Geotechnical Investigation

Upgrades to Wastewater Treatment Plant
300 Water Street West
Napanee, Ontario

Town of Greater Napanee
C/o EVB Engineering

Draft for Review

This document is in draft form. A final version of this document may differ from this draft. As such, the contents of this draft document shall not be relied upon. GHD disclaims any responsibility or liability arising from decisions made based on this draft document.

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1. Introduction

GHD was retained by The Town of Greater Napanee (Client) to undertake a Geotechnical Investigation for proposed upgrades (Project) to the Napanee Waste Water Treatment Plant (WWTP). The Napanee WWTP is located at 300 Water Street West in Napanee, Ontario (Site).

EVB Engineering Inc. (EVB or Engineer) who is retained by the Client to complete the design, was involved in the scope of work for GHD and the geotechnical investigation.

An original investigation was completed in May 2017. Subsequent changes were made to the geometry and layout of the proposed Project, and therefore a second additional investigation was requested. This additional investigation was performed in November 2017. The following report presents all findings in the following subsections.

1.1 Original Investigation (May 2017)

Originally, the Project was to consist of the design and construction of a flare stack, digester, grit chamber, aeration cells, and chlorine contact tank. The purpose of the original investigation was to evaluate the subsoil conditions at the 11 borehole locations requested by the Engineer, and to provide geotechnical parameters to the Engineer for their design of the new foundations and underground utilities.

GHD's scope of work for the original investigation was outlined in our proposal, Ref No: 11103740Dafoe-1, dated April 13, 2017, and was agreed to by Mr. Marco Vincelli of EVB Engineering Inc. on April 20, 2017 by means of a signed offer of services.

In general, GHD's scope of work for the original investigation consisted of the following activities:

- Underground Utility Locates | GHD requested utility locates using the Ontario One-Call database.
- Drilling of Boreholes | GHD retained a geotechnical drilling subcontractor to drill at 11 borehole locations. Five boreholes were drilled to practical auger refusal at depths ranging from 5.7 to 8.8 m below the existing ground surface (mbgs). Four boreholes were drilled to auger refusal at depths ranging from 6.9 to 12.8 mbgs plus an additional 3.0 m of rock coring in each. Two boreholes were drilled to an approximate depth of 9.0 mbgs without encountering refusal. A total of four monitoring wells were installed in the boreholes. One of the planned boreholes (BH2-17) could not be drilled due to existing underground services that the Owner was unable to locate.
- Borehole Supervision | GHD logged the soil conditions encountered at the boreholes based upon the samples that were collected.
- Laboratory Testing | GHD submitted one soil sample to a subcontractor laboratory for analysis of pH, conductivity, redox potential, chloride, sulphide, and sulphate. Three clay samples were tested for Atterberg limits, and three sand samples had grain size analyses performed in the GHD geotechnical laboratory.
- Reporting | GHD prepared a memo entitled "Preliminary Geotechnical Information" dated July 2017.

1.2 Additional Investigation (November 2017)

Based upon discussions with EVB, it is our understanding that the current Project is to consist of the design and construction of a headworks/primary clarifier building, a secondary treatment building, and an operations building. Associated with these new structures will also be new underground services.

The purpose of this additional investigation was to evaluate the subsoil conditions at 11 additional borehole locations, and to provide geotechnical parameters to assist in the design of the new foundations and underground utilities. This report contains the findings of our fieldwork, subsurface conditions and recommendations, and components for the design of the proposed structures.

GHD's scope of work for this current investigation was outlined in our proposal, Ref No: 1140477Dafoe-1, dated August 30, 2017, and was agreed to by Mr. Jamie Baker of EVB on October 25, 2017 by means of a signed offer of services.

In general, GHD's scope of work for the current investigation consisted of the following activities:

- Underground Utility Locates | GHD requested utility locates using the Ontario One-Call database.
- Drilling of Boreholes | GHD retained a geotechnical drilling subcontractor to drill at 11 additional borehole locations. Eight boreholes were drilled to practical auger refusal at depths ranging from 6.8 to 12.3 mbgs. Three boreholes were drilled to auger refusal at depths ranging from 6.8 to 10.7 mbgs plus an additional 3.0 m of rock coring in each. A total of three shallow and three deep monitoring wells were installed in the boreholes.
- Borehole Supervision | GHD logged the soil conditions encountered at the boreholes based upon the samples that were collected.
- Laboratory Testing | No additional laboratory testing was performed as part of the current investigation.
- Reporting | GHD reviewed the field and laboratory results and prepared this Geotechnical Investigation report.

Environmental characterization of the soils or groundwater were not part GHD's scope of work for this Project. Hydrogeological consulting in support of a Permit to Take Water (PTTW) application was also not part of GHD's scope of work.

This report has been prepared with the understanding that the design will be as described in Section 2 and will be carried out in accordance with all applicable codes and standards. Any changes to the Project described herein will require that GHD be retained to assess the impact of the changes on the report recommendations provided.

2. Site and Project Description

The Napanee WWTP is located on the north shoreline of the Napanee River at a civic address of 300 Water Street West in Napanee, Ontario. The Site is bounded to the west by vacant land owned by the Client, and bounded to the east by a residential apartment complex. The northern boundary of the Site is Water Street West, which is at a higher elevation than the Site. The southern boundary of the Site is the shoreline of the Napanee River. The Site topography is sloping downwards to the south. Water Street West is at an approximate elevation near 83 m above sea level (masl) and the Napanee River is at an approximate elevation near 76 masl. The Site is currently occupied by existing infrastructure related to the existing WWTP facility. The location of the Site within the Town of Napanee is shown on the Site Location Map attached as Figure 1 at the end of this report.

Based upon discussions with EVB, our understanding is that the WWTP upgrades will consist of the design and construction of multiple new structures to the existing facility. The three structures discussed within this Geotechnical Investigation are described as follows. They are shown on the drawing entitled Proposed New Structures, attached as Figure 3 at the end of this report.

- Construction of a new headworks/primary clarifier building. We understand that the headworks is proposed be founded at approximately 6.0 mbgs on a slab-on-grade with conventional pad and strip footings. We understand that the primary clarifier is proposed be founded at approximately 5.0 – 6.0 mbgs on a raft foundation.
- Construction of a new secondary treatment building. We understand that the secondary treatment is proposed be founded at approximately 4.0 mbgs on a raft foundation.
- Construction of a new operations building. We understand that the operations building is proposed be founded at approximately 4.0 mbgs on a raft foundation.

GHD's understanding of the proposed WWTP upgrades are based on the email request from Jamie Baker of EVB on August 3, 2017 and the accompanying drawings "FIG.7: Converting Existing…" (Ref No. 17102, dated July 6, 2017) and "FIG.8 Three Train Hybas…" (Ref No. 17102, dated July 6, 2017). GHD was subsequently provided, on December 18, 2017, with a received a more current drawing "FIG.1: Conceptual Site Plan" (Ref No. 17102, dated August 17, 2017). This drawing is attached in Appendix D for reference.

3. Field Investigation

3.1 Original Drilling (May 2017)

The original geotechnical drilling consisted of drilling 11 boreholes. Boreholes were located as requested by the Engineer based on the borehole location sketch provided by the Client on April 10, 2017.

A geotechnical drilling subcontractor, GET Drilling Ltd., was retained by GHD to carry out the drilling, which was supervised by GHD technical field staff. The drilling program was performed from May 15 to 19, 2017. The following drilling was performed.

Note: The original proposed scope of work was to include BH2-17, which was to be located next to the existing clarifiers. Due to existing underground utilities, the Owner cancelled this borehole.

- Five boreholes, BH1-17, MW3-17, BH4-17, BH11-17, and MW12-17, were drilled to practical auger refusal at depths ranging from 5.7 to 8.8 mbgs. No coring was performed in these locations.

- Four boreholes MW6-17, BH7-17, BH8-17, and BH9-17, were drilled to auger refusal at depths ranging from 6.9 to 12.8 mbgs plus an additional approximately 3.0 m of rock coring in each location.
- Two boreholes, BH5-17 and MW10-17, were drilled to an approximate depth of 9.0 mbgs without encountering refusal.
- Boreholes MW3-17, MW10-17, and MW12-17 had monitoring wells installed with screens sealed into the underlying sands. Borehole MW6-17 had a monitoring will installed with a screen sealed into the bedrock.

The drilling was performed using a truck mounted drill rig adapted for geotechnical drilling. Boreholes were advanced through the overburden by means of hollow-stem continuous-flight auger equipment. Standard Penetration Tests (SPTs) were performed at regular intervals using a 50 mm diameter split-spoon sampler and a 63.5 kg hammer free falling from a distance of 760 mm, to evaluate soil consistency and to collect samples. The number of drops required to drive the sampler 0.3 m was recorded as N-Value. The shear strength of the cohesionless soils, where possible, were measured using a Field Vane Test (FVT) and estimated with a pocket penetrometer. Selected boreholes were further advanced beyond the auger refusal depth using NQ-sized double-barrel wireline diamond coring in order to confirm the existence of bedrock and to comment on the type and quality of bedrock. Boreholes were backfilled with auger cuttings and bentonite hole-plug, or outfitted with monitoring wells installed by a licensed well driller.

The location of the boreholes are shown on the Borehole Location Plan attached as Figure 2 at the end of this report. The sub-surface conditions at each of the test locations were logged by GHD technical field staff and are presented in the Borehole Logs, attached as Appendix A. Ground surface elevations at the borehole locations were surveyed by Hopkins-Chitty Surveying Ltd.

3.2 Additional Drilling (November 2017)

The additional geotechnical drilling consisted of drilling 11 additional boreholes. Boreholes were located as specified in our proposal Ref No: 1140477Dafoe-1, dated August 30, 2017.

A geotechnical drilling subcontractor, GET Drilling Ltd., was retained by GHD to carry out the drilling, which was supervised by GHD technical field staff. The drilling program was performed from November 23 to 28, 2017. The following drilling was performed:

- Eight boreholes, BH14-17, MW15-17, BH16-16, BH18-17, BH19-17, BH20-17, BH22-17, and BH23-17, were drilled to practical auger refusal at depths ranging from 6.8 to 12.3 mbgs. No coring was performed in these locations.
- Three boreholes BH13-17, MW17-17, and MW21-17, were drilled to auger refusal at depths ranging from 6.8 to 10.8 mbgs plus an additional approximately 3.0 m of rock coring in each location.
- Boreholes MW15-17, MW17-17, and MW21-17 had monitoring wells installed with shallow screens sealed into the clay, but also had additional deeper screens placed in the sandy soils.

The drilling was performed using a truck mounted drill rig adapted for geotechnical drilling. Boreholes were advanced through the overburden by means of hollow-stem continuous-flight auger equipment. SPTs were performed at regular intervals using a 50 mm diameter split-spoon sampler and a 63.5 kg hammer free falling from a distance of 760 mm, to evaluate soil consistency and to collect samples. The shear strength of the cohesionless soils, where possible, were measured using FVTs and estimated using a pocket penetrometer. Selected boreholes were further advanced beyond the auger refusal depth using NQ-sized double-barrel wireline diamond coring.

3.3 Geotechnical Laboratory Testing

The geotechnical laboratory testing component of this Geotechnical Investigation included the submittal of one soil sample to assess corrosion potential of the native soils to buried cast iron metal or concrete by analyzing the sample for pH, sulphides, chloride, sulphates, redox potential, and conductivity. Soil sample BH8-17 SS3 was delivered to Paracel Laboratories Ltd. in Kingston on May 24, 2017, under chain of custody Ref No: 113499. The results of these analyses were received back from the laboratory on May 30, 2017, under report Ref No: 1721113. The results of the corrosion package testing are summarized in the Section 6.7 below.

Four clay samples, BH1-17 SS4, BH1-17 SS7, BH9-17 SS2, and BH9-17 SS6, had Atterberg limits testing performed. Four sand samples BH1-17 SS8, BH1-17 SS9, BH9-17 SS8, and BH9-17 SS9, had grain size analyses performed in GHD's geotechnical laboratory. The results of this testing were used in the soil descriptions below and are attached in Appendix B at the end of this report.

4. Subsoil Conditions

In general, the soils encountered on this Site consisted of a sandy fill soils overlying a native silty clay to clayey silt. The clayey soils were underlain by a loose to compact sand. Refusal on assumed bedrock was found to be sloping downwards to the south at depths ranging from approximately 5.7 to 12.8 mbgs. Where coring of the bedrock was performed, a limestone bedrock was encountered. Based on the Rock Quality Designation (RQD) or recovered cores of the bedrock, the rock in the cores are of "Excellent" quality, based upon referencing the Condition Foundation Engineering Manual (CFEM) 4th edition 2006.

The depths and soil types described below and in the Borehole Logs represent the conditions at the test locations only and may vary in other areas, especially in previously excavated and/or backfilled areas, such as near existing structures, in former excavations, or utility trenches. Since the proposed structures described in this report will be constructed immediately adjacent to the existing foundations of adjacent buildings, the soil conditions may vary from the borehole logs.

General descriptions of the subsurface conditions as represented by the boreholes are summarized in the following sections, with a graphical representation of each of the borehole locations provided on the Borehole Logs. Notes on Borehole and Test Pit Logs are also provided at the end of this report.

4.1 Surficial Coverings

Boreholes BH1-17, MW3-17, MW6-17, BH7-17, BH8-17, MW10-17, BH11-17, MW12-17, MW15-17, BH16-17, MW17-17, BH19-17, MW21-17, and BH23-17 were located in grass covered areas and had a surficial covering of topsoil. The topsoil was organic, brown in colour, and was in a damp condition. The topsoil ranged in thickness in the logs from approximately 50 mm in MW3-17, MW15-17, and BH16-17 to approximately 200 mm thick in BH7-17, MW17-17, and MW21-17.

Borehole BH4-17 was located in an area with asphaltic concrete pavement which was approximately 75 mm thick followed by a granular base course. The base course consisted of a sandy gravel. It was compact in compactness, grey in colour, damp, and was approximately 230 mm thick.

Borehole BH9-17 was located in an area with gravel pavement which was approximately 200 mm thick.

Boreholes BH5-17, BH13-17, BH14-17, BH18-17, BH20-17, and BH22-17 had fill soils at the surface, with no topsoil or pavement covering.

The topsoil and asphalt depths and thicknesses described within this report are for planning purposes only and should not be used for quality determinations or quantity take-offs.

4.2 Fill Soils

In all borehole locations, a heterogeneous mix of fill soils were encountered at the surface and were generally sandy silts to gravelly sands and were loose to compact, brown to grey, and moist.

Buried topsoil layers were encountered in BH1-17, BH5-17, MW6-17, MW12-17, BH13-17, BH14-17, MW15-17, and BH20-17 at approximate depths near 1.8, 1.4, 1.6, 1.6, 1.0, 0.6, 1.1, and 1.0 mbgs, respectively.

The following table is presented which documents the depth to native soil encountered in the borehole locations:

Table 4.1 Depth to Native Soil in Boreholes

Proposed Structure	Borehole Location	Ground Surface Elevation (masl)	Approximate Native Depth (mbgs)	Approximate Native Elevation (masl)
Headworks/Primary Clarifiers	BH13-17	81.07	2.1	78.9
	BH14-17	81.09	2.2	79.0
	BW15-17	78.77	1.1	77.7
	BH16-17	78.43	0.9	77.6
Secondary Treatment	BH7-17	78.15	2.8	75.3
	BH8-17	78.73	1.2	77.6
	BH9-17	79.49	0.6	78.9
	MW10-17	77.63	0.6	77.0
	BH11-17	78.77	0.4	78.3
	MW12-17	79.80	1.6	78.2
	MW21-17	77.72	1.8	75.9
	BH23-17	80.00	1.5	78.5

Table 4.1 Depth to Native Soil in Boreholes

Proposed Structure	Borehole Location	Ground Surface Elevation (masl)	Approximate Native Depth (mbgs)	Approximate Native Elevation (masl)
Operations Building	BH5-17	77.83	2.8	75.0
	MW17-17	77.24	0.8	76.4
	BH18-17	77.62	1.1	76.6
	BH19-17	76.99	1.8	75.0
	BH20-17	77.87	2.7	75.2
	BH22-17	77.72	3.2	74.5
Other Locations	BH1-17	78.09	1.8	76.3
	MW3-17	81.30	1.4	79.9
	BH4-17	81.31	0.5	80.8
	MW6-17	77.62	1.6	76.0

Designers are cautioned that the depth of fill materials may be deeper adjacent to existing structures and foundations, and in former excavations or service trenches.

4.3 Shallow Silt Some Sand or Silty Sand

In borehole BH4-17 a native silt with some sand was encountered underlying the fill soils. This layer was loose, brown in colour, and was recovered in a damp condition. The silt with some sand in this location was found to extend to an approximately depth of 1.7 mbgs, or to an approximate elevation near 79.6 masl.

In borehole BH11-17 a native silty sand was encountered underlying the fill soils. This layer was loose, brown in colour, and was recovered in a damp condition. The silty sand in this location was found to extend to an approximately depth of 1.0 mbgs, or to an approximate elevation near 77.7 masl.

4.4 Native Clay and Silt or Silty Clay

In boreholes MW3-17, BH4-17, BH5-17, MW6-17, BH7-17, BH8-17, BH9-17, MW10-17, BH11-17, MW12-17, BH13-17, BH4-17, MW15-17, BH16-17, MW17-17, BH18-17, BH19-17, BH20-17, MW21-17, BH22-17, and BH23-17 the upper cohesive soils were described as a clay and silt. They were very stiff in consistency, brown in colour, and were recovered in a damp condition. In BH1-17, the very stiff clay and silt soil was not encountered.

In boreholes BH1-17, BH5-17, MW6-17, BH7-17, BH8-17, BH9-17, MW10-17, BH11-17, MW12-17, MW15-17, BH16-17MW17-17, BH18-17, BH19-17, BH20-17, MW21-17, BH22-17, and BH23-17, the cohesive soils transitioned to a silty clay that was slightly weaker and only firm to stiff in consistency, grey in colour and was recovered in a damp to moist condition. It is important to note that water bearing sand seams were encountered throughout this deposit becoming more frequent with depth.

4.5 Deeper Sandy Soils

In borehole locations BH1-17, MW3-17, BH4-17, MW6-17, BH7-17, BH8-17, BH9-17, MW10-17, BH11-17, MW12-17, BH13-17, BH14-17, MW15-17, BH16-17, MW17-17, BH18-17, BH19-17, BH20-17, MW21-17, BH22-17, BH23-17 a sandy soil was found to be underlying the clays. This soil was described as a silty sand in the majority of locations. In BH1-17 and BH9-17 it was described as a silty clayey sand. In MW3-17, MW6-17 and BH10-17 it was described as a silty sand with trace to some gravel. In general, the deeper sandy soils were loose to compact in compactness, brown in colour, and were recovered in a wet condition.

The following table is presented which documents the depth to sandy soils encountered in the borehole locations.

Table 4.2 Depth to Sandy Soils in Boreholes

Proposed Structure	Borehole Location	Ground Surface Elevation (masl)	Approximate Depth of Sandy Soils (mbgs)	Approximate Elevation of Sandy Soils (masl)
Headworks/Primary Clarifiers	BH13-17	81.07	6.1	75.0
	BH14-17	81.09	5.8	75.4
	MW15-17	78.77	6.7	72.1
	BH16-17	78.43	6.1	72.3
Secondary Treatment	BH7-17	78.15	8.9	69.3
	BH8-17	78.73	6.6	72.1
	BH9-17	79.49	6.0	73.5
	MW10-17	77.63	7.8	69.9
	BH11-17	78.77	7.0	71.7
	MW12-17	79.80	6.7	73.1
	MW21-17	77.72	8.4	69.3
	BH23-17	80.00	5.6	74.4
Operations Building	BH5-17	77.83	>9.0*	<68.8*
	MW17-17	77.24	9.2	68.1
	BH18-17	77.62	9.2	68.5
	BH19-17	76.99	9.9	67.1
	BH20-17	77.87	10.2	67.7
	BH22-17	77.72	9.8	68.0
Other Locations	BH1-17	78.09	7.8	70.3
	MW3-17	81.30	3.6	77.6
	BH4-17	81.31	3.9	77.4
	MW6-17	77.62	9.2	68.5

*Sandy soils not encountered within 9.0 m drill depth.

4.6 Refusal

The following table is presented which summarizes the refusal observations in the borehole locations.

Table 4.3 Refusal Observations in Boreholes

Proposed Structure	Borehole Location	Ground Surface Elevation (masl)	Approx. Refusal Depth (mbgs)	Approx. Refusal Elevation (masl)	Notes
Headworks /Primary Clarifiers	BH13-17	81.07	6.8	74.2	Confirmed limestone by coring
	BH14-17	81.09	6.8	74.3	Auger refusal
	MW15-17	78.77	7.8	71.0	Auger refusal
	BH16-17	78.43	88.4	70.1	Auger refusal
Secondary Treatment	BH7-17	78.15	11.2	67.0	Confirmed limestone by coring
	BH8-17	78.73	8.4	70.4	Confirmed limestone by coring
	BH9-17	79.49	6.9	72.6	Confirmed limestone by coring
	MW10-17	77.63	> 9.0	< 68.6	Refusal not encountered
	BH11-17	78.77	8.3	70.5	Auger refusal
	MW12-17	79.80	7.2	72.6	Auger refusal
	MW21-17	77.72	10.3	67.4	Confirmed limestone by coring
	BH23-17	80.00	6.9	73.1	Auger refusal
Operations Building	BH5-17	77.83	> 9.0	< 68.8	Refusal not encountered
	MW17-17	77.24	10.7	66.6	Confirmed limestone by coring
	BH18-17	77.62	11.3	66.3	Auger refusal
	BH19-17	76.99	11.4	65.6	Auger refusal
	BH20-17	77.87	12.1	65.8	Auger refusal
	BH22-17	77.72	12.3	65.4	Auger refusal
Other Locations	BH1-17	78.09	8.8	69.3	Auger refusal
	MW3-17	81.30	6.4	74.9	Auger refusal
	BH4-17	81.31	5.7	75.6	Auger refusal
	MW6-17	77.62	12.8	64.9	Confirmed limestone by coring

All boreholes except BH5-17 and MW10-17 were advanced to practical refusal on assumed bedrock. The bedrock was confirmed in seven boreholes, MW6-17, BH7-17, BH8-17, BH9-17, BH13-17, MW17-17, and MW21-17 by means of double walled wire-line diamond coring methods. In general, the rock identified in the boreholes was found to be limestone with good to excellent quality based on the RQD.

Designers and Contractors are cautioned that cobbles and boulders may be present in the sandy soils. Therefore the auger refusal depths presented above may represent refusal on cobbles or boulders as opposed to the bedrock surface.

5. Groundwater Conditions

A detailed groundwater study was not included as a part of the Geotechnical Investigation scope of work. Borehole locations MW3-17, MW6-17, MW10-17, and MW12-17 were outfitted with piezometer standpipes screened at various levels. Borehole locations MW15-17, MW17-17, and MW21-17 had monitoring wells installed with both a screen in the clay and a screen in the underlying sand. The water levels recorded in the piezometer standpipes are presented in the following table as a guidance for Designers and Contractors.

Table 5.1 Groundwater Observations in Standpipes

Location	Ground Surface Elevation (masl)	Screen Elevation (masl)	Soil Deposit at Screen Elevation	Water Level Recorded in Standpipes		
				Date of Measurement	Depth (mbgs)	Elevation (masl)
MW3-17	81.30	76.4 – 74.9	Silty Sand	May 19, 2017	4.2	77.1
MW6-17	77.62	63.6 – 61.9	Bedrock	May 19, 2017	-1.7*	79.3*
MW10-17	77.63	69.6 – 68.6	Silty Sand	May 19, 2017	1.2	76.5
MW12-17	79.80	73.4 – 72.6	Silty Sand	May 19, 2017	3.0	76.9
MW15-17-d	78.77	72.9 – 71.0	Sand	Nov 27, 2017	0.4	78.4
MW15-17-s	78.79	76.1 – 74.2	Clay and Silt	Nov 27, 2017	0.6	78.2
MW17-17-d	77.24	68.4 – 66.6	Sand	Nov 27, 2017	0.7	76.5
MW17-17-s	77.22	71.5 – 69.6	Silty Clay	Nov 27, 2017	0.6	76.6
MW21-17-d	77.72	66.5 – 64.1	Bedrock	Nov 27, 2017	0.9	76.8
MW21-17-s	77.71	74.9 – 73.1	Clay and Silt	Nov 27, 2017	0.9	76.8
*Artesian groundwater conditions were noted in MW6-17.						

Artesian groundwater conditions were noted in MW6-17. The monitoring well was installed on May 16, 2017 with a screen sealed into the bedrock. The monitoring well was extended above grade in response to the artesian condition and after three days reached 1.7 m above the existing ground surface. At the request of the Engineer, the monitoring well was abandoned on May 19, 2017.

Based on our email correspondence with EVB Engineering Inc. GHD understands that the mean water level in the Napanee River at outfall for this Site is approximately 74.86 masl, and the high water level is approximately 75.31 masl.

It should be noted that the groundwater table is subject to seasonal fluctuations and in response to precipitation and snowmelt events, and is anticipated to be at its highest level during the thaw in early spring. Sand and silt seams were encountered in the clay soils; these seams are zones of higher permeability, thus higher rates of seepage. Higher rates of seepage would also be expected at the fill-native interface.

6. Discussion and Recommendations

6.1 General Considerations

The recommendations provided in this report are based our understanding of the proposed Project which is described in Section 2 above, and that it will be carried out in accordance with all applicable codes and standards. Any changes to the Project described will require a review by GHD to assess the impact of the changes on the report recommendations provided.

Based on our understanding of the proposed Project, the subsurface conditions encountered in the boreholes, and assuming them to be representative of the subsurface conditions across the Site, the following recommendations are provided. The most important geotechnical considerations for the design and construction of the proposed Project are expected to be the following:

- Groundwater Management | All of the planned excavations will require control of groundwater. GHD recommends that the Client have a hydrogeological investigation completed in support of Site planning for dewatering, de-pressurization, and a PTTW.
- Artesian Groundwater Conditions | The excavations for the Headworks and the Secondary Treatment may extend below the water table and may penetrate through the clays into the more permeable sand deposits. A comprehensive dewatering plan will be necessary to avoid base heave and disturbance. The well, MW6-17, was sealed into the bedrock below elevation 63.5 m. It is suspected that a confined but permeable seam in the bedrock was intercepted. The water level in the well rose to elevation 79.3 m or about 1.7 m above the ground surface were encountered in MW6-17. In addition, the excavations for the headworks and the secondary treatmentmay will extend below the water table and may penetrate through the clays into the more permeable sand deposits. A Comprehensive dewatering and depressurizing system will likely be necessary to avoid base heave.
- Planning and Execution of Excavations | Based on design elevations provided to GHD, construction techniques including sheet pile shoring, groundwater control methods (possible well point systems, etc.) will be required. Excavations within these soils will encounter wet silt and possibly running sand seams. Tender documents and specifications are recommended to include requirements for Contractors to show they have significant experience working in similar conditions and on similar projects.
- Protection of Subgrades | Due to groundwater conditions disturbance of the subgrades will result. Placement of bulk fill concrete or other measures for working mats/concrete mud slabs to protect the base, may also be required. The soils that are expected at the subgrade levels are subject to softening upon excavation or disturbance and Contractors should employ construction methods which limit construction traffic over exposed subgrade surfaces.
- Multiple Recommended Design Bearing Pressures | Different recommended design bearing pressures have been presented for the different structures planned for this Site. This includes recommended bearing pressures and/or modulus of subgrade reaction values for each structure. Designers and Contractors should be aware that footing geometries, depths, and subgrade soils affect bearing pressures and associated settlements.
- The Tender and Specification documents are recommended to include requirements for the bidders to submit Excavation Plans, Groundwater Control and Management Plans and Excess Soil Management Plans with their bid submission. These plans should form part of the basis of the selection process for the winning contractor.
- It is recommended that GHD be retained to review these plans prior to construction and pre-construction meetings with the selected contractor are also strongly recommended.

6.2 Site Preparation

The Site should be graded in the early stages of construction to provide for positive control of surface water, directing it away from excavations and subgrades. An adequate ditching and pumping system will be necessary in order to collect any surface runoff.

Based on our discussions with the Engineer at the time of proposal, the following are the anticipated subgrade conditions for each of the proposed structures:

- The headworks is proposed to be founded at an approximate elevation near 75.5 masl. The corresponding subgrade at this depth is anticipated to be clay, but may encounter the underlying sands on the north side of the building. The water level is expected near 78.4 masl.
- The primary clarifier is proposed to be founded at an approximate elevation near 75.0 masl. The corresponding subgrade at this depth is anticipated to be clay. The water level is expected near 78.4 masl.
- The secondary treatment is proposed to be founded will be founded at an approximate depth of 4.0 mbgs or an approximate elevation near 74.8 masl. The corresponding subgrade at this depth is anticipated to be clay, but may encounter the underlying sands on the north side of the building. The water level is expected near 76.9 masl.
- The operations building is proposed to be founded at an approximate depth of 3.0 mbgs, or an approximate elevation near 74.8 masl. The corresponding subgrade at this depth is anticipated to be clay. The water level is expected near 76.8 masl.

Subgrade preparation for soil subgrades will involve removal of all fills, organics, or disturbed soil to expose a native undisturbed subgrade. The exposed surface should be examined by the Geotechnical Engineer or a qualified technologist working under the supervision of a Geotechnical Engineer to assess the competency. Any identified local anomalies or soft spots should be subsequently sub-excavated, replaced with suitable imported fill, and compacted.

Any imported fill underlying footings or raft foundations should be considered as Engineered Fill and treated in accordance to the comments in Section 6.10.1. Field verification should be carried out by qualified geotechnical personnel during construction.

The soils at this Site are subject to strength loss upon disturbance, especially when these soils are subjected to elevated moisture content or improper management of excavations below the water table. Disturbed soils will need to be removed. Specifications should make some allowance for this issue, but contractors will need to use construction practices, methods, and equipment that minimize the risk of remolding or disturbance. It is recommended that a mud-slab be employed as a protective layer and to provide a clean surface to build rebar and formwork.

Based on the foundation depths proposed by the Engineer, the excavations for the Headworks and the Secondary Treatment may penetrate through the clays and into the underlying permeable sands. The water levels recorded in the stand pipes that were screened within the sands were found to range from approximately 76.5 to 78.4 masl, meaning that the excavations will be below the water level. The Designer and Contractors are cautioned that in monitoring well MW6-17 artesian water conditions were encountered up to an approximate elevation near of 79.3 masl. As stated previously GHD recommends submission of Excavation Plans, Groundwater Control and Management Plan and Excess Soil Management plans with bid submission. These plans should form part of the basis of the selection process for the winning contractor. Pre-construction meetings with the selected contractor are also strongly recommended.

A deep well or multiple well point system should be used to lower the piezometric surface to 1.0 m below the base of the proposed excavations, and possibly also used in conjunction with sheet piling or other hydraulic cut-off temporary wall. This would have to be sustained throughout construction until the structures are filled are filled backfilled.

Excavations will penetrate below the piezometric surface and therefore the permanent buoyancy and or drainage schemes will need to be reviewed and incorporated into the design.

6.2.1 Interference with Existing Service Trenches

GHD understands that there are existing underground services on Site. It is recommended that Designers and Contractors be aware of these and ensure the design and construction properly address this conflict or interference. Typically, any existing underground services are removed and re-routed around the future structures. If any of the inverts are lower than proposed founding levels of new foundations, then the removal and remediation should be planned and GHD be retained to review these plans. The existing trench excavations will need to have existing fills and services removed from the trenches and then have the subgrades confirmed. Then the excavations may be backfilled with Engineered Fill to ensure proper support for foundations. Alternatively, it may be an option that foundations are stepped down to below the service elevations.

6.3 Excavations & Construction Dewatering

The comments in this subsection are based on our understanding that excavations will be range from approximately 3.0 to 5.0 mbgs for the proposed structures and the underground services, and therefore will encounter fill soils, native clayey soils or native sandy soils. No bedrock excavation is anticipated.

All excavations should be completed and maintained in accordance with the current Occupational Health and Safety Act (OHSA) and Regulations for Construction. The following recommendations for excavations should be considered as a supplement to and not a replacement of the current OSHA requirements:

- The larger excavations should be planned assuming soils would be considered as "Type 4 Soils" according to Article 226 of O. Reg. 213/91

The water bearing sand seams within the silt and clay deposits will run/seep and if not controlled will cause sloughing of unsupported and sloped excavations.

Any softened or disturbed soils should be removed from the excavated foundations or service trench subgrades, however, it is recommended that, immediately upon excavation and approval of subgrade by the Geotechnical Engineer, that exposed subgrade be covered with concrete slabs.

Designers and Contractors should review the geometry of planned excavations regarding their depths and sloping requirements. This should be compared to the location of adjacent infrastructure or structures to ensure they are not undermined. Undermining is prevented by ensuring that no excavation penetrates below an imaginary line constructed outwards and downwards 10H:7V through soil, from the toe of structures or load bearing elements.

If the limitation of not undermining existing or proposed structures cannot be met, then an Engineered Shoring system may be required. Underpinning methods are not recommended in general for this Site. GHD should be retained for review if underpinning in load area becomes necessary.

6.3.1 Engineered Shoring

If an Engineered Shoring system is employed, shoring systems recommended for this Site are sheet piles. However, the method should be selected by Contractors based on Site conditions in the proposed building excavations. Shoring systems must be designed by a Professional Engineer taking into consideration not only the lateral earth pressures but also the hydraulic pressures of the groundwater, weight of the adjacent structures being retained, any possible surcharge loadings throughout construction (i.e., trucks, equipment, stockpiles, etc.), and vibrations caused by construction methods. The Canadian Foundation Engineering Manual (CFEM-2006) is recommended for reference. Shop drawings should be submitted to the Design team and GHD should be retained for review prior to the start of construction.

Design and execution of the excavations should be designed and performed by Designers and Contractors that have considerable experience working on similar projects, and in similar soil conditions.

The lateral pressure parameters to assist designers are discussed in Section 6.5.

6.3.2 Construction Dewatering

Both surface water and groundwater seepage are expected in all excavations. Water quantities will depend on seasonal conditions, depth of excavations, presence and lateral extents of water bearing sand seams, and the duration that excavations are left open. Comprehensive construction dewatering techniques will be required during construction, such as pumping from sumps, ditches, or well points. The silt and clay deposits contain water bearing silt and sand seams.

Based on the foundation depths proposed by the Engineer, the excavations for north side of the headworks and the north side of the secondary treatment may penetrate through the clays and into the underlying sands. The water levels recorded in the stand pipes that were screened within the sands were found to range from approximately 76.5 to 78.4 masl, meaning that the excavations will be below the water level. The Designer and Contractors are cautioned that monitoring well, MW6-17, which was screened within the rock had artesian water conditions encountered up to an approximate elevation near of 79.3 masl. This is a condition or a result of the grades of the Site, relative to the higher grades to the north and the local hydraulic confinement of competent clay deposits and bedrock properties. Based on the depths of excavations proposed by the Engineer and the water levels recorded in the wells, GHD recommends that hydrogeological investigations be carried out for this Site and be used for support of the design, planning and construction for this Site.

6.4 Foundations

6.4.1 Recommended Design Bearing Pressures for Pad and Strip Footings

The Ontario Building Code (OBC-2012) requires that buildings governed under Part Four of the code to be designed using the Limit States Design (LSD) values of Serviceability Limit States (SLS) and Ultimate Limit States (ULS).

Based on the soil conditions encountered in the boreholes, and our discussions with the Engineer at the time of proposal, the following are the anticipated foundation depths, subgrade soils, and recommended design bearing pressures and for each of the proposed structures:

Table 6.1 Recommended Design Bearing Pressures

Structure	Founding Elevation (masl)	Foundation Subgrade Soil	Recommended Design SLS Bearing Pressure	Factored ULS Bearing Capacity (φ = 0.5)
Headworks	75.5	Clay	100 kPa	190 kPa
Primary Clarifiers	75.0	Clay	75 kPa	190 kPa
Secondary Treatment	74.8	Clay	75 kPa	190 kPa
Operations Building	74.8	Clay	100 kPa	190 kPa
Note: Values above are for footings set on native undisturbed soils or Engineered Fill which have been prepared as per Section 6.10.1				

For foundation elements placed on native soils, we estimate that total and differential settlements will not exceed 25 mm and 19 mm, respectively under the SLS loading conditions provided above. Increased bearing pressures and/or significant grade raises (>1.0 m) would require additional specific settlement estimates, and may decrease the available bearing pressures.

Footings at varying levels and/or constructed adjacent to utility trenches, sump pits or similar should be constructed such that the higher footings be set at a level below an imaginary line constructed 10H:7V from the base of the lower excavation. Step footings will be problematic for construction due to soil conditions.

Designers should review the proposed founding elevations and compare them to depth and locations of foundations of neighbouring structures. Depending on the depth of the existing foundations, the proposed new foundations may need to be stepped down to the depth of the existing. There may also be a deeper backfill zone surrounding existing structures which will not be a suitable bearing soil. As stated previously, underpinning methods are problematic and not recommended in these soil conditions.

Final footing excavations in the clays and sands should be performed with a smooth-edged ditching bucket to ensure that the footing subgrade is undisturbed. It is recommended that Contractors employ a lean mix concrete mud-slab on the approved subgrade surface. This will serve as a clean and level working mat upon which to perform the construction.

It is recommended that GHD be retained to complete a review for compliance with our recommendations and during construction to verify suitability of subgrade materials.

6.4.2 Recommended MSRs for Raft Foundations

In the case that raft foundations are used for the primary clarifiers and secondary treatment, then the following comments are provided regarding the design Modulus of Subgrade Reaction (MSR). It is understood that MSR values will be used in packaged structural engineering software that will compute structural deformations with the vertical deformations at the structural slab level. The intent of the discussion herein is to present an estimated MSR values to allow the Client to model the structure using spring constants.

The benefit of the MSR approach is that it would take in to consideration the stiffness of the actual slab and the surrounding structure. It would also allow for modelling of areas under perimeter walls and columns. The estimated MSR is presented to the Designer for use in their structural modelling.

The Designer is cautioned that at the outset these value seems much lower than typical tabulated MSR values. This is because typical tabulated MSRs follow the standard of assuming a 0.3 m by 0.3 m loading footprint. A 0.3 m by 0.3 m footprint only mobilizes the top 1.0 to 1.5 m of soil, whereas in the case of the this Site, the rafts would have a dimension up to 45 m, therefore it would mobilize the entire soil thickness above the bedrock.

For the primary clarifier, the raft will be founded at an approximate elevation near 75.0 masl. Therefore this raft will be founded on native undisturbed clay. For permanent loads, an estimated MSR value of 5.6 MPa/m is provided to the Designers for use in their structural modelling.

For the secondary treatment, the raft will be founded at an approximate elevation near 74.8 masl Therefore this raft will be founded on native undisturbed clay. For permanent loads, an estimated MSR value of 3.0 MPa/m is provided to the Designers for use in their structural modelling.

For a raft foundation supporting a number of columns and walls, raft width should not be taken as the overall width of the entire building but the raft should be subdivided into smaller sizes taking into account the column and wall locations. For initial estimation purposes, subdivided raft widths should be assumed as 14 times the raft thickness. The design of rafts is an iterative process where additional geotechnical consulting is required to verify the subgrade moduli once structural elements are sixed and building load distributions are estimated.

It is understood that the rafts are being designed so as to structurally limit concentrated point loads under walls and columns.

Designers and Contractors must ensure that any Engineered Fill used to raise the grade below raft foundations, has the lateral extent of Engineered Fill beneath foundations extend laterally a distance equivalent to 1.5 D from any edge of the foundation, where D is depth of the Engineered Fill below the Raft. Specific comments for Engineered Fill are presented in Section 6.10.1. The silty clay subgrade below the Engineered Fill should similarly be prepared as if it was a footing base, and reviewed by the Engineer prior to placement of the fill, as outlined above.

6.5 Frost Protection

All footings for heated structures must be provided with a minimum of 1.2 m of earth cover, and 1.5 m of earth cover for unheated or isolated structures, or an equivalent insulation detail, in order to provide adequate protection against detrimental frost action.

Where soil cover cannot be provided, an insulation detail should be designed or approved by a Geotechnical Engineer. Designers and Contractors must be aware that this detail may be such that the insulation may need to be placed below the footing and then the footing poured on top, and therefore pre-approval is recommended to ensure excavations and backfill are properly planned.

Should construction take place during winter, the exposed surfaces to support foundations or Engineered Fill must be protected by Contractors against freezing for the entire duration of construction or until adequate soil cover is in place and interior of the building is heated.

Backfill soils should not be placed in a frozen condition, or placed on a frozen subgrade.

6.6 Seismic Site Classification

In accordance with OBC-2012, buildings and their structural elements must be designed to resist a minimum earthquake force. Based upon the results of the drilling program, we recommend that structures be designed to the following Site Classes, with respect to Table 4.1.8.4.A of the OBC-2012.

Table 6.2 Seismic Site Classification

Structure	Founding Elevation (masl)	Seismic Site Class
Headworks	75.5	C
Primary Clarifiers	75.0	D
Secondary Treatment	74.8	C
Operations Building	74.8	D

In addition to the above, it should be noted that no soil deposit with a thickness of 3.0 m or more, was found within the borehole locations which would be considered as "soft soils" as defined in Table 4.1.8.4.A of OBC-2012. In order to be considered as "soft soils" all of the following criteria must be satisfied:

- Plastic Index: Ip > 20 percent
- Moisture Content: w ≥ 40 percent
- Undrained Shear: Strength Su < 25 kPa

6.7 Resistance to Foundation Uplift

For this project it is understood that uplift resistance to foundations will be necessary. This is due to the fact that several of the structures will be below the groundwater level, and will occasionally be emptied for cleaning maintenance. Therefore buoyant forces will need to be resisted.

Resistance to foundation uplift and overturning or other anchoring requirements can be provided by the dead weight of structures or mass foundations or by means of grouted rock anchors. Grouted rock anchors include a free zone or unbonded zone followed by an anchor or bond zone. In order to mobilize the shear stress in the rock, anchor designers, manufacturers and installers must ensure that the load stresses at the top of the anchor zone must be properly transferred through the anchor zone to prevent progressive grout fail and ensure proper grout-to-rock bond or anchor performance.

These types of permanent anchors should be designed with double corrosion protection by the manufacturer/installer.

Free zone or unbonded zone, are typically recommended to be a minimum of 3.5 m above the anchor zone and typically includes the length of the anchor that penetrates through soil overburden and weathered rock zones. The anchor or bond zone relies on the frictional stress between grout and the bedrock within an anchor or bond zone. The bond zone is recommended to be entirely within "sound bedrock" which is below the weathered zone.

As the anchors will be drilled through the overburden, anchor holes should be drilled using a cased drilling system to ensure the anchor hole is free of debris and open to the design depth. A minimum 0.3 m sump should be incorporated below the tip of the anchor.

The design of grouted rock anchors is an iterative process and the process follows into the construction period. The initial stage is to create preliminary designs of based upon typical published values and conservative approach, to be followed by load testing during construction that may include performance tests to confirm frictional stress between grout and the bedrock within an anchor or bond zone. Performance tests setup must be designed, planned, and coordinated with the Geotechnical Engineer and the test must be done such that it is evaluating the bond/anchor zone only. Testing setups and temporary reaction members may be required. It is recommended that specifications include requests for Contractors to provide their test setups for review prior to mobilization to Site. Once the tests are successfully completed and then the final design lengths are modified and anchors manufactured. Alternatively, if time or other constraints dictate, then design and construction may be based upon the conservative, typical industry and/or published values.

For this Site, the working stress value, or if using LSD method, the SLS value, of the grouted anchor bond zone, may be assumed for design to be 500 kPa. This value is provided for designers and is subject to diligent and good construction installation. This value is also considered to be virtually equal to the ULS factored value, which, as per the Canadian Foundation Engineering Manual 4th Edition (CFEM-2006), incorporates the geotechnical resistance factor of $\Phi = 0.3$.

The mass of rock mobilized by a rock anchor may be assumed to be based upon a 60^{o} cone drawn up from a point located at the lower one-third point of the anchor or bond zone. Designers should review the spacing of anchors and take into account any overlapping cones (i.e., avoid doubling-up on rock mass calculations for overlapping cones).The bulk unit weight of bedrock may be assumed to be approximately 26 kN/m^3. The corresponding buoyant unit weight would be approximately 16 kN/m^3.

For this Site, the groundwater table within the overburden was found to be near an approximate elevation of 77.0 masl. However, as stated earlier, artesian groundwater conditions were noted in the bedrock of MW6-17 up to an approximate elevation of 79.3 masl. For the purpose of buoyancy calculations of the structures the 79.3 masl elevation should be used.

GHD recommends that independent monitoring by Geotechnical Engineer be carried out during the installation of the anchors to monitor depths, diameters, and quality of installation as well as sampling and testing of the grout during the grouting of the anchors. Proof testing of anchors is recommended to be carried out by the Contractor and monitored by the Geotechnical Engineer following adequate time to allow for the setting of the grout.

It is noted that fractured or high permeable zones may be expected in these types of sedimentary rocks. These types of fractured or permeable zones if encountered may result in interconnection of adjacent anchor holes. The interconnected adjacent rock anchor holes may experience grout loss/infiltration. Therefore it is recommended that the designers, specification writers and contractors allow for this "interconnect ability" issue and that some or all holes may require to be drilled, grouted and once the grout is fully set then re-drilled to allow proper installing of the anchor and final bond/anchor grout.

Based on the observations of artesian groundwater noted in the bedrock of MW6-17, there may be an upward flow of ground water during anchor installation, which will be difficult to hold grout. Contractors should be prepared to use casings which extend above the ground surface to equalize any artesian flow, then the grout be installed while the water pressure is equalized. It is recommended that the designers, specification writers, and contractors allow for this water flow issue and that some or all holes may require to be, pre-grouted several times, or even pressure grouted to allow for proper installing of the anchor and final bond/anchor grout. It is important that the Client select a contractor who has extensive experience with rock anchor installations under similar conditions.

6.8 Corrosion Potential of Native Soils

The geotechnical laboratory testing component of this Geotechnical Investigation included the submittal of one soil sample for testing of the standard corrosion package (pH, sulphides, chloride, sulphates, redox potential, and conductivity). Soil sample BH8-17 SS3, was delivered to Paracel Laboratories Ltd. in Kingston on May 24, 2017, under chain of custody Ref No: 113499. The results of these analyses were received back from the laboratory on May 30, 2017, under report Ref No: 1721113. The results of the corrosion package testing are summarized in the Section 6.7 below.

Table 6.3 Results of the Corrosion Package Testing

Sample ID	BH8-17 SS3
pH	6.93
Redox Potential (mV)	217
Resistivity (ohm.cm)	8470
Sulphide (%)	< 0.02*
Chloride (µg/g)	11
Sulphate (µg/g)	10
*Reportable detection limit (RDL) = 0.02 percent	

The American Water Works Association (AWWA) publication 'Polyethylene Encasement for Ductile Iron Pipe Systems' ANSI/AWWA C105/A21.5 10 dated October 1, 2010 assigns points based on the results of the above tests. A soil that has a total point score of ten or more is considered to be potentially corrosive to ductile iron pipe. Based on the results obtained for the samples submitted, only four points can be assigned due to traces of sulphides and an assumption of a continuously wet soil condition. Based on the laboratory test results, the tested soil suggests non-corrosive conditions. Therefore the Site soils, as represented by the analyzed samples, are not considered to be potentially corrosive to ductile iron pipe.

Table 3 of the Canadian Standards Association (CSA) document A23.1 14/A23.2 14 'Concrete Materials and Methods of Concrete Construction/Methods of Test and Standard Practices for Concrete' divides the degree of exposure into the following three classes:

- Very Severe (S-1) > 2.0 percent water soluble SO4
- Severe (S-2) 0.2 - 2.0 percent water soluble SO4
- Moderate (S-3) 0.1 – 0.2 percent water soluble SO4

A review of the analytical test results shows the sulfate contents in the tested samples were found to be less than 0.1 percent, which indicates the degree of exposure of the subsurface concrete structures to sulphate attack is low. Therefore normal Portland cement can be used for below grade concrete structures.

6.9 Lateral Earth Pressures

The soil parameters in the following subsections can be used for designing retaining walls and temporary Engineered Shoring in regards to lateral earth pressures.

6.9.1 Static Conditions

The soil parameters are presented to assist Designers in the designing retaining walls for this Site under static conditions:

Table 6.4 Lateral Earth Pressures (Static Conditions)

Soil	Bulk Density	Angle of Internal Friction	Rankin Earth Pressure Coefficients (1)		
	kN/m³	φ	K_a	K_o	K_p
Existing Fill Soils (for Temporary Shoring)	18	20	0.49	0.66	2.04
Existing Native Clayey Soils (for Temporary Shoring)	18	18	0.53	0.69	1.89
Existing Native Sandy Soils (for Temporary Shoring)	20	28	0.36	0.53	2.77
Compacted Granular Backfill comprised of OPSS Granular 'B', Type II or Granular 'A' (for Temporary Shoring or Permanent Backfill)	22	32	0.31	0.47	3.25
Note: (1) Assumes level/flat backfill surface					

For yielding retaining walls the active earth pressure coefficients K_a is recommended to be used. For non-yielding the at-rest K_o should be used.

The resultant of the applicable static or at-rest force is assumed to act at 1/3H above the base of the wall where H is the Height of the wall.

These statements are based on the assumption that there is a perimeter drainage system installed at the base of the retaining walls draining under gravity to a frost free outlet, to prevent the build-up of hydrostatic pressure behind the wall; hydrostatic pressures may not be included in the design.

6.9.2 Dynamic Conditions

The below grade walls subjected to lateral forces due to seismic forces can be designed using the pseudo-static approach using the Mononobe-Okabe equations, shown in Section 24.9 of CFEM-2006. In these formulas, there are both geotechnical and geometric components.

The total active thrust under seismic loading (P_{ae}) is recommended to be expressed as follows:

- $P_{ae} = ½ K_{ae}γ H^2 x (1 - k_v)$

Where:

- H = Height of the wall
- K_{ae} = horizontal component of active earth pressure coefficient including effects of earthquake loading
- k_v = Vertical component of the earthquake acceleration typically a range of 2/3 x k_h to 1/3 k_h is considered but a value closer to 2/3 x k_h is recommended
- k_h = Horizontal component of the earthquake acceleration, typically = Peak Ground Acceleration (PGA) or a factor thereof. PGA for the Site is 0.12 g, where g is the acceleration due to gravity.

For passive earthquake pressure (P_{pe}) the following equation can be used:

- $P_{pe} = ½ K_{pe}γ H^2 x (1 - k_v)$

Where:

- K_{pe} = horizontal component of passive earth pressure coefficient including effects of earthquake loading

The above equation includes both the active pressures under static (P_a) as well as the increased force due to seismic forces.

The active force under static conditions is assumed to act at a point of (0.3 x H) above the base and the seismic force is assumed to act near (0.6 x H) above the base, where H is the height of the wall. Therefore the point of applying P_{ae} may be calculated from the following:

- $H = [(0.33HxP_a) + (0.6H x P_e)] / P_{ae}$

The following soil parameters are presented to assist Designers in designing retaining walls for this Site under seismic conditions using the pseudo-static approach:

Table 6.5 Lateral Earth Pressures (Dynamic Conditions)

Soil	Bulk Density 'Y' (kN/m³)	Angle of Internal Friction	Seismic Lateral Pressure Coefficients (1)	
		φ	K_{ae}	K_{pe}
Existing Fill Soils	18	20	0.59	1.86
Existing Native Clayey Soils	18	18	0.63	1.71
Existing Native Sandy Soils	20	28	0.44	2.56
Compacted Granular Backfill comprised of OPSS Granular 'B', Type II or Granular 'A'	22	32	0.38	3.03
Note: (1) Assumes level/flat backfill surface				

6.10 Backfill

The placement and compaction of granular materials that will support, rafts, footings, or floor slabs are considered as Engineered Fill, and must be treated as such.

6.10.1 Engineered Fill

For this Project, Engineered Fill will be required to backfill below foundation elements once fill soils are removed, to raise the grade between the approved subgrades and final raft elevations, below floor slabs, and for interior foundation wall backfill. Fill operations for Engineered Fill placement must satisfy the following criteria. All fill materials placed below footings or floor slabs should be considered as Engineered Fill.

- Engineered Fill must be placed under the continuous supervision of the Geotechnical Engineer. Prior to placing any Engineered Fill, all unsuitable fill materials must be removed, and the subgrade approved. Any deficient areas should be repaired.
- Prior to the placement of Engineered Fill, the source or borrow areas for the Engineered Fill must be evaluated for its suitability. Samples of proposed fill material must be provided to the Geotechnical Engineer and tested in the geotechnical laboratory for SPMDD and grain size.
- The Engineered Fill must consist of environmentally suitable soils (as per industry standard procedures of federal or provincial guidelines/regulations), free of organics and other deleterious material (building debris such as wood, bricks, metal, and the like), compactable, and of suitable moisture content so that it is within -2 percent to +0.5 percent of the Optimum Moisture as determined by the Standard Proctor Test. Imported well-graded, crushed, granular soils such as an OPSS 1010 "Granular A" are generally suitable.
- Engineered Fill must be placed in maximum loose lift thicknesses of 0.2 m. Each lift of Engineered Fill must be compacted with a heavy roller to 100 percent of its SPMDD.
- Field density tests must be taken by the Geotechnical Engineer, on each lift of Engineered Fill. Any Engineered Fill, which is tested and found to not meet the specifications, shall be either removed or reworked and retested.
- The lateral extent of Engineered Fill beneath foundations should be equivalent to 1.5 D from any edge of the foundation, where D is depth of the Engineered Fill below the footings.

6.10.2 Exterior Foundation Wall Backfill

The backfill placed against foundations should be a free draining granular material meeting the grading requirements of an OPSS 1010 "Granular B, Type I" or "Granular B, Type II". In landscaped areas the upper 0.3 m below landscape details should be a low permeable soil to reduce surface water infiltration. Foundation backfill should be placed and compacted as outlined below.

- Free-draining granular backfill should be used for the foundation exterior foundation walls.
- Backfill should not be placed in a frozen condition, or place on a frozen subgrade.
- Backfill should be placed and compacted in uniform lift thickness compatible with the selected construction equipment, but not thicker than 0.2 m. Backfill should be placed uniformly on both sides of the foundation walls to avoid build-up of unbalanced lateral pressures.

- At exterior flush door openings the underside of sidewalks should be insulated, or the sidewalk should be placed on frost walls to prevent heaving. Granular backfill should be used and extended laterally beneath the entire area of the entrance slab. The entrance slab should slope away from the building.
- For backfill that would underlie paved areas, sidewalks or exterior slabs-on-grade, each lift should be uniformly compacted to at least 98 percent of its SPMDD.
- For backfill on the building exterior that would underlie landscaped areas, each lift should be uniformly compacted to at least 95 percent of its SPMDD.
- In areas on the building exterior where an asphalt or concrete pavement will not be present adjacent to the foundation wall, the upper 0.3 m of the exterior foundation wall backfill should be a low permeable soil to reduce surface water infiltration.
- Exterior grades should be sloped away from the foundation wall, and roof drainage downspouts should be placed so that water flows away from the foundation wall.

6.11 Permanent Drainage and Waterproofing

If oversized back-sloped excavations are used the options for a perimeter drainage system are to use conventional drainage tile or use a composite drainage blanket such as Miradrain 6200 or equivalent.

If a traditional perimeter drain system is installed, it may be constructed with 100 mm diameter weeping tiles placed on a 150 mm bed of 19 mm clear stone and then covered with 150 mm of the same stone. The stone and weeping tile should be enveloped on the bottom, sides and top with a non-woven geotextile filter cloth (such as Terrafix 270 or equivalent). The drainage weeping tile system should be placed at the footing level and be connected to a "frost-free" outlet, such as a sump or storm sewer. Perimeter drains should not be connected to the interior under-floor systems.

If a composite drainage blanket or geodrain is used, it is still recommended that the exterior foundation walls be backfilled with a free-draining non-frost susceptible soil. The perimeter drains should be connected to a frost-free outlet for year round drainage. They should not be connected to the interior under-floor drainage system.

In areas on the building exterior where an asphalt or concrete pavement will not be present adjacent to the foundation wall, the upper 0.3 m of the exterior foundation wall backfill should be a low permeable soil to reduce surface water infiltration. Exterior grades should be sloped away from the foundation wall. All roof drain downspouts should be led directly to a frost-free outlet away from the building.

If a shoring system is used, then a composite drainage system will placed directly against the shoring, and Designers will need to design the details of the permanent drainage system, and the connection to a frost-free sump.

Based on the elevation of the water table we recommend a water proofing membrane such as a WR Meadows MEL-ROL PRECON or equivalent for walls and under-slab. These types of membranes adhere to the concrete and provide a waterproof seal between the membrane and poured concrete. Water stops should be installed at cold joints in the foundation walls and floor-wall joint.

6.12 Floor Slabs

Conventional slab-on-grade construction is considered suitable for floor slabs. In this case we are assuming that the buildings will have light floor loadings only, i.e., considered to be less than 24 kPa. Higher loading requirements will require additional consultation and analysis.

A layer consisting of Granular 'A at least 200 mm thick should be placed to support the slab-on-grade. This layer should be compacted to 100 percent of its SPMDD and placed on approved subgrade surfaces.

For design purposes and based upon a properly prepared subgrade surface covered with 200 mm of Granular A, the modulus of subgrade reaction appropriate for the slab design is 30 MPa/m.

Slabs should not be tied into foundation walls. The placement of construction and control joints in the concrete should be in accordance with generally accepted practice.

6.13 Underground Services

The recommendations within this section are intended to be a supplement to, and not a replacement of the most recent local municipal requirements.

6.13.1 Bedding and Cover

The following are recommendations for service trench bedding and cover materials:

- Bedding for buried utilities should consist of an OPSS 1010 "Granular A" or "Granular B Type II" material and placed in accordance with municipal requirements, assuming the subgrade soils are not allowed to become disturbed.
- The use of clear stone is not recommended for use as pipe bedding. The voids in the stone may result in a low gradient water flow and infiltration of fines from the surrounding soils and cover materials, causing settlement and loss of support to pipes and structures.
- The cover material should be a service sand material or an OPSS 1010 "Granular A". The dimensions should comply with pertinent spec section.
- The bedding material and cover materials should be compacted to at least 95 percent of its SPMDD.
- Compaction equipment should be used in such a way that the utility pipes are not damaged during construction.

6.13.2 Service Trench Backfill

Backfill above the cover for buried utilities should be in accordance with the following recommendations:

- For service trenches underlying pavement areas, the backfill should be placed and compacted in uniform lift thickness compatible with the selected compaction equipment and not thicker than 200 mm. Each lift should be compacted to a minimum of 95 percent SPMDD.
- The backfill placed in the upper 0.3 m below the pavement subgrade elevation should be compacted to a minimum of 100 percent of its SPMDD.

- Excavation backfill should attempt to match texture of the existing adjacent soils. If imported materials are used, side slopes with frost tapers are recommended. Frost tapers should be a back-slope of 10H:1V through the frost zone, (i.e., 1.5 m from finished grade).
- Excavated soils that are too wet (i.e., greater than 5 percent above the optimum moisture content based upon a Standard Proctor Test) will become problematic to compact and may not perform properly during construction period. If such conditions occur, the options include drying of the soils, compacting and leaving the area untraveled for a period of time, importation of more suitable material, or a combination of above and the use of geotextiles at the base and possibly additional layers within the pavement structure's granular base courses. The appropriate measures will need to be discussed during construction period and be such to achieve adequate performance from the pavement structure.

6.14 Construction Review

GHD requests to be retained to review the drawings and specifications, once complete, to verify that the recommendations within this report have been adhered to, and to look for other geotechnical problems.

The recommendations provided in this report are based on an adequate level of construction monitoring being conducted during construction of the proposed Project. Due to the nature of the proposed development, an adequate level of construction monitoring is considered to be as follows:

- Prior to construction of footings or rafts, the exposed foundation subgrade should be examined by a Geotechnical Engineer, to assess whether the subgrade conditions correspond to those encountered in the boreholes, and the recommendations provided in this report have been implemented.
- A qualified Technologist acting under the supervision of a Geotechnical Engineer should monitor the placement of Engineered Fill underlying footings and floor slabs on a full time basis.
- Backfilling operations should be conducted in the presence of a qualified Technologist to ensure that proper material is employed and specified compaction is achieved.
- Placement of concrete should be periodically tested to ensure that job specifications are being achieved.
- Engineered Fill must be placed in accordance with the requirements outlined in Section 6.10.1, and must be placed under the full time supervision of the Geotechnical Engineer.
- Underground Utilities/Service Utilities should be inspected during excavation, installation, and backfill tested by a qualified Engineering Technologist.
- Placement of concrete reinforcement in foundations and floor slabs should be reviewed prior to concrete placement and tested by a qualified Engineering Technologist.

7. Report Conditions and Limitations

This report is intended solely for The Town of Greater Napanee, EVB Engineering Inc. and the other parties explicitly identified within the report. It is prohibited for use by others without GHD's prior written consent. This report is considered GHD's professional work product and shall remain the sole property of GHD. Any unauthorized reuse, redistribution of or reliance on the report shall be at the Client and recipient's sole risk, without liability to GHD. Client shall defend, indemnify and hold GHD harmless from any liability arising from or related to Client's unauthorized distribution of the report. No portion of this report may be used as a separate entity; it is to be read in its entirety and shall include all supporting drawings and appendices.

The recommendations made in this report are in accordance with our present understanding of the project, the current site use, ground surface elevations and conditions, and are based on the work scope approved by the Client and described in the report. The services were performed in a manner consistent with that level of care and skill ordinarily exercised by members of geotechnical engineering professions currently practicing under similar conditions in the same locality. No other representations, and no warranties or representations of any kind, either expressed or implied, are made. 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.

All details of design and construction are rarely known at the time of completion of a geotechnical study. The recommendations and comments made in the study report are based on our subsurface investigation and resulting understanding of the project, as defined at the time of the study. We should be retained to review our recommendations when the drawings and specifications are complete. Without this review, GHD will not be liable for any misunderstanding of our recommendations or their application and adaptation into the final design.

By issuing this report, GHD is the geotechnical engineer of record. It is recommended that GHD be retained during construction of all foundations and during earthwork operations to confirm the conditions of the subsoil are actually similar to those observed during our study. The intent of this requirement is to verify that conditions encountered during construction are consistent with the findings in the report and that inherent knowledge developed as part of our study is correctly carried forward to the construction phases.

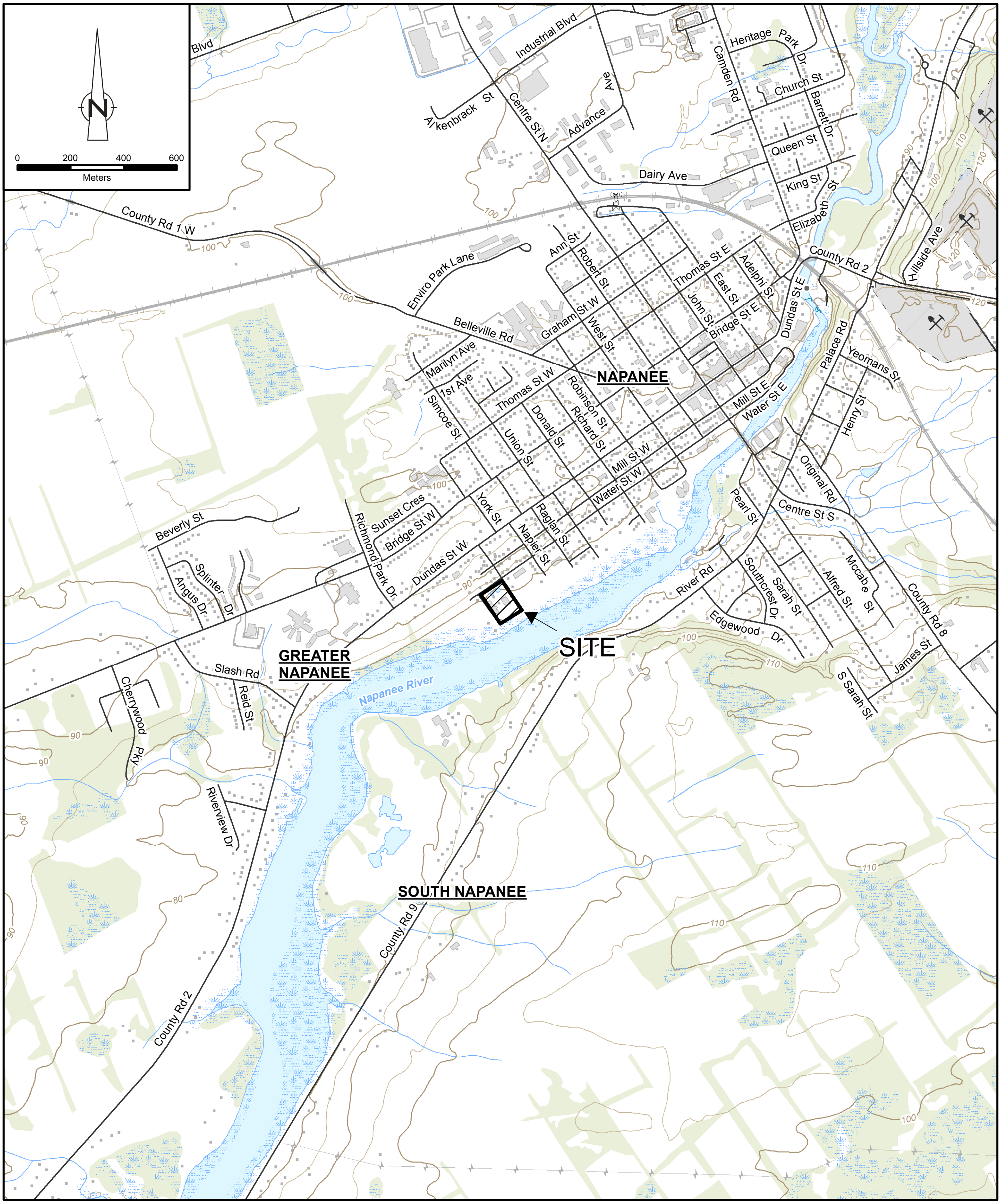
It is important to emphasize that a soil investigation is, in fact, a random sampling of a site and the comments included in this report are based on the results obtained at the 22 borehole locations only. The subsurface conditions confirmed at these 22 borehole locations may vary at other locations. Soil and groundwater conditions between and beyond the test locations may differ both horizontally and vertically from those encountered at the test locations and conditions may become apparent during construction, which could not be detected or anticipated at the time of our investigation. Should any conditions at the Site be encountered which differ from those found at the test locations, we request that we be notified immediately in order to permit a reassessment of our recommendations. If changed conditions are identified during construction, no matter how minor, the recommendations in this report shall be considered invalid until sufficient review and written assessment of said conditions by GHD is completed.

All of Which is Respectfully Submitted,

GHD

Ryan Vanden Tillaart, EIT

Joseph Bennett, P. Eng.



Source: MNRF NRVIS, 2015. Produced by GHD under licence from Ontario Ministry of Natural Resources and Forestry, © Queen's Printer 2017;
Coordinate System: NAD 1983 UTM Zone 18N

TOWN OF GREATER NAPANEE
300 WATER STREET WEST, NAPANEE ONTARIO
GEOTECHNICAL INVESTIGATION FOR WWTP UPGRADES

NAPANEE WWTP
SITE LOCATION MAP

11140477-A2
Dec 18, 2017

FIGURE 1

GIS File: Q:\GIS\PROJECTS\11140000s\11140477\Layouts\001\11140477-A2(001)GIS-OT004.mxd

Source: Microsoft product screen shot(s) reprinted with permission from Microsoft Corporation, September 2015
Coordinate System: NAD 1983 UTM Zone 18N

0 10 20 30
Meters
Coordinate System:
NAD 1983 UTM Zone 18N

TOWN OF GREATER NAPANEE
300 WATER STREET WEST, NAPANEE ONTARIO
GEOTECHNICAL INVESTIGATION FOR WWTP UPGRADES

NAPANEE WWTP
BOREHOLE LOCATION PLAN

11140477-A2
Jan 4, 2018

FIGURE 2

GIS File: Q:\GIS\PROJECTS\11140000s\11140477\Layouts\001\11140477-A2(001)GIS-OT005.mxd

Source: Microsoft product screen shot(s) reprinted with permission from Microsoft Corporation, September 2015
Coordinate System: NAD 1983 UTM Zone 18N

0 10 20 30
Meters
Coordinate System:
NAD 1983 UTM Zone 18N

TOWN OF GREATER NAPANEE
300 WATER STREET WEST, NAPANEE ONTARIO
GEOTECHNICAL INVESTIGATION FOR WWTP UPGRADES

NAPANEE WWTP
PROPOSED NEW STRUCTURES

11140477-A2
Jan 4, 2018

FIGURE 3

GIS File: Q:\GIS\PROJECTS\11140000s\11140477\Layouts\001\11140477-A2(001)GIS-OT006.mxd

Appendices

Appendix A

Borehole Logs

Notes on Borehole and Test Pit Logs

Explanation of Terms Used in the Bedrock Core Logs

REFERENCE No.: 11140477-A1 ENCLOSURE No.: 1

BOREHOLE No.: **BH1-17**
ELEVATION: 78.09 m

BOREHOLE LOG

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.
PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant
LOCATION: 300 Water Street West, Napanee, On
DESCRIBED BY: S.Wheeler CHECKED BY: S. Dunstan
DATE (START): 15 May 2017 DATE (FINISH): 15 May 2017

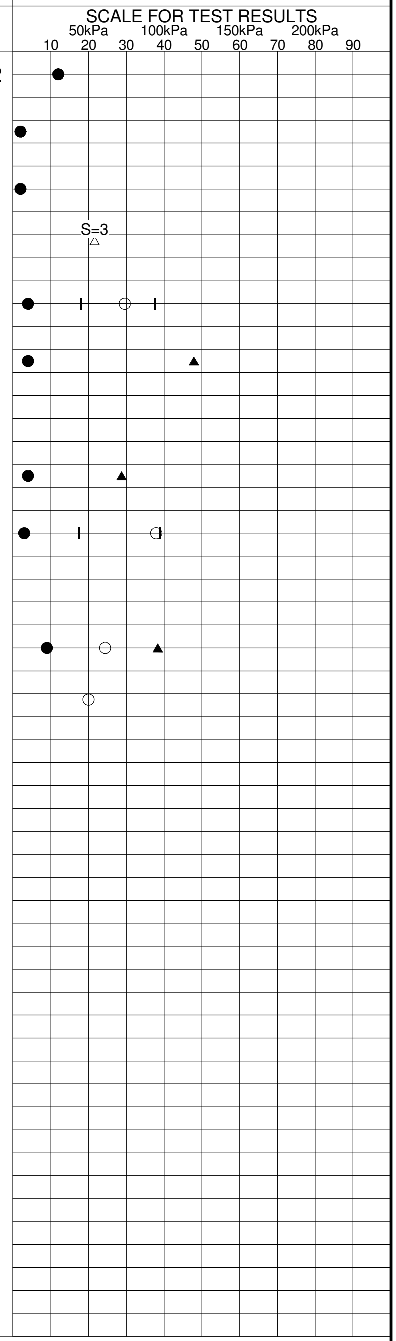
LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	Description of Soil and Bedrock	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	78.09	GROUND SURFACE				
	78.0	**TOPSOIL-** Brown, damp. (Approximately 75 mm)	SS1	11/24		12
	77.9	**FILL-** Gravel, some silt, compact, brown, damp.				
1.0		**FILL-** Sandy silt, loose, brown, damp. *Becoming moist.	SS2	11/24		2
	76.4	**BURIED TOPSOIL-** Brown, moist.	SS3	20/24		2
2.0	76.3	**SILTY CLAY-** Stiff, grey, moist. *Becoming wet.	FV1			
3.0			SS4	24/24		4
4.0		*Becoming very stiff.	SS5	24/24		4
5.0			ST1			
6.0		*Becoming stiff.	SS6	24/24		4
			SS7	24/24		3
7.0		*FV > 90 kPa vane capacity.	FV2			
8.0	70.3	**SILTY CLAYEY SAND-** Loose, brown, wet.	SS8	24/24		9
			SS9	12/18		R
9.0	69.3	Auger refusal at approximately 8.8 m.				

Depth scale continues: 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0

SCALE FOR TEST RESULTS



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by Hopkins-Chitty Surveying Ltd.
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A2 ENCLOSURE No.: 13

BOREHOLE No.: BH13-17

ELEVATION: 81.07 m

BOREHOLE LOG

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan

DATE (START): 23 November 2017 DATE (FINISH): 23 November 2017

LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	DESCRIPTION OF SOIL AND BEDROCK	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	81.07	GROUND SURFACE				
		FILL- Sandy Silt some Gravel, loose, grey, damp.	SS1	7/24		8
1.0	80.1	**BURIED TOPSOIL-** (Approximately 50 mm thick)	SS2	14/24		9
	80.1	**FILL-** Silt some Sand and Gravel, compact, grey, damp. *Becoming Sandy Silt trace Gravel, loose, brown, damp	SS3	15/24		6
2.0	78.9	**CLAY AND SILT-** Very stiff, brownish grey, damp.	SS4	24/24		7
3.0			SS5	24/24		9
4.0		*Becoming grey	SS6	24/24		7
5.0			SS7	24/24		6
		*Becoming brown	SS8	24/24		6
6.0	75.0	**SAND-** Compact, light brown, wet. *Becoming Silty Sand	SS9	24/24		10
7.0	74.2	**LIMESTONE-** Medium strong, thickly bedded, horizontal, slightly weathered, excellent quality based on RQD.	RC1	63/63		97
9.0			RC2	60/61		93
10.0	71.1	End of borehole at approximately 10.0 m in limestone.				

SCALE FOR TEST RESULTS: 50kPa, 100kPa, 150kPa, 200kPa; 10 20 30 40 50 60 70 80 90

NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A2 ENCLOSURE No.: 14

BOREHOLE LOG

BOREHOLE No.: BH14-17

ELEVATION: 81.09 m

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan

DATE (START): 23 November 2017 DATE (FINISH): 23 November 2017

LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

SCALE FOR TEST RESULTS: 50kPa, 100kPa, 150kPa, 200kPa; 10, 20, 30, 40, 50, 60, 70, 80, 90

Depth BGS (meters)	Elevation (m)	Description of Soil and Bedrock	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	81.09	GROUND SURFACE				
	80.5	**FILL-** Sandy Silt some Gravel, compact, light brown, damp.	SS1	20/24		16
1.0	80.5	**BURIED TOPSOIL-** (Approximately 50 mm thick)	SS2	14/14		R
		FILL- Silty Gravel some Sand, dense, dark grey, damp. *Becoming Sandy Silt trace Gravel, concrete piece limited recovery	SS3	6/11		R
2.0	79.0	**CLAY AND SILT-** Very stiff, brownish grey, damp.	SS4	24/24		12
3.0			SS5	24/24		9
4.0			SS6	22/24		17
5.0			SS7	5/24		8
6.0	75.4	**SAND-** Compact, brown, wet.	SS8	18/24		20
		*Becoming some gravel, very dense, light brown, wet, limestone chips in tip of split spoon.	SS9	14/15		R
7.0	74.3	Auger refusal at approximately 6.8 m.				
8.0						
9.0						
10.0						
11.0						
12.0						
13.0						
14.0						
15.0						
16.0						

NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A2 ENCLOSURE No.: 15

BOREHOLE LOG

BOREHOLE No.: MW15-17-d

ELEVATION: 78.77 m

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan

DATE (START): 23 November 2017 DATE (FINISH): 23 November 2017

LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

SCALE FOR TEST RESULTS: 50kPa, 100kPa, 150kPa, 200kPa; 10, 20, 30, 40, 50, 60, 70, 80, 90

Stratigraphy

Elevation (m)	Description of Soil and Bedrock
78.77	GROUND SURFACE
78.7	**TOPSOIL-** (Approximately 50 mm thick)
	FILL- Sandy Silt some Gravel, loose, dark brown, damp.
77.7	**BURIED TOPSOIL-** Organic, dark brown to black.
77.7	**CLAY AND SILT-** Very stiff, brown, damp.
74.2	**SILTY CLAY-** Very stiff, grey, damp.
72.1	**SAND-** Compact, brown, wet, some silt seams (approximately 125 mm thick).
71.0	Auger refusal at approximately 7.8 m.

Depth BGS scale (meters): 1.0 to 16.0

Monitor Well

Depth (m)	Annotation
0.70	(top of casing)
0.62	
0.37	WL
0.46	
	Bentonite
5.79	
	Riser
6.25	
	Screen
	Sand
7.77	

Sample Data

Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
SS1	18/24		7
SS2	22/24		5
SS3	24/24		15
SS4	24/24		12
SS5	24/24		7
SS6	24/24		17
SS7	24/24		7
SS8	24/24		11
SS9	24/24		12
SS10	24/24		10
SS11	5/5		R

NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

BOREHOLE No.: MW15-17-s
ELEVATION: 78.79 m

BOREHOLE LOG

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.
PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant
LOCATION: 300 Water Street West, Napanee, On
DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan
DATE (START): 23 November 2017 DATE (FINISH): 23 November 2017

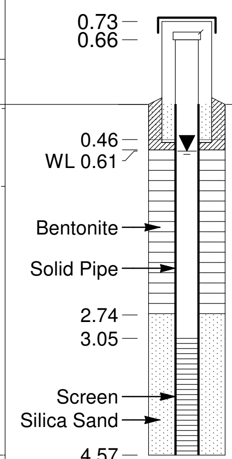
LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	Description of Soil and Bedrock	Monitor Well	State	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	78.79	GROUND SURFACE	0.73, 0.66					
	78.7	**TOPSOIL-** (Approximately 50 mm thick)	0.46; WL 0.61					
1.0	77.7	Inferred fill based on MW15-17-d	Bentonite					
		Inferred clay and silt based on MW15-17-d	Solid Pipe; 2.74; 3.05; Screen; Silica Sand					
	74.2	End of borehole at approximately 4.6 m.	4.57					

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0

SCALE FOR TEST RESULTS: 50kPa, 100kPa, 150kPa, 200kPa; 10, 20, 30, 40, 50, 60, 70, 80, 90



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A2 ENCLOSURE No.: 17

BOREHOLE No.: BH16-17
ELEVATION: 78.43 m

BOREHOLE LOG

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.
PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant
LOCATION: 300 Water Street West, Napanee, On
DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan
DATE (START): 23 November 2017 DATE (FINISH): 23 November 2017

LEGEND
- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	DESCRIPTION OF SOIL AND BEDROCK	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	78.43	GROUND SURFACE				
	78.4	**TOPSOIL-** (Approximately 50 mm thick)	SS1	18/24		7
		FILL- Sandy Silt some Gravel, loose, dark brown, damp.				
1.0	77.6	**CLAY AND SILT-** Very stiff, brown, damp.	SS2	24/24		8
2.0			SS3	24/24		12
			SS4	24/24		16
3.0			SS5	24/24		16
4.0	74.5	**SILTY CLAY-** Very stiff, grey, damp, trace sand veins.	SS6	24/24		18
5.0		*Becoming stiff	SS7	24/24		7
			SS8	24/24		5
6.0	72.3	**SAND-** Compact, brown, wet, some silt seams (approximately 125 to 150 mm thick).	SS9	24/24		8
7.0			SS10	24/24		12
8.0			SS11	24/24		R
	70.1	Auger refusal at approximately 8.4 m.				
9.0						
10.0						
11.0						
12.0						
13.0						
14.0						
15.0						
16.0						

SCALE FOR TEST RESULTS: 50kPa 100kPa 150kPa 200kPa; 10 20 30 40 50 60 70 80 90

NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A2

ENCLOSURE No.: 18

BOREHOLE No.: MW17-17-d

ELEVATION: 77.24 m

BOREHOLE LOG

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan

DATE (START): 24 November 2017 DATE (FINISH): 24 November 2017

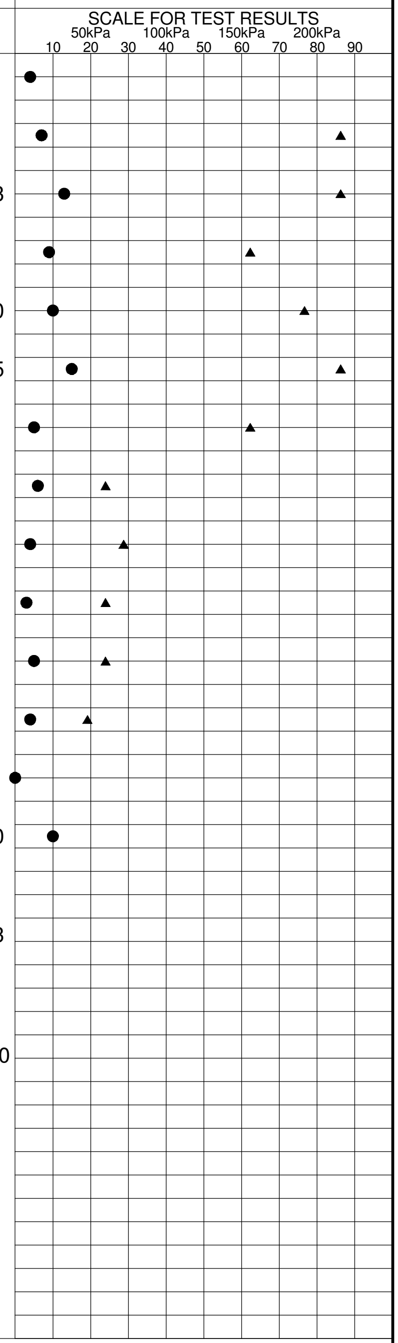
LEGEND

- ☒ SS Split Spoon
- GS Auger Sample
- ▨ ST Shelby Tube
- ▼ Water Level
- ○ Water content (%)
- ⊢⊣ Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Elevation (m)	Description of Soil and Bedrock
77.24	GROUND SURFACE
77.0	**TOPSOIL-** (Approximately 200 mm thick)
76.4	**FILL-** Sandy Silt, loose, brown, damp.
	CLAY AND SILT- Very stiff, brown, damp.
74.2	**SILTY CLAY-** Very stiff, grey, damp, trace sand veins. *Becoming stiff *Becoming firm
68.1	**SAND-** Compact, light brown, wet.
66.6	**LIMESTONE-** Medium strong, thickly bedded, horizontal, slightly weathered, good quality based on RQD. *Becoming excellent quality based on RQD
63.4	End of borehole at approximately 13.8 m in limestone.

Monitor well: 0.70, 0.63, 0.46, WL 0.71, 0.91, Cuttings, 6.40, Bentonite, 8.84, 9.09, Sand, Screen, 10.62, 10.67, Bentonite Seal in Rock, 13.82

Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
SS1	12/24		4
SS2	24/24		7
SS3	24/24		13
SS4	24/24		9
SS5	24/24		10
SS6	24/24		15
SS7	24/24		5
SS8	24/24		6
SS9	24/24		4
SS10	24/24		3
SS11	24/24		5
SS12	24/24		4
SS13	24/24		0
SS14	24/24		10
	61/65		83
	59/59		100



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A2 ENCLOSURE No.: 19

BOREHOLE No.: MW17-17-s
ELEVATION: 77.22 m

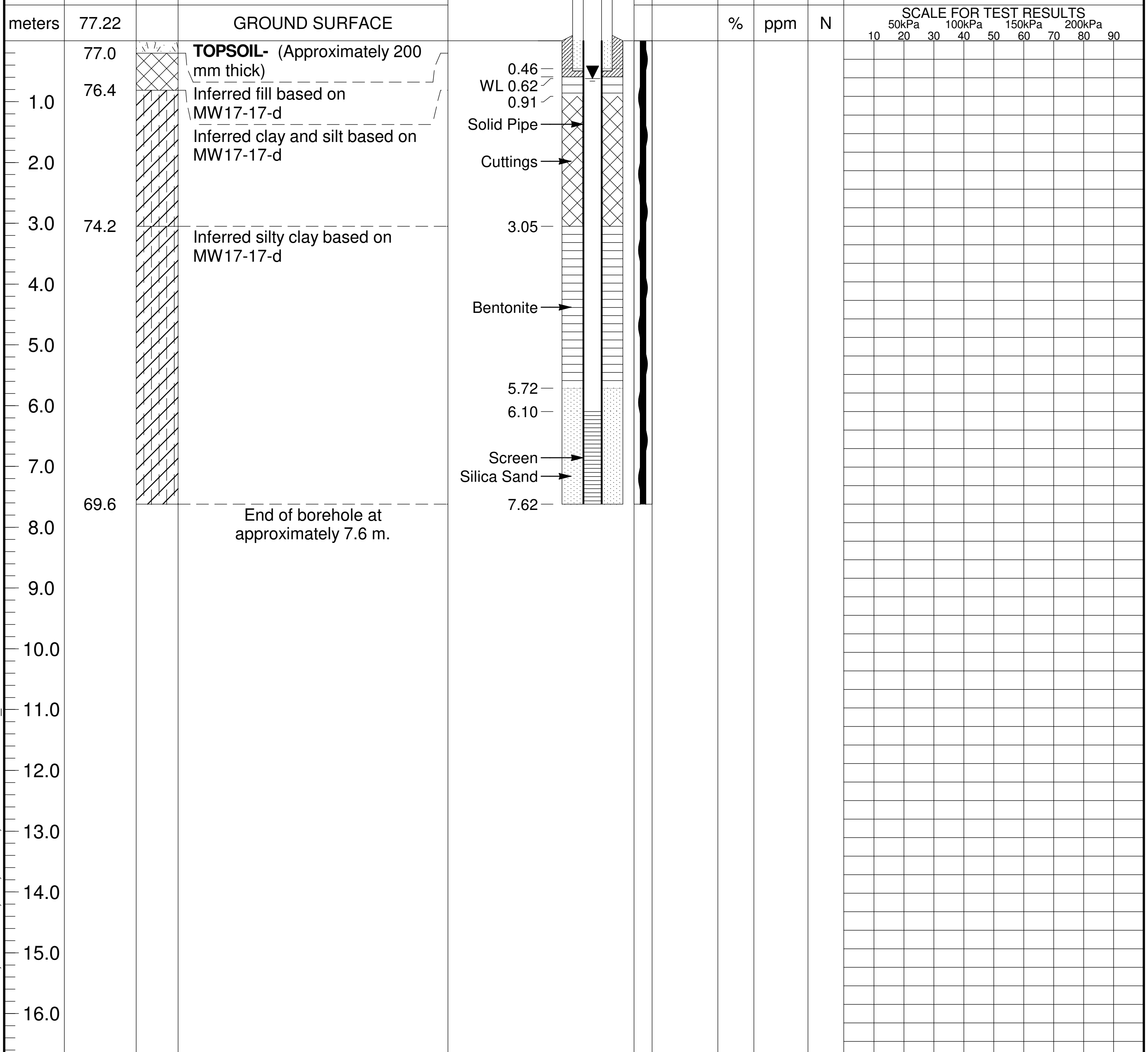
BOREHOLE LOG

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.
PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant
LOCATION: 300 Water Street West, Napanee, On
DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan
DATE (START): 24 November 2017 DATE (FINISH): 24 November 2017

LEGEND
- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- ▼ Water Level
- ○ Water content (%)
- ⊢⊣ Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	DESCRIPTION OF SOIL AND BEDROCK	MONITOR WELL
	77.22	GROUND SURFACE	0.83, 0.76
	77.0	**TOPSOIL-** (Approximately 200 mm thick)	0.46
	76.4	Inferred fill based on MW17-17-d	WL 0.62; 0.91; Solid Pipe; Cuttings
		Inferred clay and silt based on MW17-17-d	
	74.2	Inferred silty clay based on MW17-17-d	3.05; Bentonite; 5.72; 6.10; Screen; Silica Sand
	69.6	End of borehole at approximately 7.6 m.	7.62



Sample data columns: State | Type and Number | Recovery (%) | OVC (ppm) | Penetration Index / RQD (N)

NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A2 ENCLOSURE No.: 20

BOREHOLE No.: BH18-17
ELEVATION: 77.62 m

BOREHOLE LOG

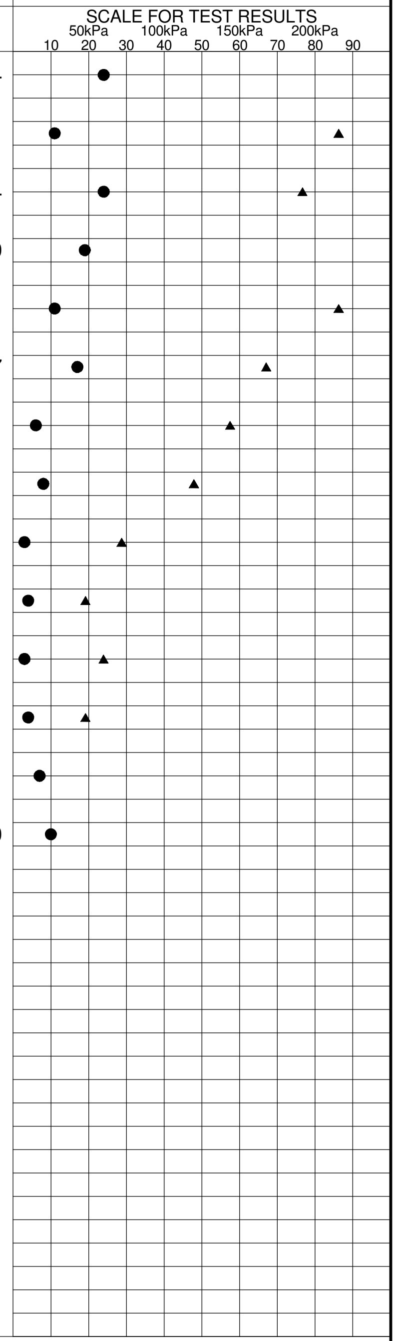
Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.
PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant
LOCATION: 300 Water Street West, Napanee, On
DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan
DATE (START): 24 November 2017 DATE (FINISH): 24 November 2017

LEGEND

- ☒ SS Split Spoon
- GS Auger Sample
- ▨ ST Shelby Tube
- ▼ Water Level
- ○ Water content (%)
- ⊢⊣ Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	DESCRIPTION OF SOIL AND BEDROCK	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	77.62	GROUND SURFACE				
		FILL- Gravel, dense, grey, damp. *Becoming Gravel some Sand and Silt, brown and grey.	SS1	20/24		24
1.0	76.6	*Becoming Gravelly Silt, dark brown, damp	SS2	22/24		11
		CLAY AND SILT- Very stiff, brown, damp.				
2.0			SS3	24/24		24
			SS4	24/24		19
3.0			SS5	24/24		11
4.0			SS6	24/24		17
	73.1	**SILTY CLAY-** Very stiff, grey, damp, trace sand veins.				
5.0			SS7	24/24		6
6.0			SS8	24/24		8
		*Becoming stiff	SS9	24/24		3
7.0		*Becoming firm, moist	SS10	24/24		4
8.0			SS11	24/24		3
			SS12	24/24		4
9.0	68.5	**SAND-** Loose, light brown, wet, some silt seams (approximately 200 mm thick).	SS13	24/24		7
10.0			SS14	24/24		10
11.0			SS15	24/24		R
	66.3	Auger refusal at approximately 11.3 m.				
12.0						
13.0						
14.0						
15.0						
16.0						



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

BOREHOLE No.: BH19-17
ELEVATION: 76.99 m

BOREHOLE LOG

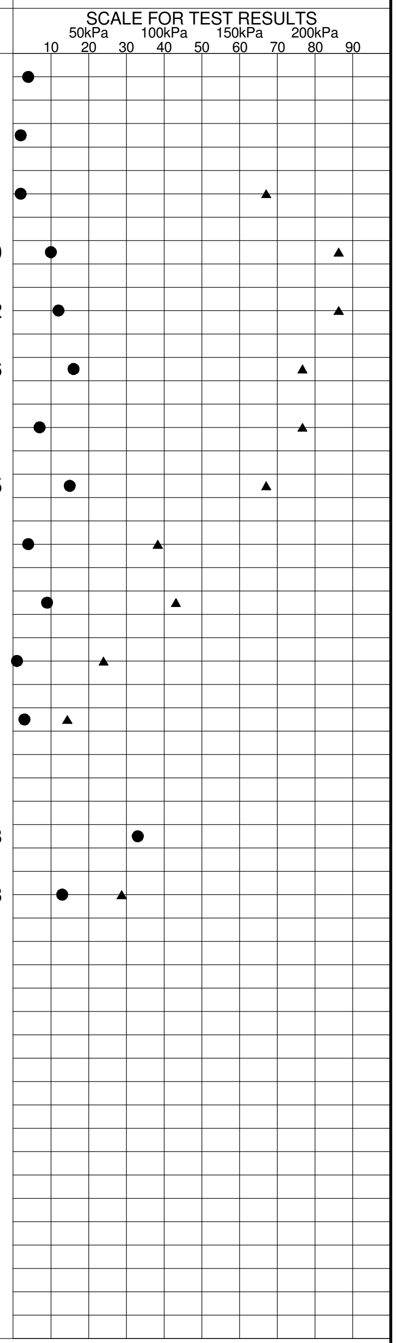
Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.
PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant
LOCATION: 300 Water Street West, Napanee, On
DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan
DATE (START): 24 November 2017 DATE (FINISH): 24 November 2017

LEGEND
- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Elevation (m)	DESCRIPTION OF SOIL AND BEDROCK	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
76.99	GROUND SURFACE				
76.9	**TOPSOIL-** (Approximately 125 mm thick)	SS1	6/24		4
	FILL- Sand, very loose, brown, damp.	SS2	24/24		2
	*Becoming wet	SS3	22/24		2
75.2	**CLAY AND SILT-** Very stiff, brown, damp.	SS4	14/24		10
		SS5	24/24		12
		SS6	24/24		16
72.4	**SILTY CLAY-** Very stiff, grey, damp, trace sand veins.	SS7	24/24		7
		SS8	24/24		15
	*Becoming stiff and moist	SS9	24/24		4
		SS10	24/24		9
		SS11	24/24		1
	*Becoming firm	SS12	24/24		3
	*FV > 90 kPa vane capacity.	FV1			
67.1	**SAND-** Dense, light brown, wet.	SS13	24/24		33
	*Silt seam (approximately 125 mm thick)	SS14	24/24		13
65.6	Auger refusal at approximately 11.4 m.				

Depth BGS (meters): 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A2 ENCLOSURE No.: 22

BOREHOLE No.: BH20-17

ELEVATION: 77.87 m

BOREHOLE LOG

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan

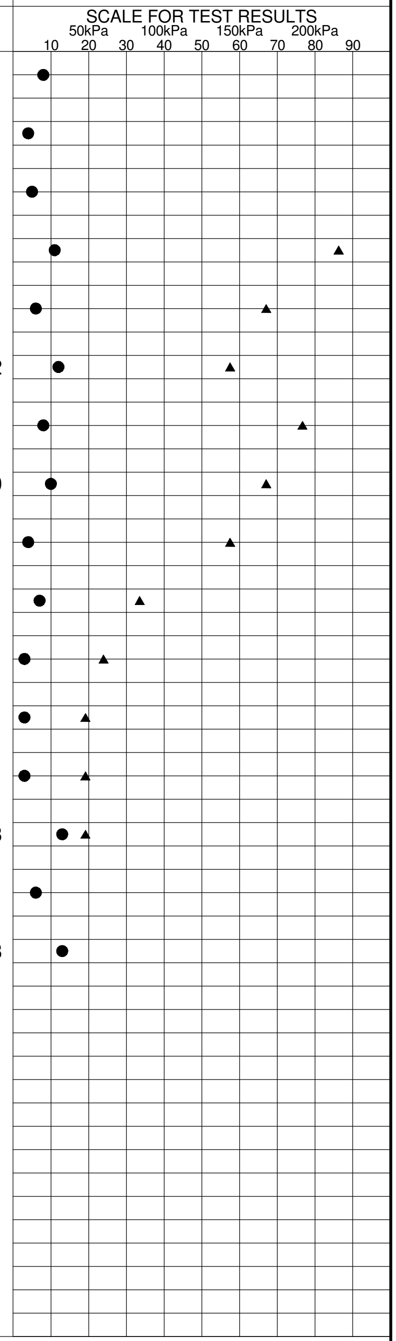
DATE (START): 27 November 2017 DATE (FINISH): 27 November 2017

LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	Description of Soil and Bedrock	State	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	77.87	GROUND SURFACE					
		FILL- Gravelly Sand, loose, brown, damp.	X	SS1	18/24		8
1.0	76.9	*Becoming Sandy Silt some Gravel, dark brown	X	SS2	16/24		4
	76.9	**BURIED TOPSOIL-** (Approximately 50 mm thick)					
		FILL- Sand some Silt, loose, dark brown, damp.	X	SS3	15/24		5
2.0			X	SS4	20/24		11
3.0	75.2	**CLAY AND SILT-** Very stiff, brown, damp.					
	74.7	**SILTY CLAY-** Very stiff, grey, damp, trace sand veins.	X	SS5	24/24		6
4.0			X	SS6	24/24		12
5.0			X	SS7	24/24		8
6.0			X	SS8	24/24		10
			X	SS9	24/24		4
7.0		*Becoming stiff	X	SS10	24/24		7
8.0			X	SS11	24/24		3
		*Becoming firm	X	SS12	24/24		3
9.0			X	SS13	24/24		3
10.0	67.7	**SAND SOME SILT AND GRAVEL-** Compact, light brown, wet.	X	SS14	24/24		13
11.0		*Becoming Sand, loose	X	SS15	20/24		6
		*Becoming compact	X	SS16	24/24		13
12.0	65.8	Auger refusal at approximately 12.1 m.					
13.0							
14.0							
15.0							
16.0							

SCALE FOR TEST RESULTS



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A2 ENCLOSURE No.: 23

BOREHOLE No.: MW21-17-d
ELEVATION: 77.72 m

BOREHOLE LOG

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.
PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant
LOCATION: 300 Water Street West, Napanee, On
DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan
DATE (START): 28 November 2017 DATE (FINISH): 28 November 2017

LEGEND
- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Elevation (m)	Description of Soil and Bedrock
77.72	GROUND SURFACE
77.5	**TOPSOIL-** (Approximatley 200 mm thick)
	FILL- Silt some Sand and Gravel, loose, dark brown, damp. *Becoming some Clayey Silt some Sand, compact
75.9	**CLAY AND SILT-** Very stiff, brown, damp.
73.1	**SILTY CLAY-** Very stiff, grey, damp, trace sand veins.
69.3	**SANDY SILT-** Some Sand veins, stiff, grey, moist to wet.
67.4	**LIMESTONE-** Medium strong, thickly bedded, horizontal, slightly weathered, good quality based on RQD. *Becoming excellent quality based on RQD
64.1	End of borehole at approximately 13.6 m in limestone.

Monitor well: 0.96, 0.91 (top of casing); 0.46; WL 0.89; 0.91; Cuttings; 4.27; Riser; Bentonite; Packer 10.59; 10.74; 11.05; Open Hole; 13.61

Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
SS1	14/24		9
SS2	21/24		12
SS3	16/24		8
SS4	21/24		15
SS5	24/24		11
SS6	24/24		14
SS7	24/24		9
SS8	24/24		14
SS9	24/24		6
SS10	24/24		13
SS11	24/24		7
SS12	22/24		9
SS13	22/24		16
SS14	12/15		R
RC1	64/68		87
RC2	63/63		98

SCALE FOR TEST RESULTS: 50kPa 100kPa 150kPa 200kPa; 10 20 30 40 50 60 70 80 90

Depth BGS (meters): 1.0 – 16.0

NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

BOREHOLE LOG

BOREHOLE No.: MW21-17-s

ELEVATION: 77.71 m

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan

DATE (START): 28 November 2017 DATE (FINISH): 28 November 2017

LEGEND

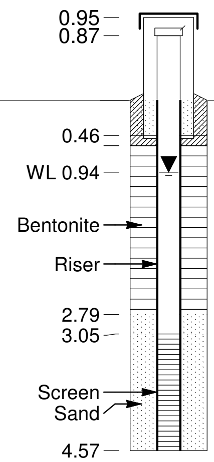
- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- ▼ Water Level
- ○ Water content (%)
- ⊢⊣ Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	Description of Soil and Bedrock	State	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	77.71	GROUND SURFACE					
	77.5	**TOPSOIL-** (Approximatley 200 mm thick)					
		Inferred fill based on MW17-17-d					
	75.9	Inferred clay and silt based on MW17-17-d					
	73.1	End of borehole at approximately 4.6 m.					

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0

SCALE FOR TEST RESULTS: 50kPa, 100kPa, 150kPa, 200kPa; 10, 20, 30, 40, 50, 60, 70, 80, 90

MONITOR WELL



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A2 ENCLOSURE No.: 25

BOREHOLE No.: BH22-17

ELEVATION: 77.72 m

BOREHOLE LOG

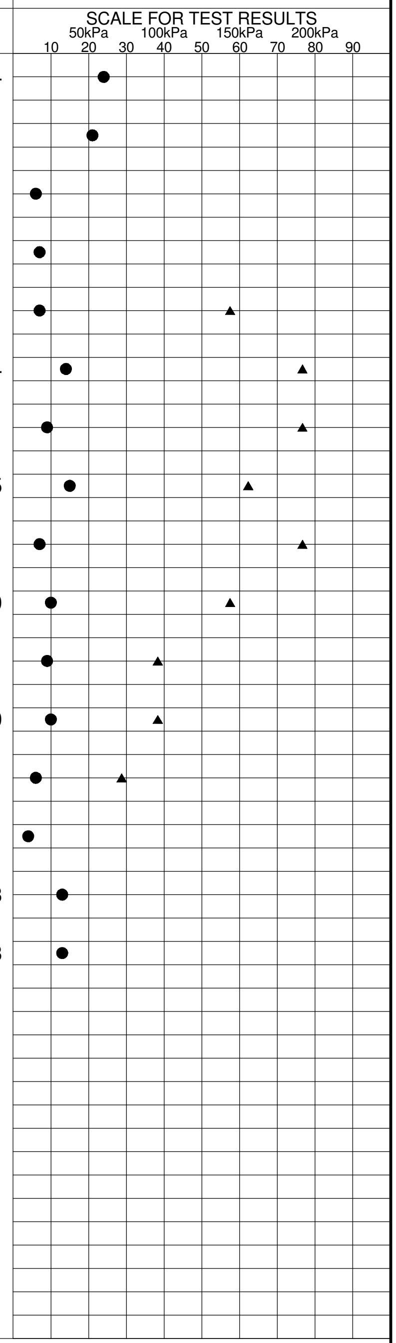
Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.
PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant
LOCATION: 300 Water Street West, Napanee, On
DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan
DATE (START): 27 November 2017 DATE (FINISH): 27 November 2017

LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	DESCRIPTION OF SOIL AND BEDROCK	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
0	77.72	GROUND SURFACE				
		FILL- Gravelly Sand, compact, grey, damp. *Becoming Silt some Sand and Gravel, dark brown	SS1	20/24		24
1.0			SS2	24/24		21
		*Becoming Silty Sand, loose, greyish brown	SS3	15/24		6
2.0			SS4	22/24		7
3.0	74.5	*Becoming Sandy Clay, grey, damp				
		CLAY AND SILT- Very stiff, brown, damp.	SS5	24/24		7
4.0			SS6	24/24		14
5.0			SS7	24/24		9
	72.4	**SILTY CLAY-** Very stiff, grey, damp, trace sand veins.	SS8	24/24		15
6.0			SS9	24/24		7
7.0			SS10	24/24		10
8.0		*Becoming stiff, moist	SS11	24/24		9
			SS12	24/24		10
9.0			SS13	24/24		6
10.0	68.0	**SAND SOME SILT-** Trace Gravel, loose, light greyish brown, wet.	SS14	24/24		4
11.0		*Becoming Gravelly Sand, compact	SS15	1/24		13
12.0			SS16	10/24		13
	65.4	Auger refusal at approximately 12.3 m.				
13.0						
14.0						
15.0						
16.0						



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A2 ENCLOSURE No.: 26

BOREHOLE No.: BH23-17

ELEVATION: 80.00 m

BOREHOLE LOG

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan

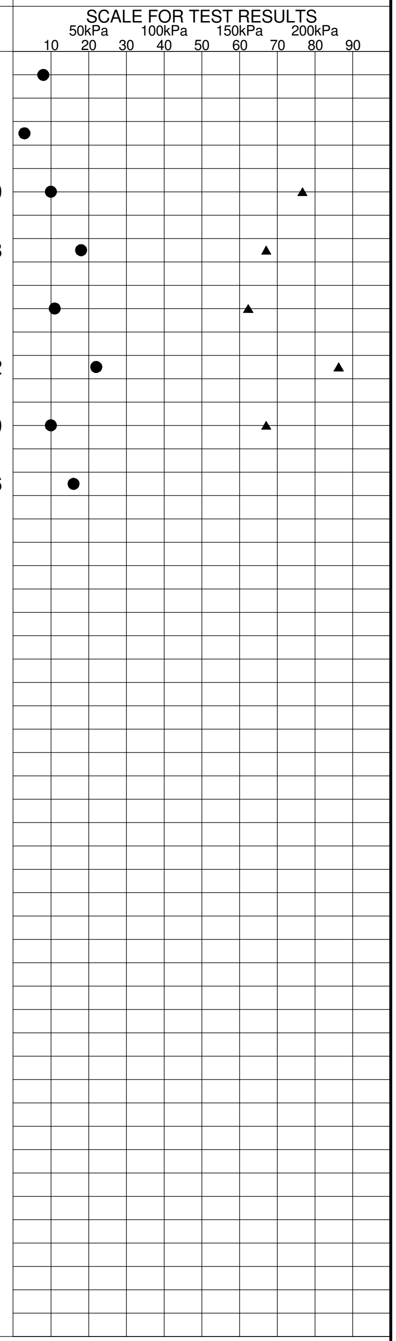
DATE (START): 27 November 2017 DATE (FINISH): 27 November 2017

LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	Description of Soil and Bedrock	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	80.00	GROUND SURFACE				
	79.8	**TOPSOIL-** (Approximately 175 mm thick)	SS1	12/24		8
1.0		**FILL-** Sandy Silt, loose, dark brown, damp.	SS2	22/24		3
2.0	78.5	**CLAY AND SILT-** Very stiff, brown, damp.	SS3	24/24		10
3.0			SS4	24/24		18
			SS5	24/24		11
4.0			SS6	14/24		22
5.0	75.4	**SILTY CLAY-** Very stiff, grey, damp, trace sand veins.	SS7	17/24		10
6.0	74.4	**SAND-** Compact, brown, wet, some silt seams (approximately 125 to 150 mm thick).	SS8	24/24		16
			SS9	24/24		R
7.0	73.1	Auger refusal at approximately 6.9 m.				

Depth scale continues: 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by GHD field staff
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A1 ENCLOSURE No.: 3

BOREHOLE LOG

BOREHOLE No.: MW3-17

ELEVATION: 81.30 m

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan

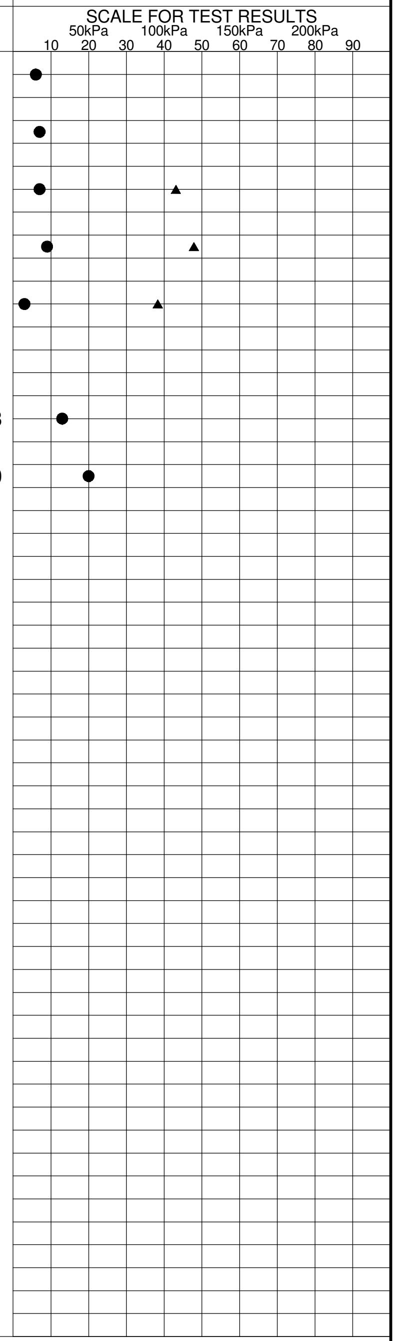
DATE (START): 15 May 2017 DATE (FINISH): 15 May 2017

LEGEND

- ⊠ SS Split Spoon
- GS Auger Sample
- ▨ ST Shelby Tube
- ▼ Water Level
- ○ Water content (%)
- ⊢⊣ Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	DESCRIPTION OF SOIL AND BEDROCK	MONITOR WELL	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	81.30	GROUND SURFACE	0.76, 0.70				
	81.2	**TOPSOIL-** Brown, damp. (Approximately 50 mm)	0.30	SS1	14/24		6
1.0	80.4	**FILL-** Silt Some Sand, loose, brown, damp.		SS2	16/24		7
	79.9	**FILL-** Sand Some Silt, loose, brown, damp.	Solid Pipe	SS3	22/24		7
2.0–3.0		**CLAY AND SILT-** Very stiff, brown, damp, contains thin (approximately 2 mm) sand veins. *Becoming stiff, grey and moist.	Bentonite	SS4	24/24		9
				SS5	24/24		3
4.0	77.6	**SILTY SAND TRACE GRAVEL-**Compact, brown, wet. *FV > 90 kPa vane capacity.	WL 4.24 5/19/2017	FV1			
5.0			4.57, 4.88, Silica Sand	SS6	15/24		13
6.0			Screen	SS7	20/24		20
	74.9	Auger refusal at approximately 6.4 m.	6.40	SS8	10/12		R

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by Hopkins-Chitty Surveying Ltd.
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A1 ENCLOSURE No.: 4

BOREHOLE No.: **BH4-17**

ELEVATION: 81.31 m

BOREHOLE LOG

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan

DATE (START): 15 May 2017 DATE (FINISH): 15 May 2017

LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	Description of Soil and Bedrock	State	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
0	81.31	GROUND SURFACE					
	81.2	**ASPHALT-** Approximately 75 mm thick.					
	81.0	**FILL-** Sandy Gravel, compact, grey, damp.	SS	SS1	14/24		18
	80.8	**FILL-** Sand some Silt, compact, brown, damp.					
1.0		**SILT SOME SAND-** loose, brown, damp.	SS	SS2	20/24		8
	79.6	**CLAY AND SILT-** Very stiff, brown, damp. *Gravelly Sand seam	SS	SS3	18/24		12
2.0			SS	SS4	22/24		7
3.0			SS	SS5	24/24		8
4.0	77.4	**SILTY SAND-** Compact, brown, wet.	SS	SS6	11/24		18
5.0			SS	SS7	13/24		12
			SS	SS8	8/19		R
6.0	75.6	Auger refusal at approximately 5.7 m.					

SCALE FOR TEST RESULTS: 50kPa, 100kPa, 150kPa, 200kPa; 10, 20, 30, 40, 50, 60, 70, 80, 90

Depth scale: 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0

NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by Hopkins-Chitty Surveying Ltd.
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A1 ENCLOSURE No.: 5

BOREHOLE No.: BH5-17
ELEVATION: 77.83 m

BOREHOLE LOG

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.
PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant
LOCATION: 300 Water Street West, Napanee, On
DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan
DATE (START): 19 May 2017 DATE (FINISH): 19 May 2017

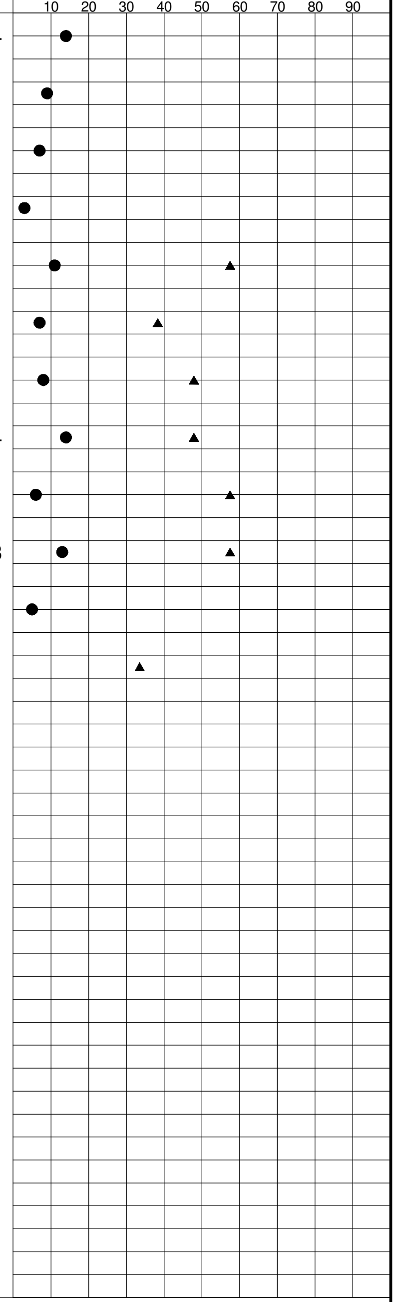
LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	Description of Soil and Bedrock	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	77.83	GROUND SURFACE				
0.0		**FILL-** Gravelly Sandy Silt, compact, brown, damp.	SS1	7/24		14
1.0			SS2	12/24		9
	76.3 / 76.2	**BURIED TOPSOIL-** Brown, damp. (Approximately 100 mm) **FILL-** Sand, loose, brown, damp.	SS3	8/24		7
2.0			SS4	11/24		3
3.0	75.0	**CLAY AND SILT-** Very stiff, brown, damp.	SS5	24/24		11
4.0			SS6	24/24		7
5.0	73.2	**SILTY CLAY** Very stiff, grey, damp, contains thin (approximately 2 mm) sand veins throughout.	SS7	24/24		8
6.0			SS8	19/24		14
7.0			SS9	24/24		6
			SS10	24/24		13
8.0		*Becoming trace sand	SS11	24/24		5
		*Becoming some silt, stiff and moist.	SS12	22/24		R
9.0	68.8	End of borehole at approximately 9.0 m in silty clay.				

Depth scale continues: 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0

SCALE FOR TEST RESULTS: 50kPa, 100kPa, 150kPa, 200kPa; 10, 20, 30, 40, 50, 60, 70, 80, 90



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by Hopkins-Chitty Surveying Ltd.
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A1 ENCLOSURE No.: 6

BOREHOLE No.: MW6-17

ELEVATION: 77.62 m

BOREHOLE LOG

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S.Wheeler CHECKED BY: S. Dunstan

DATE (START): 16 May 2017 DATE (FINISH): 16 May 2017

LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- ▼ Water Level
- ○ Water content (%)
- ⊢⊣ Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

STRATIGRAPHY

Elevation (m)	DESCRIPTION OF SOIL AND BEDROCK
77.62	GROUND SURFACE
77.5	**TOPSOIL-** Brown, damp.(Approximately 100 mm)
77.3	**FILL-** Sandy Gravel, compact, brown, damp.
76.1	**FILL-** Silt and Sand, compact, brown, damp.
76.0	**BURIED TOPSOIL-** Brown, damp. (Approximately 75 mm)
	CLAY AND SILT- Very stiff, brown, damp. *FV > 90 kPa vane capacity.
72.7	**SILTY CLAY-** Very stiff, grey, damp. *Becoming moist.
68.5	**SAND AND SILT TRACE GRAVEL-** Loose, brown, wet. *Becoming sand some silt and compact.
64.9	**LIMESTONE-** Medium strong, thickly bedded, horizontal, slightly weathered, excellent quality based on RQD. *Horizontal closed joint apptoximately 2 mm thick.
61.7	End of borehole at approximately 15.9 m in limestone.

MONITOR WELL

WL 1.70 / 0.94 / 0.70 — 5/19/2017

0.30 — Backfill — 0.91

Solid Pipe

Bentonite

Silica Sand 14.02 — 14.17

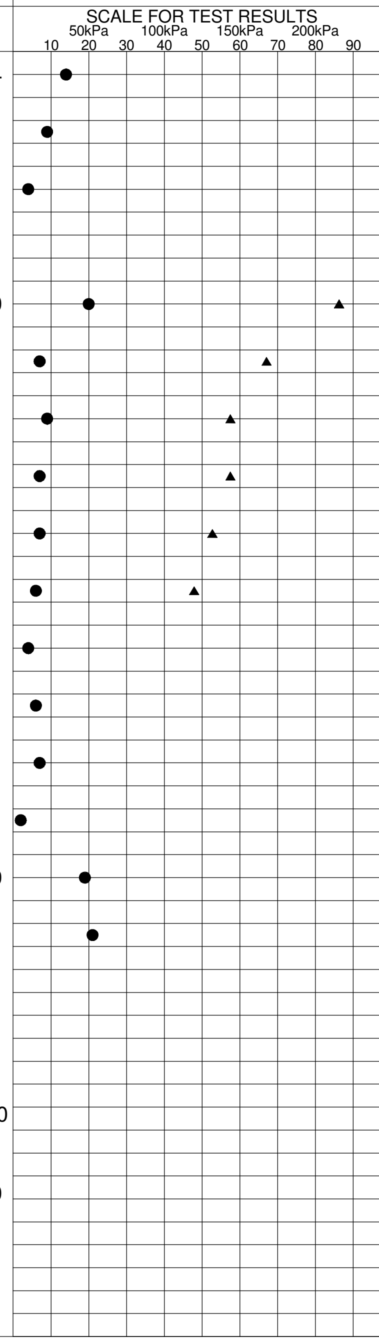
Screen

15.70

SAMPLE DATA

Depth BGS (m, approx.)	Type and Number	Recovery	OVC (ppm)	Penetration Index / RQD (N)
0.3	SS1	15/24		14
1.1	SS2	17/24		9
1.8	SS3	12/24		4
2.6	FV1			
3.3	SS4	19/24		20
4.1	SS5	24/24		7
4.9	SS6	22/24		9
5.6	SS7	18/24		7
6.4	SS8	24/24		7
7.1	SS9	24/24		6
7.9	SS10	24/24		4
8.7	SS11	24/24		6
9.4	SS12	24/24		7
10.2	SS13	2/24		2
10.9	SS14	22/24		19
11.7	SS15			21
12.4	SS16			R
13.1	RC1	42/46		91
14.0	RC2	23/23		100
15.0	RC3	53/59		90

SCALE FOR TEST RESULTS



NOTES:
*No sheen odour or staining noted in borehole
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.<<CR>>*Artesian groundwater in rock approximately 1.7 m above the existing surface.

REFERENCE No.: 11140477-A1 ENCLOSURE No.: 7

BOREHOLE LOG

BOREHOLE No.: BH7-17
ELEVATION: 78.15 m

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.
PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant
LOCATION: 300 Water Street West, Napanee, On
DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan
DATE (START): 17 May 2017 DATE (FINISH): 17 May 2017

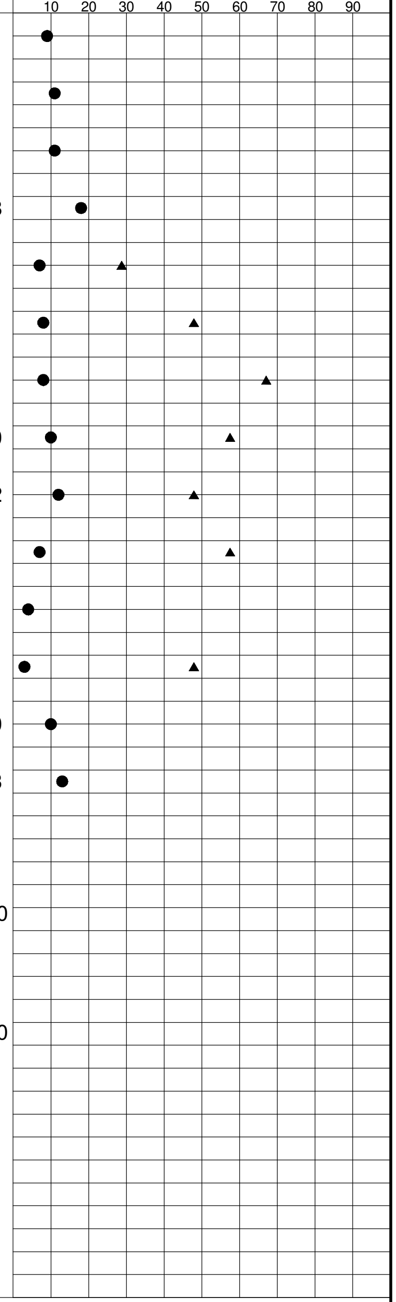
LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Elevation (m)	DESCRIPTION OF SOIL AND BEDROCK	Type and Number	Recovery	OVC (ppm)	Penetration Index / RQD (N)
78.15	GROUND SURFACE		%	ppm	N
77.9	**TOPSOIL-** Brown, damp. (Approximately 200 mm)				
	FILL- Sandy Silt, hard, brown, damp.	SS1	18/24		9
77.3	**FILL-** Sandy Gravel, compact, brown, wet.	SS2	8/24		11
		SS3	11/24		11
		SS4	14/24		18
75.3	**CLAY AND SILT-** Stiff, brown, damp.	SS5	24/24		7
	*Becoming very stiff.	SS6	24/24		8
		SS7	24/24		8
		SS8	23/24		10
72.2	**SILTY CLAY-** Very stiff, grey, damp, cut with sand seams up to approximately 75 mm.	SS9	24/24		12
		SS10	24/24		7
		SS11	24/24		4
		SS12	24/24		3
69.3	**SILTY SAND-** Compact, brown, wet.	SS13	16/24		10
		SS14	22/24		13
		SS15	15/20		R
67.0	**LIMESTONE-** Medium strong, thickly bedded, horizontal, slightly weathered, excellent quality based on RQD. *Horizontal closed joint, approximately 2mm thick.	RC1	61/61		100
	*Horizontal closed joint, approximately 2mm thick.	RC2	62/62		100
63.8	End of borehole at approximately 14.3 m in limestone.				

Depth BGS (meters): 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0

SCALE FOR TEST RESULTS



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by Hopkins-Chitty Surveying Ltd.
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A1 | ENCLOSURE No.: 8

BOREHOLE LOG

BOREHOLE No.: BH8-17

ELEVATION: 78.73 m

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S. Wheeler | CHECKED BY: S. Dunstan

DATE (START): 18 May 2017 | DATE (FINISH): 18 May 2017

LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Elevation (m)	Description of Soil and Bedrock
78.73	GROUND SURFACE
78.7	**TOPSOIL-** Brown, damp. (Approximately 50 mm thick)
78.6	**FILL-** Sand, compact, brown, damp.
78.1	**FILL-** Silt some gravel, loose, brown, damp.
77.6	**FILL-** Sand, loose, brown, damp.
	CLAY AND SILT- Very stiff, brown, damp.
72.6	**SILTY CLAY-** Stiff, grey, damp, contains thin sand veins throughout.
72.1	**SILTY SAND-** Compact, brown, wet.
70.4	**LIMESTONE-** Medium strong, thickly bedded, horizontal, slightly weathered, excellent quality based on RQD. *Multiple horizontal closed joints apptoximately 2 mm thick through rock core.
67.4	End of borehole at approximately 11.4 m in limestone.

Type and Number	Recovery	OVC (ppm)	Penetration Index / RQD (N)
SS1	18/24		10
SS2	22/24		4
SS3	22/24		17
SS4	12/24		13
SS5	20/24		10
SS6	18/24		13
SS7	23/24		10
SS8	23/24		6
SS9	24/24		5
SS10	24/24		20
SS11	24/28		R
RC1	56/59		95
RC2	59/60		98

SCALE FOR TEST RESULTS: 50kPa, 100kPa, 150kPa, 200kPa; 10 20 30 40 50 60 70 80 90

Depth BGS (meters): 1.0 – 16.0

NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by Hopkins-Chitty Surveying Ltd.
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A1 ENCLOSURE No.: 9

GHD

BOREHOLE No.: BH9-17

ELEVATION: 79.49 m

BOREHOLE LOG

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

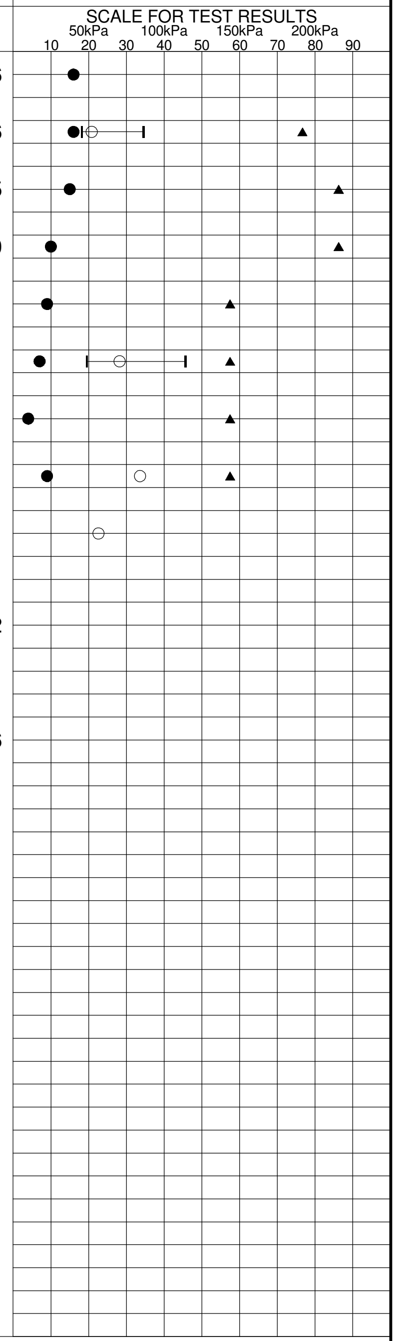
DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan

DATE (START): 18 May 2017 DATE (FINISH): 18 May 2017

LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	Description of Soil and Bedrock	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	79.49	GROUND SURFACE				
	79.3	**FILL-** Gravelly Sand, compact, brown, damp.	SS1	19/24		16
	78.9	**FILL-** Silt some Gravel, compact, brown, damp.				
1.0		**CLAY AND SILT-** Hard, brown, damp.	SS2	16/24		16
2.0			SS3	21/24		15
			SS4	23/24		10
3.0		*Becoming very stiff.	SS5	23/24		9
4.0	75.6	**SILTY CLAY-** Very stiff, grey, damp.	SS6	24/24		7
5.0		*75 mm sand seam	SS7	24/24		4
		*Becoming trace gravel, stiff, brown and contains thin (approximately 2 mm)	SS8	24/24		9
6.0	73.5	**SILTY CLAYEY SAND-** Compact, brown, moist.	SS9	24/24		R
7.0	72.6	**LIMESTONE-** Medium strong, thickly bedded, horizontal, slightly weathered, excellent quality based on RQD. *Multiple horizontal closed joints, approximately 2mm thick throughout rock core.	RC1	54/59		92
8.0						
9.0			RC2	58/60		96
10.0	69.6	End of borehole at approximately 9.9 m in limestone.				
11.0						
12.0						
13.0						
14.0						
15.0						
16.0						



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by Hopkins-Chitty Surveying Ltd.
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A1 ENCLOSURE No.: 10

BOREHOLE No.: MW10-17
ELEVATION: 77.63 m

BOREHOLE LOG

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.
PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant
LOCATION: 300 Water Street West, Napanee, On
DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan
DATE (START): 16 May 2017 DATE (FINISH): 16 May 2017

LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	Description of Soil and Bedrock
0.0	77.63	GROUND SURFACE
	77.6	**TOPSOIL-** Brown, damp.
	77.0	**FILL-** Silty Gravel, loose, brown, damp.
		CLAY AND SILT- Stiff, brown, damp. *Becoming very stiff.
	72.2	**SILTY CLAY-** Very stiff, grey, damp, contains thin sand veins approximately 15 cm apart *50mm sand seam. *Becoming moist.
	69.9 / 69.9	**SILT SOME CLAY SOME SAND TRACE GRAVEL-** Stiff, grey, wet.
	68.9	**SILTY SAND-** Compact, brown, moist. *Gravel seam
	68.6	**SAND-** Loose, brown, wet.
		End of borehole at approximately 9.0 m in sand.

MONITOR WELL: 0.69, 0.61, 0.30, WL 1.17 5/19/2017, Solid Pipe, Bentonite, Silica Sand 8.08, 8.38, Screen, 8.99

Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
SS1	8/24		8
SS2	5/24		4
SS3	16/24		9
SS4	24/24		15
SS5	19/24		10
SS6	24/24		12
SS7	16/24		12
SS8	18/24		7
SS9	24/24		6
SS10	24/24		4
SS11	24/24		12
SS12	24/24		R

SCALE FOR TEST RESULTS: 50kPa 100kPa 150kPa 200kPa; 10 20 30 40 50 60 70 80 90

NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by Hopkins-Chitty Surveying Ltd.
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A1 ENCLOSURE No.: 11

BOREHOLE LOG

Page: 1 of 1

BOREHOLE No.: BH11-17

ELEVATION: 78.77 m

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan

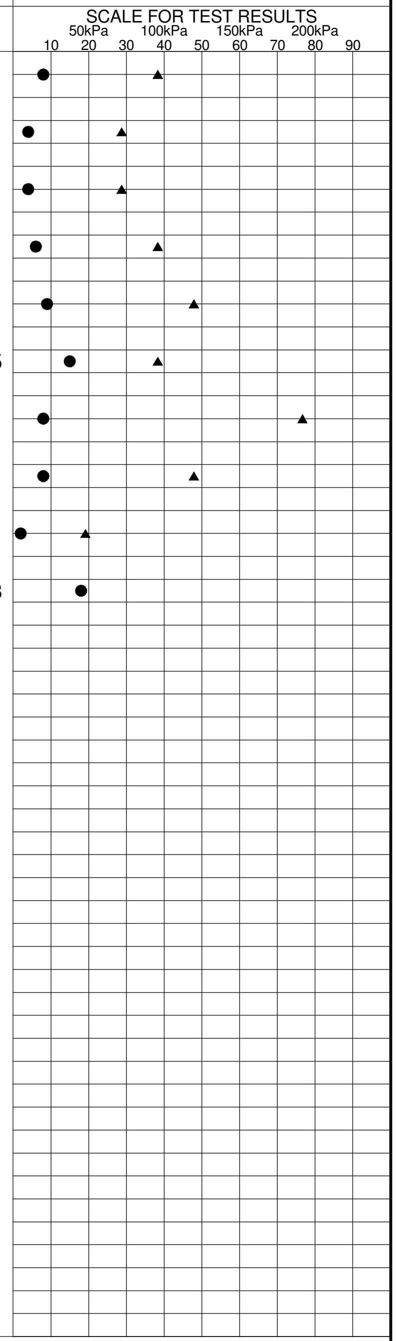
DATE (START): 18 May 2017 DATE (FINISH): 18 May 2017

LEGEND

- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- Water Level
- ○ Water content (%)
- Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	DESCRIPTION OF SOIL AND BEDROCK	Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
	78.77	GROUND SURFACE				
	78.7	**TOPSOIL-** Brown, damp.	SS1	17/24		8
	78.3	**FILL-** Gravelly Sand, loose, brown, damp.				
1.0	77.7	**SILTY SAND-** Loose, brown, damp.	SS2	19/24		4
		CLAY AND SILT- Stiff, brown, damp.				
2.0			SS3	21/24		4
		*Becoming very stiff.	SS4	19/24		6
3.0			SS5	24/24		9
4.0			SS6	24/24		15
	74.1	**SILTY CLAY-** Very stiff, grey, damp, contains thin (approximately 2 mm) sand veins throughout.				
5.0			SS7	14/24		8
6.0			SS8	24/24		8
		*Becoming trace sand.	SS9	24/24		2
7.0	71.7	**SAND SOME SILT-** Compact, brown, moist.	SS10	20/24		18
	71.5	**SILTY SAND-** Compact, brown, wet.	SS10			
8.0			SS11	24/24		R
	70.5	Auger refusal at approximately 8.3 m.				
9.0						
10.0						
11.0						
12.0						
13.0						
14.0						
15.0						
16.0						

SCALE FOR TEST RESULTS



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by Hopkins-Chitty Surveying Ltd.
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

REFERENCE No.: 11140477-A1 ENCLOSURE No.: 12

BOREHOLE LOG

BOREHOLE No.: MW12-17

ELEVATION: 79.80 m

Page: 1 of 1

CLIENT: Town of Greater Napanee C/o EVB Engineering Inc.

PROJECT: Geotechnical Investigation for Upgrades to Napanee Wastewater Treatment Plant

LOCATION: 300 Water Street West, Napanee, On

DESCRIBED BY: S. Wheeler CHECKED BY: S. Dunstan

DATE (START): 17 May 2017 DATE (FINISH): 17 May 2017

LEGEND

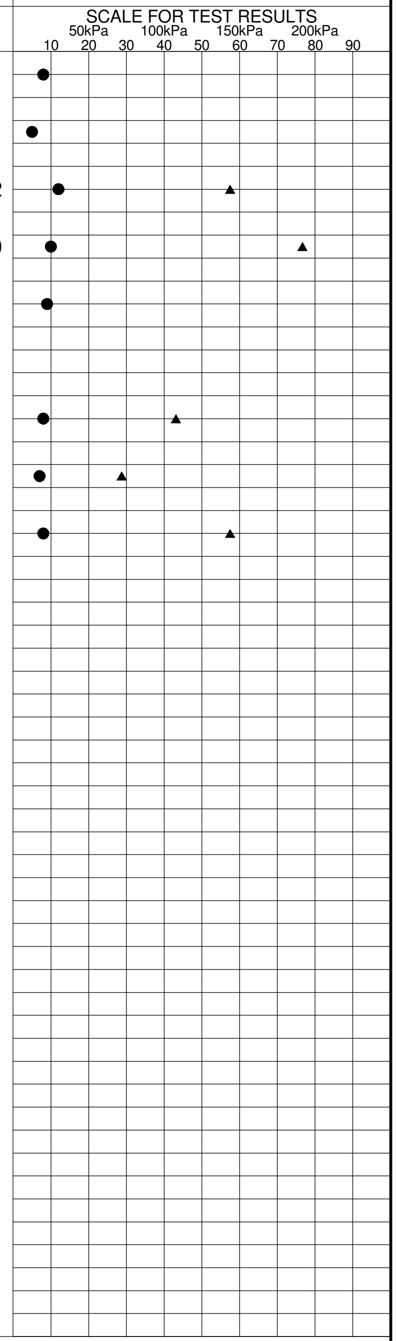
- SS Split Spoon
- GS Auger Sample
- ST Shelby Tube
- ▼ Water Level
- ○ Water content (%)
- ├─┤ Atterberg limits (%)
- ● N Penetration Index based on Split Spoon sample
- • N Penetration Index based on Dynamic Cone sample
- △ Cu Shear Strength based on Field Vane
- □ Cu Shear Strength based on Lab Vane
- S Sensitivity Value of Soil
- ▲ Shear Strength based on Pocket Penetrometer

Depth BGS (meters)	Elevation (m)	DESCRIPTION OF SOIL AND BEDROCK
	79.80	GROUND SURFACE
	79.7	**TOPSOIL-** Brown, damp. (Approximately 100 mm)
	79.5	**FILL-** Sandy Gravel, loose, brown, damp.
	78.3	**FILL-** Sandy SIlt, very stiff, brown, moist.
	78.2	**BURIED TOPSOIL-** Brown, moist. (Approximately 25 mm)
		CLAY AND SILT- Very stiff, brown, damp. *FV > 90 kPa vane capacity.
	75.4	**SILTY CLAY-** Stiff, brown, damp, contains thin sand veins throughout.
	73.1	**SILTY SAND-** Loose, brown, wet.
	72.6	Auger refusal at approximately 7.2 m.

MONITOR WELL: 0.97, 0.85, 0.30, Solid Pipe, WL 2.95 5/19/2017, Bentonite, 6.40, 6.58, Screen, 7.19

SAMPLE DATA: Type and Number	Recovery (%)	OVC (ppm)	Penetration Index / RQD (N)
SS1	12/24		8
SS2	18/24		5
SS3	24/24		12
SS4	22/24		10
SS5	14/24		9
FV1			
SS6	22/24		8
SS7	24/24		7
SS8	21/24		8
SS9	13/13		R

SCALE FOR TEST RESULTS



NOTES:
*No sheen odour or staining noted in borehole
*Borehole location and elevation surveyed by Hopkins-Chitty Surveying Ltd.
*Pocket penetrometer readings are for internal GHD use only and should not be relied upon by others.

Notes on Borehole and Test Pit Reports

Soil description :

Each subsurface stratum is described using the following terminology. The relative density of granular soils is determined by the Standard Penetration Index ("N" value), while the consistency of clayey sols is measured by the value of undrained shear strength (Cu).

Classification (Unified system)

Clay	< 0.002 mm		
Silt	0.002 to 0.075 mm		
Sand	0.075 to 4.75 mm	fine	0.075 to 4.25 mm
		medium	0.425 to 2.0 mm
		coarse	2.0 to 4.75 mm
Gravel	4.75 to 75 mm	fine	4.75 to 19 mm
		coarse	19 to 75 mm
Cobbles	75 to 300 mm		
Boulders	>300 mm		

Terminology

"trace"	1-10%
"some"	10-20%
adjective (silty, sandy)	20-35%
"and"	35-50%

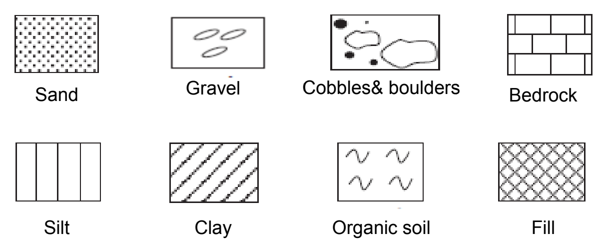
Relative density of granular soils	Standard penetration index "N" value (BLOWS/ft – 300 mm)
Very loose	0-4
Loose	4-10
Compact	10-30
Dense	30-50
Very dense	>50

Consistency of cohesive soils	Undrained shear strength (Cu) (P.S.F)	Undrained shear strength (Cu) (kPa)
Very soft	<250	<12
Soft	250-500	12-25
Firm	500-1000	25-50
Stiff	1000-2000	50-100
Very stiff	2000-4000	100-200
Hard	>4000	>200

Rock quality designation

"RQD" (%) Value	Quality
<25	Very poor
25-50	Poor
50-75	Fair
75-90	Good
>90	Excellent

STRATIGRAPHIC LEGEND



Samples:

Type and Number

The type of sample recovered is shown on the log by the abbreviation listed hereafter. The numbering of samples is sequential for each type of sample.

SS: Split spoon
SSE, GSE, AGE: Environmental sampling
ST: Shelby tube
PS: Piston sample (Osterberg)
AG: Auger
RC: Rock core
GS: Grab sample

Recovery

The recovery, shown as a percentage, is the ratio of length of the sample obtained to the distance the sampler was driven/pushed into the soil

RQD

The "Rock Quality Designation" or "RQD" value, expressed as percentage, is the ratio of the total length of all core fragments of 4 inches (10 cm) or more to the total length of the run.

IN-SITU TESTS:

N: Standard penetration index
R: Refusal to penetration
N_c: Dynamic cone penetration index
Cu: Undrained shear strength
Pr: Pressure meter
k: Permeability
ABS: Absorption (Packer test)

LABORATORY TESTS:

I_p: Plasticity index
W_l: Liquid limit
Wp: Plastic limit
H: Hydrometer analysis
GSA: Grain size analysis
A: Atterberg limits
w: Water content
γ: Unit weight
C: Consolidation
CS: Swedish fall cone
CHEM: Chemical analysis
O.V.: Organic vapor

Explanation of Terms Used in the Bedrock Core Log

Strength (ISRM)

Terms	Grade	Description	Unconfined Compressive Strength (MPa)	(psf)
Extremely Weak Rock	RQ	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.		3625-7250
Strong Rock	R4	Specimen requires 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.	>150	>16250

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 rum and expressed as a percentage

SCR (Solid Core Recover)

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

Explanation of Terms Used in the Bedrock Core Log

Weathering (ISRM)

Terms	Grade	Description
Fresh	W1	No visible sign of rock material weathering.
Slightly	W2	Discolouration indicates weathering of rock weathered material and discontinuity surfaces. All the rock material may be discoloured by weathering and may be somewhat weaker than in its fresh condition.
Moderately	W3	Less than half of the rock material is weathered decomposed and/or disintegrated a soil. Fresh or discoloured rock is present either as a corestone.
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 been significantly transported.

ROD (Rock Quality Designation, after Deere, 1968)

Sum of lengths of pieces of rock core measured along centerline of core equal to or greater than 100 mm from a core run, divided by the length of the 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 core.

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

(FI) Fracture Index

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

Broken Zone
Zone where core 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

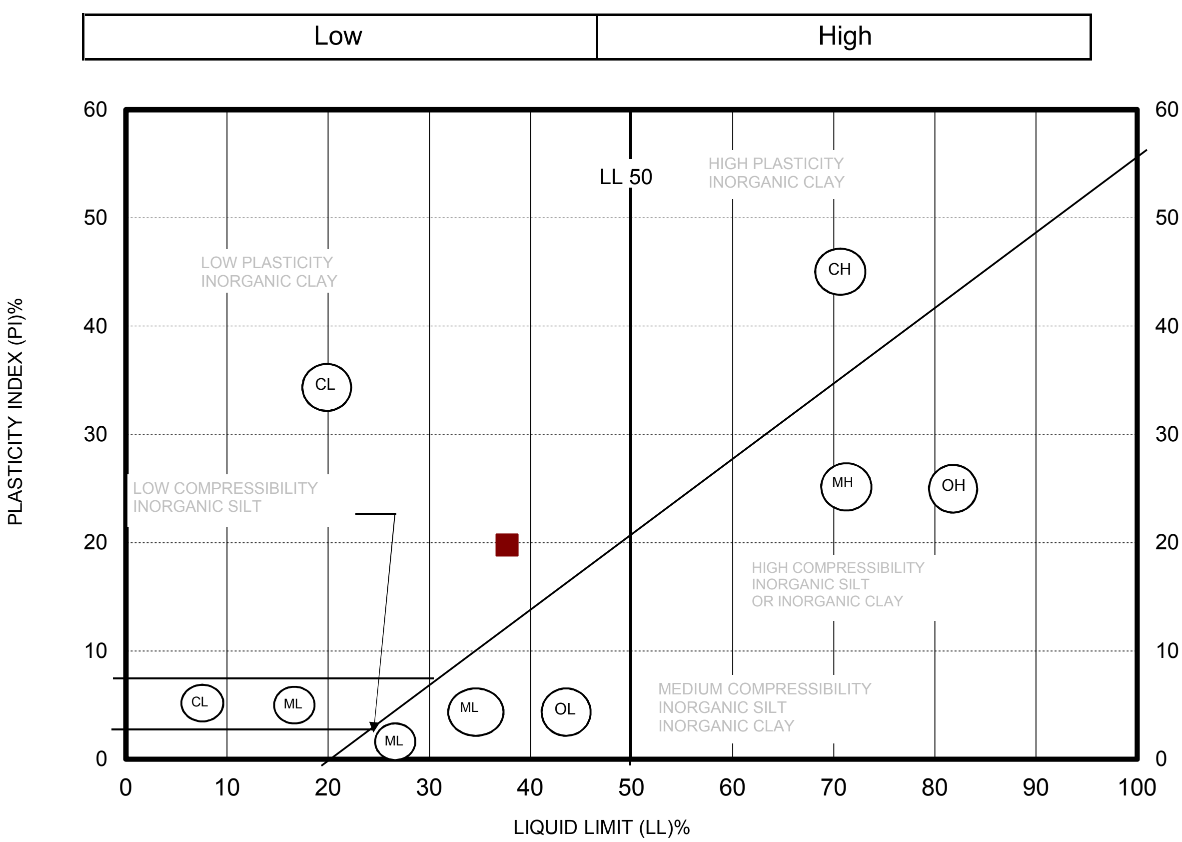
Discontinuity, fracture, and bedding plane orientations are cited as the acute angle measured with respect to the core axis. Fractures perpendicular to the core axis are at 90 degrees and those parallel to the core axis are at 0 degrees.

Appendix B
Laboratory Testing

Plasticity Index and Liquid Limit Testing
LS-703

PLASTICITY CHART

Project Name:	Napanee WWTP	Project No.:	11140477 A1
Client:	Town of Greater Napanee	Depth:	3.4 m
Borehole No.:	BH1-17	Sample No.:	SS-4



Symbol	Borehole	Sample	Depth	Sample Results	Value
■	BH1-17	SS-4	n/a	Plasticity Index (%)	19.8
				Liquid Limit (%)	37.7

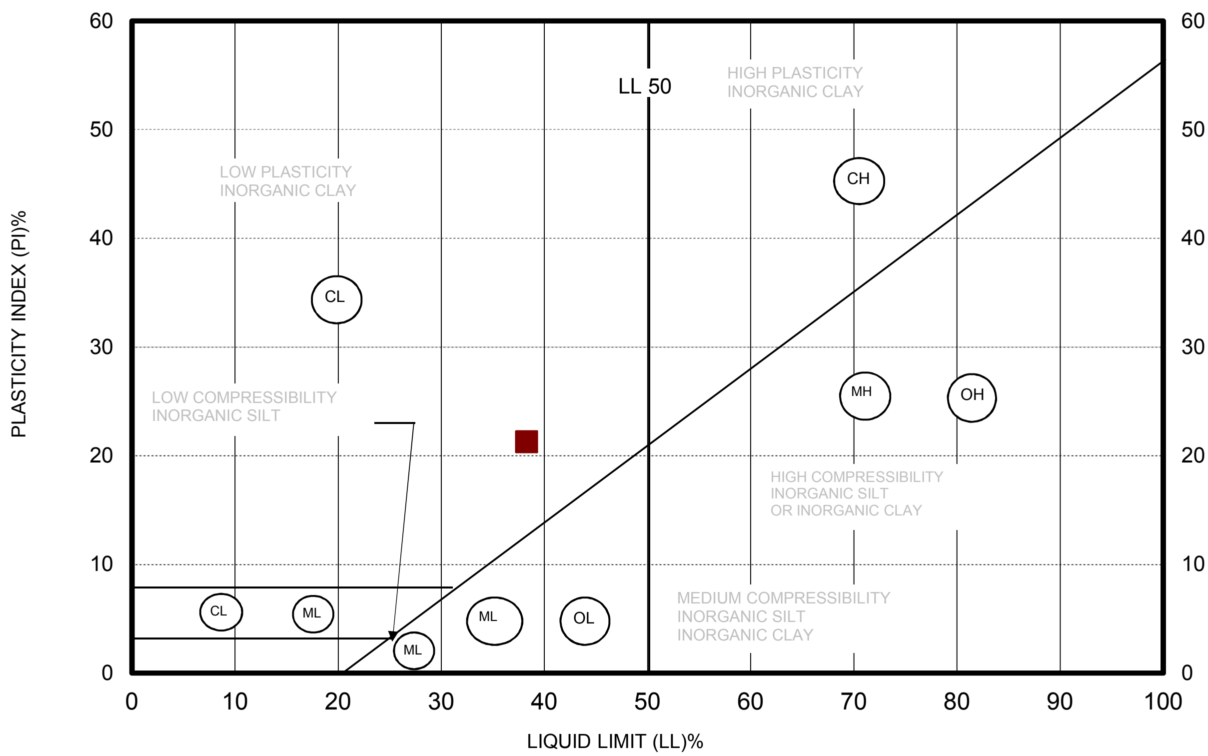
Performed By:	J. Sullivan	Date:	June 1, 2017
Verified By:		Date:	June 1, 2017

Plasticity Index and Liquid Limit Testing
LS-703

PLASTICITY CHART

Project Name:	Napanee WWTP	Project No.:	11140477 A1
Client:	Town of Greater Napanee	Depth:	6.4 m
Borehole No.:	BH1-17	Sample No.:	SS-7

Low	High



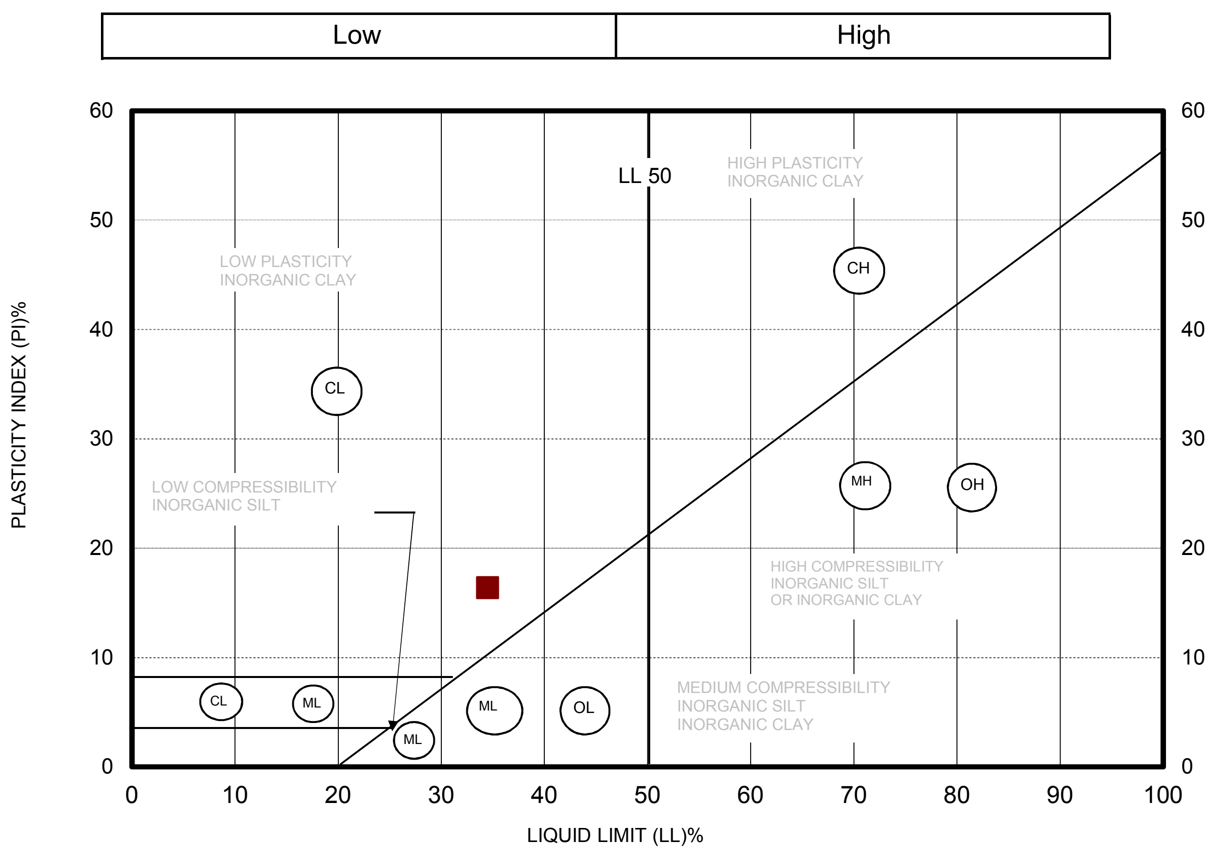
Symbol	Borehole	Sample	Depth	Sample Results	Value
■	BH1-17	SS-7	n/a	Plasticity Index (%)	21.3
				Liquid Limit (%)	38.3

Performed By:	J. Sullivan	Date:	June 1, 2017
Verified By:		Date:	June 1, 2017

Plasticity Index and Liquid Limit Testing
LS-703

PLASTICITY CHART

Project Name:	Napanee WWTP	Project No.:	11140477 A1
Client:	Town of Greater Napanee	Depth:	1.1 m
Borehole No.:	BH9-17	Sample No.:	SS-2



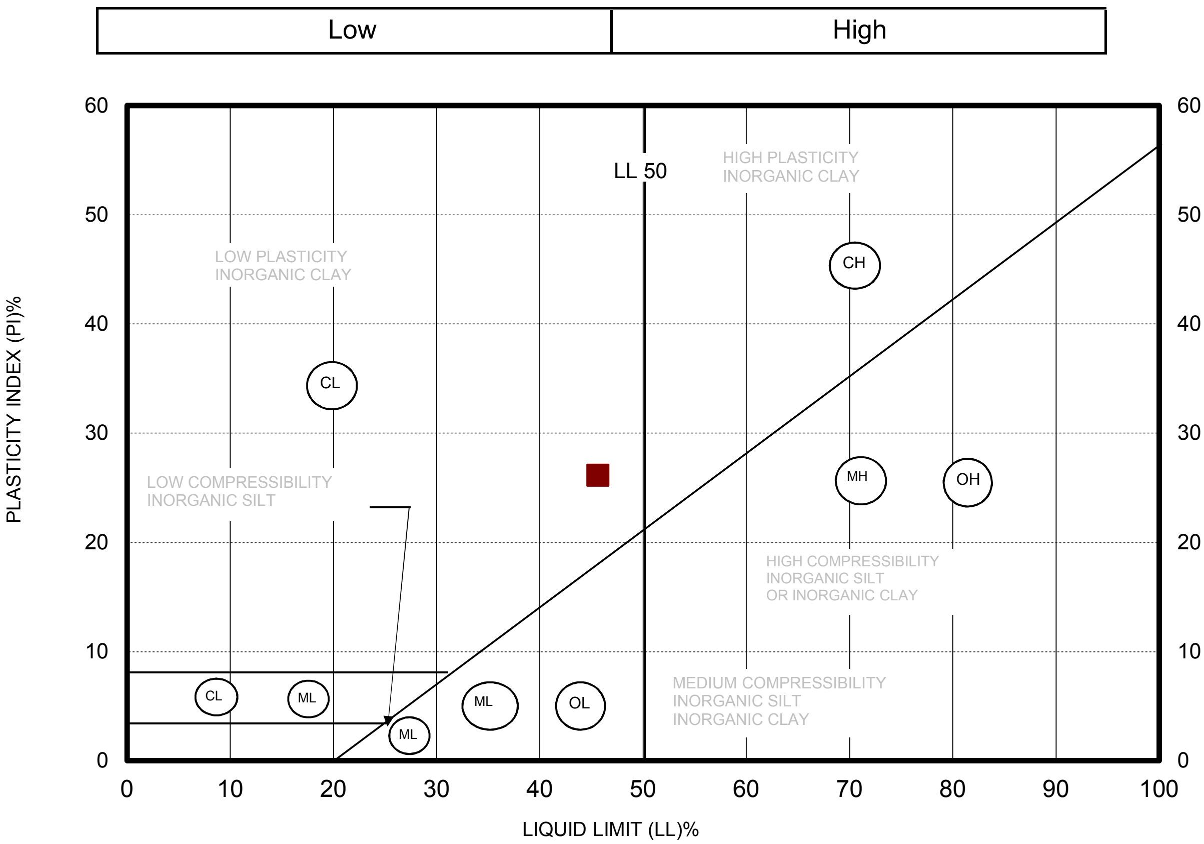
Symbol	Borehole	Sample	Depth	Sample Results	Value
■	BH9-17	SS-2	n/a	Plasticity Index (%)	16.4
				Liquid Limit (%)	34.5

Performed By:	J. Sullivan	Date:	June 1, 2017
Verified By:		Date:	June 1, 2017

Plasticity Index and Liquid Limit Testing
LS-703

PLASTICITY CHART

Project Name:	Napanee WWTP	Project No.:	11140477 A1
Client:	Town of Greater Napanee	Depth:	4.2 m
Borehole No.:	BH9-17	Sample No.:	SS-6

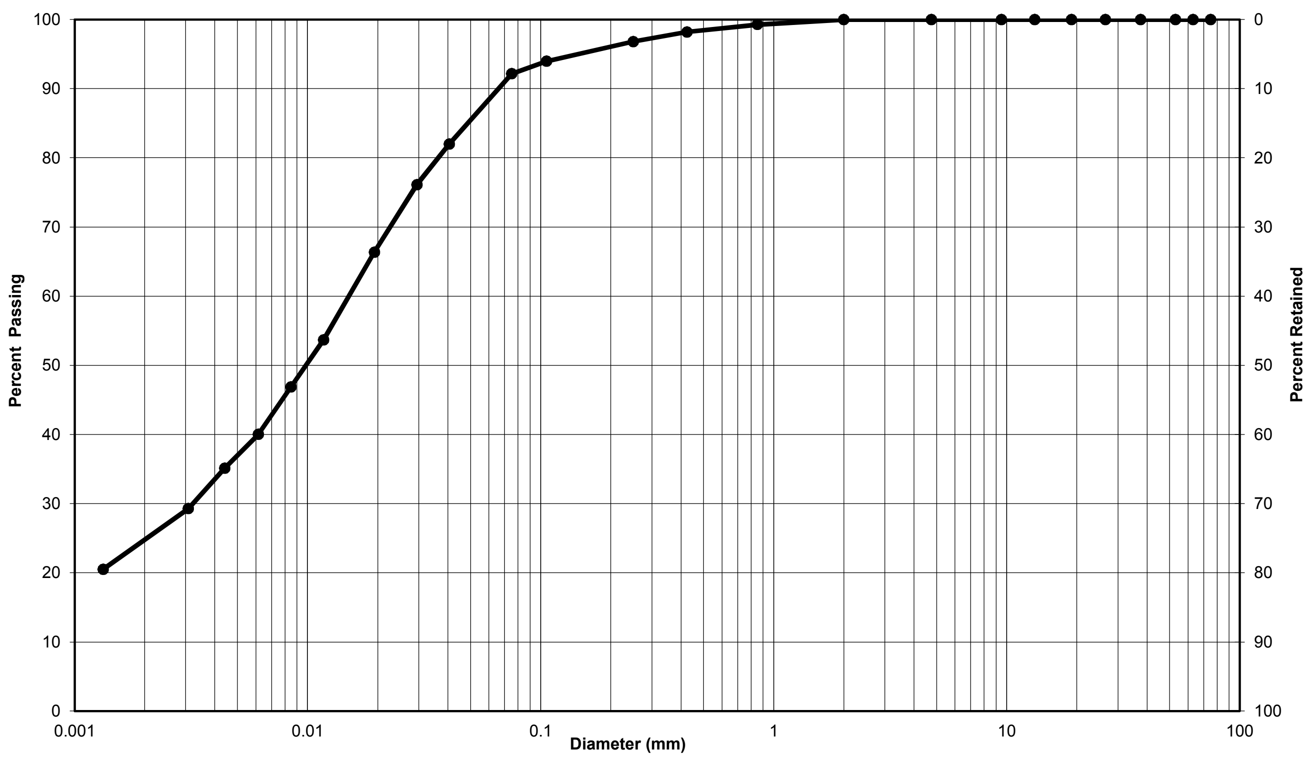


Symbol	Borehole	Sample	Depth	Sample Results	Value
■	BH9-17	SS-6	n/a	Plasticity Index (%)	26.1
				Liquid Limit (%)	45.6

Performed By:	J. Sullivan	Date:	June 1, 2017
Verified By:		Date:	June 1, 2017

Particle-Size Analysis of Soils (Geotechnical) (USCS) (ASTM D422)

Client:	Town of Greater Napanee	**Lab no.:**	2017-Geo-007
Project/Site:	Napanee WWTP, 300 Water Street West	**Project no.:**	11140477 A1
Borehole no.:	BH1-17	Sample no.:	SS-8
Depth:	7.8 m	Enclosure:	5



Clay & Silt	Sand			Gravel	
	Fine	Medium	Coarse	Fine	Coarse
Unified Soil Classification System					

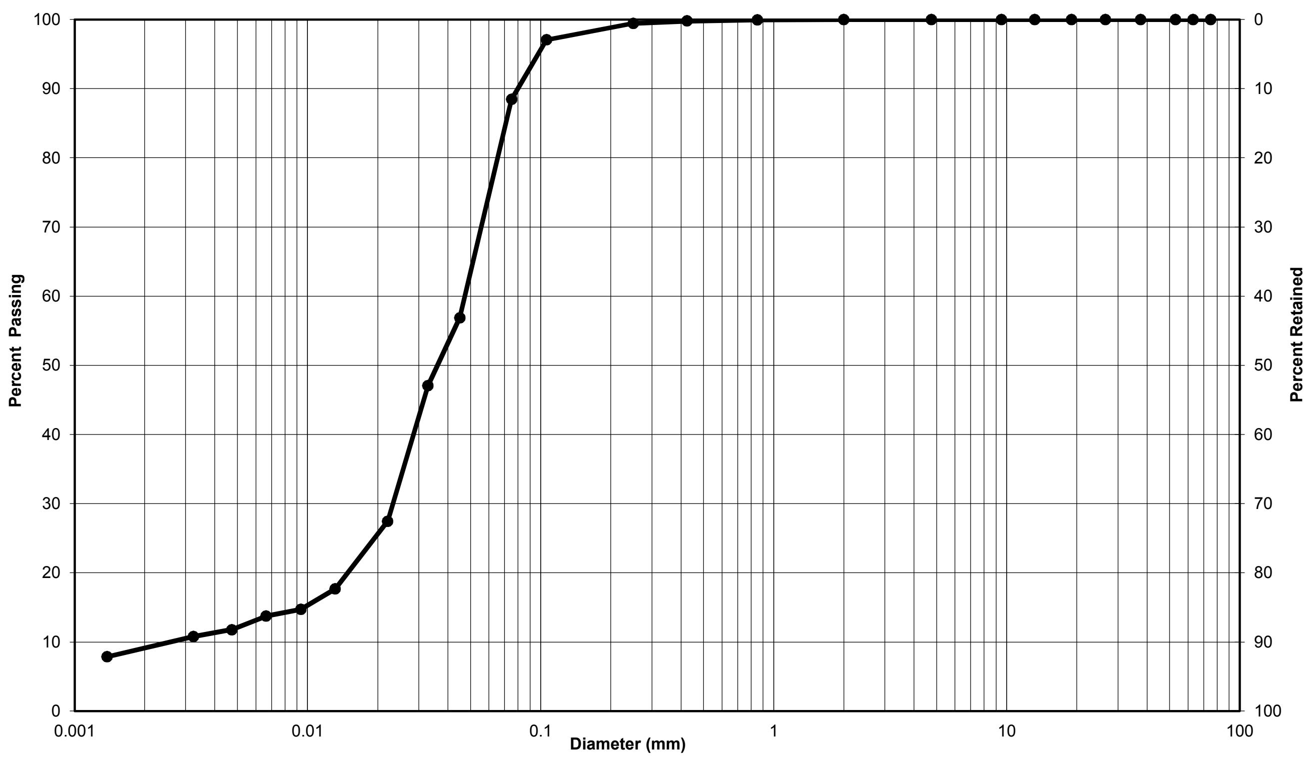
Soil Description	Gravel	Sand	Clay & Silt
BH1-17 SS-8	0	8	92

Remarks:

Performed by:	J. Sullivan	**Date:**	June 1, 2017
Verified by:	[signature]	**Date:**	June 1, 2017

Particle-Size Analysis of Soils (Geotechnical) (USCS) (ASTM D422)

Client:	Town of Greater Napanee	**Lab no.:**	2017-Geo-007
Project/Site:	Napanee WWTP, 300 Water Street West	**Project no.:**	11140477 A1
Borehole no.:	BH1-17	Sample no.:	SS-9
Depth:	8.6 m	Enclosure:	6



Clay & Silt	Sand			Gravel	
	Fine	Medium	Coarse	Fine	Coarse
Unified Soil Classification System					

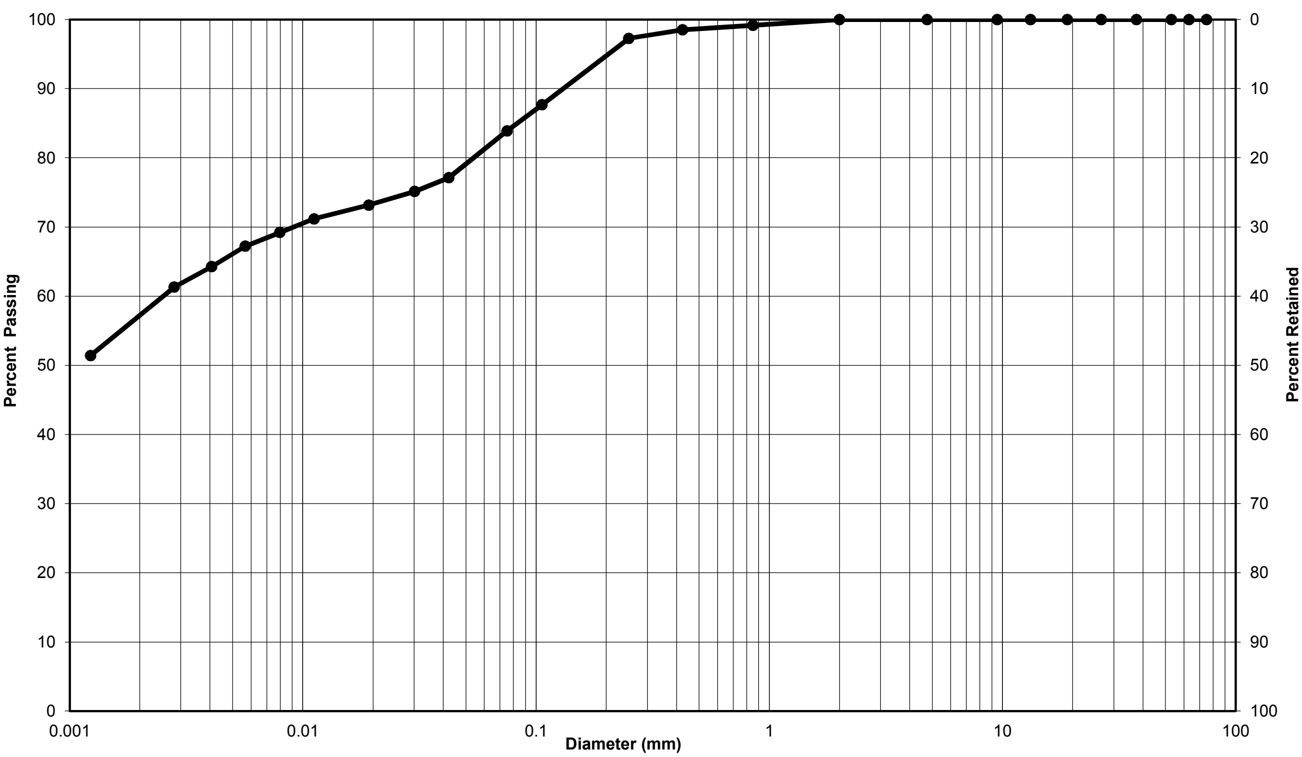
Soil Description	Gravel	Sand	Clay & Silt
BH1-17 SS-9	0	12	88

Remarks:

Performed by:	J. Sullivan	**Date:**	June 1, 2017
Verified by:		**Date:**	June 1, 2017

Particle-Size Analysis of Soils (Geotechnical) (USCS) (ASTM D422)

Client:	Town of Greater Napanee	**Lab no.:**	2017-Geo-007
Project/Site:	Napanee WWTP, 300 Water Street West	**Project no.:**	11140477 A1
Borehole no.:	BH9-17	Sample no.:	SS-8
Depth:	5.4 m	Enclosure:	7



Clay & Silt	Sand			Gravel	
	Fine	Medium	Coarse	Fine	Coarse
Unified Soil Classification System					

Soil Description	Gravel	Sand	Clay & Silt
BH9-17 SS-8	0	16	84

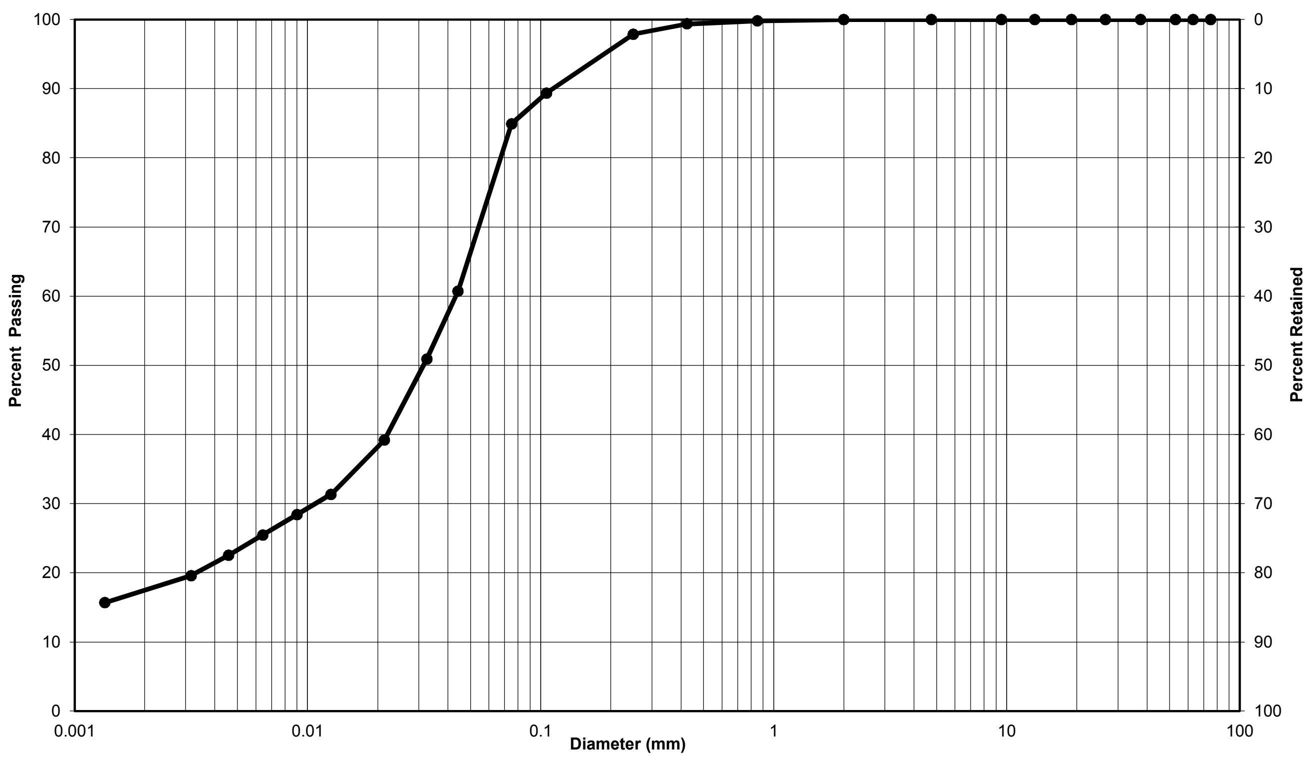
Remarks:

Performed by:	J. Sullivan	**Date:**	June 1, 2017
Verified by:	[signature]	**Date:**	June 1, 2017

Particle-Size Analysis of Soils (Geotechnical) (USCS) (ASTM D422)

Client:	Town of Greater Napanee	**Lab no.:**	2017-Geo-007
Project/Site:	Napanee WWTP, 300 Water Street West	**Project no.:**	11140477 A1

Borehole no.:	BH9-17	Sample no.:	SS-9
Depth:	6.4 m	Enclosure:	8



Clay & Silt	Sand			Gravel	
	Fine	Medium	Coarse	Fine	Coarse
Unified Soil Classification System					

Soil Description	Gravel	Sand	Clay & Silt
BH9-17 SS-9	0	15	85

Remarks:

Performed by:	J. Sullivan	**Date:**	June 1, 2017
Verified by:	[signature]	**Date:**	June 1, 2017

Appendix C
Seismic Site Classification

Project No: **11140477-A1**
Client: **Town of Greater Napanee C/o EVB Engineering**
Site: **300 Water Street West, Napanee, ON**
Mandate: **Geotechnical Investigation for WWTP Upgrades**
Date: **9-Jan-18**
By: **Shane Dunstan**

Seismic Site Classification for Headworks
(Based on Cohesive Layers in MW15-17)

Site Classification for Seismic Site Response Calculations (Commentary J)

Elevation From (m)	Elevation To (m)	Soil	Layer Thickness t (m)	Undrained Shear Strength s_u (kPa)	t/s_u	
75.5	75.0	CLAY AND SILT	0.5	220	0.0023	(1)
75.0	74.3	CLAY AND SILT	0.7	330	0.0021	
74.3	73.5	SILTY CLAY	0.8	120	0.0067	
73.5	72.8	SILTY CLAY	0.7	168	0.0042	
72.8	72.1	SILTY CLAY	0.7	168	0.0042	
		TOTAL =	**3.4**	Sum t/s =	**0.0194**	

NOTES:
(1) The founding depth is approximately 75.5 masl as provided by the Client.

The average undrained shear strength is calculated using the following formula:
(as per OBC 2006 Table 4.1.8.4.A.):

$$\text{Avg}(s_u) = \frac{\text{Total Thickness of all Layers}}{\sum \frac{\text{Layer Thickness } (t)}{\text{Layer Undrained Shear Strength } (s_u)}}$$

$$\text{Avg}(s_u) = \frac{3.4}{0.0194}$$

$\text{Avg}(s_u)$ = 175.3

Average Undrained Shear Strength for the Site is greater than 100kPa.
∴ Seismic Site Class = 'C' based on average undrained shear strength.

Seismic Site Classification for Headworks
(Based on Cohesionless Layers in MW15-17)

Site Classification for Seismic Site Response Calculations (Commentary J)

Elevation From (m)	Elevation To (m)	Soil	Layer Thickness t (m)	Corrected N-Value N_{60} ( )	t/N_{60}	
72.1	71.0	SAND	1.1	8	0.1467	
71.0	45.5	BEDROCK	25.5	100	0.2550	(2)
		TOTAL =	**26.6**	Sum t/N_{60} =	**0.4017**	

NOTES:
(2) The N-Value of bedrock is conservatively taken as 100.

The average standard penetration resistance is calculated using the following formula:
(as per OBC 2006 Table 4.1.8.4.A.):

$$\text{Avg}(N_{60}) = \frac{\text{Total Thickness of all Layers}}{\sum \frac{\text{Layer Thickness } (t)}{\text{Layer Corrected N-Value } (N_{60})}}$$

$$\text{Avg}(N_{60}) = \frac{26.6}{0.4017}$$

$\text{Avg}(N_{60})$ = 66.2

Average Standard Penetration Resistance for the Site is greater than 50.
∴ Seismic Site Class = 'C' based on average standard penetration resistance.

SITE CLASS =	**C**	(Based on cohesive and cohesionless layers)

Project No: **11140477-A1**
Client: **Town of Greater Napanee C/o EVB Engineering**
Site: **300 Water Street West, Napanee, ON**
Mandate: **Geotechnical Investigation for WWTP Upgrades**
Date: **9-Jan-18**
By: **Shane Dunstan**

Seismic Site Classification for Primary Clarifier (Based on Cohesive Layers in MW16-17)

Site Classification for Seismic Site Response Calculations (Commentary J)

Elevation From (m)	Elevation To (m)	Soil	Layer Thickness t (m)	Undrained Shear Strength s_u (kPa)	t/s_u	
75.0	74.5	CLAY AND SILT	0.5	220	0.0023	(1)
74.5	73.9	SILTY CLAY	0.6	147	0.0041	
73.9	73.0	SILTY CLAY	0.9	75	0.0120	
73.0	72.3	SILTY CLAY	0.7	75	0.0093	
		TOTAL =	**2.7**	Sum t/s =	**0.0277**	

NOTES:
(1) The founding depth is approximately 75.0 masl as provided by the Client.

The average undrained shear strength is calculated using the following formula:
(as per OBC 2006 Table 4.1.8.4.A.):

$$Avg(s_u) = \frac{\text{Total Thickness of all Layers}}{\sum \frac{\text{Layer Thickness } (t)}{\text{Layer Undrained Shear Strength } (s_u)}}$$

$$Avg(s_u) = \frac{2.7}{0.0277}$$

$Avg(s_u)$ = 97.5

Average Undrained Shear Strength for the Site is between 50 kPa and 100 kPa
∴ Seismic Site Class = 'D' based on average undrained shear strength.

Seismic Site Classification for Primary Clarifier (Based on Cohesionless Layers in MW16-17)

Site Classification for Seismic Site Response Calculations (Commentary J)

Elevation From (m)	Elevation To (m)	Soil	Layer Thickness t (m)	Corrected N-Value N_{60} ( )	t/N_{60}	
72.3	71.6	SAND	0.7	6	0.1167	
71.6	70.8	SAND	0.8	9	0.0889	
70.8	70.1	SAND	0.7	75	0.0093	
70.1	45.0	BEDROCK	25.1	100	0.2510	(2)
		TOTAL =	**27.3**	Sum t/N_{60} =	**0.4659**	

NOTES:
(2) The N-Value of bedrock is conservatively taken as 100.

The average standard penetration resistance is calculated using the following formula:
(as per OBC 2006 Table 4.1.8.4.A.):

$$Avg(N_{60}) = \frac{\text{Total Thickness of all Layers}}{\sum \frac{\text{Layer Thickness } (t)}{\text{Layer Corrected N-Value } (N_{60})}}$$

$$Avg(N_{60}) = \frac{27.3}{0.4659}$$

$Avg(N_{60})$ = 58.6

Average Standard Penetration Resistance for the Site is greater than 50.
∴ Seismic Site Class = 'C' based on average standard penetration resistance.

SITE CLASS =	**D**	(Based on cohesive and cohesionless layers)

Project No: **11140477-A1**
Client: **Town of Greater Napanee C/o EVB Engineering**
Site: **300 Water Street West, Napanee, ON**
Mandate: **Geotechnical Investigation for WWTP Upgrades**
Date: **9-Jan-18**
By: **Shane Dunstan**

Seismic Site Classification for Secondary Treatment (Based on Cohesive Layers in BH7-17)

Site Classification for Seismic Site Response Calculations (Commentary J)

Elevation From (m)	Elevation To (m)	Soil	Layer Thickness t (m)	Undrained Shear Strength s_u (kPa)	t/s_u	
74.8	74.5	CLAY AND SILT	0.3	75	0.0040	(1)
74.5	73.8		0.7	120	0.0058	
73.8	73.0		0.8	160	0.0050	
73.0	72.4		0.6	140	0.0043	
72.4	71.6	SILTY CLAY	0.8	120	0.0067	
71.6	70.8		0.8	140	0.0057	
70.8	70.1		0.7	65	0.0108	
70.1	69.3		0.8	120	0.0067	
		TOTAL =	**5.5**	Sum t/s =	**0.0489**	

NOTES:
(1) The founding depth is approximately 74.8 masl. (Based on 4mbgs provided by the Client)

The average undrained shear strength is calculated using the following formula:
(as per OBC 2006 Table 4.1.8.4.A.):

$$\text{Avg}(s_u) = \frac{\text{Total Thickness of all Layers}}{\sum \frac{\text{Layer Thickness } (t)}{\text{Layer Undrained Shear Strength } (s_u)}}$$

$$\text{Avg}(s_u) = \frac{5.5}{0.0489}$$

Avg(s_u) = 112.4

Average Undrained Shear Strength for the Site is greater than 100kPa.
∴ Seismic Site Class = 'C' based on average undrained shear strength.

Seismic Site Classification for Secondary Treatment (Based on Cohesionless Layers in BH7-17)

Site Classification for Seismic Site Response Calculations (Commentary J)

Elevation From (m)	Elevation To (m)	Soil	Layer Thickness t (m)	Corrected N-Value N_{60} ( )	t/N_{60}	
69.3	68.4	SAND	0.9	8	0.1200	
68.4	67.6		0.8	10	0.0821	
67.6	67.0		0.6	75	0.0080	
67.0	44.8	BEDROCK	22.2	100	0.2220	(2)
		TOTAL =	**24.5**	Sum t/N_{60} =	**0.4321**	

NOTES:
(2) The N-Value of bedrock is conservatively taken as 100.

The average standard penetration resistance is calculated using the following formula:
(as per OBC 2006 Table 4.1.8.4.A.):

$$\text{Avg}(N_{60}) = \frac{\text{Total Thickness of all Layers}}{\sum \frac{\text{Layer Thickness } (t)}{\text{Layer Corrected N-Value } (N_{60})}}$$

$$\text{Avg}(N_{60}) = \frac{24.5}{0.4321}$$

Avg(N_{60}) = 56.7

Average Standard Penetration Resistance for the Site is greater than 50.
∴ Seismic Site Class = 'C' based on average standard penetration resistance.

SITE CLASS = C (Based on cohesive and cohesionless layers)

Project No: **11140477-A1**
Client: **Town of Greater Napanee C/o EVB Engineering**
Site: **300 Water Street West, Napanee, ON**
Mandate: **Geotechnical Investigation for WWTP Upgrades**
Date: **9-Jan-18**
By: **Shane Dunstan**

Seismic Site Classification for Operations Building (Based on Cohesive Layers in BH22-17)

Site Classification for Seismic Site Response Calculations (Commentary J)

Elevation From (m)	Elevation To (m)	Soil	Layer Thickness t (m)	Undrained Shear Strength s_u (kPa)	t/s_u	
74.8	73.9	CLAY AND SILT	0.9	146	0.0062	(1)
73.9	73.3	CLAY AND SILT	0.6	193	0.0031	
73.3	72.4	SILTY CLAY	0.9	193	0.0047	
72.4	71.7	SILTY CLAY	0.7	157	0.0045	
71.7	70.9	SILTY CLAY	0.8	193	0.0041	
70.9	70.1	SILTY CLAY	0.8	146	0.0055	
70.1	69.4	SILTY CLAY	0.7	97	0.0072	
69.4	68.5	SILTY CLAY	0.9	97	0.0093	
68.5	68.0	SILTY CLAY	0.5	75	0.0067	
		TOTAL =	**6.8**	Sum t/s =	**0.0512**	

NOTES:
(1) The founding depth is approximately 74.8 (Based on 3.0 mbgs provided by the Client).

The average undrained shear strength is calculated using the following formula:
(as per OBC 2006 Table 4.1.8.4.A.):

$$\text{Avg}(s_u) = \frac{\text{Total Thickness of all Layers}}{\sum \frac{\text{Layer Thickness } (t)}{\text{Layer Undrained Shear Strength } (s_u)}}$$

$$\text{Avg}(s_u) = \frac{6.8}{0.0512}$$

Avg(s_u) = 132.9

Average Undrained Shear Strength for the Site is greater than 100kPa.
∴ Seismic Site Class = 'C' based on average undrained shear strength.

Seismic Site Classification for Operations Building (Based on Cohesionless Layers in BH22-17)

Site Classification for Seismic Site Response Calculations (Commentary J)

Elevation From (m)	Elevation To (m)	Soil	Layer Thickness t (m)	Corrected N-Value N_{60} ( )	t/N_{60}	
68.0	67.1	SAND	0.9	3	0.3000	
67.1	66.3	SAND	0.8	10	0.0821	
66.3	65.4	SAND	0.9	10	0.0923	
65.4	44.8	BEDROCK	20.6	100	0.2060	(2)
		TOTAL =	**23.2**	Sum t/N_{60} =	**0.6804**	

NOTES:
(2) The N-Value of bedrock is conservatively taken as 100.

The average standard penetration resistance is calculated using the following formula:
(as per OBC 2006 Table 4.1.8.4.A.):

$$\text{Avg}(N_{60}) = \frac{\text{Total Thickness of all Layers}}{\sum \frac{\text{Layer Thickness } (t)}{\text{Layer Corrected N-Value } (N_{60})}}$$

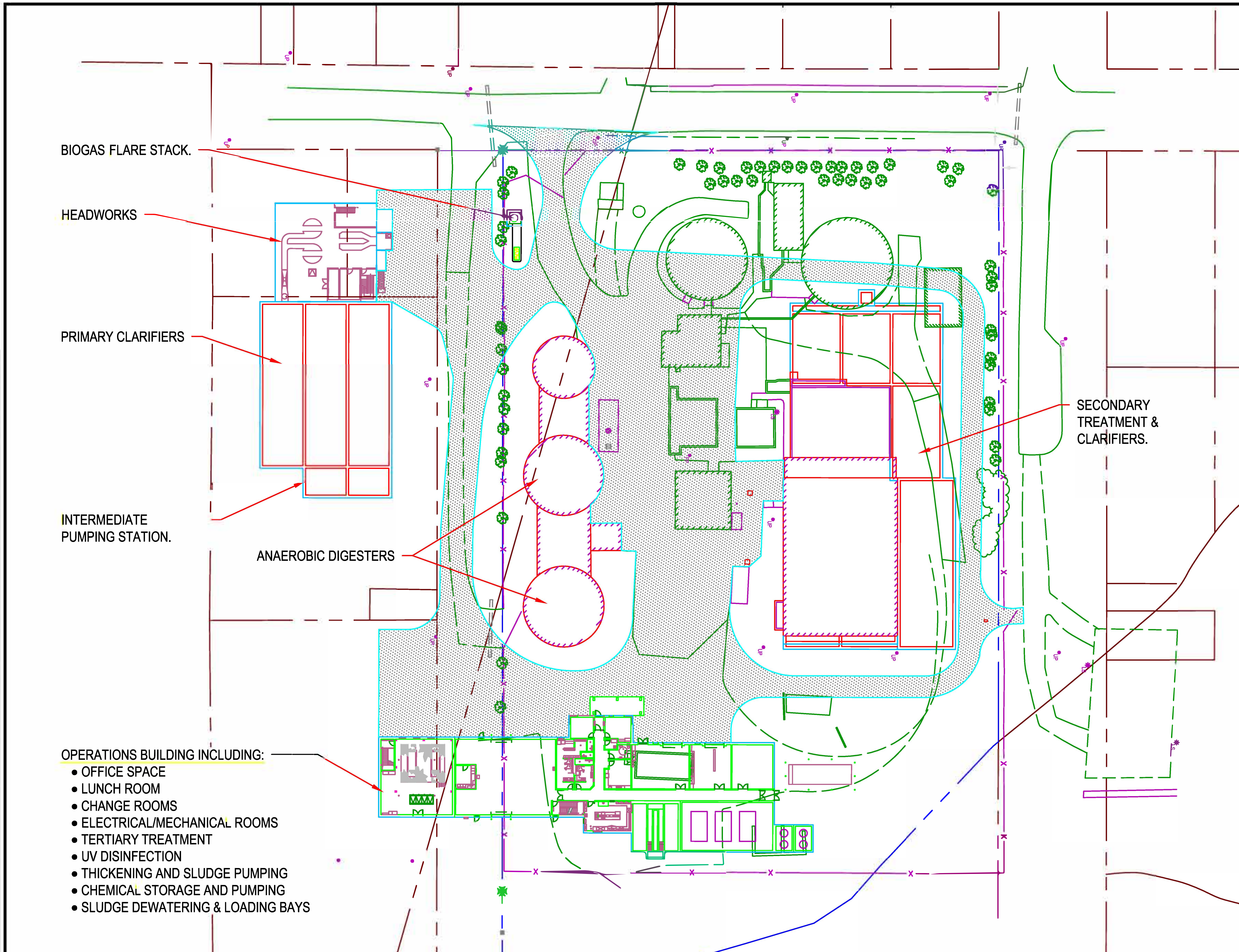
$$\text{Avg}(N_{60}) = \frac{23.2}{0.6804}$$

Avg(N_{60}) = 34.1

Average Standard Penetration Resistance for the Site is between 15 and 50.
∴ Seismic Site Class = 'D' based on average standard penetration resistance.

SITE CLASS = D (Based on cohesive and cohesionless layers)

Appendix D
"FIG.1: Conceptual Site Plan
(Ref No. 17102, dated August 17, 2017)



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CLIENT:
TOWN OF GREATER NAPANEE

PROJECT:
NAPANEE WWTP

TITLE:
CONCEPTUAL SITE PLAN

SCALE: 1:750	JOB NO: 17102
DESIGNED BY: J.B.	DATE: 2017/08/17
DRAWN BY: K.B.W.	DRAWING NO.
CHECKED BY: J.B.	FIG.1

about GHD

GHD is one of the world's leading professional services companies operating in the global markets of water, energy and resources, environment, property and buildings, and transportation. We provide engineering, environmental, and construction services to private and public sector clients.

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