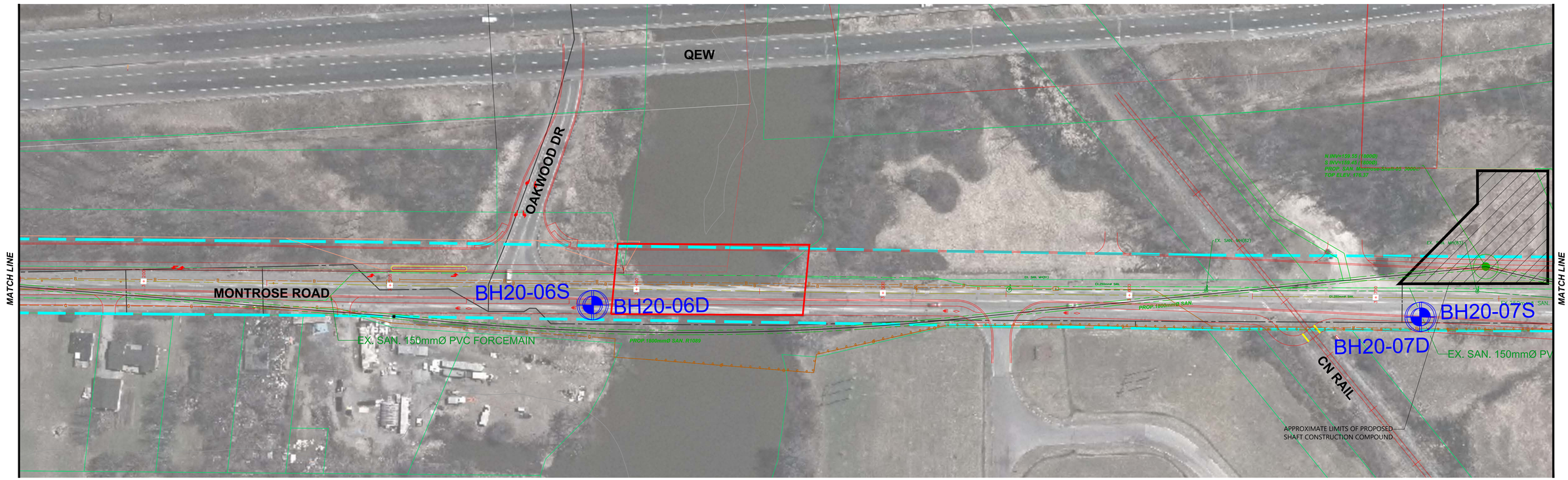
CLIENT: REGION OF NIAGARA		PROJECT NO: 201-11602-00	DRAWING NO: 5
TITLE: BOREHOLE LOCATION PLAN AND PROFILE STA 2+600 TO STA 3+160		DRAWN BY: WSL	CHECKED BY: MK
PROJECT: PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT FOR PROPOSED SOUTH NIAGARA FALLS WASTEWATER TREATMENT PLANT (WWTP) AND ASSOCIATED TRUNK SEWER, TOWNSHIP OF WILLOUGHBY, REGION OF NIAGARA		DATE: OCT. 28, 2021	SCALE: AS SHOWN
		ORIGINAL SIZE: ARCH D	REV. # N/A



LEGEND

- Fill
- Topsoil
- Sand and Gravel + Boulders
- Asphalt
- Silty Clay
- Silt
- Gravelly Sand and Silt
- Organic Clayey Silt
- Clayey Silt Till
- Sand
- Clayey Silt Till/Shale Complex
- Bedrock
- BOREHOLE LOCATION
- BOREHOLE WITH MONITORING WELL LOCATION

10 0 10 20 40 (m)

2 INTERNATIONAL BLVD
TORONTO, ONTARIO CANADA M9W 1A2
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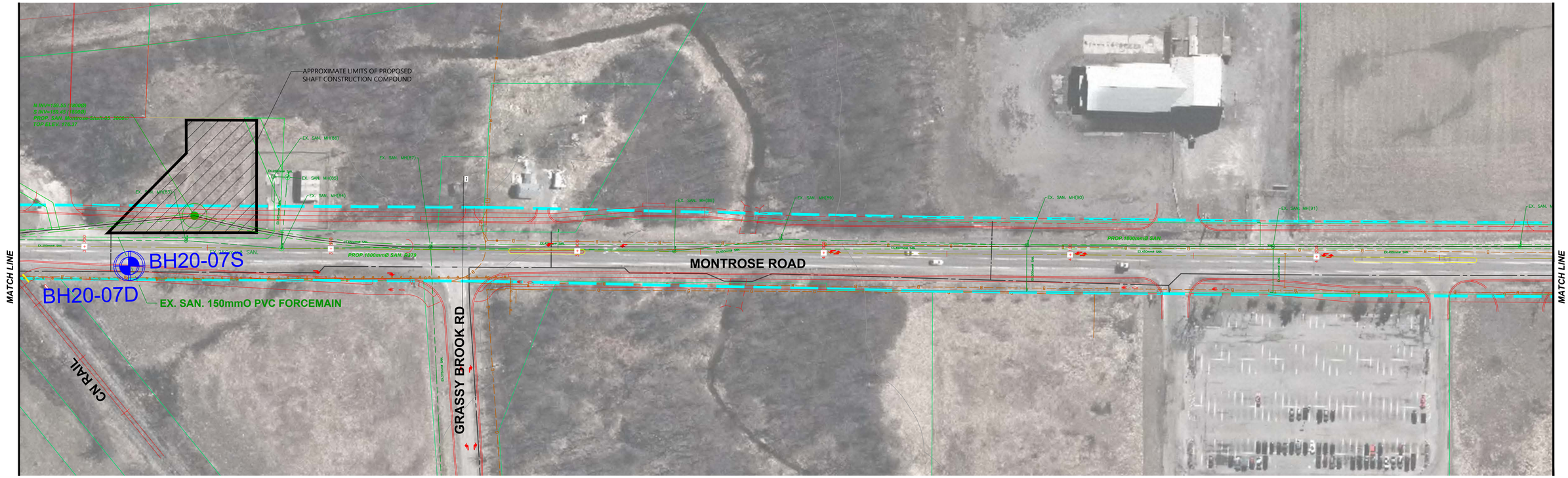
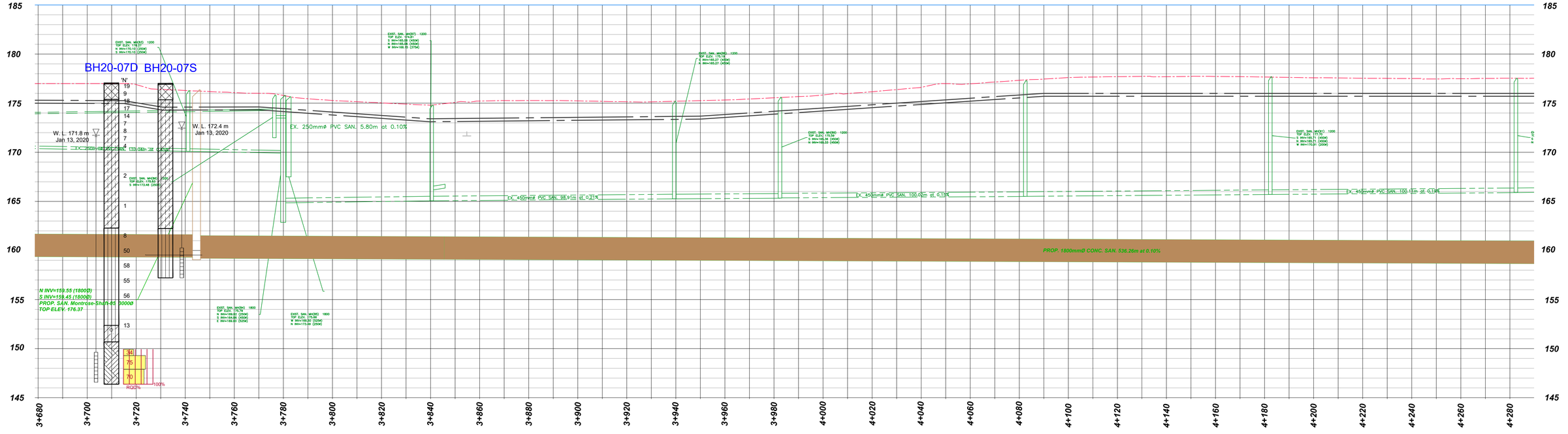
CLIENT: REGION OF NIAGARA		PROJECT NO: 201-11602-00	DRAWING NO: 6
TITLE: BOREHOLE LOCATION PLAN AND PROFILE STA 3+160 TO STA 3+760		DRAWN BY: WSL	CHECKED BY: MK
PROJECT: PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT FOR PROPOSED SOUTH NIAGARA FALLS WASTEWATER TREATMENT PLANT (WWTP) AND ASSOCIATED TRUNK SEWER, TOWNSHIP OF WILLOUGHBY, REGION OF NIAGARA		DATE: OCT. 28, 2021	SCALE: AS SHOWN
		ORIGINAL SIZE: ARCH D	REV. # N/A





LEGEND

- Fill
- Topsoil
- Sand and Gravel + Boulders
- Asphalt
- Silty Clay
- Silt
- Gravelly Sand and Silt
- Organic Clayey Silt
- Clayey Silt Till
- Sand
- Clayey Silt Till/Shale Complex
- Bedrock

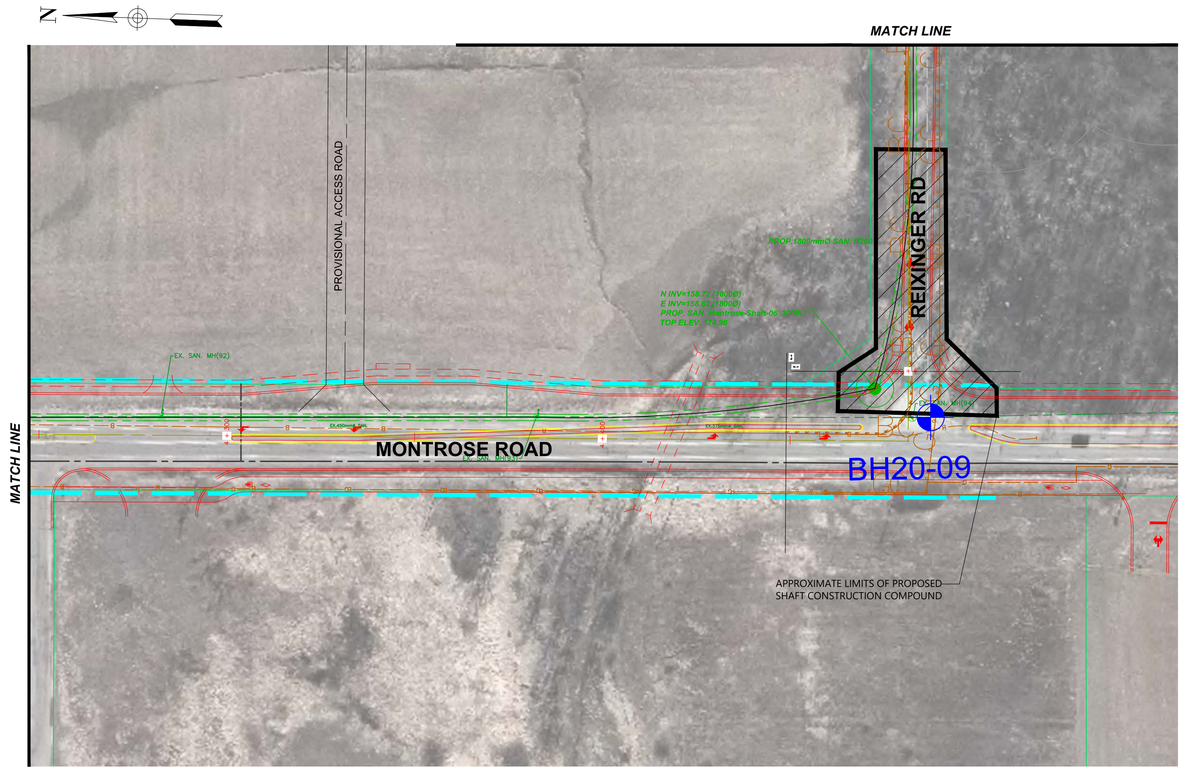
BOREHOLE LOCATION

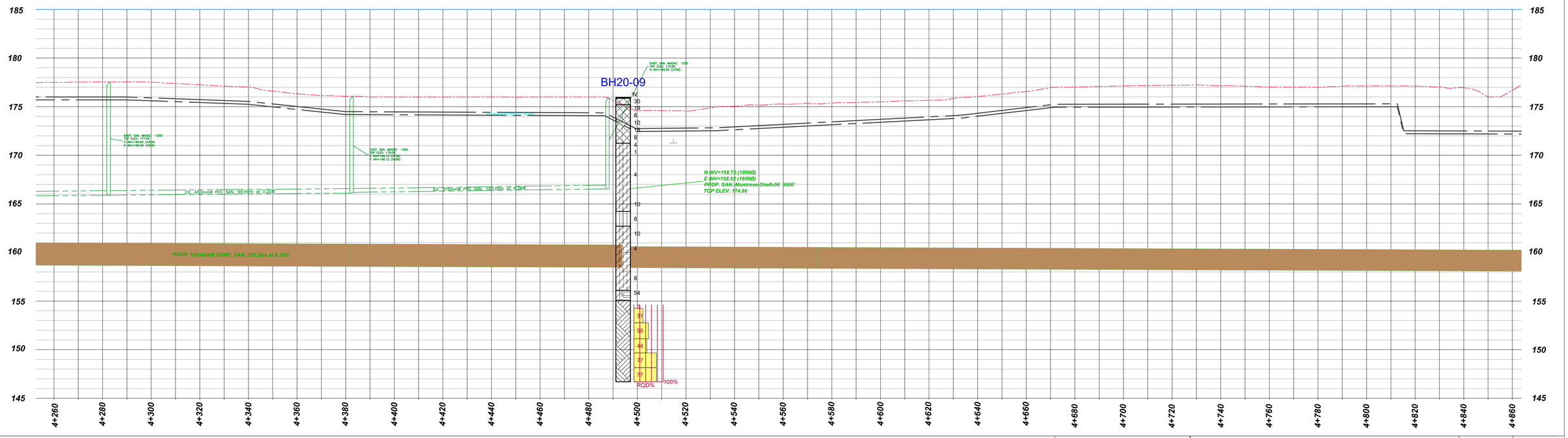
BOREHOLE WITH MONITORING WELL LOCATION

10 0 10 20 40 (m)

2 INTERNATIONAL BLVD
TORONTO, ONTARIO CANADA M9W 1A2
TEL.: 416-798-0065 | FAX: 416-798-0518 | WWW.WSP.COM

CLIENT: REGION OF NIAGARA		PROJECT NO: 201-11602-00	DRAWING NO: 7
TITLE: BOREHOLE LOCATION PLAN AND PROFILE STA 3+680 TO STA 4+280		DRAWN BY: WSL	CHECKED BY: MK
PROJECT: PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT FOR PROPOSED SOUTH NIAGARA FALLS WASTEWATER TREATMENT PLANT (WWTP) AND ASSOCIATED TRUNK SEWER, TOWNSHIP OF WILLOUGHBY, REGION OF NIAGARA		DATE: OCT. 28, 2021	SCALE: AS SHOWN
		ORIGINAL SIZE: ARCH D	REV. # N/A





LEGEND

- Fill
- Topsoil
- Sand and Gravel + Boulders
- Asphalt
- Silty Clay
- Silt
- Gravelly Sand and Silt
- Organic Clayey Silt
- Clayey Silt Till
- Sand
- Clayey Silt Till/Shale Complex
- Bedrock

BOREHOLE LOCATION

BOREHOLE WITH MONITORING WELL LOCATION

10 0 10 20 40 (m)

2 INTERNATIONAL BLVD
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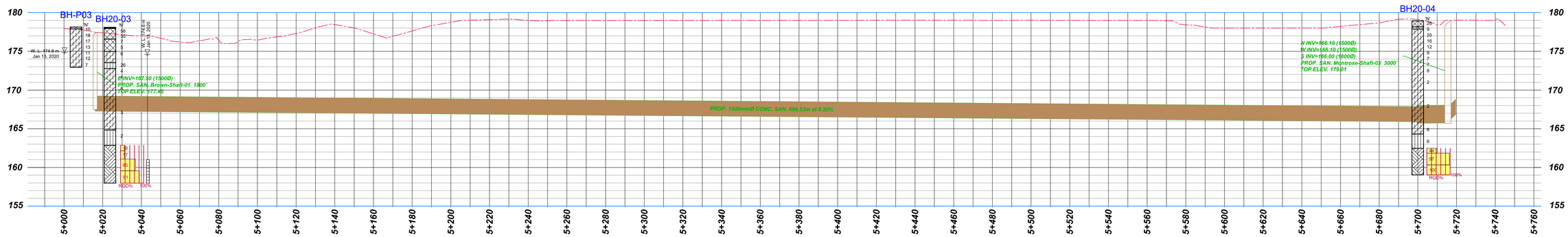
CLIENT: REGION OF NIAGARA		PROJECT NO: 201-11602-00	DRAWING NO: 8
TITLE: BOREHOLE LOCATION PLAN AND PROFILE STA 4+260 TO STA 4+860		DRAWN BY: WSL	CHECKED BY: MK
PROJECT: PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT FOR PROPOSED SOUTH NIAGARA FALLS WASTEWATER TREATMENT PLANT (WWTP) AND ASSOCIATED TRUNK SEWER, TOWNSHIP OF WILLOUGHBY, REGION OF NIAGARA		DATE: OCT. 28, 2021	SCALE: AS SHOWN
		ORIGINAL SIZE: ARCH D	REV. # N/A



LEGEND

- Fill
- Topsoil
- Sand and Gravel + Boulders
- Asphalt
- Silty Clay
- Silt
- Gravelly Sand and Silt
- Organic Clayey Silt
- Clayey Silt Till
- Sand
- Clayey Silt Till/Shale Complex
- Bedrock
- BOREHOLE LOCATION
- BOREHOLE WITH MONITORING WELL LOCATION

10 0 10 20 40 (m)

2 INTERNATIONAL BLVD
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CLIENT: REGION OF NIAGARA		PROJECT NO: 201-11602-00	DRAWING NO: 9
TITLE: BOREHOLE LOCATION PLAN AND PROFILE STA 5+000 TO STA 5+760		DRAWN BY: WSL	CHECKED BY: MK
PROJECT: PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT FOR PROPOSED SOUTH NIAGARA FALLS WASTEWATER TREATMENT PLANT (WWTP) AND ASSOCIATED TRUNK SEWER, TOWNSHIP OF WILLOUGHBY, REGION OF NIAGARA		DATE: OCT. 28, 2021	SCALE: AS SHOWN
		ORIGINAL SIZE: ARCH D	REV. # N/A

LEGEND

BOREHOLE LOCATION

BOREHOLE WITH MONITORING WELL LOCATION

20 0 10 20 80 (m)

2 INTERNATIONAL BLVD
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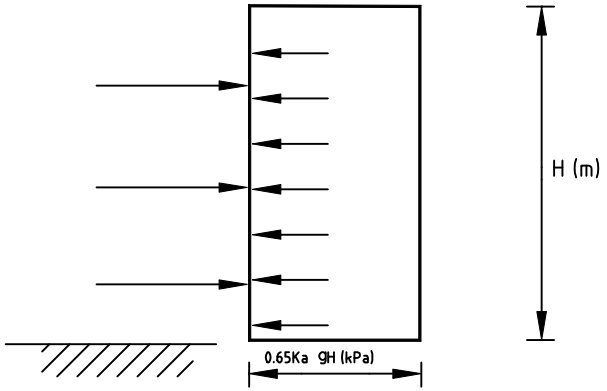
CLIENT: REGION OF NIAGARA		PROJECT NO: 201-11602-00	DRAWING NO: 10
TITLE: BOREHOLE LOCATION PLAN		DRAWN BY: WSL	CHECKED BY: MK
PROJECT: PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT FOR PROPOSED SOUTH NIAGARA FALLS WASTEWATER TREATMENT PLANT (WWTP) AND ASSOCIATED TRUNK SEWER, TOWNSHIP OF WILLOUGHBY, REGION OF NIAGARA		DATE: OCT. 28, 2021	SCALE: AS SHOWN
		ORIGINAL SIZE: ARCH D	REV. # N/A

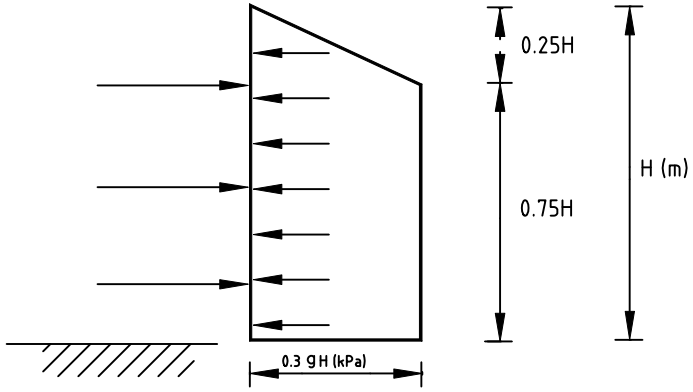


g = unit weight of soil = 21.0 kN/m^3

g' = submerged unit weight of soil (i.e. below ground water level)= 11.2 kN/m^3

Ka = 0.3

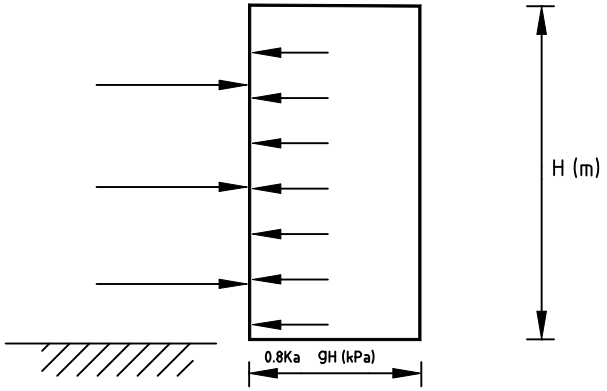
IN COMPACT TO VERY DENSE NON-COHESIVE SOILS (SANDS AND SILTS)



g = unit weight of soil = 21.5 kN/m^3

g' = submerged unit weight of soil (i.e. below ground water level)= 11.7 kN/m^3

IN COHESIVE CLAYS OR CLAYEY SOILS

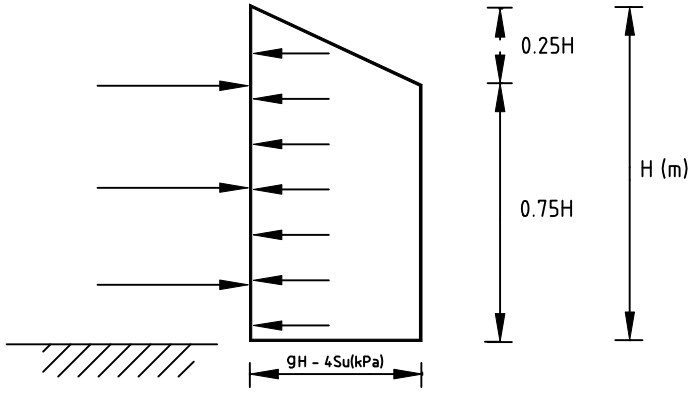


g = unit weight of soil = 19.0 kN/m^3

g' = submerged unit weight of soil (i.e. below ground water level)= 9.2 kN/m^3

Ka = 0.36

IN LOOSE OR DISTURBED NON-COHESIVE SOILS (SANDS AND SILTS)



g = unit weight of soil = 19.0 kN/m^3

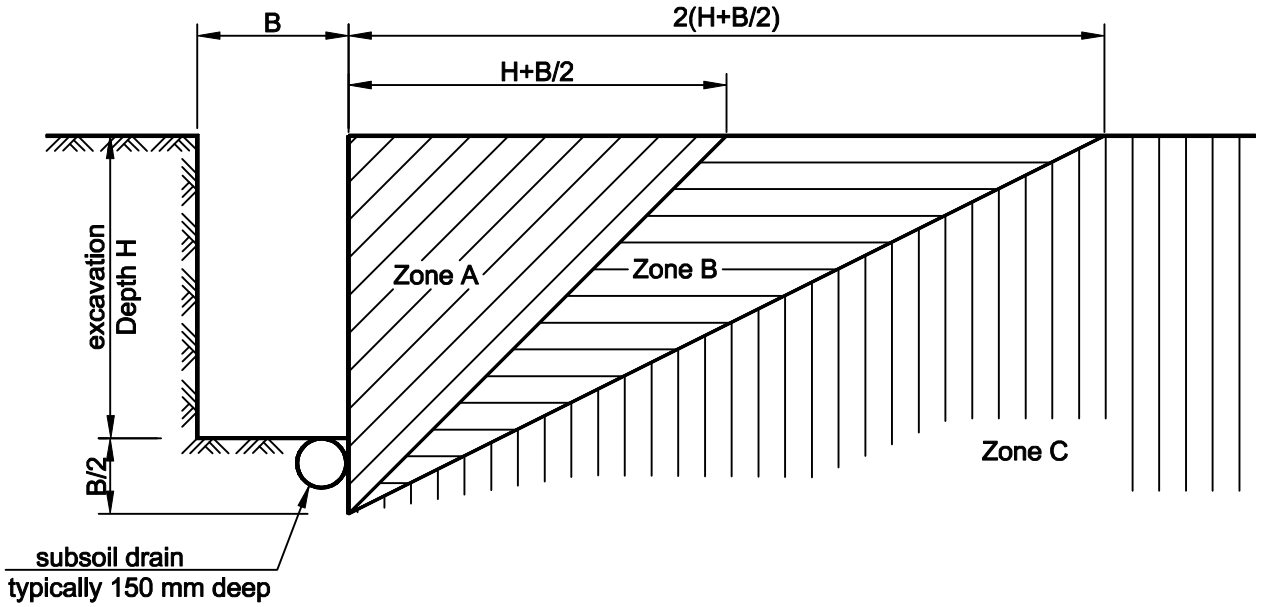
g' = submerged unit weight of soil (i.e. below ground water level)= 9.2 kN/m^3

Su = 10 KPa

IN VERY SOFT TO FIRM COHESIVE CLAYS OR CLAYEY SOILS

Notes:
1. Check system for partial excavation condition.
2. If the free water level is above the base of the excavation, the hydrostatic pressure must be added to the above pressure distribution.
3. If surcharge loadings are present near the excavation, these must be included in the lateral pressure calculation.

CLIENT: THE REGIONAL MUNICIPALITY OF NIAGARA		PROJECT NO: 201-11602-00	DRAWING NO: 11
TITLE: EARTH PRESSURE DISTRIBUTION ON BRACED EXCAVATIONS		DRAWN BY: ZMO	CHECKED BY: LC
PROJECT: GEOTECHNICAL INVESTIGATION - NIAGARA REGION SANITARY SEWER		DATE: FEB 26, 2021	SCALE: N.T.S
		ORIGINAL SIZE: LETTER	REV. # N/A



RISK ZONES (after Howe et al., 1980): Zone A is zone of long term risk,Zone B is zone of intermediate risk, Zone C is zone of no risk.

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CLIENT: THE REGIONAL MUNICIPALITY OF NIAGARA		PROJECT NO: 201-11602-00	DRAWING NO: 12
TITLE: RISK ZONE		DRAWN BY: ZMO	CHECKED BY: LC
PROJECT: GEOTECHNICAL INVESTIGATION - NIAGARA REGION SANITARY SEWER		DATE: FEB 26, 2021	SCALE: N.T.S
		ORIGINAL SIZE: LETTER	REV. # N/A

A EXPLANATION OF TERMS USED IN THE RECORD OF BOREHOLE, LOGS OF BOREHOLES (BH20-1 TO BH20-12)

Explanation of Terms Used in the Record of Borehole

Sample Type

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO	Drive open
DS	Dimension type sample
FS	Foil sample
NR	No recovery
RC	Rock core
SC	Soil core
SS	Spoon sample
SH	Shelby tube sample
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

Penetration Resistance

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

WH – Samples sinks under "weight of hammer"

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

Textural Classification of Soils (ASTM D2487-10)

Classification	Particle Size
Boulders	> 300 mm
Cobbles	75 mm - 300 mm
Gravel	4.75 mm - 75 mm
Sand	0.075 mm - 4.75 mm
Silt	0.002 mm - 0.075 mm
Clay	<0.002 mm(*)

(*) Canadian Foundation Engineering Manual (4th Edition)

Coarse Grain Soil Description (50% greater than 0.075 mm)

Terminology	Proportion
Trace	0-10%
Some	10-20%
Adjective (e.g. silty or sandy)	20-35%
And (e.g. sand and gravel)	> 35%

Soil Description

a) Cohesive Soils(*)

Consistency	Undrained Shear Strength (kPa)	SPT "N" Value
Very soft	<12	0-2
Soft	12-25	2-4
Firm	25-50	4-8
Stiff	50-100	8-15
Very stiff	100-200	15-30
Hard	>200	>30

(*) Hierarchy of Shear Strength prediction
1. Lab triaxial test
2. Field vane shear test
3. Lab. vane shear test
4. SPT "N" value
5. Pocket penetrometer

b) Cohesionless Soils

Density Index (Relative Density)	SPT "N" Value
Very loose	<4
Loose	4-10
Compact	10-30
Dense	30-50
Very dense	>50

Soil Tests

w	Water content
w_P	Plastic limit
w_l	Liquid limit
C	Consolidation (oedometer) test
CID	Consolidated isotropically drained triaxial test
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement
D_R	Relative density (specific gravity, Gs)
DS	Direct shear test
ENV	Environmental/ chemical analysis
M	Sieve analysis for particle size
MH	Combined sieve and hydrometer (H) analysis
MPC	Modified proctor compaction test
SPC	Standard proctor compaction test
OC	Organic content test
U	Unconsolidated Undrained Triaxial Test
V	Field vane (LV-laboratory vane test)
γ	Unit weight

Explanation of Terms Used in the Bedrock Core Log

Strength (ISRM)

Term	Grade	Description	Unconfined Compressive Strength (MPa)	(psi)
Extremely weak rock	RO	Indented by thumbnail	0.25-1.0	36-145
Very weak	R1	Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife	1.0-5.0	145-725
Weak rock	R2	Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer	5.0-25	725-3625
Medium Strong	R3	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of geological hammer	25-50	3625-7250
Strong rock	R4	Specimen require more than one blow of geological hammer to fracture it	50-100	7250-14500
Very strong rock	R5	Specimen requires many blows of geological hammer to fracture it	100-250	14500-36250
Extremely strong rock	R6	Specimen can only be chipped with geological hammer	>250	>36250

Bedding (Geological Society Eng. Group Working Party, 1970. Q.J. of Eng. Geol. Vol. 3)

Term	Bed Thickness	
Very thickly bedded	>2 m	>6.5 ft
Thickly bedded	600 mm-2 m	2.00-6.50 ft
Medium bedded	200 mm-600 mm	0.65-2.00 ft
Thinly bedded	60 mm-200 mm	0.20-0.65 ft
Very thinly bedded	20 mm-60 mm	0.06-0.20 ft
Laminated	6 mm-20 mm	0.02-0.06 ft
Thinly laminated	<6 mm	<0.02 ft

TCR (Total Core Recovery)

Sum of lengths of rock core recovered from a core run, divided by the length of the core run and expressed as a percentage.

SCR (Solid Core Rocovery)

Sum length of solid, full diameter drill core recovered expressed as a percentage of the total length of the core run.

RQD (Rock Quality Designation, after Deere, 1968)

Sum of lengths of pieces of rock core measured along centreline of core equal to or greater than 100 mm from a core run, divided by the length of the core run and expressed as a percentage. Core fractured by drilling is considered intact. RQD normally quoted for N-size or H-size core.

RQD(%)	Rock Quality
90-100	Excellent
75-90	Good
50-75	Fair
25-50	Poor
0-25	Very poor

Weathering (ISRM)

Term	Grade	Description
Fresh	W1	No visible sign of rock material weathering
Slightly weathered	W2	Discolouration indicates weathering of rock material and discontinuity surface. All the rock material may be discoloured by weathering and may be somewhat weaker than in its fresh condition
Moderately weathered	W3	Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a either as a continuous framework or as corestones
Highly weathered	W4	More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discoloured rock is present either as a continuous framework or as corestones
Completely weathered	W5	All rock material is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact
Residual soil	W6	All rock material is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported

(FI) Fracture Index

Expressed as the number of discontinuities per 300mm (1 ft). Excludes drill-induced fractures and fragmented zones. Reported as ">25" if frequency exceeds 25 fractures/0.3m.

Broken Zone

Zone of full diameter core of very low RQD which may include some drill-induced fractures.

Fragmented Zone

Zone where core is less than full diameter and RQD = 0.

Discontinuity Spacing (ISRM)

Term	Average Spacing	
Extremely widely spaced	>6 m	>20.00 ft
Very widely spaced	2 m-6 m	6.50-20.00 ft
Widely spaced	600 mm-2 m	2.00-6.50 ft
Moderately spaced	200 mm-600 mm	0.65-2.00 ft
Closely spaced	60 mm-200 mm	0.20-0.65 ft
Very closely spaced	20 mm-60 mm	0.06-0.20 ft
Extremely closely spaced	<20 mm	>0.06 ft

Note: Excludes drill-induced fractures and fragmented rock.

Discontinuity Orientation

Discontinuity, fracture and bedding plane orientations are cited as the acute angle measured with respect to the core axis. Fractures perpendicular to the core axis are at 90° and those parallel to the core axis are at 0°.

LOG OF BOREHOLE BH20-01

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 1D
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-09-2020 to Dec-09-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769584.2 E 653265.365
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w_L	WATER CONTENT (%) 10 20 30	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
180.5	Ground Surface														
0.0	**FILL:** silty clay, some sand to sandy, trace gravel, trace organics, trace rootlet, brownish grey, moist, stiff to very stiff.	1	SS	11		Concrete									
						Sand									
1		2	SS	15											
178.9						179									
1.5	**SILTY CLAY:** trace sand, contains silt seams, brown, moist, very stiff to very soft.	3	SS	23											
2		4	SS	13		178									
3		5	SS	7								51		8.4	0 1 (99)
4	brownish grey	6	SS	4		177									
		1	Vane			176		3.3 +35							
5	125mm reddish brown silt layer														
	grey, wet	8	SS	4		175									
6		1	TW			174									
7		9	SS	4											0 1 55 44
						173									
		10	SS	1		Holeplug									
8						172									
9		2	Vane			171		1.3 +28							
10					▽	W. L. 170.7 m									

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-01

PROJECT: Geotechnical Investigation
CLIENT: Regional Municipality of Niagara
PROJECT LOCATION: Niagara Region Sanitary Sewer
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan N 4769584.2 E 653265.365

Method: Hollow Stem Augers/HQ Core
Diameter: 203 mm/63mm
Date: Dec-09-2020 to Dec-09-2020
Equipment: Pontil Drilling CME 75 (Truck)

REF. NO.: 201-11602-00
ENCL NO.: 1D
ORIGINATED BY SL
COMPILED BY BW
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	TYPE	BLOWS "N" 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa): ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued							20 40 60 80 100	10 20 30			
170.3							W. L. 170.5 m Dec 18, 2020					
10.2	**CLAYEY SILT TILL:** sandy, trace gravel, reddish brown, moist to wet, firm.						170					
11			12	SS	7				○			11 32 45 12
168.7							169					
11.7	**SILTY SAND:** gravelly, trace clay, contains silty clay pockets, reddish brown, wet, dense to very dense.											
12			13	SS	48				○			26 40 27 7
13							168					
	75mm silty clay layer						167		○			
14			14	SS	50/ 150mm							
166.1							166					
14.3	**BEDROCK:** Coring began at 14.02m Refer to Rock Core Log		1	RC								
15							Sand					
							165					
16			2	RC			Screen					
							164					
163.7												
16.8	**END OF BOREHOLE** Note: 1) TW denotes thin wall shelby tube sample. 2) 50 mm monitoring well was installed upon completion, screened between 15.24m and 16.76m. Water Level measured in monitoring well: Date W.L.Depth (m) Dec. 18, 2020 10.96 Dec. 23, 2020 9.77											

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: +3, ×3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF ROCK CORE BH20-01

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 1D
LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-09-2020 to Dec-09-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769584.2 E 653265.365
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	ROCK DESCRIPTION	GROUND WATER CONDITIONS	CORE SAMPLE NUMBER	CORE SAMPLE SIZE	TOTAL CORE RECOVERY (%)	SOLID CORE RECOVERY (%)	HARD LAYER (%)	RQD (%)	FRACTURE INDEX (per 0.3 m)	DISCONTINUITIES	Weathering Index	HYDRAULIC CONDUCTIVITY (cm/sec)	POINT LOAD TEST UCS AXIAL (MPa)*	POINT LOAD TEST UCS DIAMETRAL (MPa)*	UNIAXIAL COMPRESSION (MPa)	DENSITY (g/cm^3) E (GPa)
166.1	Rock Surface															
14.3	**SALINA FORMATION:** Bedding almost horizontal (θ=90°)								0	Fragmented zone: 14.67m-14.72m						
15			1	HQ	100	95		95	5		W2 to W1					
165.1									0							
15.4									0	Fracture: 15.88m-15.90m, θ=0° and 15°, two sets			108	40		
16			2	HQ	100	93		80	4	16.34m-16.35m, θ=80°	W2 to W1					
									4	Soft layer 16.17m ~ 16.2m (W5)			66	68		
163.7									1							
16.8	**END OF BOREHOLE** Note: 1) 50 mm monitoring well was installed upon completion, screened between 15.24m and 16.76m. Water Level measured in monitoring well: Date W.L.Depth (m) Dec. 18, 2020 10.96 Dec. 23, 2020 9.92								5	16.69m ~ 16.74m (W5)						

Weathering Index: W1-Fresh, W2-Slightly weathered, W3-Moderately weathered, W4-Highly weathered, W5-Completely weathered θ = angle to the core axis

E = Modulus of Elasticity
*: UCS [Mpa] ≈ 24 $I_{S(50)}$

LOG OF BOREHOLE BH20-02

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 2
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY AKJ
DATUM: Geodetic
Date: Dec-14-2020 to Dec-14-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769568.12 E 652816.68
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS / 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION
181.2	Ground Surface						
181.0 0.2	**ASPHALT:** 150mm						
	FILL: crusher run limestone mix with silty clay pockets, grey, moist, compact.		1	SS	16		181
			2	SS	15		180
178.9 2.3	**FILL:** crusher run limestone, grey, moist, compact to loose.		3	SS	16		179
			4	SS	8		178
			5	SS	20		177
			6	SS	14		176
			7	SS	8		175
174.7 6.6	**SILTY CLAY:** trace sand, contains silt seams, reddish brown, moist, firm to very soft.		8	SS	6		174
			9	SS	2		173
			1	Vane			172

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100

SHEAR STRENGTH (kPa)
○ UNCONFINED + FIELD VANE & Sensitivity
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%)
10 20 30

POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m³)
REMARKS AND GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

+ 2.7 28

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-02

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 2
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY AKJ
DATUM: Geodetic
Date: Dec-14-2020 to Dec-14-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769568.12 E 652816.68
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued							
	SILTY CLAY: trace sand, contains silt seams, reddish brown, moist, firm to very soft.(Continued)						171	
	grey, wet		10	SS	3			
							170	
			1	TW			169	
							168	
	contains dilatant reddish brown silt layers		11	SS	3			0 0 63 37
166.4							167	
14.8	**SILT:** some clay to clayey, trace sand, dilatant, reddish brown, wet, compact.							
165.7			12	SS	15		166	
15.5	**CLAYEY SILT TILL:** sandy, trace gravel, contains shale/limestone fragments, reddish brown, moist, stiff to hard.							
			13	SS	>50/ Initial50mm		165	
164.4								
16.8								

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH (kPa) 20 40 60 80 100
○ UNCONFINED + FIELD VANE & Sensitivity
● QUICK TRIAXIAL × LAB VANE

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%) 10 20 30

POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m³)

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-03

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 3
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-02-2020 to Dec-03-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769057.248 E 652136.143
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

ELEV / DEPTH (m)	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS "N" 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
178.1	Ground Surface											
178.0	**ASPHALT:** 150mm						178					
0.2	**GRANULAR FILL:** sand and gravel, trace silt, trace clay, grey, moist, very dense to dense,		1	SS	58							
			2	SS	35		177					
176.6												
1.5	**FILL:** silty clay, trace sand, trace gravel, trace organics, brown, moist, firm.		3	SS	7		176					
	reddish brown		4	SS	5							
175.0			1	Vane			175					
3.1	**SILTY CLAY:** trace sand, occasional gravel, reddish brown, moist, firm.		6	SS	6	▽						0 1 (99)
			1	TW		W. L. 174.6 m Jan 13, 2020	174					
173.5												
4.6	**SILT:** trace to some clay, trace sand, dilatant, reddish brown, wet, compact.		8	SS	26		173					
172.8												
5.3	**SILTY CLAY:** trace sand, occasional gravel, contains dilatant silt seams/layers,reddish brown, wet, firm to soft		9	SS	4							
			2	Vane			172	3.0 +42				
			11	SS	4							
			2	TW			171					
			13	SS	6		170					
			3	Vane			169	2.3 +24				

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-03

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 3
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-02-2020 to Dec-03-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769057.248 E 652136.143
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS "N" 0.3 m	ELEVATION	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued					
	SILTY CLAY: trace sand, occasional gravel, contains dilatant silt seams/layers,reddish brown, wet, firm to soft(Continued)				168	
11		15	SS	3	167	0 0 67 33
12		3	TW		166	
13					165	
164.8						
13.3	**SILT:** trace to some clay, trace sand, dilatant, reddish brown, wet to saturated, very loose.					
14		17	SS	2	164	3 5 (92)
15					163	spoon got hard
162.9						
15.2	**BEDROCK:**					
	Coring began at 15.24m Refer to Rock Core Log	1	RC			
16		2	RC		162	
17					161	
18		3	RC		160	
19		4	RC		159	
20						

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE 20 40 60 80 100
PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L
WATER CONTENT (%) 10 20 30
[Non-Plastic]
POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m³)

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ε=3% Strain at Failure

LOG OF BOREHOLE BH20-03

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 3
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-02-2020 to Dec-03-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769057.248 E 652136.143
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued											
158.0							158					
20.1	**END OF BOREHOLE** Note: 1) TW denotes thin wall shelby tube sample. 2) 50 mm monitoring well was installed upon completion, screened between 4.50m and 7.60m. Water Level measured in monitoring well: Date W.L.Depth (m) Jan. 13, 2021 3.5											

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF ROCK CORE BH20-03

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 3
LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-02-2020 to Dec-03-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769057.248 E 652136.143
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	ROCK DESCRIPTION	GROUND WATER CONDITIONS	CORE SAMPLE NUMBER	CORE SAMPLE SIZE	TOTAL CORE RECOVERY (%)	SOLID CORE RECOVERY (%)	HARD LAYER (%)	RQD (%)	FRACTURE INDEX (per 0.3 m)	DISCONTINUITIES	Weathering Index	HYDRAULIC CONDUCTIVITY (cm/sec)	POINT LOAD TEST UCS AXIAL (MPa)*	POINT LOAD TEST UCS DIAMETRAL (MPa)*	UNIAXIAL COMPRESSION (MPa)	DENSITY (g/cm³) E (GPa)
162.9	Rock Surface															
15.2	**SALINA FORMATION:** Bedding almost horizontal (θ=90°)		1	HQ	100	23		18	>25 10 10	Fragmented zone:15.24m-15.57m 15.81m-15.95m Fracture: 15.57m-15.61m, θ=45° 15.57m-15.65m, θ=10° 15.65m-15.67m, θ=65° 15.75m-15.81m, θ=20° Lost zone: 15.95m-16.33m(inferred)	W2					
162.2																
16.0			2	HQ	64	38		17	>25 >25 3 4	Fragmented zone:16.33m-16.54m Fracture: 16.74m-16.80m, θ=40° 16.83m-16.87m, θ=70° 16.92m-16.94m, θ=50° 16.93m-16.97m, θ=60° 16.97m-17.02m, θ=45°	W4 to W1					
161.1																
17.0			3	HQ	100	97		65	7 6 3 0 1	Fragmented zone: 17.02m-17.04m Fracture: 17.46m-17.48m, θ=80° 17.61m-17.67m, θ=40° 18.42m-18.44m, θ=70°	W2 to W1		189	87	215.1	2.71
159.6																
18.5			4	HQ	95	92		81	0 7 1 0 0	Fracture: 18.85m-18.90m, θ=0° and 5°, two sets 18.94m-18.96m, θ=80° 18.98m-19.01m, θ=65°	W4 to W1		40	26		
158.0																
20.1	**END OF BOREHOLE** Note: 1) 50 mm monitoring well was installed upon completion, screened between 4.50m and 7.60m. Water Level measured in monitoring well: Date W.L.Depth (m) Jan. 13, 2021 3.5															

Weathering Index: W1-Fresh, W2-Slightly weathered, W3-Moderately weathered, W4-Highly weathered, W5-Completely weathered

θ = angle to the core axis

E = Modulus of Elasticity

*: UCS [Mpa] ≈ 24 $I_{S(50)}$

LOG OF BOREHOLE BH20-04

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 4
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-07-2020 to Dec-08-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769091.167 E 652847.816
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION
178.9	Ground Surface					
0.0	**FILL:** crusher run limestone, contains silty sand pockets, brownish grey, moist, compact.	1	SS	26		
178.2						
0.8	**FILL:** silty clay, trace sand, trace gravel, trace organics, trace rootlet, brownish grey, moist, stiff.	2	SS	9		178
177.9 1.1	**SILTY CLAY:** trace sand, contains silt seams, brown, moist, very stiff to very soft.	3	SS	20		177
		4	SS	16		
	reddish brown	5	SS	12		176
		6	SS	9		175
		7	SS	7		174
		8	SS	7		
		9	SS	8		173
	grey, wet	10	SS	2		172
		1	Vane			171
						170
						169

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH (kPa) 20 40 60 80 100
○ UNCONFINED + FIELD VANE & Sensitivity
● QUICK TRIAXIAL × LAB VANE
2.5
+35

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%) 10 20 30

POCKET PEN. (Cu) (kPa)

NATURAL UNIT WT (kN/m³)

REMARKS AND GRAIN SIZE DISTRIBUTION (%)

GR	SA	SI	CL
0	4	(96)	

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GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-04

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 4
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-07-2020 to Dec-08-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769091.167 E 652847.816
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued										
	SILTY CLAY: trace sand, contains silt seams, brown, moist, very stiff to very soft.(Continued)										
11			12	SS	2		168				0 0 68 32
12							167				
			1	TW							
13							166				
14			14	SS	6		165				0 0 70 30
164.3											
14.6	**SILT:** some sand, trace gravel, trace clay, contains clayey silt layers/pockets, dilatant, reddish brown, wet, loose.										
15	trace gravel, contains shale fragments		15	SS	6		164		[Non-Plastic]		8 20 64 8
16							163				
162.5											
16.5	**BEDROCK:**		1	RC			162				
17	Coring began at 16.31m Refer to Rock Core Log										
18			2	RC			161				
19			3	RC			160				
159.0											

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GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-04

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 4
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-07-2020 to Dec-08-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769091.167 E 652847.816
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

SOIL PROFILE			SAMPLES						DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%)
(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION						GR SA SI CL
	Continued												
19.9	**END OF BOREHOLE** Note: 1) TW denotes thin wall shelby tube sample.												

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF ROCK CORE BH20-04

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 4
LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-07-2020 to Dec-08-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769091.167 E 652847.816
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	ROCK DESCRIPTION	GROUND WATER CONDITIONS	CORE SAMPLE NUMBER	CORE SAMPLE SIZE	TOTAL CORE RECOVERY (%)	SOLID CORE RECOVERY (%)	HARD LAYER (%)	RQD (%)	FRACTURE INDEX (per 0.3 m)	DISCONTINUITIES	Weathering Index	HYDRAULIC CONDUCTIVITY (cm/sec)	POINT LOAD TEST UCS AXIAL (MPa)*	POINT LOAD TEST UCS DIAMETRAL (MPa)*	UNIAXIAL COMPRESSION (MPa)	DENSITY (g/cm³) E (GPa)
162.5	Rock Surface															
16.5 – 17.1 (161.8)	**SALINA FORMATION:** Bedding almost horizontal (θ=90°)		1	HQ	100	44		44	>25 6	Fragmented zone: 16.46m-16.81m Fracture: 16.81m-16.82m, θ=0° to 50°	W2					
17.1 – 18.6 (160.3)			2	HQ	100	100		97	0 0 0 2 0	Joint: 17.09m-17.25m, θ=0° 17.42m-17.50m, θ=0°	W2 to W1				100	2.61
18.6 – 19.9 (159.0)			3	HQ	100	100		100	0 0 0 0	Joint: 18.69m-18.71m, θ=65° 18.75m-18.77m, θ=70°	W2 to W1		48	24		
19.9	**END OF BOREHOLE** Note:															

Weathering Index: W1-Fresh, W2-Slightly weathered, W3-Moderately weathered, W4-Highly weathered, W5-Completely weathered θ = angle to the core axis

E = Modulus of Elasticity
*: UCS [Mpa] ≈ 24 $I_{S(50)}$

LOG OF BOREHOLE BH20-05

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 5
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-04-2020 to Dec-04-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4768160.887 E 652873.207
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS / 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
177.8	Ground Surface											
177.7 / 0.0	**ASPHALT:** 150mm											
177.6 / 0.2	**GRANULAR FILL:** 50mm		1	SS	50/ initial125mm							
	FILL: crusher run limestone, contains silty sand pockets, brownish grey, moist, very dense to compact.											
176.8 / 1.1	**FILL:** silty clay, trace sand, trace gravel, trace organics, trace rootlet, brownish grey, moist, stiff.		2	SS	13		177					
176.0 / 1.8	**SILTY CLAY:** trace sand, contains silt seams, brown, moist, very stiff to very soft.		3	SS	14		176					
			4	SS	19		175					
			5	SS	18							
	---------- brown to reddish brown		6	SS	6		174					
			1	Vane			173	+ 3.0				
			8	SS	11		172					
	contains grey silt seams		9	SS	10							0 2 (98)
							171					
			10	SS	9		170					
							169					
			11	SS	9						8.4	
							168					

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES + 3, × 3: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-05

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 5
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-04-2020 to Dec-04-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4768160.887 E 652873.207
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS "N" 0.3 m	ELEVATION
	Continued				
	SILTY CLAY: trace sand, contains silt seams, brown, moist, very stiff to very soft.(Continued)				
	grey, wet	12	SS	2	167
		2	Vane		166
		14	SS	2	164
		1	TW		163
161.5					162
16.3	**SAND AND GRAVEL:** trace silt, trace clay, reddish brown, wet, compact to loose.	16	SS	15	161
159.4					160
18.4	**SILTY CLAY:** trace sand, trace gravel, trace shale fragments, reddish brown, wet, stiff to firm.	17	SS	8	159
					158

SHEAR STRENGTH (kPa): ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE
DYNAMIC CONE PENETRATION RESISTANCE PLOT
WATER CONTENT (%): PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L

REMARKS AND GRAIN SIZE DISTRIBUTION (%)	GR	SA	SI	CL
	0	5		(95)

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: +3, ×3: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-05

PROJECT: Geotechnical Investigation
CLIENT: Regional Municipality of Niagara
PROJECT LOCATION: Niagara Region Sanitary Sewer
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan N 4768160.887 E 652873.207

Method: Hollow Stem Augers/HQ Core
Diameter: 203 mm/63mm
Date: Dec-04-2020 to Dec-04-2020
Equipment: Pontil Drilling CME 75 (Truck)

REF. NO.: 201-11602-00
ENCL NO.: 5
ORIGINATED BY SL
COMPILED BY BW
CHECKED BY MK

(m) ELEV DEPTH	DESCRIPTION (Continued)	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	SILTY CLAY: trace sand, trace gravel, trace shale fragments, reddish brown, wet, stiff to firm.(Continued)		18	SS	5				o (~26)			
21							157					
			3	Vane				+ 59 (2.4)				
22							156					
23							155					
154.1 / 23.8	**BEDROCK:** Coring began at 23.77m Refer to Rock Core Log		1	RC			154					
152.9 / 25.0	**END OF BOREHOLE** Notes: 1) Borehole was sealed with bentonite and cement grouting. 2) TW denotes thin wall shelby tube sample.						153					

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100. PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30.

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3$, $\times^3$: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF ROCK CORE BH20-05

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 5
LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-04-2020 to Dec-04-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4768160.887 E 652873.207
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	ROCK DESCRIPTION	GROUND WATER CONDITIONS	CORE SAMPLE NUMBER	CORE SAMPLE SIZE	TOTAL CORE RECOVERY (%)	SOLID CORE RECOVERY (%)	HARD LAYER (%)	RQD (%)	FRACTURE INDEX (per 0.3 m)	DISCONTINUITIES	Weathering Index	HYDRAULIC CONDUCTIVITY (cm/sec)	POINT LOAD TEST UCS AXIAL (MPa)*	POINT LOAD TEST UCS DIAMETRAL (MPa)*	UNIAXIAL COMPRESSION (MPa)	DENSITY (g/cm^3) E (GPa)
154.1	Rock Surface															
23.8 24	**SALINA FORMATION:** Bedding almost horizontal (θ=90°)		1	HQ	100	71		48	17 5 3 3	Fragmented zone: 23.91m-24.09m Fracture: 24.42m-24.47m, θ=0° 24.83m-24.99m, θ=10° 24.84m-24.94m, θ=30°	W2 to W1					
152.9																
25.0	**END OF BOREHOLE** Note:															

Weathering Index: W1-Fresh, W2-Slightly weathered, W3-Moderately weathered, W4-Highly weathered, W5-Completely weathered

θ = angle to the core axis

E = Modulus of Elasticity

*: UCS [Mpa] ≈ 24 $I_{S(50)}$

LOG OF BOREHOLE BH20-06D

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/Mud Rotory
ENCL NO.: 6D
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY AKJ
DATUM: Geodetic
Date: Dec-15-2020 to Dec-16-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4767709.7 E 652872.7
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS / 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION
175.8	Ground Surface						
175.8 / 0.0	**ASPHALT:** 100mm						
175.7 / 0.1	**FILL:** crusher run limestone, grey, moist, very dense to compact.		1	SS	70/200mm		
	contains silty sand pockets,		2	SS	35		175
174.0			3	SS	10		174
1.8	**FILL:** silty clay, some sand, trace gravel, trace organics, greyish brown, moist, stiff to firm.		4	SS	7		
			5	SS	8	▽	173
172.0							
3.8	**FILL:** crusher run limestone, grey, wet, very loose to loose.		6	SS	4		
171.2							
4.6	**FILL:** clayey silt, sandy, trace gravel, trace organics, brown, moist to wet, firm to soft.		7	SS	4		171
170.1	75mm crushed stone layer		8	SS	3		
5.7	**SILTY CLAY:** some sand, trace gravel, trace organics, trace peat, grey, moist, soft (Alluvial Deposit).		1	Vane			170
168.6							169
7.2	**ORGANIC CLAYEY SILT:** interval with peat seams and layer, sandy, trace rootlets, dark brown, moist, soft to firm.		10	SS	4		168
166.5							167
9.3	**SILTY CLAY:** trace sand, contains reddish brown silt layers, grey, wet, very soft to hard.		11	SS	0		166

W. L. 172.3 m
Jan 13, 2020

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100

SHEAR STRENGTH (kPa)
○ UNCONFINED + FIELD VANE & Sensitivity
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%)
10 20 30

POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m³)

REMARKS AND GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-06D

PROJECT: Geotechnical Investigation
CLIENT: Regional Municipality of Niagara
PROJECT LOCATION: Niagara Region Sanitary Sewer
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan N 4767709.7 E 652872.7

Method: Hollow Stem Augers/Mud Rotory
Diameter: 203 mm
Date: Dec-15-2020 to Dec-16-2020
Equipment: Pontil Drilling CME 75 (Truck)

REF. NO.: 201-11602-00
ENCL NO.: 6D
ORIGINATED BY AKJ
COMPILED BY BW
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS "N" 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued											
	SILTY CLAY: trace sand, contains reddish brown silt layers, grey, wet, very soft to hard.(Continued)											
			2	Vane			165	1.0 +28				
	reddish grey		13	SS	1		164		○			
			1	TW			163					
	150mm wet grey sandy silt layer		15	SS	16		162		○			
	contains reddish brown silt seams		16	SS	31		161		○			4 3 51 42
158.0							160					
17.8	**SANDY GRAVEL:** trace silt, trace clay, reddish grey, wet, dense.		17	SS	48		159		○			
156.5							158					
19.4	**COARSE SAND:** trace to some gravel, trace silt, trace clay, grey, wet, compact to very dense.						157		○			
							156					

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-06D

PROJECT: Geotechnical Investigation
CLIENT: Regional Municipality of Niagara
PROJECT LOCATION: Niagara Region Sanitary Sewer
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan N 4767709.7 E 652872.7

Method: Hollow Stem Augers/Mud Rotory
Diameter: 203 mm
Date: Dec-15-2020 to Dec-16-2020
Equipment: Pontil Drilling CME 75 (Truck)

REF. NO.: 201-11602-00
ENCL NO.: 6D
ORIGINATED BY AKJ
COMPILED BY BW
CHECKED BY MK

ELEV / DEPTH (m)	DESCRIPTION	NUMBER	TYPE	BLOWS "N" 0.3 m	ELEVATION
	Continued				
	COARSE SAND: trace to some gravel, trace silt, trace clay, grey, wet, compact to very dense.(Continued)	18	SS	28	
	150mm dilatant reddish brown sandy silt layer, trace cobbles/boulders	19	SS	92/ 300mm	
153.4					
22.4	**SANDY GRAVEL:** trace silt, trace clay, trace cobbles, grey, wet, very dense.	20	SS	50/ 100	
148.4					
27.4	**BEDROCK:**	21	SS/NR	50/ initial0mm	
		22	SS	50/ initial25mm	

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-06D

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/Mud Rotory
ENCL NO.: 6D
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY AKJ
DATUM: Geodetic
Date: Dec-15-2020 to Dec-16-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4767709.7 E 652872.7
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS/0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued											
145.3	**BEDROCK:**(Continued)											
30.5	**END OF BOREHOLE** Note: 1) TW denotes thin wall shelby tube sample. 2) 50 mm monitoring well was installed upon completion, screened between 28.35m and 30.48m. Water Level measured in monitoring well: Date W.L.Depth (m) Jan. 13, 2021 3.5		23	SS	50/ initial25mm							

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-06S

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 6S
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
DATUM: Geodetic
Date: Dec-17-2020
BH LOCATION: See Borehole Location Plan N 4767710.5 E 652872.6
Equipment: Pontil Drilling CME 75 (Truck)

ELEV / DEPTH (m)	DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT / WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
175.8	Ground Surface											
175.7 / 0.1	Direct Drilling to Depth of 15.24 Without Sampling Lithology Inferred from BH-06 (Deep)											
174.0 / 1.8												
172.0 / 3.8						W. L. 171.9 m Jan 13, 2020						
171.2 / 4.6												
170.1 / 5.7												
168.6 / 7.2												
166.5 / 9.3												

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-06S

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 6S
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
DATUM: Geodetic
Date: Dec-17-2020
BH LOCATION: See Borehole Location Plan N 4767710.5 E 652872.6
Equipment: Pontil Drilling CME 75 (Truck)

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued											
11							165					
12							164					
13							163					
14							162					
15							161					
160.6												
15.2	Note: 1) Borehole was sealed with bentonite. 2) 50 mm monitoring well was installed upon completion, screened between 12.19m and 15.24m. Water Level measured in monitoring well: Date W.L.Depth (m) Jan. 13, 2021 3.9											

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-07D

PROJECT: Geotechnical Investigation
CLIENT: Regional Municipality of Niagara
PROJECT LOCATION: Niagara Region Sanitary Sewer
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan N 4767374.6 E 652880.1

Method: Hollow Stem Augers//Mud Rotory/HQ Core
Diameter: 203 mm/63mm
Date: Dec-21-2020 to Dec-22-2020
Equipment: Pontil Drilling CME 75 (Truck)

REF. NO.: 201-11602-00
ENCL NO.: 7D
ORIGINATED BY SL
COMPILED BY BW
CHECKED BY MK

ELEV / DEPTH (m)	DESCRIPTION	NUMBER	TYPE	BLOWS "N" 0.3 m
177.1	Ground Surface			
177.0 / 0.1	**GRANULAR FILL:** crusher run limestone, grey, moist, compact.	1	SS	19
	FILL: silty clay, trace sand, trace gravel, trace organics, grey, moist, very stiff to stiff.	2	SS	9
175.4 / 1.7	**SILTY CLAY:** trace sand, contains reddish brown silt seams, brown, moist, very stiff to very soft.	3	SS	18
		4	SS	17
		5	SS	14
		6	SS	7
		7	SS	8
	grey	8	SS	7
		9	SS	4
		1	Vane	2.0 +35
	contains dilatant silt layers	11	SS	2

GROUND WATER CONDITIONS: W. L. 171.8 m Jan 13, 2020

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100)

SHEAR STRENGTH (kPa) (20 40 60 80 100)
○ UNCONFINED + FIELD VANE & Sensitivity
● QUICK TRIAXIAL × LAB VANE

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%) (10 20 30)

POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m³)
REMARKS AND GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-07D

PROJECT: Geotechnical Investigation
CLIENT: Regional Municipality of Niagara
PROJECT LOCATION: Niagara Region Sanitary Sewer
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan N 4767374.6 E 652880.1

Method: Hollow Stem Augers//Mud Rotory/HQ Core
Diameter: 203 mm/63mm
Date: Dec-21-2020 to Dec-22-2020
Equipment: Pontil Drilling CME 75 (Truck)

REF. NO.: 201-11602-00
ENCL NO.: 7D
ORIGINATED BY SL
COMPILED BY BW
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L — WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued											
	SILTY CLAY: trace sand, contains reddish brown silt seams, brown, moist, very stiff to very soft.(Continued)						167					
11			1	TW			166					
12							165					
			13	SS	1			○				
13							164					
14			2	Vane			163	+2.0 28				
162.3												
14.8	**SILT:** trace to some clay, trace sand, dilatant, reddish brown, wet, loose to very dense.											
15			15	SS	8		162		○			
16							161					
17	some sand to sandy between 16.8m to 20.4m		17	SS	50		160					
18							159					
			18	SS	58				○			0 15 81 4
19							158					
20												

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-07D

PROJECT: Geotechnical Investigation
CLIENT: Regional Municipality of Niagara
PROJECT LOCATION: Niagara Region Sanitary Sewer
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan N 4767374.6 E 652880.1

Method: Hollow Stem Augers//Mud Rotory/HQ Core
Diameter: 203 mm/63mm
Date: Dec-21-2020 to Dec-22-2020
Equipment: Pontil Drilling CME 75 (Truck)

REF. NO.: 201-11602-00
ENCL NO.: 7D
ORIGINATED BY SL
COMPILED BY BW
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	"N" BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued											
	SILT: trace to some clay, trace sand, dilatant, reddish brown, wet, loose to very dense.(Continued)		19	SS	55		157					
							156					
			20	SS	56		155					
							154					
152.4							153					
24.7	**CLAYEY SILT TILL:** sandy, trace to some gravel, grey, moist to wet, stiff.		21	SS	13		152					
150.7							151					
26.4	**BEDROCK:** Coring began at 27.13m Refer to Rock Core Log		1	RC			150					
			2	RC			149					
			3	RC			148					

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-07D

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers//Mud Rotory/HQ Core
ENCL NO.: 7D
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-21-2020 to Dec-22-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4767374.6 E 652880.1
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: "N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued											
	BEDROCK:						147					
	Coring began at 27.13m Refer to Rock Core Log(Continued)											
146.4												
30.7	**END OF BOREHOLE**											
	Note: 1) TW denotes thin wall shelby tube sample. 2) 50 mm monitoring well was installed upon completion, screened between 27.43m and 30.48m.											
	Water Level measured in monitoring well: Date W.L.Depth (m) Jan. 13, 2021 5.3											

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF ROCK CORE BH20-07D

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers//Mud Rotory/HQ Core
ENCL NO.: 7D
LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-21-2020 to Dec-22-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4767374.6 E 652880.1
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	ROCK DESCRIPTION	GROUND WATER CONDITIONS	CORE SAMPLE NUMBER	CORE SAMPLE SIZE	TOTAL CORE RECOVERY (%)	SOLID CORE RECOVERY (%)	HARD LAYER (%)	RQD (%)	FRACTURE INDEX (per 0.3 m)	DISCONTINUITIES	Weathering Index	HYDRAULIC CONDUCTIVITY (cm/sec)	POINT LOAD TEST UCS AXIAL (MPa)*	POINT LOAD TEST UCS DIAMETRAL (MPa)*	UNIAXIAL COMPRESSION (MPa)	DENSITY (g/cm^3) E (GPa)
150.0	Rock Surface															
27.1 149.3	**SALINA FORMATION:** Bedding almost horizontal (θ=90°) *(continued)*		1	HQ	100	84		34	15 5	Fragmented zone:27.37m-27.42m 27.51m-27.55m Fracture: 27.13m-27.23m, θ=10° 27.27m-27.31m, θ=15° to 0°	W2				223.5	2.75
27.8 28 29 147.9			2	HQ	100	95		75	3 3 6 0 4	Fragmented zone: 27.87m-27.88m;28.65m-28.68m Fracture: 28.15m-28.16m, θ=70° 28.33m-28.36m, θ=60° to 65° 29.07m-29.10m, θ=0° and 0°,two sets Joint: 28.18m-28.19m, θ=75° 28.27m-28.28m, θ=80°	W2 to W1					
29.2 30 146.4			3	HQ	100	93		70	6 4 2 1 2	Soft layer 29.29m ~ 29.31m (W5) Fracture: 29.16m-29.21m, θ=0° and 5°,two sets 29.74m-29.76m, θ=75°	W2 to W1					
30.7	**END OF BOREHOLE** Note: 1) 50 mm monitoring well was installed upon completion, screened between 27.43m and 30.48m. Water Level measured in monitoring well: Date W.L.Depth (m) Jan. 13, 2021 5.3															

Weathering Index: W1-Fresh, W2-Slightly weathered, W3-Moderately weathered, W4-Highly weathered, W5-Completely weathered θ = angle to the core axis

E = Modulus of Elasticity
*: UCS [Mpa] ≈ 24 $I_{S(50)}$

LOG OF BOREHOLE BH20-07S

PROJECT: Geotechnical Investigation		REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara	Method: Hollow Stem Augers	ENCL NO.: 7S
PROJECT LOCATION: Niagara Region Sanitary Sewer	Diameter: 203 mm	ORIGINATED BY AKJ
DATUM: Geodetic	Date: Dec-23-2020	COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4767373.8 E 652880.3	Equipment: Pontil Drilling CME 75 (Truck)	CHECKED BY MK

(m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L — WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
177.0	Ground Surface											
176.9 / 0.1	Direct Drilling to Depth of 19.81 Without Sampling Lithology Inferred from BH-07 (Deep)						176					
175.3 / 1.7							175					
							174					
							173					
						W. L. 172.4 m Jan 13, 2020	172					
							171					
							170					
							169					
							168					

Continued Next Page

GROUNDWATER ELEVATIONS

Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-07S

PROJECT: Geotechnical Investigation
CLIENT: Regional Municipality of Niagara
PROJECT LOCATION: Niagara Region Sanitary Sewer
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan N 4767373.8 E 652880.3

Method: Hollow Stem Augers
Diameter: 203 mm
Date: Dec-23-2020
Equipment: Pontil Drilling CME 75 (Truck)

REF. NO.: 201-11602-00
ENCL NO.: 7S
ORIGINATED BY AKJ
COMPILED BY BW
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued											
11							166					
12							165					
13							164					
14							163					
162.2 14.8												
15							162					
16							161					
17							160					
18							159					
19							158					
157.2 19.8	**END OF BOREHOLE**											

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-07S

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 7S
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY AKJ
DATUM: Geodetic
Date: Dec-23-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4767373.8 E 652880.3
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE 20 40 60 80 100	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT w_P w w_L WATER CONTENT (%) 10 20 30	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%)
(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m						GR SA SI CL
	Continued										
	Note: 1) 50 mm monitoring well was installed upon completion, screened between 16.76m and 19.81m. Water Level measured in monitoring well: Date W.L.Depth (m) Jan. 13, 2021 4.6										

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES + 3, × 3: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-08

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 8
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-18-2020 to Dec-18-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766690.054 E 654312.344
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	BLOWS 0.3 m "N"
176.9	Ground Surface			
0.0	**FILL:** topsoil with silty clay pockets, trace sand, trace gravel, greyish brown, moist, firm.	1	SS	5
176.1				
0.8	**FILL:** silty clay, trace sand, trace gravel, trace organics, greyish brown, stiff.	2	SS	11
175.4				
1.5	**SILTY CLAY:** trace sand, brown, moist, very stiff to very soft.	3	SS	17
	---------- contains reddish brown silt seams	4	SS	13
		5	SS	9
		6	SS	9
	---------- grey	7	SS	6
		8	SS	6
	---------- reddish grey, wet	9	SS	4
		1	Vane	
		11	SS	3

GROUND WATER CONDITIONS: Concrete; Sand; W. L. 171.1 m Jan 13, 2020 Jan 28, 2021; W. L. 170.4 m Dec 23, 2020

ELEVATION: 176, 175, 174, 173, 172, 170, 169, 168, 167

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100)

SHEAR STRENGTH (kPa) (20 40 60 80 100)
○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%) (10 20 30)

2.0
+28

POCKET PEN. (Cu) (kPa)

NATURAL UNIT WT (kN/m³)

REMARKS AND GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-08

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 8
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-18-2020 to Dec-18-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766690.054 E 654312.344
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued											
	SILTY CLAY: trace sand, brown, moist, very stiff to very soft.(Continued)											
			1	TW			166					0 4 48 48
							165					
			13	SS	0		164					
163.6												
13.3	**SILT:** trace to some clay, trace sand, dilatant, reddish brown, wet, compact.											
			14	SS	18		163					
162.1												
14.8	**SILTY CLAY:** trace sand, contains dilatant silt seams, grey, wet, very soft to stiff.						162					
			15	SS	0		161					
			2	Vane			160	2.0 +31				
							159					
			17	SS	5		Holeplug					
							158					
	trace gravel, trace limestone						157					

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-08

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 8
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-18-2020 to Dec-18-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766690.054 E 654312.344
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	BLOWS 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued											
	fragments, contains dilatant silt layers **SILTY CLAY:** trace sand, contains dilatant silt seams, grey, wet, very soft to stiff.(Continued)		18	SS	7							1 5 59 35
			19	SS	12		156					
							155					
153.7							154					
23.2	**SILT:** trace to some clay, trace sand, trace gravel, dilatant, reddish brown, wet, compact.		20	SS	26		153					
							152					
							151					
							150					
	some gravel, trace shale fragments		21	SS	14		149					
147.6							148					
29.3	**BEDROCK:** Coring began at 29.26m Refer to Rock Core Log		1	RC			147					

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-08

PROJECT: Geotechnical Investigation
CLIENT: Regional Municipality of Niagara
PROJECT LOCATION: Niagara Region Sanitary Sewer
DATUM: Geodetic
BH LOCATION: See Borehole Location Plan N 4766690.054 E 654312.344

Method: Hollow Stem Augers/HQ Core
Diameter: 203 mm/63mm
Date: Dec-18-2020 to Dec-18-2020
Equipment: Pontil Drilling CME 75 (Truck)

REF. NO.: 201-11602-00
ENCL NO.: 8
ORIGINATED BY SL
COMPILED BY BW
CHECKED BY MK

ELEV / DEPTH (m)	DESCRIPTION	NUMBER	TYPE	BLOWS "N" 0.3 m	ELEVATION
	Continued				
	BEDROCK:				
	Coring began at 29.26m Refer to Rock Core Log(Continued)	2	RC		
31		3	RC		146
32		4	RC		145
33		5	RC		144
34					143
35		6	RC		142
36					141
					Sand
37		7	RC		140
38					139
					Screen
39		8	RC		138
137.3					
39.6	**END OF THE BOREHOLE** Note: 1) 50 mm monitoring well was				

Continued Next Page

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%): 10 20 30
POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m³)
REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES: $+^3$, $\times^3$: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-08

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 8
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-18-2020 to Dec-18-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766690.054 E 654312.344
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT / WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%)
(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m							GR SA SI CL
	Continued installed upon completion, screened between 36.55m and 39.60m. Water Level measured in monitoring well: Date W.L.Depth (m) Dec. 23, 2020 6.50 Jan. 13, 2021 4.61 Jan. 28, 2021 4.71							DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30			

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ε=3% Strain at Failure

LOG OF ROCK CORE BH20-08

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 8
LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-18-2020 to Dec-18-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766690.054 E 654312.344
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	ROCK DESCRIPTION	GROUND WATER CONDITIONS	CORE SAMPLE NUMBER	CORE SAMPLE SIZE	TOTAL CORE RECOVERY (%)	SOLID CORE RECOVERY (%)	HARD LAYER (%)	RQD (%)	FRACTURE INDEX (per 0.3 m)	DISCONTINUITIES	Weathering Index	HYDRAULIC CONDUCTIVITY (cm/sec)	POINT LOAD TEST UCS AXIAL (MPa)*	POINT LOAD TEST UCS DIAMETRAL (MPa)*	UNIAXIAL COMPRESSION (MPa)	DENSITY (g/cm^3) E (GPa)
147.6	Rock Surface															
29.3	**SALINA FORMATION:** Bedding almost horizontal (θ=90°)								20	Fragmented zone:29.26m-29.43m Gysum:30.12m-30.13m Fracture:						
30			1	HQ	100	78		36	7	29.51m-29.63m, θ=5° 29.63m-29.67m, θ=0° and 0°,two sets	W2					
146.7									3	29.83m-29.92m, θ=5°					149.4	2.72
30.2			2	HQ	58	58		58	13	Lost zone:30.38m-30.51m(inferred) Joint:31.28m-31.29m, θ=75°	W2 to W4					
146.4																
30.5									0							
31									2	Gysum: 31.23m-31.24m 31.28m-31.29m 31.67m-31.69m						
			3	HQ	100	98		98	1		W2 to W1					
									1							
32									0							
144.9																
32.0									1	Gysum: 32.03m-32.04m;32.51m-32.53m						
									1	32.91m-32.92m;32.96m-32.97m 33.05m-33.06m;33.10m-33.11m						
			4	HQ	100	100		100	1	33.13m-33.14m;33.19m-33.20m 33.29m-33.30m;33.31m-33.32m	W2 to W1					
33									1	33.34m-33.35m;33.39m-33.41m 33.47m-33.48m Joint:						
									1	32.04m-32.51m, θ=75° 32.75m-32.92m, θ=75°						
143.4																
33.5									4	Fragmented zone: 33.53m-33.55m						
34									2	Gysum: 33.57m-33.58m;33.62m-33.63m						
			5	HQ	100	97		90	2	33.67m-33.68m;33.80m-33.81m 34.06m-34.07m;34.42m-34.44m	W2 to W1					
									2	34.54m-34.55m						
35									1							
141.9																
35.0									1	Gysum: 35.32m-35.33m;35.84m-35.85m						
									0	35.92m-35.93m;36.02m-36.03m 36.04m-36.05m;36.13m-36.14m						
			6	HQ	100	98		78	3	36.25m-36.26m;36.35m-36.36m 36.40m-36.41m;36.46m-36.47m	W2 to W1					
36									1	Fracture: 35.65m-35.67m, θ=55°						
									5	36.25m-36.26m, θ=80°						
140.3																
36.6									3							
37									0	Fracture: 37.55m-37.57m, θ=0°						
			7	HQ	100	100		87	0	Joint: 37.57m-37.62m, θ=0°	W2 to W1					
									1							
38									0							
138.8																
38.1									1	Gysum: 38.48m-38.49m;38.55m-38.56m					160.4	2.78
									4	38.62m-38.63m;38.95m-38.96m 39.27m-39.28m;39.38m-39.39m						
39			8	HQ	100	100		85	2	39.45m-39.46m;39.54m-39.55m 39.59m-39.60m	W2 to W1					
									2	Fracture: 38.95m-38.96m, θ=0°						

Continued Next Page

Weathering Index: W1-Fresh, W2-Slightly weathered, W3-Moderately weathered, W4-Highly weathered, W5-Completely weathered θ = angle to the core axis

E = Modulus of Elasticity

*: UCS [Mpa] ≈ 24 $I_{S(50)}$

LOG OF ROCK CORE BH20-08

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 8
LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-18-2020 to Dec-18-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766690.054 E 654312.344
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	ROCK DESCRIPTION	GROUND WATER CONDITIONS	CORE SAMPLE NUMBER	CORE SAMPLE SIZE	TOTAL CORE RECOVERY (%)	SOLID CORE RECOVERY (%)	HARD LAYER (%)	RQD (%)	FRACTURE INDEX (per 0.3 m)	DISCONTINUITIES	Weathering Index	HYDRAULIC CONDUCTIVITY (cm/sec)	POINT LOAD TEST UCS AXIAL (MPa)*	POINT LOAD TEST UCS DIAMETRAL (MPa)*	UNIAXIAL COMPRESSION (MPa)	DENSITY (g/cm^3) E (GPa)
	Continued															
137.3	**SALINA FORMATION:** Bedding almost horizontal (θ=90°) *(continued)*								1							
39.6	**END OF THE BOREHOLE** Note: 1) 50 mm monitoring well was installed upon completion, screened between 36.55m and 39.60m. Water Level measured in monitoring well: Date W.L.Depth (m) Dec. 23, 2020 6.50 Jan. 13, 2021 4.61 Jan. 28, 2021 4.71															

Weathering Index: W1-Fresh, W2-Slightly weathered, W3-Moderately weathered, W4-Highly weathered, W5-Completely weathered θ = angle to the core axis

E = Modulus of Elasticity
*: UCS [Mpa] ≈ 24 $I_{S(50)}$

LOG OF BOREHOLE BH20-09

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 9
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-09-2020 to Dec-10-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766605.863 E 652916.408
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS / 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION
176.0	Ground Surface						
175.9 / 0.1	**ASPHALT:** 100mm						
	GRANULAR FILL: sand and gravel, trace silt, trace clay, grey, moist, compact to dense,		1	SS	30		
175.2 / 0.8	**FILL:** crusher run limestone, contains silty sand pockets, grey, moist, compact to loose.		2	SS	19		175
			3	SS	8		174
			4	SS	10		
			5	SS	18		173
			6	SS	8		172
171.2 / 4.7	**SILTY CLAY:** trace sand, contains silt seams, grey, moist, very soft to stiff.		7	SS	4		171
			8	SS	1		
			1	Vane			170
	---------- reddish brown,wet		10	SS	4		169
			1	TW			168
							167

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100

SHEAR STRENGTH (kPa)
○ UNCONFINED + FIELD VANE & Sensitivity
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%)
10 20 30

+49 1.8

POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m³)
REMARKS AND GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-09

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 9
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-09-2020 to Dec-10-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766605.863 E 652916.408
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa) / WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued										
	SILTY CLAY: trace sand, contains silt seams, grey, moist, very soft to stiff.(Continued)										
11			12	SS	10		165				0 5 (95)
164.2											
11.7 12	**SILT:** trace clay, trace sand, dilatant, reddish brown, wet, firm to stiff.						164				
			13	SS	8						
13 162.7							163				
13.3	**SILTY CLAY:** trace sand, trace gravel, contains dilatant silt seams and shale fragments, reddish brown, wet, stiff to firm.										
14			14	SS	10		162				
15							161				
			15	SS	4						5 8 (87)
16							160				
17			2	Vane			159	2.3 +56			
18							158				
			17	SS	8						0 4 58 38
19							157				
156.1 20 19.9											

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-09

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 9
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-09-2020 to Dec-10-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766605.863 E 652916.408
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: BLOWS 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L / WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued											
	CLAYEY SILT TILL (RESIDUAL SOIL): sandy, trace gravel, contains dolostone/limestone fragments, grey, wet, hard.(Continued)		18	SS	54				○			
155.1												
21 20.9	**BEDROCK:** Coring began at 21.34m Refer to Rock Core Log		1	RC			155					
22			2	RC			154					
23							153					
24			3	RC			152					
25			4	RC			151					
26							150					
27			5	RC			149					
28			6	RC			148					
29							147					
146.7												
29.3	**END OF BOREHOLE** Notes: 1) Borehole was sealed with bentonite and cement grouting. 2) TW denotes thin wall shelby tube											

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-09

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 9
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-09-2020 to Dec-10-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766605.863 E 652916.408
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

SOIL PROFILE			SAMPLES						DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT w_P w w_L WATER CONTENT (%) 10 20 30	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%)
(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION	SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE 20 40 60 80 100					GR SA SI CL
	Continued sample.												

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES + 3, × 3: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF ROCK CORE BH20-09

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers/HQ Core
ENCL NO.: 9
LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm/63mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-09-2020 to Dec-10-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766605.863 E 652916.408
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	ROCK DESCRIPTION	GROUND WATER CONDITIONS	CORE SAMPLE NUMBER	CORE SAMPLE SIZE	TOTAL CORE RECOVERY (%)	SOLID CORE RECOVERY (%)	HARD LAYER (%)	RQD (%)	FRACTURE INDEX (per 0.3 m)	DISCONTINUITIES	Weathering Index	HYDRAULIC CONDUCTIVITY (cm/sec)	POINT LOAD TEST UCS AXIAL (MPa)*	POINT LOAD TEST UCS DIAMETRAL (MPa)*	UNIAXIAL COMPRESSION (MPa)	DENSITY (g/cm^3) E (GPa)
155.8	Rock Surface															
20.1	**SALINA FORMATION:** Bedding almost horizontal (θ=90°)															
21																
154.6																
21.3			1	HQ	100	80		0	19	Fragmented zone:21.34m-21.39m 21.48m-21.49m Gysum:21.64m-21.65m	W2					
154.2																
21.7									23	21.70m-21.71m Fracture:	W2 to W1					
22									17	21.46m-21.48m, θ=0° and 0°, two sets 21.49m-21.64m, θ=10°						
			2	HQ	100	67		31	3	Fragmented zone:21.74m-21.91m 22.06m-22.16m;22.71m-22.73m						
									9	22.89m-22.97m;23.15m-23.19m Fracture:					180.3	2.72
23									13	21.93m-21.98m, θ=5° 22.00m-22.03m, θ=45°						
152.8																
23.2									11	22.03m-22.06m, θ=0° and 20°, two sets	W2 to W1					
									4	22.25m-22.30m, θ=35° and 65°, two sets						
24			3	HQ	100	85		50	6	22.30m-22.35m, θ=0° 22.40m-22.42m, θ=70°			106	96		
									5	22.45m-22.48m, θ=65° 22.86m-22.89m, θ=20°						
									16	22.97m-23.00m, θ=0° 23.11m-23.13m, θ=75° Soft layer Joint: 24.57m ~ 24.65m (W5 to W4)						
151.1										22.24m-22.27m, θ=75°						
24.8									2	22.52m-22.59m, θ=0° Fragmented zone:	W4 to W1					
25									17	23.28m-23.34m Gysum:						
			4	HQ	95	79		44	5	24.37m-24.48m Fracture:						
									16	23.25m-23.28m, θ=0° 23.58m-23.62m, θ=0°						
26									4	24.08m-24.09m, θ=15° Joint:						
149.7										22.34m-22.39m, θ=5°						
26.3									6	Fragmented zone:25.15m-25.22m	W4 to W1					
									1	25.41m-25.46m;25.57m-25.60m 25.78m-25.82m;25.98m-26.04m						
27			5	HQ	98	95		77	2	Gysum:25.91m-25.92m Fracture: 25.22m-25.25m, θ=0°						
									2	25.25m-25.34m, θ=0° 25.34m-25.36m, θ=50°						
									8	25.87m-25.88m, θ=10° 26.04m-26.21m, θ=0°						
148.2										Gysum:27.25m-27.27m						
27.8									11	27.62m-27.63m;27.65m-27.66m 27.69m-27.70m;27.71m-27.72m	W2 to W1					
28									4	27.74m-27.75m Fracture:						
			6	HQ	100	96		77	3	26.29m-26.33m, θ=5° 26.38m-26.41m, θ=0°						
									0	Fragmented zone:27.81m-27.86m Gysum:28.02m-28.03m						
29									0	28.13m-28.14m;28.16m-28.17m 28.21m-28.22m;28.34m-28.35m						
146.7										~~28.45m-28.46m;28.49m-28.50m~~						
29.3	**END OF BOREHOLE** Note:									28.68m-28.69m Fracture: 27.88m-27.90m, θ=0°						

Weathering Index: W1-Fresh, W2-Slightly weathered, W3-Moderately weathered, W4-Highly weathered, W5-Completely weathered θ = angle to the core axis E = Modulus of Elasticity

*: UCS [Mpa] ≈ 24 $I_{S(50)}$

LOG OF BOREHOLE BH20-10

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 10
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY AKJ
DATUM: Geodetic
Date: Dec-11-2020 to Dec-11-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766859.246 E 654268.177
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS / 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
176.7	Ground Surface							
0.0 / 176.5	**TOPSOIL:** 200mm						Concrete	
0.2	**FILL:** silty clay, trace sand, trace gravel, trace organics, greyish brown, moist, firm to very stiff.		1	SS	6		Sand	
			2	SS	14		176	
175.1								
1.7	**SILTY CLAY:** trace sand, contains silt seams, brown, moist, very stiff to firm.		3	SS	21		175	
	---------- reddish brown		4	SS	19		174	
			5	SS	13		Holeplug	
			6	SS	11		173	
	brownish grey		7	SS	9		172	
	---------- grey, wet		8	SS	6		W. L. 171.5 m Dec 23, 2020	
			9	SS	5		171 W. L. 170.6 m Dec 18, 2020	
							Sand 170	
			1	Vane			169 +1.0 28	
							Screen 168	
	contains reddish brown silt layers		11	SS	6			1 5 54 40
167.0							167	
9.8	**END OF THE BOREHOLE**							

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE 20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L

WATER CONTENT (%) 10 20 30

POCKET PEN. (Cu) (kPa)

NATURAL UNIT WT (kN/m³)

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES + 3, × 3: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-10

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 10
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY AKJ
DATUM: Geodetic
Date: Dec-11-2020 to Dec-11-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766859.246 E 654268.177
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT / WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%)
(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m							GR SA SI CL
	Continued											
	Note: 1) 50 mm monitoring well was installed upon completion, screened between 6.71m and 9.75m. Water Level measured in monitoring well: Date W.L.Depth (m) Dec. 18, 2020 6.16 Dec. 23, 2020 5.23											

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-11

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 11
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY AKJ
DATUM: Geodetic
Date: Dec-11-2020 to Dec-11-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766986.744 E 654318.837
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	BLOWS 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
176.5	Ground Surface							
176.3	**TOPSOIL:** 150mm						Concrete	
0.2	**FILL:** silty clay, trace sand, trace gravel, trace organics, brown, moist, firm to very stiff.		1	SS	7		Sand	
			2	SS	27		175	
174.6			3	SS	19			
1.8	**SILTY CLAY:** trace sand, contains silt seams, brown, moist, very stiff to very soft.							
	reddish brown		4	SS	14		174	
			5	SS	8		Holeplug	
			6	SS	8		172	
			7	SS	10			
	grey		8	SS	6		171	
	wet		9	SS	2		170 Sand	
						▽	W. L. 169.8 m Dec 23, 2020	
						▽	W. L. 169.3 m Dec 18, 2020	
							169	
			1	Vane			+24 1.0	
							Screen	
							168	
			11	SS	4		167	0 4 49 47
166.7								
9.8	**END OF THE BOREHOLE**							

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE 20 40 60 80 100
PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L
WATER CONTENT (%) 10 20 30
POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m³)

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-11

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 11
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY AKJ
DATUM: Geodetic
Date: Dec-11-2020 to Dec-11-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4766986.744 E 654318.837
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH (kPa)	PLASTIC LIMIT / NATURAL MOISTURE CONTENT / LIQUID LIMIT / WATER CONTENT (%)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%)
(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m			20 40 60 80 100	10 20 30			GR SA SI CL
	Continued											
	Note: 1) 50 mm monitoring well was installed upon completion, screened between 6.71m and 9.75m. Water Level measured in monitoring well: Date W.L.Depth (m) Dec. 18, 2020 7.12 Dec. 23, 2020 6.66											

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-12D

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 12A
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY AKJ
DATUM: Geodetic
Date: Dec-10-2020 to Dec-10-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4767290.374 E 654078.539
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

ELEV / DEPTH (m)	DESCRIPTION	NUMBER	TYPE	BLOWS / 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
174.9	Ground Surface						
0.0 / 174.7	**TOPSOIL:** 230mm					Concrete	
0.2	**FILL:** silty clay, trace sand, trace gravel, trace organics, greyish brown, moist, stiff.	1	SS	9		Sand	
	100mm silty sand layers	2	SS	11		174	
173.4							
1.5	**SILTY CLAY:** trace sand, contains silt seams, reddish brown, moist, very stiff to very soft.	3	SS	19		173	
	reddish brown to grey	4	SS	10		172	
	grey	5	SS	8		Holeplug	
	wet	6	SS	5		171	
		1	Vane			170	
	contains dilatant silt layers	8	SS	1	▽	W. L. 169.1 m W. L. 169.0 m Dec 18, 2020	
		1	TW			Sand	
						168	
		10	SS	3		167	
						Screen	
						166	
	trace shale fragments	11	SS	2			1 6 55 38
165.1							
9.8	**END OF THE BOREHOLE**						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%): 10 20 30
POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m³)
1.4 / 24

Continued Next Page

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES: +3, ×3: Numbers refer to Sensitivity; ○ε=3% Strain at Failure

LOG OF BOREHOLE BH20-12D

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 12A
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY AKJ
DATUM: Geodetic
Date: Dec-10-2020 to Dec-10-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4767290.374 E 654078.539
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

SOIL PROFILE (m) ELEV DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT W_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT W_L — WATER CONTENT (%) 10 20 30	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m^3)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
	Continued Note: 1) 50 mm monitoring well was installed upon completion, screened between 6.71m and 9.75m. Water Level measured in monitoring well: Date W.L.Depth (m) Dec. 18, 2020 5.93 Dec. 23, 2020 5.80											

WSP-SOIL-ROCK-MAY-29-2017.GLB WSP SOIL LOG 201-11602-00.GPJ 21-2-26

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-12S

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 12B
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY AKJ
DATUM: Geodetic
Date: Dec-10-2020 to Dec-10-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4767289.917 E 654080.153
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	BLOWS / 0.3 m "N"	GROUND WATER CONDITIONS	ELEVATION	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH (kPa) ○ UNCONFINED ● QUICK TRIAXIAL + FIELD VANE & Sensitivity × LAB VANE (20 40 60 80 100)	PLASTIC LIMIT w_P / NATURAL MOISTURE CONTENT w / LIQUID LIMIT w_L WATER CONTENT (%) (10 20 30)	POCKET PEN. (Cu) (kPa)	NATURAL UNIT WT (kN/m³)	REMARKS AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
174.9	Ground Surface											
174.8 0.0	**TOPSOIL:** 150mm						Concrete					
0.2	**FILL:** silty clay, trace sand, trace gravel, trace organics, brownish grey, moist, stiff to very stiff.		1	SS	11		Sand					
1	300mm silty sand layers		2	SS	17		Holeplug					
173.6							Sand					
1.3	**SILTY CLAY:** trace sand, contains silt seams, reddish brown, moist, very stiff to firm.		3	SS	17		173					
2			4	SS	13							
3	grey		5	SS	6		172 Screen					
						▽	W. L. 171.3 m Dec 23, 2020					
4	wet		6	SS	6	▽	W. L. 170.9 m Dec 18, 2020					
170.4												
4.6	**END OF THE BOREHOLE**											

Note:
1) 50 mm monitoring well was installed upon completion, screened between 1.52m and 4.57m.

Water Level measured in monitoring well:

Date	W.L.Depth (m)
Dec. 18, 2020	4.01
Dec. 23, 2020	3.67

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

GRAPH NOTES + 3, × 3: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH-P01

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 1S
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
ORIGINATED BY SL
DATUM: Geodetic
Date: Dec-09-2020 to Dec-09-2020
COMPILED BY BW
BH LOCATION: See Borehole Location Plan N 4769629.776 E 653228.046
Equipment: Pontil Drilling CME 75 (Truck)
CHECKED BY MK

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	NUMBER	TYPE	"N" BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION
180.5	Ground Surface						
0.0	Direct Drilling to Depth of 7.62 Without Sampling Lithology Inferred from BH-06 (Deep)						Concrete Sand 180
179.0							179
1.5						W. L. 178.2 m Dec 23, 2020	
						W. L. 177.1 m Dec 18, 2020	
							Sand 176
							175
							Screen 174
172.9							173
7.6	**END OF BOREHOLE** Note: 1) 50 mm monitoring well was installed upon completion, screened between 4.57m and 7.62m. Water Level measured in monitoring well: Date W.L.Depth (m) Dec. 18, 2020 3.5 Dec. 23, 2020 2.3						

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100

SHEAR STRENGTH (kPa)
○ UNCONFINED + FIELD VANE & Sensitivity
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%)
10 20 30

POCKET PEN. (Cu) (kPa)

NATURAL UNIT WT (kN/m³)

REMARKS AND GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ε=3% Strain at Failure

LOG OF BOREHOLE BH-P03

PROJECT: Geotechnical Investigation
REF. NO.: 201-11602-00
CLIENT: Regional Municipality of Niagara
Method: Hollow Stem Augers
ENCL NO.: 3S
PROJECT LOCATION: Niagara Region Sanitary Sewer
Diameter: 203 mm
DATUM: Geodetic
Date: Dec-11-2020
BH LOCATION: See Borehole Location Plan N 652135.207 E 4769057.188
Equipment: Pontil Drilling CME 75 (Truck)

(m) ELEV / DEPTH	DESCRIPTION	STRATA PLOT	SAMPLES NUMBER	TYPE	"N" BLOWS 0.3 m	GROUND WATER CONDITIONS	ELEVATION
178.1	Ground Surface						
0.0 / 177.9	**FILL:** granular sand and gravel, brown, moist, compact		1	SS	10		Concrete
0.3	**SILTY CLAY:** trace sand, occasional gravel, reddish brown, moist, firm.						Sand
1			2	SS	18		177
			3	SS	17		Holeplug
2							176
			4	SS	13		
3							Sand
			5	SS	11		175 W. L. 174.8 m Jan 13, 2020
4			6	SS	12		
							Screen
5			7	SS	7		
172.9							173
5.2	**END OF BOREHOLE**						

Note:
1) 50 mm monitoring well was installed upon completion, screened between 3.70m and 5.20m.

Water Level measured in monitoring well:

Date	W.L.Depth (m)
Jan. 13, 2021	3.3

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100

SHEAR STRENGTH (kPa)
○ UNCONFINED + FIELD VANE & Sensitivity
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

PLASTIC LIMIT w_P | NATURAL MOISTURE CONTENT w | LIQUID LIMIT w_L
WATER CONTENT (%)
10 20 30

POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m³)
REMARKS AND GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

GROUNDWATER ELEVATIONS
Measurement 1st ▽ 2nd ▼ 3rd ▼ 4th ▼

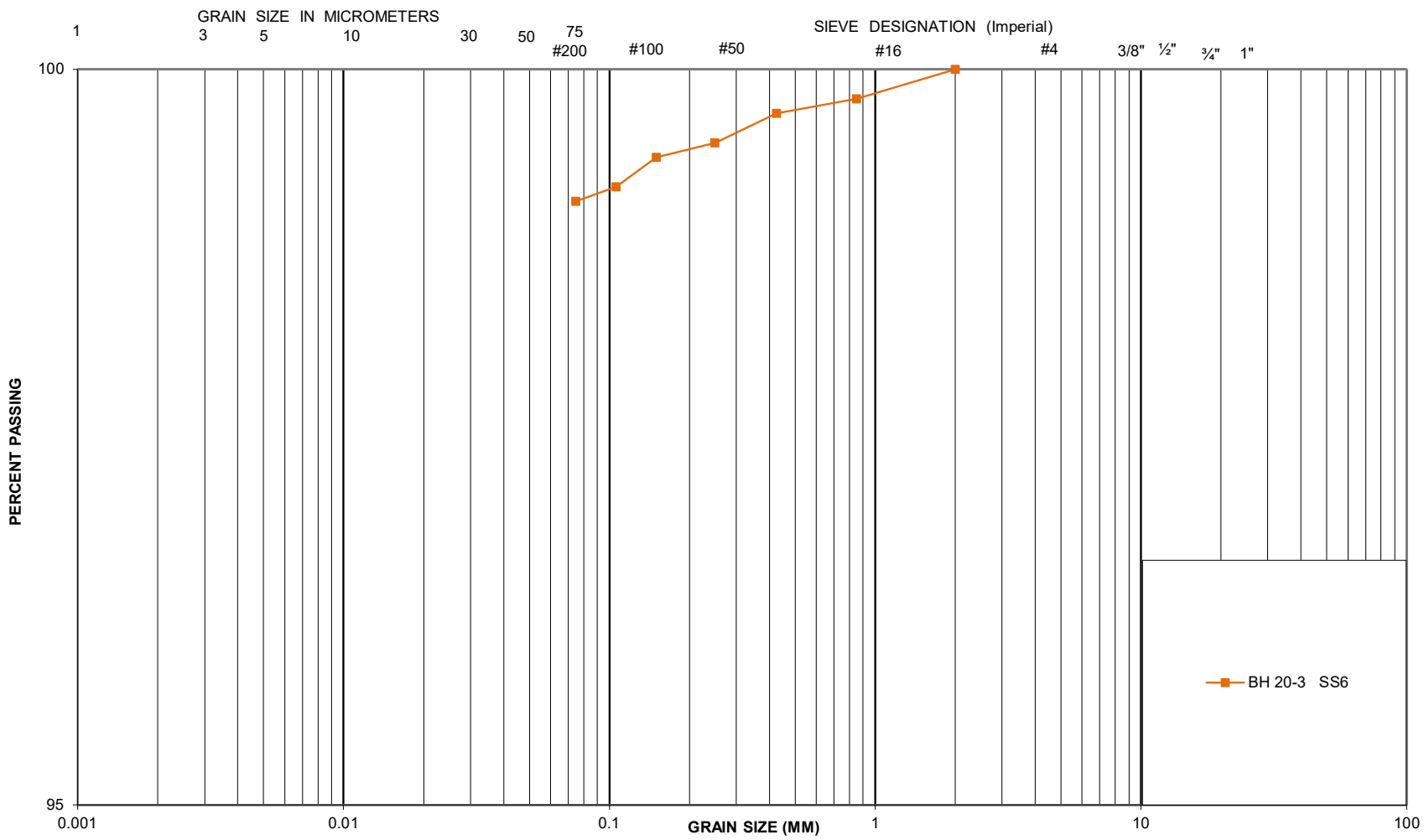
GRAPH NOTES
+ 3, × 3: Numbers refer to Sensitivity
○ ε=3% Strain at Failure

B

GRAIN SIZE DISTRIBUTION CURVES AND ATTERBERG LIMITS TESTS RESULTS

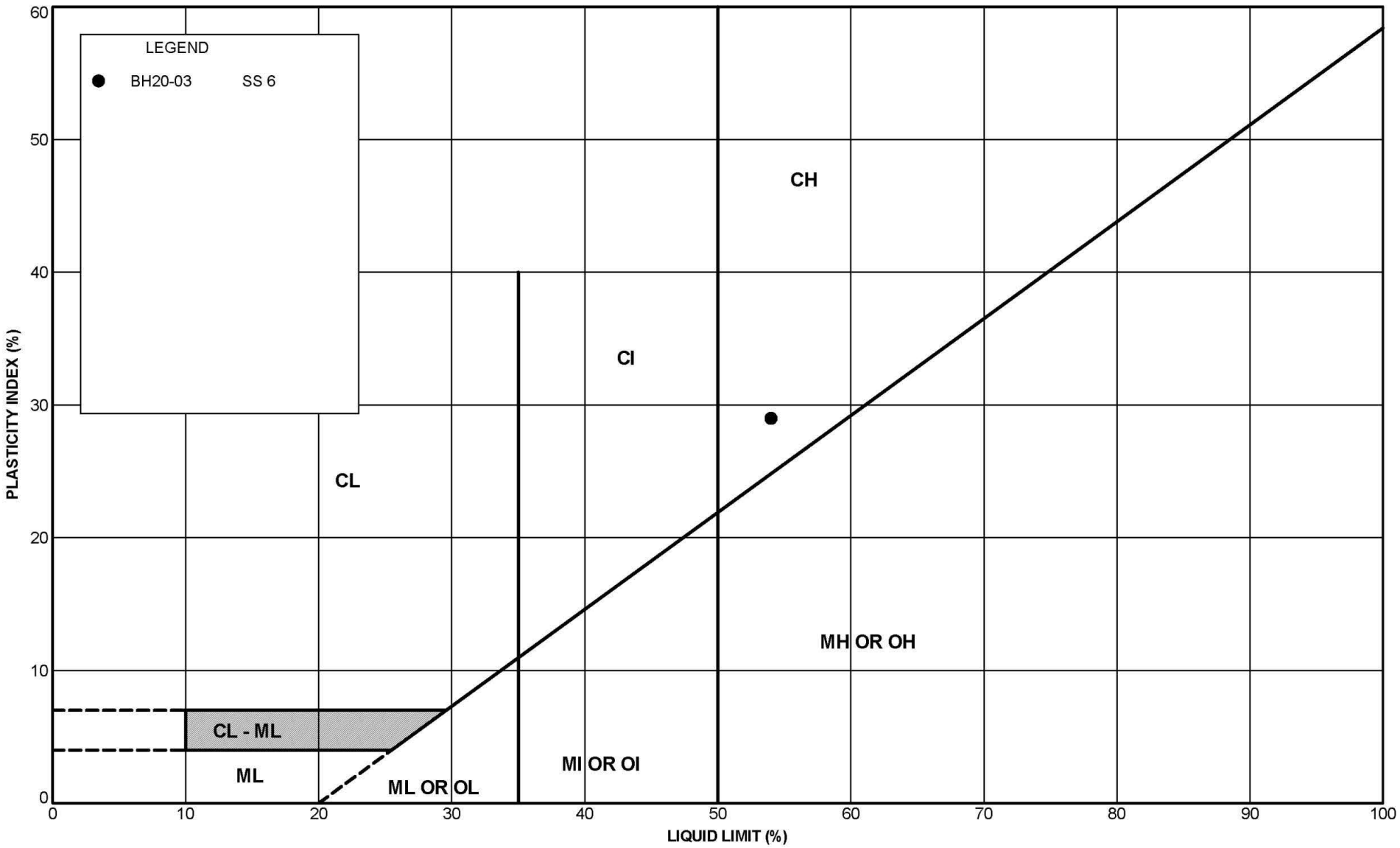
UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



GRAIN SIZE DISTRIBUTION

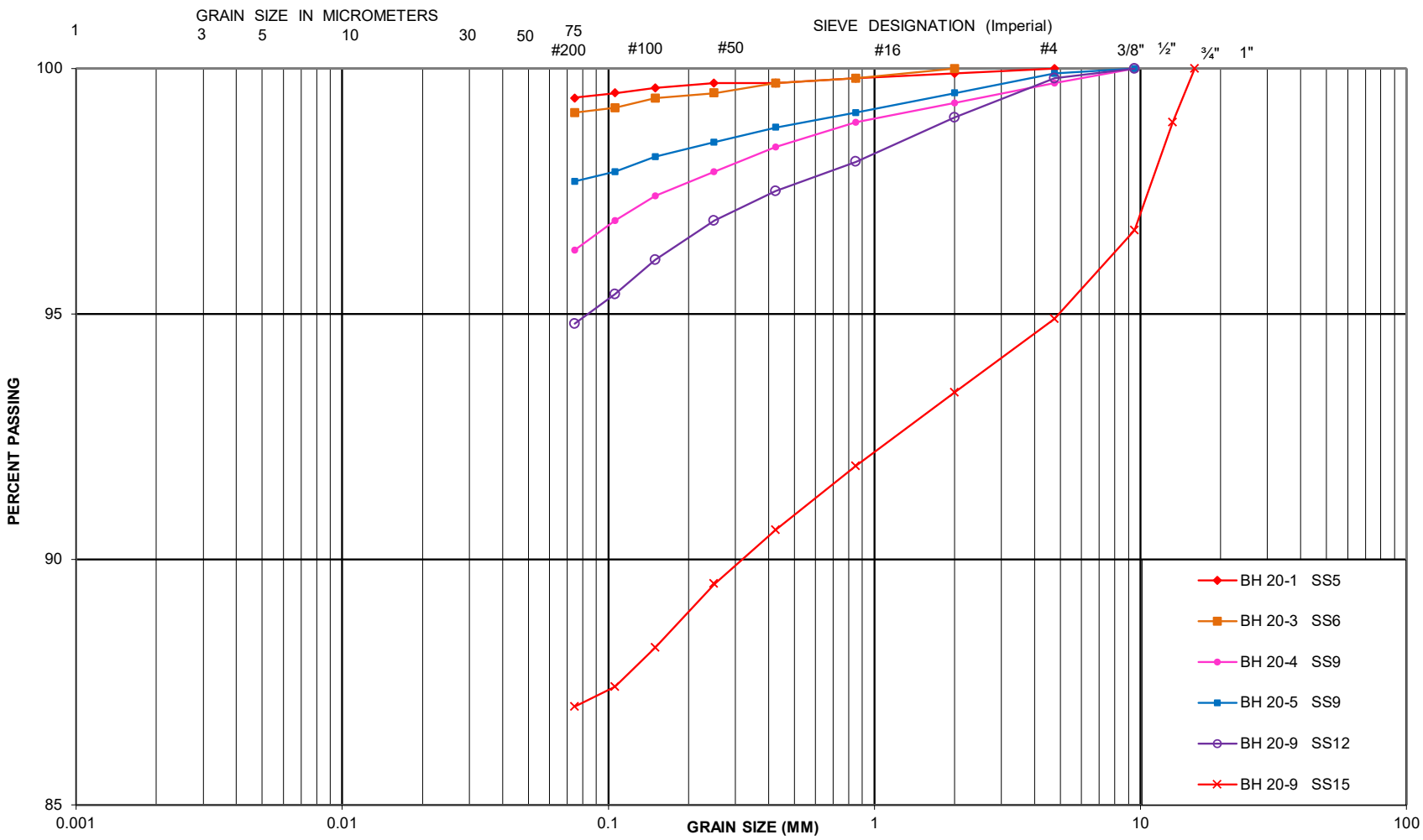
Figure No:	1
Project No.	201-11602-00
Date :	January 07, 2021



wsp	PLASTICITY CHART	FIGURE NO.	2
		JOB NO.	201-11602-00
		DATE	2021-02-26

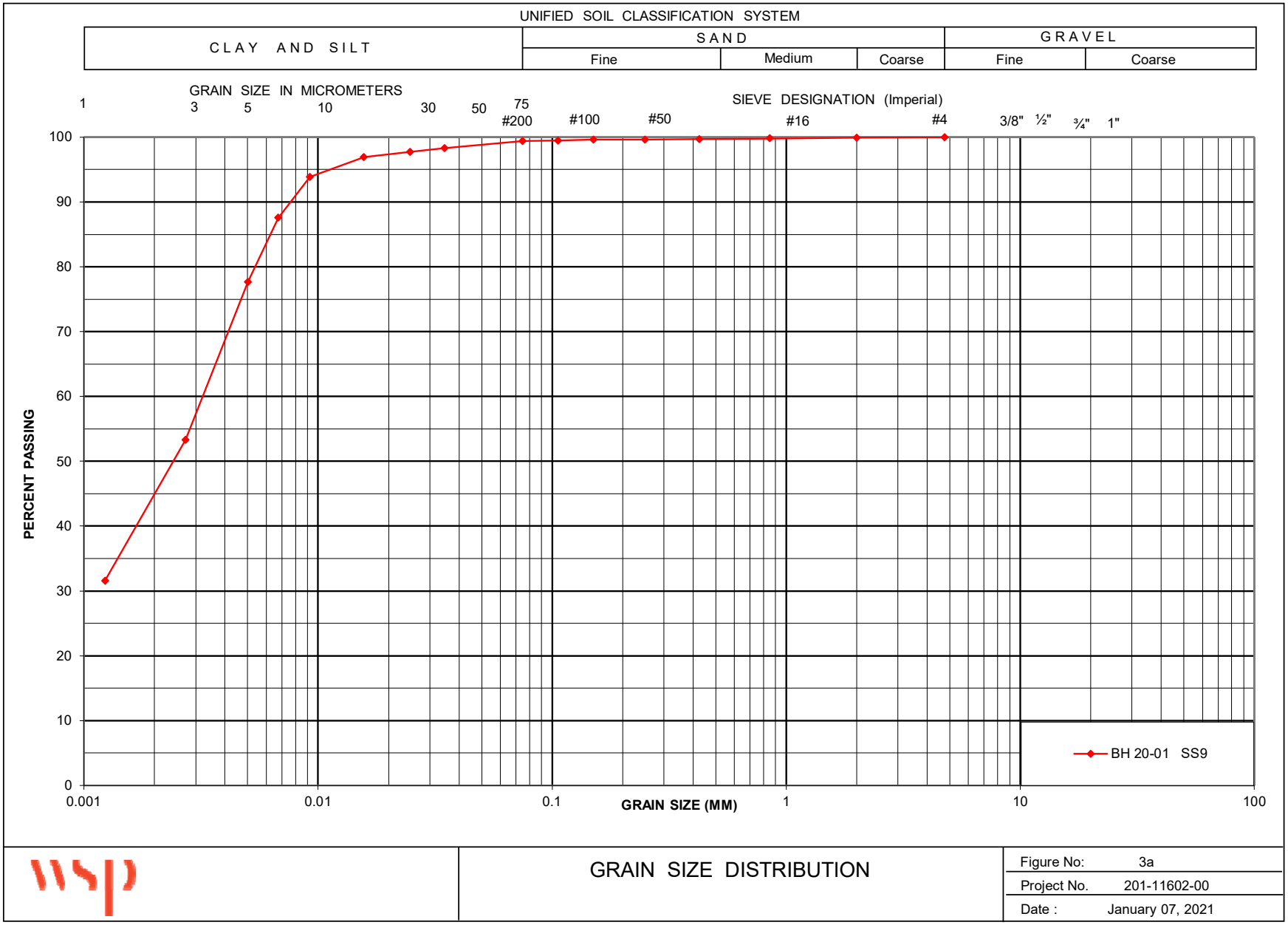
UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



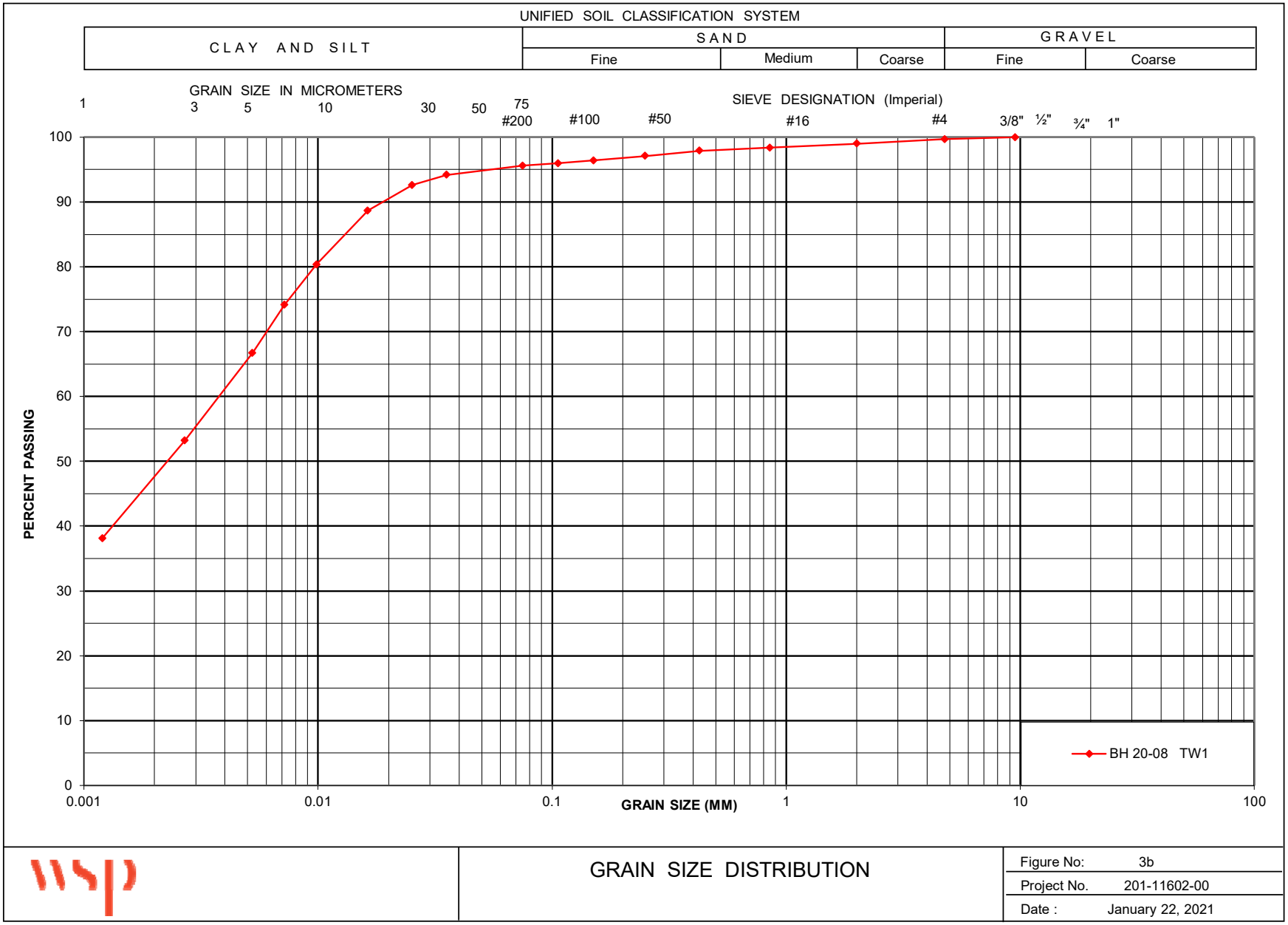
GRAIN SIZE DISTRIBUTION

Figure No:	3
Project No.	201-11602-00
Date :	January 07, 2021



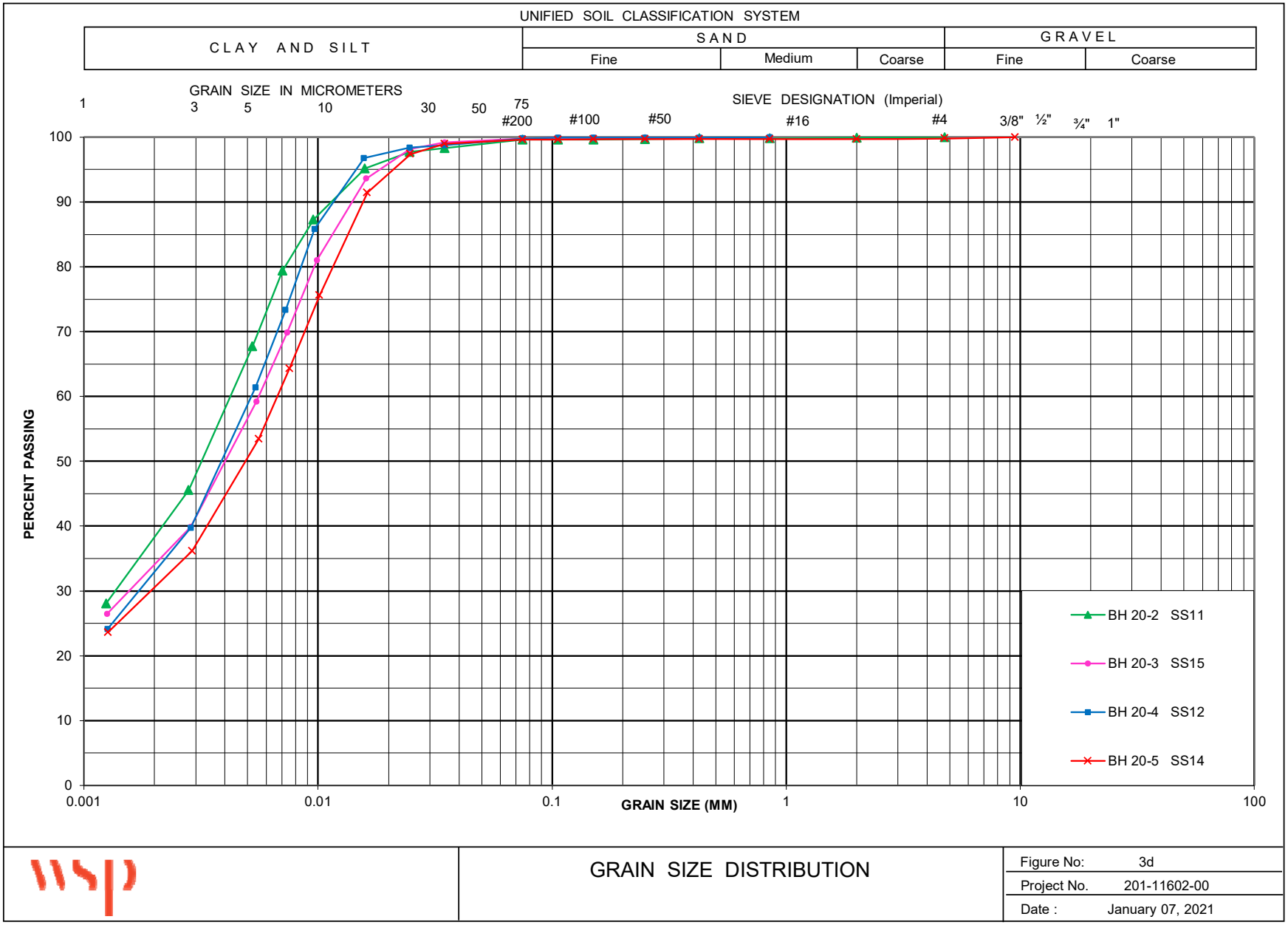
GRAIN SIZE DISTRIBUTION

Figure No:	3a
Project No.	201-11602-00
Date :	January 07, 2021



GRAIN SIZE DISTRIBUTION

Figure No:	3b
Project No.	201-11602-00
Date :	January 22, 2021

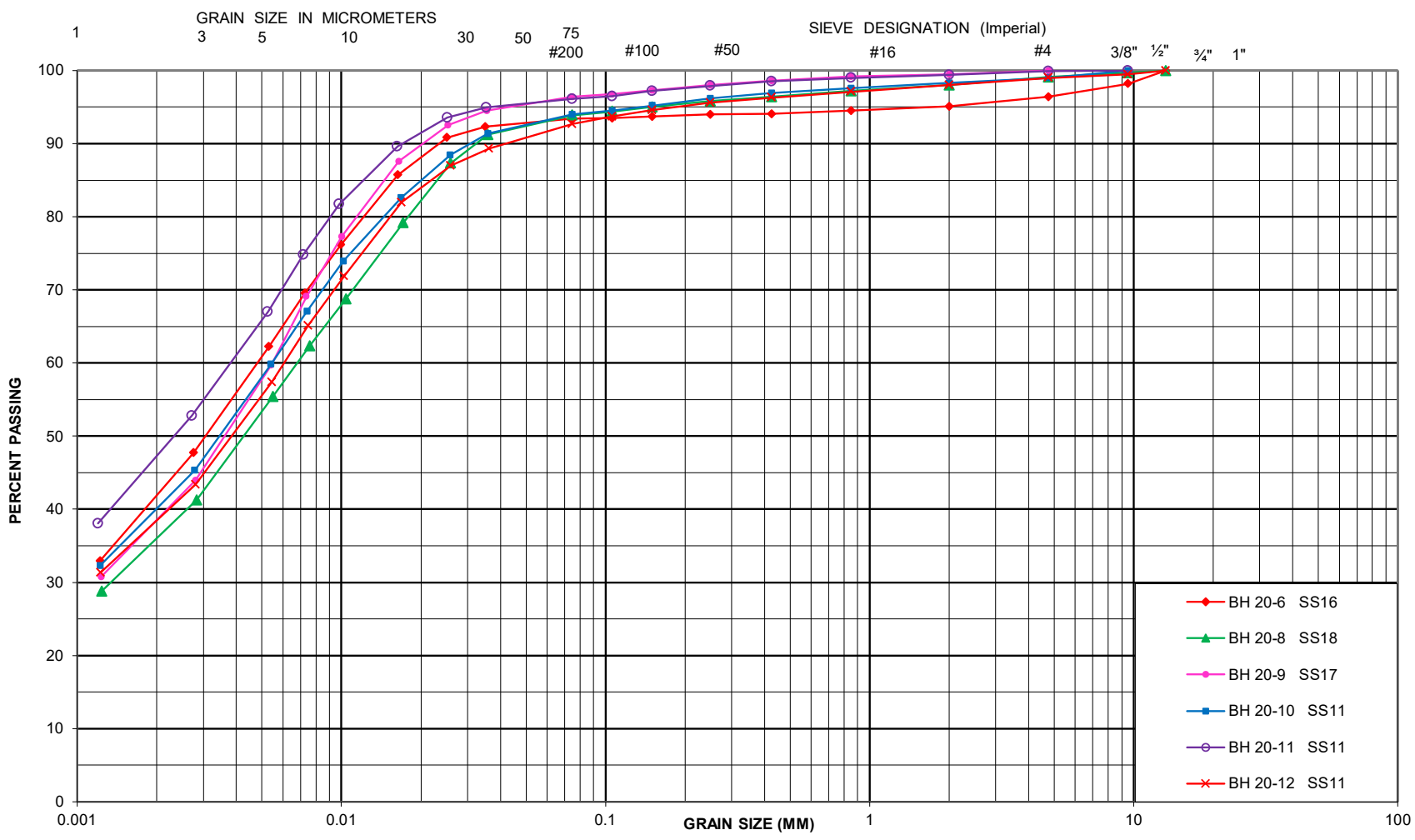


GRAIN SIZE DISTRIBUTION

Figure No:	3d
Project No.	201-11602-00
Date :	January 07, 2021

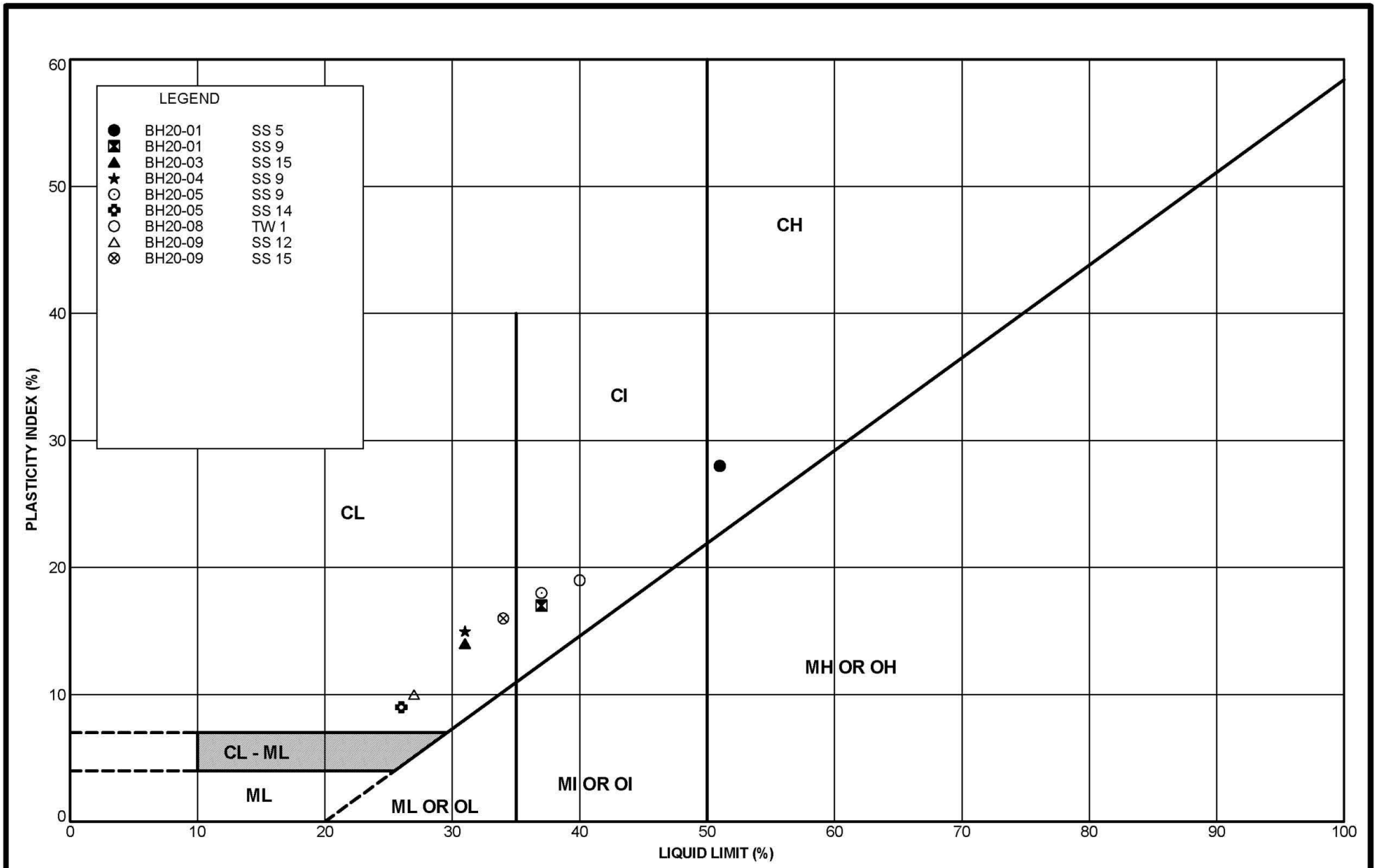
UNIFIED SOIL CLASSIFICATION SYSTEM

CLAY AND SILT	SAND			GRAVEL	
	Fine	Medium	Coarse	Fine	Coarse



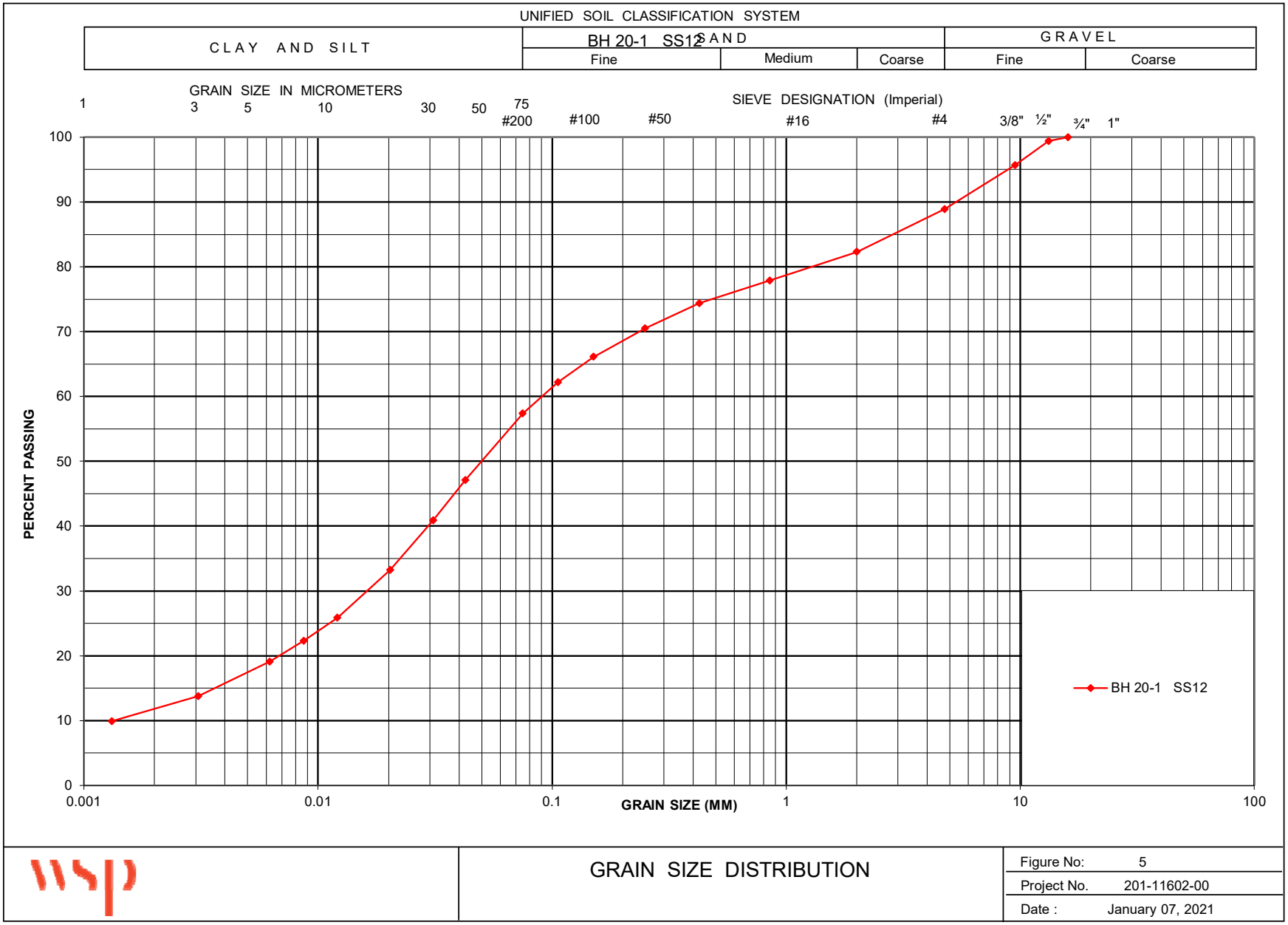
GRAIN SIZE DISTRIBUTION

Figure No:	3e
Project No.	201-11602-00
Date :	January 07, 2021



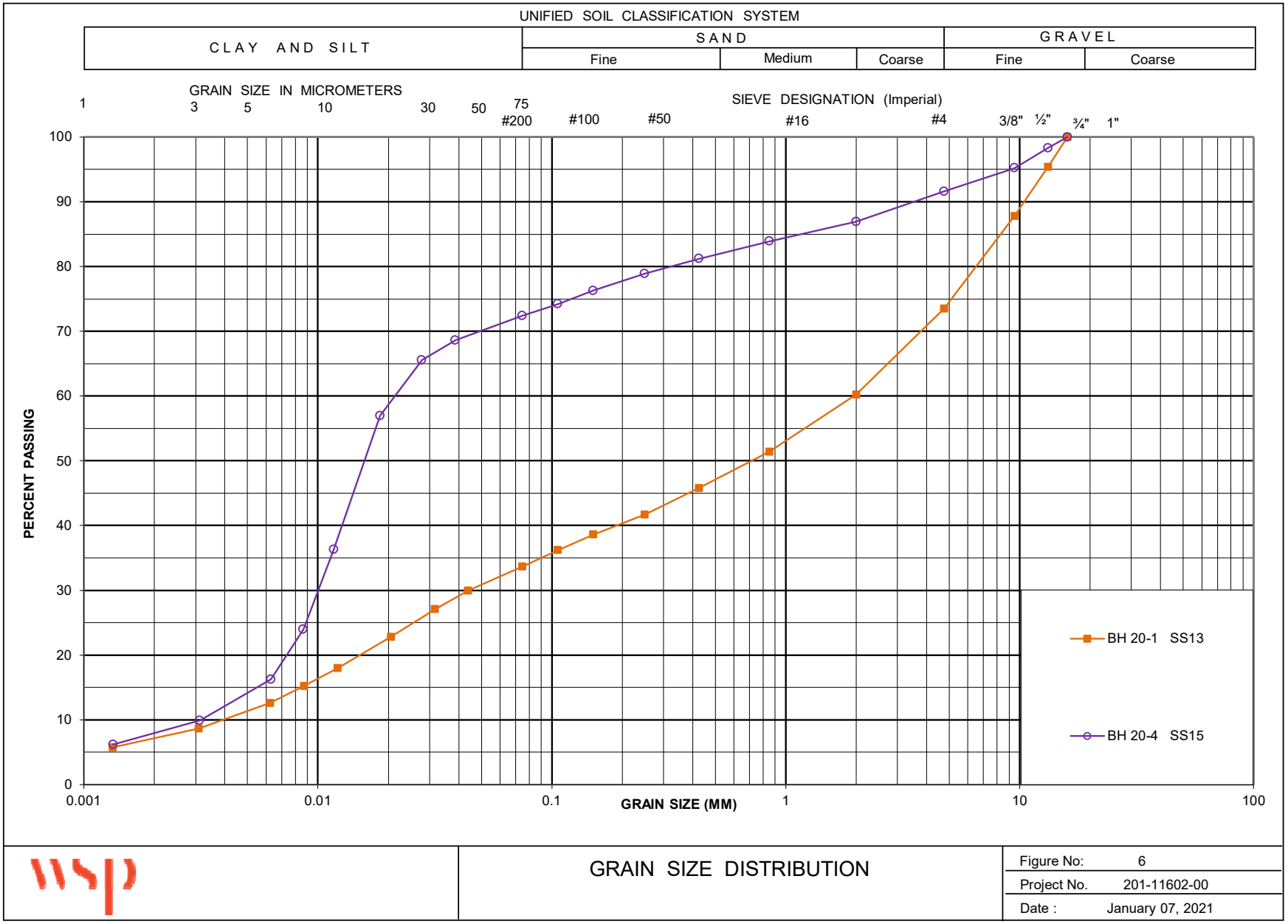
PLASTICITY CHART

FIGURE NO.	4
JOB NO.	201-11602-00
DATE	2021-02-26



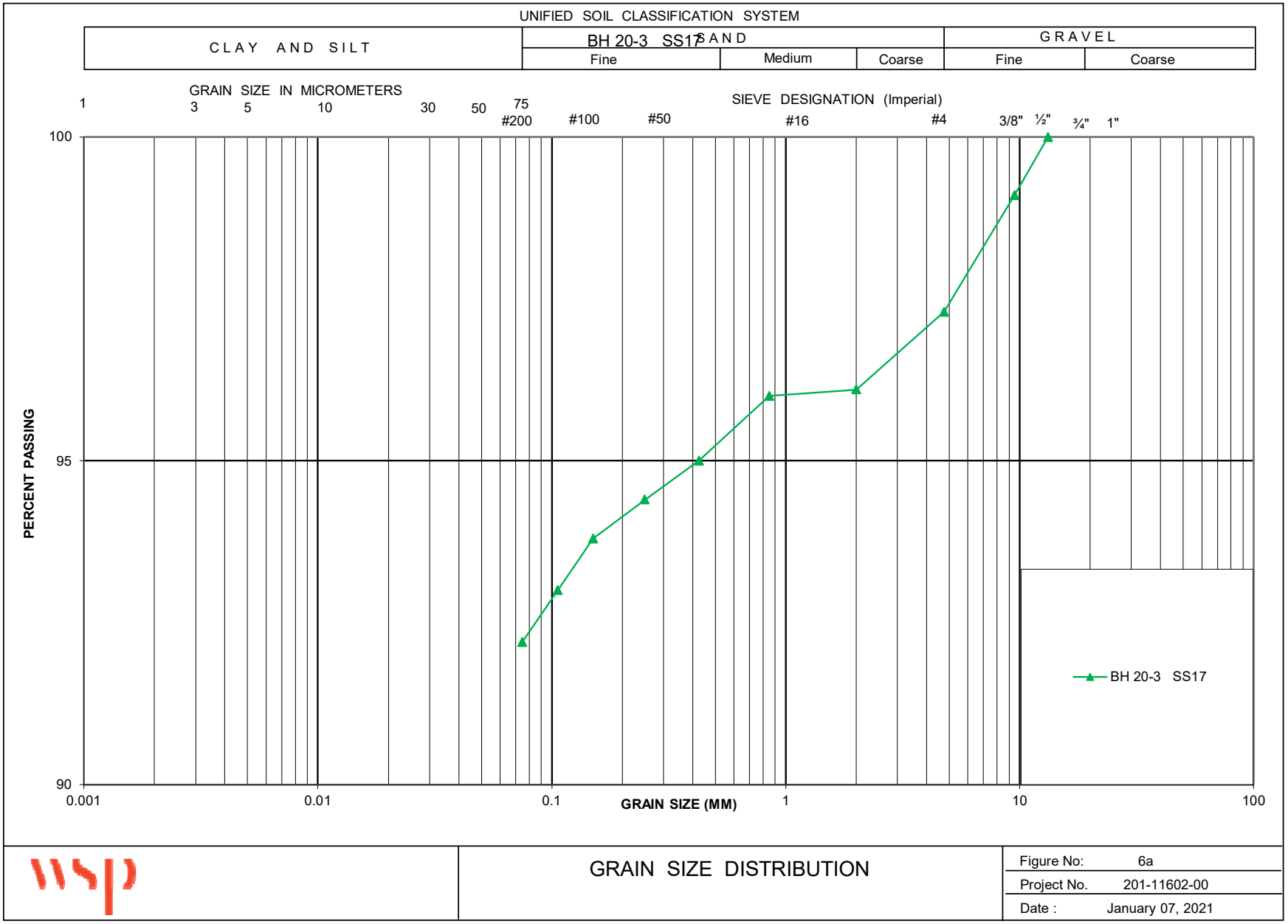
GRAIN SIZE DISTRIBUTION

Figure No:	5
Project No.	201-11602-00
Date :	January 07, 2021



GRAIN SIZE DISTRIBUTION

Figure No: 6
Project No. 201-11602-00
Date : January 07, 2021



GRAIN SIZE DISTRIBUTION

Figure No:	6a
Project No.	201-11602-00
Date :	January 07, 2021

C

RESULTS OF ROCK UNCONFINED COMPRESSIVE STRENGTH TESTS

Uniaxial Compressive Strength of Intact Rock Core Specimens
(ASTM D7012 - Method C)

CLIENT:	WSP Canada Inc.	**LAB No.:**	WLT507-1
PROJECT/ SITE:	2020 Testing Services	**PROJECT No.:**	11189956
Borehole No.:	BH20-7	**Sampled ID:**	Run 1
Depth:	27.56 - 27.71 m (90'5" - 90'11")	**Date Sampled:**	n/a
Lithological Description:	Dolostone		

Initial Specimen Parameters	
Diameter, mm	62.3
Height, mm	133.4
Height-to-Diameter Ratio	2.1
Volume, cm^3	406.4
Mass, g	1137.5
Bulk Density, kg/m^3	2799
Moisture Condition	As Received
Moisture Content, %	0.1

Maximum Applied Load, kN	650.5
Compressive Strength, MPa	213.5

REMARKS: WSP #201-11602-00

PERFORMED BY:	Owen Reynolds	**DATE:**	February 8, 2021
VERIFIED BY:	Michael Braverman	**DATE:**	February 11, 2021

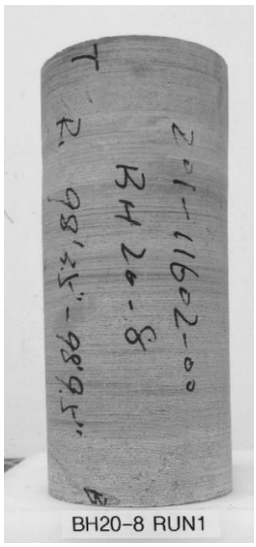
Uniaxial Compressive Strength of Intact Rock Core Specimens
(ASTM D7012 - Method C)

CLIENT:	WSP Canada Inc.	**LAB No.:**	WLT507-2
PROJECT/ SITE:	2020 Testing Services	**PROJECT No.:**	11189956
Borehole No.:	BH20-8	**Sampled ID:**	Run 1
Depth:	29.93 - 30.11 m (98'2.5" - 98'9.5")	**Date Sampled:**	n/a

Lithological Description: Dolostone

Initial Specimen Parameters	
Diameter, mm	62.9
Height, mm	144.0
Height-to-Diameter Ratio	2.3
Volume, cm^3	446.9
Mass, g	1239.6
Bulk Density, kg/m^3	2774
Moisture Condition	As Received
Moisture Content, %	0.3

Maximum Applied Load, kN	463.7
Compressive Strength, MPa	149.4



REMARKS: WSP #201-11602-00

PERFORMED BY: Keisuke Adachi **DATE:** January 26, 2021

VERIFIED BY: Michael Braverman **DATE:** February 5, 2021

Uniaxial Compressive Strength of Intact Rock Core Specimens
(ASTM D7012 - Method C)

CLIENT:	WSP Canada Inc.	**LAB No.:**	WLT507-3
PROJECT/ SITE:	2020 Testing Services	**PROJECT No.:**	11189956
Borehole No.:	BH20-8	**Sampled ID:**	Run 8
Depth:	38.25 - 38.4 m (125'6" - 126'0")	**Date Sampled:**	n/a
Lithological Description:	Dolostone		

Initial Specimen Parameters	
Diameter, mm	63.1
Height, mm	139.3
Height-to-Diameter Ratio	2.2
Volume, cm^3	435.9
Mass, g	1236.6
Bulk Density, kg/m^3	2837
Moisture Condition	As Received
Moisture Content, %	0.0

Maximum Applied Load, kN	502.0
Compressive Strength, MPa	160.4

REMARKS: WSP #201-11602-00

PERFORMED BY:	Owen Reynolds	**DATE:**	February 8, 2021
VERIFIED BY:	Michael Braverman	**DATE:**	February 11, 2021

Uniaxial Compressive Strength of Intact Rock Core Specimens
(ASTM D7012 - Method C)

CLIENT:	WSP Canada Inc.	**LAB No.:**	WLT 499-1
PROJECT/ SITE:	2021 Testing Services	**PROJECT No.:**	11222768-B1

Borehole No.:	BH20-3	**Sampled ID:**	Run 3
Depth:	17.27 - 17.45 m (56'8" - 57'3")	**Date Sampled:**	n/a
Lithological Description:	Siltstone/Limestone		

Initial Specimen Parameters	
Diameter, mm	63.3
Height, mm	127.1
Height-to-Diameter Ratio	2.0
Volume, cm^3	399.7
Mass, g	1105.8
Bulk Density, kg/m^3	2766
Moisture Condition	As Received
Moisture Content, %	0.3

Maximum Applied Load, kN	676.4
Compressive Strength, MPa	215.1

REMARKS: WSP Job Number: 201-11602-00

PERFORMED BY:	Owen Reynolds	**DATE:**	January 4, 2021
VERIFIED BY:	Michael Braverman	**DATE:**	January 13, 2021

Uniaxial Compressive Strength of Intact Rock Core Specimens
(ASTM D7012 - Method C)

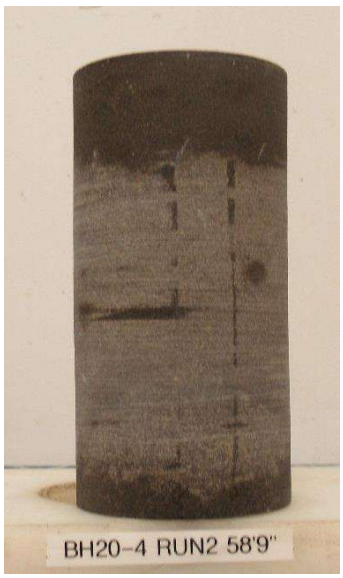
CLIENT:	WSP Canada Inc.	**LAB No.:**	WLT 499-2
PROJECT/ SITE:	2021 Testing Services	**PROJECT No.:**	11222768-B1

Borehole No.:	BH20-4	**Sampled ID:**	Run 2
Depth:	17.91 - 18.08 m (58'9" - 59'4")	**Date Sampled:**	n/a

Lithological Description: Limestone/Siltstone

Initial Specimen Parameters	
Diameter, mm	63.1
Height, mm	128.4
Height-to-Diameter Ratio	2.0
Volume, cm^3	401.1
Mass, g	1066.7
Bulk Density, kg/m^3	2659
Moisture Condition	As Received
Moisture Content, %	0.4

Maximum Applied Load, kN	312.4
Compressive Strength, MPa	100.0



REMARKS: WSP Job Number: 201-11602-00

PERFORMED BY:	Owen Reynolds	**DATE:**	January 4, 2021
VERIFIED BY:	Michael Braverman	**DATE:**	January 13, 2021

Uniaxial Compressive Strength of Intact Rock Core Specimens
(ASTM D7012 - Method C)

CLIENT:	WSP Canada Inc.	**LAB No.:**	WLT 499-3
PROJECT/ SITE:	2021 Testing Services	**PROJECT No.:**	11222768-B1

Borehole No.:	BH20-9	**Sampled ID:**	Run 2
Depth:	22.73 - 22.91 m (74'7" - 75'2")	**Date Sampled:**	n/a

Lithological Description: Siltstone/Limestone

Initial Specimen Parameters	
Diameter, mm	62.8
Height, mm	117.0
Height-to-Diameter Ratio	1.9
Volume, cm^3	362.8
Mass, g	1006.0
Bulk Density, kg/m^3	2773
Moisture Condition	As Received
Moisture Content, %	0.4

Maximum Applied Load, kN	559.1
Compressive Strength, MPa	180.3

REMARKS: WSP Job Number: 201-11602-00

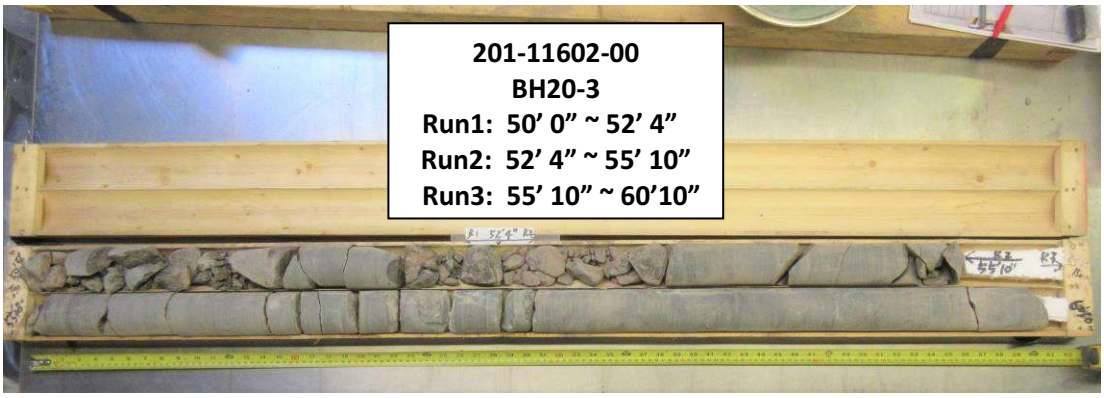
PERFORMED BY:	Owen Reynolds	**DATE:**	January 4, 2021
VERIFIED BY:	Michael Braverman	**DATE:**	January 13, 2021

D

PHOTOGRAPHS OF ROCK CORE

Run 1: 47' 0" – 50' 6" (14.33m – 15.39m)

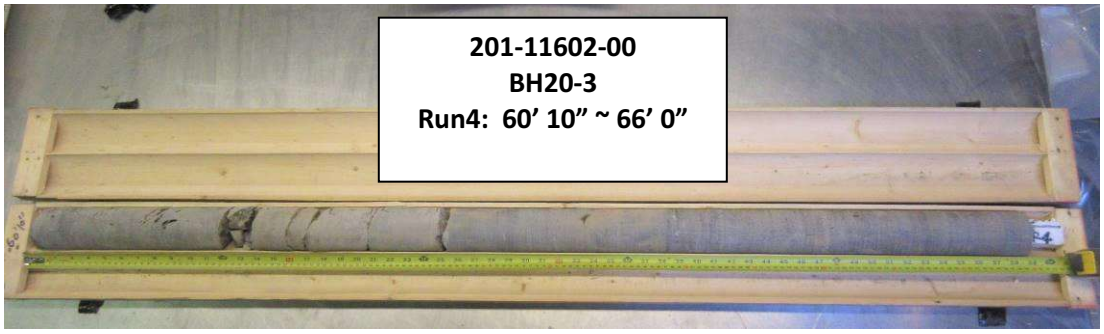
Run 2: 50' 6" – 55' 0" (15.39m – 16.76m)



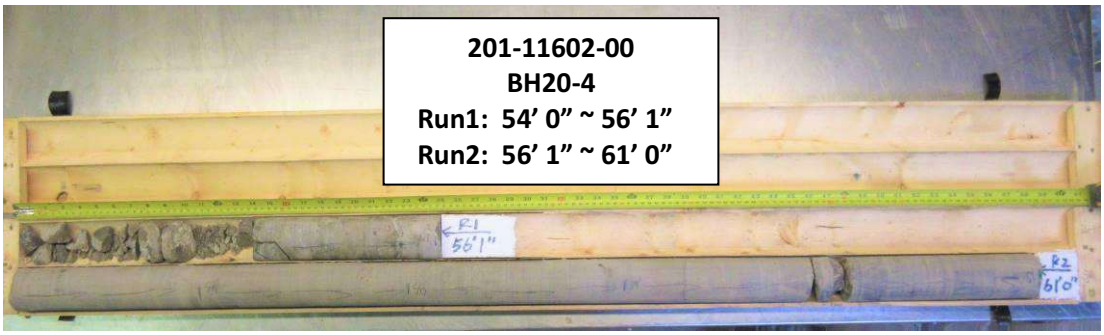
Run 1: 50' 0" – 52' 4" (15.24m – 15.95m)

Run 2: 52' 4" – 55' 10" (15.95m – 17.02m)

Run 3: 55' 10" – 60' 10" (17.02m – 18.54m)

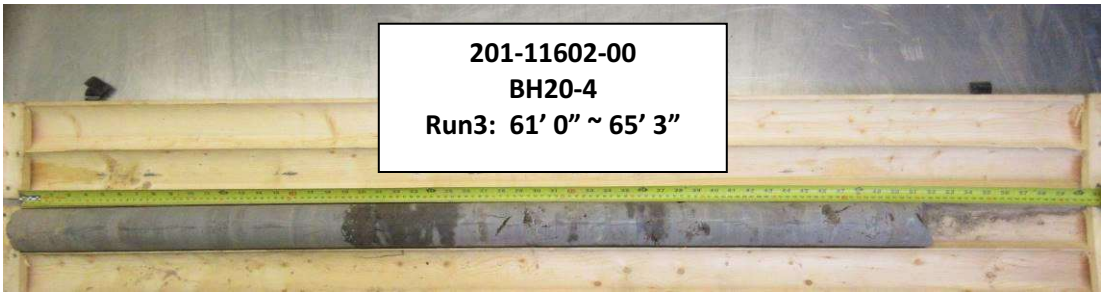


Run 4: 60' 10" – 66' 0" (18.54m – 20.12m)

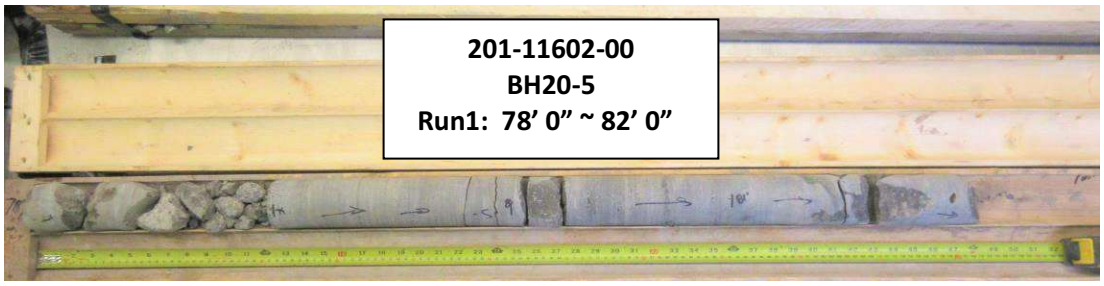


Run 1: 54' 0" – 56' 1" (16.46m – 17.09m)

Run 2: 56' 1" – 61' 0" (17.09m – 18.59m)



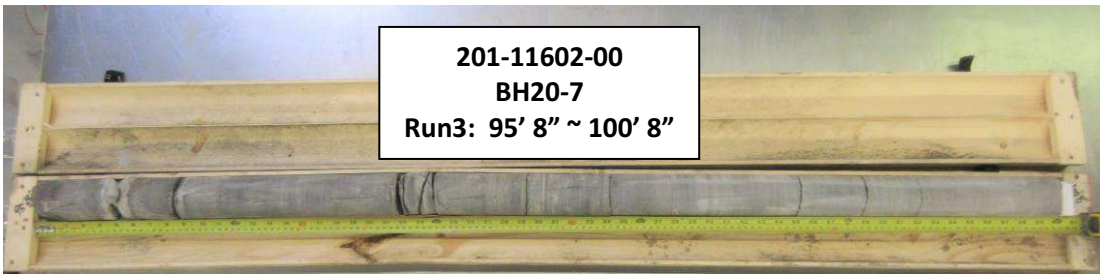
Run 3: 61' 0" – 65' 3" (18.59m – 19.89m)



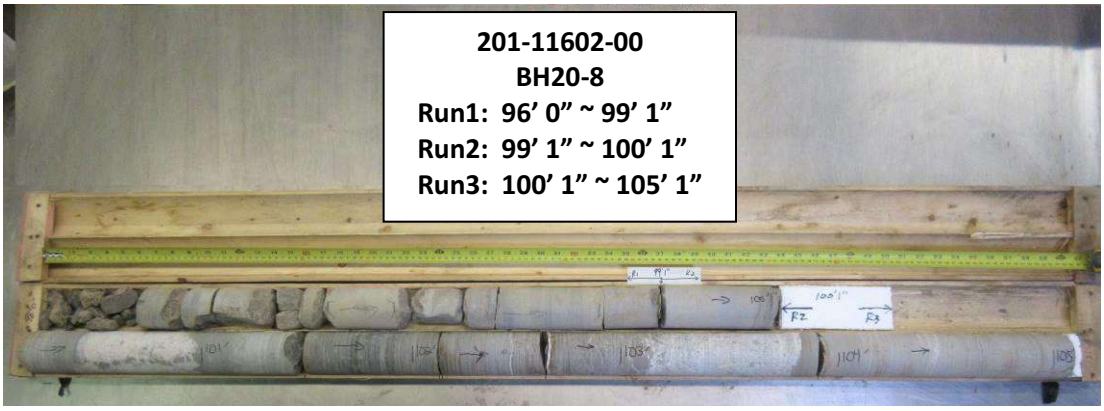
Run 1: 78' 0" – 82' 0" (23.77m – 24.99m)

Run 1: 89' 0" – 91' 1" (27.13m – 27.76m)

Run 2: 91' 1" – 95' 8" (27.76m – 29.16m)



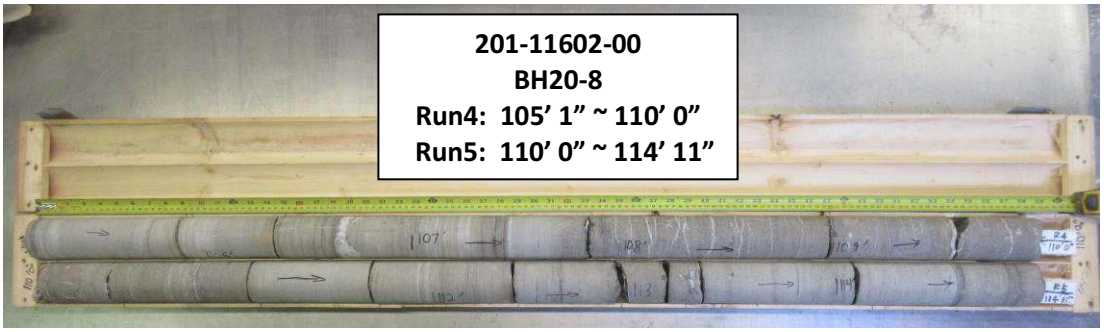
Run 3: 95' 8" – 100' 8" (29.16m – 30.68m)



Run 1: 96' 0" – 99' 1" (29.26m – 30.20m)

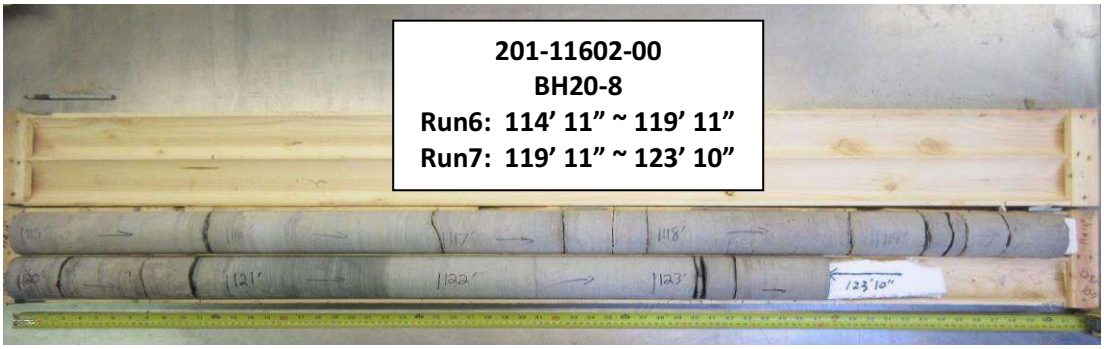
Run 2: 99' 1" – 100' 1" (30.20m – 30.51m)

Run 3: 100' 1" – 105' 1" (30.51m – 32.03m)



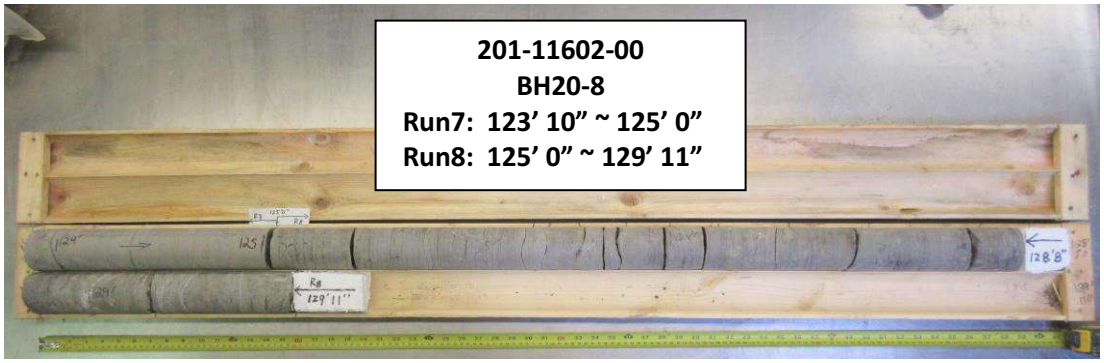
Run 4: 105' 1" – 110' 0" (32.03m – 33.53m)

Run 5: 110' 0" – 114' 11" (33.53m – 35.03m)



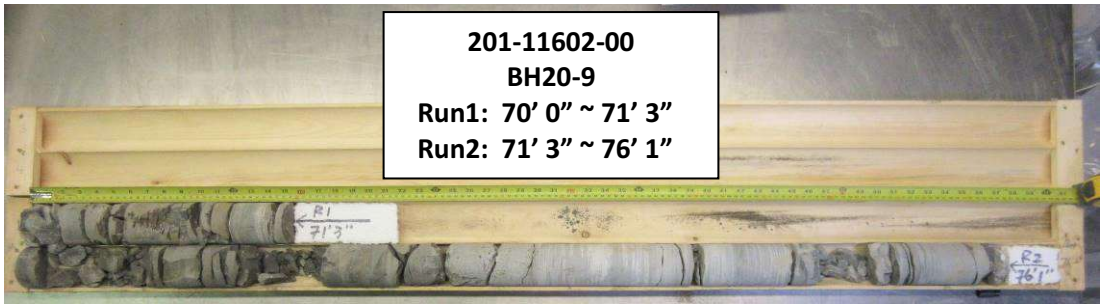
Run 6: 114' 11" – 119' 11" (35.03m – 36.55m)

Run 7: 119' 11" – 123' 10" (36.55m – 37.74m)



Run 7: 123' 10" – 125' 0" (37.74m – 38.10m)

Run 8: 125' 0" – 129' 11" (38.10m – 39.60m)



Run 1: 70' 0" – 71' 3" (21.34m – 21.72m)

Run 2: 71' 3" – 76' 1" (21.72m – 23.19m)

Run 3: 76' 1" – 81' 6" (23.19m – 24.84m)

Run 4: 81' 6" – 86' 3" (24.84m – 26.29m)

Run 5: 86' 3" – 91' 3" (26.29m – 27.81m)

Run 6: 91' 3" – 96' 0" (27.81m – 29.26m)

E

ONE-DIMENSIONAL CONSOLIDATION TEST

252 Galaxy Boulevard
Toronto, ON M9W 5R8

One-Dimensional Consolidation Test

(ASTM D2435/D2435M-11R20)

LAB NO.: 1528

Specimen & Test Data

Client	**Niagara Region**	**Project ID**	**201-11602-00**	**Depth (ft)**	**21'6-21'7"**
Project Name	**a Region Sanitary - Geote**	**Borehole ID**	**BH-01**	**Test Start Date**	**23-Dec-20**
Project Location	**Niagara**	**Sample ID**	**SS9**	**Test End Date**	**07-Jan-21**

Apparatus/Test Procedure		**Specimen Data**			**Sample Description**	
ASTM Testing Method	**B**		Initial	Final	**Silty Clay**	
Equipment	**GDS-3**	**Wet Mass of Sample (g)**	**117.86**	**108.16**	**Specific Gravity Gs (assumed):**	**2.72**
Ring Height (mm)	**19.93**	**Dry Mass of the Sample (g)**		**84.82**	**Sand (%)**	**1**
Ring Int. Diameter (mm)	**63.44**	**Water Content, Trimmings (%)**	**38.95**		**Silt (%)**	**55**
Ring Int. Area (mm^2)	**3160.94**	**Water Content, Specimen (%)**	**36.86**	**25.59**	**Clay (%)**	**44**
Ring Mass (g)	**107.21**	**Wet Density (kg/m^3)**	**1870.87**	**2132.35**	**Liquid Limit (%)**	**37**
Trimming Procedure	**Cutting Shoe**	**Dry Density (kg/m^3)**	**1346.431**	**1672.246**	**Plastic Limit (%)**	**20**
Test Condition	**Inundated**	**Void Ratio**	**1.02**	**0.53**	**Pre-consolidation Pressure, P'_c (kPa)**	**N/A**
Interpretation Procedure	**Root Time**	**Saturation (%)**	**100.0**	**100.0**	**Compression Index, C_c**	**0.72**
		Heights of Specimen (mm)	**19.930**	**16.047**	**Recompression Index, C_r**	**0.06**

Load Incr.	**Axial Stress σ_a (kPa)**	**Deformation ΔH (mm)**	**Specimen Height H (mm)**	**Axial Strain ε_a (%)**	**Void Ratio e (--)**	**Modulus of vol. change m_v (m^2/kN)**	**Deformation ΔH_{50} (mm)**	**Specimen Height H_{50} (mm)**	**Axial Strain $\varepsilon_{a,50}$ (%)**	**Void Ratio e_{50} (--)**	**Time t_{90} (min)**	**Coef. of Consolidation c_v (m^2/year)**	**Hydraulic Conductivity k (m/s)**
Initial	**Seating**										**Root Time Method**		
1	**10**	**0.147**	**19.783**	**0.74**	**1.01**								
2	**25**	**0.310**	**19.620**	**1.56**	**0.99**	**5.39E-04**	**0.247**	**19.683**	**1.24**	**1.00**	**2.0**	**88.14**	**1.48E-08**
3	**50**	**0.515**	**19.416**	**2.58**	**0.97**	**4.10E-04**	**0.419**	**19.511**	**2.10**	**0.98**	**2.9**	**58.75**	**7.50E-09**
4	**100**	**0.742**	**19.188**	**3.72**	**0.94**	**2.29E-04**	**0.612**	**19.318**	**3.07**	**0.96**	**2.0**	**82.57**	**5.87E-09**
5	**200**	**1.138**	**18.793**	**5.71**	**0.90**	**1.98E-04**	**0.909**	**19.021**	**4.56**	**0.93**	**3.2**	**49.82**	**3.07E-09**
6	**400**	**2.231**	**17.699**	**11.19**	**0.79**	**2.74E-04**	**1.462**	**18.468**	**7.33**	**0.87**	**4.0**	**38.03**	**3.25E-09**
7	**100**	**1.953**	**17.977**	**9.80**	**0.82**	**4.64E-05**							
8	**200**	**2.059**	**17.871**	**10.33**	**0.81**	**5.33E-05**							
9	**400**	**2.283**	**17.647**	**11.46**	**0.79**	**5.62E-05**							
10	**800**	**3.187**	**16.743**	**15.99**	**0.70**	**1.13E-04**	**2.614**	**17.316**	**13.12**	**0.76**	**3.6**	**37.16**	**1.31E-09**
11	**200**	**2.878**	**17.052**	**14.44**	**0.73**	**2.58E-05**							
12	**400**	**3.016**	**16.914**	**15.13**	**0.71**	**3.45E-05**							
13	**800**	**3.304**	**16.626**	**16.58**	**0.69**	**3.62E-05**							
14	**1600**	**4.099**	**15.831**	**20.57**	**0.60**	**4.99E-05**	**3.622**	**16.308**	**18.17**	**0.65**	**3.2**	**36.63**	**5.68E-10**
15	**3200**	**4.856**	**15.074**	**24.37**	**0.53**	**2.37E-05**	**4.379**	**15.551**	**21.97**	**0.58**	**2.4**	**44.90**	**3.31E-10**
16	**100**	**3.883**	**16.047**	**19.48**	**0.63**	**1.58E-05**							

Remarks:

M. Macquarrie	2021-01-06	H. Rashid	07-Jan-21
TESTED BY	DATE	REVIEWED BY	DATE
Laifa, Cao, P. Eng			
REVIEWED BY			

252 Galaxy boulevard
Toronto, ON M9W 5R8

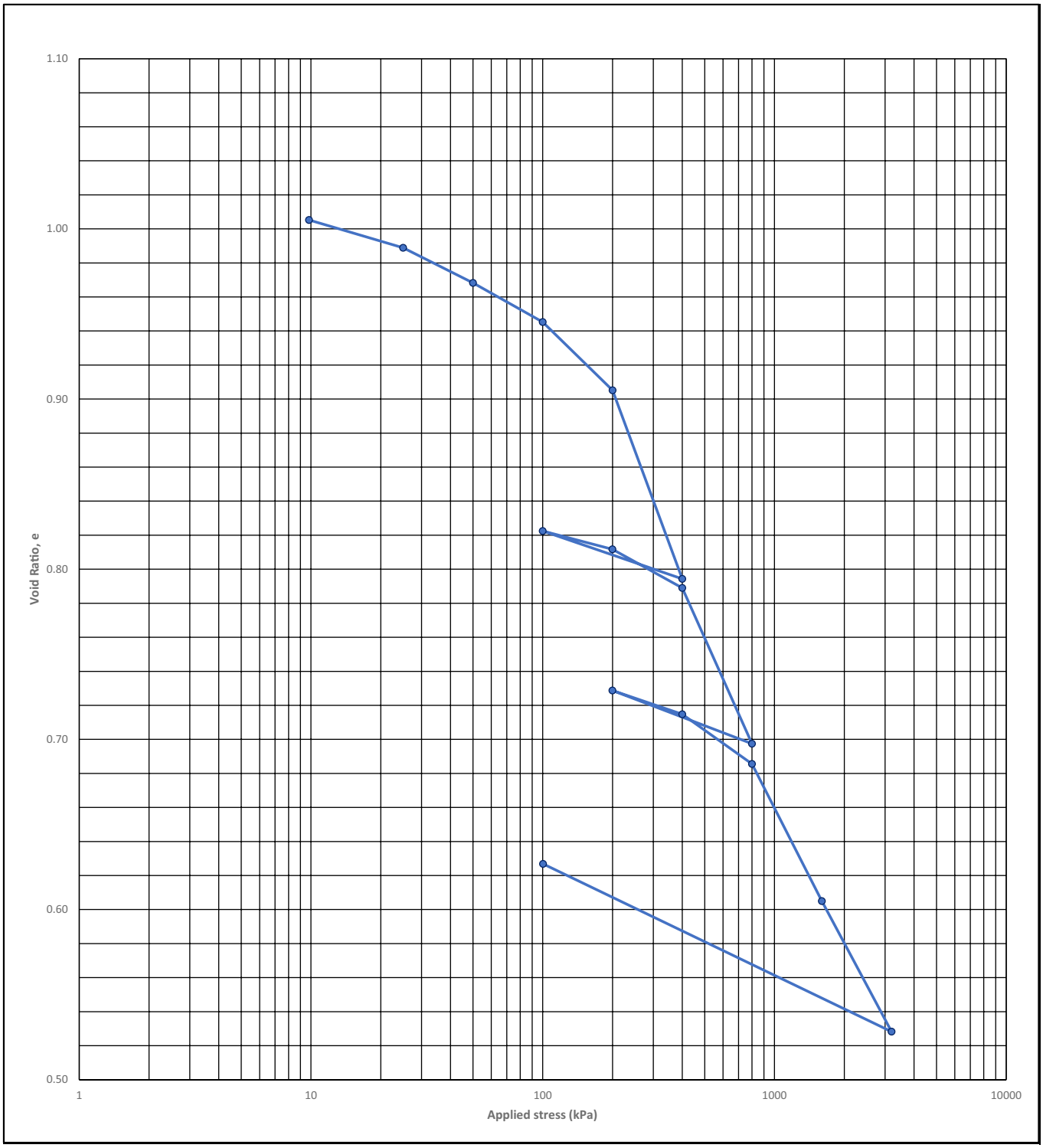
One-Dimensional Consolidation Test

(ASTM D2435/D2435M-11R20)

LAB NO.: 1528

Graph-1

Client	**Niagara Region**	**Project ID**	**201-11602-00**	**Depth (ft)**	**21'6-21'7"**
Project Name	**a Region Sanitary - Geote**	**Borehole ID**	**BH-01**	**Test Start Date**	**23-Dec-20**
Project Location	**Niagara**	**Sample ID**	**SS9**	**Test End Date**	**07-Jan-21**



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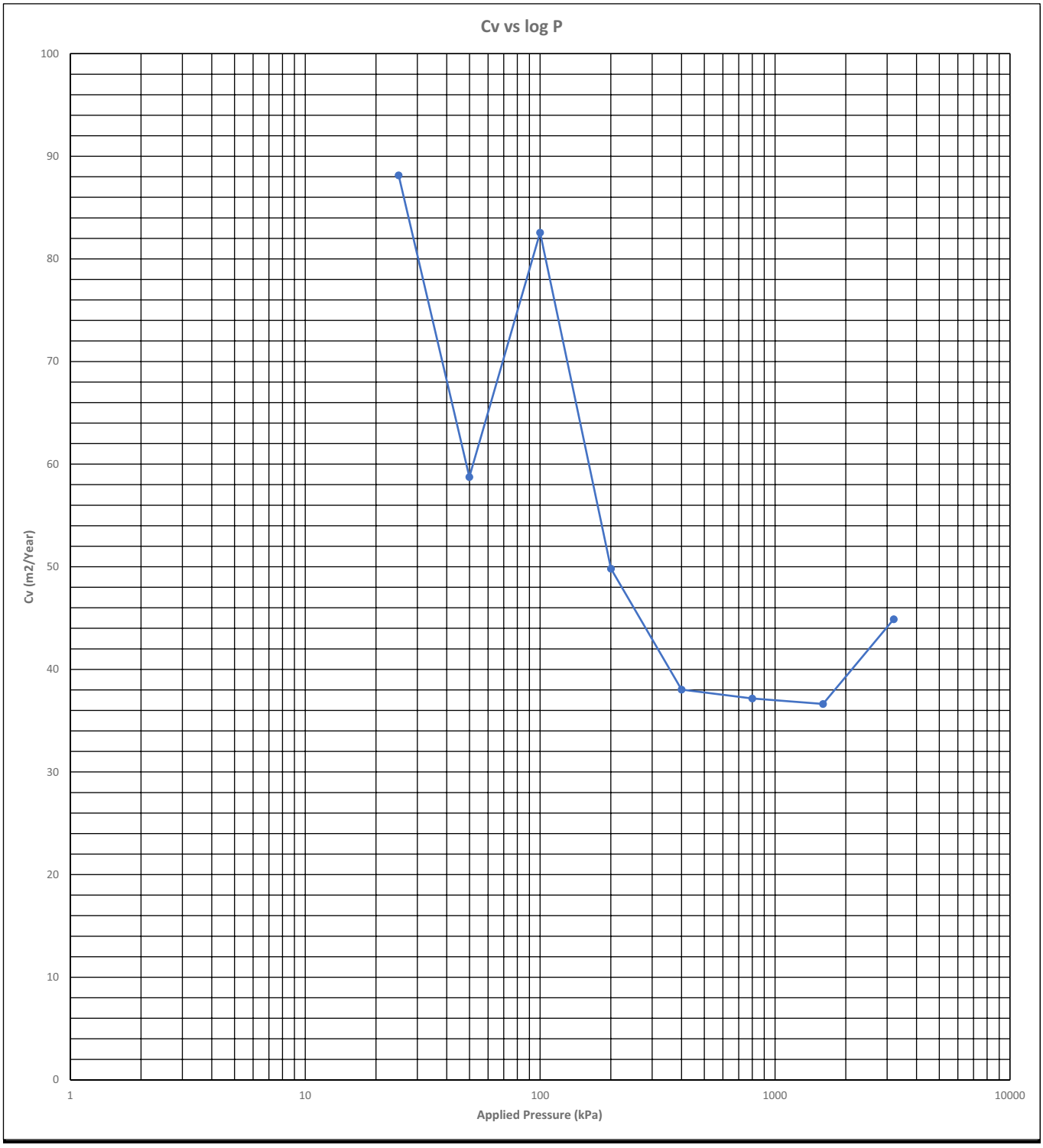
One-Dimensional Consolidation Test

(ASTM D2435/D2435M-11R20)

LAB NO.: 1528

Graph-2

Client	**Niagara Region**	**Project ID**	**201-11602-00**	**Depth (ft)**	**21'6-21'7"**
Project Name	**a Region Sanitary - Geote**	**Borehole ID**	**BH-01**	**Test Start Date**	**23-Dec-20**
Project Location	**Niagara**	**Sample ID**	**SS9**	**Test End Date**	**07-Jan-21**



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Toronto, ON M9W 5R8

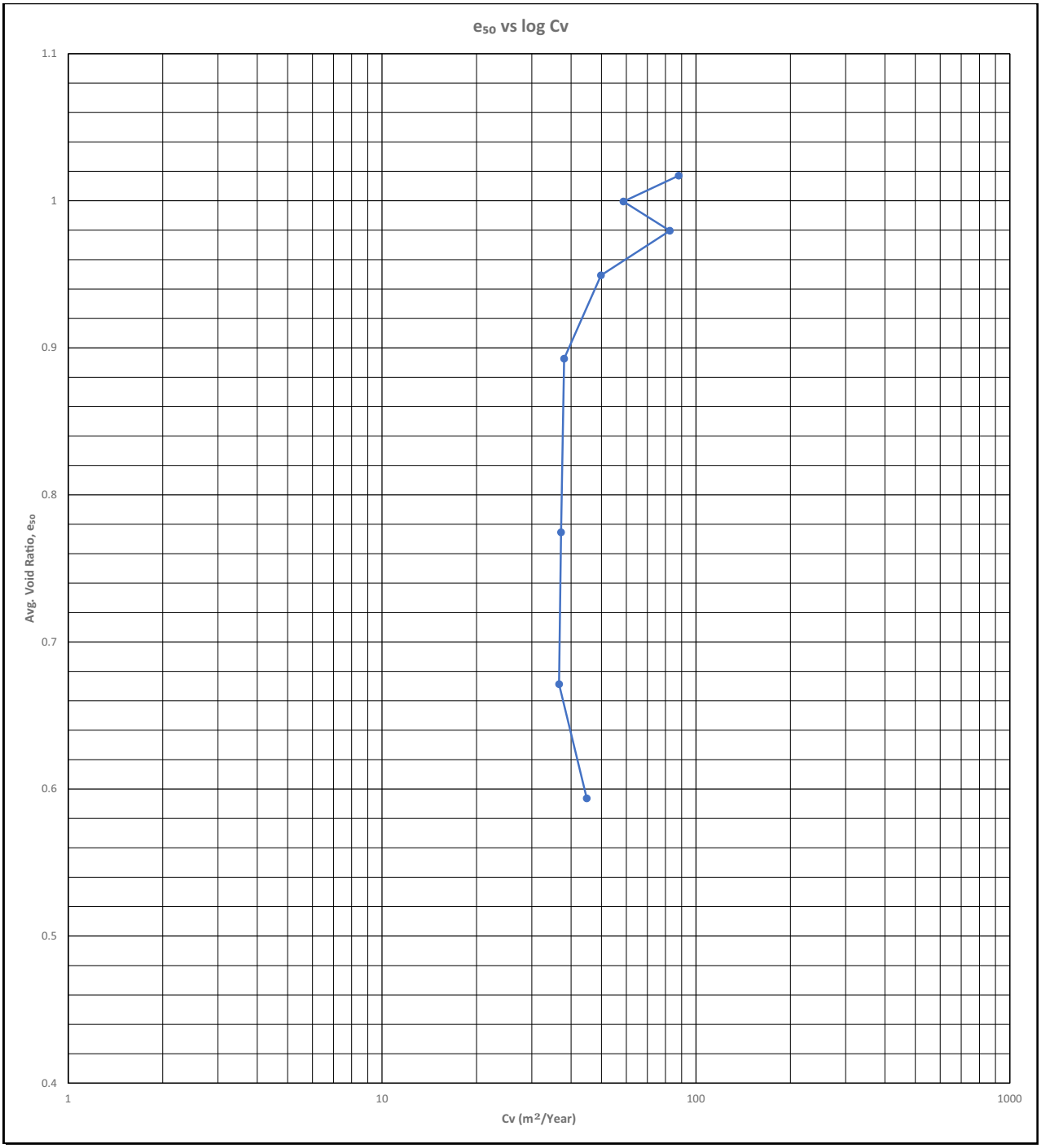
One-Dimensional Consolidation Test

(ASTM D2435/D2435M-11R20)

LAB NO.: 1528

Graph-3

Client	**Niagara Region**	**Project ID**	**201-11602-00**	**Depth (ft)**	**21'6-21'7"**
Project Name	**ra Region Sanitary - Geote**	**Borehole ID**	**BH-01**	**Test Start Date**	**23-Dec-20**
Project Location	**Niagara**	**Sample ID**	**SS9**	**Test End Date**	**07-Jan-21**



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TUNNELMAN'S GROUND CLASSIFICATION AND PROBABLE WORKING CONDITIONS

Tunnelman's Ground Classification and Probable Working Conditions

Soil Classification	Representative Soil Samples	Tunnel Working Conditions
Hard	Very hard calcareous clay; Cemented sand and gravel	Tunnel heading may be advanced without roof support.
Firm	Loess above GWT; Various calcareous clay with low plasticity	Tunnel heading may be advanced without roof support. Permanent support can be constructed before the ground will start to move.
Slow Ravelling and Fast Ravelling	Fast ravelling occurs in residual soils or in sand with clay binder below the GWT. Above the GWT, the same soils may be Slow Ravelling or even Firm.	Chunks of material may drop out of the crown or the sides some me after the ground has been exposed. In Fast Ravelling ground, the process starts within a few minutes; otherwise, it is classed as Slow Ravelling.
Squeezing	Soft or medium-soft clay	Ground slowly advances into tunnel without fracturing and without perceptible increase of water content in ground surrounding the tunnel.
Swelling	Heavily pre-compressed clays with a plasticity index greater than 30. Sedimentary formations containing layers of anhydrite.	Like squeezing ground, moves slowly into tunnel, but the movement is associated with a very considerable volume increase in the ground surrounding the tunnel.
Cohesive Running and Running	Occurs in clean, fine moist sand Occurs in clean, coarse or medium sand above the GWT	Removal of the lateral support of any surface rising at an angle of more than about 34° to the horizontal is followed by a 'run', whereby the material flows like granulated sugar until the slope angle is approx. 34°. If the 'run' is preceded by a brief period of ravelling, the ground is called Cohesive Running.
Very Soft Squeezing	Clays and silts with high plasticity indices	Ground advances rapidly into the tunnel in a plastic flow
Flowing	Any ground below the GWT that has an effective grain size in excess of about 0.00mm	Flowing ground moves like a viscous liquid. It can invade the tunnel not only through the roof and the sides, but also through the invert. If the flow is not stopped, it will eventually completely fill the tunnel.
Bouldery	Boulder glacial till; riprap fill; some land slide deposits, some residual soils. The matrix between boulders may be gravel, sand, silt, clay and in any combination.	Problems incurred in advancing shield or in forepoling; blasting or hand mining ahead of machine may become necessary.