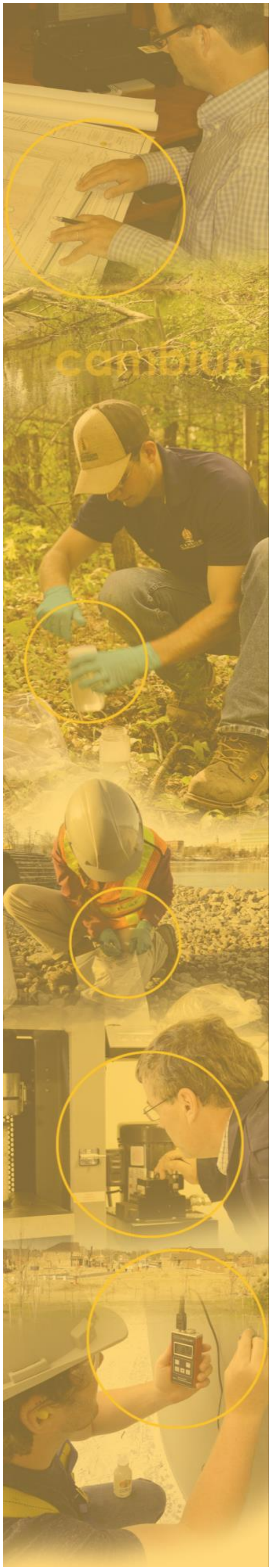

Geotechnical Investigation Report & Hydrogeological Study Petawawa Waste Water Treatment Plant

Cambium Reference No.: 11757-001

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Prepared for: Anaergia c/o City of Petawawa

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TABLE OF CONTENTS

LIST OF INSERTED TABLES

LIST OF APPENDED FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

Cambium Inc. (Cambium) was retained by Anaergia on behalf of the City of Petawawa (Client) to undertake a geotechnical investigation within the property limits of the Petawawa Waste Water Treatment Plant in Petawawa, Ontario (Site). The investigation was focused in areas where the proposed developments are to be located. The proposed development consists of three areas of improvement; the first area includes a buffer tank, slurry holding tank, reception and thickening building, and truck reception pad to be located directly west of the existing digesters. The second includes a new flare, gas conditioning, and CHP area north of the existing boiler building. The third development consisting of a dewatering building to be located directly east of the existing sludge tanks. The purpose of the investigation was to identify the subsurface conditions and provide specific geotechnical recommendations as input into the planning and design of the proposed development. The investigation was to identify the existing site conditions including topsoil thicknesses, sub surface soils, groundwater conditions and include recommendations pertaining to soil strengths and properties, foundations, dewatering, and other engineering properties.

The geotechnical investigation was conducted in conjunction with a hydrogeological study which will be provided in a separate letter and will provide further detail to the groundwater analysis throughout the footprint of the subject Site.

2.0 METHODOLOGY

2.1 BOREHOLE INVESTIGATION

A borehole investigation was conducted at the Site on May 17 to 18, 2021 to assess subsurface conditions. A total of seven (7) boreholes, designated as BH101-21 through BH108-21, were strategically placed and advanced to depths ranging between approximately 2 to 6.5 meters below ground surface (mbgs) or refusal. All borehole locations are shown in Figure 1. The location of each borehole was referenced locally by a Cambium technician with UTM coordinates and relative elevations included on the borehole logs provided in Appendix A. The elevations provided were taken relative to the surface of a manhole cover located on top of a large concrete slab at the entry to 560 Abbie Lane.

Drilling and sampling was completed using a track-mounted drill rig operating under the supervision of a Cambium technician. The boreholes were advanced to the sampling depths by means of continuous flight hollow stem augers. Soil samples were collected at approximately 0.75 m intervals or whenever a change in soil type occurred. The encountered soil units were logged in the field using visual and tactile methods, and samples were placed in labelled plastic bags for transport, future reference, possible laboratory testing, and storage. Open boreholes were checked for groundwater and general stability prior to backfilling. All boreholes were backfilled in accordance with O.Reg. 903, as amended, and the property was reinstated to pre-existing conditions. Boreholes BH101-21 through BH103-21 were fitted with groundwater monitoring wells upon completion of the geotechnical investigation, and are labelled as MW101-21 through MW103-21 on Figure 1. Monitoring well MW108-21, as shown on Figure 1, was advanced strictly for groundwater monitoring purposes only and soils were not logged during the advancement of the well.

Borehole logs are provided in Appendix A. Site soil and groundwater conditions are described and geotechnical recommendations are discussed in the following sections of this report.

2.2 PHYSICAL LABORATORY TESTING

Physical laboratory testing, including four (4) grain size distribution analyses (LS-702) and two (2) grain size distribution and hydrometer analyses (LS-702,705), was completed on selected soil samples to confirm textural classification and granular reuse potential, and to assess geotechnical parameters. Moisture content testing was completed on all soil samples prior to completing the sieve analysis. Results are presented in Appendix B and are discussed in Section 3.0.

3.0 SUBSURFACE CONDITIONS

The general site conditions consist of 100 mm to 150 mm of topsoil overlying fill material mixed with sands, gravels, and rock. Beneath the fill material the general stratigraphy includes sand with varying amounts of gravel, underlain by finer grained sands and occasional silt or clay matrices. The individual soil units are described in detail below with borehole logs for each location attached in Appendix A. Due to the variable nature of the soils onsite, and to provide simplicity to designers, subsurface conditions for the subject site have been separated into three areas, as shown on Figure 1. Table 1 below shows each area with the corresponding boreholes advanced within the area.

Table 1 Areas of Investigation

Area	Boreholes
Area 1	BH101-21 BH105-21
Area 2	BH102-21
Area 3	BH103-21 BH104-21 BH106-21 BH107-21 MW108-21

3.1 ORGANIC TOPSOIL

All seven (7) boreholes were advanced into the existing organic topsoil material. The encountered topsoil thicknesses are summarized in Table 2 below:

Table 2 Exisiting Topsoil Thickness

Boreholes	Topsoil Thickness (mm)
BH101-21	150
BH102-21	150
BH103-21	100
BH104-21	150
BH105-21	150
BH106-21	150
BH107-21	100

The topsoil encountered appeared to be dark brown to black in colour and consisted of sand with trace amounts of silt and organic material such as roots present. The topsoil was visibly loose to compact and appeared to be moist in the field.

3.2 FILL

Throughout much of the site and directly underlying the topsoil, what appeared to be a layer of artificial fill material was encountered. The following sections outline the fill encountered in the areas of investigation throughout the site.

3.2.1 AREA 1

Area 1 is intended to provide insight to the subsurface conditions along the south east side of the site where the proposed buffer tank, slurry tank, and truck reception pad are to be located. Boreholes BH101-21 and BH105-21 were advanced in this area and encountered a layer of fill consisting of sand and gravel from the bottom of the topsoil layer and extending to in 1.5 and 0.75 mbgs in BH101-21 and BH105-21, respectively.

3.2.2 AREA 2

Area 2 is intended to provide insight to the subsurface conditions in the northern area of the site where the proposed gas conditioning and CHP area is to be located. Borehole BH102-21 was advanced in this area and the borehole encountered a fill material consisting of sand and silt with trace gravel and extended from 0.2 mbgs to approximately 0.75 mbgs.

3.2.3 AREA 3

Area 3 is intended to provide insight to the subsurface conditions in the northern area of the site where the proposed dewatering building and digester upgrades are to be located. Boreholes BH103-21, BH104-21, BH106-21, BH107-21, and MW108-21 were advanced in this area and the boreholes encountered fill materials consisting of sand and gravels to gravels from directly below to topsoil to depths ranging from 1.0 to 1.5 mbgs. In boreholes BH104-21 and BH107-21, the fill was found to consist of brown sand with trace gravel. In borehole BH106-21, the fill consisted of brown and grey gravel and sand, and in borehole BH103-21, the fill material encountered was found to be predominately grey and brown gravel with some sand.

The fill was slightly moist to wet at the time of the investigation with natural moisture content varying from 2.8% to 27% based on laboratory testing. The fill material has a loose to very dense relative density based on SPT N values ranging from 6 to over 50 blows for 180 mm of penetration.

Laboratory particle size distribution analyses were completed for three (3) samples of the fill material, taken from immediately below the topsoil surface. The analysis results, based on the Unified Soil Classification System (USCS) scale, are summarized in Table 3 with full results provided in Appendix B.

Table 3 Particle Size Distribution Analysis – Fill

Sample	Depth (mbgs)	Soil	Gravel (%)	Sand (%)	Silt and Clay (%)	Moisture (%)
BH102-21, SS1	0.1 – 0.6	Sand and Silt trace gravel	9	56	35	12.0
BH105-21, SS2	0.8 – 1.2	Silty Sand trace gravel	6	60	34	12.4
BH106-21, SS1	0.2 – 0.3	Gravel and Sand some silt	48	37	15	2.8

In boreholes BH101-21, BH103-21, and BH106-21, the boreholes encountered difficult drilling conditions at the beginning of each test hole. Several attempts were made prior to successfully advancing each borehole deeper than 0.3 mbgs and it was believed that the augers were being refused by blasted rock. In each of the boreholes, the difficult drilling conditions were encountered within the artificial fill material. Therefore, it is possible that the artificial fill consisted of blasted rock fill with the aforementioned sand and gravel soils embedded within the rock fill matrix. This material may have been placed previously to fill in low lying areas or bridge soft, weaker materials. Due to the nature of split spoon sampling, the samples gathered reflect the material found between the blasted rock fill, without being able to capture the rock fill itself. The footprint of the treatment plant appeared to be built up approximately 1 meter higher than the surrounding area. This is likely due to the swampy, saturated nature of the area which was evident by the standing surface water located surrounding the treatment plant footprint. By raising the elevation of the footprint of the treatment plant, surface water would be diverted around the plant, while providing more suitable bearing material for the associated infrastructure. To confirm the presence of blasted rock fill within the footprint of the treatment, excavator conducted test pits would be required.

3.3 NATIVE SUBGRADE SOILS

Native subgrade soils encountered at the site were variable but generally identified to consist of fluvial deposits overlying Glaciofluvial Outwash Deposits. The Ministry of Energy, Northern Development and Mines' Ontario Geological Survey (OGS) describes fluvial deposits in the area as gravel, sand, silt and clay, deposited on abandoned flood plains as terrace remnants and of the Pleistocene Age. The Glaciofluvial Outwash Deposits are described as gravel and sand, includes proglacial river and deltaic deposits and of the Pleistocene age. The following sections outline the native subgrades encountered in the areas of investigation throughout the site.

3.3.1 AREA 1

Boreholes BH101-20 and BH103-20 encountered native soil which included fluvial deposits consisting of sands to sandy silty clays overlying Glaciofluvial deposits predominately consisting of sands with varying amount of gravels, silts, and clays. In borehole BH101-21, brown sand with trace amounts of silt was observed directly beneath the fill material before transitioning to a grey clay with some sand and some silt from 2.29 to 3.05 mbgs. From 3.05 m to 4.57 mbgs, the material transitioned to a grey clayey silt with some sand and trace gravel. The borehole then transitioned to a more dense sand with a mixture of gravel, silt, and clay and extended to the maximum depth explored (6.5 mbgs). In borehole BH103-21, grey to brown sand with some to trace amounts of gravel was found to a depth of 2.44 mmbgs. The soil transitioned to a grey silt and clay material with trace amounts of sand to a depth of 3.05 mbgs. At approximately 3.05 m, the silt content in the soil decreased and the material became predominately grey clay with some silt and trace amounts of sand.

3.3.2 AREA 2

In borehole BH102-21, the native soil encountered consisted of fluvial sand with trace clay and silts overlying Glaciofluvial sands with trace gravel. The fluvial sands were found to be light brown, moist at the time of the investigation and compact based on SPT blow counts. The fluvial sands extended from 0.75 mbgs to 1.5 mbgs where the soil transitioned to Glaciofluvial sands extending to the maximum depth explored (5.0 mbgs).

3.3.3 AREA 3

Borehole BH103-21, BH104-21, BH106-21, and BH107-21 encountered native soils consisting of fluvial deposits overlying Glaciofluvial deposits. In borehole BH103-21, native subgrades were encountered at a depth of 1.5 mbgs and extended to the maximum depth explored. Fluvial sands extended from below the fill to approximate 2.4 mbgs and consists of grey and brown, very loose, wet sands with varying amounts of fine gravel. Boreholes BH104-21 and BH107-21 encountered fluvial brown – grey sands directly below the artificial fill. The sands transition to a silty sand at approximately 1.5 mbgs; in borehole Bh107-21 the silty sands extend to the maximum depth explored (2.74 mbgs). In borehole BH104-21, a sand layer is encountered from 3.0 mbgs to the maximum depth explored (3.5 mbgs). Directly below the artificial fill layer, borehole BH106-21 encountered a Glaciofluvial sand layer from 1.2 mbgs to the maximum depth explored (2.4 mbgs).

The native material was moist to saturated at the time of the investigation with natural moisture content varying from 9.6% to 49.7% based on laboratory testing. The native material is variable in relatively density and has a soft / very loose to firm and very dense relative density based on SPT N values ranging from 2 to over 50 blows for 180 mm of penetration.

Laboratory particle size distribution analyses were completed for three (3) samples of the fill material, taken from immediately below the topsoil surface. The analysis results, based on the Unified Soil Classification System (USCS) scale, are summarized in Table 4 with full results provided in Appendix B.

Table 4 Particle Size Distribution Analysis – Native Material

Sample	Depth (mbgs)	Soil	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Moisture (%)
BH101-21, SS5	3.0 – 3.5	Clayey Silt some Sand trace Gravel	1	10	59	30	26.7
BH103-21, SS4	2.4 – 2.7	Silt and Clay trace Sand	0	9	54	37	33.7
BH104-21	1.5 - 2	Silty Gravelly Sand	24	47	29		11.0

3.4 GROUNDWATER & HYDROGEOLOGY

A review of the Ontario Geological Survey database shows that the area is dominated by “Older Alluvial deposits” of Pleistocene age. The older alluvial deposits consist of, from dominant to least dominant: clay, silt, sand, gravel, may contain organic remains (*Ontario Geological Survey 2010. Surficial geology of Southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 128-REV*). Bedrock was not encountered during the drilling investigation. The bedrock geology is described in the OGS database as consisting of felsic igneous rocks: tonalite, granodiorite, monzonite, granite, syenite and derived gneisses (*Ontario Geological Survey 2011. 1:250 000 scale bedrock geology of Ontario; Ontario Geological Survey, Miscellaneous Release---Data 126-Revision 1.*).

The borehole program was designed to provide both geotechnical and hydrogeological data. Four of the boreholes were instrumented with monitoring wells. Sediment/soil types were described during borehole advancement and sample collected and submitted for grainsize analysis. All boreholes were checked for caving (sloughing) and/or groundwater seepage upon completion. Table 5 shows the groundwater level and caving depths at the time of the investigation.

Table 5 Groundwater Level and Borehole Caving Depths

Borehole	Groundwater Level in Borehole Upon Completion (mbgs)	Depth of Borehole Caving (mbgs)
BH101-21	2.89	4.72
BH102-21	3.05	-
BH103-21	0.46	-
BH104-21	2.74	-
BH105-21	-*	1.52
BH106-21	0.53	1.52
BH107-21	2.29	-
MW108-21	1.6	-

*groundwater level below depth of borehole caving

It should be noted that soil moisture and groundwater levels at the Site are expected to fluctuate seasonally and in response to climatic events.

Monitoring wells were installed in BH101-21, BH102-21, and BH103-21. A 4th monitoring well was installed in the vicinity of BH106-21 but not within borehole BH106-21 itself as it could not be advanced to a suitable depth. The monitoring well installed separately form BH106-21 is shown as MW108-21 in Figure 1 and the well construction is shown in Appendix A. Monitoring wells BH101-21, BH102-21, and MW108-21 extend from the surface to 4.57 mbgs and are fitted with screens between 0.91 to 3.96 m. Groundwater was encountered almost near surface in BH103-21, a monitoring well was installed from surface and extended to the maximum depth of the hole, 3 mbgs.

A Cambium technician returned to the site on June 18 and July 26, 2021 to conduct slug testing and complete water level readings as part of the hydrogeological study. Table 6 below shows the ground water level readings from the initial investigation as well as during the follow up slug testing.

Table 6 Groundwater Levels

Borehole	Groundwater Level May 17 - 18, 2021 (mbgs)	Groundwater Level June 18, 2021 (mbgs)	Groundwater Level July 26, 2021 (mbgs)
BH101-21	2.89	1.87	0.82
BH102-21	3.05	1.64	1.16
BH103-21	0.46	0.58	0.37
BH104-21	2.74	-	-
BH105-21	-	-	-
BH106-21	0.53	-	-
BH107-21	2.29	-	-
MW108-21	1.6	0.83	0.40

The piezometric water levels in the four wells were (July 26, 2021) were used to produce a piezometric contour map Figure 2. The contour map shows that groundwater flow radiates outward toward the Ottawa River. The upper aquifer is interpreted to be unconfined with groundwater flowing outward at ninety degree angles with the shoreline. The site surface appears to be reclaimed wetlands as evidenced by the presence of coarse grained fill and stranded ponds.

Hydraulic conductivity for the aquifer was approximated using slug testing. Following measurement of piezometric water levels at assumed static conditions, a slug of deionized water of know volume was introduced to each monitoring well and the levels and times monitored while the piezometric surface approaches static conditions. The data were uploaded to Aquifer Test (v10.0) software and the hydraulic conductivities estimated using the Hvorslev method in Aquifer Test (v10.0). The hydraulic conductivities (K) for the four monitoring wells are summarized in Table 7 below. The Aquifer Test outputs/graphs are provided in Appendix D.

Table 7 Hydraulic Conductivities

Monitoring Well	Hydraulic Conductivity (m/s)
MW101-21	4.89×10^{-7}
MW102-21	1.27×10^{-5}
MW103-21	8.24×10^{-6}
MW108-21	3.81×10^{-5}

The K values shown in Table 7 show a wide variation in magnitude from 4.89×10^{-7} to 1.27×10^{-5} . Based on the particle size analysis of the native soils (see Table 4), the native soils encountered are consistent with the Ontario Geological Survey report of the area being dominated by "older alluvial sediments" (silt, clay with some sand and gravel).

These values are consistent with the geologic soil types encountered. Note that the material is heterogeneous and shows wide spatial range of K-values.

3.5 AUGER REFUSAL

Auger refusal was encountered in the majority of boreholes. Based on known local geology and knowledge of site history it is presumed that refusal was encountered due to boulders or highly variable, highly fractured bedrock. To confirm the presence of bedrock, excavator dug test pit or borehole rock coring would be required. Table 8 shows the depth at which refusal was encountered in each borehole.

Table 8 Depth to Refusal

Boreholes	Refusal Depth (mbgs)
BH101-21	6.55
BH102-21	-
BH103-21	-
BH104-21	3.65
BH105-21	3.95
BH106-21	2.45
BH107-21	2.75

*'-' denotes refusal not encountered at borehole termination depth

4.0 ENGINEERING RECOMMENDATIONS

The following recommendations are based on borehole information and are intended to assist designers for the proposed retaining wall and road widening leading to the generating station. Recommendations should not be construed as providing instructions to contractors, who should form their own opinions about site conditions. It is possible that subsurface conditions beyond the borehole locations may vary from those observed. If significant variations are found before or during construction, Cambium should be contacted so that we can reassess our findings, if necessary.

4.1 SITE PREPARATION

Any topsoil, organic fill, and any other disturbed material or native soils encountered should be excavated and removed beneath the proposed development footprints. These material should be excavated and removed to a minimum distance of 1 m around the proposed footprint. Any topsoil and materials with significant quantities of organics and deleterious materials (i.e., construction debris, asphalt etc.) are not appropriate for use as fill. Subgrades should be inspected by a qualified geotechnical engineer prior to construction of the proposed developments.

Any exposed subgrades should be proof-rolled and inspected by a qualified geotechnical engineer prior to placement of any granular fill. Any loose/soft soils identified at the time of proof-rolling that are unable to uniformly be compacted should be sub-excavated and removed. The excavations created through the removal of these materials should be backfilled with approved engineered fill consistent with the recommendations provided below.

The encountered sand soils can be unstable if they are wet or saturated. Such conditions are common in the spring and late fall. Under these conditions, temporary use of granular fill, and possible reinforcing geotextiles, may be required to prevent severe rutting on construction access routes. Where possible, the existing roadways should be used for construction access routes.

4.2 FROST PENETRATION

Based on climate data and design charts, the maximum frost penetration depth below the surface at the site is estimated at 1.9 mbgs. Exterior strip and / or spread footings should be founded at or below a depth of 1.9 mbgs. Due to the shallow nature of groundwater throughout much of the site, buildings constructed with strip and / or spread footings will likely require the footprint to be built up to elevation that allows the foundations to be constructed above the groundwater table while remaining below the maximum frost depth penetration depths. Where strip and spread footings are not utilized, the foundations should be constructed on non-frost susceptible fill materials or consist of insulated foundations.

4.3 EXCAVATION AND SHORING

All excavations must be carried out in accordance with the latest edition of the Occupational Health and Safety Act (OHSA). The generally gravelly sand to sandy gravel fill material and compact silty sand and sandy silts may be classified as Type 3 soils above the groundwater table in accordance with OHSA. Type 3 soils may be excavated with unsupported side slopes no steeper than 1H:1V. If the groundwater table is encountered during construction, below the groundwater table the soils may be classified as Type 4 soils and may be excavated with unsupported side slopes no steeper than 3H:1V.

Excavation side slopes should be protected from exposure to precipitation and associated ground surface runoff and should be inspected regularly for signs of instability. If localized instability is noted during excavation or if wet conditions are encountered, the side slopes should be flattened as required to maintain safe working conditions or the excavation sidewalls must be fully supported (shored). If temporary shoring is required, lateral pressures outlined in Section 4.7 should be applied to determine the appropriate shoring requirements. In the event that shoring is required, sheet piles or soldier piles and lagging is likely the most cost-effective method.

4.4 DEWATERING

Groundwater was encountered in all boreholes and monitoring wells advanced at the site as noted in Section 3.6.. It is noted that the elevation of the groundwater table will vary due to seasonal conditions and in response to heavy precipitation events.

Based on the groundwater conditions measured after completing the borehole drilling and provided the following foundation recommendations are followed, little to no groundwater seepage is anticipated. However, if excavations are advanced below the ground water table, groundwater seepage is to be expected and a Permit to Take Water (PTTW) or registration on the Environmental Activity and Sector Registry (EASR) through the Ministry of the Environment Conservation and Parks (MOECP) may be required if pumping rates exceed 50,000 L/day. The hydrogeological study provided by Cambium should address subsurface groundwater requirements and recommendations for the site.

4.5 BACKFILL AND COMPACTION

Excavated gravelly sand to sandy gravel below the surface from the Site is appropriate for use as fill below grading areas. Excavated native soil not containing organics or significant deposits of silt and clay may also be appropriate for use as fill below grading areas, provided that the actual or adjusted moisture content at the time of construction is within a range that permits compaction to required densities. The native soils at the subject site contain a significant amount of silt and clays, and would not be suitable for re-use at the site as fill materials. Some moisture content adjustments may be required depending upon seasonal conditions. Geotechnical inspections and testing of engineered fill are required to confirm acceptable quality.

Retaining wall or foundation backfill should consist of imported, free-draining granular material as described in Section 4. Any engineered fill for foundations should be placed in maximum 200 mm thick lifts, consist of materials described in the following section and be compacted to a minimum of 100% of standard Proctor maximum dry density (SPMDD). If engineered fill is being placed for general site backfill and grading then compaction to 98% of SPMDD is applicable.

4.5.1 ENGINEERED FILL

When the fill is treated as an engineered fill to support structural elements such as foundations and/or floor slabs the following is recommended for the construction of engineered fill:

I. Remove any and all existing vegetation, surficial topsoil/ organics, organic fills or fills and any loose soils to a competent subgrade for a suitable envelope;

II. As a minimum, the area of the engineered fill should extend horizontally 1 m beyond the outside edge of the foundations then extend downward at a 1:1 slope to the competent native soil;

III. The subgrade or base of the engineered fill area must be approved by Cambium prior to placement of any new fill, to ensure that suitability of subgrade condition;

IV. Place approved OPSS 1010 SSM or Granular 'B' Type I material at a moisture content at or near optimum moisture in suitable maximum 200 mm thick lifts, compacted to 100% of SPMDD. Any frost penetration into the fill material must be removed prior to placement of subsequent lifts of fill and reviewed by Cambium;

V. Full time testing and inspection of the engineered fill will be required for it to be used as a founding material, as outlined in Section 4.2.2.2 of the Ontario Building Code.

4.6 FOUNDATION DESIGN

Design and construction recommendations for potential foundation systems are outlined below. In the event that the site is be regraded, our foundation recommendations may change depending upon the final grades. Cambium should be contacted to review the final grading plan and provide any necessary changes to our foundation recommendations.

The quality of the subgrade should be inspected by Cambium during construction, prior to constructing the footings, to confirm bearing capacity estimates. Settlement potential at the noted serviceability limit state (SLS) loadings should be less than 25 mm and differential settlement should be less than 10 mm.

4.6.1 BUILDING FOUNDATION DESIGN

For the proposed support buildings, including the dewatering building and the reception and thickening building, Cambium recommends the foundations be designed as continuous perimeter footings and isolated spread footings bearing on compact/firm native soils or engineered fill. All shallow footings should have a minimum 1.9 m soil cover to protect from frost penetration unless the foundations are insulated or bearing on non-frost susceptible material.

4.6.1.1 FOUNDATIONS ON NATIVE SUBGRADE SOILS

Based on the undisturbed compact to very dense native fluvial and Glaciofluvial deposits encountered throughout the site, footings situated throughout the development area may be designed for an allowable bearing capacity of 75 kPa at serviceability limit state (SLS) and 100 kPa at ultimate limit state (ULS). Cambium personnel should inspect footings excavations prior to placing foundations, where material is found to be loose or unable to be uniformly compacted should be removed and replaced with engineered fill. Throughout the site, the groundwater table was encountered at or below the native subgrade material, therefore, designers will need to consider dewatering activities if placing foundations at this level

4.6.1.2 FOUNDATIONS ON ENGINEERED FILL

If engineered fill is prepared per the requirements outlined in Section 4.5.1, footings may be founded on engineered fill. Footings placed on a minimum of 1.0 metre of approved engineered fill can be designed for an allowable bearing capacity of 90 kPa at SLS and 115 kPa at ULS. Where non-frost susceptible OPSS 1010 Granular ‘B’ Type II granular material is utilized as an engineered fill extending from 1.6 mbgs up to the underside of proposed footing elevation, the footings may be designed for an allowable bearing capacity of 125 kPa at SLS and 150 kPa at ULS.

4.6.1.3 INSULATED SHALLOW FOUNDATIONS

Insulated shallow foundations may be utilized and may bear on the previously placed, compact to very dense fill material encountered onsite within 1.2 to 1.5 mbgs. Insulated shallow footings bearing on the material can be designed for an allowable bearing capacity of 100 kPa at SLS and 125 kPa at ULS. Bearing material should be inspected by Cambium personnel prior to placement of footings, and any areas of soft or deleterious material not captured during the investigation should be removed and replaced.

4.6.2 PROCESS INFRASTRUCTURE FOUNDATIONS

For the proposed process infrastructure buildings, including the buffer tank, slurry tank, digester 3 & 4 upgrade, and gas condition and CHP area, Cambium recommends the foundations be designed as mat foundations bearing on non-frost susceptible material or a mat foundation consisting of insulated concrete bearing on compact to very dense native sand.

We recommend designing the mat foundation for an allowable dead plus live load bearing pressure of 100 kpa, with a one-third increase for total loads, including wind and/or seismic loads. The actual settlement for the mat foundation will depend on the actual building foundation pressures and the rigidity of the mat foundation. For calculating the settlement across the mat foundation, we recommend using a modulus of subgrade reaction of 150 MPa/m. The modulus value is representative of the anticipated static settlement of the undocumented fill under the allowable bearing pressure – approximately 25 mm. After a mat analysis is completed, Cambium should review the computed settlement and bearing pressure profiles to check that the recommended modulus value is appropriate.

Resistance to lateral loads can be mobilized by a combination of passive pressure acting against the vertical faces of the foundations and friction along their base. Passive resistance may be calculated using the procedure outlined in Section 4.7

Uplift loads may be resisted by the weight of the mat and any overlying soil. Uplift loads from overturning moments caused by wind and seismic loads or from hydrostatic uplift pressures from sand boils can impact the proposed structure.

The quality of the subgrade should be inspected by Cambium during construction, prior to constructing the footings, to confirm bearing capacity estimates.

4.7 LATERAL EARTH PRESSURES

The design of the retaining walls, foundation walls, and mat foundations should consider the horizontal soil loads, as well as surcharge loads that may occur during or after construction. The backfill materials should consist of imported free-draining granular soils (e.g. OPSS Granular B, Type I or Granular A and Granular B Type II) as approved by a Geotechnical Engineer.

The backfill materials should be placed in lifts not exceeding 200 mm thick. The layers should be compacted to at least 95% of SPMDD. Lateral earth pressure coefficients (K) are shown in Table 9. It is assumed that potential lateral loads will result from cohesion less, frictional materials.

Table 9 Lateral Earth Pressure Coefficients

Soil	Bulk Unit Weight γ (kN/m³)	Internal Friction Angle Φ' (°)	Active earth pressure coefficient Ka (Rankine)	Passive earth pressure coefficient Kp (Rankine)	At-rest earth pressure coefficient Ko (Rankine)
Compacted Granular A and Granular B Type II	22	34	0.28	3.54	0.44
Compacted Granular B Type I	21	32	0.31	3.25	0.47
Silty or Gravelly Sand*	19	30	0.33	3.00	0.5

**Values derived from empirical relationships based on soil types and SPT N-values*

The earth pressure coefficient adopted will depend on whether the retaining structure is restrained or some movement can occur such that the active state of earth pressure can develop. The use of vibratory compaction equipment immediately behind the retaining walls should be restricted in size.

The coefficients provided in Table 9 assume that the surface of the granular backfill or native material is horizontal against any proposed retaining wall, and the wall is vertical and smooth. Cambium should be contacted to provide updated lateral earth pressure coefficients should the assumptions differ to those noted.

The following formula may be used to calculate active lateral thrust (Pa) on yielding retaining structures;

$$P_a = (H/2)(K_a)(\gamma H + 2q)$$

where,

H = Height of retaining structure (m)

γ = unit weight of retained soil (kN/m³)

q = surcharge (kPa)

Unit weights found in Table 7 should be used for compacted loadings of the appropriate material.

Where traffic loads are expected within 3 meters of the retaining walls, foundation walls, or temporary shoring, a vehicle surcharge pressure of at least 3 and up to 6 kPa should be applied to the upper 3 meters of the wall; the actual surcharge pressure should depend on the type of traffic. Where construction equipment will be working behind the walls within a horizontal distance equal to the wall height (1H:1V), the design should include a surcharge pressure of 12 kPa. The above pressures should be assumed to act over the entire width of the retaining wall.

4.7.1 EARTHQUAKE-INDUCED PRESSURES

Earthquakes will induce additional pressures on retaining structures. For active earth pressure loads:

$$P_{ae} = \frac{1}{2}\gamma H^2(1 - k_v)K_{ae}$$

Where,

P_{ae} = resultant active lateral earth load inducing static and dynamic loads;

γ = unit weight of the soil behind the wall;

k_v = vertical component of the earthquake acceleration (as a decimal fraction of the acceleration due to gravity);

k_h = horizontal component of the earthquake acceleration (as a decimal fraction of the acceleration due to gravity); and

K_{ae} = horizontal component of active earth pressure coefficient including effects of earthquake loading;

And

$$K_{ae} = \frac{\cos(\delta + \alpha cos^2(\phi' - \varphi - i))}{cos^2 i \ \cos\delta \cos(\delta + i + \varphi)(1 + X_a^{1/2})^2}$$

$$X_a = \frac{\sin(\delta + \varphi')\sin(\phi' - \varphi - \beta)}{\cos(\delta + i + \varphi)\cos(\beta - i)}$$

$$\varphi = \tan^{-1}[k_h/(1 - k_v)]$$

$$i = 90 - \alpha$$

For the site, γ is as provided in Table 6, α=90° and i=0. Using Coulomb's theory, the angle of wall friction (δ) is related to both the internal angle of friction of the soil (Φ') as provided in Table 6 and the roughness of the wall. For smooth vertical walls δ=0, and the recommended maximum value for rough concrete walls δ = 14. If the walls are not smooth, Cambium would recommend reviewing the design δ values.

4.8 SUB-DRAINS

Provisions should be made for draining the retaining wall backfill to prevent buildup of hydrostatic pressures; this could consist of geotextile-wrapped perforated plastic sub-drain appropriately sloped and drained to the stormwater management system or other suitable frost-free outlet, or geotextile-wrapped perforated plastic sub-drains draining through the wall itself would be considered suitable provided they are could be kept frost-free.

4.9 BURIED UTILITIES

Trench excavations above the groundwater table should generally consider Type 3 soil conditions, which require side slopes no steeper than 1H:1V, otherwise shoring would be required. Any excavations below the water table should generally consider Type 4 soil conditions which require side slopes of 3H:1V or flatter.

Bedding and cover material for any services should consist of OPSS 1010 Granular A or B Type II, placed in accordance with pertinent Ontario Provincial Standard Drawings (OPSD 802.013). The bedding and cover material shall be placed in maximum 200 mm thick lifts and should be compacted to at least 98 percent of SPMDD. The cover material shall be a minimum of 300 mm over the top of the pipe and compacted to 98 percent of SPMDD, taking care not to damage the utility pipes during compaction. If bedding is being placed in wet conditions consideration should be given to using 19 mm crushed clear stone underlain by a geotextile (Terrafix 270R or similar).

4.10 SEISMIC SITE CLASSIFICATION

The Ontario Building Code (OBC) specifies that the structures should be designed to withstand forces due to earthquakes. For the purpose of earthquake design, geotechnical information shall be used to determine the “Site Class”. The parameters for determination of Site Classification for Seismic Site Response are set out in Table 4.1.8.4A of the OBC (2012). The classification is based on the determination of the average shear wave velocity in the top 30 metres of the site stratigraphy, where shear wave velocity (v_s) measurements have been taken. Alternatively, the classification is estimated on the basis of rational analysis of undrained shear strength (s_u) or penetration resistances (N_{60} values). Based on the explored soil properties and in accordance with Table 4.1.8.4.A, it is recommended that Site Class “D” (stiff soils) be applied for structural design at the Site and founding on Precambrian granite bedrock.

Peak ground acceleration and spectral acceleration (period of 0.2 seconds) for the site are calculated to be 0.168g and 0.380g respectively using the 2015 National Building Code Seismic Hazard Calculation. Calculation results are shown in Appendix C.

Consideration could be given to carrying out shear wave velocity testing (“MASW”) to evaluate whether an improved seismic site class can be obtained.

4.10.1 LIQUEFACTION HAZARDS

When a saturated, cohesionless soil liquefies, it experiences a temporary loss of shear strength created by a transient rise in excess pore pressure generated by strong ground motion. Soil susceptible to liquefaction includes loose to medium dense sand and gravel, low-plasticity silt, and some low-plasticity clay deposits. Flow failure, lateral spreading, differential settlement, loss of bearing strength, ground fissures, and sand boils are evidence of excess pore pressure generation and liquefaction. Very loose to loose soils were encountered onsite and may present a seismic hazard to the existing and proposed infrastructure onsite. To determine the extent of the potential for liquefaction at site, a Cone Penetration Test and subsequent liquefaction analysis would need to be conducted.

4.11 PAVEMENT DESIGN

If the proposed developments also includes paving of the roadways leading to the proposed or existing buildings, the following pavement design recommendations should be followed. The performance of the pavement is dependent upon proper subgrade preparation. All topsoil and organic materials should be removed down to native material and backfilled with approved engineered fill or native material, compacted to 98% of SPMDD. The subgrade should be proof rolled and inspected by a Geotechnical Engineer. Any areas where boulders, rutting, or appreciable deflection is noted should be subexcavated and replaced with suitable fill. The fill should be compacted to at least 98% of SPMDD.

The recommended pavement structure should meet the Ministry standards for parking and driving areas and should, as a minimum, consist of the pavement layers identified in Table 9. The light duty pavement structure is intended for parking areas while the heavy duty pavement structure is appropriate for areas where heavy traffic or heavy loads are anticipated.

Table 10 Recommended Minimum Pavement Structure

Pavement Layer	Light Duty	Heavy Duty
Surface Course Asphalt	45 mm HL3 or HL4	45 mm HL3 or HL4
Binder Course Asphalt	50 mm HL8	60 mm HL8
Granular Base	150 mm OPSS 1010 Granular A	150 mm OPSS 1010 Granular A
Granular Subbase	300 mm OPSS 1010 Granular B	450 mm OPSS 1010 Granular B

Material and thickness substitutions must be approved by the Design Engineer.

The thickness of the subbase layer could be increased at the discretion of the Engineer, to accommodate site conditions at the time of construction, including soft or weak subgrade soil replacement.

Compaction of the subgrade should be verified by the Engineer prior to placing the granular fill. Granular layers should be placed in 200 mm thick maximum loose lifts and compacted to at least 98% of SPMDD (ASTM D698) standard. The granular materials specified should conform to OPSS standards, as confirmed by appropriate materials testing.

Subdrains are recommended beneath the pavement structure, connecting to the storm sewer or an alternate frost-free outlet as outlined above, to extend the lifespan of the structure.

The final asphalt surface should be sloped at a minimum of 2% to shed runoff. Abutting pavements should be saw cut to provide clean vertical joints with new pavement areas.

5.0 DESIGN REVIEW AND INSPECTIONS

Cambium should be retained to complete testing and inspections during construction operations to examine and approve subgrade conditions, placement and compaction of fill materials, granular base courses, and asphaltic concrete.

We should be contacted to review and approve design drawings, prior to tendering or commencing construction, to ensure that all pertinent geotechnical-related factors have been addressed. It is important that onsite geotechnical supervision be provided at this site for excavation and backfill procedures, deleterious soil removal, subgrade inspections and compaction testing.

6.0 CLOSING

We trust that the information contained in this report meets your current requirements. If you have questions or comments regarding this document, please do not hesitate to contact the undersigned at (613) 389 - 2323.

Respectfully submitted,

CAMBIUM INC.

Prepared By:

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Project Coordinator

Christopher C. Rancourt, M.Sc., P.Geo., QPESA

Group Manager - Property Assessment and Due Diligence

Reviewed By:

Stuart Baird, M.Eng. P.Eng.
General Manager – Geotechnical & Construction Monitoring

SEB/mdg/CCR

P:\11700 to 11799\11757-001 JDM Designworks - GEO - Petawawa STP\Deliverables\REPORT - GEO\Final\ RPT - Petawawa STP - GEO Report

Appended Figures

GEOTECHNICAL INVESTIGATION

JDM DESIGNWORKS
560 Abbie Lane
Petawawa, Ontario

LEGEND

- Borehole
- Monitoring Well

Notes:
- Base mapping features are © Queen's Printer of Ontario, 2019 (this does not constitute an endorsement by the Ministry of Natural Resources or the Ontario Government).
- Distances on this plan are in metres and can be converted to feet by dividing by 0.3048.
- Cambium Inc. makes every effort to ensure this map is free from errors but cannot be held responsible for any damages due to error or omissions. This map should not be used for navigation or legal purposes. It is intended for general reference use only.

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BOREHOLE LOCATION PLAN

Project No.: 11757-001	Date: August 2021 Rev.:
Scale: 1:1,200	Projection: NAD 1983 UTM Zone 18N
Created by: TLC / Checked by: CR	Figure: 1

O:\GIS\MXDs\11700-11799\11757-001 JDM Designworks - GEO - Petawawa STP\2021-08-13 Hydro G FIG 1 - Borehole Location Plan.mxd

GEOTECHNICAL INVESTIGATION

JDM DESIGNWORKS
560 Abbie Lane
Petawawa, Ontario

LEGEND

(196.715) Groundwater Elevation

Borehole

Monitoring Well

Groundwater Contour

Groundwater Flow Direction

Notes:
- Base mapping features are © Queen's Printer of Ontario, 2019 (this does not constitute an endorsement by the Ministry of Natural Resources or the Ontario Government).
- Distances on this plan are in metres and can be converted to feet by dividing by 0.3048.
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GROUNDWATER FLOW CONTOURS

Project No.:	11757-001	Date:	August 2021
		Rev.:	
Scale:	1:1,200	Projection:	NAD 1983 UTM Zone 18N
Created by: TLC	Checked by: CR	Figure:	2

O:\GIS\MXDs\11700-11799\11757-001 JDM Designworks - GEO - Petawawa STP\2021-08-13 Hydro G FIG 2 - Groundwater Flow Contours.mxd

Appendix A
Borehole Logs

Peterborough
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Oshawa
Kingston
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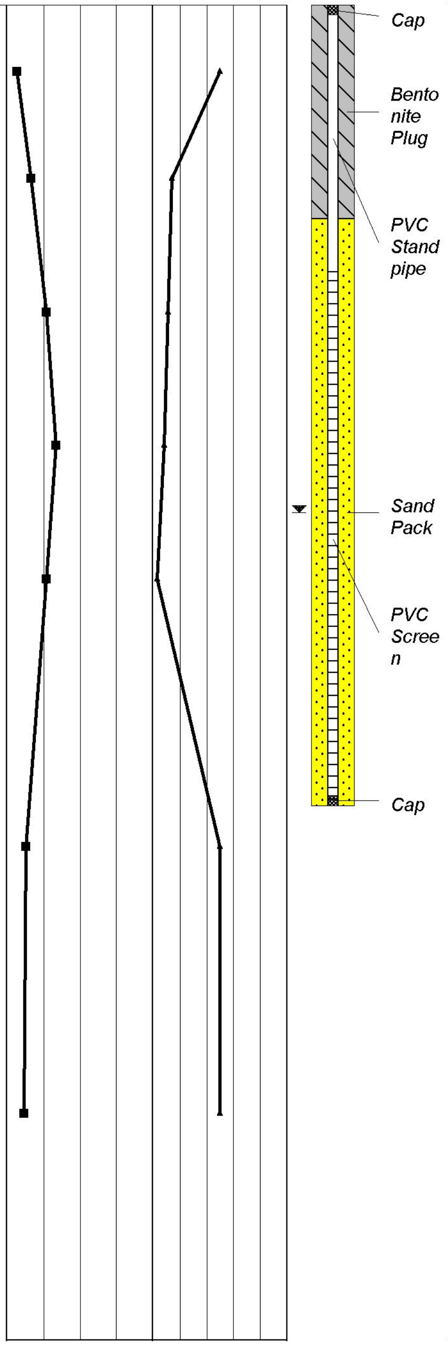
Log of Borehole: BH101-21

Client:	City of Petawawa	**Project Name:**	Geotechnical Drilling	**Project No.:**	11757-001
Contractor:	Canadian Environmental Drilling	**Method:**	Hollow Stem Auger	**Date Completed:**	May 17, 2021
Location:	560 Abbie Lane, Petawawa	**UTM:**	18N 325555.65 5085417.78	**Elevation:**	Rel.198.02 mASL

SUBSURFACE PROFILE / SAMPLE

Elevation (m rel)	Depth (m)	Description	Number	Type	% Recovery / TCR (%)	SPT (N) / RQD (%)	Remarks
198	0	SAND AND SILT: Black to brown, moist, very dense, trace gravel [TOPSOIL]	1	SS			Auger grinding, possible boulders.
		GRAVEL: grey, very dense, moist, occasional cobbles [ARTIFICIAL FILL]					
197	1	SAND: dark grey, compact, moist, trace gravel [ARTIFICIAL FILL]	2	SS			SPT and Auger refusal due to possible boulders.
		SAND: brown, compact, moist, trace silt [ALLUVIAL]	3	SS			
196	2	CLAYEY SILT: grey, firm, moist, some silt, some sand	4	SS			Depth of first groundwater encounter.
195	3	CLAYEY SILT: grey, soft, moist, some sand, trace gravel	5	SS			Water level in open borehole upon completion.
194	4						
		GRAVELLY SAND: grey, very dense, moist, trace clay, trace silt	6	SS			Depth of borehole caving.
193	5						
192	6						Auger grinding, possible boulders present.
		SAND: grey, very dense, some gravel, trace clay, trace silt	7	SS			
191	7	Borehole terminate at 6.55 m in sand due to difficult drilling conditions of possible boulders.					

% Moisture (25 50 75) · SPT (N) (20 40 60 80) · Well Installation



Logged By: F. Imtiaz **Input By:** M. Garrison

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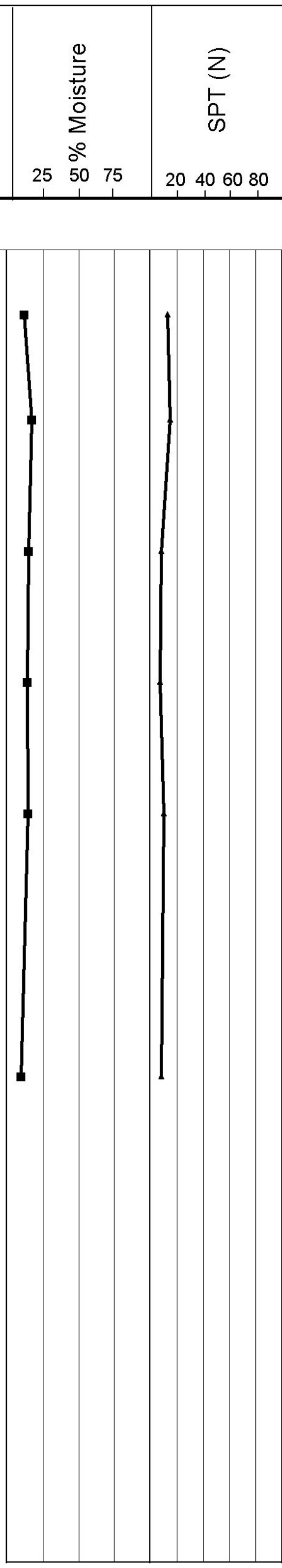
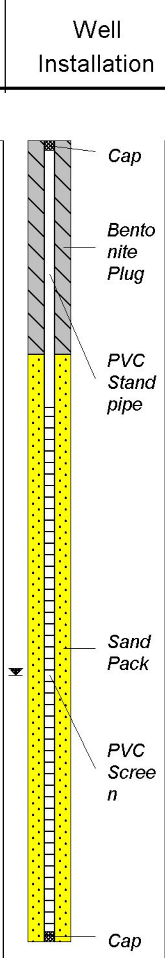
Log of Borehole: BH102-21

Client:	City of Petawawa	**Project Name:**	Geotechnical Drilling	**Project No.:**	Rel.197.875 mASL
Contractor:	Canadian Environmental Drilling	**Method:**	Hollow Stem Auger	**Date Completed:**	May 17, 2021
Location:	560 Abbie Lane, Petawawa	**UTM:**	18N 325522.77 5085490.87	**Elevation:**	121 mASL

SUBSURFACE PROFILE / SAMPLE

Elevation (m rel)	Depth (m)	Lithology	Description	Number	Type	% Recovery / TCR (%)	SPT (N) / RQD (%)	Remarks
	0		SAND AND SILT: Black to brown, moist, very dense, trace gravel [TOPSOIL]	1	SS			
			SAND AND SILT: brown, compact, moist, trace gravel [ARTIFICIAL FILL]					
197	1		SAND: light brown, moist, compact, trace clay, trace silt [ALLUVIAL]	2	SS			
196	2		SAND: brown to grey, loose, moist, trace gravel	3	SS			Depth of first groundwater encounter.
			-grey, loose, moist, trace gravel	4	SS			
195	3		-becomes saturated, compact	5	SS			Water level in open borehole upon completion.
194	4							
193	5			6	SS			
			Borehole terminated as target depth achieved at 5 m in sand.					
192	6							
191	7							





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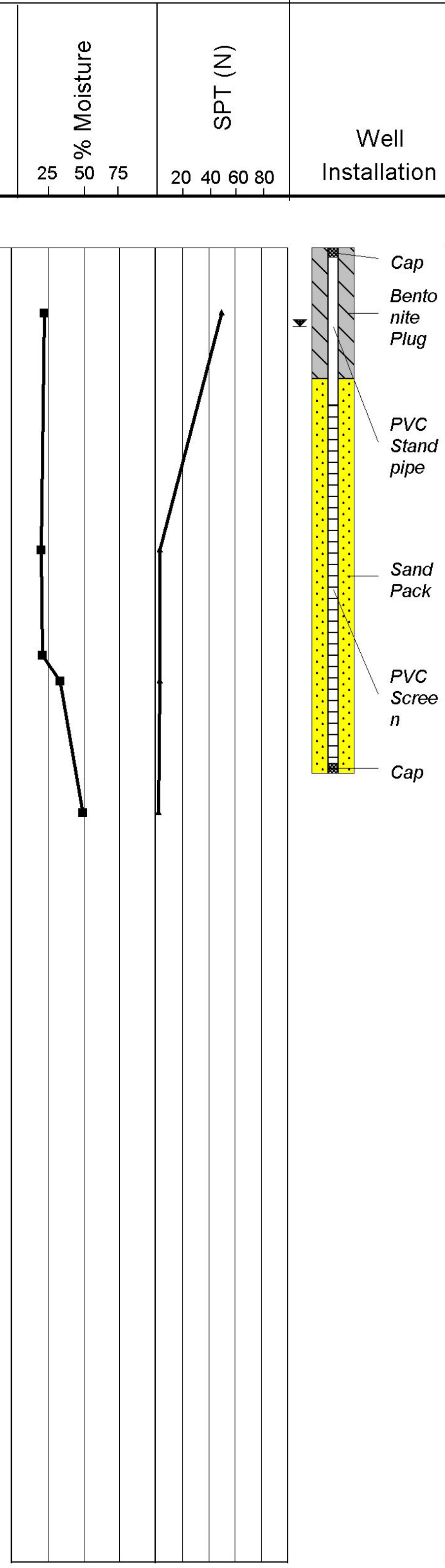
Log of Borehole: BH103-21

Client:	City of Petawawa	***Project Name:***	Geotechnical Drilling	***Project No.:***	11757-001
Contractor:	Canadian Environmental Drilling	***Method:***	Hollow Stem Auger	***Date Completed:***	May 17, 2021
Location:	560 Abbie Lane, Petawawa	***UTM:***	18N 325475.67 5085362.32	***Elevation:***	Rel.198.075 mASL

SUBSURFACE PROFILE / **SAMPLE**

Elevation (m rel)	Depth (m)	Description	Number	Type	% Recovery / TCR (%)	SPT (N) / RQD (%)	Remarks
198	0	SAND AND SILT: Black to brown, moist, very dense, trace gravel [TOPSOIL]	1	SS			Auger grinding, possible boulders. Water level in upon completion.
197	1	GRAVEL: grey and brown, very dense, moist to wet, some sand [ARTIFICIAL FILL]					Depth of first groundwater encounter. SPT sample not taken due to possible boulders.
196	2	SAND: grey, very loose, wet, some gravel [ALLUVIAL]	2	SS			@1.5m auger grinding ceased.
		SAND: grey - brown, very loose, wet, trace gravel	3				
195	3	SILT AND CLAY: grey, soft, wet, trace sand	4	SS			
			5	SS			
194	4	Borehole terminated at 3.5 m in silty clay, water level higher than anticipated - attempted alternate borehole location.					
193	5						
192	6						
191	7						



Logged By: F. Imtiaz ***Input By:*** M. Garrison

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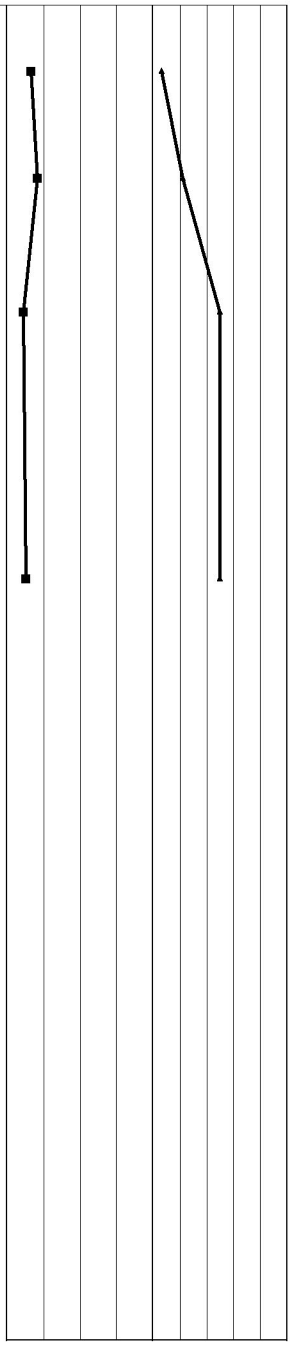
Log of Borehole: BH104-21

Client:	City of Petawawa	***Project Name:***	Geotechnical Drilling	***Project No.:***	11757-001
Contractor:	Canadian Environmental Drilling	***Method:***	Hollow Stem Auger	***Date Completed:***	May 17, 2021
Location:	560 Abbie Lane, Petawawa	***UTM:***	18N 325471 5085425	***Elevation:***	Rel.199.075 mASL

SUBSURFACE PROFILE				SAMPLE							
Elevation (m rel)	Depth (m)	Lithology	Description	Number	Type	% Recovery / TCR (%)	SPT (N) / RQD (%)	% Moisture (25 50 75)	SPT (N) (20 40 60 80)	Well Installation	Remarks
199	0		SAND AND SILT: Black to brown, moist, very dense, trace gravel [TOPSOIL]								Auger grinding, possible boulders.
				1	SS						
			SAND: Brown, moist, loose to compact, trace gravel [ARTIFICIAL FILL]								
198	1			2	SS						
			SAND: Brown-grey, compact, moist, some gravel [ALLUVIAL]								
			SILTY SAND: Brown-grey, very dense, moist, with gravel and trace clay	3	SS						@2.3m SPT sample not taken due to possible boulders.
197	2		-increase in gravel content, wet								Water level upon completion.
196	3		SAND: Grey, very dense, saturated, trace gravel	5	SS						Depth of first groundwater encounter.
195	4		Borehole terminated at 3.5 m due to auger refusal on boulder, potential bedrock.								
194	5										
193	6										
192	7										



Logged By: F. Imtiaz ***Input By:*** M. Garrison

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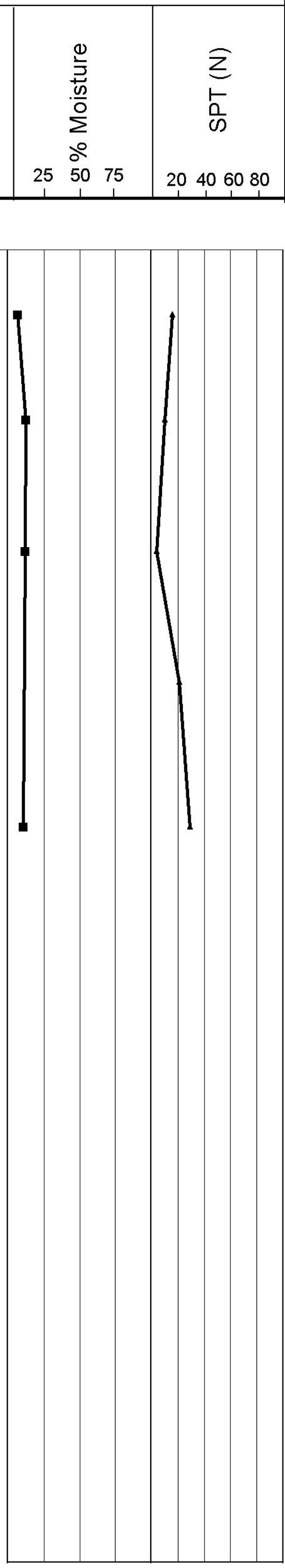
Log of Borehole: BH105-21

Client: City of Petawawa | **Project Name:** Geotechnical Drilling | **Project No.:** 11757-001
Contractor: Canadian Environmental Drilling | **Method:** Hollow Stem Auger | **Date Completed:** May 17, 2021
Location: 560 Abbie Lane, Petawawa | **UTM:** 18N 325553.85 5085436.51 | **Elevation:** Rel.197.86 mASL

Elevation (m rel)	Depth (m)	Description	Number	Type	% Recovery / TCR (%)	SPT (N) / RQD (%)	Remarks
	0	SAND AND SILT: Black to brown, moist, very dense, trace gravel [TOPSOIL]	1	SS			
		SAND: Brown, moist, compact, trace gravel [ARTIFICIAL FILL]					
197	1	SILTY SAND: Brown-grey, moist, compact, trace gravel [GLACIOFLUVIAL]	2	SS			
		-veneer of brown fluvial silty sands					@ 1.5 m depth of borehole caving. Depth of first groundwater encounter.
196	2	-becomes very loose	NR	SS			
		- increased gravel diameter in cuttings	3	SS			
195	3	SAND AND GRAVEL: Grey, saturated, compact, cobbles up to 50 mm in diameter [GLACIOFLUVIAL]	4	SS			
194	4	Borehole terminated at 4.0 m in sand and gravel due to auger refusal, difficult drilling.					
193	5						
192	6						
191	7						



Well Installation

Logged By: F. Imtiaz **Input By:** M. Garrison

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Log of Borehole: BH106-21

Client:	City of Petawawa	**Project Name:**	Geotechnical Drilling	**Project No.:**	11757-001
Contractor:	Canadian Environmental Drilling	**Method:**	Hollow Stem Auger	**Date Completed:**	May 17, 2021
Location:	560 Abbie Lane, Petawawa	**UTM:**	18N 325477.11 5085385.63	**Elevation:**	Rel.198.83 mASL

SUBSURFACE PROFILE			SAMPLE							
Elevation (m rel) / Depth (m)	Lithology	Description	Number	Type	% Recovery / TCR (%)	SPT (N) / RQD (%)	% Moisture (25 50 75)	SPT (N) (20 40 60 80)	Well Installation	Remarks
0		SAND AND SILT: Black to brown, moist, very dense, trace gravel [TOPSOIL]	1	SS						Auger grinding, possible boulders.
198 / 1		GRAVEL AND SAND: Grey and brown, very dense, moist, trace silt [ARTIFICIAL FILL]								Water level upon completion. Depth of first groundwater encounter. Split spoon not conducted in possible boulders.
		SAND: Grey, dense, some gravel, trace silt [ALLUVIAL]	2	SS						@1.2m auger grinding ceased.
197 / 2			3	SS						@1.5m Depth of borehole caving upon completion.
196 / 3		Borehole terminated at 2.4 m due to auger difficult drilling through possible boulders.								
195 / 4										
194 / 5										
193 / 6										
192 / 7										

Logged By: F. Imtiaz **Input By:** M. Garrison

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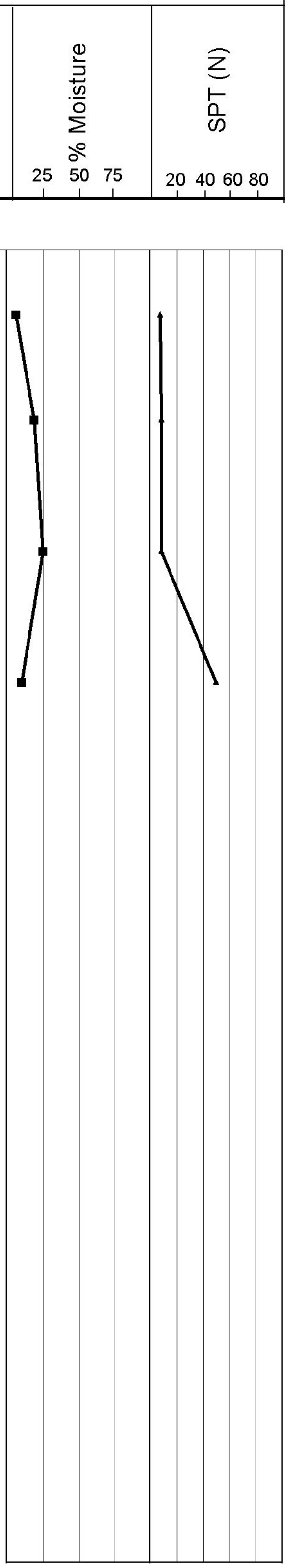
Log of Borehole: BH107-21

Client: City of Petawawa
Project Name: Geotechnical Drilling
Project No.: 11757-001
Contractor: Canadian Environmental Drilling
Method: Hollow Stem Auger
Date Completed: May 17, 2021
Location: 560 Abbie Lane, Petawawa
UTM: 18N 325173.00 5085404.99
Elevation: Rel.198.875 mASL

Elevation (m rel)	Depth (m)	Description	Number	Type	% Recovery / TCR (%)	SPT (N) / RQD (%)	Remarks
	0	SAND AND SILT: Black to brown, moist, very dense, trace gravel [TOPSOIL]	1	SS			
		SAND: Brown, loose, moist, trace gravel, trace silt [ARTIFICIAL FILL]					
198	1	SAND: Brown-grey, compact, moist, some gravel [ALLUVIAL]	2	SS			Depth of first groundwater encounter.
197	2	SILTY SAND: Grey, loose, wet, trace clay	3	SS			
		-becomes very dense, saturated	4	SS			Water level in borehole upon completion.
196	3	Borehole terminated at 2.74 m due to auger difficult drilling through possible boulders.					



Well Installation

Logged By: F. Imtiaz **Input By:** M. Garrison

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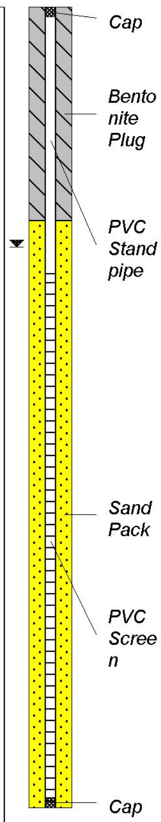
Log of Borehole: MW108-21

Client:	City of Petawawa	**Project Name:**	Geotechnical Drilling	**Project No.:**	11757-001
Contractor:	Canadian Environmental Drilling	**Method:**	Hollow Stem Auger	**Date Completed:**	May 17, 2021
Location:	560 Abbie Lane, Petawawa	**UTM:**	18N 325481.15 5085391.41	**Elevation:**	Rel.198.445 mASL

SUBSURFACE PROFILE			SAMPLE							
Elevation (m rel) / Depth (m)	Lithology	Description	Number	Type	% Recovery / TCR (%)	SPT (N) / RQD (%)	% Moisture (25 50 75)	SPT (N) (20 40 60 80)	Well Installation	Remarks
198–191 / 0–7										Several attempts required to advance borehole past ~3 meters due to boulders, lithology comparable to BH106-21, BH107-21.

Logged By: F. Imtiaz **Input By:** M. Garrison

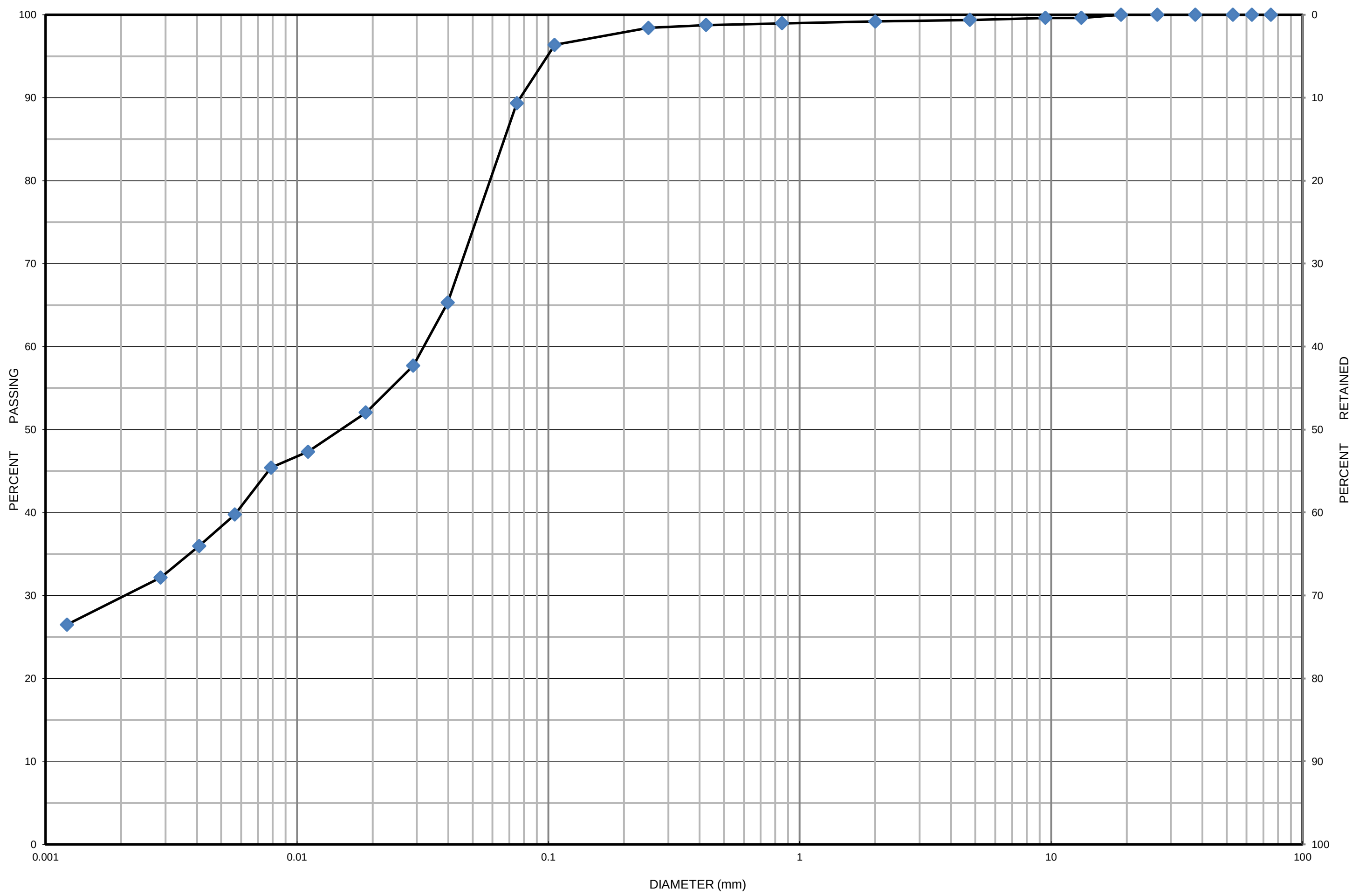
Appendix B

Physical and Chemical Laboratory Testing Results

Grain Size Distribution Chart

Project Number:	*11757-001*	**Client:**	*JDM Designworks Inc*		
Project Name:	*Geotechnical Investigation - Petawawa Sewage Treatment Plan*				
Sample Date:	*May 17 & 18, 2021*	**Sampled By:**	*Farhan Imtiaz - Cambium Inc.*		
Location:	*BH 101-21 SS 5*	**Depth:**	*3 m to 3.5 m*	**Lab Sample No:**	*S-21-0555*

UNIFIED SOIL CLASSIFICATION SYSTEM					
CLAY & SILT (<0.075 mm)	SAND (<4.75 mm to 0.075 mm)			GRAVEL (>4.75 mm)	
	FINE	MEDIUM	COARSE	FINE	COARSE



MIT SOIL CLASSIFICATION SYSTEM								
CLAY	SILT	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	BOULDERS
		SAND			GRAVEL			

Borehole No.	Sample No.	Depth	Gravel	Sand	Silt	Clay	Moisture
BH 101-21	SS 5	3 m to 3.5 m	1	10	59	30	26.7

Description	Classification	D_{60}	D_{30}	D_{10}	C_u	C_c
Clayey Silt some Sand trace Gravel	ML	0.032	0.002	0.000	-	-

Additional information available upon request

Issued By: (Senior Project Manager)

Date Issued: *June 8, 2021*

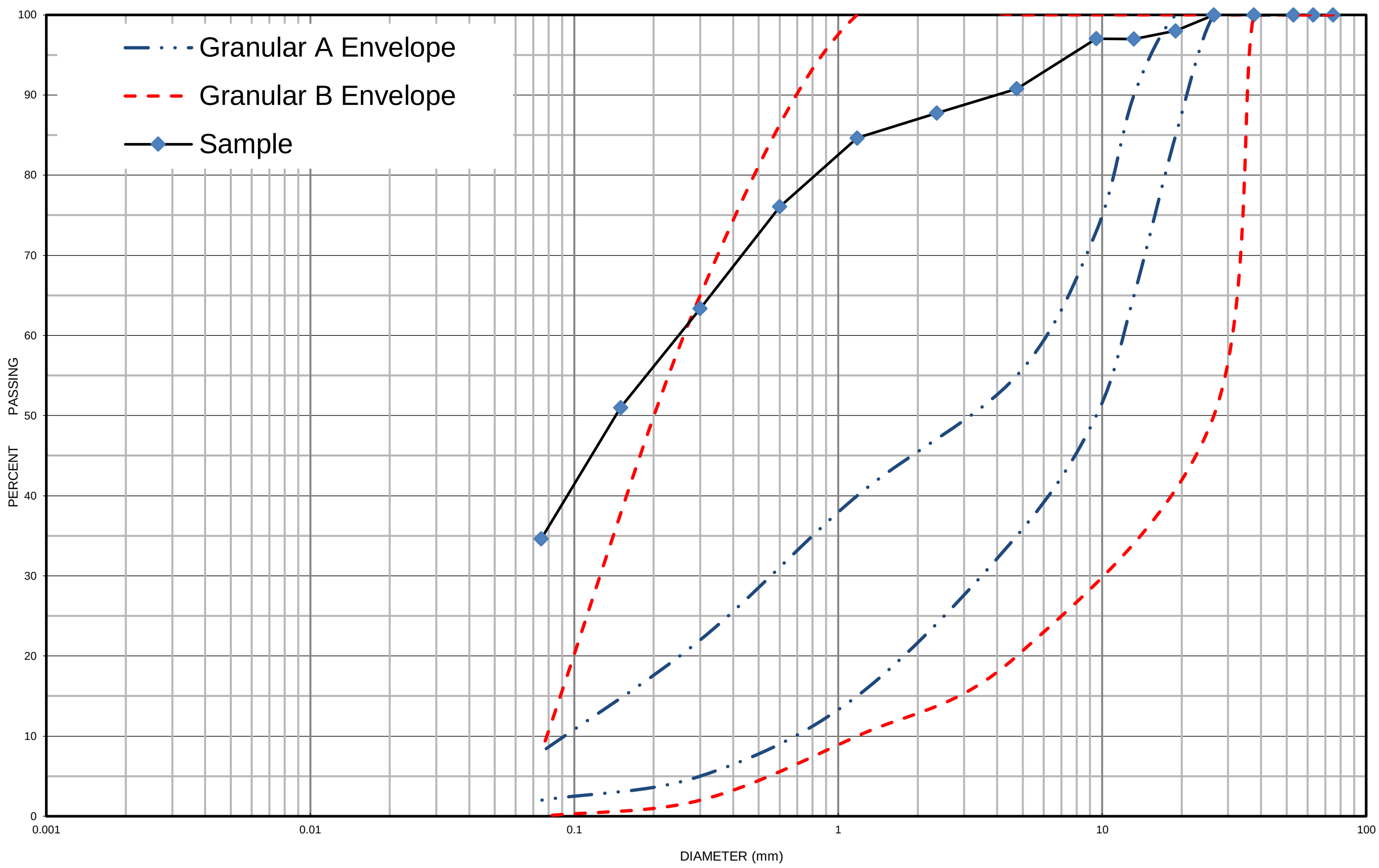
Cambium Inc. (Laboratory)
866.217.7900 | cambium-inc.com
194 Sophia St. | Peterborough | ON | K9H 1E5

Form: L6V.2 - Grad.Hydo

Grain Size Distribution Chart

Project Number:	*11757-001*	**Client:**	*JDM Designworks Inc*		
Project Name:	*Geotechnical Investigation - Petawawa Sewage Treatment Plan*				
Sample Date:	*May 17 & 18, 2021*	**Sampled By:**	*Farhan Imtiaz - Cambium Inc.*		
Location:	*BH 102-21 SS 1*	**Depth:**	*0.1 m to 0.6 m*	**Lab Sample No:**	*S-21-0556*

UNIFIED SOIL CLASSIFICATION SYSTEM					
CLAY & SILT (<0.075 mm)	SAND (<4.75 mm to 0.075 mm)			GRAVEL (>4.75 mm)	
	FINE	MEDIUM	COARSE	FINE	COARSE



MIT SOIL CLASSIFICATION SYSTEM								
CLAY	SILT	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	BOULDERS
		SAND			GRAVEL			

Borehole No.	Sample No.	Depth	Gravel	Sand	Silt	Clay	Moisture
BH 102-21	SS 1	0.1 m to 0.6 m	9	56	35		12.0

Description	Classification	D_{60}	D_{30}	D_{10}	C_u	C_c
Sand and Silt trace Gravel	SM	0.250	0.000	0.000	-	-

Additional information available upon request

Issued By: (Senior Project Manager) *Date Issued:* *June 8, 2021*

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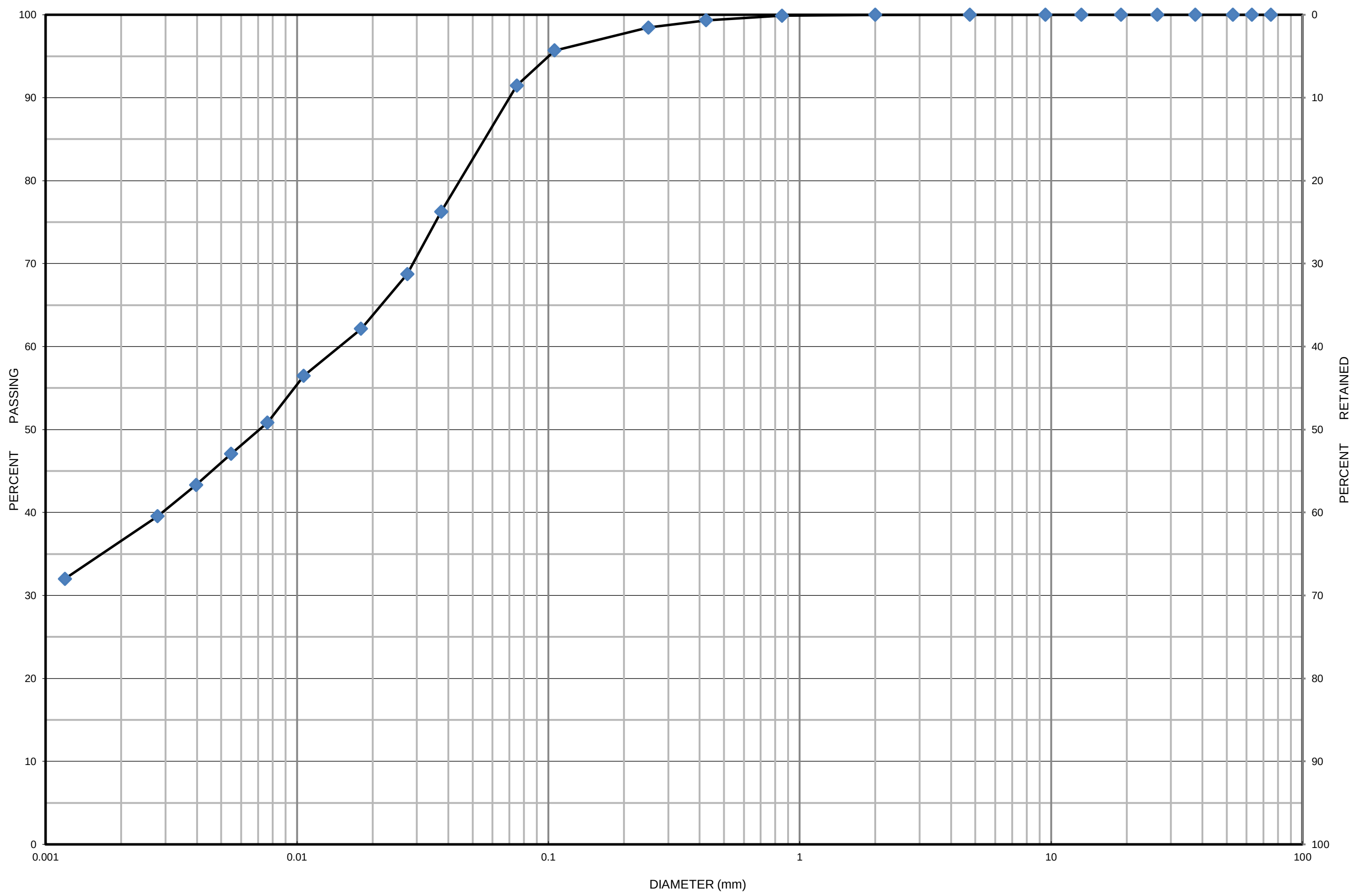
Form: L6V.2 - Grad.Hydo

Grain Size Distribution Chart

Project Number:	*11757-001*	**Client:**	*JDM Designworks Inc*		
Project Name:	*Geotechnical Investigation - Petawawa Sewage Treatment Plan*				
Sample Date:	*May 17 & 18, 2021*	**Sampled By:**	*Farhan Imtiaz - Cambium Inc.*		
Location:	*BH 103-21 SS 4*	**Depth:**	*2.4 m to 2.7 m*	**Lab Sample No:**	*S-21-0557*

UNIFIED SOIL CLASSIFICATION SYSTEM					
CLAY & SILT (<0.075 mm)	SAND (<4.75 mm to 0.075 mm)			GRAVEL (>4.75 mm)	
	FINE	MEDIUM	COARSE	FINE	COARSE



MIT SOIL CLASSIFICATION SYSTEM								
CLAY	SILT	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	BOULDERS
		SAND			GRAVEL			

Borehole No.	Sample No.	Depth	Gravel	Sand	Silt	Clay	Moisture
BH 103-21	SS 4	2.4 m to 2.7 m	0	9	54	37	33.7

Description	Classification	D_{60}	D_{30}	D_{10}	C_u	C_c
Silt and Clay trace Sand	ML	0.016	0.000	0.000	-	-

Additional information available upon request

Issued By: (Senior Project Manager)

Date Issued: *June 8, 2021*

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Form: L6V.2 - Grad.Hydo

Grain Size Distribution Chart

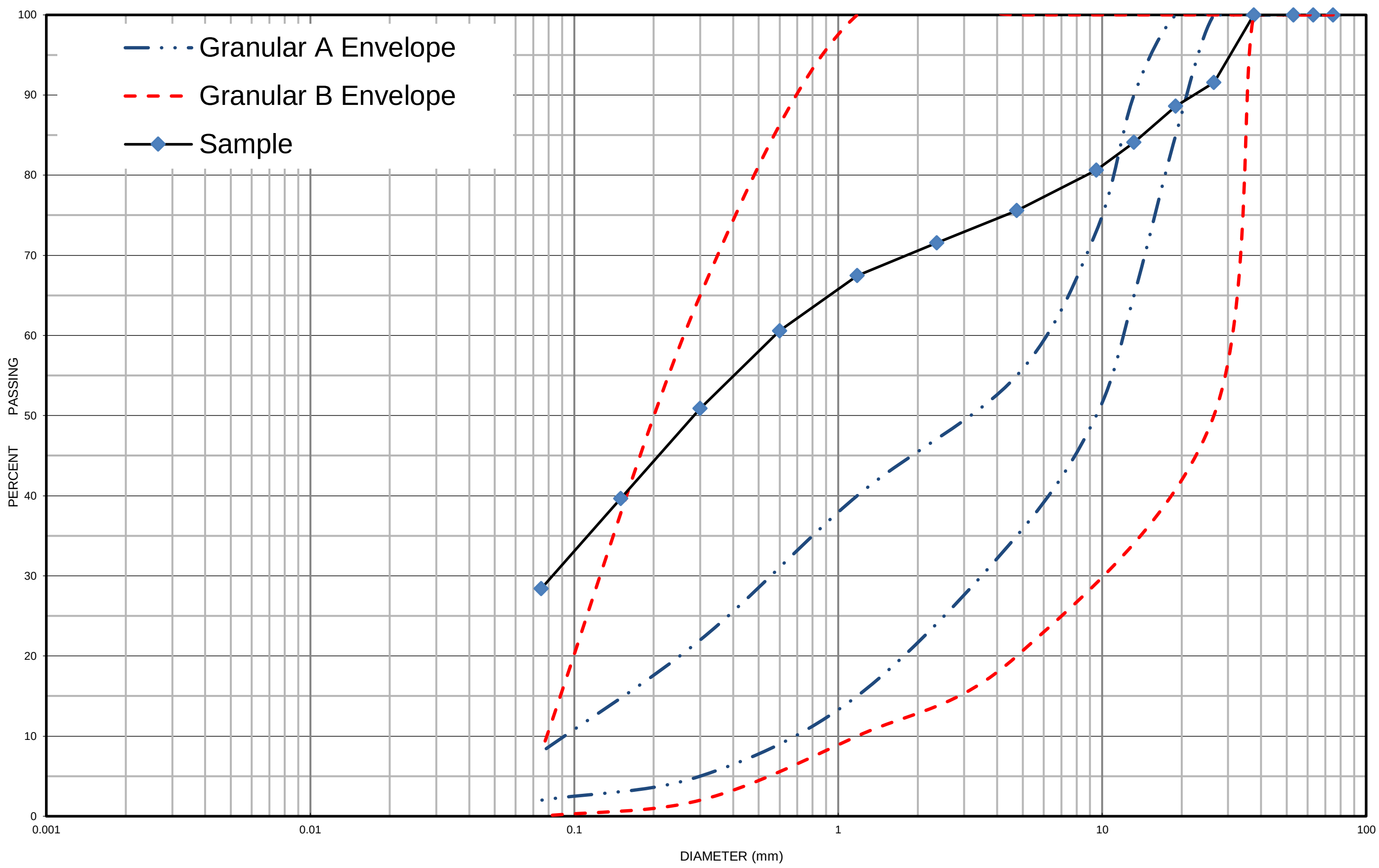
Project Number: *11757-001* **Client:** *JDM Designworks Inc*

Project Name: *Geotechnical Investigation - Petawawa Sewage Treatment Plan*

Sample Date: *May 17 & 18, 2021* **Sampled By:** *Farhan Imtiaz - Cambium Inc.*

Location: *BH 104-21 SS 3* **Depth:** *1.5 m to 2 m* **Lab Sample No:** *S-21-0558*

UNIFIED SOIL CLASSIFICATION SYSTEM					
CLAY & SILT (<0.075 mm)	SAND (<4.75 mm to 0.075 mm)			GRAVEL (>4.75 mm)	
	FINE	MEDIUM	COARSE	FINE	COARSE



MIT SOIL CLASSIFICATION SYSTEM								
CLAY	SILT	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	BOULDERS
		SAND			GRAVEL			

Borehole No.	Sample No.	Depth	Gravel	Sand	Silt	Clay	Moisture
BH 104-21	SS 3	1.5 m to 2 m	24	47	29		11.0

Description	Classification	D_{60}	D_{30}	D_{10}	C_u	C_c
Silty Gravelly Sand	SM	0.590	0.082	0.000	-	-

Additional information available upon request

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Grain Size Distribution Chart

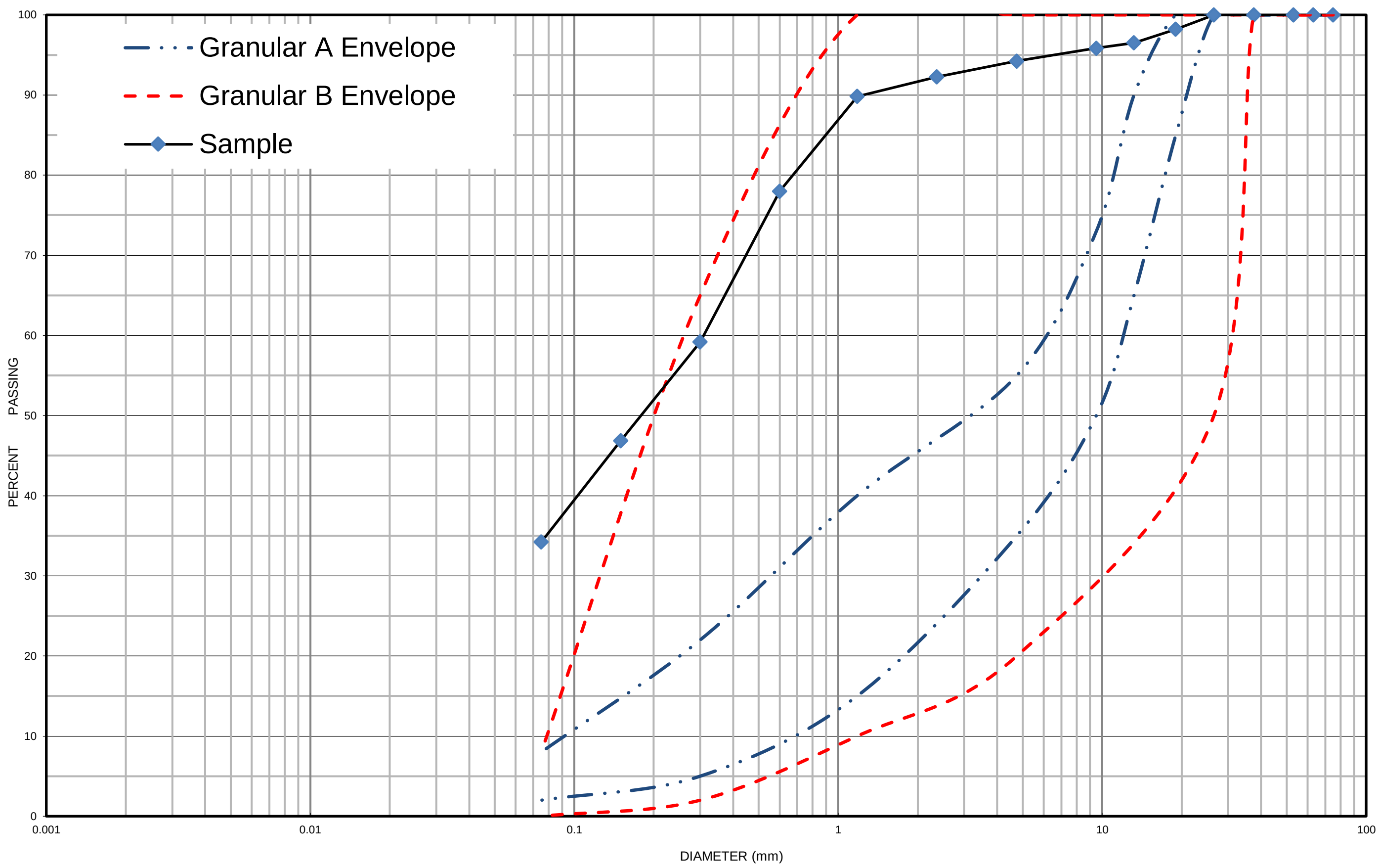
Project Number: *11757-001* **Client:** *JDM Designworks Inc*

Project Name: *Geotechnical Investigation - Petawawa Sewage Treatment Plan*

Sample Date: *May 17 & 18, 2021* **Sampled By:** *Farhan Imtiaz - Cambium Inc.*

Location: *BH 105-21 SS 2* **Depth:** *0.8 m to 1.2 m* **Lab Sample No:** *S-21-0559*

UNIFIED SOIL CLASSIFICATION SYSTEM					
CLAY & SILT (<0.075 mm)	SAND (<4.75 mm to 0.075 mm)			GRAVEL (>4.75 mm)	
	FINE	MEDIUM	COARSE	FINE	COARSE



MIT SOIL CLASSIFICATION SYSTEM								
CLAY	SILT	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	BOULDERS
		SAND			GRAVEL			

Borehole No.	Sample No.	Depth	Gravel	Sand	Silt	Clay	Moisture
BH 105-21	SS 2	0.8 m to 1.2 m	6	60	34		12.4

Description	Classification	D_{60}	D_{30}	D_{10}	C_u	C_c
Silty Sand trace Gravel	SM	0.310	0.000	0.000	-	-

Additional information available upon request

Issued By: (Senior Project Manager) *Date Issued:* *June 8, 2021*

CAMBIUM

CERTIFIED BY CCIL Canadian Council of Independent Laboratories For specific tests as listed on www.ccil.com

Grain Size Distribution Chart

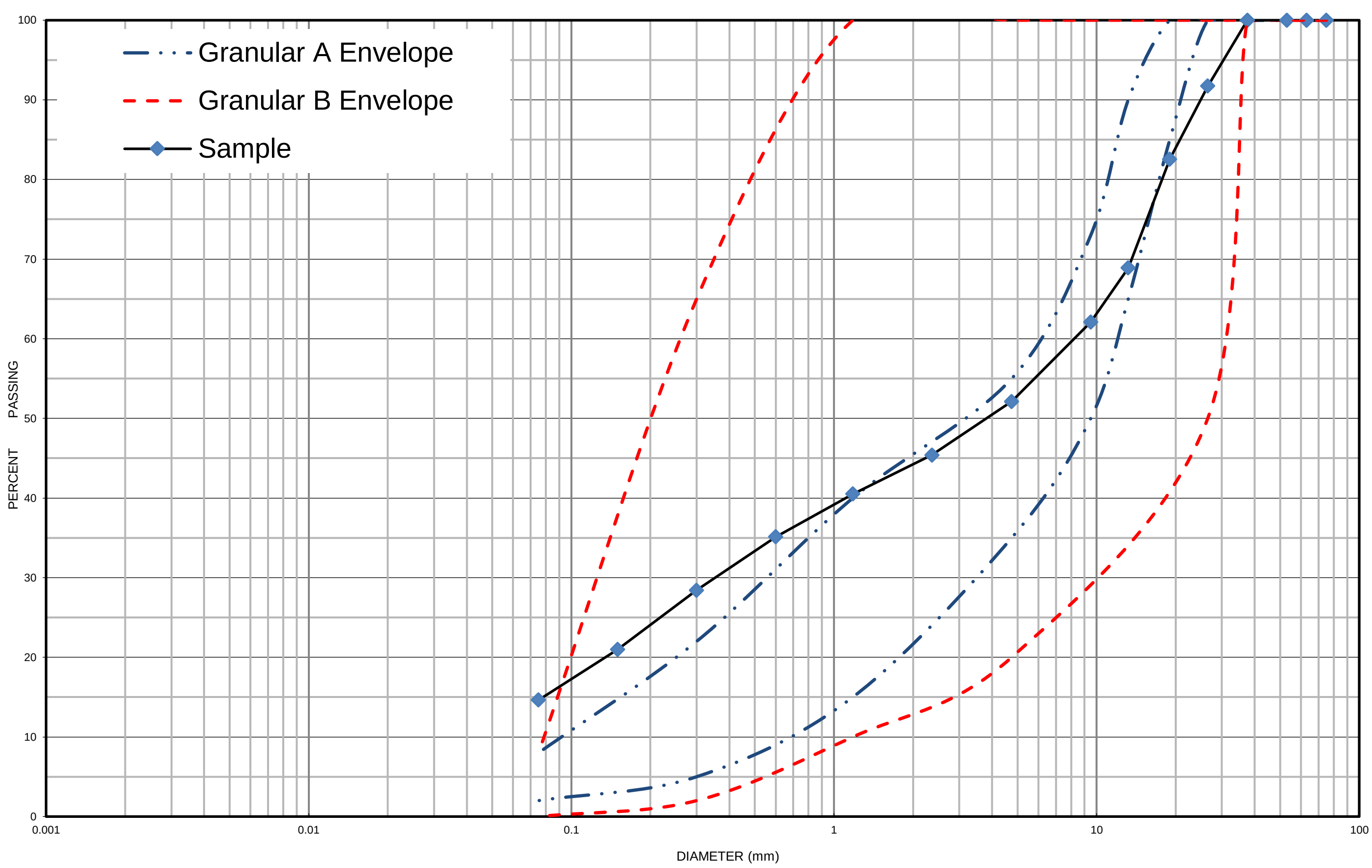
Project Number: *11757-001* **Client:** *JDM Designworks Inc*

Project Name: *Geotechnical Investigation - Petawawa Sewage Treatment Plan*

Sample Date: *May 17 & 18, 2021* **Sampled By:** *Farhan Imtiaz - Cambium Inc.*

Location: *BH 106-21 SS 1* **Depth:** *0.2 m to 0.3 m* **Lab Sample No:** *S-21-0560*

UNIFIED SOIL CLASSIFICATION SYSTEM					
CLAY & SILT (<0.075 mm)	SAND (<4.75 mm to 0.075 mm)			GRAVEL (>4.75 mm)	
	FINE	MEDIUM	COARSE	FINE	COARSE



MIT SOIL CLASSIFICATION SYSTEM							
CLAY	SILT	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	BOULDERS
		SAND			GRAVEL			

Borehole No.	Sample No.	Depth	Gravel	Sand	Silt	Clay	Moisture
BH 106-21	SS 1	0.2 m to 0.3 m	48	37	15		2.8

Description	Classification	D_{60}	D_{30}	D_{10}	C_u	C_c
Gravel and Sand some Silt	SM	8.000	0.360	0.000	-	-

Additional information available upon request

Issued By: [signature] (Senior Project Manager) *Date Issued:* *June 8, 2021*

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Moisture Content

Project Number: 11757-001
Project Name: Geotechnical Investigation - Petawawa Sewage Treatment Plan
Client: JDM Designworks Inc
Date Taken: 2021-05-17
Lab Number: S-21-0554
Date Tested: 2021-05-31
Tested By: Caleb J.

Borehole Number	Sample Number	Sample Depth (m)	Water Weight (g)	Water Content (%)	Additional Observations
101	5	3.048-3.505	273.3	26.7	NR
102	1	0.122-0.610	78.7	12.0	NR
103	4	2.438-2.743	177.2	33.7	NR
104	3	1.524-1.981	79.6	11.0	NR
105	2	0.762-1.219	78.9	12.4	NR
106	1	0.152-0.335	11.4	2.8	NR
101	1	0.000-0.305	10.6	6.8	1
101	2	0.762-1.219	45.3	16.2	
101	3	1.524-1.981	40.9	27.0	
101	4	2.286-2.743	86.1	33.7	
101	6	4.572-5.029	37.5	12.6	NR
101	7	6.096-6.248	39.6	11.4	
102	2	0.762-1.219	26.6	17.2	
102	3	1.524-1.981	34.5	14.8	
102	4	2.286-2.743	33.0	14.0	
102	5	3.048-3.505	32.1	14.6	
102	6	4.572-5.029	35.9	9.6	
103	4	2.286-2.438	43.4	21.2	
103	1	0.000-0.229	34.0	22.4	1
103	5	3.048-3.505	62.3	49.2	
103	3	1.524-1.981	44.3	20.2	
104	1	0.183-0.610	31.9	16.3	
104	4	2.286-3.505	31.6	12.9	
104	2	0.762-1.219	31.3	20.5	
105	4	3.048-3.505	23.3	10.6	
105	1	0.122-0.610	14.4	6.6	
105	3	2.286-2.743	31.4	11.9	

1 – Contains organics
2 – Contains rubble
3 – Hydrocarbon Odour
4 – Unknown Chemical Odour
5 – Saturated – free water visible
6 – Very moist – near optimum moisture content
7 – Moist – below optimum moisture
8 – Dry – dry texture – powdery
9 – Very small – caution may not be representative
10 – Hold sample for gradation analysis

Moisture Content

Project Number: 11757-001
Project Name: Geotechnical Investigation - Petawawa Sewage Treatment Plan
Client: JDM Designworks Inc
Date Taken: 2021-05-17
Lab Number: S-21-0554
Date Tested: 2021-05-31
Tested By: Caleb J.

Borehole Number	Sample Number	Sample Depth (m)	Water Weight (g)	Water Content (%)	Additional Observations
106	3	1.829-1.981	34.8	12.7	
106	2	0.762-1.219	35.6	15.4	
107	4	2.286-2.652	22.9	10.3	
107	2	0.762-1.219	30.8	18.9	
107	3	1.524-1.981	47.9	25.3	
107	1	0.091-0.610	14.1	6.0	

1 – Contains organics
2 – Contains rubble
3 – Hydrocarbon Odour
4 – Unknown Chemical Odour
5 – Saturated – free water visible
6 – Very moist – near optimum moisture content
7 – Moist – below optimum moisture
8 – Dry – dry texture – powdery
9 – Very small – caution may not be representative
10 – Hold sample for gradation analysis

Appendix C

Seismic Hazard Calculation

2015 National Building Code Seismic Hazard Calculation

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

Site: 45.900N 77.249W **User File Reference:** Petawawa Waste Water Treatment Plant 2021-07-02 18:59 UT

Requested by: City of Petawawa

Probability of exceedance per annum	0.000404	0.001	0.0021	0.01
Probability of exceedance in 50 years	2 %	5 %	10 %	40 %
Sa (0.05)	0.388	0.201	0.115	0.032
Sa (0.1)	0.457	0.248	0.148	0.046
Sa (0.2)	0.380	0.212	0.130	0.043
Sa (0.3)	0.288	0.163	0.102	0.035
Sa (0.5)	0.203	0.117	0.074	0.026
Sa (1.0)	0.102	0.060	0.038	0.013
Sa (2.0)	0.049	0.028	0.018	0.005
Sa (5.0)	0.013	0.007	0.004	0.001
Sa (10.0)	0.005	0.003	0.002	0.001
PGA (g)	0.244	0.135	0.081	0.025
PGV (m/s)	0.168	0.093	0.056	0.017

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

References

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

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

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

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

Natural Resources Canada   Ressources naturelles Canada

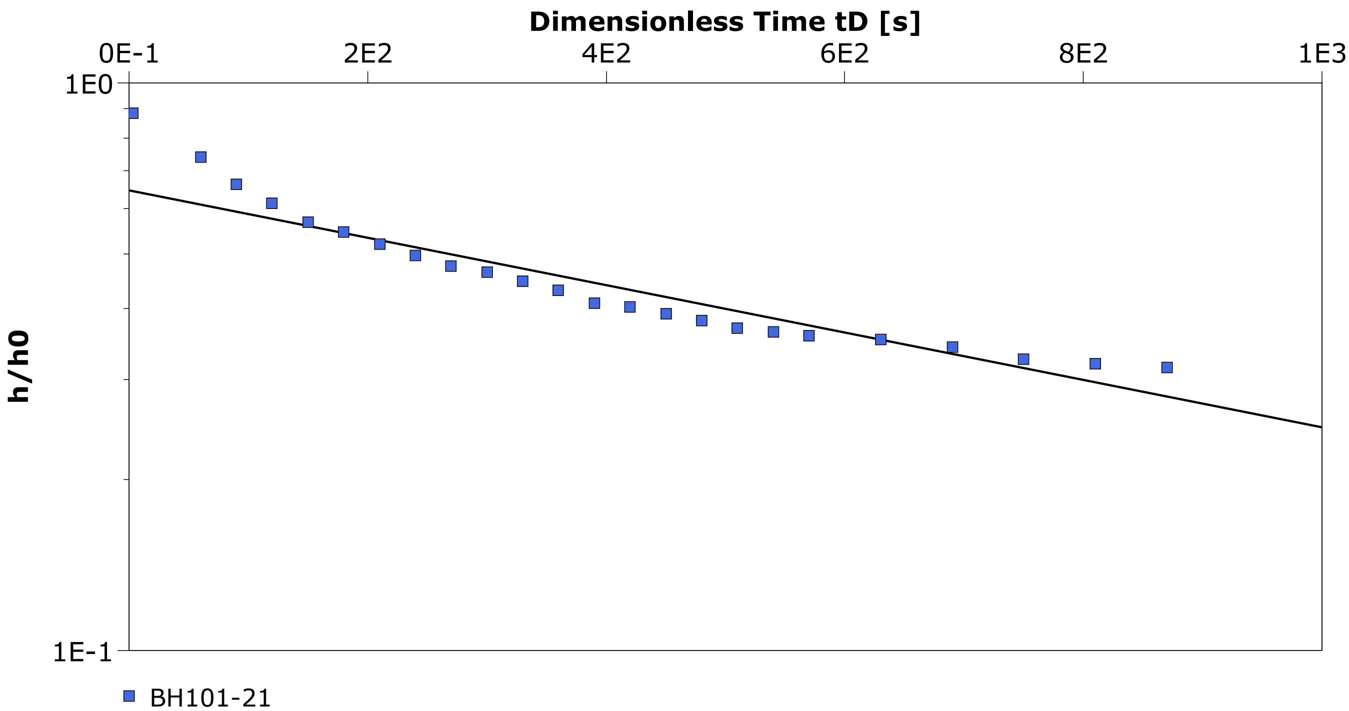
Canada

Appendix D

Aquifer Test Outputs / Graphs

	Slug Test Analysis Report
	Project: Geotechnical Investigation
	Number: 11757-001
	Client: Ontario Clean Water Agency

Location: Petawawa WWTP	Slug Test: Slug Test 1	Test Well: BH101-21
Test Conducted by: F. Imtiaz		Test Date: 6/18/2021
Analysis Performed by: P. Garrett	BH101-21	Analysis Date: 6/24/2021
Aquifer Thickness: 2.70 m		

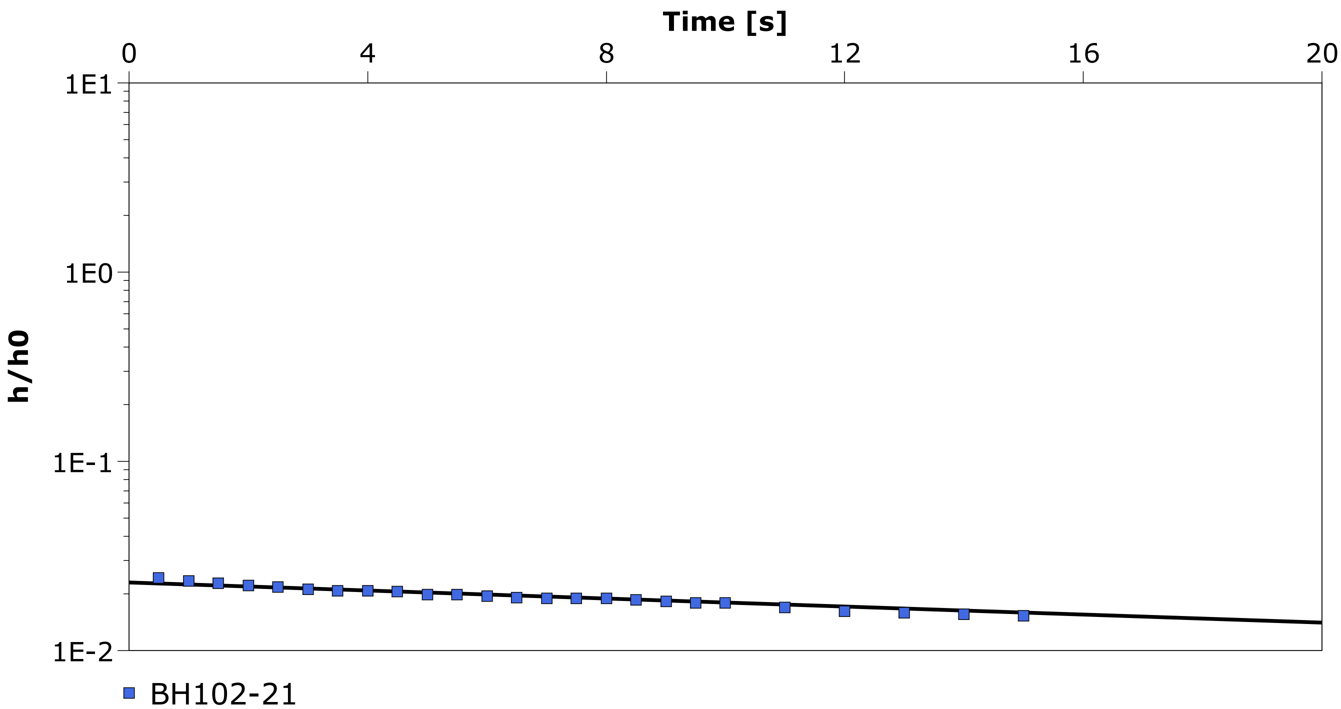


Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
BH101-21	4.89×10^{-7}	

	Slug Test Analysis Report
	Project: Geotechnical Investigation
	Number: 11757-001
	Client: Ontario Clean Water Agency

Location: Petawawa WWTP	Slug Test: Slug Test 1	Test Well: BH102-21
Test Conducted by: F. Imtiaz		Test Date: 6/18/2021
Analysis Performed by: P. Garrett	BH102-21	Analysis Date: 6/24/2021
Aquifer Thickness: 2.94 m		

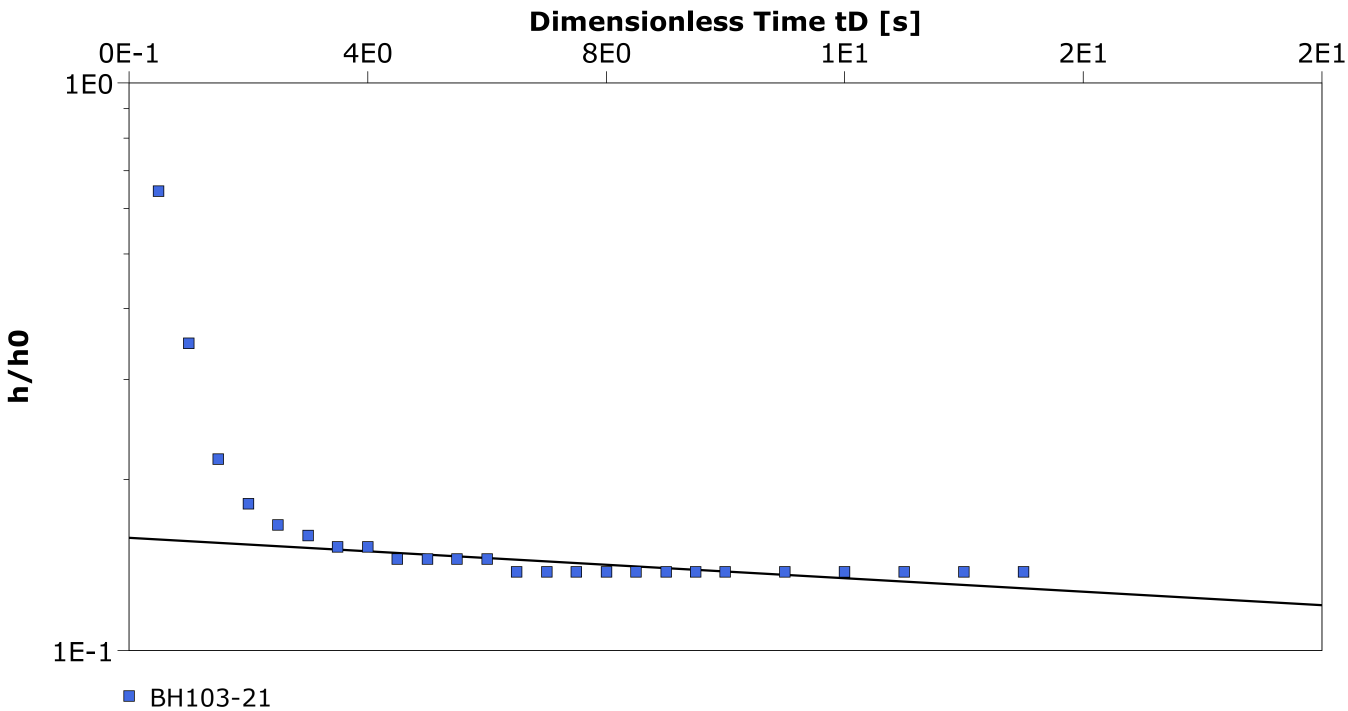


Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
BH102-21	1.27×10^{-5}	

	Slug Test Analysis Report
	Project: Geotechnical Investigation
	Number: 11757-001
	Client: Ontario Clean Water Agency

Location: Petawawa WWTP	Slug Test: Slug Test 1	Test Well: BH103-21
Test Conducted by: F. Imtiaz		Test Date: 6/18/2021
Analysis Performed by: P. Garrett	BH103-21	Analysis Date: 6/24/2021
Aquifer Thickness: 2.13 m		

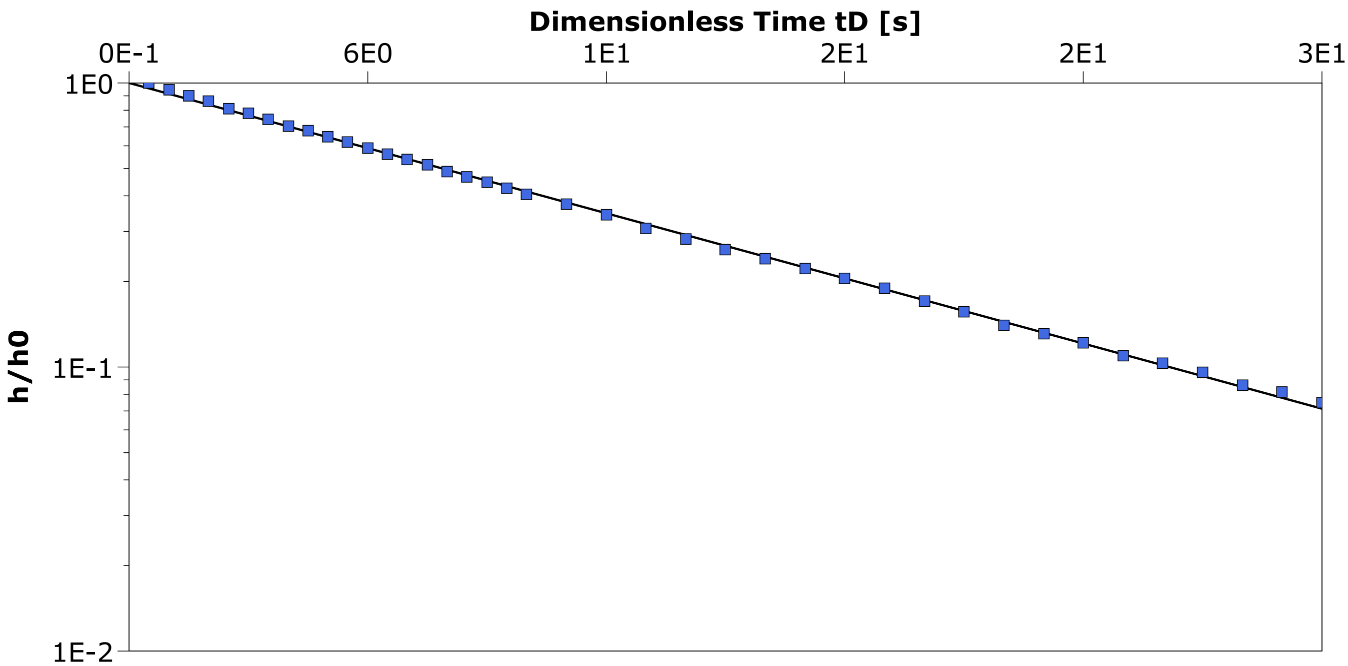


Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
BH103-21	8.24×10^{-6}	

	Slug Test Analysis Report
	Project: Geotechnical Investigation
	Number: 11757-001
	Client: Ontario Clean Water Agency

Location: Petawawa WWTP	Slug Test: Slug Test 1	Test Well: MW108-21
Test Conducted by: F. Imtiaz		Test Date: 6/18/2021
Analysis Performed by: P. Garrett	MW108-21	Analysis Date: 6/24/2021
Aquifer Thickness: 3.75 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
MW108-21	3.81×10^{-5}	