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**A REPORT TO**
**2596843 ONTARIO INC.**

# HYDROGEOLOGICAL ASSESSMENT
# PROPOSED MIXED-USE DEVELOPMENT

**224 ARDARGH ROAD**
**CITY OF BARRIE**

**REFERENCE NO. 1802-W072**

**JULY 2019**

## DISTRIBUTION

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## 1.0 EXECUTIVE SUMMARY

Soil Engineers Ltd. conducted a hydrogeological assessment for a proposed mixed-use development, located at 224 Ardagh Road, in the City of Barrie. Surrounding land use includes; existing residential developments to the north; Ferndale Drive South and commercial development to the east, and Ardagh Road and existing residential housing to the south, along with the Barrie Fire and Emergency Service building to the west. The site currently consists of a vacant land, which is mainly covered by grass and shrubs. It is proposed to construct a six (6) storey mixed used building having a one (1) level underground parking structure, and five (5) blocks of 3- storey townhouses (Blocks A through E), each to be completed with a standard basement foundation structure.

The subject site is located within the Physiographic Region of Southern Ontario known as the Peterborough Drumlin Field, within the mapped physiographic feature known as Till Plains (drumlinized) which is underlain by the mapped Glaciolacustrine (sandy) deposits, sand and gravel representing a nearshore depositional environment.

The subject site is located within the Barrie Creek sub-watershed, within the Lake Simcoe Watershed.

A review of the topography mapping for the area shows that the subject site is relatively flat having a gentle decline in elevation relief towards its northern limits.

The study has disclosed that beneath a layer of topsoil or asphalt pavement, a layer of earth fill was contacted in places beneath the site which is underlain by deposits

of sand and silt with occasional layers of silty clay extending to the maximum investigated depth of 10.8 m.

The findings of this current study confirm that the groundwater levels range from an elevation of 255.75 to greater than 255.7 masl (i.e., 4.15 to > 6.10 below ground surface). Review of the average of shallow groundwater elevations suggests that it flows in northwest and south-easterly directions, towards a tributary of Lake Simcoe to the east and to Bear Creek to the west.

The single well response tests yielded hydraulic conductivity (K estimates) for the earth fill and silt subsoil is $1.90 \times 10^{-6}$ m/s. The above results suggest that the hydraulic conductivity for the groundwater-bearing sub-soils at the depths of the well screens is moderate, with corresponding moderate anticipated groundwater seepage rates into open excavations, below the water table.

The Hazen Equation calculated K estimate for the silt, having some clay and fine sand, retrieved from a depth of 4.7 mbgs at BH/MW 2 is $1.96 \times 10^{-8}$ m/sec, and the K estimate for the silt, have traces of clay and fine sand, retrieved from a depth of 4.7 mbgs at BH/MW 4 is $7.84 \times 10^{-8}$ m/sec. The K estimate retrieved for the fine to medium sand, having some silt and a trace of gravel, retrieved from a depth of 0.7 mbgs at BH/MW 4 is $1.60 \times 10^{-5}$ m/sec. The K estimate determined from the Hazen method suggests low to high hydraulic conductivities (K) for the shallow layers sub-soil for any encountered shallow perched groundwater found beneath the subject site.

The groundwater levels beneath the site are approximately 0.98 to 4.10 m below the proposed townhouse blocks buildings, and basement structures for Blocks A to E, and it is approximately 0.45 m below the proposed 1- level underground parking

structure for Block F, and it is 0.25 m above the proposed elevator pit structure being proposed for Block F. The groundwater levels at the site are approximately 1.37 to 5.43 m below the invert depths for the proposed underground services.

The dewatering flow estimates for construction of the proposed Block C, F structures, and the elevator pit structure beneath Block F suggests that the dewatering flow rate range between 4,707 L/day and 87, 116 L/day; by applying a safety factor of three (3), it could reach maximums of between 14, 122 L/day and 261,348 L/day. The construction dewatering flow rates for the excavations are below the 50,000 L/day threshold limit for requiring an approval for any proposed construction related groundwater takings, will not require any registration or filing with the MECP. The construction dewatering rates which are below the PTTW threshold limit of 400,000 L/day but are above 50,000 L/day groundwater taking approval requirement threshold, would be required to be registered through an Environmental Activity and Sector Registry (EASR) with the EASR filing through the MECP.

The groundwater elevation is approximately 1.37 to 5.43 m below the estimated lowest invert elevations for the proposed underground services where it is not anticipated that construction dewatering will be required for the installation of the underground services beneath the site.

The estimated zone of influence for construction dewatering could reach a maximum of 15.0 m away from the conceptual dewatering alignments. There are neighbouring residential properties that are within the conceptual zone of influence for construction dewatering; however, no groundwater receptors, such as water wells, bodies of water, watercourses or wetlands are present within the conceptual zone of influence for construction dewatering for the proposed development.

The local shallow groundwater flow pattern may be temporarily affected during construction.

The long-term foundation drainage rates from both an under-slab floor drainage network and from a footing drainage network for a conventionally side-sloped excavation foundation and for the proposed elevator pit structure for the proposed apartment building is approximately 80.0 L/day. By applying a safety factor of three (3), the long-term foundation drainage flow rates could reach a maximum of 240 L/day.

The groundwater levels lie at depths, ranging from between 3.55 m to greater than 6.10 m beneath the existing ground surface. The existing shallow sand unit could facilitate the infiltration of precipitation to the sub-surface beneath the site to replenish the shallow aquifer at depth, where possible, to address Low Impact Development (LID) future stormwater management planning for the proposed development

# 2.0 INTRODUCTION

## 2.1 Project Description

In accordance with the authorization dated February 22, 2018, from Mr. John Stante, of 2596843 Ontario Inc., Soil Engineers Ltd. (SEL) has conducted a hydrogeological assessment for a proposed residential development, at a site located northwest of the intersection of Ardagh Road and Ferndale Drive South at 224 Ardagh Road, in the City of Barrie. The location of the subject site is shown on Drawing No. 1.

The site is located within an existing developed area of Barrie. Surrounding land use includes; existing residential developments to the north; Ferndale Drive to the east, and an existing commercial development to the east, Ardagh Road and existing housing developments to the south, and the Barrie Fire and Emergency Service building to the west. The subject property currently consists of an unoccupied land, which mainly is grass covered along with the occasional shrubs and trees. An earth berm, approximately 3 m in height was observed at the south portions of the property, and a paved parking lot was located within the eastern portion of the site, at the time of investigation. A 6-storey mixed-use building having a 1-level underground parking structure, and 31-3 storey townhouse units, are to be completed on site, along with associated municipal services meeting urban standards, which are proposed for construction at the site.

This report summarizes the findings from the field study and associated groundwater level monitoring and hydraulic testing, providing a description and characterization of the hydrogeostratigraphy for the site and local surrounding area. The current study provides preliminary recommendations for any construction dewatering needs, or for any anticipated long-term foundation drainage needs prior to detailed design.

The report also provides a recommendation for any need to acquire an Environmental Activity and Sector Registry (EASR) approval, or a Permit-To-Take Water (PTTW) to facilitate groundwater taking for any construction dewatering program, or for any anticipated long-term foundation drainage needs.

## 2.2 Project Objectives

The major objectives of this Hydrogeological Assessment Report are as follows:

1. Establish the local hydrogeological setting for the site and local surrounding area;
2. Interpret shallow groundwater flow and runoff patterns;
3. Identify zones of higher groundwater yield as potential sources for ongoing shallow groundwater seepage;
4. Characterization of the hydraulic conductivity (K) for the groundwater-bearing subsoil strata;
5. Prepare an interpreted hydrostratigraphic cross-section across the subject site;
6. Estimate the anticipated temporary dewatering flows that may be required to lower the water table to facilitate construction, or for any anticipated long term permanent, foundation drainage, following construction, if required;
7. Describing the groundwater function for the site area, evaluating potential impacts to groundwater receptors within the anticipated zone of influence for construction dewatering; and develop preliminary estimates for the dewatering flow rates to facilitate excavation and construction, if required.
8. Comment on the feasibility of implementing of Low Impact Development (LID) stormwater management infrastructure at the developed site.

## 2.3 Scope of Work

The scope of work for this Hydrogeological Study is summarized below:

1. Installation of four (4) monitoring wells within the site's development footprint;
2. Monitoring well development and groundwater level measurements at the four installed (4) monitoring wells;
3. Performance of Single Well Response Tests (SWRTs) at the monitoring wells to estimate the hydraulic conductivity (K) for the groundwater-bearing subsoils at the depths of the well screens;
4. Describing the geological and hydrogeological setting for the site and surrounding local area; and,
5. Estimating the hydraulic conductivity (K) for the groundwater bearing subsoil strata, based on the SWRT results and from soil gram size analyses.
6. Review of the findings of the concurrent geotechnical study; review of available engineering development plans and profiles for the proposed mixed-use development; assessing the preliminary dewatering needs and estimation of any anticipated dewatering flows to lower the groundwater level for construction, or for any anticipated long-term foundation drainage after construction.

# 3.0 METHODOLOGY

## 3.1 Borehole Advancement and Monitoring Well Installation

Borehole drilling and monitoring well construction were conducted on March 28, 2018. The program consisted of the drilling of five (5) boreholes (BHs) and the installation of four (4) monitoring wells (MWs), one in each of four (4) selected geotechnical boreholes at the time of drilling. The locations of the boreholes/monitoring wells are shown on Drawing No. 2.

The borehole drilling and monitoring well construction were completed by the licensed water well contractor, DBW Drilling Ltd., under the full-time supervision of a geotechnical technician from SEL, who also logged the subsoil strata encountered during borehole advancement and collected representative soil samples for textural classification. Detailed descriptions of the encountered subsurface soil strata and groundwater conditions are presented on the borehole and monitoring well logs, enclosed as Figures 1 to 5, inclusive.

The monitoring wells were constructed using 50-mm diameter PVC riser pipe and screens, which were installed in the boreholes in accordance with Ontario Regulation (O. Reg.) 903. All of the monitoring wells were provided with steel, monument-type, protective casings at the ground surface. The details for the monitoring well construction are provided on the enclosed Borehole Logs (Figures 2, 3, 4 and 5).

The UTM coordinates and ground surface elevations at the borehole/monitoring well locations, together with the monitoring well construction details, are provided in Table 3-1.

**Table 3-1** - Monitoring Well Installation Details

| Well ID | Installation Date | UTM Coordinates | | Ground | BH Depth (mbgs) | Screen Interval (mbgs) | Casing Dia. (mm) |
|---|---|---|---|---|---|---|---|
| | | East | North | El. (masl) | | | |
| BH/MW 2 | 28-Mar-18 | 602378 | 4912165 | 259.9 | 10.8 | 3.1-6.1 | 50 |
| BH/MW 3 | 28-Mar-18 | 602346 | 4912130 | 260.5 | 6.5 | 3.1-6.1 | 50 |
| BH/MW 4 | 28-Mar-18 | 602318 | 4912088 | 261.7 | 8.1 | 3.1-6.1 | 50 |
| BH/MW 5 | 28-Mar-18 | 602392 | 4912112 | 261.6 | 9.6 | 3.1-6.1 | 50 |

Notes:
mbgs -- metres below ground surface
masl -- metres above sea level

## 3.2 Groundwater Monitoring

The groundwater levels in the monitoring wells were measured manually, on April 11, April 27, and May 7, 2018, to record the fluctuation of the shallow groundwater table beneath the site.

## 3.3 Mapping of Ontario Water Well Records

SEL received the Ministry of Environment and Climate and Change (MECP) Water Well Records (WWRs) for the registered wells located on the subject site and within 500 m of the site boundaries (study area). The records indicate that (20) twenty wells are located within the 500 m zone influence study area relative to the subject site boundaries. The WWR well locations are shown on Drawing No. 3, and the WWRs reviewed for this study are listed in Appendix 'A'.

## 3.4 Monitoring Well Development and Single Well Response Tests

BH/MW 2 underwent development in preparation for single well response testing (SWRT) to estimate the hydraulic conductivity (K) for saturated sub-soil strata at the

depths of the monitoring well screens. Well development involved the purging and removal of several casing volumes of groundwater from each monitoring well to remove remnants of clay, silt and other debris introduced into the monitoring wells during construction, and to induce the flow of formation groundwater through the well screens, thereby improving the transmissivity of the sub-soil strata formation at the well screen depths.

The K values derived from the SWRT's provide an indication of the yield capacity for the groundwater-bearing subsoil strata, at the well screen depths, and can be used to estimate the flow of groundwater through the water-bearing soil.

The SWRT involves the placement of a slug of known volume into the monitoring well, below the water table, to displace the groundwater level upward. The rate at which the water level recovers to static conditions (falling head) is tracked using a data logger/pressure transducer, and/or manually using a water level tape. The rate at which the water table recovers to static conditions is used to estimate the K value for the water-bearing substrata formation at the well screen depth interval.

The SWRT could not be performed on BH/MWs 3,4 and 5 due to due to insufficient groundwater volume within the monitoring well as recorded throughout the monitoring period.

## 3.5 Estimating Hydraulic Conductivity using the Hazen Equation Method

The Hazen equation estimation method was also used to estimate the hydraulic conductivity (K) for saturated subsoils at or below the anticipated groundwater level depths, beneath the subject site. The method provides alternative K estimates which are derived from the soil grain particle size diameter, whereby 10% by weight of the

soil particles are finer and 90% are coarser (Freeze and Cherry, 1979).

### 3.6 **Review Summary of Concurrent Report**

The following report was reviewed in preparation for this hydrogeological study:

A Report to 2596843 Ontario Inc., Proposed Mixed-Use Building with Underground Parking, 224 Ardagh Road, City of Barrie, Soil Engineers Ltd. Reference No. 1802-S072, dated May 2018.

# 4.0 REGIONAL AND LOCAL SETTING

## 4.1 Regional Geology

The study area lies within the physiographic region of Southern Ontario known as the Peterborough Drumlin Field, within the mapped physiographic feature known as Till Plains (drumlinized). The Peterborough Drumlin Field lies between the Oak Ridges Moraine and an area of shallow overburden subsoil overlying limestone of the Gull River Formation. The Peterborough Drumlin Field encompasses an area of about 4,500 $km^2$, and constitutes a rolling till plain, extending from Hastings County in the east to Simcoe County in the west, which includes drumlins situated south of the moraine within Northumberland County. This belt contains approximately 3,000 drumlins in addition to many other drumlinoid hills and surface flutings of the surficial till sheet. The drumlins throughout are composed of highly calcareous till soil but there are local differences. The Peterborough Drumlin Field is also notable for its eskers and its drumlins. The eskers comprise linear gravel ridges affording poor soils for agriculture, but they are valuable as sources of road aggregate material since other gravels of good quality are rather scarce (Chapman and Putnam, 1984).

Based on a review of a surface geological map of Ontario, the subject site is located on the mapped Glaciolacustrine (sandy) deposits, sand and gravel representing a nearshore depositional environment. The Newmarket Till deposits, are situated less than 0.5 km south east of the subject site. Drawing No. 4, as reproduced from Ontario Geological Survey (OGS) mapping, illustrates the quaternary surface soil geology for the site and surrounding area.

The bedrock underlying the site is comprised mainly of shale, limestone, dolostone, arkose and sandstone from the Ottawa and Simcoe Groups. The approximate

Elevation for the top of the bedrock beneath the site is at about 350 masl (Bedrock Geology of Ontario, 1993) which is about 90 m below the existing surface grade.

## 4.2 Physical Topography

A review of the local topography shows that the subject site is undulating, exhibiting a decline in elevation relief towards its northern limits. Surface runoff from the site is expected to drain in a northerly direction. Based on the topographic map for the area and from review of the ground surface elevations at the borehole and monitoring well locations, the total elevation relief across the subject site is about 2 m. Drawing No. 5 shows the mapped topographical contours for the site and surrounding area.

## 4.3 Watershed Setting

The subject site is located within the Barrie Creek sub-watersheds of the Lake Simcoe Watershed. The Lake Simcoe Watershed comprises a total land and water surface area of 3,324 $km^2$, of which the lake occupies about 20 percent, or 722 $km^2$. The land portion of the watershed is approximately 2,600 $km^2$ which is drained by 35 tributary creeks and rivers, where five major tributaries account for more than 60 percent of the total drainage area within the watershed. The Lake Simcoe watershed has been divided into 18 sub-watersheds, or hydrological units (excluding Lake Simcoe Islands) (LSRCA). Drawing No. 6 shows the location of the subject site within the Barrie Creek Sub-watershed.

## 4.4 Local Surface Water and Natural Features

A tributary of Lake Simcoe is located approximately 200 m east of the subject site, and the Bear Creek is located approximately 300 m west of the site. Both watercourses flow in general south to north directions in the vicinity of the site. The closest wooded areas lie approximately 65 m northeast of and 130 m west of the site. Wooded areas were also observed along the banks of the watercourses and their associated tributaries. Wetlands designated as being Provincially Significant (PSW's) are also located approximately 780 m north of and 650 m northwest of the site. Wetlands, which have not been classified under the Ontario Wetland Evaluation system (OWES) are also located approximately 1,000 m northeast of and 1,100 m south and southwest of the site.

A ponded body of water lies approximately 70 km, southwest of the site, within a wooded area.

The locations of the site and the noted features are shown on Drawing No. 7.

## 5.0 SOIL LITHOLOGY

The study has disclosed that beneath a layer of topsoil or asphalt pavement, a layer of earth fill was contacted in places beneath the site, which is underlain by deposits of sand and silt with occasional layers of silty clay. A Key Plan and the interpreted geological cross-sections along the delineated northeast-to-southwest, and northwest-to-southeast transects are presented on Drawing Nos. 7-1, 7-2 and 7-3 respectively. A summary of the different types of subsoils revealed beneath the subject site are discussed below:

### 5.1 **Topsoil** (BH 1 and BH/MWs 3, 4, and 5)

Topsoil approximately 160 to 210 mm thick was observed at the ground surface at BH 1 and BH/MWs 3, 4, and 5 locations.

### 5.2 **Pavement Structure** (BH/MW 2)

Pavement structure consisting of asphaltic concrete and granular fill were observed at the ground surface at the BH/ MW 2 location. It is approximately 610 mm thick.

### 5.3 **Earth Fill** (BH 1, BH/MWs 2 and 5)

Earth fill was observed at depths ranging between 0.2 to 0.6 mbgs at the BH 1 location and at the BH/MW 2 and 5 locations. It is approximately 0.4 to 0.8 m in thickness, and consists of silty sand, concreter rubble, some silt and organics.

5.4 **Sand** (All BH and BH/MWs)

Sand was encountered at depths ranging from between 0.2 to 9.5 mbgs. It is brown in colour, fine to medium-grained in texture, and is compact to very dense in consistency, having traces of silt to silty, with occasional layers of sandy silt. A lower sand unit was also encountered in BH 1 and at BH/MW 5, at depths ranging from 4.4 mbgs and 7.3 mbgs respectively. The thickness of the upper unit ranges from between 2.1 to 4.6 m. The lower unit extends from depths ranging between 4.4 mbgs and 7.3 mbgs to the maximum investigated depths of between 6.5 m and 9.6 m. The moisture content for the retrieved soil samples range from 4% to 24%, indicating that it is in a damp to moist condition.

The estimated permeability for the sand unit at the BH /MW 4 location, at a depth of 0.7 mbgs is about $10^{-5}$ m/sec.

Grain size analysis was performed on one selected soil sample, and the gradation is plotted on Figure 6.

5.5 **Silt** (BH 1, and BH/MWs 2, 4, and 5)

Silt was encountered at the BH 1, and BH/MWs 2, 4, and 5 locations. It was encountered at depths, ranging from 2.5 to 4.9 mbgs. The silt is brown in colour, and is compact to very dense in consistency, having some clay and seams of sand and silty clay, with occasional layers of silty clay. At BH1, BH/MWs 4 and 5, the silt unit was encountered beneath the upper sand unit, and at BH/MW 2, it was encountered beneath the earth fill unit. The thickness for the unit ranges from between 1.3 to 4.6 m. The moisture content for the retrieved subsoil samples ranges from 9% to 25%, indicating that it is in a damp to moist condition.

The estimated permeability for the silt unit at the BH/MW 2 location, at a depth of 4.7 mbgs is about $10^{-8}$ m/sec, for the silt unit at BH/MW 4 at a depth of 4.7 m, it is about $10^{-7}$ m/sec.

Grain size analyses were performed on two selected soil samples, and their gradations are plotted on Figures 7 and 8.

5.6 **Silty Clay** (BH/MW 3)

Silty clay was encountered beneath the sand unit at a depth of 4.8 m at the BH/MW 3 location. It is brown in colour, and is stiff in consistency, having seams of fine sand and silt. This unit extends to the maximum investigated depth of 6.5 m. The moisture content for the retrieved samples ranges from 22% and 25%, indicating very moist conditions.

Grain size analysis was performed on one selected soil sample, and the gradation is plotted on Figure 9.

# 6.0 GROUNDWATER STUDY

## 6.1 Review Summary of Concurrent Reports

A review of the findings from the concurrent Geotechnical Investigation Report, (SEL, Reference No. 1802-S072) indicates that beneath a veneer of topsoil or asphalt pavement, and beneath a layer of earth fill in places, the site is underlain by deposits of loose to very dense, generally, compact to very dense sand, and compact silt, with occasional layers of stiff silty clay. Cave-in occurred at BHs 1, 2 and 3, at depths ranging from 2.3 to 5.8 m below the prevailing ground surface or from elevations ranging from between 253.7 masl and 258.2 masl. BHs 4 and 5 were dry upon completion of the drilling program.

## 6.2 Review of Ontario Water Well Records

The Ministry of the Environment, Conservation and Parks (MECP) water well records for the subject site and for the properties within a 500 m radius of the boundaries of the site (study area) were reviewed.

The records indicate that twenty (20) well records are located within the study area. The locations of these wells records, based on the UTM coordinates provided by the records, are shown on Drawing No 3. Details of the MECP water well records that were reviewed are provided in Appendix 'A'.

A review of the first status of the wells shows that sixteen (16) are registered as supply wells, three (3) are abandoned-other wells, and one (1) is an observation well.

A review of the final status of the well records within the study area reveals that sixteen (16) wells are registered as domestic wells, three (3) are unknown wells, and one (1) is registered as a monitoring well.

There is a record for one well located within the subject site. A review of first use and final use of this well indicates that it is registered as a domestic well and water supply well, respectively. Groundwater level in this well was encountered at a depth of 29.89 mbgs, with a static groundwater level being at 10.37 mbgs.

## 6.3 Groundwater Monitoring

The groundwater levels in the monitoring wells were measured on three occasions over the study period, on the following dates; April 11, 27, and May 7, 2018 to record the fluctuation of the groundwater table beneath the site. The water levels and their corresponding elevations are provided in Table 6-1.

**Table 6-1** - Groundwater Level Measurements

| Well ID | | April 11, 2018pr-18 | April 27, 2018 | May 7, 2018 | Average | Fluctuation (m) |
|---|---|---|---|---|---|---|
| BH/MW 2 | mbgs | 4.15 | 3.74 | 3.55 | 3.81 | 0.60 |
| | masl | 255.75 | 256.16 | 256.35 | 256.09 | |
| BH/MW 3 | mbgs | 4.33 | 4.17 | 3.65 | 4.05 | 0.68 |
| | masl | 256.17 | 256.33 | 256.85 | 256.45 | |
| BH/MW 4 | mbgs | >6.10 | >6.10 | >6.10 | >6.10 | - |
| | masl | <255.1 | <255.1 | <255.1 | <255.1 | |
| BH/MW 5 | mbgs | >6.10 | >6.10 | 5.85 | - | - |
| | masl | <255.7 | <255.7 | 255.95 | - | |

Notes
mbgs -- metres below ground surface
masl -- metres above sea level

As shown above, the groundwater at BH/MW 2 and 3 exhibited a consistent rising trend throughout the monitoring period. The groundwater level at BH/MW 5 was

consistently below the depth of the monitoring well where this well was recorded as being dry between April 11 and 27, 2018 and where the groundwater level increased between April 27, and May 7, 2018 throughout the monitoring period. The groundwater level at BH/MW 4 was consistently below the depth of the monitoring well and this well was recorded as being dry throughout the monitoring period. The greatest fluctuation was observed at BH/MW 3 where the groundwater level increased by 0.68 m over the study period.

## 6.4 Shallow Groundwater Flow Pattern

The shallow groundwater flow pattern was interpreted from the average of groundwater level measurements recorded at BH/MWs 2, 3 and 4 locations. The measured groundwater levels recorded at BH/MWs 2 and 3 indicate that shallow groundwater flows in southeasterly and southwesterly directions from a localized higher area or groundwater mound located approximately within the central portion of the site. It should be noted that the shallow groundwater level elevation was deeper than the depths of the monitoring well installed at the BH/MW 4 location during the study; as such, the shallow groundwater level at this location was inferred and is illustrated as being 255.1 masl. The interpreted shallow groundwater flow pattern for the subject site area is illustrated on Drawing No. 9

## 6.5 Single Well Response Test Analysis

BH/MW 2 underwent single well response tests (SWRTs) to assess the hydraulic conductivity (K) for saturated aquifer subsoils at the depths of the well screens. The SWRTs tests were not performed on BH/MWs 3, 4 and 5, due to the insufficient volumes of groundwater within the well throughout the monitoring period. The

results of the SWRTs are presented in Appendix 'B', with a summary of the findings shown in Table 6-2.

**Table 6-2** - Summary of SWRT Results

| Well ID | Ground El. (masl) | Borehole Depth (mbgs) | Top of Screen Depth (mbgs) | Screen Interval (mbgs) | Screened Subsoil Strata | Hydraulic Conductivity (K) (m/sec) |
|---|---|---|---|---|---|---|
| BH/MW 2 | 259.9 | 10.8 | 255.30 | 3.1-6.1 | Earth Fill and Silt | $1.9 \times 10^{-6}$ |

Notes
mbgs -- metres below ground surface
masl -- metres above sea level

The SWRT results indicate that the K value for the earth fill and silt is $1.9 \times 10^{-6}$ m/sec. The results of the SWRT provide an indication of the yield capacity for the groundwater-bearing sub-soil strata at the depths of the screens. The above results suggest that the hydraulic conductivity for the groundwater-bearing soils at the depths of the well screens is moderate, with corresponding moderate anticipated groundwater seepage rates into open excavations, below the water table.

## 6.6 Assessment of Hydraulic Conductivity based on Hazen Equation

The Hazen Equation method was adopted to estimate the hydraulic conductivity (K) for subsoil different layers which may contain groundwater during the seasonal high-water table. These layers are primarily above the well screen depths.

The Hazen equation relies on the interrelationship between hydraulic conductivity and effective grain size, $d_{10}$, in the soil media. This empirical relation predicts a power-law relation with $K$, as follows:

$$K = Ad_{10}^2$$

where;

$d_{10}$: Value of the soil grain size gradation curve as determined by sieve analysis whereby 10% by weight of the soil particles are finer and 90% by weight of the soil particles are coarser.

$A$: Coefficient; it is equal to 1 when $K$ in cm/sec and $d_{10}$ is in mm

The Hazen Equation estimation provides an indication of the yield capacity for groundwater-bearing sub-soil strata at the depths where the soil samples that underwent grain size analyses were collected. The calculated results indicate that the K estimate for the silt, having some clay and fine sand, retrieved from a depth of 4.7 mbgs at BH/MW 2 is $1.96 \times 10^{-8}$ m/sec, and the K estimate for the silt, have traces of clay and fine sand, retrieved from a depth of 4.7 mbgs at BH/MW 4 is $7.84 \times 10^{-8}$ m/sec. The K estimate for the fine to medium sand, having some silt and a trace of gravel, retrieved from a depth of 0.7 mbgs at BH/MW 4 is $1.60 \times 10^{-5}$ m/sec. The K estimate determined from the Hazen method suggests low to high hydraulic conductivities (K) for the shallow sub-soil and any encountered shallow perched groundwater found beneath the subject site.

**Table 6-3** - Summary of Hazen Equation Estimated K Results

| Well ID | Sample Depth (mbgs) | Sample El. (masl) | Description of Soil Strata | $D_{10\,(mm)}$ | Hydraulic Conductivity (K) (m/sec) |
|---|---|---|---|---|---|
| BH/MW 2 | 4.7 | 255.2 | Silt, some clay and fine Sand | 0.00148 | $1.96 \times 10^{-8}$ |
| BH/MW 4 | 4.7 | 256.5 | Silt, traces of clay and fine Sand | 0.0028 | $7.84 \times 10^{-8}$ |
| BH/MW 4 | 0.7 | 260.5 | Fine to medium Sand, some silt, a trace of gravel | 0.70 | $1.60 \times 10^{-5}$ |

Notes

mbgs -- metres below ground surface
masl -- metres above sea level

## 7.0 GROUNDWATER CONTROL DURING CONSTRUCTION

The estimated hydraulic conductivity (K) estimates for the sand, silt, and silty clay, sub-soils, suggest that groundwater seepage rates into open excavations below the groundwater table will range from high to moderate. To provide safe, dry and stable conditions for earthworks excavations for construction of the proposed underground parking structure, the water table should be lowered in advance of or during construction. Preliminary estimates for construction dewatering flows required to locally lower the water table, based on the Hazen Equation Estimated K test results, are discussed in the following sections.

### 7.1 Groundwater Construction Dewatering Rates

The proposed development plans, provided by the client indicate that the mixed-use development will consist of a 6-storey mixed-use building having a 1-level underground parking structure, and 31-3 storey townhouse units, which are proposed for construction at the site. The details for each portion of the site are discussed in the following sections:

**Block A – 4 Units - 3 Storey Townhouse Units (23.20 m x 11.50 m) – Site Elevation of 260.33 masl:**

For Block A which is to consist of 4 units, with each unit having a 3-storey townhouse unit with a walk out basement, for the preliminary dewatering calculations, an estimated area for the excavation for the average construction footprint is 266.80 square meters. The anticipated grading site elevation ranges from 260.33 to 260.62 masl. An assumed excavation depth of up to 2.4 m (El. 257.93 to

258.22 masl) was considered for the construction of the housing basement structure foundation and footings. To facilitate excavation and construction in dry and stable subsoil conditions, it is proposed that the shallow groundwater table be lowered to an elevation of 256.93 masl, which is about 1.0 m below the lowest proposed excavation depth elevation of 257.93 masl. The subsoil comprises earth fill, extending to the maximum proposed depths for the excavation. Comparison of the lowest proposed excavation depth with the highest measured shallow groundwater level indicates that the lowest proposed excavation elevation is about 1.58 above the highest measured shallow groundwater level elevation of 256.35 masl, as recorded at the BH/MW 2 location. As such, it is not anticipated that construction dewatering will be required for the proposed earthworks program for this section of the proposed housing development.

**Block B – 6 Units - 3 Storey Townhouse Units (32.19 m x 11.50 m) – Site Elevation of 260.30 masl:**

For Block B which consists of 6 units, each consisting of a 3-storey townhouse unit with a walk out basement, for the preliminary dewatering calculation, an estimated area of excavation for the average construction footprint is 266.80 square meters. The anticipated site grading elevation ranges from 260.30 to 260.33 masl. An assumed excavation depth of up to 2.4 m (El. 257.90 to 257.93 masl) was considered for the construction of the housing basement structure and foundation and footings. To facilitate excavation and construction in dry and stable subsoil conditions, it is proposed that the shallow groundwater table be lowered to an elevation of 256.90 masl, which is about 1.0 m below the lowest proposed excavation depth elevation of 257.90 masl. The subsoil comprises topsoil, and sand, extending to the maximum proposed depths for the excavation. Comparison of the lowest proposed excavation depth with the highest measured shallow groundwater level indicates that

the lowest proposed excavation elevation is about 1.05 m above the highest measured shallow groundwater level elevation of 256.85 masl, as recorded at the BH/MW 3 location. As such, it is not anticipated that construction dewatering will be required for the proposed earthworks program for this section of the proposed housing development.

**Block C – 6 Units - 3 Storey Townhouse Units (32.19 m x 11.50 m) – Site Elevation of 260.23 masl:**

For Block C which consists of 6 units, each consisting of a 3-storey townhouse unit with a walk out basement, for the preliminary dewatering calculation, an estimated area of excavation for the average construction footprint is 266.80 square meters. The anticipated site grading elevation ranges from 260.23 to 261.95 masl. An assumed excavation depth of up to 2.4 m (El. 257.83 to 259.55 masl) was considered for the construction of the housing basement structure foundation and footings. To facilitate excavation and construction in dry and stable subsoil conditions, it is proposed that the shallow groundwater table be lowered to an elevation of 256.83 masl, which is about 1.0 m below the lowest proposed excavation depth elevation of 257.83 masl. The subsoil comprises topsoil, and sand, extending to the maximum proposed depths for the excavation. Comparison of the lowest proposed excavation depth with the highest measured shallow groundwater level indicates that the lowest proposed excavation elevation is about 0.98 m above the highest measured shallow groundwater level elevation of 256.85 masl, as recorded at the BH/MW 3 location. By having the anticipated groundwater table lowered by one (1) additional meter, it is anticipated that limited construction dewatering will be required for the earthworks for this section of the proposed housing development.

Assuming an excavation, being approximately 32.19 m long by 11.50 m wide for the proposed Block C development area, having a perimeter of about 87.38 m, and using the estimated hydraulic conductivity of 1.60 x $10^{-5}$ m/s, the anticipated dewatering flow rate could reach an estimated daily rate of 41,945 L/day. By applying a safety factor of three (3), it could reach a maximum of 125,835 L/day. This dewatering flow rate for excavation, is below the PTTW threshold of 400,000 L/day, but, is above 50,000 L/day threshold limit for requiring an approval, with the recommended approval for proposed groundwater takings being required to be registered through an Environmental Activity and Sector Registry (EASR), with the EASR filing through the MECP.

The higher dewatering flow estimates may only occur at the beginning of the dewatering process, and includes any rapid removal of collected runoff within the excavations after a high intensity storm. It is anticipated that, following lowering of the localized groundwater table, groundwater seepage removed via dewatering from the open excavation will be a fraction of the above estimate, since much of the groundwater in the proposed construction footprint areas will have been removed from local storage. Furthermore, upon excavation for, any encountered perched groundwater within the shallow fill horizons is expected to dissipate relatively quickly following commencement of earthworks. If construction is completed during the dry season (Summer), there may be only minimal or negligible construction dewatering required as the shallow perched groundwater conditions may not be present during the dry season, typically expected between mid-July through mid-October.

**Block D – 10 Units - 3 Storey Townhouse Units (61.05 m x 11.50 m) – Site Elevation of 261.95 masl:**

For Block D which is to consist of 10 units with each consisting of a 3-storey townhouse unit with a walk out basement, for the preliminary dewatering calculation, an estimated area for the excavation for the average construction footprint is 266.80 square meters. The anticipated site grading elevation ranges from 261.95 to 262.54 masl. An assumed excavation depth of up to 2.4 m (El. 259.55 to 260.14 masl) was considered for the construction of the housing basement structure foundation and footings. To facilitate excavation and construction in dry and stable subsoil conditions, it is proposed that the shallow groundwater table be lowered to an elevation of 258.55 masl, which is about 1.0 m below the lowest proposed excavation depth elevation of 259.55 masl. The subsoil is anticipated to be comprised of topsoil, silt and sand, extending to the maximum proposed depths for the excavation. Comparison of the lowest proposed excavation depth with the highest measured shallow groundwater level indicates that the lowest proposed excavation elevation is about 3.85 above the interpolated shallow groundwater level elevation of 255.70 masl. As such, it is not anticipated that construction dewatering will be required for the proposed earthworks for this section of the proposed housing development.

**Block E – 5 Units - 3 Storey Townhouse Units (27.92 m x 11.50 m) – Site Elevation of 262.10 masl:**

For Block E which is to consist of 5 units with each consisting of a 3-storey townhouse units with a walk out basement, for the preliminary dewatering calculation, an estimated area of excavation for the average construction footprint is

321.08 square meters. The anticipated site grading elevation ranges from 262.10 to 262.59 masl. An assumed excavation depth of up to 2.4 m (El. 259.70 to 260.19 masl) was considered for the construction of the housing basement structure foundation and footings. To facilitate excavation and construction in dry and stable subsoil conditions, it is proposed that the shallow groundwater table be lowered to an elevation of 258.70 masl, which is about 1.0 m below the lowest proposed excavation depth elevation of 259.70 masl. The subsoil is anticipated to be comprised of topsoil, silt and sand, extending to the maximum proposed depths for excavation. Comparison of the lowest proposed excavation depth with the interpolated shallow groundwater level indicates that the lowest proposed excavation elevation is about 4.10 above the interpolated shallow groundwater level elevation of 255.60 masl. As such, it is not anticipated that construction dewatering will be required for the proposed earthworks for this section of the proposed housing development.

**Block F- 6- Storey Mixed Use Development (72.74 m x 36.25 m) – 1- Level Underground Parking Garage Footing at an Elevation of 256.75 masl:**

For the 6- storey mixed used building having a 1-level underground parking structure, for the preliminary dewatering calculation, an estimated area for the excavation for the average construction footprint is 2,637 square meters. The anticipated underground parking foundation and footing elevation is anticipated to be at a depth of 5.2 m (to an Elevation of 256.75 masl). To facilitate excavation and construction in dry and stable subsoil conditions, it is proposed that the shallow groundwater table be lowered to an elevation of 255.75 masl, which is about 1.0 m below the lowest proposed excavation depth. The subsoil comprises earth fill, sand and silt, extending to the maximum proposed depths for the excavation. Comparison of the lowest proposed excavation depth with the interpolated shallow groundwater level elevation of 256.30 masl, indicates that the lowest proposed excavation

elevation is about 0.45 m above the shallow groundwater elevation. By having the anticipated groundwater table lowered by one (1) additional meter, it is anticipated that limited construction dewatering will be required for the earthworks for this section of the proposed housing development.

Assuming an excavation, being approximately 72.74 m long by 36.25 m wide for the proposed 1-level underground parking structure, having a perimeter of about 218.0 m, and using the estimated hydraulic conductivity of $1.60 \times 10^{-5}$ m/s, the anticipated dewatering flow rate could reach an estimated daily rate of 87,116 L/day. By applying a safety factor of three (3), it could reach a maximum of 261,348 L/day. This dewatering flow rate for excavation, is below the PTTW threshold limit of 400,000 L/day, but, is above 50,000 L/day threshold limit for requiring an approval, with the recommended approval for proposed groundwater takings being required to be registered through an Environmental Activity and Sector Registry (EASR), with the EASR filing through the MECP.

The higher dewatering flow estimates may only occur at the beginning of the dewatering process, which includes any rapid removal of collected runoff following a high intensity storm event. It is anticipated that, following lowering of the localized groundwater table, groundwater seepage removed via dewatering from the open excavation will be a fraction of the above estimate, since much of the groundwater in the proposed construction footprint areas will have been removed from local storage. Furthermore, upon excavation for, any encountered perched groundwater within the shallow fill horizons is expected to dissipate relatively quickly following commencement of earthworks. If construction is completed during the dry season (Summer), there may be only minimal or negligible construction dewatering required as shallow perched groundwater conditions may not be present during the dry season, typically expected between mid-July through mid-October.

**Installation of Elevator Pit Beneath Block F:**

The estimated finished floor elevation for the proposed underground parking structure is at 257.75 masl. An excavation depth of approximately 1.70 m (El. 256.05 masl) below the proposed elevation of the underground parking structure was considered to accommodate the proposed elevator pit structure. The lowest proposed excavation depth elevation of 256.05 masl was considered for the construction dewatering assessment estimation to accommodate the proposed elevator pit structure. To facilitate excavation and construction in dry and stable subsoil conditions, it is proposed that the groundwater table be lowered to an elevation of 255.05 masl, which is about 1 m below the lowest proposed excavation depth. The subsoil at this depth is comprised of earth fill, sand and silt, extending to the proposed excavation depth. Comparison of the lowest proposed excavation depth with the interpolated groundwater elevation of 256.30 masl, indicated that the proposed elevation for the elevator pit footing is about 0.25 m below the highest shallow groundwater level. By having the anticipated groundwater table lowered by one (1) additional meter, it is anticipated that limited construction dewatering will be required for the proposed earthworks for construction of this portion of the proposed mixed-use residential building.

Assuming an excavation, being approximately 4 m long by 4 m wide for the proposed elevator pit structure, having a perimeter of about 16 m, and using the estimated hydraulic conductivity of $1.60 \times 10^{-5}$ m/s, the anticipated dewatering flow rate could reach an estimated daily rate of 4,707 L/day. By applying a safety factor of three (3), the dewatering flow rate could reach a maximum of 14,122 L/day. The estimated zone of influence could extend to a maximum of 15.0 m away from the conceptual dewatering alignment considered for construction of the proposed underground elevator pit structure.

This construction estimation dewatering rate for excavation is below the 50,000 L/day limit threshold for requiring an approval for any proposed construction related groundwater takings, which will not require any registration or filing with the MECP.

It is anticipated that, following the localized lowering of the groundwater table, the groundwater seepage removal via dewatering from the open excavation will be a fraction of the above estimate, since much of the shallow groundwater in the proposed development footprint area will have been removed from local storage. If construction is completed during the dry season (late Summer and early Fall), this might minimize the construction dewatering requirements as the groundwater levels are anticipated to be significantly lower during the dry season, typically expected between mid-July through mid-October.

**Installation of Underground Services within the Eastern Central Portions of the Site- Road Elevation of 261.33 masl:**

The dewatering needs assessment was based on the proposed underground servicing invert depths of between 2.0 m and 4.0 m below the proposed road elevations. Based on the proposed road elevation of about 261.33 masl, and using the maximum anticipated depth for underground services, the lowest depth elevation for the underground services is approximately 257.33 masl. To facilitate excavation and construction in dry and stable subsoil conditions, it is proposed that the water table be lowered to an elevation of 260.33 masl, which is about 1.0 m below the lowest proposed servicing invert excavation depth. Comparison of the lowest proposed excavation depth with the interpolated shallow groundwater level indicates that the lowest proposed excavation elevation is about 5.43 m above the interpolated shallow groundwater level elevation of 255.90 masl. As such, it is not anticipated that

construction dewatering will be required for the proposed earthworks for the installation of the underground services within this area section of the housing development.

**Installation of Underground Services Within the Central Portion of the Site-Road Elevation of 261.62 masl:**

The dewatering needs assessment was based on the proposed servicing invert depths of between 2.0 m and 4.0 m below the proposed road elevations. Based on the proposed road elevation of about 261.62 masl, and using the maximum anticipated depth for the underground services, the depth elevations for the underground services is approximately 257.62 masl. To facilitate excavation and construction in dry and stable subsoil conditions, it is proposed that the water table be lowered to an elevation of 260.33 masl, which is about 1.0 m below the lowest proposed servicing invert excavation depth. Comparison of the lowest proposed excavation depth with the highest measured shallow groundwater level indicates that the lowest proposed excavation elevation is about 5.12 m above the highest measured shallow groundwater level elevation of 256.85 masl, as recorded at the BH/MW 3 location. As such, it is not anticipated that construction dewatering will be required for the proposed earthworks for the installation of the underground services within this area section of the proposed housing development.

**Installation of Underground Services Within the West Central Portion of the Site-Road Elevation of 261.87 masl:**

The dewatering needs assessment was based on the proposed servicing invert depths of between 2.0 m and 4.0 m below the proposed road elevation. Based on a proposed road elevation of about 261.872 masl, and using the maximum anticipated depth for

the underground services, the depth elevations for the underground services is approximately 257.87 masl. To facilitate excavation and construction in dry and stable subsoil conditions, it is proposed that the water table be lowered to an elevation of 256.87 masl, which is about 1.0 m below the lowest proposed servicing invert excavation depth. Comparison of the lowest proposed excavation depth with the interpolated shallow groundwater level indicates that the lowest proposed excavation elevation is about 1.37 m above the interpolated shallow groundwater level elevation of 255.50 masl. As such, it is not anticipated that construction dewatering will be required for the proposed earthworks for the installation of the underground services beneath this area section of the proposed housing development.

**Installation of Underground Services Within the South West Portion of the Site-Road Elevation of 262.67 masl:**

The dewatering needs assessment was based on the proposed underground servicing invert depths of between 2.0 m and 4.0 m below the proposed road elevation. Based on the proposed road elevation of about 262.67 masl, and using the maximum anticipated depth for the underground services, the depth elevations for the services is approximately 258.67 masl. To facilitate excavation and construction in dry and stable subsoil conditions, it is proposed that the water table be lowered to an elevation of 261.67 masl, which is about 1.0 m below the lowest proposed servicing invert excavation depth.

Comparison of the lowest proposed excavation depth with the interpolated shallow groundwater level indicates that the lowest proposed excavation elevation is about 3.37 m above the interpolated shallow groundwater level elevation of 255.30 masl. As such, it is not anticipated that construction dewatering will be required for the

proposed earthworks for the installation of the underground services beneath this area section of the proposed housing development.

## 7.2 Groundwater Control Methodology

Given that low groundwater seepage rates are being anticipated into open excavations below the water table, any construction dewatering can likely be controlled by occasional pumping from sumps when and where required during construction. Well points can be employed to lower the water table if wet sand or unstable soils are encountered and seepage cannot be controlled via sump pit pumping. The final design for the dewatering system will be the responsibility of the construction contractors.

Tables 7-1 and 7-2, which follows, summarizes the dewatering flow estimates for the proposed residential structures and proposed underground services.

**Table 7-1** - Summary of Dewatering Flow Estimates-Proposed Residential and Mixed-Use Buildings Structures

| Phase of Development | Estimated Dimensions (L x W) m | Site Grade Elevation (masl) | Depth Elevation for Basement (masl) | Highest Interpreted Water Level Elevation (masl) | Estimated Zone of Influence (m) | Anticipated Maximum Drawdown (m) | Dewatering Flow Estimates (L/day) | Flow Estimates with x 3 Safety Factor (L/day) |
|---|---|---|---|---|---|---|---|---|
| Block A- 3-Storey Townhouse | (23.20 x 11.50) | 260.33 | 257.93 | 256.35 (BH/MW 2) | No dewatering anticipated | | | |
| Block B- 3 Storey Townhouse | (32.19 x 11.50) | 260.30 | 257.90 | 256.85 (BH/MW 3) | No dewatering anticipated | | | |
| Block C- 3 Storey Townhouse | (32.19 x 11.50) | 260.23 | 257.83 | 256.85 (BH/MW 3) | 0.2 | 0.02 | 41,945 | 125,835 |
| Block D- 3 Storey Townhouse | (61.05 x 11.50) | 261.95 | 259.55 | 255.70 (Interpolated from groundwater level contour map) | No dewatering anticipated | | | |
| Block E- 3-Storey Townhouse | (27.92 x 11.50) | 262.10 | 259.70 | 255.60 (Interpolated from groundwater level contour map) | No dewatering anticipated | | | |
| Block F- 1 - 6-Storey Mixed Used Building having 1 Level Underground Parking Structure | (72.74 x 36.25) | 257.75 | 256.75 | 256.30 (Interpolated from groundwater level contour map) | 6.6 | 0.55 | 87,116 | 261,348 |
| Elevator Pit Structure Beneath Building F | (4 x4) | 255.75 | 256.05 | 256.30 (Interpolated from groundwater level contour map) | 15.0 | 1.25 | 4,707 | 14,122 |

Notes:
masl -- metres above sea level

**Table 7-2** - Summary of Dewatering Flow Estimates-Proposed Underground Services

| Site Area | Minimum Invert Elevation (masl) | Highest/ Interpreted Water Level Elevation (masl) | Estimated Zone of Influence (m) | Anticipated Maximum Drawdown (m) | Dewatering Flow Estimates (L/day) | Flow Estimates with x 3 Safety Factor (L/day) |
|---|---|---|---|---|---|---|
| East Central Portion of Site | 261.33 | 255.90 (Interpolated) | No dewatering anticipated | | | |
| Central Portion of Site | 261.62 | 256.50 (BH/MW 3) | No dewatering anticipated | | | |
| West Central Portion of Site | 261.87 | 255.50 (Interpolated) | No dewatering anticipated | | | |
| South West Portion of Site | 262.67 | 255.30 (Interpolated) | No dewatering anticipated | | | |

Notes:
masl -- metres above sea level

## 7.3 Mitigation of Potential Impacts Associated with Dewatering

The zones of influence for any dewatering well or dewatering array used during construction could range between 0.2 m and 15.0 m away from the considered dewatering array wells/or sumps alignments. There is a record for a domestic water supply well located on the subject site. However, this well was not observed on the site, during the monitoring period. The subject site is located within an existing residential area, surrounded by existing housing and roads that could potentially be affected by ground settlement associated with the zone of influence for any construction dewatering. It is recommended that a geotechnical engineer be consulted to review potential ground settlement concerns prior to earthworks.

## 7.4 Permanent Foundation Drainage for Underground Structures

The proposed development plans, provided by the client indicate that the proposed mixed-use development will consist of a 6-storey mixed-use building having a 1-level

underground parking area, and 31-3 storey townhouse units, which are also proposed for construction at the site.

The proposed basement structures for the townhouse blocks are about 0.98 to 4.10 m above the shallow groundwater elevations, and it is not anticipated that permanent foundation drainage will be required after construction for the proposed basement structures for the proposed townhouse Blocks A to E buildings.

The proposed 1-level underground parking structure beneath Block F is about 0.45 m above the high groundwater elevation, and it it is not anticipated that permanent foundation drainage will be required after construction for the proposed underground parking footings for the proposed Block F building. The groundwater elevation is about 1.25 m above the proposed elevator pit structure, and it is anticipated that long-term foundation drainage will likely be required for the elevator pit structure beneath the Block F underground parking structure.

**Permanent Drainage for Elevator Pit Beneath the Proposed Mixed-Used Building Block F:**

An excavation depth elevation of 256.06 masl was estimated as the proposed basement floor elevation for the proposed underground parking structure. An additional excavation depth of 1.7 m (El. 178.95 masl) was considered below the base for the proposed elevator pit/shaft structure. Based on this depth, the shallow groundwater level elevation is about 2.79 m above the base for the proposed elevator pit structure. Given the low anticipated groundwater seepage rate estimates for any long-term foundation drainage, a standard drainage network can be included with the design for a conventionally shored excavation, along with a simple basement under-slab drainage network to address any long-term foundation seepage to the excavation and the

completed underground elevator pit structures. These systems can be drained to sump pits. The drainage network should be designed by a qualified mechanical engineer, having experience with the designs for under-slab and footing drainage networks. It is our understanding, that a sump pit is required within an elevator pit to satisfy building code requirements for fire retardant sprinklers to meet fire protection codes. The sump pit to meet fire protection codes can be drained to the sanitary sewer.

In order to estimate the long-term foundation drainage needs associated with a perimeter foundation drainage network and the under-slab basement and floor elevator pit structure drainage system, Darcy's Equation was used, as described below:

$$Q = KiA$$

Where:

- Q = Estimated seepage drainage flow rate ($m^3$/day)
- K = $1.60 \times 10^{-5}$ m/sec (highest hydraulic conductivity (K) assessed for the fine to medium sand encountered during the study)
- A = 4.0 $m^2$ for the surface area for the mira drain shored wall perimeter around the proposed elevator pit and 1.0 $m^2$ for the total under-slab floor drainage network beneath the elevator pit, which are the approximate total surface areas for weeper tiles used to estimate groundwater seepage to under slab drainage network, below the water table (cross-sectional area of flow) (m)
- iv = 0.0140 [unitless], Vertical Hydraulic Gradient for groundwater considered for the under-slab basement drainage system
- ih = 0.00174 [unitless], Horizontal Hydraulic Gradient for groundwater considered for the perimeter, shore wall, mira drainage system.

Based on the proposed underground elevator pit structure, the long-term seepage drainage flow rate to the Mira perimeter drainage network for a conventionally shored excavation is 77.58 L/day. The long-term, average drainage seepage rate for an under-slab elevator pit floor drainage network is 2.42 L/day. The combined, long-term seepage rate from both the perimeter foundation and the under-slab basement floor drainage networks are estimated at 80.0 L/day. By applying a safety factor of three (3), the combined drainage flow rate is estimated at 240 L/day.

The pumping facility and sump systems should be designed for the maximum expected drainage flow rate. The systems should be designed by a qualified mechanical engineer with experience in design for foundation drainage systems. The drainage piping should be properly constructed using weeper tiles surrounded by filter cloth, in turn surrounded by bedding stone or concrete sand to minimize potential losses of fines and to prevent silt from clogging of weeper tiles. Over time, the foundation drainage flows for the underground structures may diminish to a lower, or possibly negligible rate, but more likely to a lower, steady- state rate that will remain relatively constant over time. During the expected dry season, minimal or negligible long-term foundation flows may be experienced. The drainage networks should have separate connections to the proposed sump pits, with one pit connected to the shored wall/mira drainage network and a second pit connected to the basement underslab drainage network.

## 7.5 **Groundwater Function of the Subject Site**

A tributary of Lake Simcoe is located approximately 200 east of the subject site, and the Bear Creek is located approximately 300 m west of the site. Both watercourses flow in general south to north directions in the vicinity of the site. The closest wooded

areas lie approximately 65 m northeast of, 130 m west, and 33 m south of the site. Wooded areas were also observed along the banks of the watercourses and their associated tributaries. Wetlands designated as being Provincially Significant (PSW's) are located approximately 780 m north of, and 650 m northwest of the site. Wetlands, which have not been classified under the Ontario Wetland Evaluation system (OWES) are located approximately 1,000 m northeast and 1,100 m of the site. A ponded body of water lies approximately 70 km southwest of the site, and is within a wooded area. Based on the WWR review, a private water supply well is located on the subject property; however, this well was not observed onsite during the monitoring period.

## 7.6 Low Impact Development (LID)

The surficial soil at the site consists, predominantly of silt and sand. The groundwater lies at depths, ranging between 3.55 m to greater than 6.10 m below the ground surface. The existing shallow sand could facilitate the infiltration of precipitation to the sub-surface beneath the site to replenish the shallow aquifer at depth. Low Impact Development (LID) infrastructure could be implemented in areas where the shallow groundwater level is deeper than 1.0 m below the ground surface and where it is possible to maintain a minimum of 1.0 m separation between the bases for any proposed LID stormwater management infiltration infrastructure and the high groundwater table. Any proposed LID infrastructure should be designed by the stormwater engineer for the project.

## 8.0 CONCLUSIONS

Based on the findings of this Hydrogeological Study, the following summary of conclusions and recommendations are provided:

1. The subject site is located within the physiographic region of Southern Ontario known as the Peterborough Drumlin Field, within the mapped physiographic feature known as Till Plains (drumlinized).
2. The site is underlain by the mapped the mapped Glaciolacustrine (sandy) deposits, sand and gravel representing a nearshore depositional environment.
3. The subject site is located within the Barrie Creek sub-watershed, of the Lake Simcoe Watershed.
4. A review of the topography mapping for the area shows that the subject site is relatively flat having a gentle decline in elevation relief towards its northern limits.
5. The study has disclosed that beneath a layer of topsoil or asphalt pavement, a layer of earth fill was contacted in places beneath the site which is underlain by deposits of sand and silt with occasional layers of silty clay extending to the maximum investigated depth of 10.8 m.
6. The findings of this current study confirm that the groundwater levels range from El. 255.75 to greater than 255.7 masl (i.e. 4.15 to > 6.10 below ground surface). Review of the average of shallow groundwater elevations suggests that it flows in northwest and south-easterly directions, towards a tributary of Lake Simcoe to the east and towards Bear Creek to the west.
7. The single well response tests yielded hydraulic conductivity (K estimates) for the earth fill and silt is $1.90 \times 10^{-6}$ m/s. The above results suggest that the hydraulic conductivity for the groundwater-bearing sub-soils at the depths of the well

screens is moderate, with corresponding moderate anticipated groundwater seepage rates into open excavations, below the water table.

8. The Hazen Equation calculated K estimate for the silt, having some clay and fine sand, retrieved from a depth of 4.7 mbgs at BH/MW 2 is $1.96 \times 10^{-8}$ m/sec, and the K estimate for the silt, have traces of clay and fine sand, retrieved from a depth of 4.7 mbgs at BH/MW 4 is $7.84 \times 10^{-8}$ m/sec. The K estimate retrieved for the fine to medium sand, having some silt and a trace of gravel, retrieved from a depth of 0.7 mbgs at BH/MW 4 is $1.60 \times 10^{-5}$ m/sec. The K estimate determined from the Hazen method suggests low to high hydraulic conductivities (K) for the shallow sub-soil shallow for any shallow perched groundwater found beneath the subject site.
9. The groundwater levels beneath the site are approximately 0.98 to 4.10 m below the proposed townhouse blocks building, basement structures for Blocks A to E, and it is approximately 0.45 m below the 1-level underground parking structure for Block F, and it is 0.25 m above the proposed elevator pit structure for Block F. The groundwater levels at the site are approximately 1.37 to 5.43 m below the lowest invert levels for the proposed underground services.
10. The dewatering flow estimates for construction of the proposed Block C, F and the elevator pit structure beneath Block F suggests that the dewatering flow rates range from between 4,707 and 87, 116 L/day; by applying a safety factor of three (3), it could reach maximums of between 14, 122 L/day and 261,348 L/day. The construction dewatering flow rates for the excavations are below the 50,000 L/day threshold limit for requiring an approval for any proposed construction related groundwater takings, which will not require any registration or filing with the MECP. The construction dewatering rates which are below the PTTW threshold limit of 400,000 L/day but are above 50,000 L/day water taking approval requirement threshold, the recommended approval for groundwater

taking would be required to be registered through an Environmental Activity and Sector Registry (EASR) with the EASR filing through the MECP.

11. The groundwater elevation is approximately 1.37 to 5.43 m below the estimated minimum invert elevation of the proposed underground services and it is not anticipated that construction dewatering will be required for the installation of the underground services beneath the site.
12. The estimated zone of influence for construction dewatering could reach a maximum of 15.0 m away from the conceptual dewatering alignments. There are neighbouring residential properties that are within the conceptual zone of influence for construction dewatering; however, there are no groundwater receptors, such as water wells, bodies of water, watercourses or wetlands that are present within the conceptual zone of influence for construction dewatering for the proposed development. The local shallow groundwater flow pattern may be temporarily affected during construction.
13. The Long-term foundation drainage rates from both an under-slab floor drainage network and from a mira drainage network for a conventionally shored excavation foundation and for the proposed elevator pit structure for the apartment building is approximately 80.0 L/day. By applying a safety factor of three (3), the foundation drainage seepage flow rates could reach a maximum of 240 L/day.
14. The groundwater levels lie at depths, ranging from between 3.55 m to greater than 6.10 m beneath the existing ground surface. The existing shallow sand could facilitate the infiltration of precipitation to the sub-surface beneath the site to replenish the shallow aquifer at depth, within LID infrastructure, where

possible, to address future stormwater management planning for the proposed development

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## 9.0 REFERENCES

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# FIGURES 1 to 5

## BOREHOLE AND MONITORING WELL LOGS

## REFERENCE NO. 1802-W072

# LIST OF ABBREVIATIONS AND DESCRIPTION OF TERMS

The abbreviations and terms commonly employed on the borehole logs and figures, and in the text of the report, are as follows:

## SAMPLE TYPES

AS Auger sample
CS Chunk sample
DO Drive open (split spoon)
DS Denison type sample
FS Foil sample
RC Rock core (with size and percentage recovery)
ST Slotted tube
TO Thin-walled, open
TP Thin-walled, piston
WS Wash sample

## PENETRATION RESISTANCE

Dynamic Cone Penetration Resistance:

A continuous profile showing the number of blows for each foot of penetration of a 2-inch diameter, 90° point cone driven by a 140-pound hammer falling 30 inches.

Plotted as '—●—'

Standard Penetration Resistance or 'N' Value:

The number of blows of a 140-pound hammer falling 30 inches required to advance a 2-inch O.D. drive open sampler one foot into undisturbed soil.

Plotted as '○'

WH Sampler advanced by static weight
PH Sampler advanced by hydraulic pressure
PM Sampler advanced by manual pressure
NP No penetration

## SOIL DESCRIPTION

Cohesionless Soils:

| 'N' (blows/ft) | Relative Density |
|---|---|
| 0 to 4 | very loose |
| 4 to 10 | loose |
| 10 to 30 | compact |
| 30 to 50 | dense |
| over 50 | very dense |

Cohesive Soils:

| Undrained Shear Strength (ksf) | 'N' (blows/ft) | Consistency |
|---|---|---|
| less than 0.25 | 0 to 2 | very soft |
| 0.25 to 0.50 | 2 to 4 | soft |
| 0.50 to 1.0 | 4 to 8 | firm |
| 1.0 to 2.0 | 8 to 16 | stiff |
| 2.0 to 4.0 | 16 to 32 | very stiff |
| over 4.0 | over 32 | hard |

Method of Determination of Undrained Shear Strength of Cohesive Soils:

x 0.0 Field vane test in borehole; the number denotes the sensitivity to remoulding

△ Laboratory vane test

□ Compression test in laboratory

For a saturated cohesive soil, the undrained shear strength is taken as one half of the undrained compressive strength

## METRIC CONVERSION FACTORS

1 ft = 0.3048 metres
1lb = 0.454 kg
1 inch = 25.4 mm
1ksf = 47.88 kPa

**JOB NO.:** 1802-W072

# LOG OF BOREHOLE NO.: BH 1

**FIGURE NO.:** 1

**PROJECT DESCRIPTION:** Proposed 3-Storey Mixed Use Building with 1-Level Underground Parking

**METHOD OF BORING:** Flight-Auger (Hollow-Stem)

**PROJECT LOCATION:** 224 Ardagh Road, City of Barrie

**DRILLING DATE:** March 28, 2018

| El. (m) / Depth (m) | SOIL DESCRIPTION | SAMPLES Number | Type | N-Value | Depth Scale (m) | Dynamic Cone (blows/30 cm) 10 30 50 70 90 / Shear Strength ($kN/m^2$) 50 100 150 200 / Penetration Resistance (blows/30 cm) 10 30 50 70 90 | Atterberg Limits PL LL / Moisture Content (%) 10 20 30 40 | WATER LEVEL |
|---|---|---|---|---|---|---|---|---|
| 259.8 | Ground Surface | | | | | | | |
| 0.0 | **21 cm TOPSOIL** | | | | 0 | | | |
| 0.2 | **EARTH FILL**<br>brown to dark brown silty sand<br>trace of organics | 1 | DO | 6 | | | 6 | |
| 258.8 | | 2 | DO | 21 | 1 | | 13 | |
| 1.0 | Brown, compact to very dense | | | | | | | |
| | **SAND**<br>fine to medium grained<br>some silt to silty<br>trace of gravel | 3 | DO | 24 | 2 | | 17 | |
| | | 4 | DO | 50/3 cm | | | 8 | |
| 256.7 | | 5A | | | 3 | | 12 | |
| 3.1 | Brown, very dense | 5B | AS | 63 | | | 9 | |
| | **SILT**<br>trace of clay<br>seams of fine sand | | | | 4 | | | |
| 255.4 | | | | | | | | |
| 4.4 | Brown, very dense | 6 | DO | 70 | 5 | | 4 | |
| | **SAND**<br>fine grained<br>silty | | | | 6 | | 24 | |
| 253.3 | | 7 | DO | 57 | | | | |
| 6.5 | **END OF BOREHOLE** | | | | 7 | | | |
| | | | | | 8 | | | |
| | | | | | 9 | | | |
| | | | | | 10 | | | |
| | | | | | 11 | | | |
| | | | | | 12 | | | |
| | | | | | 13 | | | |
| | | | | | 14 | | | |

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**JOB NO.:** 1802-W072

# LOG OF BOREHOLE NO.: BH/MW 2

**FIGURE NO.:** 2

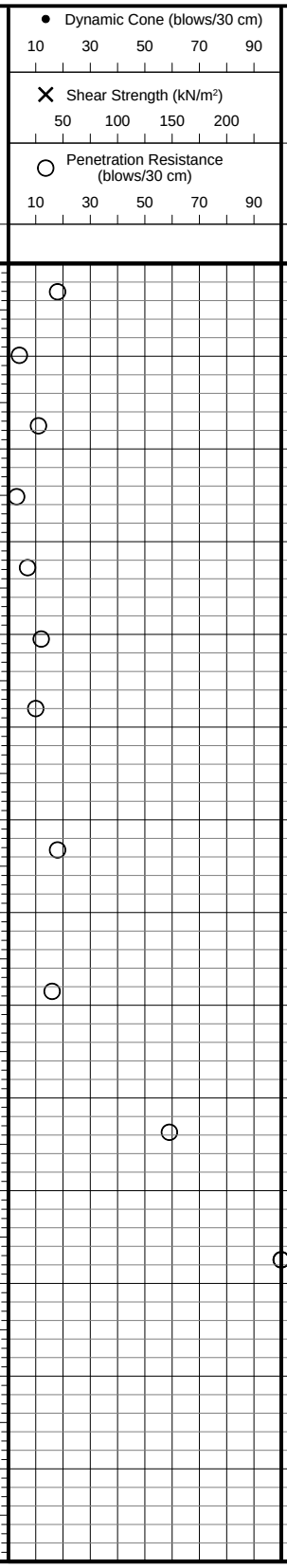
**PROJECT DESCRIPTION:** Proposed 3-Storey Mixed Use Building with 1-Level Underground Parking

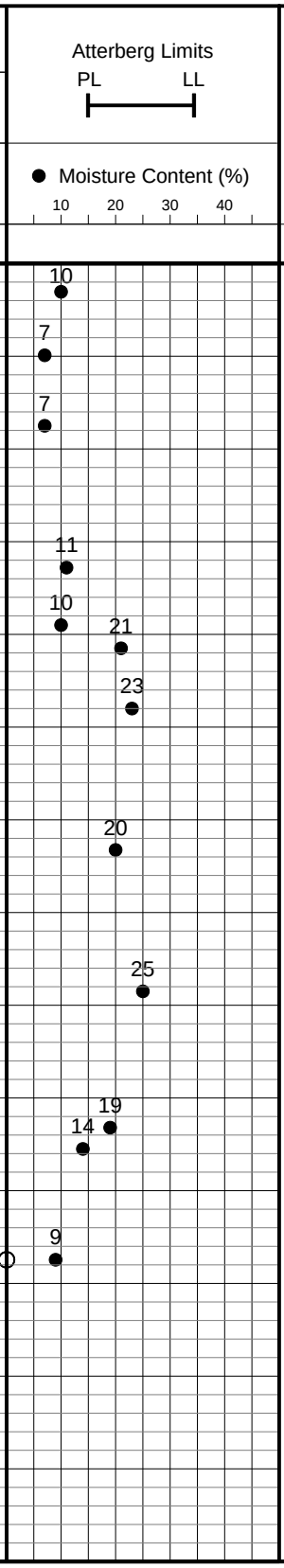
**METHOD OF BORING:** Flight-Auger (Hollow-Stem)

**PROJECT LOCATION:** 224 Ardagh Road, City of Barrie

**DRILLING DATE:** March 28, 2018

| El. (m) / Depth (m) | SOIL DESCRIPTION | SAMPLES Number | Type | N-Value | Depth Scale (m) |
|---|---|---|---|---|---|
| 259.9 / 0.0 | Ground Surface | | | | |
| 259.8 / 0.1 | **8 cm ASPHALT** | 1 | DO | 18 | 0 |
| 259.3 / 0.6 | **530 mm GRANULAR FILL** | | | | |
| | **EARTH FILL**<br>brown silty sand<br>concrete rubble below 1.6 m | 2 | DO | 4 | 1 |
| | | 3 | DO | 11 | 2 |
| | | 4 | DO | 3 | 3 |
| | | 5 | DO | 7 | |
| | | 6A<br>6B | DO | 12 | 4 |
| 255.0 / 4.9 | Brown, compact to dense | 7 | DO | 10 | 5 |
| | **SILT**<br>some clay<br>seams of fine sand and silty clay<br>occ. layers of silty clay below 7.0 m | 8 | DO | 18 | 6 |
| | | 9 | DO | 16 | 7<br>8 |
| 250.4 / 9.5 | Brown, very dense | 10A<br>10B | DO | 59 | 9 |
| | **SAND**<br>fine grained<br>silty | 11 | DO | 55/15 cm | 10 |
| 249.1 / 10.8 | **END OF BOREHOLE** | | | | 11 |
| | Installed 50 mm Ø monitoring well to 6.1 m<br>Slotted screen from 3.1 to 6.1 m<br>Sand backfill from 2.4 to 6.1 m<br>Bentonite seal from 0 to 2.4 m<br>Provided with a protective monument casing | | | | 12<br>13<br>14 |




WATER LEVEL

W.L @ 255.75 masl on April 11, 2018
W.L @ 256.16 masl on April 27, 2018
W.L @ 256.35 masl on May 7, 2018

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**JOB NO.:** 1802-W072

# LOG OF BOREHOLE NO.: BH/MW 3

**FIGURE NO.:** 3

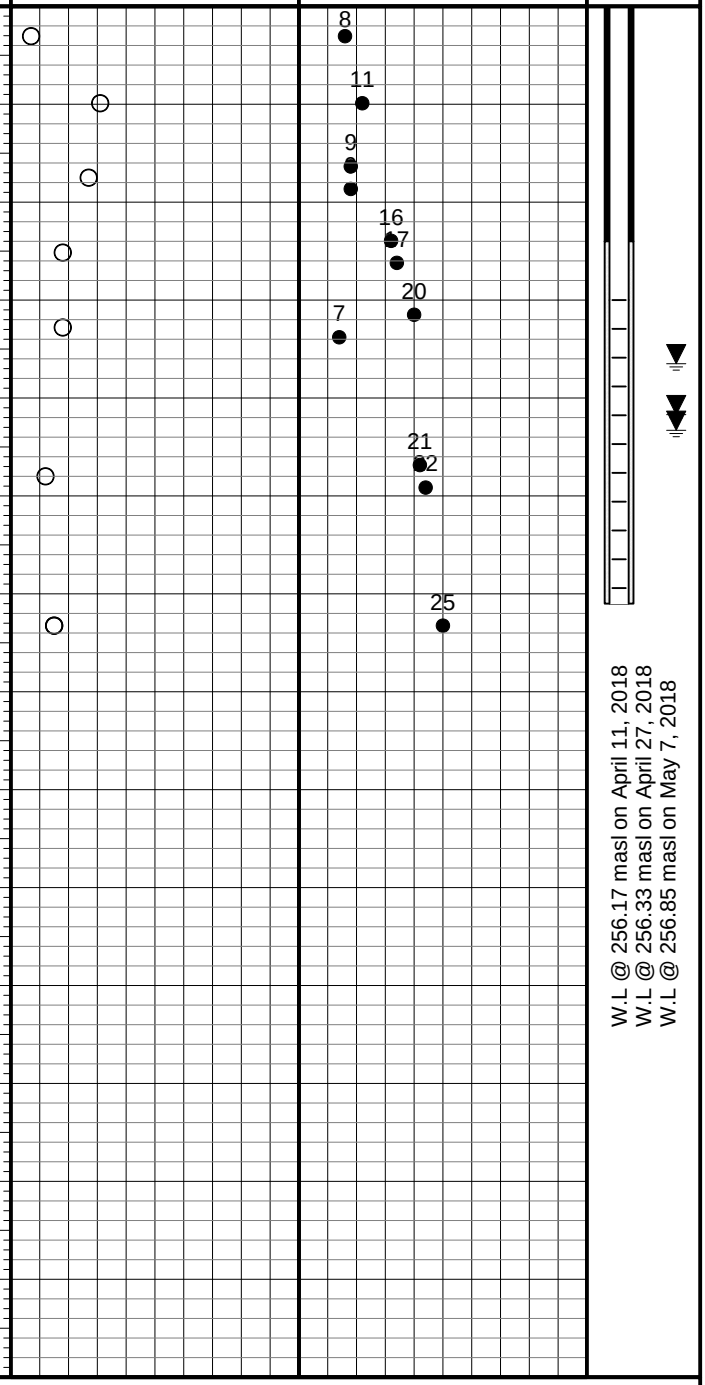
**PROJECT DESCRIPTION:** Proposed 3-Storey Mixed Use Building with 1-Level Underground Parking

**METHOD OF BORING:** Flight-Auger (Hollow-Stem)

**PROJECT LOCATION:** 224 Ardagh Road, City of Barrie

**DRILLING DATE:** March 28, 2018

| El. (m) / Depth (m) | SOIL DESCRIPTION | SAMPLES Number | Type | N-Value | Depth Scale (m) |
|---|---|---|---|---|---|
| 260.5 | Ground Surface | | | | |
| 0.0 | **16 cmTOPSOIL** | | | | 0 |
| 0.2 | Brown, loose to dense | 1 | DO | 7 | |
| | **SAND**<br>fine to medium grained<br>some silt to silty<br>occ. layers os sandy silt<br>fine grained below 1.6 m | 2 | DO | 31 | 1 |
| | | 3A<br>3B | DO | 27 | 2 |
| | | 4A<br>4B | DO | 18 | |
| | | 5A<br>5B | DO | 18 | 3 |
| | | | | | 4 |
| 255.7 | | 6A<br>6B | DO | 12 | |
| 4.8 | Brown, stiff<br>**SILTY CLAY**<br>seams of fine sand and silt | | | | 5 |
| | | | | | 6 |
| 253.9 | | 7 | DO | 15 | |
| 6.5 | **END OF BOREHOLE**<br>Installed 50 mm Ø monitoring well to 6.1 m<br>Slotted screen from 3.1 to 6.1 m<br>Sand backfill from 2.4 to 6.1 m<br>Bentonite seal from 0 to 2.4 m<br>Provided with a protective monument casing | | | | 7<br>8<br>9<br>10<br>11<br>12<br>13<br>14 |

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**JOB NO.:** 1802-W072

# LOG OF BOREHOLE NO.: BH/MW 4

**FIGURE NO.:** 4

**PROJECT DESCRIPTION:** Proposed 3-Storey Mixed Use Building with 1-Level Underground Parking

**METHOD OF BORING:** Flight-Auger (Hollow-Stem)

**PROJECT LOCATION:** 224 Ardagh Road, City of Barrie

**DRILLING DATE:** March 28, 2018

| El. (m) / Depth (m) | SOIL DESCRIPTION | SAMPLES Number | Type | N-Value | Depth Scale (m) | Dynamic Cone (blows/30 cm) 10 30 50 70 90 / Shear Strength (kN/m²) 50 100 150 200 / Penetration Resistance (blows/30 cm) 10 30 50 70 90 | Atterberg Limits PL LL / Moisture Content (%) 10 20 30 40 | WATER LEVEL |
|---|---|---|---|---|---|---|---|---|
| 261.2 | Ground Surface | | | | | | | |
| 0.0 | **21 cm TOPSOIL** | | | | 0 | | | |
| 0.2 | Brown, compact to dense | 1 | DO | 19 | | | 9 | |
| | **SAND** fine to medium grained occ. layers of sandy silt | 2 | DO | 27 | 1 | | 6 | |
| | | 3 | DO | 16 | 2 | | 9 | |
| 258.7 | | 4A | DO | 44 | | | 6 | |
| 2.5 | Brown, compact to dense | 4B | | | | | 18 | |
| | **SILT** trace of clay seams of fine sand | 5A | DO | 16 | 3 | | 15 19 | |
| | | 5B | | | | | | |
| 256.4 | | 6A | DO | 36 | 4 | | 19 | |
| 4.8 | Brown, dense to very dense | 6B | | | 5 | | 14 | |
| | **SAND** fine grained silty seams of silt | 7 | DO | 52 | 6 | | 7 | |
| | | | | | 7 | | | |
| 253.1 | | 8 | DO | 56 | 8 | | 5 | |
| 8.1 | **END OF BOREHOLE** | | | | 9 | | | |
| | Installed 50 mm Ø monitoring well to 6.1 m<br>Slotted screen from 3.1 to 6.1 m<br>Sand backfill from 2.4 to 6.1 m<br>Bentonite seal from 0 to 2.4 m<br>Provided with a protective monument casing | | | | 10 | | | Dry on April 11, 2018<br>Dry on April 27, 2018<br>Dry on May 7, 2018 |
| | | | | | 11 | | | |
| | | | | | 12 | | | |
| | | | | | 13 | | | |
| | | | | | 14 | | | |

**JOB NO.:** 1802-W072

# LOG OF BOREHOLE NO.: BH/MW 5

**FIGURE NO.:** 5

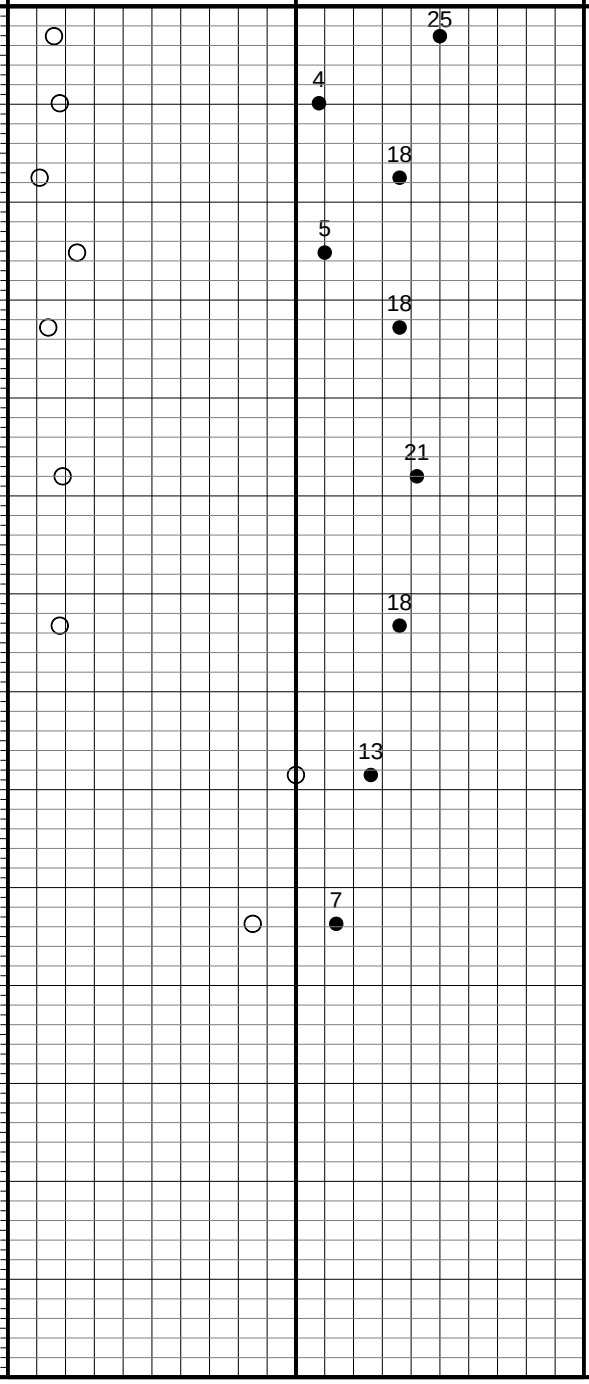
**PROJECT DESCRIPTION:** Proposed 3-Storey Mixed Use Building with 1-Level Underground Parking

**METHOD OF BORING:** Flight-Auger (Hollow-Stem)

**PROJECT LOCATION:** 224 Ardagh Road, City of Barrie

**DRILLING DATE:** March 28, 2018

| El. (m) / Depth (m) | SOIL DESCRIPTION | SAMPLES Number | Type | N-Value | Depth Scale (m) |
|---|---|---|---|---|---|
| 261.8 | Ground Surface | | | | |
| 0.0 | **21 cm TOPSOIL** | | | | 0 |
| 0.2 | **EARTH FILL**<br>dark brown sand and gravel<br>some silt and rootlets | 1 | DO | 16 | |
| 0.6 | Brown, compact | 2 | DO | 18 | 1 |
| | **SAND**<br>fine to medium grained<br>some silt to silty<br>weathered to 2.0 m | 3 | DO | 11 | |
| | | 4 | DO | 24 | 2 |
| | | 5 | DO | 14 | 3 |
| 257.5 | | | | | 4 |
| 4.3 | Brown, compact<br>**SILT**<br>some clay<br>occ. sand seams | 6 | DO | 19 | 5 |
| | | 7 | DO | 18 | 6 |
| 254.5 | | | | | 7 |
| 7.3 | Brown, very dense<br>**SAND**<br>fine grained<br>silty<br>occ. cobbles | 8 | DO | 50/15 cm | 8 |
| | | 9 | DO | 85 | 9 |
| 252.2 | | | | | 10 |
| 9.6 | **END OF BOREHOLE** | | | | 11 |
| | Installed 50 mm Ø monitoring well to 6.1 m<br>Slotted screen from 3.1 to 6.1 m<br>Sand backfill from 2.4 to 6.1 m<br>Bentonite seal from 0 to 2.4 m<br>Provided with a protective monument casing | | | | 12 |
| | | | | | 13 |
| | | | | | 14 |




WATER LEVEL

Dry on April 11, 2018
Dry on April 27, 2018
W.L @ 255.75 masl on May 7, 2018

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# FIGURES 6 to 9

## GRAIN SIZE DISTRIBUTION GRAPHS

## REFERENCE NO. 1802-W072

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# GRAIN SIZE DISTRIBUTION

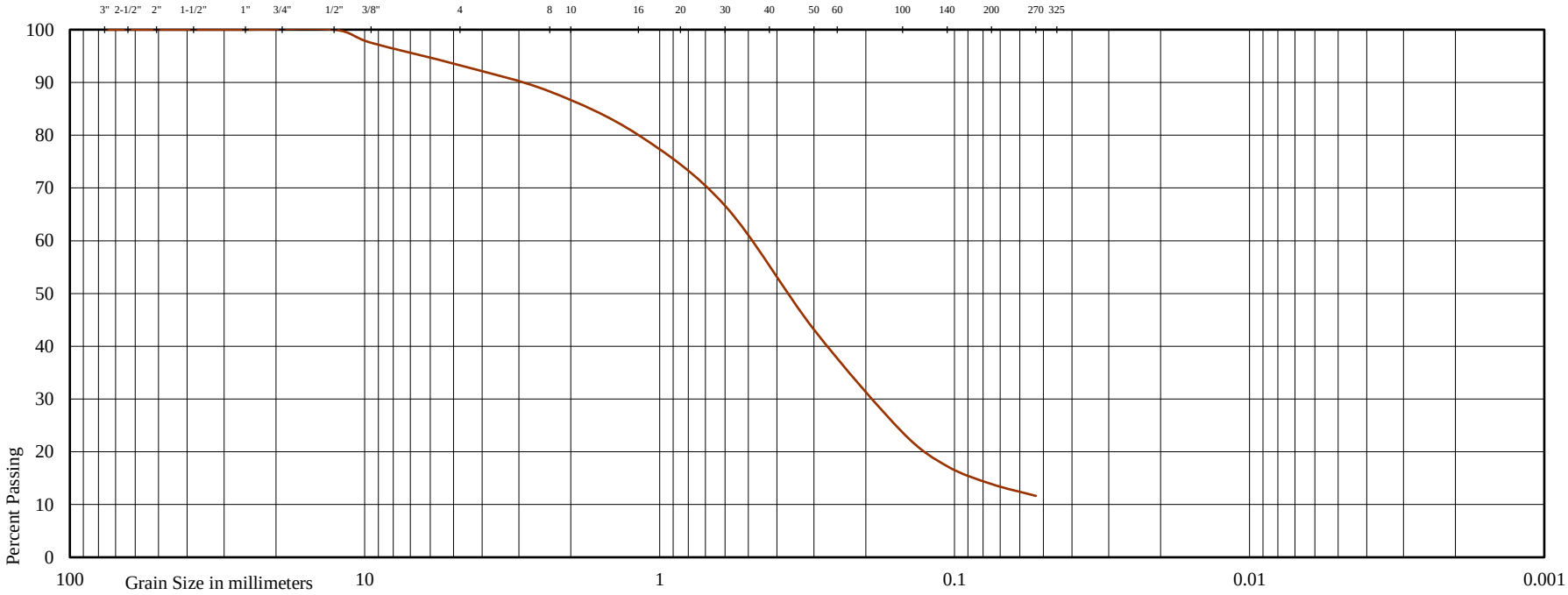
Reference No: 1802-W072

U.S. BUREAU OF SOILS CLASSIFICATION

| GRAVEL | | SAND | | | | SILT | CLAY |
|---|---|---|---|---|---|---|---|
| COARSE | FINE | COARSE | MEDIUM | FINE | V. FINE | | |

UNIFIED SOIL CLASSIFICATION

| GRAVEL | | SAND | | | SILT & CLAY |
|---|---|---|---|---|---|
| COARSE | FINE | COARSE | MEDIUM | FINE | |




Project: Proposed Mixed-Use Development

Location: 224 Ardagh Road, City of Barrie

Borehole No: 4

Sample No: 1B

Depth (m): 0.7

Elevation (m): 260.5

Estimated Permeability (m./sec.) = $10^{-5}$

Classification of Sample [& Group Symbol]: FINE TO MEDIUM SAND, some silt, a trace of gravel

Figure: 6

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# GRAIN SIZE DISTRIBUTION

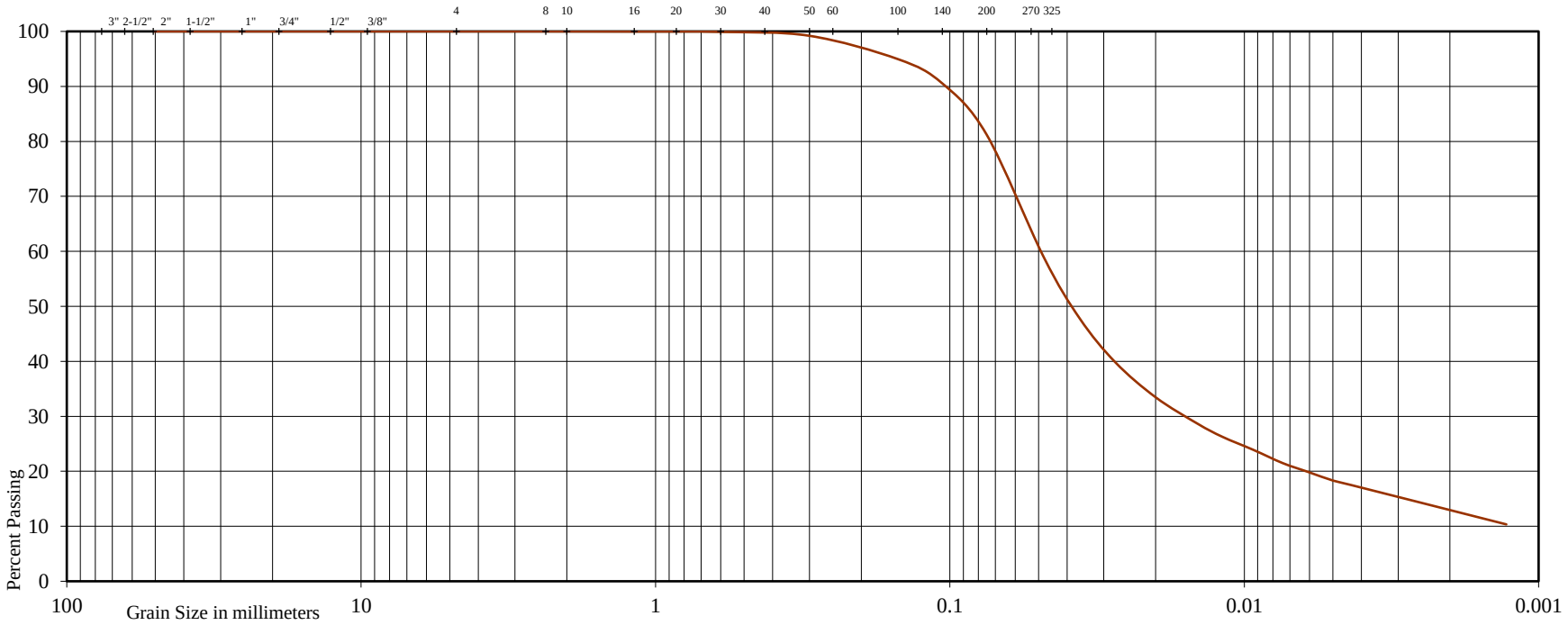
Reference No: 1802-W072

U.S. BUREAU OF SOILS CLASSIFICATION

| GRAVEL | | SAND | | | | SILT | CLAY |
|---|---|---|---|---|---|---|---|
| COARSE | FINE | COARSE | MEDIUM | FINE | V. FINE | | |

UNIFIED SOIL CLASSIFICATION

| GRAVEL | | SAND | | | SILT & CLAY |
|---|---|---|---|---|---|
| COARSE | FINE | COARSE | MEDIUM | FINE | |




Project: Proposed Mixed-Use Development

Location: 224 Ardagh Road, City of Barrie

Borehole No: 2

Sample No: 7

Depth (m): 4.7

Elevation (m): 255.2

Estimated Permeability (m./sec.) = $10^{-8}$

Classification of Sample [& Group Symbol]: SILT, some clay and fine sand

Figure: 7

**Soil Engineers Ltd.**

# GRAIN SIZE DISTRIBUTION

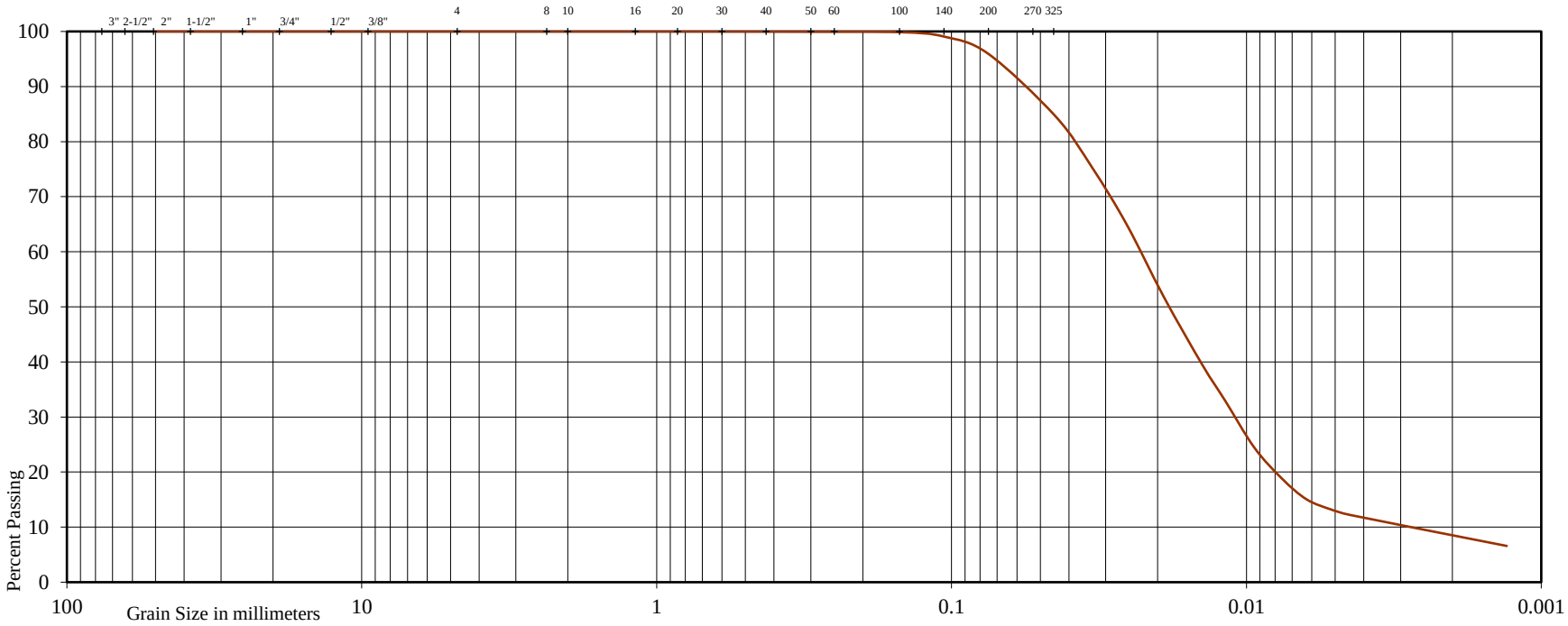
Reference No: 1802-W072

U.S. BUREAU OF SOILS CLASSIFICATION

| GRAVEL | | SAND | | | | SILT | CLAY |
|---|---|---|---|---|---|---|---|
| COARSE | FINE | COARSE | MEDIUM | FINE | V. FINE | | |

UNIFIED SOIL CLASSIFICATION

| GRAVEL | | SAND | | | SILT & CLAY |
|---|---|---|---|---|---|
| COARSE | FINE | COARSE | MEDIUM | FINE | |




Project: Proposed Mixed-Use Development

Location: 224 Ardagh Road, City of Barrie

Borehole No: 4

Sample No: 6A

Depth (m): 4.7

Elevation (m): 256.5

Estimated Permeability (m./sec.) = $10^{-7}$

Classification of Sample [& Group Symbol]: SILT, traces of clay and fine sand

Figure: 8

**Soil Engineers Ltd.**

# GRAIN SIZE DISTRIBUTION

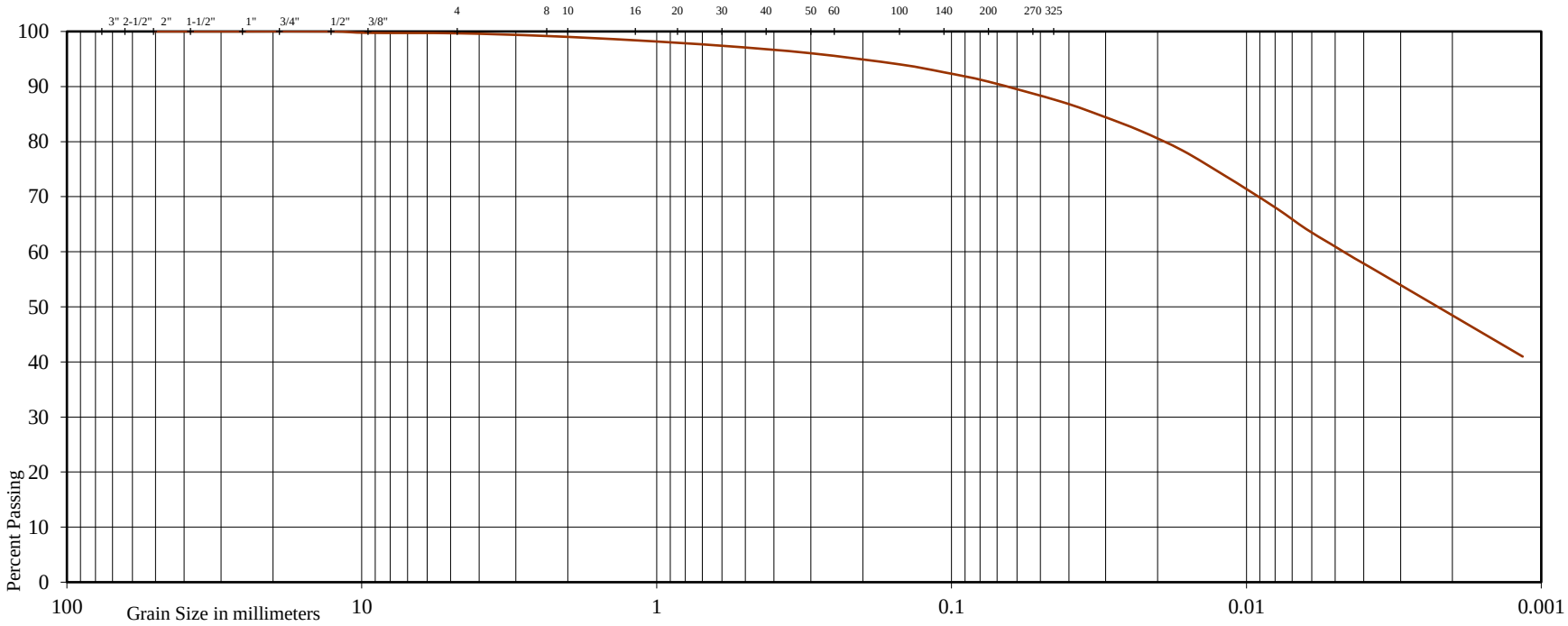
Reference No: W072

U.S. BUREAU OF SOILS CLASSIFICATION

| GRAVEL | | SAND | | | | SILT | CLAY |
|---|---|---|---|---|---|---|---|
| COARSE | FINE | COARSE | MEDIUM | FINE | V. FINE | | |

UNIFIED SOIL CLASSIFICATION

| GRAVEL | | SAND | | | SILT & CLAY |
|---|---|---|---|---|---|
| COARSE | FINE | COARSE | MEDIUM | FINE | |




Project: Proposed Mixed-Use Development

Location: 224 Ardagh Road, City of Barrie

Borehole No: 3

Sample No: 7

Depth (m): 6.3

Elevation (m): 254.2

Estimated Permeability (m./sec.) = $10^{-9}$

Classification of Sample [& Group Symbol]: SILTY CLAY, a trace of sand

Figure: 9

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# DRAWINGS 1 to 9

## REFERENCE NO. 1802-W072


Source: Water Course, Ontario Ministry of Natural Resources and Forestry
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Source: Water Body, Ontario Ministry of Natural Resources and Forestry
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N

Approximate Boundary of Subject Site
Waterbody
Watercourse
Local Road

Soil Engineers Ltd.

Title: Site Location Plan

Project:

Hydrogeological Assessment
Proposed 3-Storey Building with 1-Level Underground Parking and Amenity Area
224 Ardagh Road
City of Barrie

Reference No. 1802-W072

Date: April 13, 2018

Scale:

0 25 50 100 150 200 250
Metres

Drawing No. 1


N

Approximate Boundary of Subject Site

Borehole

Borehole with Monitoring Well

Local Road

Soil Engineers Ltd.

Title: Borehole and Monitoring Well Location Plan

Project:

Hydrogeological Assessment
Proposed 3-Storey Building with 1-Level Underground Parking and Amenity Area
224 Ardagh Road
City of Barrie

Reference No. 1802-W072

Date: October 2, 2018

Scale:

0 4.75 9.5 19 28.5 38 47.5

Metres

Drawing No. 2


C:\GIS2018\1802-W072\

Source: Water Course, Ontario Ministry of Natural Resources and Forestry
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Source: Water Body, Ontario Ministry of Natural Resources and Forestry
©Queen's Printer for Ontario

N

Approximate Boundary of Subject Site
500 metres from Subject Site Boundary
1 Well Location from MECP Well Records (see Appendix 'A')
Waterbody
Watercourse
Local Road

Soil Engineers Ltd.

Title: MOECC Well Location Plan

Project:

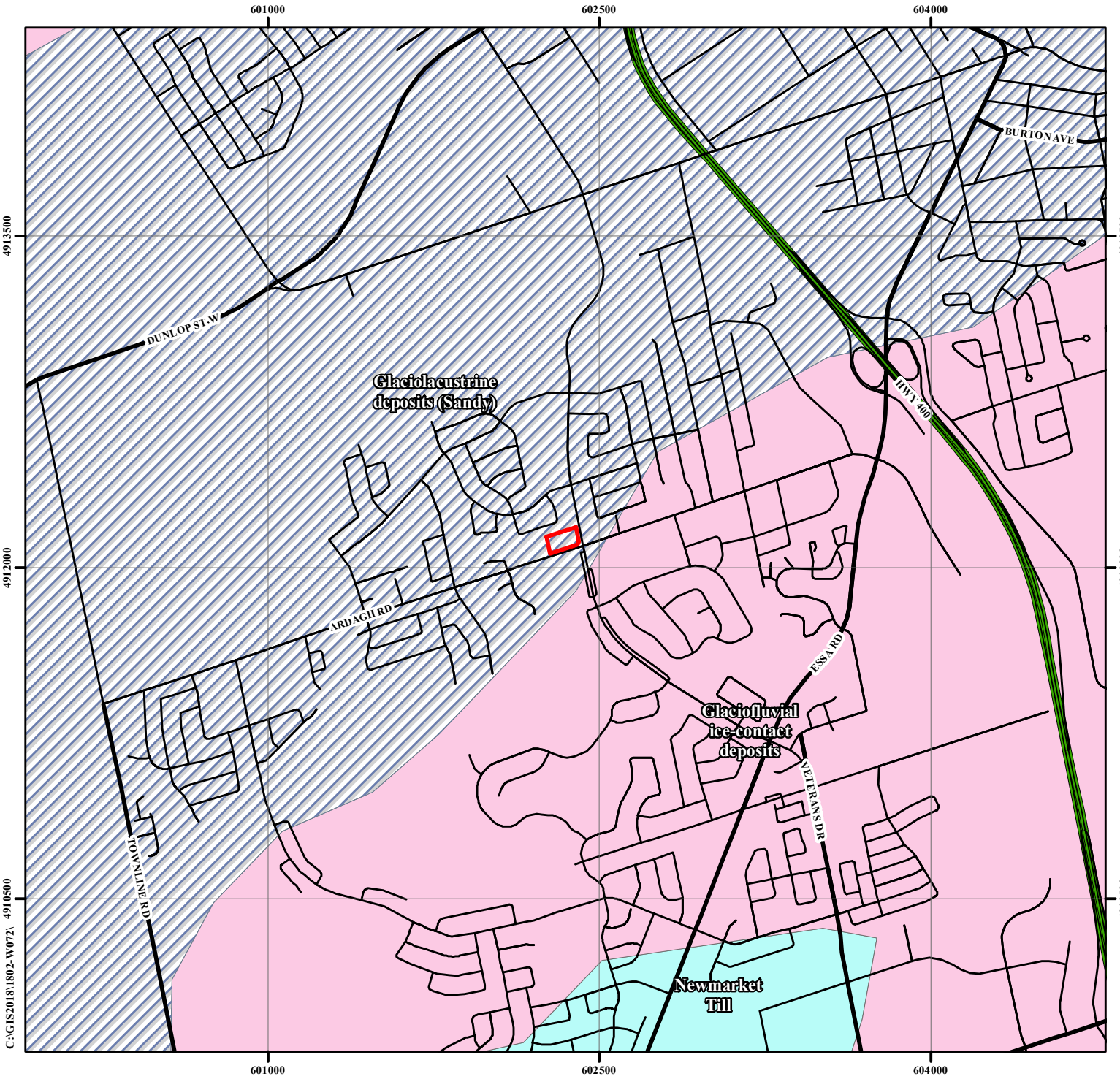
Hydrogeological Assessment
Proposed 3-Storey Building with 1-Level Underground Parking and Amenity Area
224 Ardagh Road
City of Barrie

Reference No. 1802-W072

Date: April 13, 2018

Scale:
0 30 60 120 180 240 300
Metres

Drawing No. 3




Source:Ontario Geological Survey, 1997, Surface Geology of Ontario; Ontario Geological Survey, Miscellaneous Released-Data 0014

N

Approximate Boundary of Subject Site

Glaciofluvial ice-contact deposits
Material: gravel and sand, minor till, includes esker, kame, end moraine, ice-marginal delta and subaqueous fan deposits

Glaciolacustrine deposits (Sandy)
Material: sand, gravelly sand and gravel, nearshore and beach deposits

Newmarket Till
Material: sandy silt to silt matrix, moderate to high matrix carbonate content, clast content moderate to high

Expressway/Freeway

Major Road

Local Road

*Soil Engineers Ltd.*

Title: Quarternary and Surface Geology Map

Project:

Hydrogeological Assessment
Proposed 3-Storey Building with 1-Level Underground Parking and Amenity Area
224 Ardagh Road
City of Barrie

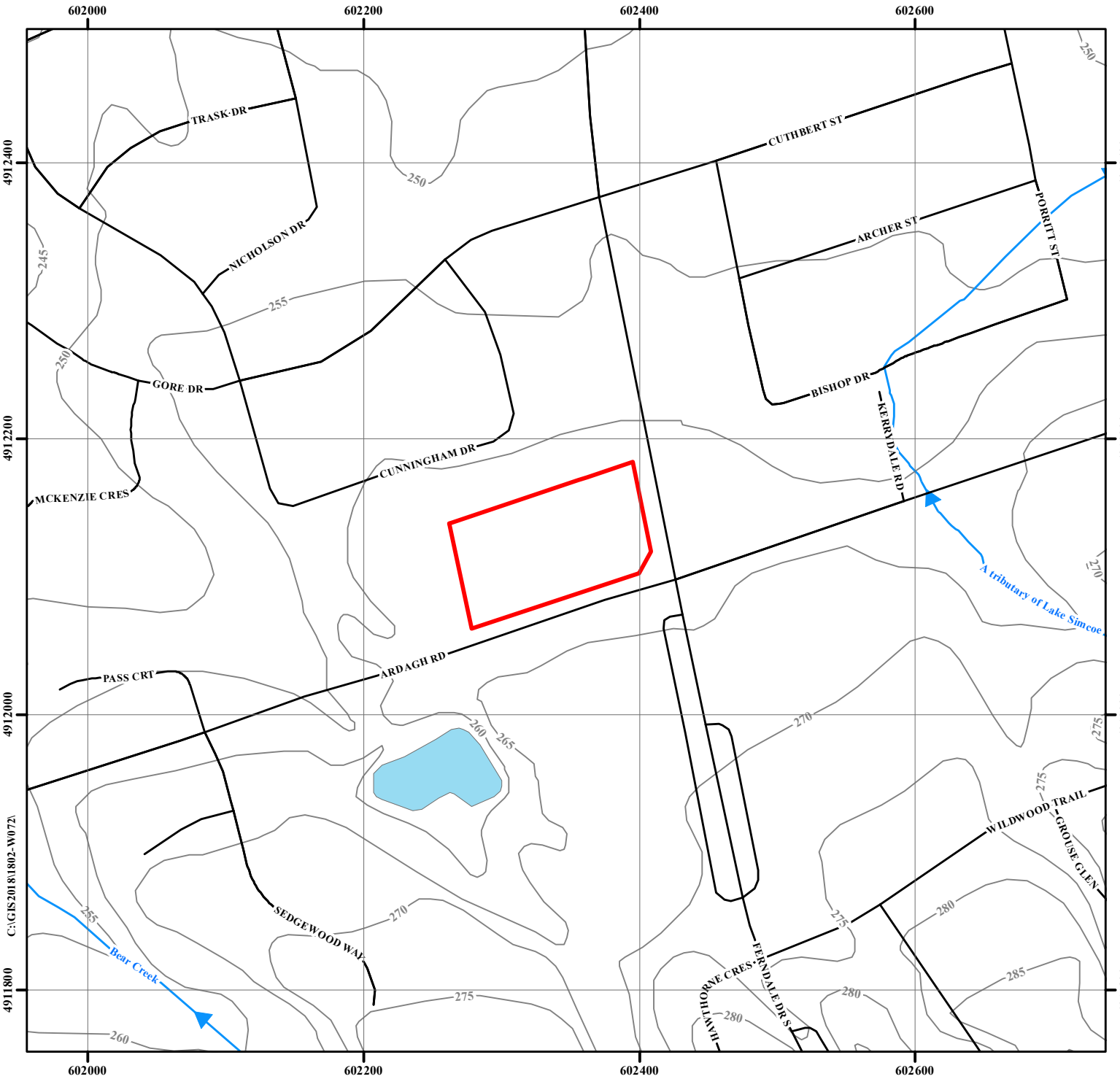
Reference No. 1802-W072

Date: April 13, 2018

Scale:

0 125 250 500 750 1,000 1,250
Metres

Drawing No. 4




N

Approximate Boundary of Subject Site

Waterbody

Watercourse

Local Road

265 Topographic Contour (masl)

Soil Engineers Ltd.

Title: Topographic Map

Project:

Hydrogeological Assessment
Proposed 3-Storey Building with 1-Level Underground Parking and Amenity Area
224 Ardagh Road
City of Barrie

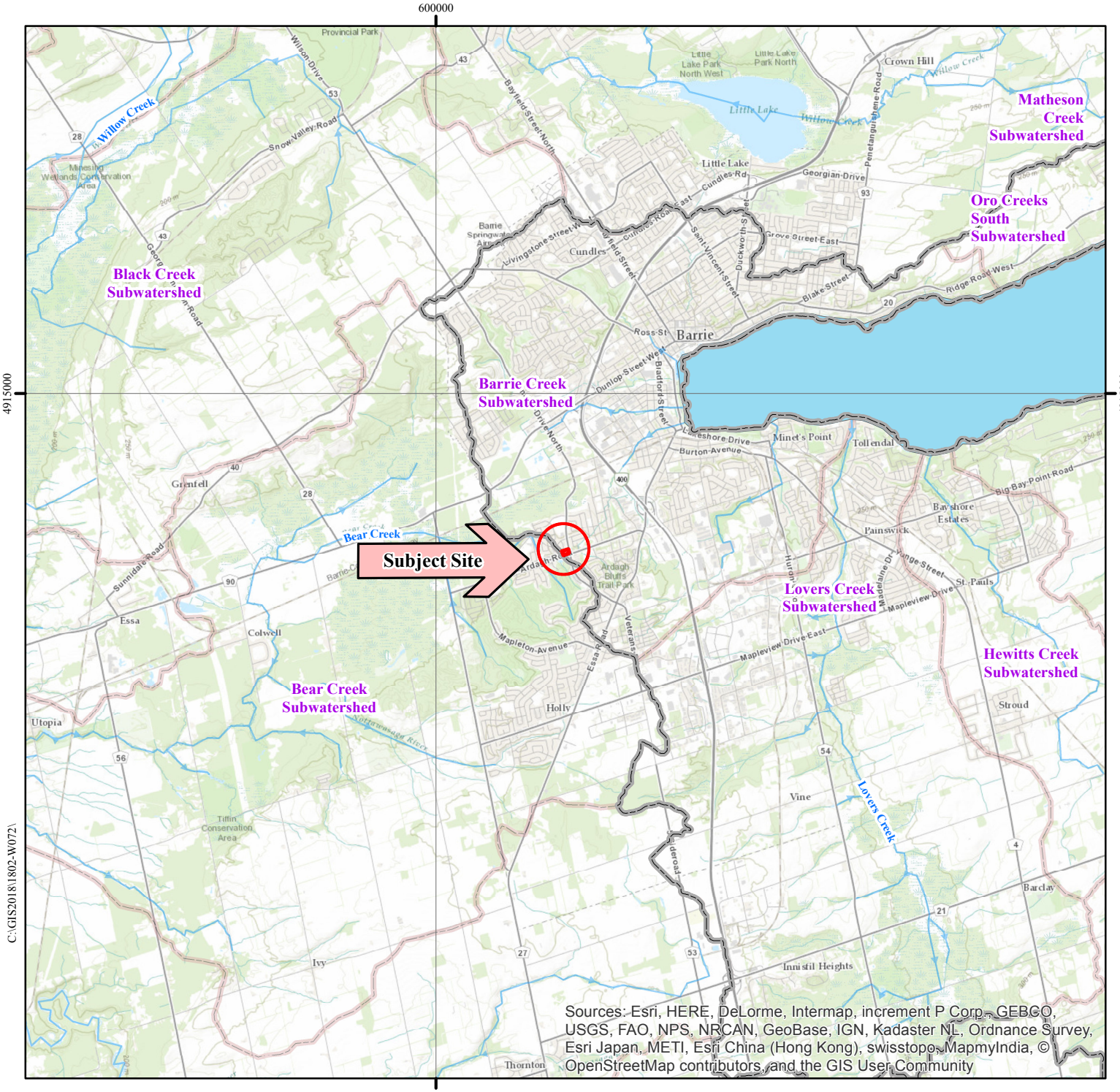
Reference No. 1802-W072

Date: April 13, 2018

Scale:

0 20 40 80 120 160 200
Metres

Drawing No. 5




N

**Watershed:**


- Approximate Boundary of the Subject Site
- Watershed Boundaries
- Water Body
- Watercourse
- Expressway/Major Road

*Soil Engineers Ltd.*

Title: Watershed and Subwatershed Map

Project:

Hydrogeological Assessment
Proposed 3-Storey Building with 1-Level Underground Parking and Amenity Area
224 Ardagh Road
City of Barrie

Reference No. 1802-W072

Date: April 13, 2018

Scale:

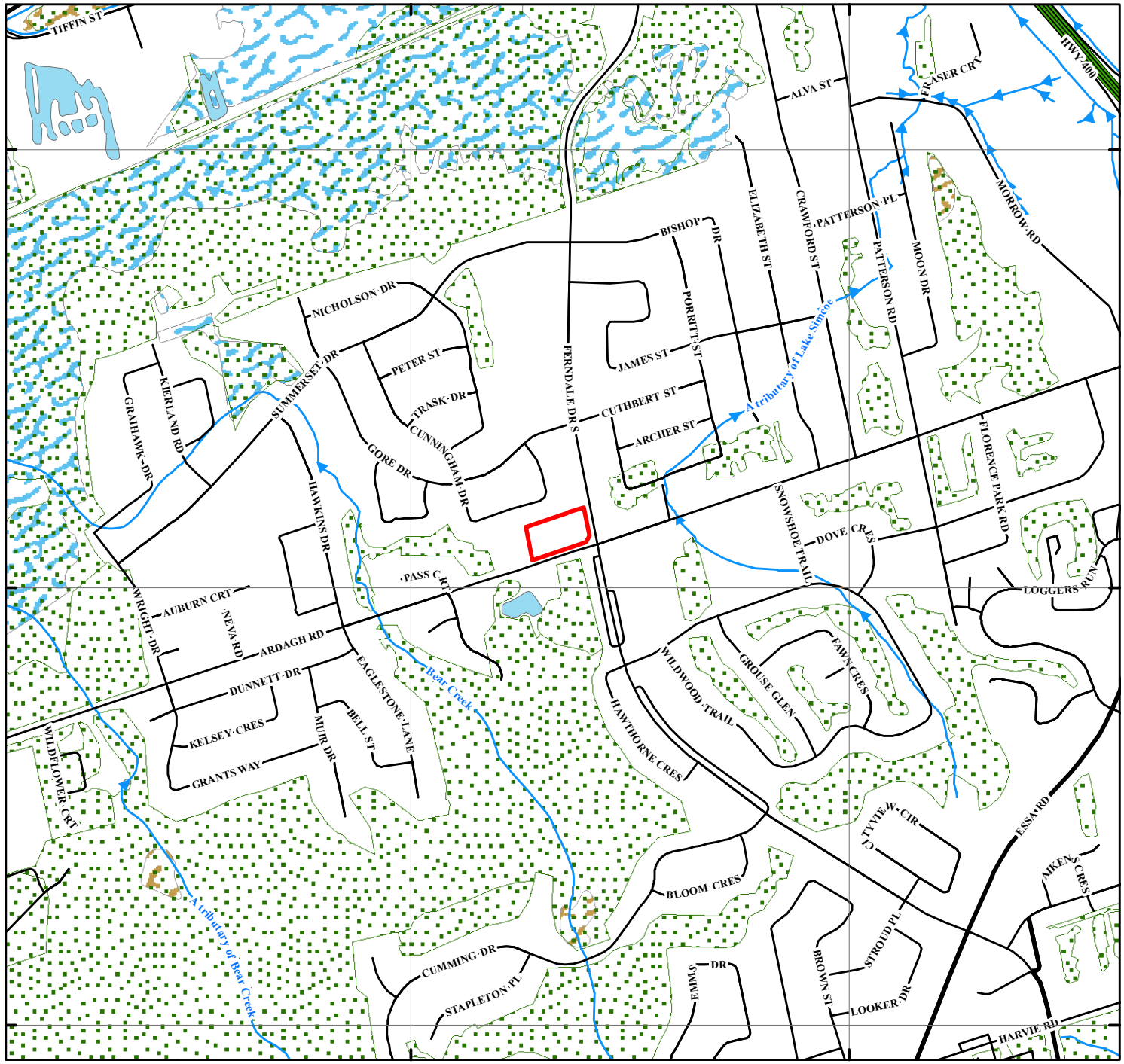
0 9,000 18,000 36,000 54,000 72,000 90,000

Metres

Drawing No. 6

C:\GIS\2018\1802-W072\

this mapping was produced by SEL and should be used for information purposes only.
Data sources used in its production are of varying quality and accuracy and all boundaries should be considered approximate.




Approximate Boundary of Subject Site

Wetland (classified as Provincial)

Wetland (Not Evaluated per OWES)

Wooded Area

Water Body

Watercourse

Expressway/Freeway

Major Road

Local Road

**Soil Engineers Ltd.**

Title: Natural Features and Protection Area Plan

Project:

Hydrogeological Assessment
Proposed 3-Storey Building with 1-Level Underground Parking and Amenity Area
224 Ardagh Road
City of Barrie

Reference No. 1802-W072

Date: April 13, 2018

Scale:

0 65 130 260 390 520 650

Metres

Drawing No. 7

C:\GIS2018\1802-W072\



OWES: Ontario Wetland Evaluatuion System


Source: Contour, Ontario Ministry of Natural Resources and Forestry, 2015
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Source: Water Body, Ontario Ministry of Natural Resources and Forestry, 2015
©Queen's Printer for Ontario, 2015

Source: Water Course, Ontario Ministry of Natural Resources and Forestry, 2015
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N

Approximate Boundary of Subject Site

Borehole

Borehole with Monitoring Well

Local Road

A A' Cross-Section Direction

265 Topographic Contour (masl)

*Soil Engineers Ltd.*

Title: Cross-Section Key Plan

Project:

Hydrogeological Assessment
Proposed 3-Storey Building with 1-Level Underground Parking and Amenity Area
224 Ardagh Road
City of Barrie

Reference No. 1802-W072

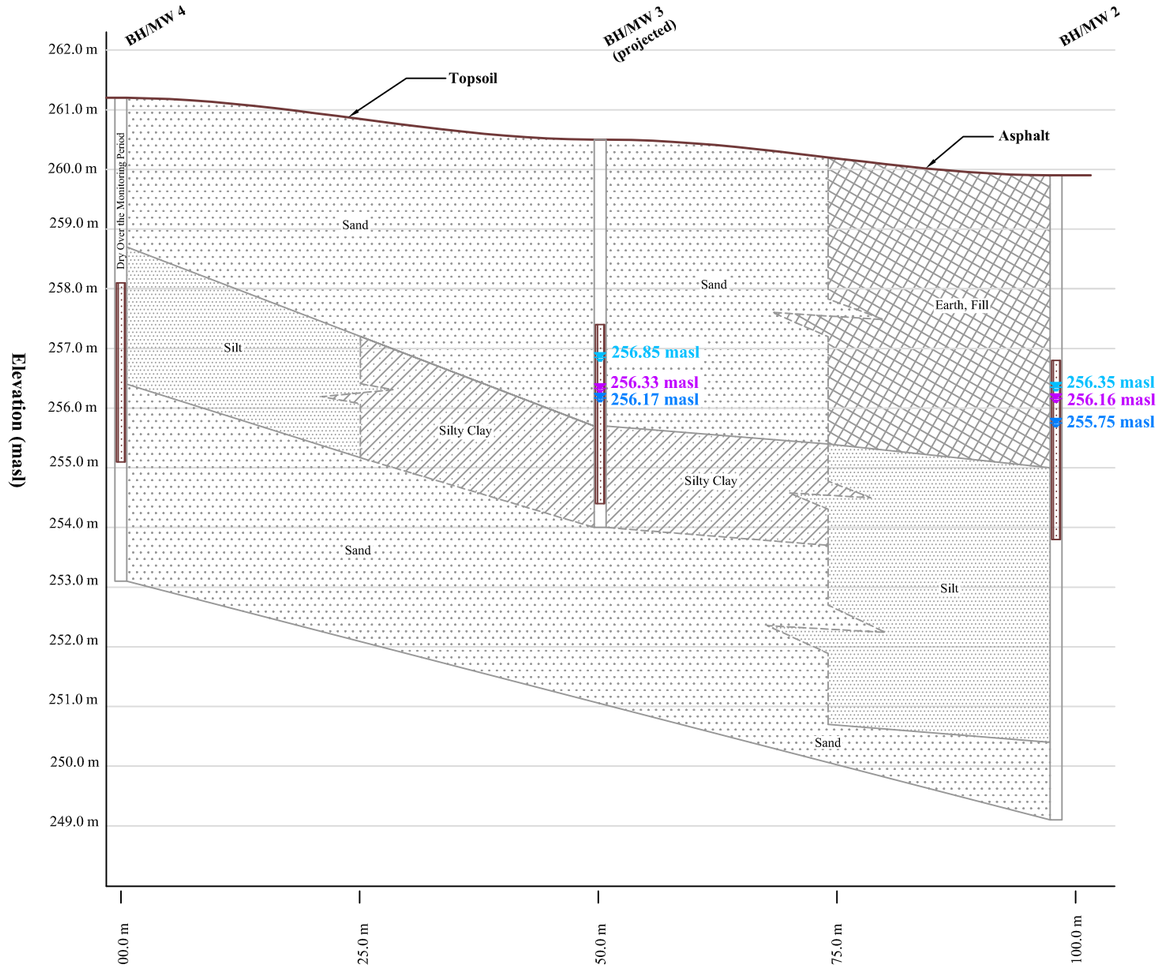
Date: October 2, 2018

Scale:

0 5 10 20 30 40 50
Metres

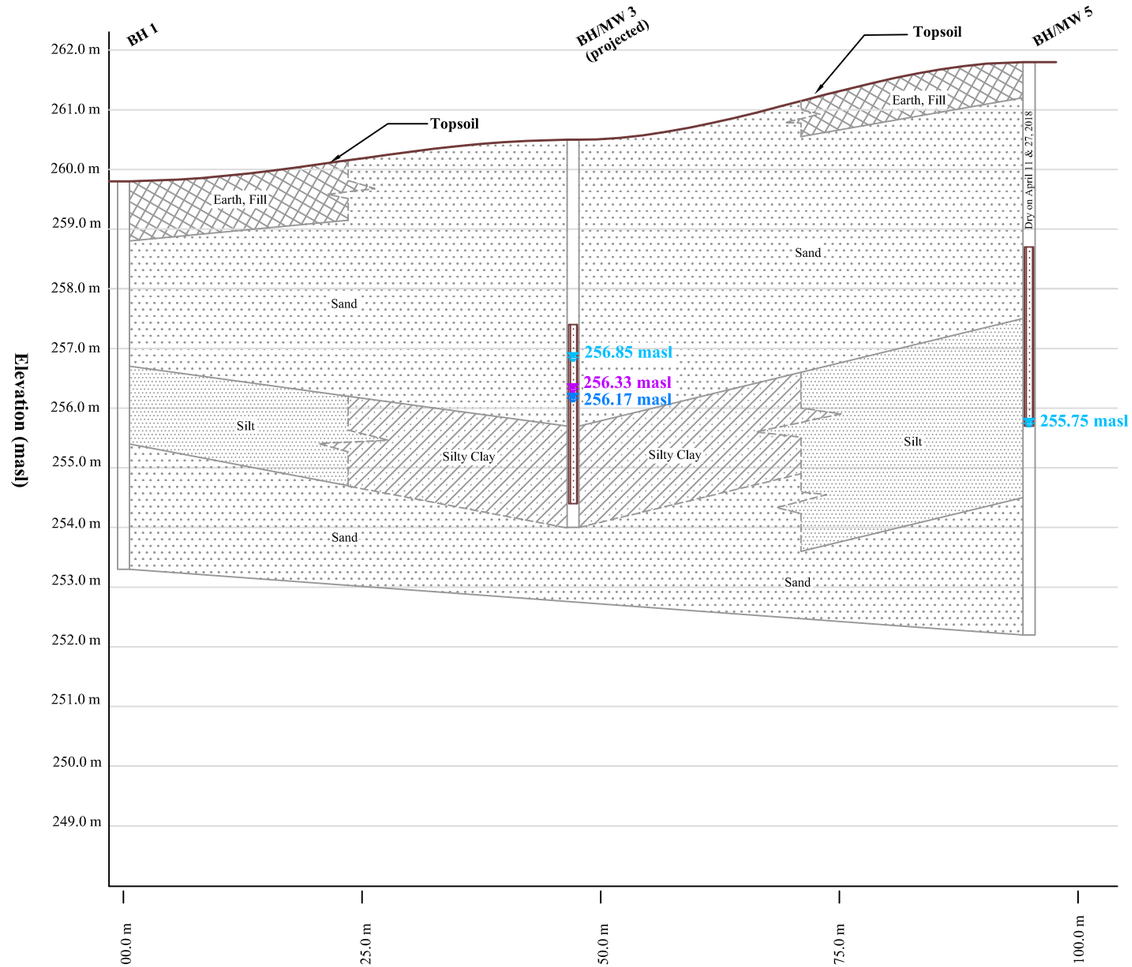
Drawing No. 8-1

**Southwest** **A** — **Northeast** **A'**




**Section A-A'**

**Northwest** **B** — **Southeast** **B'**




**Section B-B'**

C:\Projects\2018 Jobs\1802-W072

**Earth, Fill**
**Fine to Medium Sand**
**Silt**
**Silty Clay**
**3.0 m Screen**

**Water Table on April 11, 2018**
**Water Table on April 27, 2018**
**Water Table on May 7, 2018**

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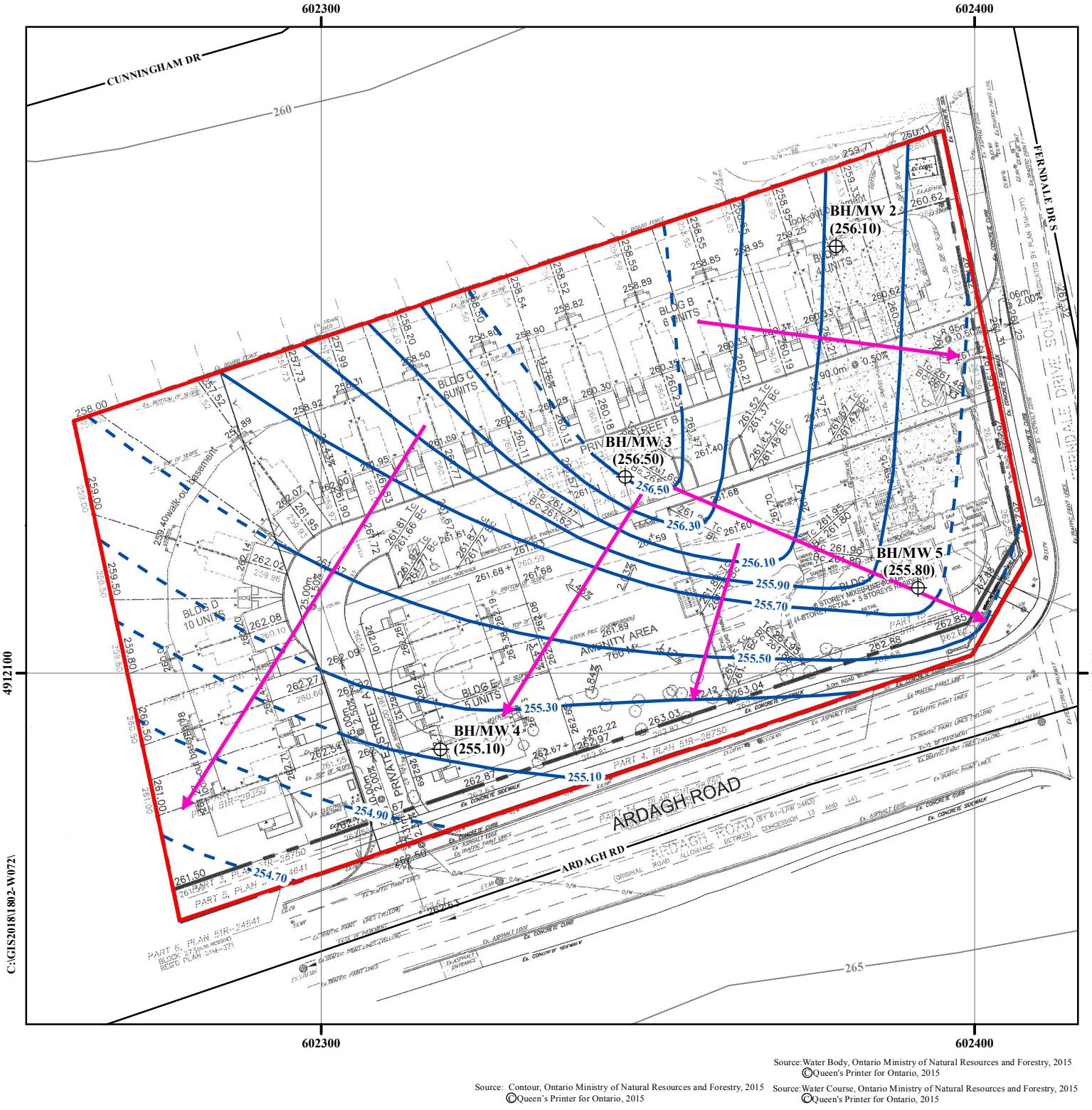
CONSULTING SOIL, FOUNDATION & ENVIRONMENTAL ENGINEERS

Title: Geological Cross-Sections (A-A' and B-B')

Project: Hydrogeological Assessment
Proposed 3-Storey Mixed Use Building with 1-Level Underground Parking
224 Ardagh Road, City of Barrie

| Reference No: | Date: | Scale: V | Scale: H | Drawing No. |
|---|---|---|---|---|
| 1802-W072 | October, 2018 | 1:100 | 1:625 | 8-2 |




Source: Contour, Ontario Ministry of Natural Resources and Forestry, 2015
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Source: Water Body, Ontario Ministry of Natural Resources and Forestry, 2015
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Source: Water Course, Ontario Ministry of Natural Resources and Forestry, 2015
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N

Approximate Boundary of Subject Site

Borehole with Monitoring Well

Interpreted Shallow Groundwater Flow Direction

Interpreted Shallow Groundwater Level Elevation (masl)

Inferred Shallow Groundwater Level Elevation (masl)

Local Road

265 Topographic Contour (masl)

256.10 Average Shallow Groundwater Level Elevation (masl)

*Soil Engineers Ltd.*

Title: Shallow Groundwater Flow Pattern Plan

Project:

Hydrogeological Assessment
Proposed 3-Storey Building with 1-Level Underground Parking and Amenity Area
224 Ardagh Road
City of Barrie

Reference No. 1802-W072

Date: October 2, 2018

Scale:

0 4.25 8.5 17 25.5 34 42.5

Metres

Drawing No. 9

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# APPENDIX 'A'

## MOECC WATER WELL RECORDS SUMMARY

## REFERENCE NO. 1806-W152

**Ontario Water Well Records**

| WELL ID | MECP WWR ID | Construction Method | Well Depth (mbgs)** | Well Usage | | Water Found (mbgs)** | Static Water Level (mbgs)** | Top of Screen Depth (mbgs)** | Bottom of Screen Depth (mbgs)** |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Final Status | First Use | | | | |
| 1 | 5701514 | Cable Tool | 18.30 | Water Supply | Domestic | 17.08 | -1.83 | 17.39 | 18.30 |
| 2 | 7150340 | - | - | Abandoned-Other | - | - | - | - | - |
| 3 | 5701688 | Cable Tool | - | Water Supply | Domestic | 9.15 | - | - | - |
| 4 | 5714480 | Cable Tool | 45.14 | Water Supply | Domestic | 43.62 | 15.25 | 44.23 | 45.14 |
| 5 | 5717014 | Rotary (Reverse) | 26.54 | Water Supply | Domestic | 22.88 | 6.10 | 25.62 | 26.54 |
| 6 | 5701690 | Cable Tool | - | Water Supply | Domestic | 29.89 | 10.37 | - | - |
| 7 | 5708187 | Boring | - | Water Supply | Domestic | 3.66 | 3.66 | - | - |
| 8 | 5701711 | Boring | - | Water Supply | Domestic | 1.83 | 1.83 | - | - |
| 9 | 7237165 | Boring | - | Observation Wells | Monitoring | 1.90 | - | - | - |
| 10 | 7172512 | - | - | Abandoned-Other | - | - | - | - | - |
| 11 | 5701708 | Cable Tool | 38.43 | Water Supply | Domestic | 37.21 | 28.06 | 37.21 | 38.43 |
| 12 | 5701522 | Cable Tool | - | Water Supply | Domestic | 15.25 | 0.61 | - | - |
| 13 | 7165916 | - | - | Abandoned-Other | - | - | - | - | - |
| 14 | 5701710 | Cable Tool | - | Water Supply | Domestic | 16.77 | 0.31 | - | - |
| 15 | 5718493 | Cable Tool | 28.67 | Water Supply | Domestic | 27.45 | 9.76 | 27.75 | 28.67 |
| 16 | 5701518 | Cable Tool | - | Water Supply | Domestic | 14.95 | 3.66 | - | - |
| 17 | 5714481 | Cable Tool | 19.22 | Water Supply | Domestic | 18.30 | 3.36 | 18.30 | 19.22 |
| 18 | 5707925 | Cable Tool | 22.57 | Water Supply | Domestic | 21.66 | 3.66 | 21.66 | 22.57 |
| 19 | 5701713 | Cable Tool | 12.81 | Water Supply | Domestic | 11.29 | 0.92 | 11.59 | 12.81 |
| 20 | 5701715 | Cable Tool | 11.59 | Water Supply | Domestic | 10.98 | 2.75 | 10.68 | 11.59 |

Notes:

*MECP WWID: Ministry of the Environment, Conservation and Parks Water Well Records Identification

**(mbgs): Metres Below Ground Surface

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# APPENDIX 'B'

## RESULT OF SINGLE WELL RESPONSE TEST

## REFERENCE NO. 1802-W072

# Falling Head Test (Slug Test)

| | | | |
|---|---|---|---|
| Test Date: | | 27-Aug-18 | |
| Piezometer/Well No.: | | BH/MW 4 | |
| Ground level: | | 157.10 | m |
| Screen top level: | | 154.00 | m |
| Screen bottom level: | | 152.50 | m |
| Test El. (at midpoint of screen): | | 153.25 | m |
| Test depth (at midpoint of screen): | | 3.85 | m |
| Screen length | L= | 1.5 | m |
| Diameter of undisturbed portion c | 2R= | 0.22 | m |
| Standpipe diameter | 2r= | 0.05 | m |
| Initial unbalanced head | Ho= | -0.496 | m |
| Initial water depth | | 3.66 | m |
| Aquifer material: | | **SILTY FINE SAND** | |

Shape factor $F = \frac{2 \times 3.14 \times L}{\ln(L/R)} = 3.607239$ m

Permeability $K = \frac{3.14 \times r2}{F \times (t2 - t1)} \times \ln(H1/H2)$ (Bouwer and Rice Method)

$\frac{\ln(H1/H2)}{(t2 - t1)} = 0.01386294$

K= **7.5E-04** cm/s

**7.5E-06** m/s