**REPORT**

# Supplementary Geotechnical Investigation

## *Block B2 (Retained Lands)- RioCan Windfields Development, Oshawa, Ontario*

Submitted to:

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# Table of Contents

**ATTACHMENTS**

**APPENDICES**

# 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by RioCan Realty Inv. Partner 11LP (RioCan) to carry out a supplementary geotechnical investigation for the proposed commercial development as part of Block B2 – RioCan Windfields Development, located at the northeast corner of Simcoe Street and Windfields Farm Drive West in Oshawa, Ontario, as shown on the Borehole Location Plan, Figure 1 (the site).

The purpose of this supplementary geotechnical investigation is to provide geotechnical engineering information on the soil and groundwater conditions within the proposed building areas and based on our interpretation of the subsurface data and to provide geotechnical engineering recommendations for the proposed commercial development.

The factual data, interpretations and recommendations contained in this report pertain to a specific project as described in the report and are not applicable to any other project or site location. If the project is modified in concept, location, or elevation, or if the project is not initiated within eighteen months of the date of the report, Golder should be given an opportunity to confirm that the recommendations are still valid. This report should be read in conjunction with the attached "*Important Information and Limitations of This Report*" which are included in Appendix A. The reader's attention is specifically drawn to this information, as it is essential for the proper use and interpretation of this report.

# 2.0 SITE DESCRIPTION

The site is bounded by Simcoe Street North to the west, Windfields Farm Drive to the south, and uncultivated lands to the north and east of the site. At the time of the investigation, the site consisted of overgrown grass and trees. An existing pond was also observed at the east side of the site. In general, the site is regarded to be relatively flat with a gentle slope observed along the southeast corner and sloping towards the existing pond.

It is understood that the commercial development area is to be comprised of commercial buildings, drive lanes, site servicing and parking lots. Based on Drawing Number A1-236 – Preliminary dated March 2, 2020 by Turner Fleischer, it is understood that Block B2 will consist of seven buildings designated as B2 to B8 and ranging between approximately 429 m$^2$ and 1161 m$^2$ in size. The proposed buildings will each consist of a single storey slab-on-grade building, the locations of which are shown on Figure 1.

Details of the proposed development (i.e. site grading, servicing depths etc.) have not been provided at the time of this report.

# 3.0 INVESTIGATION PROCEDURES

## 3.1 Previous Geotechnical Investigation

Golder previously carried out a preliminary geotechnical investigation as part of the commercial development of the site. The result of the investigation was provided in the report entitled "*Preliminary Geotechnical Investigation, Windfields Farm Property – Parcel 1 – Future Commercial Development, City of Oshawa, Ontario*" dated March 2008.

At the time of the investigation, two boreholes (designated as BH9 and BH10) were advanced within the current site boundary to depths of 6.1 m and 6.6 m below ground surface (mbgs). Groundwater levels measured in the boreholes at the completion of drilling are shown on the Record of Borehole sheets in Appendix B. The approximate borehole locations are shown in Borehole Location Plan, Figure 1. The corresponding geodetic ground surface elevations at the borehole locations were inferred from Ontario Base Map Nos. 10 17 6650 48650/48700 (air photography 1992) and are considered approximate.

## 3.2 Current Geotechnical Investigation

The geotechnical field investigation for this assignment was carried out on September 10 and 11, 2020, during which time ten boreholes (designated as Boreholes 20-1 to 20-10) were advanced to depths varying between 6.1 m and 6.5 mbgs. The borehole locations are shown on the Borehole Location Plan, Figure 1.

The boreholes were advanced using a conventional track-mounted drill rig supplied and operated by Golder. Standard penetration testing (SPT) and sampling in the overburden soils were carried out at regular intervals of depth using conventional 50 mm outer diameter split spoon sampling equipment driven by an automatic hammer in accordance with ASTM D1586. The split-spoon samplers used in the investigation limit the maximum particle size that can be sampled and tested to about 35 mm. Therefore, particles or objects that may exist within the soils that are larger than this dimension would not be sampled or represented in the grain size distributions. The results of the in-situ field tests (i.e. SPT ’N’-values) as presented on the borehole records and in Section 4 of this report are uncorrected.

The groundwater conditions were noted in the open boreholes upon completion of drilling. Monitoring wells were installed in Boreholes 20-2, 20-5, and 20-7 following the completion of drilling to allow for further groundwater measurements. Each monitoring well consisted of a 50 mm diameter PVC pipe with a slotted screen sealed at a selected depth within the borehole. A sand filter pack surrounded the screen, and above the screen the annulus was backfilled to the surface with bentonite. The monitoring well installation details, and water level reading are presented on the borehole records. The remaining boreholes were backfilled in accordance with current environmental regulations.

The field work was observed by a member of our technical staff, who arranged for the clearance of underground utility services, observed the drilling, sampling and in situ testing operations, logged the boreholes, and examined and took custody of the recovered soil samples. The samples were identified in the field, placed in appropriate containers, labelled, and transported to our Whitby geotechnical laboratory for further examination and selected laboratory testing. Index and classification tests, consisting of water content determinations as well as selective gradation and Atterberg limit testing were carried out on the recovered soil samples. The results of the geotechnical laboratory tests are presented on Figures 2 to 6 and on the borehole records.

The ground surface elevations of the boreholes and the corresponding Universal Transverse Mercator (UTM) coordinates were obtained using a GPS from a mobile device and should be considered approximate.

# 4.0 SITE GEOLOGY AND STRATIGRAPHY

## 4.1 Regional Geology

The surficial geology aspects of the general Site area are referenced from: Chapman, L.J., and Putnam, D.F., 2007, *“The Physiography of Southern Ontario”*; 4th Edition, Ontario Geological Survey. Based on the physiographic mapping tor the vicinity of the Site, the Site lies within the physiographic region of Southern Ontario known as the South Slope.

The South Slope region slopes gradually downward towards Lake Ontario. The overburden immediately below ground surface within the South Slope generally consists of silty clay to clayey silt till and at depth consists of alternating deposits of dense lacustrine sands and silts and over consolidated lacustrine clays and clay tills overlying the bedrock.

## 4.2 Subsurface Conditions

The subsurface soil and shallow groundwater conditions encountered in the boreholes, as well as the results of the field and laboratory testing are shown on the borehole records in Appendix C and on Figures 2 to 6, respectively, following the text of this report. Golder's "*Method of Soil Classification*", "*Abbreviations and Terms Used on Records of Boreholes and Test Pits*" and "*List of Symbols*" are attached to assist in the interpretation of the borehole logs. It should be noted that the boundaries between the soil strata have been inferred from drilling observations and non-continuous samples. They generally represent a transition from one soil type to another and should not be inferred to represent an exact plane of geological change. Further, conditions will vary between and beyond the boreholes.

The following is a summarized account of the subsurface conditions encountered in the boreholes drilled during this investigation, followed by more detailed descriptions of the major soil strata and shallow groundwater conditions.

In general, the subsurface conditions within the proposed building areas consist of topsoil and reworked native materials underlain by the predominant non-cohesive and cohesive glacial till deposit. Interlayers of silty sand, sandy silt and silty clay were encountered at most locations within the till deposits. The recent groundwater levels measured in the monitoring wells ranged between 2.7 mbgs and 3.8 mbgs.

### 4.2.1 Topsoil

Between approximately 230 mm and 610 mm of topsoil was encountered in Boreholes BH9, BH10, 20-2, and 20-4 to 20-10 at ground surface. Topsoil was not encountered in Boreholes 20-1 and 20-3 possibly due to previous construction of the pavement structure on Windfields Farm Drive. Scarce vegetation was also observed within this localized area. Approximate topsoil thicknesses in each borehole are provided in the table below.

| **Borehole** | **Thickness (mm)** |
|---|---|
| 20-2 | 410 |
| 20-4 | 610 |
| 20-5 | 330 |
| 20-6 | 310 |
| 20-7 | 300 |
| 20-8 | 430 |
| 20-9 | 610 |

| Borehole | Thickness (mm) |
|---|---|
| 20-10 | 360 |
| BH 9 | 250 |
| BH 10 | 230 |

The SPT ‘N’-values measured in the topsoil ranges from about 9 and 16 blows per 0.3 m of penetration indicating a firm consistency. The in situ water contents measured on samples of the topsoil ranges from about 15 percent to 28 percent.

Materials designated as topsoil in this report were classified based solely on visual and textural evidence. Testing of organic content, pH, alkalinity, acidity or for other soil nutrients was not carried out. Accordingly, materials classified as topsoil herein cannot necessarily be relied upon for the support and growth of landscaping vegetation without supplemental soil fertility analyses.

### 4.2.2 Reworked Native

Reworked native soil consisting of silty clay was encountered in Boreholes 20-1, 20-3, and 20-6. The cohesive reworked soils were encountered underlying the topsoil and extended to depths between 0.3 m and 1.4 mbgs. Non-cohesive reworked sandy silt was encountered in Borehole BH10. The fill contained organic inclusions and rootlets.

The SPT ‘N’-values measured within the reworked soils range from 8 blows to 21 blows per 0.3 of penetration indicating a stiff to very stiff consistency. The in situ water contents measured on the silty clay/reworked soil samples ranges from about 8 percent to 12 percent.

### 4.2.3 Glacial Till

A deposit of glacial till was encountered in all boreholes advanced at the site. The till ranges in composition from non-cohesive silty sand to sandy silt to cohesive sandy silty clay to clayey silt. The deposit generally extends to the borehole termination depths and contains non-cohesive and cohesive interlayers. Although cobbles and boulders were not noted during drilling through the till deposits at this site, cobbles and boulders are commonly encountered in glacially derived materials and should be expected within these deposits. Further, the presence of cobbles and/or boulders in the cohesive and non-cohesive till deposits can be inferred from the multiple instances of auger grinding during drilling as well as the split-spoon sampler not advancing the full sample depth. In addition, oxidation staining was encountered in the glacial deposit in the upper zones.

#### *(SM/ML) Silty Sand and Sandy Silt (Till)*

A non-cohesive till deposit comprising of silty sand or sandy silt, containing trace to some gravel was encountered in Boreholes 20-1 to 20-8, 20-10, BH9 and BH10. The non-cohesive till deposit was generally encountered underlying the cohesive till and interlayers of silt, silty clay, silty sand, and sand.

The SPT ‘N’-values measured within the silty sand till deposit ranges from 16 blows per 0.3 m of penetration to 50 blows per 0.05 m of penetration, indicating a compact to very dense state of compactness, and generally dense to very dense. The natural water content measured on selected samples ranges from about 7 percent to 15 percent, and generally less than 10 percent.

A grain size distribution curve for a sample of the silty sand till deposit is shown on Figure 2.

#### *(CL-ML) Silty Clay to Clayey Silt (Till)*

A cohesive till deposit comprised of sandy silty clay to clayey silt, gravelly to a trace of gravel was encountered in Boreholes 20-1 to 20-10 and BH10. The cohesive till deposit was generally encountered underlying the topsoil and reworked native soils and occasionally below or interlayered with the non-cohesive till deposit.

The SPT ‘N’-values measured within the cohesive till deposit range from 9 blows per 0.3 m of penetration to 60 blows per 0.23 m of penetration, indicating a stiff to hard consistency, and generally very stiff to hard. The natural water content measured on selected samples ranges from about 6 percent to 17 percent.

A grain size distribution curve for a sample of the cohesive till is shown on Figure 3.

Atterberg limits testing was performed a sample of the cohesive till deposit and is shown on a plasticity chart on Figure 4. The results of the Atterberg limit test indicate the material is classified as a silty clay to clayey silt of low plasticity.

### 4.2.4 (CL) Silty Clay

A cohesive silty clay deposit, sandy to some sand was encountered in Boreholes 20-2 and 20-3 interlayered within the till deposit. The top of the silty clay deposit ranged between 2.1 mbgs and 4.0 mbgs.

Two SPT ‘N’-values measured within the silty clay deposit were 26 and 29 blows per 0.3 m of penetration, indicating a very stiff consistency. The natural water content measured on three samples of the silty clay deposit ranges from about 16 percent to 18 percent.

### 4.2.5 (SM) Silty Sand

A non-cohesive silty sand deposit was encountered in Boreholes 20-4 to 20-9 interlayered within the till deposit, although Borehole 20-9 was terminated within this interlayer. Oxidation staining was observed in Borehole 20-5. The presence of cobbles and/or boulders in the silty sand deposit can be inferred from auger grinding during drilling in Borehole 20-6.

The SPT ‘N’-values measured within the silty sand deposit ranges from 28 blows to 67 blows per 0.3 m of penetration, indicating a compact to very dense state of compactness. The natural water content measured on samples of the silty sand deposit ranges from about 12 percent to 20 percent.

### 4.2.6 (ML) Silt

A non-cohesive silt deposit containing a trace of sand was encountered in Boreholes 20-1 and 20-10, interlayered within the till deposit.

Two SPT ‘N’-values measured within the silt deposit are 14 blows and 27 blows per 0.3 m of penetration, indicating a compact state of compactness. The natural water content measured on two samples of the silt deposit is about 16 percent.

A grain size distribution curve for a sample of the silt deposit is shown on Figure 5.

### 4.2.7 (SP) Sand

A non-cohesive deposit ranging in composition from sand, gravelly sand to sand and gravel, containing trace to some fines was encountered in Boreholes 20-1, 20-6, 20-9, and BH10, interlayered within the till deposit.

The SPT ‘N’-values measured within the non-cohesive deposit ranges from 51 blows per 0.3 m of penetration to 50 blows per 0.1 m of penetration, indicating a very dense state of compactness. The natural water contents measured on samples of the non-cohesive deposit ranges from about 11 percent to 15 percent.

A grain size distribution curve for a sample of the gravelly sand deposit is shown on Figure 6.

### 4.2.8 Groundwater

Groundwater observations during or upon completion of drilling ranged from 2.7 mbgs to 5.7 mbgs and are indicated on the borehole records. The groundwater level measurements in the monitoring wells ranged between 2.7 mbgs and 3.8 mbgs and are summarized in the table below.

| Borehole | Groundwater level (mbgs) | Date |
|---|---|---|
| 20-2 | 3.8 | September 18, 2020 |
| 20-5 | 3.4 | |
| 20-7 | 2.7 | |

It should be noted that these observations and measurements reflect the shallow groundwater conditions encountered in the boreholes during the time of the field investigation and that water level at the site is expected to fluctuate seasonally in response to changes in precipitation and snow melt.

## 5.0 DISCUSSION AND RECOMMENDATIONS

This section of the report provides engineering information and recommendations for the geotechnical design aspects of the project based on our interpretation of the borehole information, the laboratory test data and our understanding of the project requirements. The information in this portion of the report is provided for planning and design purposes for the design guidance of the design engineers and architects. Where comments are made on construction, they are provided only in order to highlight those aspects of construction which could affect the design of the project. Contractors bidding on or undertaking any work at the site should examine the factual results of the investigation, satisfy themselves as to the adequacy of the information for construction and make their own interpretation of the factual data as it affects their proposed construction techniques, schedule, equipment capabilities, costs, sequencing and the like.

The proposed Buildings B2 to B8 will each consist of a single storey slab-on-grade building. The finished floor elevations for the proposed buildings have not been provided at the time of this report. The table below indicates the proposed building and the closest relevant boreholes.

| Building | Relevant Borehole(s) |
|---|---|
| B2 | 20-7, 20-8 |
| B3 | 20-7 |
| B4 | 20-6 |
| B5 | 20-5, BH9 |
| B6 | 20-4 |
| B7 | 20-3 |
| B8 | 20-1, 20-2 |

Based on the result of this investigation, the subsurface soil conditions encountered at the site are considered to be generally suitable for the proposed commercial buildings utilizing conventional shallow strip/spread footings, with slab-on-grade construction and serviced shallow underground utilities.

## 5.1 Site Preparation

### 5.1.1 Topsoil Stripping and Reuse

Topsoil, soil containing organics and reworked native soils should be stripped from the site prior to placement of engineered fill. The reworked native soils can be reused as engineered fill provided that organics or deleterious materials are not present, and the materials water content is within +/- 3 percent of the standard Proctor maximum dry density (SPMDD).

### 5.1.2 Subgrade Preparation

Finished floor elevations for the proposed buildings have not been determined by the client at the time of this report. However, it is anticipated that a grade raise may be carried out within the site. As such, any filling carried out at the site in conjunction with re-grading (with exception of future green spaces) should be carried out as engineered fill. Recommendations for the placement of engineered fill are outlined in Section 5.1.3.

### 5.1.3 Engineered Fill

Where cut and fill are required to achieve final grade within the site, the reworked native soils (as noted above), glacial till, silty sand and sand deposits can be reused as engineered fill. Based on the soil classification and frost group described in Table 13.1 of the Canadian Foundation Engineering Manual (CFEM, 2006), the glacial till, silty clay, silt, and fill material encountered on the site are regarded as being susceptible to frost. This should be considered for any design elements exposed to freezing temperatures (concrete flatworks, exterior concrete slabs, and the like).

Based on the measured natural water contents, majority of the native soils are generally at or above their estimated laboratory optimum water contents for compaction.

Alternatively, imported materials may be used for engineered fill and must be approved by Golder at the source(s), prior to hauling to the site. In this regard, imported granular materials which meet the requirements for OPSS.PROV 1010 (Aggregates) Select Subgrade Material (SSM) would be suitable for use as engineered fill. In any event, the approved materials for engineered fill should be placed in maximum 300 mm loose lifts and uniformly compacted to 98 percent SPMDD.

All oversize cobbles and boulders (i.e. greater than 150 mm in size) or any other deleterious materials should be removed from engineered fill materials.

Prior to placement of engineered fill, all topsoil and fill must first be removed from the development area. The exposed native subgrade area(s) should then be heavily proofrolled in conjunction with an inspection by geotechnical personnel from Golder to confirm the base is free of ponded water, loosened/softened or any other deleterious materials. Remedial work (further sub-excavation, replacement, etc.) may be required as per recommendations from Golder during proofrolling.

Full-time monitoring and in situ density testing must be carried out by Golder during placement of engineered fill below all structures and settlement sensitive areas.

The final surface of the engineered fill should be protected as necessary from construction traffic and should be sloped to provide positive drainage for surface water prior to construction. During periods of freezing weather, additional soil cover should be placed above final subgrade to provide for temporary frost protection.

## 5.2 Foundation Design

At the time of this report, the finished floor elevation for the Buildings B2 to B8 have not been finalized. As a result, we recommend that the proposed buildings be supported on conventional spread/strip footings founded on the competent engineered fill or native soils which consists of very stiff to hard silty clay till, very dense silty sand to sandy silt till and very stiff silty clay within the upper 3 m.

Footings for Buildings B2 to B7, founded on the native deposits at a minimum depth 1.2 m below finished grade may be designed using a factored geotechnical resistance at Ultimate Limit States (ULS) of 400 kPa and a geotechnical reaction at Serviceability Limit States (SLS) of 250 kPa for 25 mm of settlement. Footings for Building B8 should be designed using a factored geotechnical resistance at Ultimate Limit States (ULS) of 225 kPa and a geotechnical reaction at Serviceability Limit States (SLS) of 150 kPa for 25 mm of settlement.

Footings founded on at least 1 m of engineered fill over native till deposits at a minimum depth of 1.2 m below finished grade may be designed using a factored geotechnical resistance at Ultimate Limit States (ULS) of 300 kPa and a geotechnical reaction at Serviceability Limit States (SLS) of 200 kPa for 25 mm of settlement.

For the soil reactions listed above, the footings must have widths ranging from 450 mm to 900 mm for strip footings and 1,000 mm to 2,500 mm for spread footings. Should larger footing sizes be required, Golder must be consulted to provide additional recommendations.

The foundation subgrade for footings founded on engineered fill is subject to inspection and approval by Golder prior to pouring concrete. Remedial action (sub-excavation and replacement, etc.) may be required during excavations of footings especially when footing design elevations coincide with softened or loosened soils or any deleterious material in engineered fill or native soils. These soils must be sub-excavated and replaced with lean mix concrete having a minimum strength of 15 MPa as directed by geotechnical personnel from Golder.

If stepped spread footings are constructed at different founding levels, the difference in elevation between individual footings should not be greater than one half the clear distance between the footings. Should this not be possible, Golder should be consulted to provide field inspection to ensure that the footings exceeding the above requirement are stable and the bearing for the upper footing is not compromised. In addition, the lower footings should be constructed first so that if it is necessary to construct the lower footings at a greater depth than anticipated, the elevations of the upper footings can be adjusted accordingly. Stepped strip footings, if required, should be constructed in accordance with the 2012 Ontario Building Code (2012 OBC), Section 9.15.3.9.

The founding materials are susceptible to disturbance by construction activity especially during wet weather and care should be taken to preserve the integrity of the bearing strata, including engineered fill. Prior to pouring concrete for the footings, the foundation excavations must be inspected by Golder to confirm that the footings are located in a competent bearing stratum, which has been cleaned of ponded water and loosened or softened material. If the concrete for the footings on the soil cannot be poured immediately after excavation and inspection, it is recommended that a working mat of lean concrete be placed in the excavation to protect the integrity of the bearing strata. The bearing soil and fresh concrete must be protected from freezing during cold weather construction.

All exterior footings and footings in unheated areas must be provided with at least 1.2 m of cover or a thermally equivalent thickness of insulation after final grading, in order to reduce the potential for damage due to frost action.

### 5.2.1 Seismic Design

The 2012 Ontario Building Code (2012 OBC) came into effect on January 1, 2014 and contains updated seismic analysis and design methodology. Seismic hazard is defined for an earthquake with a 2 percent probability of exceedance in 50 years (i.e. a return period of 2,400 years) which encompasses a larger earthquake hazard than in prior editions of the OBC. Design earthquakes are commonly defined by an earthquake magnitude, distance, and peak ground acceleration (PGA). The 2012 OBC uses the uniform hazard spectra (UHS) to define the response of the structure to the design earthquake and also considers the effects of the localized site conditions on the structural response. The 2012 OBC also uses a refined site classification system defined by the average soil/bedrock properties in the top 30 metres of the subsurface profile beneath the structure(s). There are six site classes designated as A to F related to decreasing ground stiffness from A for hard rock to E for soft soil and Site Class F for problematic soils (e.g. sites underlain by thick peat deposits and/or liquefiable soils). The site class is then used to obtain acceleration- and velocity-based site coefficients, Fa and Fv, respectively, used to modify the reference UHS to account for the effects of site-specific soil conditions in design.

Based on the results of the investigation, the building foundations may be designed using a Site Class D designation. It is possible that the site class could be improved by in situ testing. Should optimization of the site class be recommended by the structural engineer, in situ geophysical testing should be carried out at the site, although a higher site class is not guaranteed.

## 5.3 Slab-on-Grade

The floor slab for the proposed commercial buildings can be designed as a concrete slab-on-grade. The floor slab may be placed on approved engineered fill placed and compacted as per the requirements of Section 5.1.3.

Prior to the placement of new engineered fill, the exposed subgrade should be inspected by Golder. Remedial work should be carried out on any softened, disturbed, wet or poorly performing zones as directed by Golder. Any low areas may then be brought up to within at least 200 mm of the underside of the floor slab, as required, using OPSS Granular 'B', Type I material or other approved material, placed in maximum 200 mm loose lifts and uniformly compacted to at least 100 percent of the material's SPMDD.

The final lift of granular fill beneath floor slab should consist of a minimum thickness of 200 mm of OPSS Granular 'A', uniformly compacted to at least 100 percent of SPMDD. This should provide a modulus of subgrade reaction, for a 1-foot square plate placed directly on the subgrade material, $k_{v1}$, of approximately 40 MPa/m. Special care should be taken to ensure adequate compaction around columns and adjacent to foundation walls. Any filling operations should be monitored and tested by Golder.

The floor slabs should be structurally separate from the foundation walls and columns and sawcut control joints should be provided at regular intervals and along column lines to minimize shrinkage cracking and to allow for any differential settlement of the floor slabs. Depending on the fill type, additional joints should be provided within the slab at the boundaries between the new and existing engineered fill.

In general, where the floor slab is at or above the exterior final grade, no perimeter drainage at the footing level is required. Where the finished floor slab will be below exterior grade, a perimeter drainage system should be provided. The footing drainage system should be provided with a permanent frost-free outlet.

## 5.4 Excavations and Groundwater Control

Trench excavations for foundations and site servicing is generally anticipated to extend into the cohesive and non-cohesive till deposit, silty sand, sandy silt, and silty clay deposits at varying depths across the site. Conventional excavation equipment can be used to excavate through these native soils. However, occasional instances of auger grinding were noted during drilling at a variety of depths within the glacial till and silty sand deposit. As such, equipment should be chosen that can handle removal of cobbles/boulders as they are known to be present in glacially derived materials.

It is anticipated that the excavations will likely consist of conventional temporary open cuts. All excavations should be carried out in accordance with the Occupational Health and Safety Act (OHSA) and Regulations for Construction Projects. Based on the OHSA, the engineered fill is generally classified as a Type 3 soil and all excavations in excess of 1.2 m in depth through these soils should be sloped no steeper than 1 horizontal to 1 vertical above the groundwater level. However, the dense to very dense/stiff to hard native soils above the groundwater level are generally classified as Type 2 soils with a 1 horizontal to 1 vertical to 1.2 m or less from its bottom. Where excavations extend below the groundwater level, these soils are considered to be Type 3 soils, which require side slopes no steeper than 1H:1V from the base of excavation.

The groundwater level in the monitoring wells ranged between 2.7 mbgs and 3.8 mbgs on September 18, 2020. It is likely that the silty sand and sandy silt deposits confined between the glacial till deposit are pressurized and penetrating into these layers may potentially generate high volumes of water. As such, it is anticipated that trench excavations extending into these soils will require proactive dewatering. However, due to the relatively impermeable nature of the glacial till and silty clay deposits, it is anticipated that water trapped due to rainfall or surface runoff within the required excavations can likely be handled by pumping from properly constructed and filtered sumps located within the excavations. Where excavations are carried out within the silt, silty sand, sand and sand and gravel zones, increased groundwater inflow into the excavations should be expected. There is a potential for sloughing of excavation side slopes and/or disturbance of the base of the excavations. In this regard, it is recommended that test pits be carried out prior to construction activities to further assess dewatering requirements at the time of construction. Care should be taken to direct surface runoff away from the open excavations.

Where side slopes of excavations are required to be steepened to limit the extent of the excavation, then some form of trench support system may be required. It must be emphasized that a trench liner box provides protection for construction personnel but does not provide any lateral support for the adjacent excavation walls, underground services or existing structures. It is imperative that any underground services or existing structures adjacent to the excavations be accurately located prior to construction and adequate support provided where required. In addition, steepened excavations should be left open for as short a duration as possible and completely backfilled at the end of each working day.

If required to support adjacent services or structures, shoring could consist of braced soldier pile and lagging, braced sheet piles or potentially a slide rail system designed by a Professional Engineer including assessment of the potential for basal heave. If shoring is implemented at the site, the requirements of OPSS.PROV 539 should be followed. Design of temporary works will be entirely the responsibility of the contractor.

## 5.5 Site Servicing

Details of underground servicing for the proposed commercial development are not finalized at this time and as such, for the purpose of this report, we have assumed that the maximum depth of the underground services will be about 3 m to 4 m below final grade. Once detailed design is completed, a review of the site servicing recommendations should be completed by Golder.

The founding soils for the proposed services are anticipated to consist of stiff to hard/very dense till, very dense silty sand, very stiff silty clay, dense to very dense silty sand, and compact silt.

In general, these soils are considered to be suitable for supporting sewers and watermains, provided that the integrity of the base can be maintained during construction. However, if softened/loose, organic soil/topsoil or deleterious materials are encountered at the proposed founding level, these materials must be removed and replaced with approved engineered fill to provide a suitable founding stratum.

The excavation recommendations for service trenching is generally addressed in Section 5.4.

### 5.5.1 Pipe Bedding and Cover

The bedding for watermains and sewers should be compatible with the size, type, and class of pipe, surrounding soil and loading conditions and should be designed in accordance with the Regional and Municipal standards. Where granular bedding is deemed to be acceptable, it should consist of at least 150 mm of OPSS Granular ‘A’ or 19 mm crusher run limestone material. Clear stone should never be used as bedding material. Sand cover may be used from the spring line to 300 mm above the obvert of the pipes. All bedding material and cover should be placed in maximum 150 mm loose lifts and uniformly compacted to a minimum of 98 percent of the material's SPMDD.

### 5.5.2 Trench Backfill

The majority of the excavated materials from the site will generally be the reworked native soils, till deposit, silty clay, silt and engineered fill materials, with the majority of soils excavated during underground service installation anticipated to be at or above their estimated optimum water contents for compaction. Some drying of the soils may be required prior to placement and compaction.

The excavated materials at suitable water contents may be reused as trench backfill provided they are free of significant amounts of topsoil, organic or other deleterious materials. As inferred from auger grinding/refusal and split spoon refulsal, cobbles and boulders are anticipated to be widespread in the excavation spoils. Oversized cobbles and boulders (i.e. greater than 150 mm in size) should be removed from the backfill. All trench backfill from the top of the cover material to 1.0 m below subgrade elevation should be uniformly compacted to at least 95 percent of the material's SPMDD. From 1.0 m below subgrade to subgrade elevation, the materials should be placed in maximum 300 mm loose lifts and uniformly compacted to at least 98 percent of material's SPMDD.

Alternatively, if placement water content at the time of construction are too high, or if there is a shortage of suitable in situ materials, then an approved imported sandy material which meets the requirements for SSM may be used.

Backfilling during cold weather must avoid inclusions of frozen lumps of material, snow and ice.

## 5.6 Pavement Design

This section of the report provides preliminary engineering information for the pavement structures within the Windfields development.

As traffic information was not available, we have made assumptions based on the number of parking spaces available and the anticipated heavy truck traffic that could be experienced at the development. Once traffic data is known, Golder should be engaged to verify that the pavement designs are suitable to support the required traffic loading at the site.

Based on the results of the geotechnical investigation and the subgrade soils encountered, the following pavement designs may be considered for the internal roads and parking areas.

| **Material** | **Thickness of Pavement Elements (mm)** | |
|---|---|---|
| | ***Light Duty/Parking Lot*** | ***Heavy Duty/Fire Route*** |
| HL 3 (Surface)[1] | 40 | 40 |
| HL 8 Binder (Base)[1] | 50 | 75 |
| New Granular A Base[2] | 150 | 150 |
| New Granular B, Type 1 Subbase[2] | 300 | 450 |
| Subgrade | Prepared and Approved Subgrade | |

**Notes:**

[1] Asphaltic Material shall be in accordance with OPSS 1150 (November 2010)

[2] Granular Materials shall be in accordance with OPSS.MUNI 1010 (November 2013)

### 5.6.1 Drainage

Adequate surface and subsurface drainage are critical if the pavement is to provide satisfactory service over the design life. The drainage system in the parking areas could consist of a system of catchbasins connected to subdrains draining to a permanent storm water outlet. In this regard, the asphalt surface should be graded to drain towards the catchbasins and the subgrade should be carefully proof-rolled to a smooth surface and sloped towards the catchbasins to prevent ponding or entrapment of water in the subbase which would lead to weakened sections. Moderately frost susceptible soils were encountered within the footprint of the proposed parking areas. As a result, consideration should be given to installing stub-drains 6 m in length and extending in all four directions from the catchbasins.

For the fire route and driving lanes, continuous subdrains should be placed at the edge of pavement along each side of the road with intermittent catchbasins. The pavement drainage system should consist of a 150 mm diameter wrapped perforated pipe, placed inside a 300 mm by 300 mm trench and surrounded by clean free draining sand, such as concrete sand. The drain invert should be at approximately 250 mm below the bottom of the granular subbase and should be sloped to drain to the catchbasins.

### 5.6.2 General Construction Recommendations

#### *5.6.2.1 Subgrade Preparation*

Prior to placing granular materials, the exposed subgrade should be proofrolled and inspected by Golder. Remedial work (that is, further sub-excavation and replacement) should be carried out on any disturbed, softened or poorly performing areas, as directed by Golder. Additionally, subgrade soils containing organic matter should be removed and replaced with approved fill or granular material regardless of depth.

It should be noted that in some cases, even though the compaction requirements have been met, the subgrade strength may not be adequate to support heavy construction loading especially during wet weather or where subgrade soils are wet of optimum. In this regard, the design subbase thickness may not be sufficient for a construction haul road and additional granular materials (in the order of 300 mm) may be required. The subgrade should be proofrolled and inspected by Golder prior to placing the subbase and additional material placed as required to address the subgrade soil conditions and the anticipated construction traffic.

#### *5.6.2.2 Granular Materials*

The granular base and subbase materials should be uniformly placed and compacted to 100 percent of their SPMDD. Compaction of the granular materials and subgrade soils should be carried out at a moisture content that is between optimum moisture content and 2 percent of the optimum. Granular A can be used in place of Granular B Type I, but to provide adequate frost protection, the total thickness of the granular materials should not be reduced.

#### *5.6.2.3 Hot Mix Asphalt Types and Asphalt Construction*

The asphalt materials should be compacted to minimum of 92 percent of their Maximum Relative Density (MRD), as measured in the field using a nuclear density gauge; Asphalt material and placement requirements should be as per OPSS.MUNI 310 and OPSS 1150, as amended by the applicable Municipal standards.

Transverse and longitudinal joints should be cleaned, and tack coated prior to placing new asphalt. Where the new pavement abuts the existing pavement (e.g., at tie-ins to existing pavement), proper longitudinal lap joints should be constructed to key the new asphalt surface course into the existing pavement. The existing asphalt should be sawcut to provide a vertical face prior to keying-in the new asphalt surface course. Any undermined or broken edges resulting from the construction activities should be removed by the sawcut.

#### *5.6.2.4 Performance Graded Asphalt Cement (PGAC)*

It is recommended that PG 58-28 asphalt cement be used for both the HL 3 surface course and the HL 8 binder course mixes for the parking areas in accordance with OPSS.MUNI 1101. It is recommended that PG 64-28 Polymer Modified asphalt cement be used for the asphalt mixes within the Fire Route and internal roads

## 5.7 Frost Susceptibility

Based on the results of this investigation, the majority of the subsurface soils encountered in the boreholes are generally considered to be low to moderately frost susceptible. As such, any exterior unheated structures such as exterior slabs, sidewalks and other concrete flatwork could be affected by frost action. To minimize the effects of frost heave on such structures preventative measures should be considered in the design as appropriate. Such measures may include positive subgrade grading, provision of subdrains, removal and replacement of native soils with non-frost susceptible (granular) materials, provision of frost tapers and thermal insulation. Golder will be pleased to provide further structure specific recommendations on minimizing potential damage due to frost.

# 6.0 ADDITIONAL CONSIDERATIONS

The native, undisturbed, competent soils should be exposed and heavily proofrolled in conjunction with an inspection by Golder to confirm the subgrade is cleaned of ponded water, loosend/softened soils or other deleterious material. Any soft spots identified during proofrolling as directed by Golder should be subexcavated to expose competent soils prior to placement of engineered fill.

The soils at this site are sensitive to disturbance from ponded water, construction traffic and frost. During construction, sufficient foundation inspections, subgrade inspections and in situ material testing should be carried out to confirm that the conditions exposed are consistent with those encountered in the boreholes and to monitor conformance to the pertinent project specifications. All bearing surfaces must be inspected by Golder prior to concreting to ensure that strata having adequate bearing capacity have been reached and that the bearing surfaces have been properly prepared.

# 7.0 CLOSURE

This report is intended to summarize available data on subsurface soil and groundwater conditions and provide geotechnical comments and recommendations for the proposed Buildings B2 to B8. We trust that this geotechnical report provides sufficient geotechnical engineering information for the designers to proceed with detailed design.

If you have any questions regarding the contents of this report or require additional information, please do not hesitate to contact this office.

Yours truly,

**Golder Associates Ltd.**

***DRAFT*** ***DRAFT***

Timi Olumuyiwa, M.Sc., P.Eng., PMP
*Geotechnical Engineer*

Sarah E.M. Poot, P.Eng.
*Associate, Senior Geotechnical Engineer*

TO/SEMP/to/mlk

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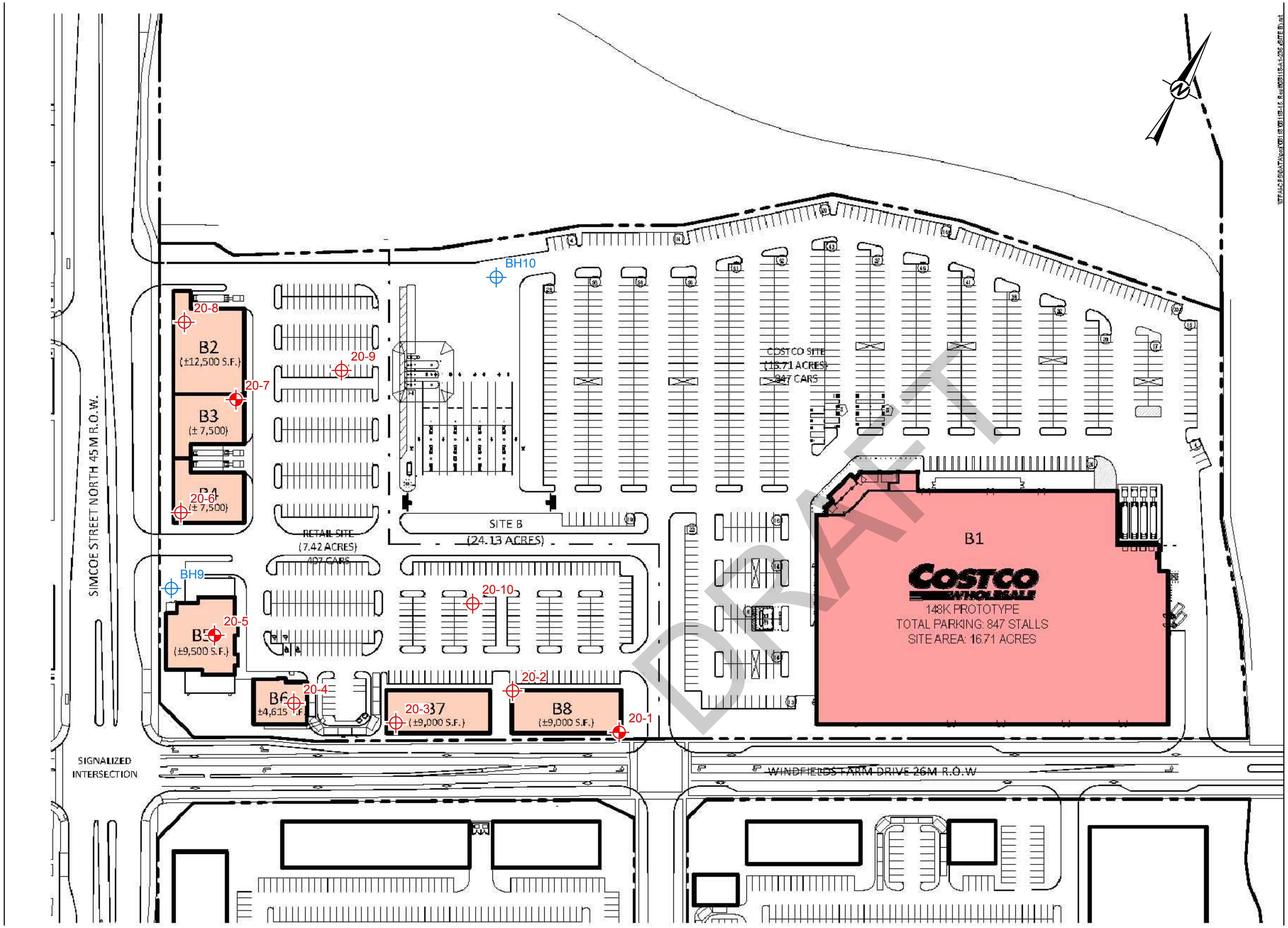
https://golderassociates.sharepoint.com/sites/129214/project files/6 deliverables/geotech/20146060 (1000) rep 2020'10'02 supplementary geotechnical report - windfields block b2 (reva).docx



**KEY MAP**

**LEGEND**

| | |
|---|---|
| ⊕ | 2020 BOREHOLE LOCATION (APPROXIMATE) |
| ● | 2020 MONITORING WELL LOCATION (APPROXIMATE) |
| ⊕ | 2008 BOREHOLE LOCATION (APPROXIMATE) |

**REFERENCE(S)**

BASE MAP TAKEN FROM TURNER FLEISCHER, DATED MARCH 2020, DELIVERED IN FORMAT PDF.

CLIENT
RIOCAN REAILTY INV PARTNER 11LP

CONSULTANT
GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2020-09-21 |
| DESIGNED | TO |
| PREPARED | JL |
| REVIEWED | |
| APPROVED | |

PROJECT
SUPPLEMENTARY GEOTECHNICAL INVESTIGATION
BLOCK B2 (RETAINED LANDS) - RIOCAN WINDFIELDS DEVELOPMENT
OSHAWA, ONTARIO

TITLE
**BOREHOLE LOCATION PLAN**

| PROJECT NO. | CONTROL | REV. | FIGURE |
|---|---|---|---|
| 20146060 | | ---- | 1 |

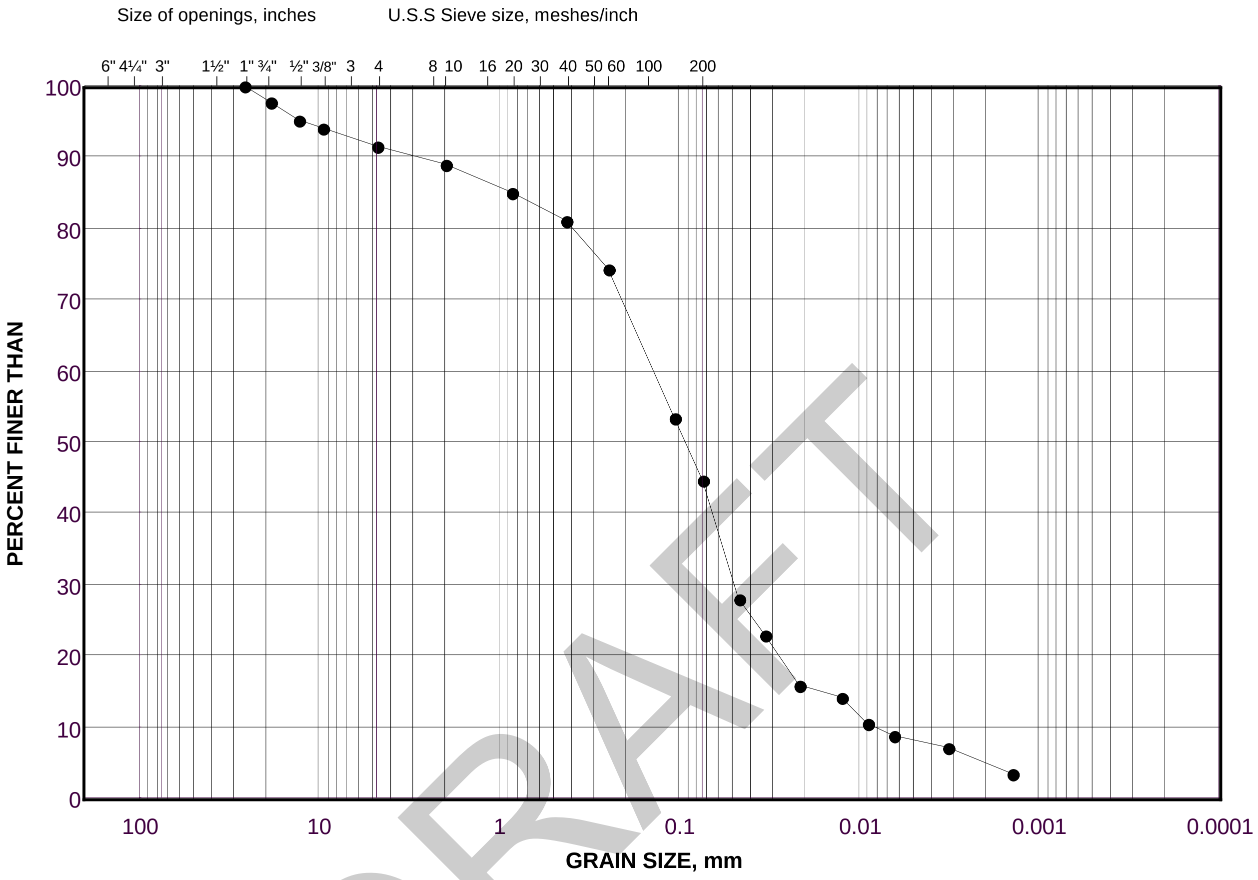
Path: \\golder.gds\complexdata\office\Mississauga\SIM\Clients\RIOCAN\Windfields_Farm\99_PROJECTS\20146060_Block_B\40_PROD\0001_Supp_Geotech_Invest\ | File Name: 20146060-0001-BG-0001.dwg | Last Edited By: hjlin Date: 2020-09-22 Time:5:19:16 PM | Printed By: HJLin Date: 2020-10-01 Time:2:08:25 PM

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

# GRAIN SIZE DISTRIBUTION

(SM) SILTY SAND (TILL)

FIGURE 2



| | | | | | | |
|---|---|---|---|---|---|---|
| **COBBLE** | COARSE | FINE | COARSE | MEDIUM | FINE | SILT AND CLAY SIZES |
| **SIZE** | **GRAVEL SIZE** | | **SAND SIZE** | | | **FINE GRAINED** |

## LEGEND

| SYMBOL | BOREHOLE | SAMPLE | DEPTH(m) |
|---|---|---|---|
| ● | 20-5 | 7 | 6.2 |

Project Number: 20146060

Checked By: TO

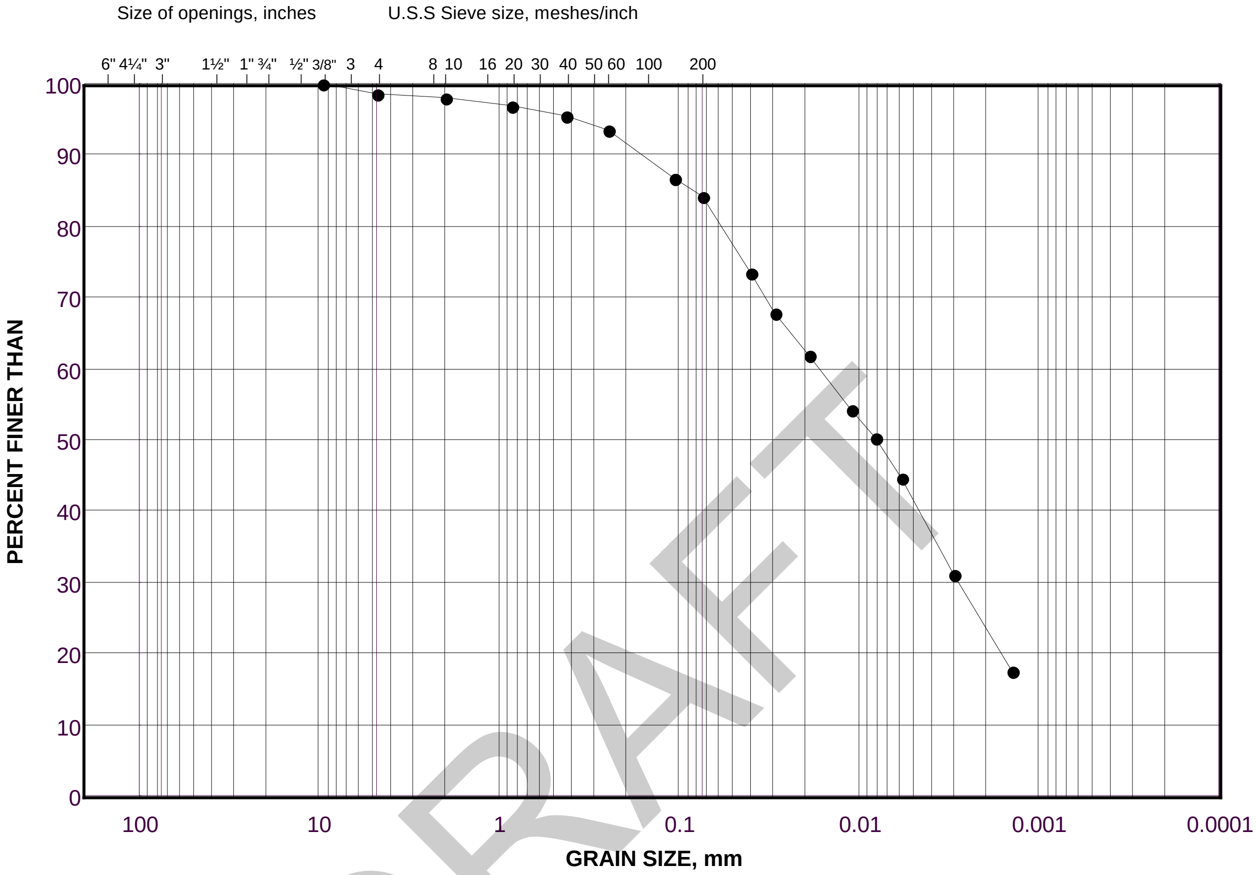
**Golder Associates**

Date: 23-Sep-20

# GRAIN SIZE DISTRIBUTION

(CL-ML) sandy SILTY CLAY to CLAYEY SILT (TILL)

FIGURE 3



| COBBLE | COARSE | FINE | COARSE | MEDIUM | FINE | SILT AND CLAY SIZES |
|---|---|---|---|---|---|---|
| SIZE | GRAVEL SIZE | | SAND SIZE | | | FINE GRAINED |

## LEGEND

| SYMBOL | BOREHOLE | SAMPLE | DEPTH(m) |
|---|---|---|---|
| ● | 20-3 | 4 | 2.5 |

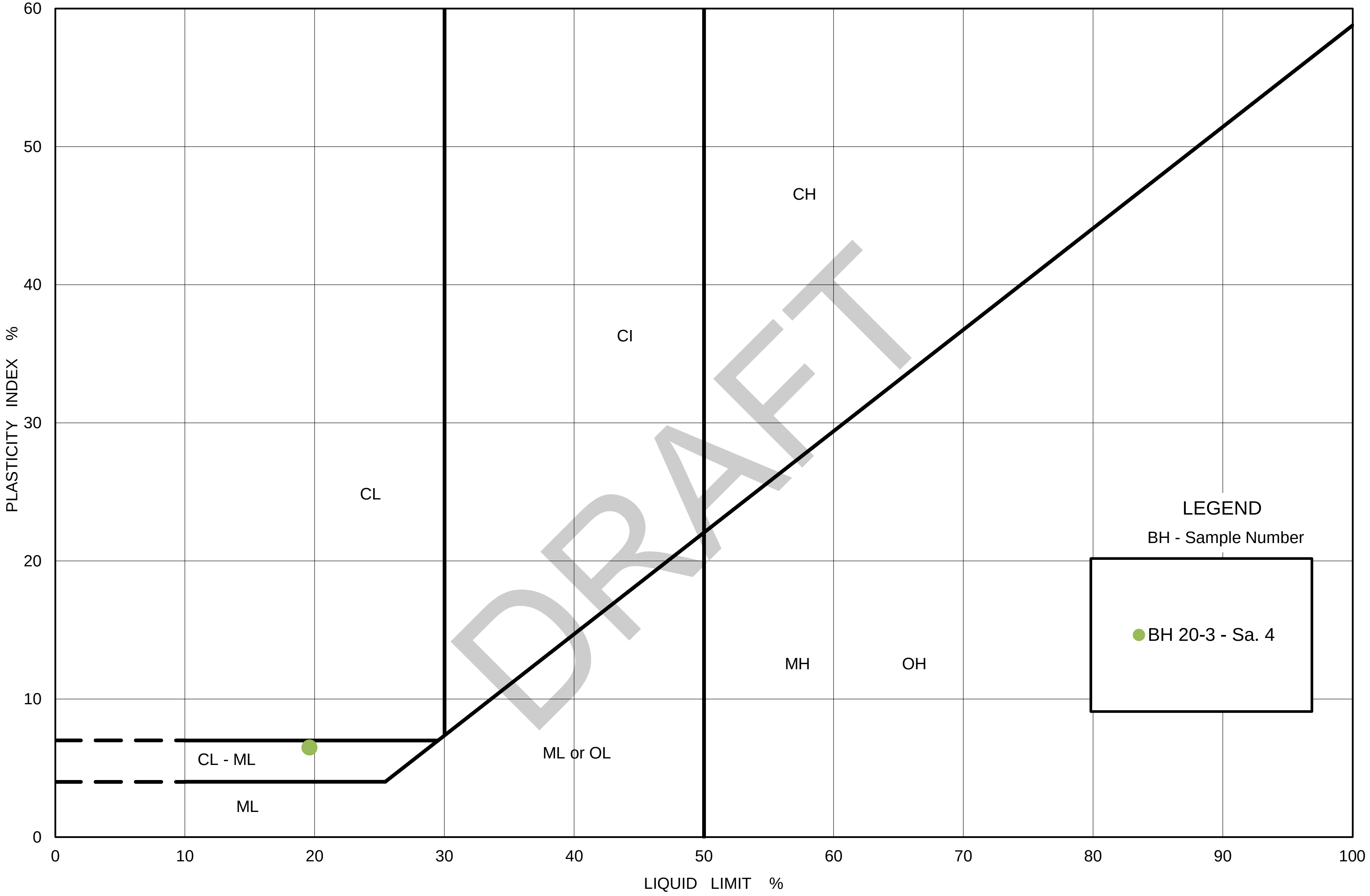
Project Number: 20146060

Checked By: TO

**Golder Associates**

Date: 23-Sep-20

# LIQUID LIMIT, PLASTIC LIMIT, AND PLASTICITY INDEX OF SOILS (ASTM D4318)



GOLDER

## PLASTICITY CHART

(CL-ML) sandy SILTY CLAY to CLAYEY SILT (TILL)

Figure No.: 4

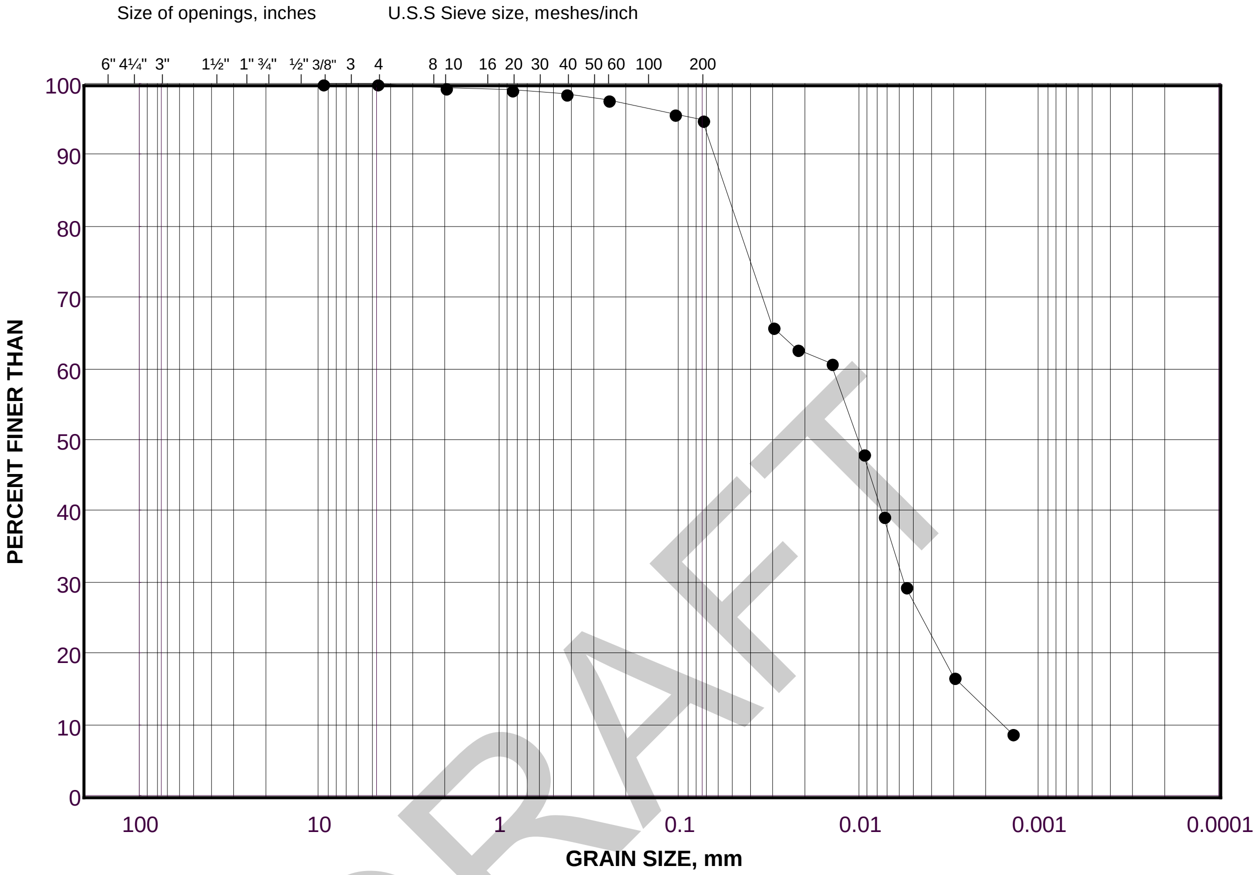
Project No.: 20146060

Checked By: TO

# GRAIN SIZE DISTRIBUTION

(ML) SILT

FIGURE 5



| | | | | | | |
|---|---|---|---|---|---|---|
| **COBBLE** | COARSE | FINE | COARSE | MEDIUM | FINE | SILT AND CLAY SIZES |
| **SIZE** | **GRAVEL SIZE** | | **SAND SIZE** | | | **FINE GRAINED** |

## LEGEND

| SYMBOL | BOREHOLE | SAMPLE | DEPTH(m) |
|---|---|---|---|
| ● | 20-1 | 5 | 3.3 |

Project Number: 20146060

Checked By: TO

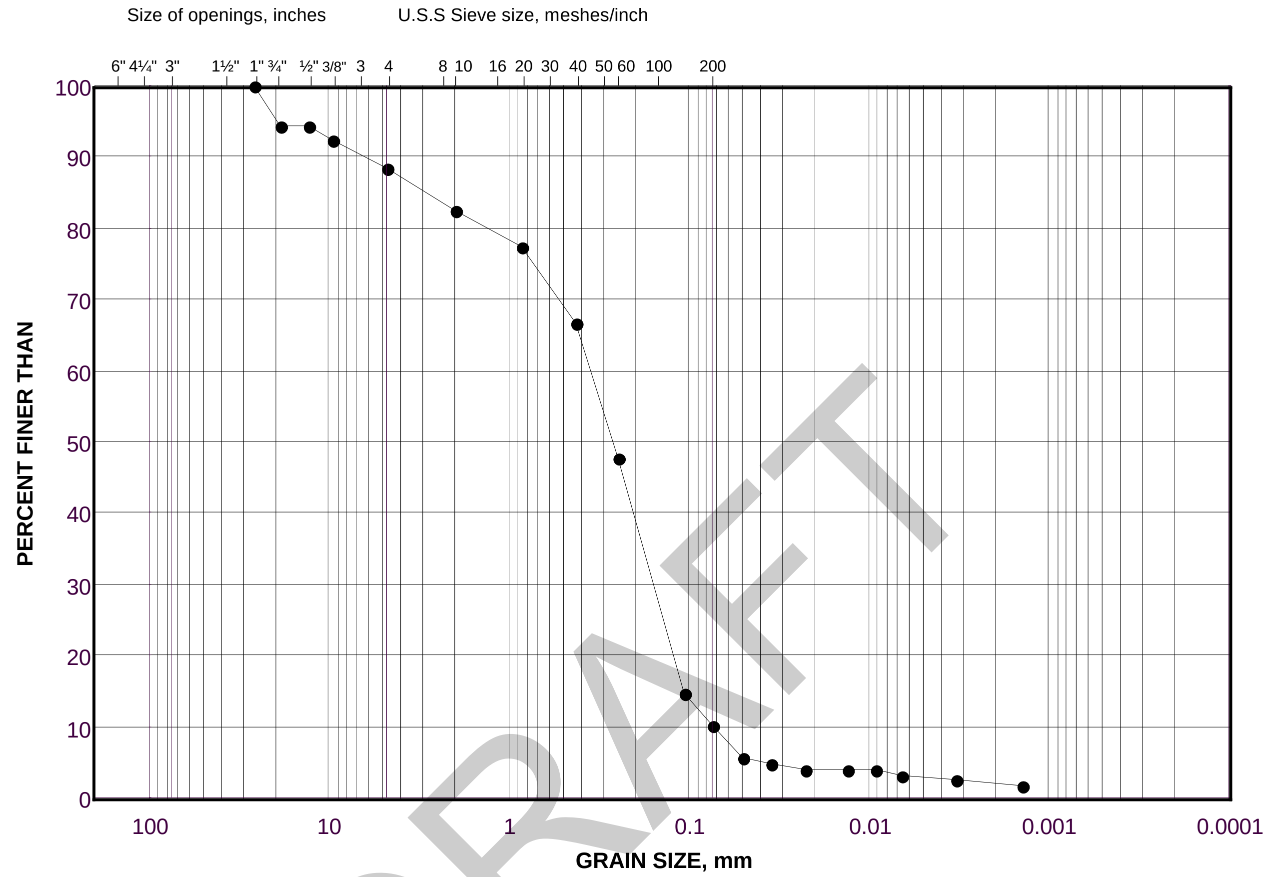
**Golder Associates**

Date: 23-Sep-20

# GRAIN SIZE DISTRIBUTION

(SP) Gravelly SAND

FIGURE 6



| | | | | | | |
|---|---|---|---|---|---|---|
| **COBBLE** | COARSE | FINE | COARSE | MEDIUM | FINE | SILT AND CLAY SIZES |
| **SIZE** | **GRAVEL SIZE** | | **SAND SIZE** | | | **FINE GRAINED** |

## LEGEND

| SYMBOL | BOREHOLE | SAMPLE | DEPTH(m) |
|---|---|---|---|
| ● | 20-9 | 6 | 6.3 |

Project Number: 20146060

Checked By: TO

**Golder Associates**

Date: 01-Oct-20

## APPENDIX A

# Important Information and Limitations of This Report

# IMPORTANT INFORMATION AND LIMITATIONS OF THIS REPORT

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

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

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

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

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

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

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

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

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

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

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

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

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

## APPENDIX B

# Previous Borehole Logs (BH9 and BH10)

# LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

## I. SAMPLE TYPE

| | |
|---|---|
| AS | Auger sample |
| BS | Block sample |
| CS | Chunk sample |
| DO | Drive open |
| DS | Denison type sample |
| FS | Foil sample |
| RC | Rock core |
| SC | Soil core |
| ST | Slotted tube |
| TO | Thin-walled, open |
| TP | Thin-walled, piston |
| WS | Wash sample |

## II. PENETRATION RESISTANCE

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

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

**PH:** Sampler advanced by hydraulic pressure
**PM:** Sampler advanced by manual pressure
**WH:** Sampler advanced by static weight of hammer
**WR:** Sampler advanced by weight of sampler and rod

**Piezo-Cone Penetration Test (CPT):**
An electronic cone penetrometer with a 60° conical tip and a projected end area of 10 $cm^2$ pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ($Q_t$), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

## III. SOIL DESCRIPTION

### (a) Cohesionless Soils

| **Density Index (Relative Density)** | **N** Blows/300 mm or Blows/ft. |
|---|---|
| Very loose | 0 to 4 |
| Loose | 4 to 10 |
| Compact | 10 to 30 |
| Dense | 30 to 50 |
| Very dense | over 50 |

### (b) Cohesive Soils

| **Consistency** | $c_u, s_u$ | |
|---|---|---|
| | kPa | psf |
| Very soft | 0 to 12 | 0 to 250 |
| Soft | 12 to 25 | 250 to 500 |
| Firm | 25 to 50 | 500 to 1,000 |
| Stiff | 50 to 100 | 1,000 to 2,000 |
| Very stiff | 100 to 200 | 2,000 to 4,000 |
| Hard | over 200 | over 4,000 |

## IV. SOIL TESTS

| | |
|---|---|
| w | water content |
| $w_p$ | plastic limit |
| $w_l$ | liquid limit |
| C | consolidation (oedometer) test |
| CHEM | chemical analysis (refer to text) |
| CID | consolidated isotropically drained triaxial test[1] |
| CIU | consolidated isotropically undrained triaxial test with porewater pressure measurement[1] |
| $D_R$ | relative density (specific gravity, $G_S$) |
| DS | direct shear test |
| M | sieve analysis for particle size |
| MH | combined sieve and hydrometer (H) analysis |
| MPC | Modified Proctor compaction test |
| SPC | Standard Proctor compaction test |
| OC | organic content test |
| $SO_4$ | concentration of water-soluble sulphates |
| UC | unconfined compression test |
| UU | unconsolidated undrained triaxial test |
| V | field vane test (LV-laboratory vane test) |
| $\gamma$ | unit weight |

Note:

1. Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

# LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

## I. GENERAL

$\pi$ = 3.1416

ln x, natural logarithm of x

$\log_{10}$ x or log x, logarithm of x to base 10

| | |
|---|---|
| g | acceleration due to gravity |
| t | time |
| F | factor of safety |
| V | volume |
| W | weight |

## II. STRESS AND STRAIN

| | |
|---|---|
| $\gamma$ | shear strain |
| $\Delta$ | change in, e.g. in stress: $\Delta \sigma$ |
| $\varepsilon$ | linear strain |
| $\varepsilon_v$ | volumetric strain |
| $\eta$ | coefficient of viscosity |
| $\nu$ | Poisson's ratio |
| $\sigma$ | total stress |
| $\sigma'$ | effective stress ($\sigma' = \sigma - u$) |
| $\sigma'_{vo}$ | initial effective overburden stress |
| $\sigma_1, \sigma_2, \sigma_3$ | principal stresses (major, intermediate, minor) |
| $\sigma_{oct}$ | mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$ |
| $\tau$ | shear stress |
| u | porewater pressure |
| E | modulus of deformation |
| G | shear modulus of deformation |
| K | bulk modulus of compressibility |

## III. SOIL PROPERTIES

### (a) Index Properties

| | |
|---|---|
| $\rho(\gamma)$ | bulk density (bulk unit weight*) |
| $\rho_d(\gamma_d)$ | dry density (dry unit weight) |
| $\rho_w(\gamma_w)$ | density (unit weight) of water |
| $\rho_s(\gamma_s)$ | density (unit weight) of solid particles |
| $\gamma'$ | unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$) |
| $D_R$ | relative density (specific gravity)of solid particles ($D_R = \rho_s / \rho_w$) (formerly $G_s$) |
| e | void ratio |
| n | porosity |
| S | degree of saturation |

* Density symbol is $\rho$. Unit weight symbol is $\gamma$ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

### (a) Index Properties (con't.)

| | |
|---|---|
| w | water content |
| $w_l$ | liquid limit |
| $w_p$ | plastic limit |
| $I_P$ | plasticity Index = $(w_l - w_p)$ |
| $w_S$ | shrinkage limit |
| $I_L$ | liquidity index = $(w - w_p) / I_p$ |
| $I_C$ | consistency index = $(w_l - w) / I_p$ |
| $e_{max}$ | void ratio in loosest state |
| $e_{min}$ | void ratio in densest state |
| $I_D$ | density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density) |

### (c) Hydraulic Properties

| | |
|---|---|
| h | hydraulic head or potential |
| q | rate of flow |
| v | velocity of flow |
| i | hydraulic gradient |
| k | hydraulic conductivity (coefficient of permeability) |
| j | seepage force per unit volume |

### (d) Consolidation (one-dimensional)

| | |
|---|---|
| $C_c$ | compression index (normally consolidated range) |
| $C_r$ | recompression index (overconsolidated range) |
| $C_S$ | swelling index |
| $C_\alpha$ | coefficient of secondary consolidation |
| $m_v$ | coefficient of volume change |
| $c_v$ | coefficient of consolidation |
| $T_v$ | time factor (vertical direction) |
| U | degree of consolidation |
| $\sigma'_p$ | pre-consolidation pressure |
| OCR | Overeonsolidation ratio $=\sigma'_p/\sigma'_{vo}$ |

### (e) Shear Strength

| | |
|---|---|
| $\tau_p, \tau_r$ | peak and residual shear strength |
| $\phi'$ | effective angle of internal friction |
| $\delta$ | angle of interface friction |
| $\mu$ | coefficient of friction = $\tan \delta$ |
| c' | effective cohesion |
| $c_u, s_u$ | undrained shear strength ($\phi = 0$ analysis) |
| p | mean total stress $(\sigma_1 + \sigma_3)/2$ |
| p' | mean effective stress $(\sigma'_1 + \sigma'_3)/2$ |
| q | $(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$ |
| $q_u$ | compressive strength $(\sigma_1 - \sigma_3)$ |
| $S_t$ | sensitivity |

Notes: 1. $\tau = c' + \sigma' \tan \phi'$

2. Shear strength = (Compressive strength)/2

PROJECT: 08-1186-0510

# RECORD OF BOREHOLE BH 9

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

BORING DATE: March 21, 2008

DATUM: GEODETIC

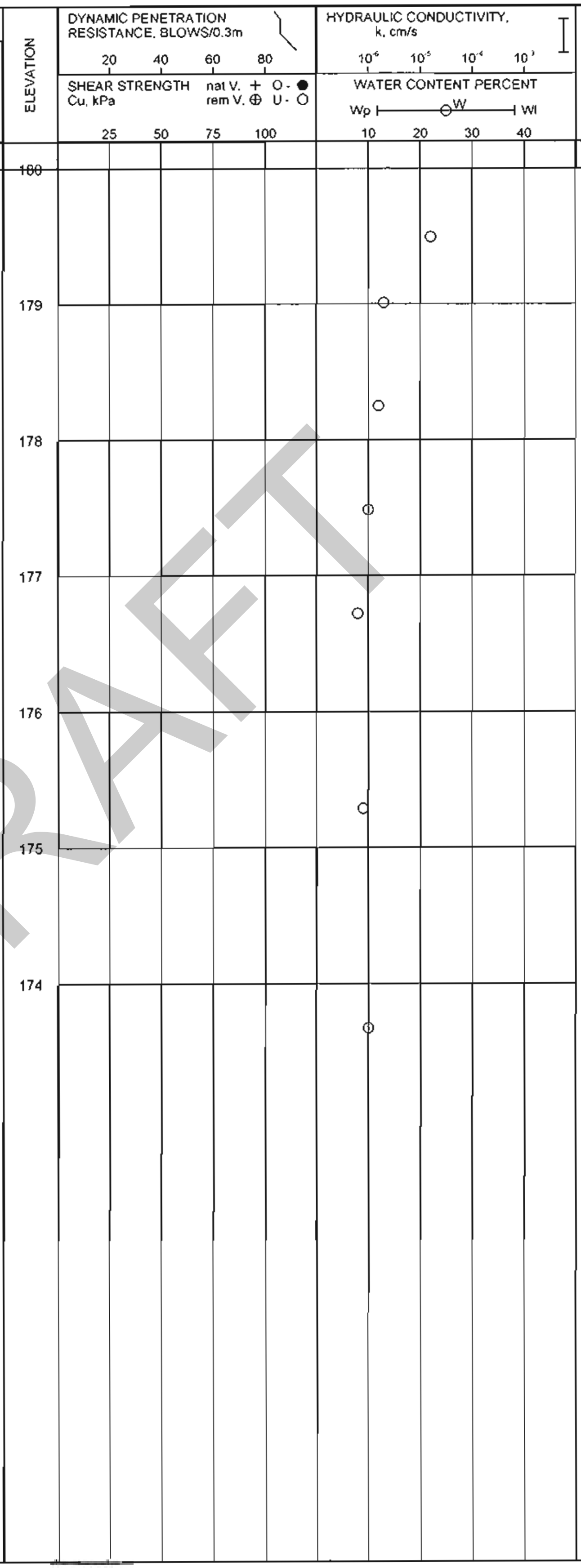
SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

BORING METHOD: TRACK MOUNTED POWER AUGER 115 mm Diameter Solid Stem Augers

| SOIL PROFILE DESCRIPTION | ELEV. DEPTH (m) |
|---|---|
| GROUND SURFACE | 180.00 |
| TOPSOIL | 0.00<br>179.75 |
| Brown CLAYEY SILT, some sand, trace organics | 0.25<br>179.24 |
| Compact to very dense brown SANDY SILT, some clay, trace gravel, cobbles and boulders (TILL) | 0.76<br>175 96 |
| Very dense to compact grey SILTY SAND, trace clay, trace gravel (TILL) | 4.04<br>173 45 |
| END OF BOREHOLE | 6.55 |

| SAMPLES NUMBER | TYPE | BLOWS/0.3m |
|---|---|---|
| 1 | AS | - |
| 2 | 50 DO | 23 |
| 3 | 50 DO | 26 |
| 4 | 50 DO | 51 |
| 5 | 50 DO | 64 |
| 6 | 50 DO | 50/ .13 |
| 7 | 50 DO | 20 |



ADDITIONAL LAB. TESTING

INSTALLATION AND GROUNDWATER OBSERVATIONS

Groundwater level in open portion of borehole at a depth of 3.4 m upon completion of drilling, Mar. 21/08

Borehole caved to a depth of 3.5 m upon completion of drilling, Mar. 21/08

DEPTH SCALE

1 : 50

Golder Associates

LOGGED: RN

CHECKED:

PROJECT: 08-1186-0510

# RECORD OF BOREHOLE BH 10

SHEET 1 OF 1

LOCATION: SEE FIGURE 2

BORING DATE: March 20, 2008

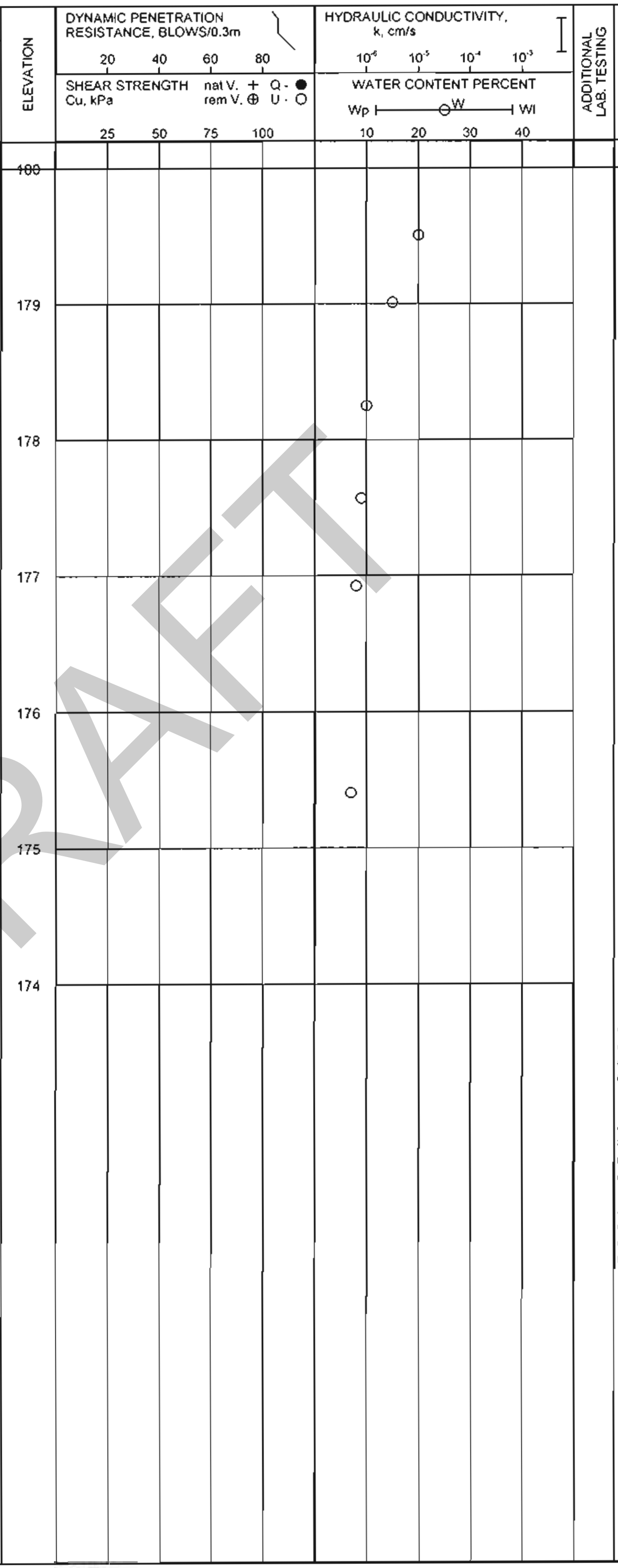
DATUM: GEODETIC

SAMPLER HAMMER, 63.5kg; DROP, 760mm

PENETRATION TEST HAMMER, 63.5kg; DROP, 760mm

BORING METHOD: TRACK MOUNTED POWER AUGER<br>115 mm Diameter Solid Stem Augers

| SOIL PROFILE |  |  | SAMPLES |  |  |
|---|---|---|---|---|---|
| DESCRIPTION | STRATA PLOT | ELEV.<br>DEPTH (m) | NUMBER | TYPE | BLOWS/0.3m |
| GROUND SURFACE |  | 180.00 |  |  |  |
| TOPSOIL |  | 0.00 |  |  |  |
| Brown sandy silt, trace clay, trace gravel (Probable FILL or disturbed native soil) |  | 179.77<br>0.23 | 1 | AS | - |
| Stiff light brown CLAYEY SILT, trace gravel, trace sand (TILL) |  | 179.24<br>0.76 | 2 | 50 DO | 11 |
| Dense brown SILTY SAND, trace gravel, trace clay (TILL) |  | 178.63<br>1.37 | 3 | 50 DO | 43 |
| Very dense grey SAND and GRAVEL, trace silt |  | 177.87<br>2.13 | 4 | 50 DO | 50/.13 |
| Very dense grey SILTY SAND, trace clay, trace gravel, cobbles and boulders (TILL) |  | 177.18<br>2.82 | 5<br>6 | 50 DO<br>50 DO | 50/.05<br>50/.05 |
| END OF BOREHOLE<br>Practical refusal to further augering on boulders |  | 173.90<br>6.10 |  |  |  |



INSTALLATION AND GROUNDWATER OBSERVATIONS

Groundwater encountered during drilling at a depth of 0.5 m, Mar. 20/08

Groundwater level in open portion of borehole at a depth of 0.6 m upon completion of drilling, Mar. 20/08

Borehole caved to a depth of 4.3 m upon completion of drilling, Mar. 20/08

LDN_BHS 08-1186-0510.GPJ GLDR_LDN.GDT 3/27/08 DATA INPUT: PJV March 19/08

DEPTH SCALE
1 : 50

Golder Associates

LOGGED: RN
CHECKED:

## APPENDIX C

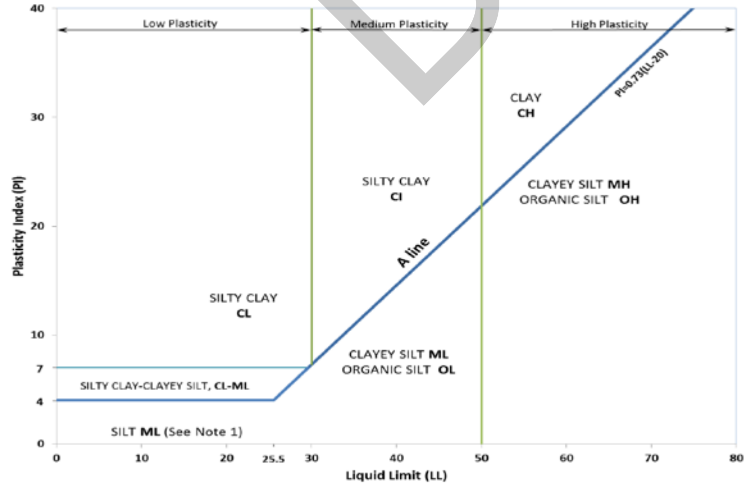
# Current Borehole Logs (Boreholes 20-1 to 20-10)

# METHOD OF SOIL CLASSIFICATION

**The Golder Associates Ltd. Soil Classification System is based on the Unified Soil Classification System (USCS)**

| Organic or Inorganic | Soil Group | Type of Soil | | Gradation or Plasticity | $Cu = \frac{D_{60}}{D_{10}}$ | $Cc = \frac{(D_{30})^2}{D_{10} x D_{60}}$ | Organic Content | USCS Group Symbol | Group Name |
|---|---|---|---|---|---|---|---|---|---|
| INORGANIC (Organic Content ≤30% by mass) | COARSE-GRAINED SOILS (>50% by mass is larger than 0.075 mm) | GRAVELS (>50% by mass of coarse fraction is larger than 4.75 mm) | Gravels with ≤12% fines (by mass) | Poorly Graded | <4 | ≤1 or ≥3 | ≤30% | GP | GRAVEL |
| | | | | Well Graded | ≥4 | 1 to 3 | | GW | GRAVEL |
| | | | Gravels with >12% fines (by mass) | Below A Line | n/a | | | GM | SILTY GRAVEL |
| | | | | Above A Line | n/a | | | GC | CLAYEY GRAVEL |
| | | SANDS (≥50% by mass of coarse fraction is smaller than 4.75 mm) | Sands with ≤12% fines (by mass) | Poorly Graded | <6 | ≤1 or ≥3 | | SP | SAND |
| | | | | Well Graded | ≥6 | 1 to 3 | | SW | SAND |
| | | | Sands with >12% fines (by mass) | Below A Line | n/a | | | SM | SILTY SAND |
| | | | | Above A Line | n/a | | | SC | CLAYEY SAND |

| Organic or Inorganic | Soil Group | Type of Soil | Laboratory Tests | Field Indicators | | | | | Organic Content | USCS Group Symbol | Primary Name |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Dilatancy | Dry Strength | Shine Test | Thread Diameter | Toughness (of 3 mm thread) | | | |
| INORGANIC (Organic Content ≤30% by mass) | FINE-GRAINED SOILS (≥50% by mass is smaller than 0.075 mm) | SILTS (Non-Plastic or PI and LL plot below A-Line on Plasticity Chart below) | Liquid Limit <50 | Rapid | None | None | >6 mm | N/A (can't roll 3 mm thread) | <5% | ML | SILT |
| | | | | Slow | None to Low | Dull | 3mm to 6 mm | None to low | <5% | ML | CLAYEY SILT |
| | | | | Slow to very slow | Low to medium | Dull to slight | 3mm to 6 mm | Low | 5% to 30% | OL | ORGANIC SILT |
| | | | Liquid Limit ≥50 | Slow to very slow | Low to medium | Slight | 3mm to 6 mm | Low to medium | <5% | MH | CLAYEY SILT |
| | | | | None | Medium to high | Dull to slight | 1 mm to 3 mm | Medium to high | 5% to 30% | OH | ORGANIC SILT |
| | | CLAYS (PI and LL plot above A-Line on Plasticity Chart below) | Liquid Limit <30 | None | Low to medium | Slight to shiny | ~ 3 mm | Low to medium | 0% to 30% **(see Note 2)** | CL | SILTY CLAY |
| | | | Liquid Limit 30 to 50 | None | Medium to high | Slight to shiny | 1 mm to 3 mm | Medium | | CI | SILTY CLAY |
| | | | Liquid Limit ≥50 | None | High | Shiny | <1 mm | High | | CH | CLAY |
| HIGHLY ORGANIC SOILS (Organic Content >30% by mass) | | Peat and mineral soil mixtures | | | | | | | 30% to 75% | PT | SILTY PEAT, SANDY PEAT |
| | | Predominantly peat, may contain some mineral soil, fibrous or amorphous peat | | | | | | | 75% to 100% | | PEAT |



**Note 1 – Fine grained materials with PI and LL that plot in this area are named (ML) SILT with slight plasticity. Fine-grained materials which are non-plastic (i.e. a PL cannot be measured) are named SILT.**

**Note 2 – For soils with <5% organic content, include the descriptor "trace organics" for soils with between 5% and 30% organic content include the prefix "organic" before the Primary name.**

**Dual Symbol** — A dual symbol is two symbols separated by a hyphen, for example, GP-GM, SW-SC and CL-ML.

For non-cohesive soils, the dual symbols must be used when the soil has between 5% and 12% fines (i.e. to identify transitional material between "clean" and "dirty" sand or gravel.

For cohesive soils, the dual symbol must be used when the liquid limit and plasticity index values plot in the CL-ML area of the plasticity chart (see Plasticity Chart at left).

**Borderline Symbol** — A borderline symbol is two symbols separated by a slash, for example, CL/CI, GM/SM, CL/ML.

A borderline symbol should be used to indicate that the soil has been identified as having properties that are on the transition between similar materials. In addition, a borderline symbol may be used to indicate a range of similar soil types within a stratum.

# ABBREVIATIONS AND TERMS USED ON RECORDS OF BOREHOLES AND TEST PITS

## PARTICLE SIZES OF CONSTITUENTS

| Soil Constituent | Particle Size Description | Millimetres | Inches (US Std. Sieve Size) |
|---|---|---|---|
| BOULDERS | Not Applicable | >300 | >12 |
| COBBLES | Not Applicable | 75 to 300 | 3 to 12 |
| GRAVEL | Coarse<br>Fine | 19 to 75<br>4.75 to 19 | 0.75 to 3<br>(4) to 0.75 |
| SAND | Coarse<br>Medium<br>Fine | 2.00 to 4.75<br>0.425 to 2.00<br>0.075 to 0.425 | (10) to (4)<br>(40) to (10)<br>(200) to (40) |
| SILT/CLAY | Classified by plasticity | <0.075 | < (200) |

## MODIFIERS FOR SECONDARY AND MINOR CONSTITUENTS

| Percentage by Mass | Modifier |
|---|---|
| >35 | Use 'and' to combine major constituents (*i.e.,* SAND and GRAVEL) |
| > 12 to 35 | Primary soil name prefixed with "gravelly, sandy, SILTY, CLAYEY" as applicable |
| > 5 to 12 | some |
| ≤ 5 | trace |

## PENETRATION RESISTANCE

### Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg (140 lb) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) split-spoon sampler for a distance of 300 mm (12 in.). Values reported are as recorded in the field and are uncorrected.

### Cone Penetration Test (CPT)

An electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm$^2$ pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ($q_t$), porewater pressure (u) and sleeve frictions are recorded electronically at 25 mm penetration intervals.

### Dynamic Cone Penetration Resistance (DCPT); $N_d$:

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

| | |
|---|---|
| **PH:** | Sampler advanced by hydraulic pressure |
| **PM:** | Sampler advanced by manual pressure |
| **WH:** | Sampler advanced by static weight of hammer |
| **WR:** | Sampler advanced by weight of sampler and rod |

## SAMPLES

| | |
|---|---|
| AS | Auger sample |
| BS | Block sample |
| CS | Chunk sample |
| DD | Diamond Drilling |
| DO or DP | Seamless open ended, driven or pushed tube sampler – note size |
| DS | Denison type sample |
| GS | Grab Sample |
| MC | Modified California Samples |
| MS | Modified Shelby (for frozen soil) |
| RC | Rock core |
| SC | Soil core |
| SS | Split spoon sampler – note size |
| ST | Slotted tube |
| TO | Thin-walled, open – note size (Shelby tube) |
| TP | Thin-walled, piston – note size (Shelby tube) |
| WS | Wash sample |

## SOIL TESTS

| | |
|---|---|
| w | water content |
| PL , $w_p$ | plastic limit |
| LL , $w_L$ | liquid limit |
| C | consolidation (oedometer) test |
| CHEM | chemical analysis (refer to text) |
| CID | consolidated isotropically drained triaxial test[1] |
| CIU | consolidated isotropically undrained triaxial test with porewater pressure measurement[1] |
| $D_R$ | relative density (specific gravity, Gs) |
| DS | direct shear test |
| GS | specific gravity |
| M | sieve analysis for particle size |
| MH | combined sieve and hydrometer (H) analysis |
| MPC | Modified Proctor compaction test |
| SPC | Standard Proctor compaction test |
| OC | organic content test |
| $SO_4$ | concentration of water-soluble sulphates |
| UC | unconfined compression test |
| UU | unconsolidated undrained triaxial test |
| V (FV) | field vane (LV-laboratory vane test) |
| γ | unit weight |

1. Tests anisotropically consolidated prior to shear are shown as CAD, CAU.

## NON-COHESIVE (COHESIONLESS) SOILS

### Compactness[2]

| Term | SPT 'N' (blows/0.3m)[1] |
|---|---|
| Very Loose | 0 to 4 |
| Loose | 4 to 10 |
| Compact | 10 to 30 |
| Dense | 30 to 50 |
| Very Dense | >50 |

1. SPT 'N' in accordance with ASTM D1586, uncorrected for the effects of overburden pressure.
2. Definition of compactness terms are based on SPT 'N' ranges as provided in Terzaghi, Peck and Mesri (1996). Many factors affect the recorded SPT 'N' value, including hammer efficiency (which may be greater than 60% in automatic trip hammers), overburden pressure, groundwater conditions, and grainsize. As such, the recorded SPT 'N' value(s) should be considered only an approximate guide to the soil compactness. These factors need to be considered when evaluating the results, and the stated compactness terms should not be relied upon for design or construction.

### Field Moisture Condition

| Term | Description |
|---|---|
| Dry | Soil flows freely through fingers. |
| Moist | Soils are darker than in the dry condition and may feel cool. |
| Wet | As moist, but with free water forming on hands when handled. |

## COHESIVE SOILS

### Consistency

| Term | Undrained Shear Strength (kPa) | SPT 'N'[1,2] (blows/0.3m) |
|---|---|---|
| Very Soft | <12 | 0 to 2 |
| Soft | 12 to 25 | 2 to 4 |
| Firm | 25 to 50 | 4 to 8 |
| Stiff | 50 to 100 | 8 to 15 |
| Very Stiff | 100 to 200 | 15 to 30 |
| Hard | >200 | >30 |

1. SPT 'N' in accordance with ASTM D1586, uncorrected for overburden pressure effects; approximate only.
2. SPT 'N' values should be considered ONLY an approximate guide to consistency; for sensitive clays (e.g., Champlain Sea clays), the N-value approximation for consistency terms does NOT apply. Rely on direct measurement of undrained shear strength or other manual observations.

### Water Content

| Term | Description |
|---|---|
| w < PL | Material is estimated to be drier than the Plastic Limit. |
| w ~ PL | Material is estimated to be close to the Plastic Limit. |
| w > PL | Material is estimated to be wetter than the Plastic Limit. |

# LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

## I. GENERAL

| | |
|---|---|
| $\pi$ | 3.1416 |
| ln x | natural logarithm of x |
| $\log_{10}$ | x or log x, logarithm of x to base 10 |
| g | acceleration due to gravity |
| t | time |

## II. STRESS AND STRAIN

| | |
|---|---|
| $\gamma$ | shear strain |
| $\Delta$ | change in, e.g. in stress: $\Delta\ \sigma$ |
| $\varepsilon$ | linear strain |
| $\varepsilon_v$ | volumetric strain |
| $\eta$ | coefficient of viscosity |
| $\upsilon$ | Poisson's ratio |
| $\sigma$ | total stress |
| $\sigma'$ | effective stress ($\sigma' = \sigma - u$) |
| $\sigma'_{vo}$ | initial effective overburden stress |
| $\sigma_1, \sigma_2, \sigma_3$ | principal stress (major, intermediate, minor) |
| $\sigma_{oct}$ | mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$ |
| $\tau$ | shear stress |
| u | porewater pressure |
| E | modulus of deformation |
| G | shear modulus of deformation |
| K | bulk modulus of compressibility |

## III. SOIL PROPERTIES

### (a) Index Properties

| | |
|---|---|
| $\rho(\gamma)$ | bulk density (bulk unit weight)* |
| $\rho_d(\gamma_d)$ | dry density (dry unit weight) |
| $\rho_w(\gamma_w)$ | density (unit weight) of water |
| $\rho_s(\gamma_s)$ | density (unit weight) of solid particles |
| $\gamma'$ | unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$) |
| $D_R$ | relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly $G_s$) |
| e | void ratio |
| n | porosity |
| S | degree of saturation |

### (a) Index Properties (continued)

| | |
|---|---|
| w | water content |
| $w_l$ or LL | liquid limit |
| $w_p$ or PL | plastic limit |
| $I_p$ or PI | plasticity index = $(w_l - w_p)$ |
| NP | non-plastic |
| $w_s$ | shrinkage limit |
| $I_L$ | liquidity index = $(w - w_p) / I_p$ |
| $I_C$ | consistency index = $(w_l - w) / I_p$ |
| $e_{max}$ | void ratio in loosest state |
| $e_{min}$ | void ratio in densest state |
| $I_D$ | density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density) |

### (b) Hydraulic Properties

| | |
|---|---|
| h | hydraulic head or potential |
| q | rate of flow |
| v | velocity of flow |
| i | hydraulic gradient |
| k | hydraulic conductivity (coefficient of permeability) |
| j | seepage force per unit volume |

### (c) Consolidation (one-dimensional)

| | |
|---|---|
| $C_c$ | compression index (normally consolidated range) |
| $C_r$ | recompression index (over-consolidated range) |
| $C_s$ | swelling index |
| $C_\alpha$ | secondary compression index |
| $m_v$ | coefficient of volume change |
| $c_v$ | coefficient of consolidation (vertical direction) |
| $c_h$ | coefficient of consolidation (horizontal direction) |
| $T_v$ | time factor (vertical direction) |
| U | degree of consolidation |
| $\sigma'_p$ | pre-consolidation stress |
| OCR | over-consolidation ratio = $\sigma'_p / \sigma'_{vo}$ |

### (d) Shear Strength

| | |
|---|---|
| $\tau_p, \tau_r$ | peak and residual shear strength |
| $\phi'$ | effective angle of internal friction |
| $\delta$ | angle of interface friction |
| $\mu$ | coefficient of friction = $\tan \delta$ |
| $c'$ | effective cohesion |
| $c_u, s_u$ | undrained shear strength ($\phi = 0$ analysis) |
| p | mean total stress $(\sigma_1 + \sigma_3)/2$ |
| $p'$ | mean effective stress $(\sigma'_1 + \sigma'_3)/2$ |
| q | $(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$ |
| $q_u$ | compressive strength $(\sigma_1 - \sigma_3)$ |
| $S_t$ | sensitivity |

**Notes:**
1 $\tau = c' + \sigma' \tan \phi'$
2 shear strength = (compressive strength)/2

* Density symbol is $\rho$. Unit weight symbol is $\gamma$ where $\gamma = \rho g$ (i.e. mass density multiplied by acceleration due to gravity)

PROJECT: 20146060

LOCATION: N 668423.00; E 4870022.00

# RECORD OF BOREHOLE: 20-1

BORING DATE: September 10, 2020

SHEET 1 OF 1

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

BORING METHOD: Powerprobe 9570 Track Mounted Rig; 100 mm Solid Stem Augers

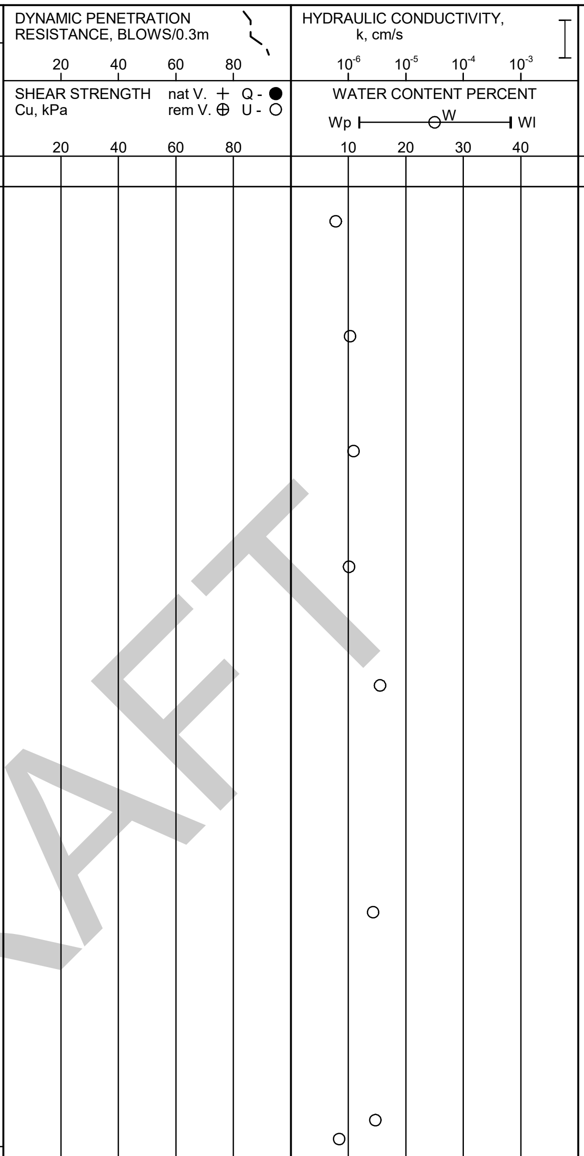
| SOIL PROFILE DESCRIPTION | ELEV. DEPTH (m) | SAMPLES NUMBER | TYPE | BLOWS/0.3m | ADDITIONAL LAB. TESTING |
|---|---|---|---|---|---|
| GROUND SURFACE | 178.00 | | | | |
| REWORKED - (CL) sandy SILTY CLAY, some to trace gravel; brown; organic inclusion at 0.8 m depth; cohesive, w<PL to w>PL, very stiff to stiff<br>- Auger grinding at a depth of 0.3 m | 0.00 | 1 | SS | 16 | |
| | | 2 | SS | 8 | |
| (CL-ML) sandy SILTY CLAY to CLAYEY SILT, trace gravel; brown, oxidation staining (TILL); cohesive, w<PL, very stiff to stiff | 176.63<br>1.37 | 3 | SS | 26 | |
| | | 4 | SS | 9 | |
| (ML) SILT, trace sand, grey; non-cohesive, wet, compact | 175.10<br>2.90 | 5 | SS | 14 | MH |
| (ML) sandy SILT, trace gravel; slightly plastic, grey (TILL); non-cohesive, moist, dense | 173.96<br>4.04 | 6 | SS | 36 | |
| (SP) SAND, some fines; brown; non-cohesive, wet, very dense | 172.44<br>5.56 | 7A | SS | 50/<br>0.1 | |
| (SM) SILTY SAND, trace gravel; grey (TILL); non-cohesive, moist, very dense | 171.75<br>6.25 | 7B | | | |
| END OF BOREHOLE | 6.35 | | | | |

NOTES:

1. Water encountered at a depth of 3.1 m during drilling.

2. Borehole caved to a depth of 5.8 m upon completion of drilling.

3. Water measured in open borehole at a depth of 4.6 m upon completion of drilling.



DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE

1 : 50

GOLDER

LOGGED: TO

CHECKED: SEMP

PROJECT: 20146060

LOCATION: N 668373.00; E 4870019.00

# RECORD OF BOREHOLE: 20-2

BORING DATE: September 10, 2020

SHEET 1 OF 1

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

BORING METHOD: Powerprobe 9570 Track Mounted Rig; 100 mm Solid Stem Augers

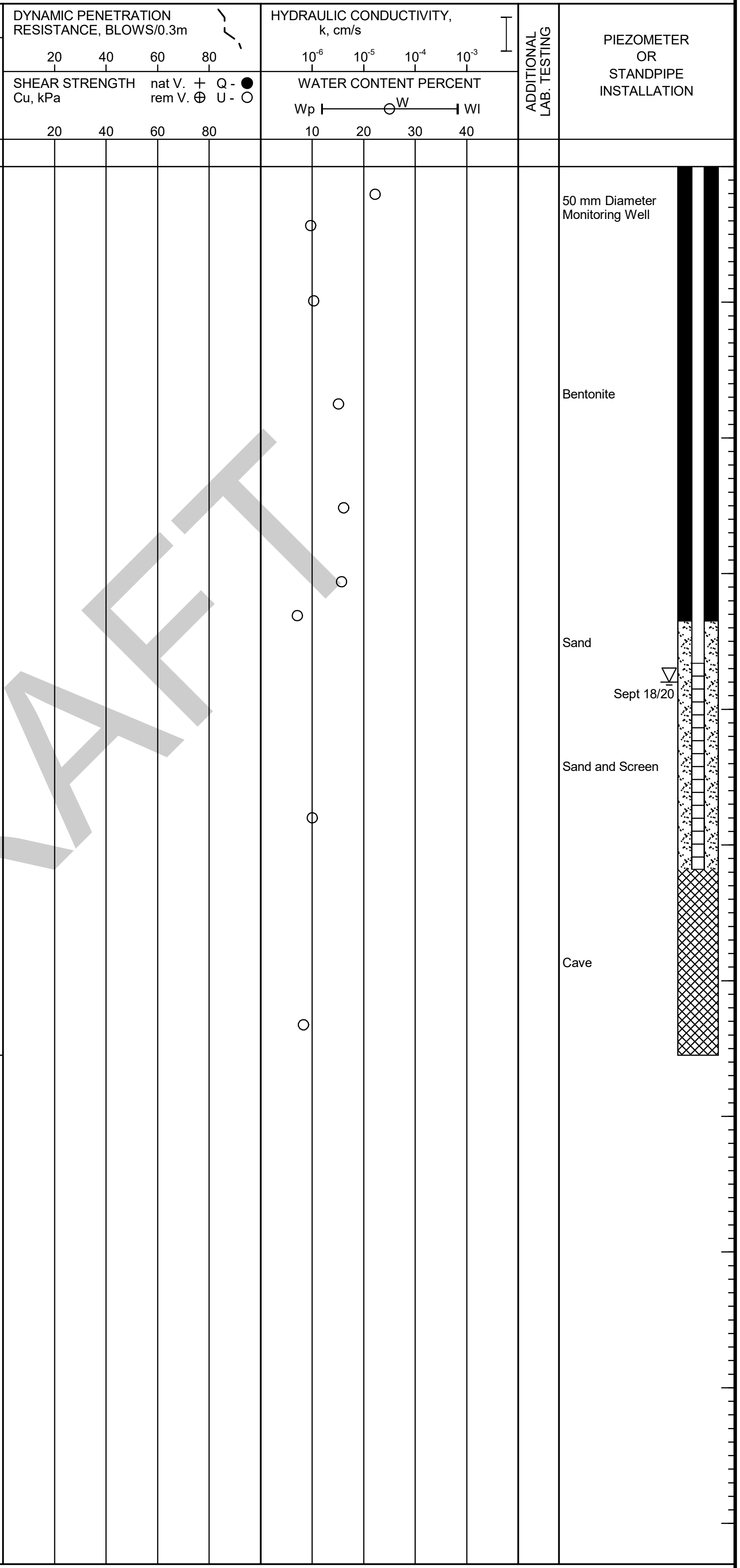
| SOIL PROFILE DESCRIPTION | ELEV. DEPTH (m) | SAMPLES NUMBER | TYPE | BLOWS/0.3m |
|---|---|---|---|---|
| GROUND SURFACE | 178.00 | | | |
| TOPSOIL | 0.00 | 1A | SS | 9 |
| (CL-ML) sandy SILTY CLAY to CLAYEY SILT, trace gravel; brown, oxidation staining (TILL); cohesive, w>PL to w>PL, stiff | 177.59<br>0.41 | 1B<br>2<br>3 | <br>SS<br>SS | <br>14<br>9 |
| (CL) SILTY CLAY; some sand, brown, oxidation staining; cohesive, w>PL, very stiff | 175.87<br>2.13 | 4<br>5A | SS | 26 |
| (SM) SILTY SAND, some gravel; brown to grey, oxidation staining to 3.5 m (TILL); non-cohesive, moist, dense<br>- Becoming grey at a depth of 4.6 m | 174.93<br>3.07 | 5B<br>6<br>7 | SS<br>SS<br>SS | 46<br>40<br>43 |
| END OF BOREHOLE | 171.45<br>6.55 | | | |

NOTES:

1. Water encountered at a depth of 4.0 m during drilling.

2. Borehole caved to a depth of 5.8 m upon completion of drilling.

3. Groundwater level was measured in monitoring well at a depth of 3.8 mbgs on September 18, 2020.



DEPTH SCALE 1 : 50

GOLDER

LOGGED: TO

CHECKED: SEMP

PROJECT: 20146060

LOCATION: N 668324.00; E 4869986.00

# RECORD OF BOREHOLE: 20-3

BORING DATE: September 10, 2020

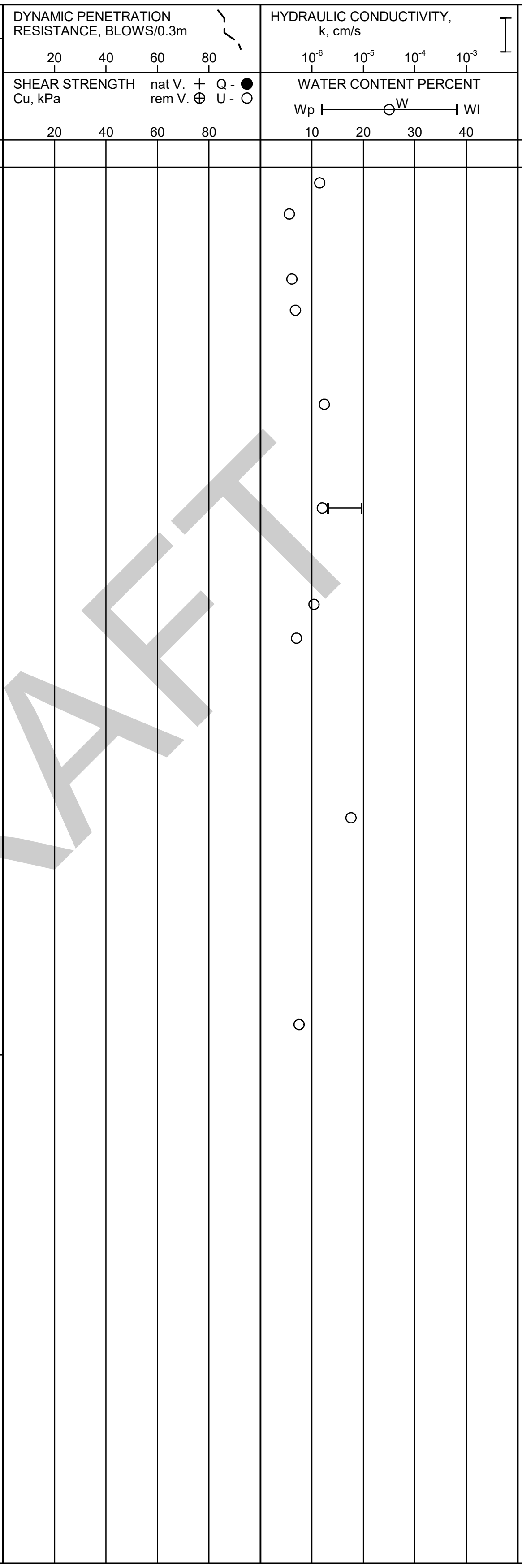
SHEET 1 OF 1

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

| DEPTH SCALE METRES | BORING METHOD | SOIL PROFILE DESCRIPTION | STRATA PLOT | ELEV. DEPTH (m) | SAMPLES NUMBER | SAMPLES TYPE | SAMPLES BLOWS/0.3m | ADDITIONAL LAB. TESTING | PIEZOMETER OR STANDPIPE INSTALLATION |
|---|---|---|---|---|---|---|---|---|---|
| | | GROUND SURFACE | | 178.00 | | | | | |
| 0 | Powerprobe 9570 Track Mounted Rig<br>100 mm Solid Stem Augers | REWORKED - (CL) sandy SILTY CLAY, trace to some gravel; brown, organic inclusions; cohesive, w>PL, very stiff | | 0.00 | 1A | SS | 21 | | |
| | | (CL-ML) sandy SILTY CLAY to CLAYEY SILT, some gravel to gravelly; brown, oxidation staining to 3.4 m (TILL); cohesive, w<PL, very stiff to hard | | 177.77<br>0.23 | 1B | | | | |
| 1 | | | | | 2A<br>2B | SS | 33 | | |
| 2 | | | | | 3 | SS | 35 | | |
| | | | | | 4 | SS | 19 | MH | |
| 3 | | - Becoming grey at a depth of 3.4 m | | | 5A<br>5B | SS | 53 | | |
| | | - Becoming gravelly at a depth of 3.4 m | | | | | | | |
| 4 | | (CL) SILTY CLAY, some sand, grey; cohesive, w>PL, very stiff | | 173.96<br>4.04 | | | | | |
| 5 | | | | | 6 | SS | 29 | | |
| | | (SM) SILTY SAND, trace gravel; grey (TILL); non-cohesive, moist, compact | | 172.44<br>5.56 | | | | | |
| 6 | | | | | 7 | SS | 16 | | |
| | | END OF BOREHOLE | | 171.45<br>6.55 | | | | | |



NOTES:

1. Water encountered at a depth of 4.6 m during drilling.

2. Borehole caved to a depth of 5.5 m upon completion of drilling.

3. Water measured in open borehole at a depth of 4.7 m upon completion of drilling.

DEPTH SCALE

1 : 50

GOLDER

LOGGED: TO

CHECKED: SEMP

GTA-BHS 001 S:\CLIENTS\RIOCAN\WINDFIELDS_FARM\02_DATA\GINT\20146060.GPJ GAL-MIS.GDT 9/30/20

PROJECT: 20146060

LOCATION: N 668283.00; E 4869987.00

# RECORD OF BOREHOLE: 20-4

BORING DATE: September 11, 2020

SHEET 1 OF 1

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

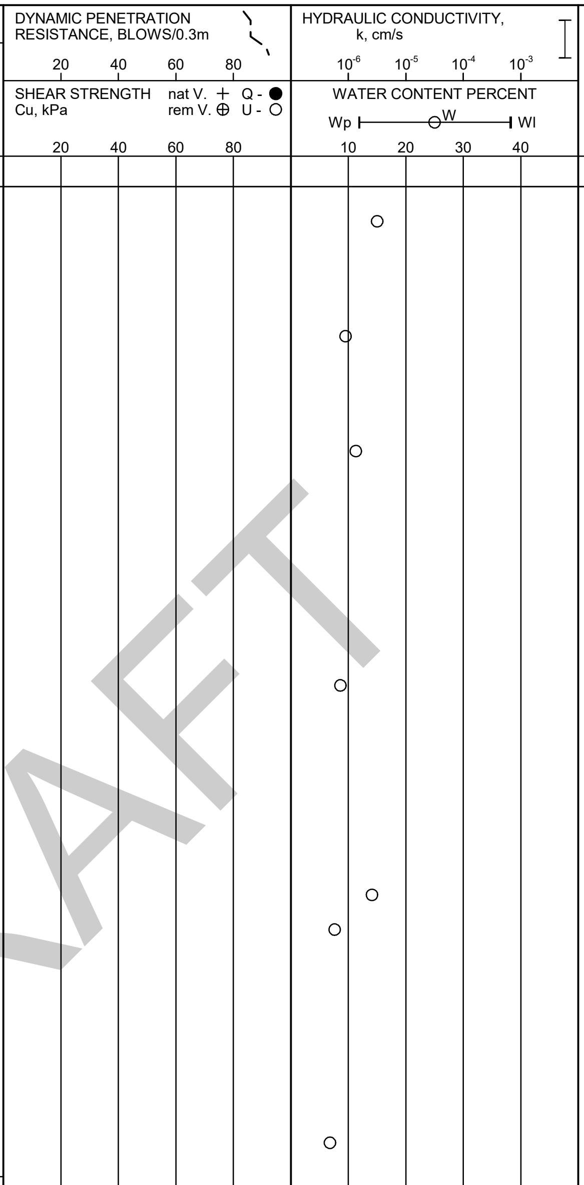
| BORING METHOD | SOIL PROFILE – DESCRIPTION | ELEV. DEPTH (m) | SAMPLES NUMBER | TYPE | BLOWS/0.3m |
|---|---|---|---|---|---|
| | GROUND SURFACE | 179.00 | | | |
| Powerprobe 9570 Track Mounted Rig<br>100 mm Solid Stem Augers | TOPSOIL | 0.00 | 1 | SS | 13 |
| | (CL-ML) sandy SILTY CLAY to CLAYEY SILT, trace gravel; brown; oxidation staining (TILL); cohesive, w<PL, very stiff to hard | 178.39<br>0.61 | 2 | SS | 20 |
| | | | 3 | SS | 24 |
| | - Auger grinding at a depth of 2.1 m | | | | |
| | - Auger grinding at a depth of 3.4 m | | 4 | SS | 75 |
| | (SM) SILTY SAND, grey; non-cohesive, wet, dense | 174.96<br>4.04 | 5A | SS | 38 |
| | (SM) SILTY SAND, some gravel; grey (TILL); non-cohesive, moist, dense to very dense | 174.20<br>4.80 | 5B | | |
| | - Auger grinding at a depth of 5.2 m | | | | |
| | - Auger grinding at a depth of 5.8 m | | 6 | SS | 85 |
| | END OF BOREHOLE | 172.45<br>6.55 | | | |

NOTES:

1. Water encountered at a depth of 4.0 m during drilling.

2. Borehole caved to a depth of 4.6 m upon completion of drilling.

3. Water measured in open borehole at a depth of 3.5 m upon completion of drilling.



GTA-BHS 001 S:\CLIENTS\RIOCAN\WINDFIELDS_FARM\02_DATA\GINT\20146060.GPJ GAL-MIS.GDT 9/30/20

DEPTH SCALE

1 : 50

GOLDER

LOGGED: TO

CHECKED: SEMP

PROJECT: 20146060

LOCATION: N 668252.00; E 4870002.00

# RECORD OF BOREHOLE: 20-5

BORING DATE: September 10, 2020

SHEET 1 OF 1

DATUM: Geodetic

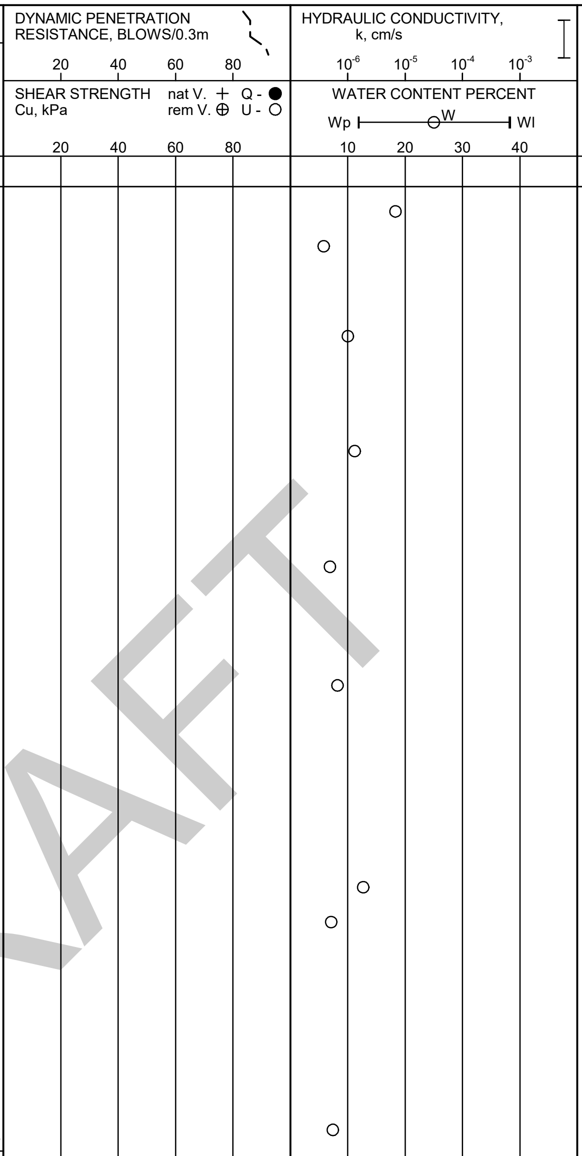
SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

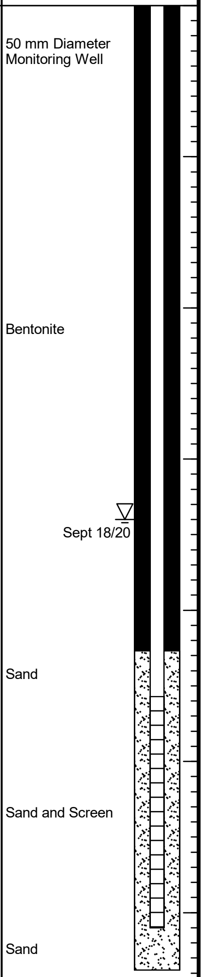
BORING METHOD: Powerprobe 9570 Track Mounted Rig; 100 mm Solid Stem Augers

| SOIL PROFILE DESCRIPTION | ELEV. DEPTH (m) |
|---|---|
| GROUND SURFACE | 180.00 |
| TOPSOIL | 0.00 |
| (CL-ML) sandy SILTY CLAY to CLAYEY SILT, trace gravel; brown, oxidation staining (TILL); cohesive, w<PL, stiff | 179.67<br>0.33 |
| (SM) SILTY SAND, trace gravel; brown, oxidation staining (TILL); non-cohesive, moist, very dense<br>- Auger grinding at a depth of 2.4 m | 177.80<br>2.20 |
| (CL-ML) sandy SILTY CLAY to CLAYEY SILT, trace gravel; brown, oxidation staining (TILL); cohesive, w<PL, hard | 177.15<br>2.85 |
| (SM) SILTY SAND; brown, oxidation staining; non-cohesive, wet, very dense | 175.96<br>4.04 |
| (SM) SILTY SAND, trace to some gravel; grey (TILL); non-cohesive, moist, very dense<br>- Auger grinding between depths of 4.9 m and 6.1 m | 175.30<br>4.70 |
| END OF BOREHOLE | 173.62<br>6.38 |

| SAMPLES NUMBER | TYPE | BLOWS/0.3m | ADDITIONAL LAB. TESTING |
|---|---|---|---|
| 1A | SS | 14 | |
| 1B | | | |
| 2 | SS | 29 | |
| 3 | SS | 21 | |
| 4 | SS | 59 | |
| 5 | SS | 34 | |
| 6A | SS | 62 | |
| 6B | | | |
| 7 | SS | 50/<br>0.13 | MH |



PIEZOMETER OR STANDPIPE INSTALLATION



NOTES:

1. Water encountered at a depth of 4.6 m during drilling.

2. Groundwater level was measured in monitoring well at a depth of 3.4 mbgs on September 18, 2020.

DEPTH SCALE

1 : 50

GOLDER

LOGGED: TO

CHECKED: SEMP

PROJECT: 20146060

LOCATION: N 668227.00; E 4870048.00

# RECORD OF BOREHOLE: 20-6

BORING DATE: September 11, 2020

SHEET 1 OF 1

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

BORING METHOD: Powerprobe 9570 Track Mounted Rig; 100 mm Solid Stem Augers

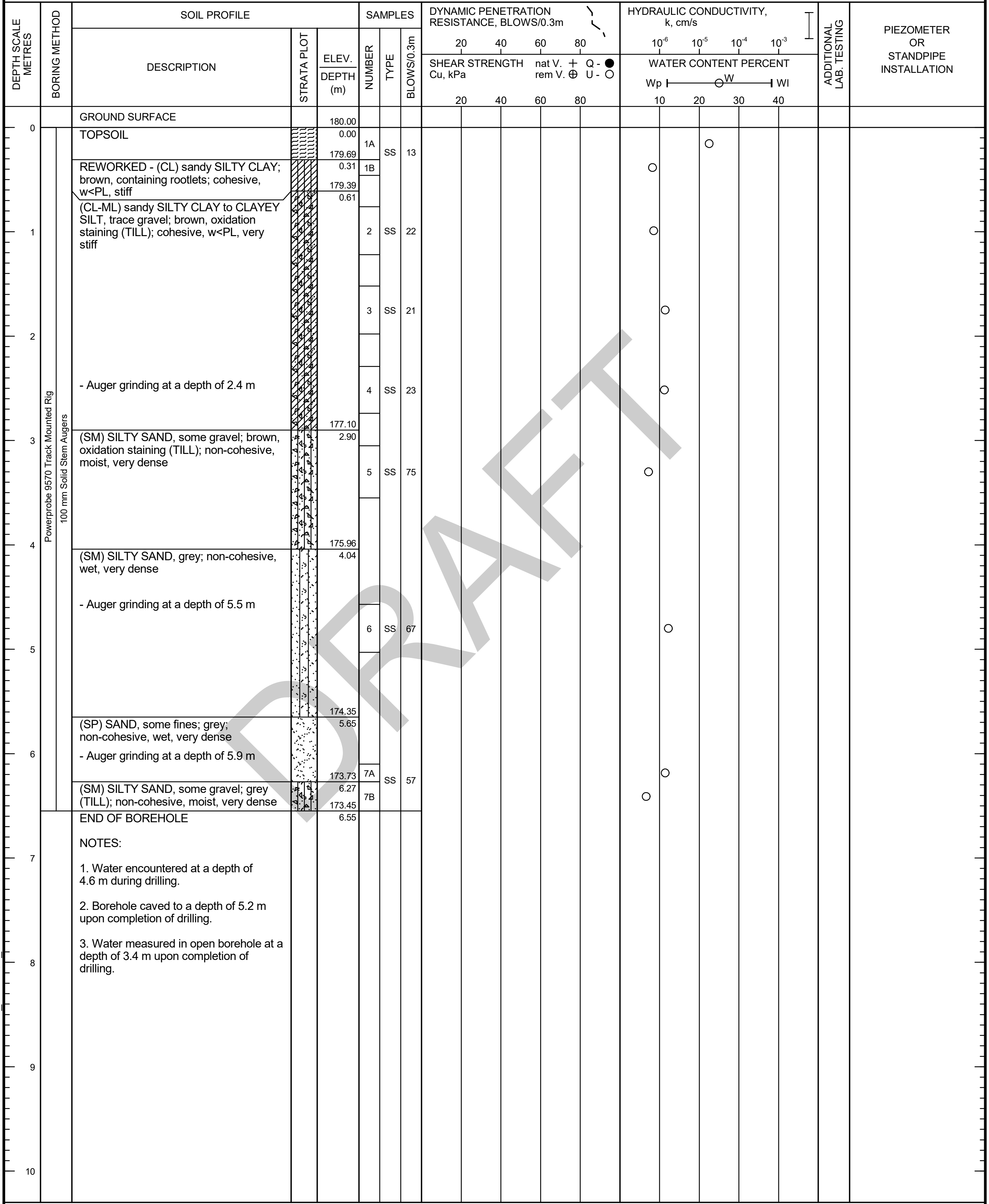
| SOIL PROFILE: DESCRIPTION | ELEV. DEPTH (m) | SAMPLES: NUMBER | TYPE | BLOWS/0.3m |
|---|---|---|---|---|
| GROUND SURFACE | 180.00 | | | |
| TOPSOIL | 0.00 | 1A | SS | 13 |
| REWORKED - (CL) sandy SILTY CLAY; brown, containing rootlets; cohesive, w<PL, stiff | 179.69<br>0.31 | 1B | | |
| (CL-ML) sandy SILTY CLAY to CLAYEY SILT, trace gravel; brown, oxidation staining (TILL); cohesive, w<PL, very stiff | 179.39<br>0.61 | 2 | SS | 22 |
| | | 3 | SS | 21 |
| - Auger grinding at a depth of 2.4 m | | 4 | SS | 23 |
| (SM) SILTY SAND, some gravel; brown, oxidation staining (TILL); non-cohesive, moist, very dense | 177.10<br>2.90 | 5 | SS | 75 |
| (SM) SILTY SAND, grey; non-cohesive, wet, very dense<br>- Auger grinding at a depth of 5.5 m | 175.96<br>4.04 | 6 | SS | 67 |
| (SP) SAND, some fines; grey; non-cohesive, wet, very dense<br>- Auger grinding at a depth of 5.9 m | 174.35<br>5.65 | 7A | SS | 57 |
| (SM) SILTY SAND, some gravel; grey (TILL); non-cohesive, moist, very dense | 173.73<br>6.27 | 7B | | |
| END OF BOREHOLE | 173.45<br>6.55 | | | |

NOTES:

1. Water encountered at a depth of 4.6 m during drilling.

2. Borehole caved to a depth of 5.2 m upon completion of drilling.

3. Water measured in open borehole at a depth of 3.4 m upon completion of drilling.



DEPTH SCALE
1 : 50

GOLDER

LOGGED: TO

CHECKED: SEMP

PROJECT: 20146060
LOCATION: N 668227.00; E 4870088.00

# RECORD OF BOREHOLE: 20-7

BORING DATE: September 11, 2020

SHEET 1 OF 1

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

BORING METHOD: Powerprobe 9570 Track Mounted Rig; 100 mm Solid Stem Augers

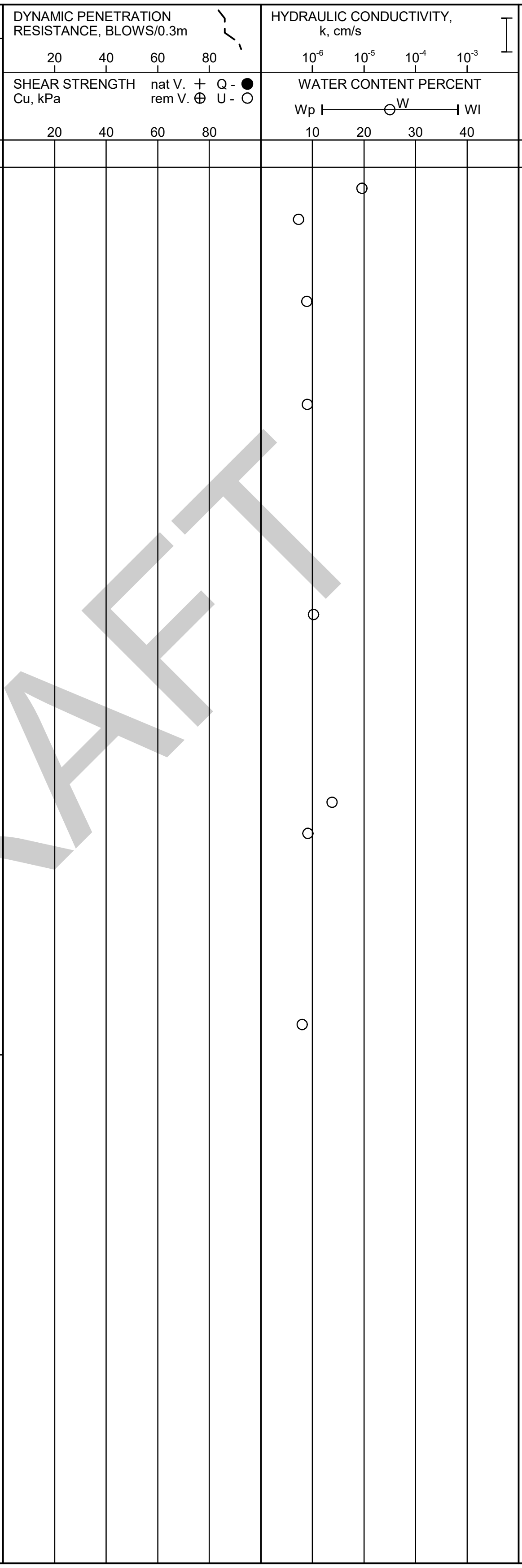
| DEPTH SCALE METRES | SOIL PROFILE DESCRIPTION | ELEV. DEPTH (m) | SAMPLES NUMBER | TYPE | BLOWS/0.3m |
|---|---|---|---|---|---|
| | GROUND SURFACE | 180.00 | | | |
| 0 | TOPSOIL | 0.00 | 1A | SS | 16 |
| | (CL-ML) sandy SILTY CLAY to CLAYEY SILT, trace gravel; brown, oxidation staining (TILL); cohesive, w<PL, very stiff to hard | 179.70<br>0.30 | 1B | | |
| 1 | | | 2 | SS | 36 |
| | | | 3 | SS | 32 |
| 3 | - Auger grinding at a depth of 2.7 m | | | | |
| | | | 4 | SS | 58 |
| 4 | (SM) SILTY SAND, grey; non-cohesive, wet, dense | 175.96<br>4.04 | | | |
| | | | 5A | SS | 35 |
| 5 | (SM) SILTY SAND, some gravel; grey (TILL); non-cohesive, moist, dense to very dense | 175.20<br>4.80 | 5B | | |
| 6 | | | 6 | SS | 51 |
| | END OF BOREHOLE | 173.45<br>6.55 | | | |

NOTES:

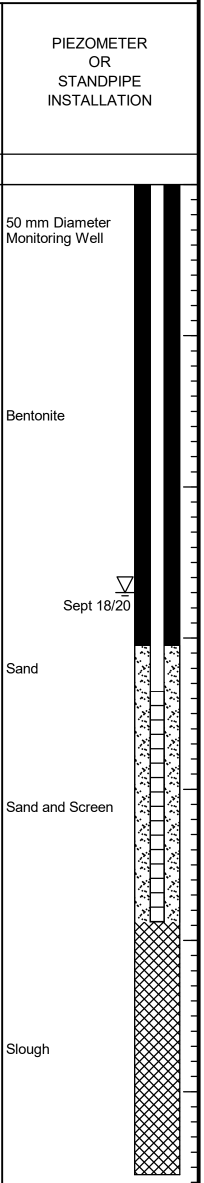
1. Water encountered at a depth of 4.6 m during drilling.

2. Borehole caved to a depth of 4.9 m upon completion of drilling.

3. Groundwater level was measured in monitoring well at a depth of 2.7 mbgs on September 18, 2020.



ADDITIONAL LAB. TESTING



DEPTH SCALE
1 : 50

GOLDER

LOGGED: TO
CHECKED: SEMP

PROJECT: 20146060

LOCATION: N 668200.00; E 4870129.00

# RECORD OF BOREHOLE: 20-8

BORING DATE: September 11, 2020

SHEET 1 OF 1

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

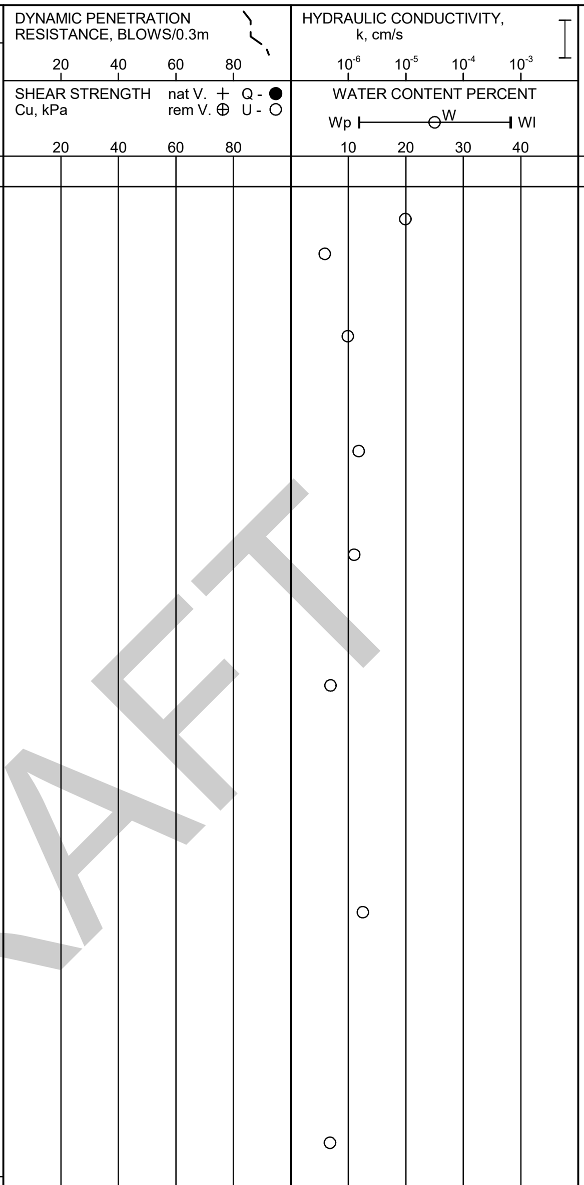
BORING METHOD: Powerprobe 9570 Track Mounted Rig; 100 mm Solid Stem Augers

| SOIL PROFILE – DESCRIPTION | ELEV. DEPTH (m) |
|---|---|
| GROUND SURFACE | 180.00 |
| TOPSOIL | 0.00 |
| (CL-ML) sandy SILTY CLAY to CLAYEY SILT, trace gravel; brown, oxidation staining at 0.8 m (TILL); cohesive, w<PL, very stiff | 179.57<br>0.43 |
| (SM) SILTY SAND, trace to some gravel; brown, oxidation staining (TILL); non-cohesive, moist, very dense<br>- Auger grinding at a depth of 3.4 m | 177.10<br>2.90 |
| (SM) SILTY SAND, trace gravel; grey; non-cohesive, wet, compact | 175.96<br>4.04 |
| (SM) SILTY SAND, trace gravel; grey (TILL); non-cohesive, moist, dense | 174.44<br>5.56 |
| END OF BOREHOLE | 173.45<br>6.55 |

| SAMPLES NUMBER | TYPE | BLOWS/0.3m |
|---|---|---|
| 1A | SS | 11 |
| 1B | | |
| 2 | SS | 17 |
| 3 | SS | 24 |
| 4 | SS | 27 |
| 5 | SS | 57 |
| 6 | SS | 28 |
| 7 | SS | 42 |

NOTES:

1. Water encountered at a depth of 4.0 m during drilling.
2. Borehole caved to a depth of 4.3 m upon completion of drilling.
3. Water measured in open borehole at a depth of 2.7 m upon completion of drilling.



ADDITIONAL LAB. TESTING

PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE METRES: 0 1 2 3 4 5 6 7 8 9 10

DEPTH SCALE

1 : 50

GOLDER

LOGGED: TO

CHECKED: SEMP

PROJECT: 20146060

LOCATION: N 668247.00; E 4870119.00

# RECORD OF BOREHOLE: 20-9

BORING DATE: September 11, 2020

SHEET 1 OF 1

DATUM: Geodetic

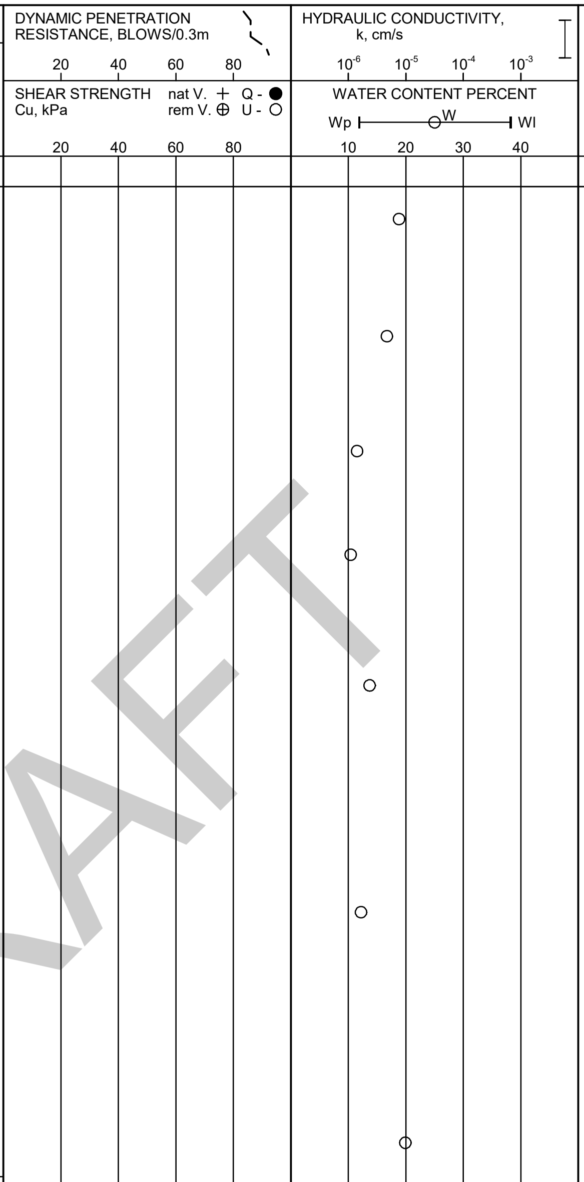
SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

BORING METHOD: Powerprobe 9570 Track Mounted Rig; 100 mm Solid Stem Augers

| SOIL PROFILE DESCRIPTION | ELEV. DEPTH (m) |
|---|---|
| GROUND SURFACE | 180.00 |
| TOPSOIL | 0.00 |
| (CL-ML) sandy SILTY CLAY to CLAYEY SILT, trace gravel; brown, oxidation staining (TILL); cohesive, w>PL to w~PL, very stiff to hard<br>- Auger grinding at a depth of 3.4 m<br>- Auger grinding at a depth of 4.0 m | 179.39<br>0.61 |
| (SP) gravelly SAND, some fines; brown, oxidation staining , non-cohesive, wet, very dense | 175.96<br>4.04 |
| (SM) SILTY SAND, grey; non-cohesive, wet, very dense | 174.44<br>5.56 |
| END OF BOREHOLE | 173.45<br>6.55 |

| NUMBER | TYPE | BLOWS/0.3m | ADDITIONAL LAB. TESTING |
|---|---|---|---|
| 1 | SS | 10 | |
| 2 | SS | 28 | |
| 3 | SS | 23 | |
| 4 | SS | 29 | |
| 5 | SS | 41 | |
| 6 | SS | 51 | MH |
| 7 | SS | 58 | |



PIEZOMETER OR STANDPIPE INSTALLATION

NOTES:

1. Water encountered at a depth of 3.1 m during drilling.

2. Borehole caved to a depth of 4.3 m upon completion of drilling.

3. Water measured in open borehole at a depth of 2.9 m upon completion of drilling.

DEPTH SCALE

1 : 50

GOLDER

LOGGED: TO

CHECKED: SEMP

PROJECT: 20146060

LOCATION: N 668335.00; E 4870030.00

# RECORD OF BOREHOLE: 20-10

BORING DATE: September 11, 2020

SHEET 1 OF 1

DATUM: Geodetic

SPT/DCPT HAMMER: MASS, 64kg; DROP, 760mm

HAMMER TYPE: AUTOMATIC

BORING METHOD: Powerprobe 9570 Track Mounted Rig; 100 mm Solid Stem Augers

| DEPTH SCALE METRES | DESCRIPTION | ELEV. DEPTH (m) | NUMBER | TYPE | BLOWS/0.3m |
|---|---|---|---|---|---|
| | GROUND SURFACE | 178.00 | | | |
| 0 | TOPSOIL | 0.00 | 1A | SS | 16 |
| | (CL-ML) sandy SILTY CLAY to CLAYEY SILT, trace to some gravel; brown to grey, oxidation staining to 1.9 m (TILL); cohesive, w<PL to w~PL, very stiff | 177.64<br>0.36 | 1B | | |
| 1 | | | 2 | SS | 23 |
| | | | 3 | SS | 60/<br>0.23 |
| 2 | - Inferred boulder/cobble at a depth of 1.8 m (auger grinding) | | | | |
| | - Auger grinding at a depth of 1.8 m | | | | |
| 3 | - Becoming grey at a depth of 3.1 m | | 4 | SS | 27 |
| 4 | (ML) SILT, trace sand, grey; non-cohesive, wet, compact | 173.96<br>4.04 | 5A | SS | 18 |
| 5 | (SM) SILTY SAND, some gravel; grey (TILL); non-cohesive, moist, compact to very dense | 173.10<br>4.90 | 5B | | |
| 6 | | 171.78 | 6 | SS | 50/<br>0.13 |
| | END OF BOREHOLE | 6.22 | | | |

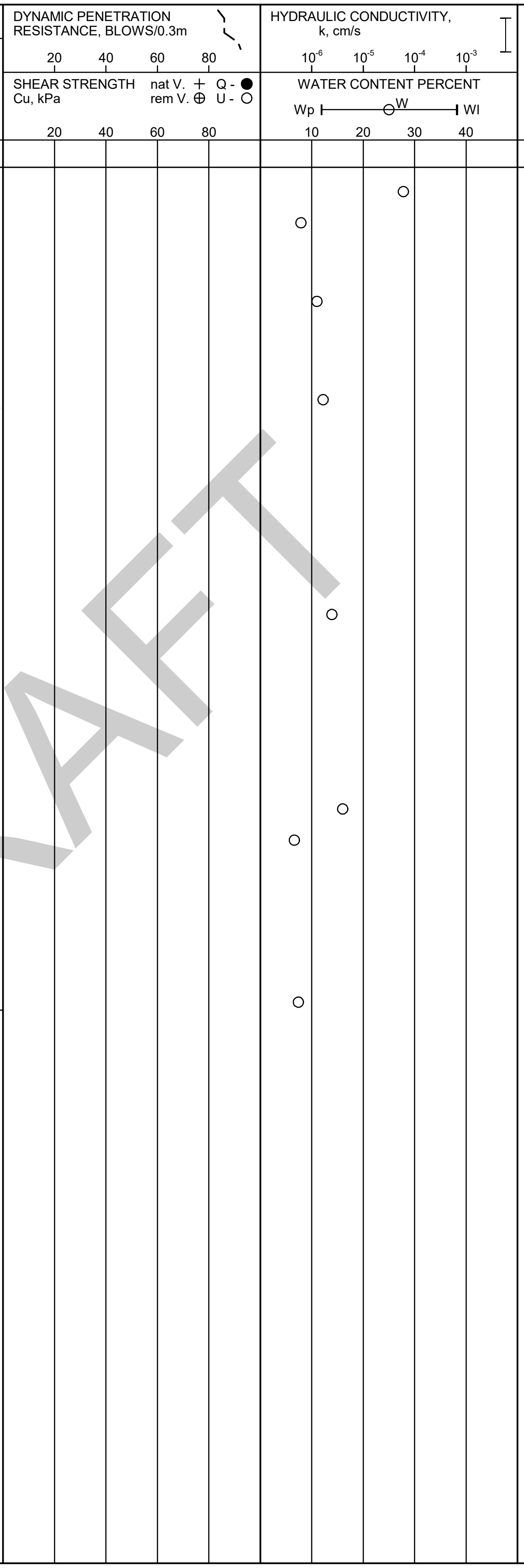
NOTES:

1. Water encountered at a depth of 5.8 m during drilling.

2. Borehole caved to a depth of 5.8 m upon completion of drilling.

3. Water measured in open borehole at a depth of 5.7 m upon completion of drilling.

4. Borehole was moved about 1 m south of original borehole due to refusal at a depth of 1.8 m on September 11, 2020.



PIEZOMETER OR STANDPIPE INSTALLATION

DEPTH SCALE 1 : 50

GOLDER

LOGGED: TO

CHECKED: SEMP

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