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Hydrogeological Study in Support of Draft Plan

Lockhart Innisfil Investments Limited & Lockhart Innisfil Investments II Limited
Barrie, Ontario

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Barrie, Ontario

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1.0 Introduction

R.J. Burnside & Associates Limited (Burnside) has been retained by Lockhart Innisfil Investments Limited and Lockhart Innisfil Investments (II) Limited (Lockhart) to complete a hydrogeological study and water balance assessment for lands located within the Hewitt's Secondary Plan Area in Barrie. The lands associated with the assessment, herein referred to as the subject lands are located between Lockhart Road and Mapleview Drive and west of Yonge Street in the City of Barrie, Ontario (Figure 1). The subject lands are located within the Barrie Annexed Lands and the OPA 39 Hewitt's Secondary Plan Area (SPA) located on the southern boundary of the City of Barrie. In 2016, a Subwatershed Impact Study (SIS) for the Hewitt's SPA was completed for the Hewitt's Creek Landowners Group that included an assessment of regional hydrogeology and water balance (Burnside, 2016). The current assessment is aimed at updating information contained in the regional assessment and providing more detailed site-specific information for the subject lands in support of an application for draft plan approval.

1.1 Scope of Work

The scope of work completed for the hydrogeological study and water balance assessment was developed to build upon the more regional work completed for the Hewitt's SPA in the SIS (Burnside, 2016) and to address requirements for hydrogeological studies in support of draft plan approval. The scope of work for the hydrogeological study and water balance assessment included the review of available regional information as well as the completion of the following site-specific tasks:

1. Review of published geological and hydrogeological information: A review of background material for the area, including topography, surficial geology and bedrock geology mapping and existing geotechnical and hydrogeological reports was completed to assess the regional hydrogeological setting.

2. Review of the Ministry of the Environment, Conservation and Parks (MECP) water well records: The MECP maintains a database that provides geological records of water supply wells drilled in the province. A list of the available MECP water well records for local wells is provided in Appendix A. It is noted that the well locations listed in the MECP records are approximations only and may not be representative of the precise well locations in the field. These well data were compiled and mapped to characterize the local groundwater resources.

3. Establish groundwater monitoring network: Groundwater monitoring locations were established to determine the depth to water table and characterize seasonal variations in the water table. Existing wells and piezometers from previous studies and wells installed as part of geotechnical investigation were

included in the monitoring program. The locations of the monitoring wells and piezometers included in the monitoring network are shown on Figure 2. The monitoring well construction details are provided on the borehole logs in Appendix B.

4. Hydraulic conductivity testing: Burnside conducted single well response tests in order to determine soil hydraulic conductivity. Single well response tests were completed at four groundwater monitoring wells (LI-BH2, LI-BH8, LI-BH10 and LI-BH15) in 2019. The hydraulic conductivity field testing results are provided in Appendix C.

5. Monitoring of groundwater levels: Monitoring has been completed to measure the depth to the water table and assess the horizontal and vertical groundwater flow conditions. Groundwater level monitoring was completed between June 2019 and December 2020 in monitoring wells and piezometers. Automatic water level recorders (dataloggers) were installed in four monitoring wells (MW12, LI-BH2, LI-BH12 and LI-BH15) and one piezometer (LM-PZ1d) to document the range of groundwater fluctuations and the response of the groundwater table to precipitation events. Barometric data from a barologger installed in the vicinity of the subject lands was used for calibration of the datalogger results. The groundwater monitoring data and hydrographs are provided in Appendix D.

6. Monitoring of surface water: Surface water monitoring was completed at two monitoring stations located along a watercourse that traverses the subject lands (Figure 2). The stations were inspected for water depth and flow on each site visit. In addition to the flow monitoring two staff gauges were also installed within the watercourse and the ponded level of water in the watercourse was recorded on each site visit. The surface water monitoring data are summarized in Appendix E.

7. Water quality testing: Water quality data were collected from selected monitoring locations to typify the groundwater quality in the vicinity of the subject lands. Samples were collected in 2019 from two monitoring wells: LI-BH2 and LI-BH15. The water samples were submitted to an accredited laboratory for analyses of general water quality indicators (e.g., pH, hardness, and conductivity), basic ions (including chloride and nitrate) and selected metals to characterize the background water quality at the property. The laboratory water quality data are provided in Appendix F.

8. Water balance calculations: Pre- and post-development water balance calculations have been completed to assess the groundwater infiltration volumes for the subject lands. The local climate data and detailed water balance calculations are provided in Appendix G.

9. Data compilation, assessment of site conditions and reporting: All data compiled as part of the above scope were analyzed and a detailed report on site-specific conditions was prepared to outline the findings and recommendations of the study. The current report provides reporting on the above items.

2.0 Physical Setting

2.1 Topography and Drainage

The subject lands are located within the Lake Simcoe watershed and are therefore a part of the jurisdiction of the Lake Simcoe Region Conservation Authority (LSRCA). The subject lands are located within the Lovers Creek subwatershed. Lovers Creek Swamp, a provincially significant wetland is located in the northwest corner of the subject lands. A tributary of Lovers Creek traverses' the subject lands flowing northwest towards the Lovers Creek swamp (Figure 3).

The regional slope is eastwards towards the Lovers Creek Swamp. Locally the topography of the subject lands is gently sloping towards the tributary of Lovers Creek which traverses the subject lands with elevations on the subject lands ranging from 265 metres above sea level (masl) in the southwest and northeast corners to 248 masl within Lovers Creek Swamp in the northwest corner of the subject lands (Figure 3).

2.2 Geology

The subject lands are located in the physiographic region known as the Peterborough Drumlin Field. The region is characterized as a rolling drumlinized till plain that contains drumlins in various morphologies and orientations. The drumlins through the region are comprised of highly calcareous till (Chapman & Putnam, 1984). Drumlins within this region can range from a few meters to more than 60 m in height.

The overburden in the area of the subject lands was deposited as a series of advances and retreats of the Simcoe glacial ice lobe. This has resulted in drumlinized sheets of glacial till (Newmarket till), stratified glaciolacustrine deposits of sand and gravel, littoral-foreshore deposits and massive-well laminated deposits of sand and gravel.

A review of the quaternary geology mapping for the area (OGS, 2010) indicates that the overburden sediments of the subject lands consist primarily of silty to sandy glacial till (Figure 4). The southeast portion of the subject lands is mapped as fine-textured massive well laminated glaciolacustrine deposits and coarse-textured glaciolacustrine deposits are mapped along the western property boundary and northwest corner of the subject lands (Figure 4).

The bedrock underlying the subject lands is mapped as the Lindsay Formation of the Simcoe Group, which consists of limestone and shale (OGS, 2007).

2.3 Regional Hydro-stratigraphy

The regional hydrogeology of an area describes the major aquifers and aquitards and the interactions between these types of hydrogeological units. Local conditions may vary from the regional interpretations, however major groundwater flow systems are assumed to be regional in nature.

The overburden deposits underlying the subject lands have been interpreted by regional studies such as the Tier 3 Water Balance (AquaResource, 2011) and Source Water Protection Assessment Report (LSRCA, 2012) to consist of alternating sequences of coarser-grained permeable layers (aquifers) and finer-grained less permeable layers (aquitards) of varying thicknesses that form the hydrostratigraphic sequence. The hydrostratigraphic sequence defined by AquaResource was also supported by the SIS (Burnside, 2016). The hydrostratigraphic sequence for the area of the subject lands includes four main aquifer layers (A1 to A4) and four main aquitards (C1 to C4) with a confining layer (UC) overlying the uppermost aquifer (A1).

A description of the interpreted regional hydrostratigraphic framework is provided below based on the Source Water Protection Assessment Report (LSRCA, 2012):

- Surficial Geology Layer – This layer represents coarse grained sediments in stream beds and at surface surficial geology areas that overly the UC. The thickness ranges from 0.1 m to 3 m.
- UC – Upper Confining Layer – Represents smaller areas of less permeable surficial material. Regional studies such as the AquaResource (2011) report indicate that the confining layer (UC) is patchy in the Barrie area and may also be patchy in the area of the subject lands.
- A1 – Represents the uppermost aquifer – Occasionally exists as a surficial unconfined aquifer and is generally associated with coarse grained glacial and interglacial sediments mapped as ice contact stratified drift. The majority of the local domestic wells in the Barrie area are completed within this aquifer.
- C1 – Upper aquitard – Described as varved clay and silt (LRSCA, 2012).
- A2 – Intermediate aquifer which is stratigraphically equivalent to areas within the Northern Till. The aquifer is generally described as being composed of sand with some clast rich portions (LRSCA, 2012). This area is used for the Innisfil Heights water supply.
- C2 – Intermediate aquitard.

- A3 – This area constitutes the main Barrie municipal aquifer and is the source of the Stroud water supply; it is stratigraphically equivalent to the Thorncliffe deposits in the Upland regions.
- C3 – Lower aquitard.
- A4 – Lower aquifer, thin and sometimes combined with A3 where C3 is thin or absent.
- C4 – Lower aquitard but may also represent weathered bedrock.

The current study is focused on the near surface sediments as impacts due to the proposed development will be restricted to these layers.

2.4 Local Stratigraphy

Boreholes were drilled across the subject lands as part of geotechnical studies on the lands by Soil Engineers Ltd. in 2019. The locations of the boreholes are shown on Figure 5 and the borehole logs are provided in Appendix B.

The boreholes indicated that the overburden stratigraphy is generally composed of layers of glacial till and sand. The till deposits were generally composed of sandy silt to silty sand with varying amounts of clay and gravel. Occasional layers of silty clay, silt, sandy silt and sand were encountered.

To illustrate the shallow stratigraphy of the subject lands, schematic geologic cross-sections have been prepared (Figures 6 and 7) using the MECP well records (Appendix A) and the soils information collected during drilling of boreholes (Appendix B). The locations of the cross sections are illustrated on Figure 5 along with the locations of water wells and boreholes used in the construction of the cross-sections.

The cross-sections illustrate that the subject lands are underlain by a layer of sandy silt till with a thickness ranging from 5 m to 24 m. The sandy silt till has occasional layers of sand. Based on cross-sections produced in the Hewitt's SIS (Burnside, 2016), the sandy silt till layer is underlain by a layer of sand and gravel between elevations of 250 masl and 220 masl. The sand layer is interpreted to form the local aquifer where private supply wells are completed (Figures 6 and 7).

2.5 Hydraulic Conductivity

The ability of soil to transmit groundwater is measured as its hydraulic conductivity. Hydraulic conductivity is low in poorly transmissive sediments (aquitards) and higher in more transmissive sediments (aquifers). The determination of hydraulic conductivity rates assists with the determinations of groundwater flow directions and relationships between various layers in the subsurface. There are various methods that can be used to assess soil hydraulic conductivity depending on the available instrumentation. Grainsize data and soil characteristics collected during a geotechnical investigation can be used to provide a general estimate of hydraulic conductivity. In situ bail-down or slug-testing methods are used in groundwater monitoring wells to assess site-specific hydraulic conductivity. Both methods have been used to estimate the hydraulic conductivity of the soils encountered in the boreholes completed on the subject lands as discussed below.

2.5.1 Grainsize Analysis

Grainsize analysis from the geotechnical investigations on the subject lands (Soil Eng., 2019) were reviewed.

To estimate hydraulic conductivity based on grainsize analysis, an empirical formula method known as the Hazen estimation is used. This method is an approximation of hydraulic conductivity based on grainsize curves for sandy soils. The approximation does not strictly apply to finer grained materials, however, it is still considered useful to provide a general indication of the range of the hydraulic conductivity values. Grainsize distribution data were available for seven samples obtained from on-site wells and these data were used to obtain hydraulic conductivity values empirically using the Hazen method. The grainsize distribution graphs are provided in Appendix C-1 and the estimated hydraulic conductivity values are provided in Table 1. It should be noted that the grainsize curves produced only allowed for hydraulic conductivity determination for four of the seven curves.

Table 1: Estimated Hydraulic Conductivity Based on Grainsize Analyses

Sample ID	Depth of Sample (mbgs*)	Soil Description	% Fines	Estimated Hydraulic Conductivity (cm/s)
MW12-SS6	15	Silty Sand	45	na
BH6-SS3	1.7	Silty Sand Till	40	7.8×10^{-6}
BH12-SS5	3.3	Silty Sand Till	37	7.8×10^{-6}
BH8-SS6	4.8	Silty Clay	93	na
BH9-SS4	2.5	Silty Clay	98	na
BH1-SS5	3.3	Sand	8	1.4×10^{-3}
BH19-SS8	7.8	Sand, some silt	18	7.8×10^{-6}

*metres below ground surface
na – Hazen formulae not applicable

Grainsize analyses results indicate that the sediments within the overburden range in composition from sand and gravel (8% fines) to silty clay (98% fines). The greater amounts of fines within a deposit impacts the ability of the material to transmit water and generally lowers the overall hydraulic conductivity. Groundwater flow is generally limited by fine grained sediments with lower hydraulic conductivity. Grainsize analysis completed indicate that the sediments generally consist of varying amounts of sand and silt with some silty clay. The hydraulic conductivities based on grainsize analyses for the majority of the sediments is estimated in the range of 10^{-6} cm/sec.

2.5.2 Single Well Response Tests

To assess the in situ hydraulic conductivity of the sediments, single well response tests (bail-down tests and slug tests) were conducted at four monitoring wells. The results from the tests were plotted (Appendix C-2) and analyzed to calculate hydraulic conductivity of the sediments screened. A summary the calculated hydraulic conductivities is provided below in Table 2.

Table 2: Single Well Response Testing Results

Monitoring Well	Screen Interval (mbgs)*	Formation Screened	Hydraulic Conductivity (cm/sec)
LI-BH2	9.8	Silty Sand Tiil	7.9×10^{-5}
LI-BH8	6.0	Silty Clay/Silty Sand Till	6.2×10^{-6}
LI-BH10	4.4	Silty Clay/Silty Sand Till	3.4×10^{-6}
LI-BH15	6.2	Silty Sand Till	3.4×10^{-5}

*metres below ground surface

Single well response tests in wells screened in the silty sand till indicated moderate hydraulic conductivities in the order of 10^{-5} cm/sec to 10^{-6} cm/sec.

3.0 Hydrogeology

3.1 Local Groundwater Use

The City of Barrie obtains its water supply from a combination of groundwater and surface water based sources. Municipal servicing is assumed to be available for lands within the municipal boundary and areas outside of the city are privately serviced. It is our understanding that municipal servicing is being extended into the area as part of the development of the Hewitt's Secondary Plan Area. Areas that were previously privately serviced are assumed to still have individual private water supply wells as the servicing works are not yet complete however the subject lands were previously farm land and did not have extensive residential use.

A review of the MECP water well records indicated that there are approximately 10 water supply well records within 500 m of the subject lands. Based on the well records and interpreted hydrostratigraphy, most of these wells are completed in the surficial (local) aquifer with depths ranging from 7 m to 38 m. The cross-sections completed indicate that the top of the shallow productive aquifer zone is located at elevations between 250 and 240 masl) and generally in excess of 7 m below grade across the subject lands. The locations of the MECP water well records are shown on Figure 8.

There are no municipal water supply wells located in the vicinity of the subject lands. The closest municipal supply wells are located on the west and northern sides of the city and more than 5 kilometers from the subject lands. The subject lands do not fall within any wellhead protection areas or intake protection zones associated with the City of Barrie water supply systems (LSRCA, 2012). The City of Barrie groundwater supply wells are located in deep aquifers (A3 and A4 in the regional hydrostratigraphy). These aquifers are interpreted to be found at elevations of 150 masl to 195 masl and 115 masl to 160 masl respectively and are therefore significantly below (approximately 70 to 100 m below the surficial layer found on the subject lands) and separated from any potential impact due to the proposed development (AquaResource et al., 2011).

3.2 Water Level Monitoring Results

Groundwater levels were monitored at 8 monitoring wells across the subject lands in order to gain information on groundwater distribution and fluctuations. Groundwater levels were monitored between June 2019 and December 2020. Groundwater level data is provided in tables and hydrographs in Appendix D. Groundwater elevations are plotted with daily precipitation data obtained from a nearby climate station – Barrie Landfill Climate Station (Climate Station ID#6110556)) which is the closest station with daily precipitation values for 2019 and 2020.

In addition to the manual water level measurements recorded at each location, automatic water level recorders (loggers) collected hourly water level data at LI-BH2, LI-BH12, LI-BH15, MW12 and LM-PZ1d. The datalogger data collected are included on the hydrographs provided in Appendix D.

The groundwater monitoring data show the following (refer to Figure 2 for the monitoring locations and the data tables and hydrographs in Appendix D):

- The groundwater table is interpreted to be dependent on the topography and local geological conditions. From June 2019 to December 2020, groundwater elevations in the monitoring wells ranged from 248.3 masl to 259.4 masl.

- Typically, in shallow wells in southern Ontario, a seasonal groundwater level pattern is apparent with highest levels occurring in the spring, declining throughout the summer and early fall and then rising again in the late fall/early winter. This pattern was observed in the on-site wells with seasonal variations ranging from 1.3 m to 4.9 m (Figures D-1 to D-8, Appendix D).

- LI-BH8 and LI-BH10 screened in silty sand till underlying a confining layer of silty clay show seasonal water levels that exhibit potentiometric (pressure) heads that are near or above grade (Figure D-2, Figure D-3, Appendix D). These heads are interpreted to be due to the wells penetrating the surficial layers and being completed in the underlying aquifer. Pressure heads are not expected to be present in the silty clay confining layer.

- LI-BH2, LI-BH12 and LI-BH15 are screened in a silty sand till that may be in contact with underlying sandy layers or aquifer units. Water levels at these wells were measured seasonally near surface (Figure D-1, Figure D-4 and Figure D-5, Appendix D).

- Groundwater levels at LI-BH19 located near the high point on the west side of the subject lands and screened at a depth of 9.1 m in sand, ranged from 5.5 m to 8.2 m bgs (Figure D-6, Appendix D).

- Continuous water level data at LI-BH2, LI-BH12 and LI-BH15 are plotted against precipitation to determine if there is a correlation between changes in water level and the occurrence of precipitation events (Figures D-1, D-4 and D-5, Appendix D). The logger data shows correlation between water levels and large precipitation events such as seen in October 2019 and January 2020. The impact on water levels differs between wells for example, in October 2019 a rain event of 52 mm over two days resulted in a groundwater level increase of 0.6 m at LI-BH2, an increase of 0.45 m at LI-BH12 and an increase of 0.3 m at LI-BH15. All of the wells are completed in the silty sand till layer found underlying the subject lands. This layer functions as a poor aquifer and the response to precipitation is interpreted to be due to fracturing of the till layer.

- MW12 was monitored as part of the Hewitt's SIS and therefore has groundwater levels starting from May 2014 (Figure D-8, Appendix D). The hydrograph indicates that over a six-year period water levels ranged from 0.4 m to 2.2 m below surface. Water levels close to surface were observed generally in the winter and spring months with seasonal lows down to 2.2 m observed in late summer/early fall. This well was also completed in the silty sand layer and is interpreted as representing potentiometric pressures below a confining surficial layer.

3.3 Interpreted Groundwater Flow Pattern

Groundwater flow on the subject lands is interpreted to be influenced by the surface topography with groundwater flow from the topographically higher areas towards topographically lower areas and surface water features. Groundwater elevation data (March 2020) obtained from the monitoring wells are shown on Figure 9, along with the interpreted groundwater elevation contours for the area. Arrows perpendicular to the groundwater elevation contours shown on Figure 9 illustrate the interpreted direction of the groundwater movement. As illustrated in Figure 9, shallow groundwater flows towards the tributary of Lovers Creek and Lovers Creek Swamp. Groundwater flow convergence is shown towards these features which suggests that groundwater discharge may be possible.

3.4 Recharge and Discharge Conditions

Areas where water from precipitation or runoff infiltrates into the ground and moves downward (i.e., areas of downward hydraulic gradients) are known as recharge areas. These areas are generally found at relatively higher topographic elevation. Areas where groundwater moves upward (i.e., areas of upward hydraulic gradients) or where groundwater intersects the ground surface are discharge areas and these generally occur in areas of relatively lower topographic elevation, such as along watercourses.

When evaluating groundwater recharge or discharge conditions, nested wells (two wells screened at different depths at the same location) can be used to determine vertical hydraulic gradients and groundwater recharge or discharge conditions in the subsurface.

There were no nested monitoring wells on the subject property however at or near surface groundwater potentiometric levels at LI-BH2, LI-BH8, LI-BH10, LI-BH15, LI-BH12 and MW12 indicate upward gradients within the underlying sandy silt till layer. It is interpreted that the high elevations on the south west and northeast portions of the subject lands serve as a driver of groundwater heads (potentiometric heads) downgradient and within the sandy silt layer. Seasonal groundwater highs based on these potentiometric surfaces are close to surface in some wells located at the lower elevations or where these wells penetrate the sandy silt layer. These conditions are interpreted as indicating the potential for seasonal groundwater discharge where appropriate geological conditions exist (sandy silt layer is at surface). It is also interpreted that local conditions within the overlying till have created semi confined conditions in the area of LI-BH8 and LI-BH10.

3.4.1 Groundwater Surface Water Interactions

To assess shallow groundwater conditions and gradients near the watercourses and wetlands three drive-point piezometer nests were monitored.

Piezometer nest LM-PZ1s/d is located at the edge of Lovers Creek Swamp (Figure 2). The hydrograph of LM-PZ1s/d (Figure D-9) indicates water levels close to or above ground surface in the winter and spring and decreasing during the summer months. The water levels are impacted by precipitation events, increasing 0.4 m after a large precipitation event in October 2019. The gradient between the shallow piezometer and deep piezometer is not very strong at this location, however a slight upward gradient is observed during the majority of monitoring events (Figure D-9, Appendix D). It is interpreted that seasonal discharge conditions are present in this area and that this groundwater discharge contributes to surface water flow and wetland conditions in Lovers Creek Swamp.

LI-PZ2s/d is located within the Lovers Creek Swamp north of the subject lands. The hydrograph for LI-PZ2s/d (Figure D-10, Appendix D) shows the water levels in the deep piezometer higher than the shallow piezometer during all monitoring rounds except for September 2019. This indicated an upward gradient and discharge conditions within the wetland.

LI-PZ3s/d is located along the tributary of Lovers Creek near Lockhart Road. The hydrograph for LI-PZ3s/d (Figure D-11, Appendix D) shows that the groundwater level ranged from 0.7 m bgs to at or above ground surface in the vicinity of this piezometer. A seasonal upward gradient (shallow water level lower than deep water level) is observed at LI-PZ3s/d confirming that groundwater discharge conditions exist in this area.

3.5 Significant Groundwater Recharge Areas and Ecologically Significant Groundwater Recharge Areas

Significant Groundwater Recharge Areas (SGRAs) can be described as areas that can effectively move water from the surface through the unsaturated soil zone to replenish available groundwater resources (LSRCA, 2012). SGRAs were mapped by the Source Water Protection Assessment Report (LSRCA, 2012) as a requirement of the Clean Water Act, 2006 and based on guidance provided by the MECP. The delineation of these areas was completed using numerical models and analyses that included the evaluation of numerous factors including precipitation, temperature and other climate data along with land use, soil type, topography and vegetation to predict groundwater recharge, runoff and evapotranspiration. SGRAs represent areas where the annual recharge rate is greater than 115% of the average recharge of 164 mm/year across the Lake Simcoe watershed (or greater than the threshold recharge rate of 189 mm/year) (LSRCA, 2012). There are no SGRAs mapped on the subject lands (Figure 10).

Ecologically Significant Groundwater Recharge Areas (ESGRAs) were delineated for the Barrie Creek, Lovers Creek and Hewitt's Creek subwatersheds by Earthfx (2012) using the model developed by AquaResources for the Source Protection studies. ESGRAs were identified as areas of land that are assumed to support groundwater systems or environmentally sensitive features like lakes, cold water streams and wetlands (Earthfx, 2012). ESGRAs were delineated by identifying pathways in which recharge, if it occurred, would reach an ecologically significant feature. Ecologically significant features used for the delineation of the ESRGAs included headwater streams, cold water fisheries, wetlands, and brook trout and sculpin capture sites.

Figure 10 shows the LSRCA mapping of ESGRAs on the subject lands. Because the mapping is based on a groundwater model the areas appear to be discontinuous patches distributed across the subject lands. Within the subject lands, areas mapped as ESRGAs are located along Lockhart Road and the eastern edge of the subject lands (Figure 10). Groundwater recharge as it occurs in this area is through the surficial silty clay and silty sand till sediments and groundwater contours interpreted for the subject lands (Figure 9) indicate that groundwater is moving towards the wetland. The actual recharge rates (based on expected groundwater flux) through the sediments confirmed on the subject lands are not expected to be significant as the silty sand till sediments that have been characterized as having a moderate hydraulic conductivity have a limited potential to move significant quantities of groundwater.

4.0 Surface Water Monitoring

To characterize the surface water flow conditions of watercourses on the subject lands monitoring locations were established and surface water flow conditions were measured during monitoring events. Surface water flow monitoring was conducted at two monitoring locations, SS2 and SS3 (Figure 2). Flow monitoring was completed as part of this study from June 2019 to December 2020. Surface water flow monitoring data is provided in Table E-1, Appendix E and summarized below. Monitoring data collected as part of the Hewitt’s Creek SIS study from 2014 to 2017 is also included in Table E-1.

- SS2 is located along a tributary to Lovers Creek within the Lovers Creek Swamp. The channel at SS2 is well defined with a rocky bottom and ranges in width from about 1 m to 1.5 m. Our field observations note the presence of tile drains from nearby agricultural fields that outlet at this location. The surface water flow data for this location show that flow ranges from 0.7 L/s up to 127 L/s (Table E-1, Appendix E) and is generally always present except for during the winter months when conditions are recorded as frozen. No flow and dry conditions were recorded in the summer of 2019 (August, September). Minimal flow of approximately 2 L/s in the watercourse in June 2014, six days after a rain event suggests that groundwater discharge supports baseflow in this watercourse during low flow conditions.

- SS3 is located upstream of SS2, also along the tributary of Lovers Creek. The channel at SS3 is vegetated, well defined with a rocky bottom and follows the fence line of an agricultural field suggesting it may have been excavated for field drainage in the past. The channel ranges in width from about 1 m to 1.5 m with recorded water depths ranging from 0.15 m to 0.3 m. Flow measurements at this location show surface water is always present with flows recorded in a range from less than 0.5 L/s up to a maximum of 46 L/s. Water levels were however dry in August and September 2019. There was minimal flow of approximately 1 L/s in this channel six days after a rain event which suggests that some minor groundwater discharge supports baseflow in this watercourse during low flow conditions. In general, the flow volumes at SS3 were less than flow volumes measured at SS2 showing that the tributary gains flow across the study area.

Surface water levels were also collected at each surface water monitoring station (SG-2 and SG-3). The surface water levels are provided in Table E-2, Appendix E. The staff gauge readings indicate that water is consistently at SG-3 and that at SG-2 surface water is generally observed in the spring and winter and dries up in the summer and fall.

5.0 Water Quality

5.1 Groundwater Quality

Water quality data was collected from selected monitoring wells to typify the groundwater quality on the subject lands. Groundwater sampling was completed on Augusts 29, 2019 at two groundwater monitoring wells (LI-BH2 and LI-BH15). The water samples were submitted to an accredited laboratory for analyses of general water quality indicators (e.g., pH, hardness, and conductivity), basic ions (including chloride and nitrate) and selected metals to characterize the background water quality.

For comparison purposes, the Ontario Drinking Water Quality Standards (ODWQS) and the Provincial Water Quality Objectives (PWQO) are provided with the results on Table E-1, Appendix E. The groundwater will not be used for drinking water however the ODWQS provides an indication of acceptable concentrations for potable water. The PWQO provide an indication of whether the groundwater on the subject lands could be discharged to surface water should pumping associated to construction be required. The groundwater testing results from the analytical laboratory are provided in Table F-1, Appendix F and discussed below.

- The results showed that the water generally met the Ontario Drinking Water Quality Standards (ODWQS) with the exception of total hardness and turbidity.
- Both samples exceeded the ODWQS for total hardness (100 mg/L) with values of 264 mg/L (LI-BH2) and 255 mg/L (LI-BH15 Hardness in groundwater is caused by dissolved calcium and magnesium and is typically related to the geologic material of the aquifer. Elevated values are typical for aquifers in Southern Ontario.
- Samples exceeded the ODWQS for turbidity (5 NTU) with values of 126000 NTU (LI-BH2) and 392 NTU (LI-BH15). The high turbidity is likely a result of high silt content in the samples. It is noted that the monitoring wells were originally constructed as geotechnical boreholes and are not likely to have been developed as part of construction. The high silt content is likely related to the lack of well development and is not considered to be a water quality issue in this area.
- Nitrate was detected in both of the samples with values of 5.87 mg/L (LI-BH2) and 8.92 mg/L (LI-BH15). Nitrate in shallow groundwater is typical of areas where agricultural activities are present such as the subject lands. Both samples were below the ODWQS for nitrate, 10 mg/L.

- The results show that the groundwater samples met the Provincial Water Quality Objectives and therefore should be suitable for discharge to surface water after sediment control.

6.0 Water Balance

In order to assess potential land development impacts on the local groundwater conditions, a detailed water balance analysis has been completed to determine the pre-development recharge volumes (based on existing land use conditions) and the post-development recharge volumes that would be expected based on the proposed land use plan. The detailed water balance calculations are provided in Appendix G.

6.1 Water Balance Components

A water balance is an accounting of the water resources within a given area. As a concept, the water balance is relatively simple and may be estimated from the following equation:

$$P = S + ET + R + I$$

Where:
P = precipitation
S = change in groundwater storage
ET = evapotranspiration/evaporation
R = surface water runoff
I = infiltration

The components of the water balance vary in space and time and depend on climatic conditions as well as the soil and land cover conditions (i.e., rainfall intensity, land slope, soil hydraulic conductivity and vegetation/ land cover). Runoff, for example, occurs particularly during periods of snowmelt when the ground is frozen, or during intense rainfall events. Precise measurement of the water balance components is difficult and as such, approximations and simplifications are made to characterize the water balance of an area. Field observations of the drainage conditions, land cover and soil types, groundwater levels and local climatic records are important input considerations for the water balance calculations. The water balance for the current assessment was calculated based on a soil moisture approach using a spreadsheet model. The input parameters are discussed below:

Precipitation (P)

The long-term average annual precipitation (Climate normal) for the area is 933 mm / year based on data from the Environment Canada Barrie WPCC (Station 6110557, 44°22'33.012" N, 79°41'23.010" W, elevation 221.0 masl) for the period between 1981 and 2010. The climate station is located 5.2 km northwest of the subject lands and was selected to be consistent with the analysis that was done during the SIS (Burnside 2016). Average monthly records of precipitation and temperature from this station have been used for the water balance calculations in this study (Appendix G).

Storage (S)

Although there are groundwater storage gains and losses on a short-term basis, the net change in groundwater storage on a long-term basis is assumed to be zero so this term is dropped from the equation for the annual calculations that were performed.

Evapotranspiration (ET)

Evapotranspiration and evaporation components vary based on the characteristics of the land surface cover (i.e., type of vegetation/land cover, soil moisture conditions, perviousness of surfaces, etc.). Potential evapotranspiration (PET) refers to the water loss from a vegetated surface to the atmosphere under conditions of an unlimited water supply. The actual rate of evapotranspiration (AET) is generally less than the PET under dry conditions (i.e., during the summer when there is a soil moisture deficit). In this report, the PET and AET have been calculated using a soil-moisture balance approach. Evaporation occurs from impervious surfaces and where these surfaces are present, the transpiration component does not occur, instead all water lost is via evaporation (E).

Water Surplus (R + I)

The difference between the mean annual P and the mean annual ET is referred to as the water surplus. When generated, part of the water surplus travels across the surface of the soil as surface or overland runoff (R) and the remainder infiltrates the surficial soil (I). The infiltration portion is comprised of two end member components: one component that moves vertically downward to the groundwater table (referred to as recharge) and a second component that moves laterally through the topsoil profile or shallow soils as interflow that re-emerges locally to surface (i.e., as runoff) at some short time following cessation of precipitation. As opposed to the “direct” component of surface runoff that occurs during precipitation or snowmelt events, interflow becomes an “indirect” component of runoff. The interflow component of surface runoff is not accounted for in the water balance equation cited above since it is often difficult to distinguish between interflow and direct (overland) runoff, however both interflow and direct runoff together form the total surface water runoff component.

6.2 Approach and Methodology

The analytical approach to calculate the water balance involves monthly soil-moisture balance calculations to determine the pre-development (based on existing land use) infiltration volumes. For the purposes of this study, the water balance calculations were undertaken using a spreadsheet model. The soil-moisture balance approach utilized assumes that soils do not release water as potential recharge while a soil moisture deficit exists. During wetter periods, any excess of precipitation over evapotranspiration first goes to restore soil moisture. Once the soil moisture deficit is overcome, any further excess water can then pass through the soil as infiltration and either become interflow (indirect runoff) or recharge (deep infiltration).

The soil moisture capacity for the soils on the subject lands were estimated based on guidance available in the MECP SWM Planning and Design Manual (2003). A soil moisture storage capacity of 150 mm was assumed for the agricultural land use within the subject lands with predominantly short to moderate-rooted vegetation (Table G-1, Appendix G). A soil moisture storage capacity of 300 mm was assumed for wooded areas within the subject lands (Table G-2, Appendix G). A soil moisture storage capacity of 75 mm was used to represent the post-development vegetation which will dominantly be urban lawn (Table G-3, Appendix G). Tables G-1, G-2 and G-3 in Appendix G detail the monthly potential evapotranspiration calculations accounting for latitude and climate, and then calculate the actual evapotranspiration and water surplus components of the water balance based on the monthly precipitation and soil moisture conditions.

The MECP SWM Planning and Design Manual (2003) methodology for calculating total infiltration based on topography, soil type and land cover was used and a corresponding runoff component was calculated for the soil moisture storage conditions. The calculated water balance components from this table are then used to assess the pre-development and post development volumes for runoff and infiltration as presented on Table G-4 in Appendix G.

6.3 Water Balance Component Values

The detailed monthly calculations of the water balance components are provided in Tables G-1, G-2 and G-3 in Appendix G. The infiltration and runoff components have been calculated using the infiltration factor methodology from Table 3.1 of MECP SWM Planning and Design Manual (2003). The methodology accounts for topography, soil type and land cover assigning a factor between 0.1 and 0.3 to each component. The infiltration factors used in this analysis and rationale behind their selection are summarized below in Table 3.

Table 3: Infiltration Factors

	Pre-Development				**Post-Development**	
	Agricultural		**Wooded Areas**		**Urban Lawn**	
	Factor	**Rational**	**Factor**	**Rational**	**Factor**	**Rational**
Topography	0.1	Slope of 5%	0.1	Similar slope	0.1	Similar to pre-conditions
Soils	0.25	Sandy clay loam soils	0.25	Sandy clay loam soils	0.25	Same soils as pre-conditions

	Pre-Development				Post-Development	
	Agricultural		Wooded Areas		Urban Lawn	
	Factor	Rational	Factor	Rational	Factor	Rational
Cover	0.1	Predominantly cultivated land	0.2	Woodland	0.1	Urban lawns
Total	0.45		0.55		0.45	

The calculations show that a water surplus is generally available from November to May. The monthly water balance calculations illustrate how infiltration occurs during periods when there is sufficient water available to overcome the soil moisture storage requirements. The monthly calculations are summed to provide estimates of the annual water balance component values (Tables G-1, G-2 and G-3, Appendix G). A summary of these values is provided in Table 4.

Table 4: Water Balance Component Values

Water Balance Component	Agricultural Lands	Wooded Areas	Urban Lawn
Average Precipitation	933 mm/year	933 mm/year	933 mm/year
Actual Evapotranspiration	593 mm/year	593 mm/year	580 mm/year
Water Surplus	340 mm/year	340 mm/year	353 mm/year
Infiltration	153 mm/year	187 mm/year	159 mm/year
Runoff	187 mm/year	153 mm/year	194 mm/year

6.4 Pre-Development Water Balance (Existing Conditions)

The water balance component values from Table G-1 and Table G-2 were used to calculate the average annual volume of infiltration across the subject lands. Based on these component values, the total pre-development infiltration volume for the subject lands is calculated to be about 84,200 m^3/year.

6.5 Potential Urban Development Impacts to Water Balance

Development of an area affects the natural water balance and results in differences between pre-development and post-development water balance due to the changes to various parameters caused by the development process. The most significant change in conditions is due to the addition of impervious surfaces as a type of surface cover (i.e., roads, parking lots, driveways, and rooftops). Impervious surfaces prevent infiltration of water into the soils and the removal of the vegetation removes the evapotranspiration component of the natural water balance. The evaporation component from impervious surfaces is relatively minor (estimated to be 10% to 20% of precipitation) compared to the evapotranspiration component that occurs with vegetation in this area (about 64% of precipitation in the study area). So, the net effect of the construction of impervious surfaces is that most of the precipitation that falls onto impervious surfaces becomes surplus water and direct runoff. The natural infiltration components (interflow and deep recharge) are reduced.

A water balance calculation of the potential water surplus for impervious areas is shown at the bottom of Table G-1 in Appendix G. For the purposes of the calculations in this study, the evaporation has been estimated to be 15% of precipitation. The remaining 85% of the precipitation that falls on impervious surfaces is assumed to become runoff. Therefore, assuming an evaporation/loss from impervious surfaces of 15% of the precipitation, there is a potential water surplus from impervious areas of 793 mm/year.

It is noted that the proposed development will be serviced by municipal water supply and wastewater services. Therefore, there will be no impact on the water balance and local groundwater or surface water quantity and quality conditions related to any on-site groundwater supply pumping or disposal of septic effluent.

6.6 Post-Development Water Balance with No Mitigation

To assess potential development impacts on infiltration, the post-development infiltration volumes have been calculated for the subject lands on Table G-4 in Appendix G. The proposed land use areas were provided by Jones Consulting Group. Since a stormwater management study has not yet been completed for the subject lands a typical percentage imperviousness for each land use that is similar to values used in previous studies in the Hewitt's SPA was used in Table G-4, Appendix G. The percentage imperviousness for the land uses will be refined during detailed design.

The infiltration and runoff components for the post-development land uses have been calculated using the MECP SWM Planning and Design Manual (2003) methodology based on topography, soil type and land cover as shown on Table G-3 in Appendix G. The calculated post-development infiltration volume (without mitigation) for the subject lands is 51,000 m^3/year.

Comparing the pre- and post-development infiltration volumes, shows that development has the potential to reduce the average infiltration on the subject lands by 39% or 33,140 m^3/year (Table G-4 in Appendix G). These calculations assume no low impact development (LID) measures for stormwater management are in place.

6.7 Mitigation Strategies for Infiltration

In order to minimize the potential impacts of development on the water balance, the use of Low Impact Development (LID) measures for stormwater management are generally recommended by the conservation authority. LID is based on the premise of trying to manage stormwater to minimize the runoff of rainfall and increase the potential for infiltration where possible. There are, as outlined in the MECP SWMP Design Manual

(2003) and Low Impact Development (LID) Stormwater Management Planning and Design Guide published by the CVC and TRCA (2010), a number of best management practices and mitigation techniques that can be used to increase the potential for post-development infiltration and mitigate the reductions in infiltration that occur with residential land development.

Techniques to maximize the water availability in pervious areas such as designing grades to direct roof runoff towards lawns, side and rear yard swales, boulevards, parks, and other open space areas throughout the development where possible can increase infiltration and reduce the volume of runoff directed to stormwater management facilities. Increasing the topsoil thickness is a method to increase the soil water storage area and potentially increase recharge volumes. Other LID practices that may be considered to control stormwater runoff for residential development areas include, but are not limited to, the use of vegetated buffer strips, rain gardens, construction of bioretention cells or bioswales, tree pits, cisterns and the use of porous pavers.

Where feasible, measures to minimize development impacts on the water balance will be incorporated into the development design. Based on the water balance calculations presented above, the difference between the pre- and post-development recharge volumes is estimated to be about 33,140 m^3/year (Table G-4, Appendix G), and can be considered as an infiltration target for the design of stormwater management and LID measures for the subject lands.

7.0 Development Considerations

7.1 Construction Below the Water Table

Based on groundwater level data collected as part of this study water table on the subject lands range from 0 m to 8 m below ground surface. Groundwater has been interpreted to exist within the local supply aquifer with seasonal variations, discharge gradients and local semi-confining conditions resulting in shallow groundwater conditions on a temporal and spatial basis. Should excavations during construction of servicing extend below the water table the local soils may need to be dewatered. Significant groundwater flows may be encountered in the deeper higher permeability sand and gravel layers while groundwater flows are expected to be minimal in the shallower low permeability till sediments.

The construction of buried services below the water table has the potential to capture and redirect groundwater flow through more permeable fill materials typically placed in the base of excavations. Groundwater may also infiltrate into joints in storm sewers and manholes. Over the long-term, these impacts can lower the groundwater table across the development area. To mitigate this effect, services to be installed below the water table should be constructed to prevent redirection of groundwater flow. This will involve the use of anti-seepage collars or clay plugs surrounding the pipes to provide barriers to flow and prevent groundwater flow along granular bedding material and erosion of the backfill materials.

Due to the potential for encountering the water table during construction, the dewatering of local aquifers may be required in order for services to be installed below the water table. The undertaking of dewatering according to industry standards and in accordance with a MECP processes will ensure that adequate attention is paid to potential adverse impacts to the environment. Currently the MECP allows for construction dewatering of less than 400,000 L/d to proceed under the Environmental Activity Sector Registry (EASR) process. If dewatering is to be above this threshold, then the standard Permit to Take Water (PTTW) process applies. In both cases, a scientific study is required in support of EASR registration or PTTW application. This scientific study must review the potential for environmental impacts and provide mitigation and monitoring measures to the satisfaction of the MECP or other review agency. The requirements for construction dewatering will be confirmed by geotechnical/hydrogeological investigations completed in support of detailed design.

7.2 Local Groundwater Supply Wells

The area surrounding the subject lands is not currently serviced and residences are supplied by private wells. A water well survey has been completed on behalf of the Hewitt’s Landowners Group to identify private water supply wells within 300 m of the Hewitt’s SPA area (Burnside, 2019). The survey confirmed the location of private wells along Lockhart Road. The private wells are assumed to be completed in the local sand and gravel layer that underlies the shallow sandy silt till zone. The low permeability of the shallow sandy silt till is expected to restrict the potential zone of influence due to construction activities and hence construction impacts are not expected to be extensive in area but rather limited to the immediate vicinity of the excavations. Dewatering of the subject lands may result in short-term removal of water from the subsurface however this impact is expected to be limited to the shallow sandy silt layer that is above and separated from the sand and gravel layer in which most of the private domestic wells are completed. A monitoring program for high-risk wells has been implemented by the Hewitt’s Landowner Group starting in the spring of 2019. An impact contingency and mitigation plan for private well impacts was included in the monitoring program. The plan provides a mechanism for interference complaints to be addressed and for a temporary alternate water supply to be provided. Details of the monitoring and mitigation plan are provided in the report entitled “Hewitt’s SPA Lands Well Survey Report” R.J. Burnside & Associates Limited (Revised June 2019).

7.3 Well Decommissioning

Prior to or during construction, it is necessary to ensure that all inactive wells within the development footprint have been located and properly decommissioned by a licensed water well contractor according to Ontario Regulation 903. This regulation applies private domestic wells and to the groundwater observation wells installed for this study unless they are maintained throughout the construction for monitoring purposes.

8.0 References

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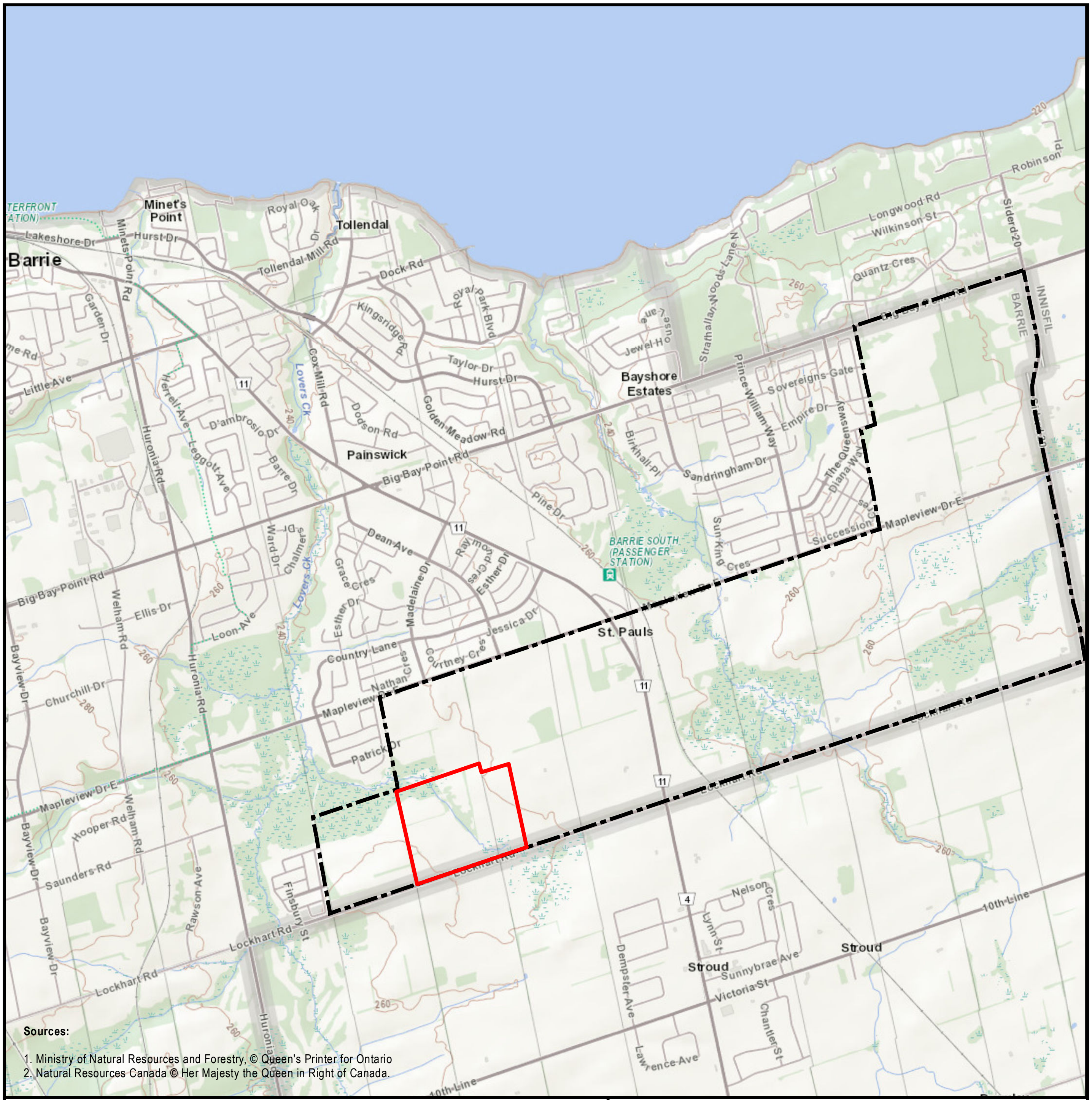
Figures



Sources:

1. Ministry of Natural Resources and Forestry, © Queen's Printer for Ontario
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LEGEND

▭ HEWITTS SECONDARY PLAN AREA

🟥 SUBJECT LANDS

0 250 500 1,000 1,500 2,000 2,500 3,000

Metres

N

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HYDROGEOLOGICAL ASSESSMENT

Figure Title:

SITE LOCATION

Drawn	Checked	Date	Figure No.
SK	SC	July 2021	1
Scale		Project No.	
1:40,000		300043818	

File Path: Nigel/Shared Work Areas/043818 Lockhart Innisfil/06_GIS/043818 Site Location.mxd

Sources:

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3. Sattelite image from Arcgis Online Base Mapping, World Imagery, Maxar 2019.

LEGEND

- 🟥 SUBJECT LANDS
- ═ WATERCOURSE
- ⊕ MONITORING WELL (RJB, 2014)
- ⊕ MONITORING WELL (SOIL ENG., 2019)
- ● DRIVE POINT PIEZOMETER
- 🟩 STAFF GAUGE
- ▲ SURFACE WATER MONITORING LOCATION

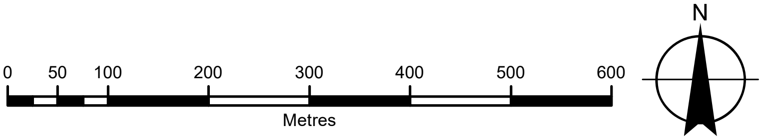

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Figure Title:

MONITORING LOCATIONS

Drawn	Checked	Date	Figure No.
SK	SC	July 2021	2
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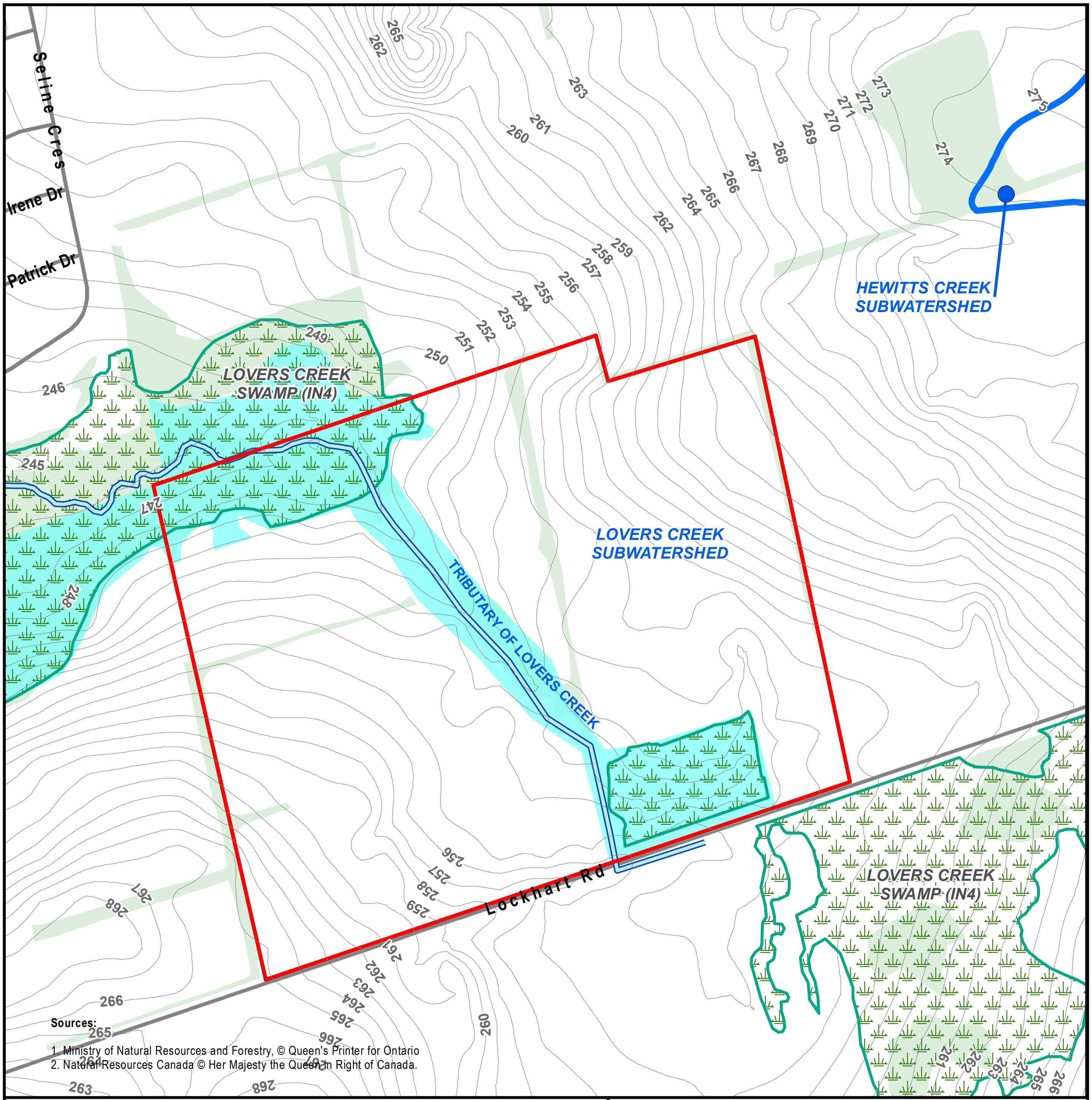

Sources:
1. Ministry of Natural Resources and Forestry, © Queen's Printer for Ontario
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LEGEND

- 🟥 SUBJECT LANDS
- SUBWATERSHED BOUNDARY
- WATERCOURSE
- CONTOUR (1m intervals - masl)
- 🟦 WETLAND (AZIMUTH, 2014)
- 🟩 WETLAND (MNRF, 2021)
- ROADWAY
- 🟩 WOODED AREA

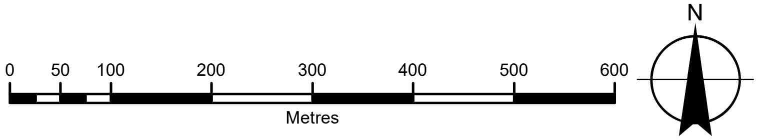

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Figure Title:

TOPOGRAPHY AND DRAINAGE

Drawn SK	Checked SC	Date July 2021	Figure No. 3
Scale 1:7,500		Project No. 300043818	

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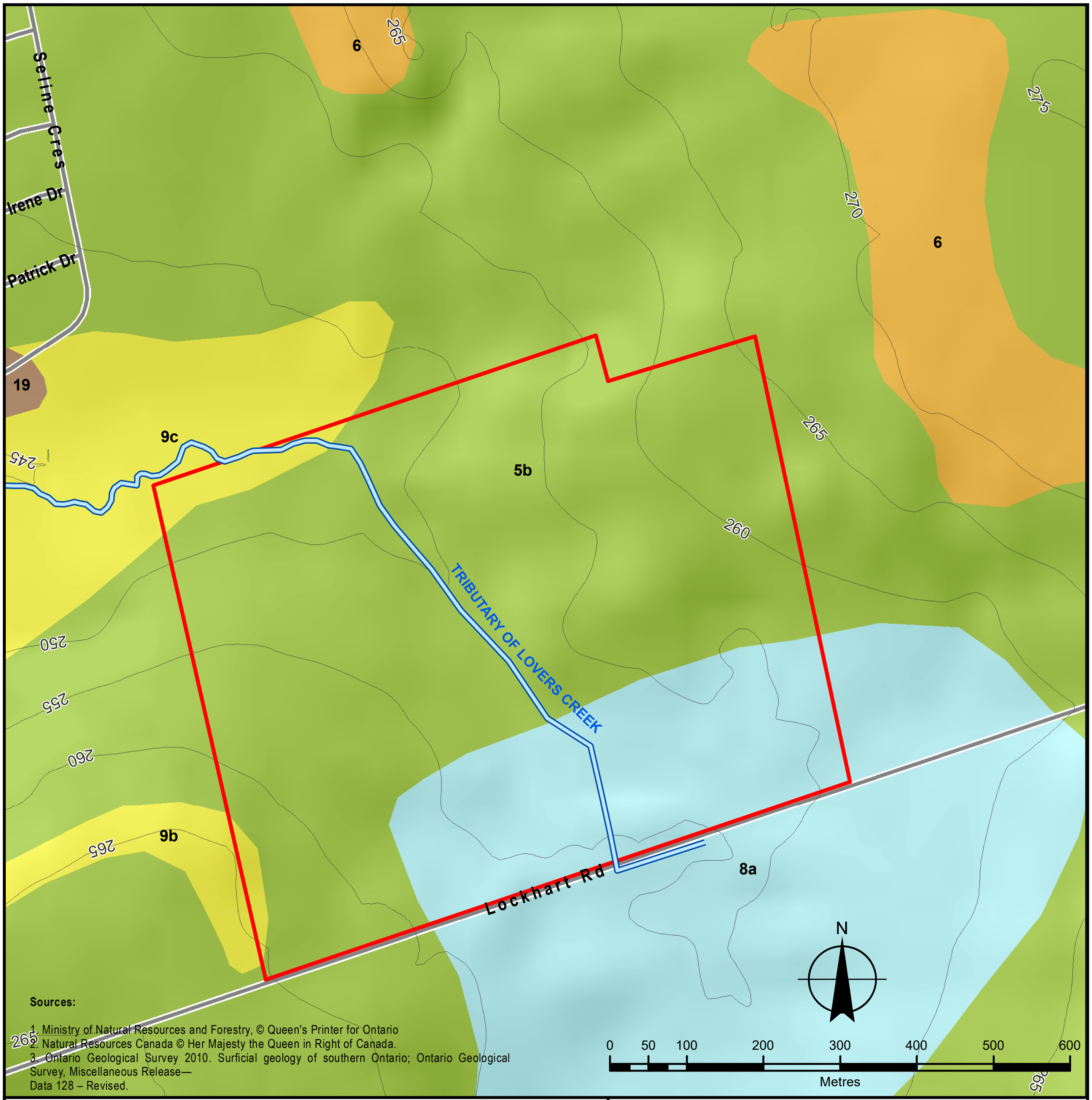

Sources:

1. Ministry of Natural Resources and Forestry, © Queen's Printer for Ontario
2. Natural Resources Canada © Her Majesty the Queen in Right of Canada.
3. Ontario Geological Survey 2010. Surficial geology of southern Ontario; Ontario Geological Survey, Miscellaneous Release— Data 128 – Revised.

LEGEND

- 🟥 SUBJECT LANDS
- — ROADWAY
- ═ WATERCOURSE
- — CONTOUR (5m intervals - masl)
- 🟩 5b: Till - Stone-poor, sandy silt to sikty sand-textured till on Paleozoic terrain
- 🟧 6: Ice-contact stratified deposits - sand and gravel, minor silt, clay and till
- 🟦 8a: Fine-textured glaciolacustrine deposits - silt and clay, minor sand and gravel - Massive-well laminated
- 🟨 9b: Coarse-textured glaciolacustrine deposits - sand, gravel, minor silt and clay - Littoral Deposits
- 🟨 9c: Coarse-textured glaciolacustrine deposits - sand, gravel, minor silt and clay - Littoral Deposits Foreshore-basinal deposits
- 🟫 19: Modern alluvial deposits - clay, silt, sand, gravel, may contain organic remains

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Figure Title:

SURFICIAL GEOLOGY

Drawn	Checked	Date	Figure No.
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Scale		Project No.	
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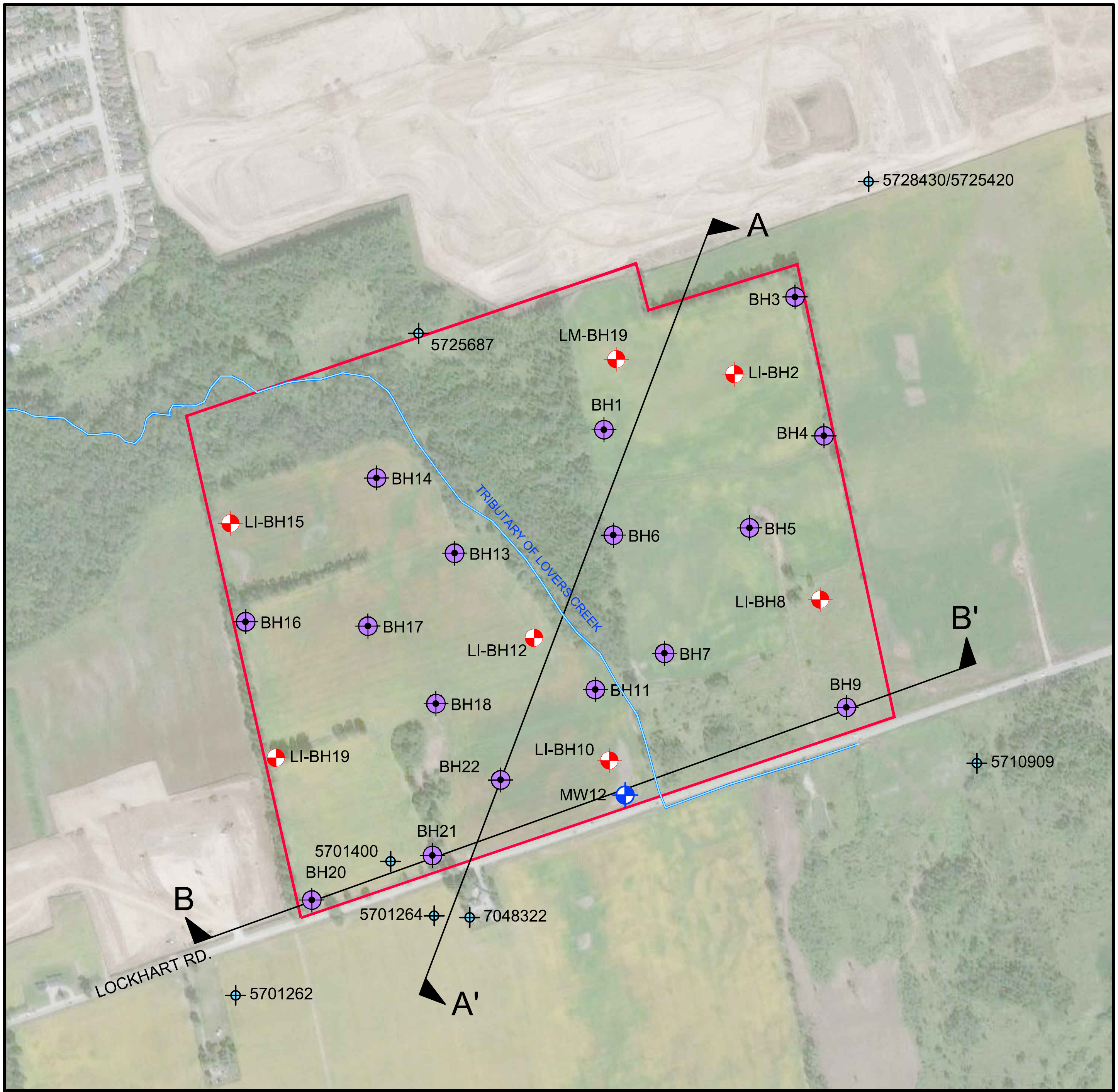

LEGEND

▭	SUBJECT LANDS
—	WATERCOURSE
⊕	MONITORING WELL (RJB, 2014)
⊕	MONITORING WELL (SOIL ENG., 2019)
⊕	BOREHOLE (SOIL ENG., 2019)
⊕	MECP WELL RECORD LOCATION
A A'	CROSS-SECTION LOCATION KEY

0 100 200 400 600

Metres

N

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Figure Title

BOREHOLE, WELL AND
CROSS-SECTION LOCATION PLAN

Drawn	Checked	Date	Figure No.
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Scale		Project No.	
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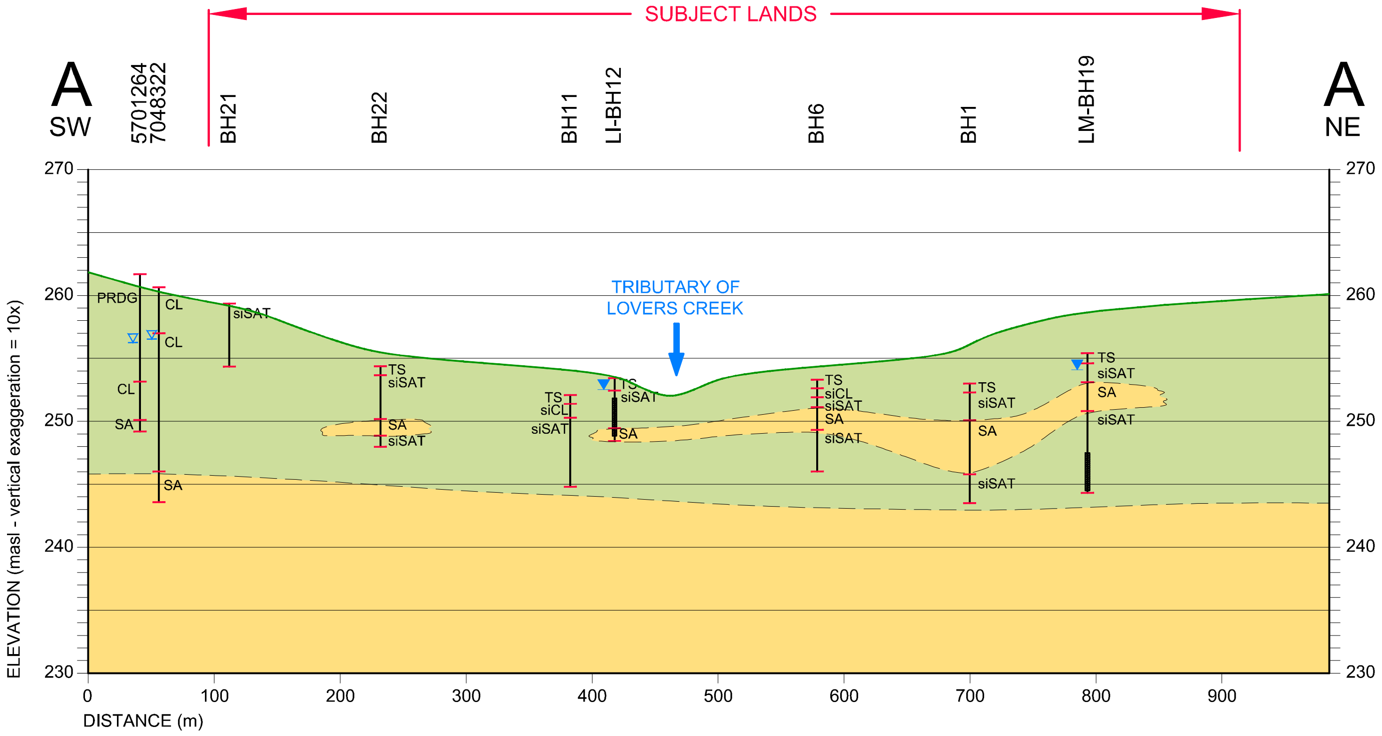

LEGEND

BH1 WELL NUMBER / ID

EXISTING GROUND PROFILE

GEOLOGICAL CONTACT

▼ MEASURED WATER LEVEL (March 26, 2020)

▽ STATIC WATER LEVEL (MECP WELL RECORD)

▨ WELL SCREEN

– – – INTERPRETED STRATIGRAPHY

si	SILTY
sa	SANDY
cl	CLAYEY
TS	TOPSOIL
PRDG	PREDUG
T	TILL
GR	GRAVEL
SA	SAND
Si	SILT
CL	CLAY
ST	STONES

🟨 SAND / SILT / GRAVEL

🟩 SILT / CLAY / TILL

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HYDROGEOLOGICAL ASSESSMENT

Figure Title

INTERPRETED GEOLOGICAL CROSS-SECTION A-A'

Drawn	Checked	Date	Figure No.
SK	SC	July 2021	6
Scale		Project No.	
1:6,000		300043818	

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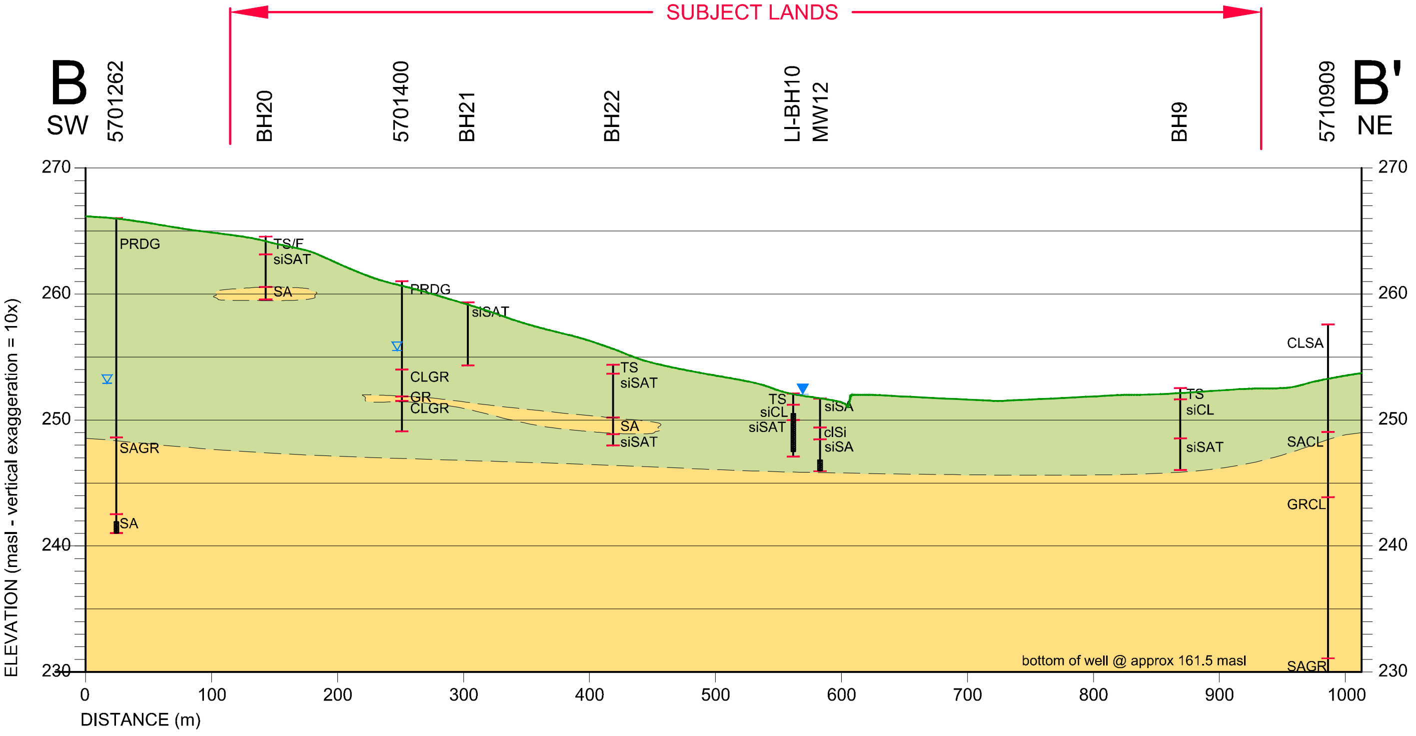

LEGEND

BH1 WELL NUMBER / ID

EXISTING GROUND PROFILE

GEOLOGICAL CONTACT

▼ MEASURED WATER LEVEL (March 26, 2020)

▽ STATIC WATER LEVEL (MECP WELL RECORD)

▨ WELL SCREEN

– – – INTERPRETED STRATIGRAPHY

si	SILTY
sa	SANDY
cl	CLAYEY
TS	TOPSOIL
PRDG	PREDUG
T	TILL
GR	GRAVEL
SA	SAND
Si	SILT
CL	CLAY
ST	STONES

🟨 SAND / SILT / GRAVEL

🟩 SILT / CLAY / TILL

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Figure Title

INTERPRETED GEOLOGICAL CROSS-SECTION B-B'

Drawn	Checked	Date	Figure No.
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Scale		Project No.	
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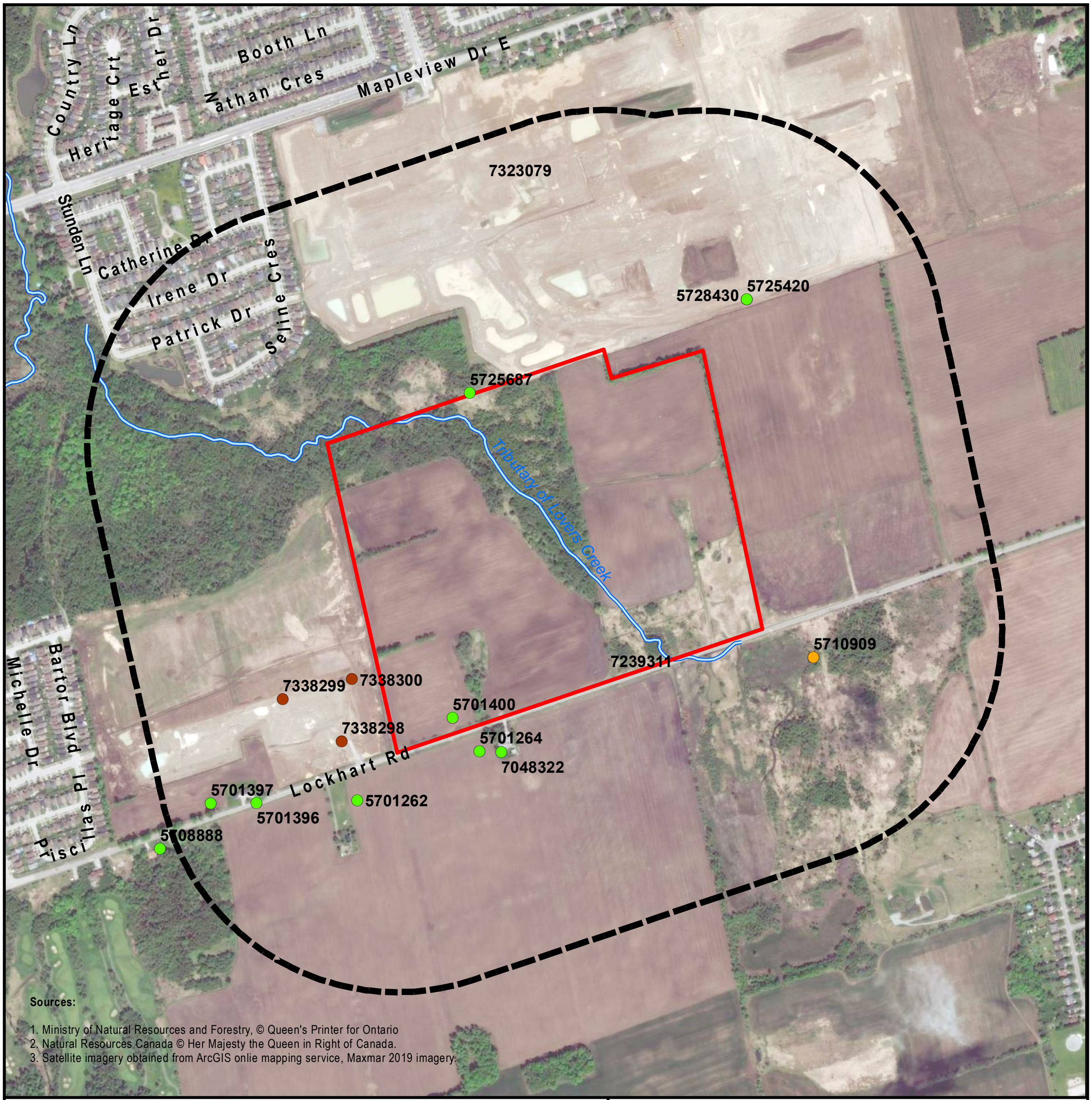

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3. Satellite imagery obtained from ArcGIS onlie mapping service, Maxmar 2019 imagery.

LEGEND

🟥 SUBJECT LANDS

▭ BUFFER (500m)

═ WATERCOURSE

WELL USE:

● WATER SUPPLY

● ABANDONED - SUPPLY

● ABANDONED - OTHER

0 100 200 400 600 800

Meters

N

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Client / Report

LOCKHART INNISFIL INVESTMENTS LIMITED &
LOCKHART INNISFIL INVESTMENTS II LIMITED
BARRIE, ONTARIO

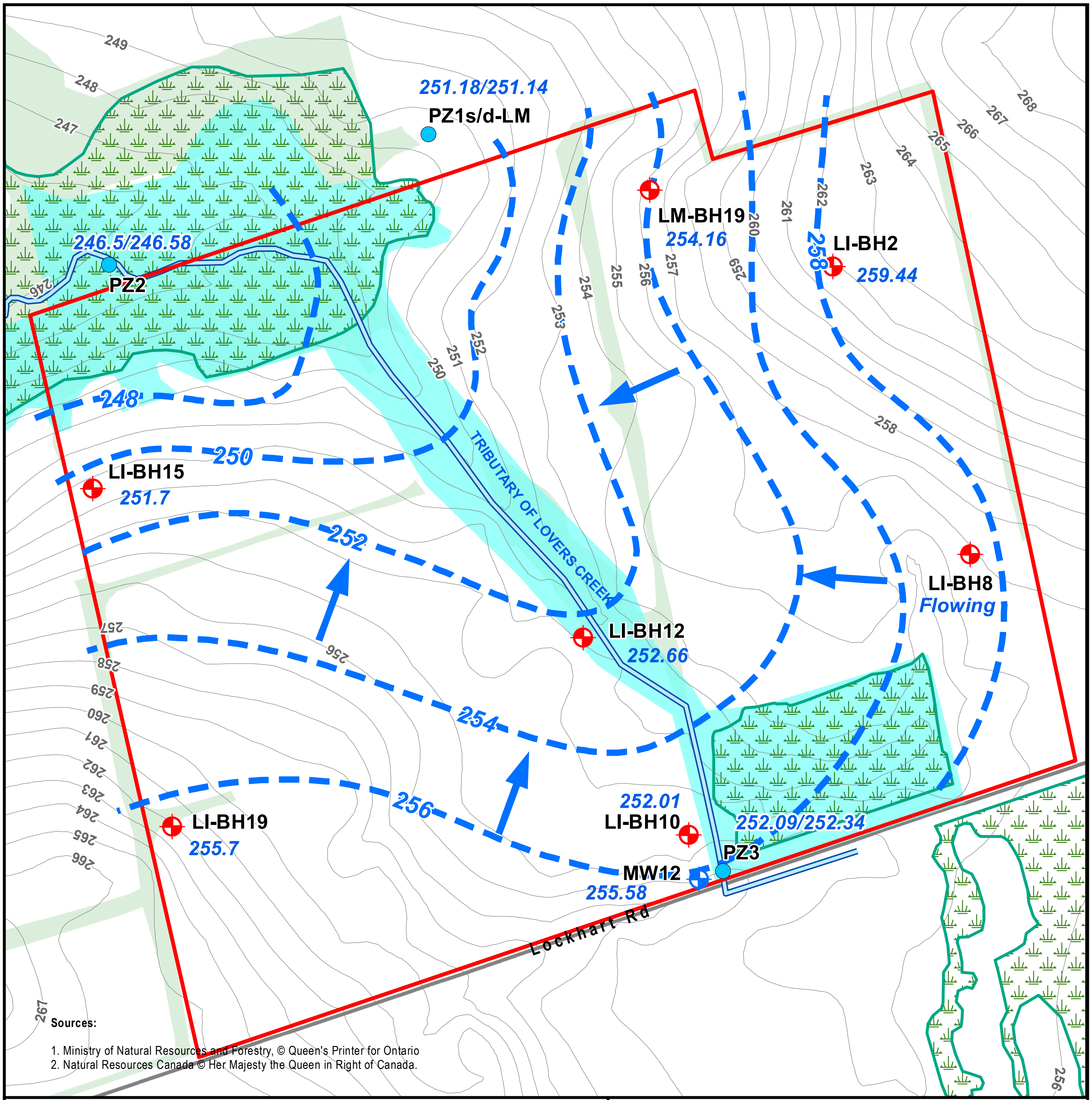
HYDROGEOLOGICAL ASSESSMENT

Figure Title:

MECP WELL LOCATION PLAN

Drawn	Checked	Date	Figure No.
SK	SC	July 2021	8
Scale		Project No.	
1:12,000		300043818	

File Path: Nigel/Shared Work Areas/043818 Lockhart Innisfil/dyn type="document" property="path"/> Print Date: 2021/07/09 Time: 12:37 PM

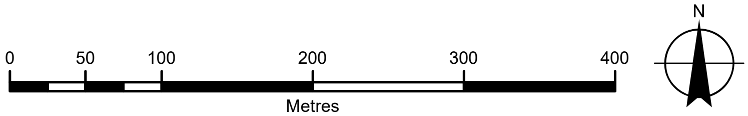


Sources:

1. Ministry of Natural Resources and Forestry, © Queen's Printer for Ontario
2. Natural Resources Canada © Her Majesty the Queen in Right of Canada.

LEGEND

▭	SUBJECT LANDS
═	WATERCOURSE
─	CONTOUR (1m intervals - masl)
━	ROADWAY
🟦	WETLAND (AZIMUTH, 2014)
▨	WETLAND (MNR, 2021)
🟩	WOODED AREA
⊕	MONITORING WELL (SOIL ENG., 2019)
⊕	MONITORING WELL (RJB, 2014)
●	DRIVE POINT PIEZOMETER (RJB, 2014)
- -	INTERPRETED GROUNDWATER CONTOUR (masl)
→	GROUNDWATER FLOW DIRECTION
255.7	MEASURED WATER LEVEL (March 26, 2020)



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LOCKHART INNISFIL INVESTMENTS LIMITED &
LOCKHART INNISFIL INVESTMENTS II LIMITED
BARRIE, ONTARIO

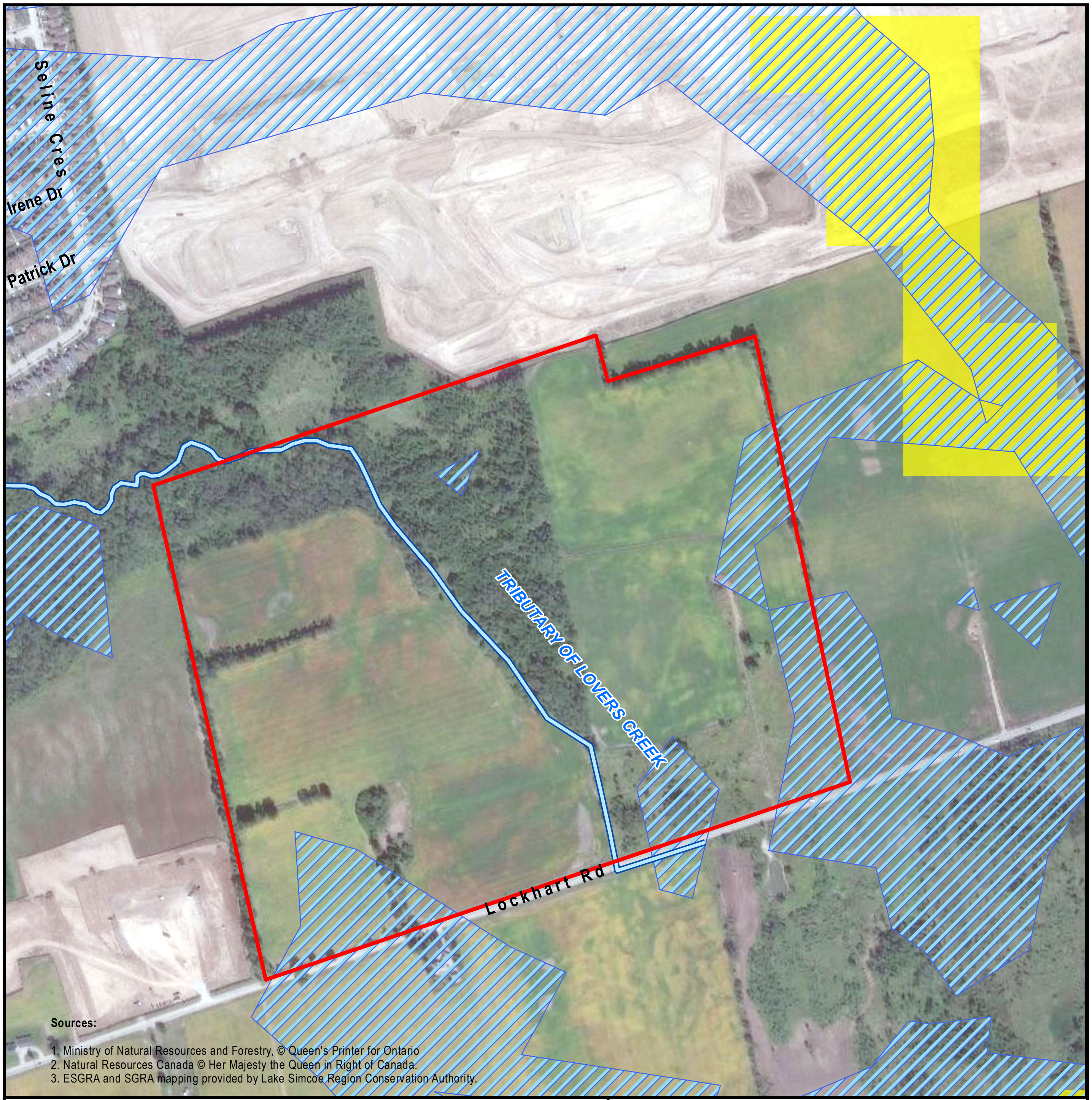
HYDROGEOLOGICAL ASSESSMENT

Figure Title:

INTERPRETED GROUNDWATER FLOW

Drawn SK	Checked SC	Date July 2021	Figure No. 9
Scale 1:5,000		Project No. 300043818	

File Path: Nigel/Shared Work Areas/043818 Lockhart Innisfil/06_GIS/043818 Groundwater Flow.mxd



Sources:

1. Ministry of Natural Resources and Forestry, © Queen's Printer for Ontario
2. Natural Resources Canada © Her Majesty the Queen in Right of Canada.
3. ESGRA and SGRA mapping provided by Lake Simcoe Region Conservation Authority.

LEGEND

🟥	SUBJECT LANDS
═	WATERCOURSE
▨	ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS (ESGRA, LSRCA)
🟨	SIGNIFICANT GROUNDWATER RECHARGE AREAS (SGRA, LSRCA)

0 100 200 300 400 500 600

Metres

N

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LOCKHART INNISFIL INVESTMENTS LIMITED &
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BARRIE, ONTARIO

HYDROGEOLOGICAL ASSESSMENT

Figure Title:

RECHARGE AREAS

Drawn	Checked	Date	Figure No.
SK	SC	July 2021	10
Scale		Project No.	
1:7,500		300043818	

File Path: Nigel/Shared Work Areas/043818 Lockhart Innisfil/06_GIS/043818 Recharge Areas.mxd

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Appendix A

MECP Water Well Records

Water Well Records

Thursday, April 22, 2021

12:53:54 PM

TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
BARRIE CITY (INNISFI	17 608260 4910840 W	7314						7323079 (C38641) A139433 P	
INNISFIL TOWNSHIP CON 10 012	17 607985 4909544 W	1961/09 2514	6	FR 0080	43/55/25/2:30	ST DO	0079 3	5701262 ()	PRDG 0057 MSND GRVL CLAY 0077 CSND 0082
INNISFIL TOWNSHIP CON 10 012	17 607574 4909443 W	1969/12 3203	5	FR 0060	24/45/2/2:0	DO		5708888 ()	BLCK LOAM 0002 BRWN CLAY MSND 0010 BRWN CLAY MSND STNS 0038 GREY CLAY GRVL 0060 GREY MSND GRVL 0061
INNISFIL TOWNSHIP CON 10 013	17 608240 4909646 W	1960/11 2514	6	FR 0041	18/40/2/2:0	DO		5701264 ()	PRDG 0028 BRWN CLAY 0038 MSND GRVL 0041
INNISFIL TOWNSHIP CON 10 013	17 608286 4909644 W	2007/08 3413	6		15/42/10/2:	PS		7048322 (Z63967) A058559	BRWN CLAY 0012 GREY CLAY 0048 GREY SAND 0056
INNISFIL TOWNSHIP CON 10 014	17 608937 4909842 W	1973/06 4816						5710909 () A	CLAY SAND 0028 SAND CLAY 0045 GRVL CLAY 0087 SAND GRVL 0098 CLAY SILT 0174 CLAY GRVL 0226 CLAY 0267 MSND 0273 CLAY SILT 0315
INNISFIL TOWNSHIP CON 11 012	17 607830 4909755 W	2019/07 7147	0.70		///:			7338299 (H8H4JRRG) _NO_TAG A	
INNISFIL TOWNSHIP CON 11 012	17 607953 4909666 W	2019/07 7147	1.97		///:		0021 5	7338298 (MZ8B4ZOM) _NO_TAG A	
INNISFIL TOWNSHIP CON 11 012	17 607775 4909538 W	1959/12 4102	30	FR 0065	20//1/:	ST DO		5701396 ()	BLUE CLAY MSND 0065
INNISFIL TOWNSHIP CON 11 012	17 607974 4909796 W	2019/07 7147	0.70		///:			7338300 (B6P8RBG6) _NO_TAG A	
INNISFIL TOWNSHIP CON 11 012	17 607679 4909537 W	1964/09 3109	30	FR 0075	57//2/:	ST DO		5701397 ()	LOAM 0002 BLUE CLAY 0030 CLAY MSND STNS 0075 GRVL 0080
INNISFIL TOWNSHIP CON 11 013	17 608184 4909716 W	1964/11 2514	6	FR 0030	18/30/4/2:0	ST DO		5701400 ()	PRDG 0023 BLUE CLAY GRVL BLDR 0030 GRVL 0031 BLUE CLAY GRVL BLDR 0039
INNISFIL TOWNSHIP CON 11 013	17 608220 4910394 L	1989/09 3030	36	UK 0006	6///:	DO		5725687 (61061)	BRWN LOAM 0001 BRWN SAND 0006 BRWN SAND 0023
INNISFIL TOWNSHIP CON 11 013	17 608514 4909816 W	2014/03 6809						7239311 (C25733) A152308 P	
INNISFIL TOWNSHIP CON 11 014	17 608798 4910589 L	1990/09 3660	6	FR 0032	32/57/4/1:0	DO	0064 5	5728430 (87995)	BLCK LOAM 0001 GREY GRVL 0008 GREY CLAY HARD 0032 BRWN SAND SILT WBRG 0070 GREY SAND SILT CLAY 0075

TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
INNISFIL TOWNSHIP CON 11 014	17 608798 4910589 L	1989/08 1583	6 5	FR 0116	32//12/1:0	DO	0109 2	5725420 (64384)	BRWN CLAY TILL SNDY 0040 BLUE CLAY 0073 GREY CLAY GRVL STNS 0103 BRWN FSND 0118 GREY CLAY 0125

Notes:

UTM: UTM in Zone, Easting, Northing and Datum is NAD83; L: UTM estimated from Centroid of Lot; W: UTM not from Lot Centroid

DATE CNTR: Date Work Completedand Well Contractor Licence Number

CASING DIA: .Casing diameter in inches

WATER: Unit of Depth in Fee. See Table 4 for Meaning of Code

PUMP TEST: Static Water Level in Feet / Water Level After Pumping in Feet / Pump Test Rate in GPM / Pump Test Duration in Hour : Minutes

WELL USE: See Table 3 for Meaning of Code

SCREEN: Screen Depth and Length in feet

WELL: WEL (AUDIT #) Well Tag . A: Abandonment; P: Partial Data Entry Only

FORMATION: See Table 1 and 2 for Meaning of Code

1. Core Material and Descriptive terms

Code	Description
BLDR	BOULDERS
BSLT	BASALT
CGRD	COARSE-GRAINED
CGVL	COARSE GRAVEL
CHRT	CHERT
CLAY	CLAY
CLN	CLEAN
CLYY	CLAYEY
CMTD	CEMENTED
CONG	CONGLOMERATE
CRYS	CRYSTALLINE
CSND	COARSE SAND
DKCL	DARK-COLOURED
DLMT	DOLOMITE
DNSE	DENSE
DRTY	DIRTY
DRY	DRY
FCRD	FRACTURED
FGRD	FINE-GRAINED
FGVL	FINE GRAVEL
FILL	FILL
FLDS	FELDSPAR
FLNT	FLINT
FOSS	FOSILIFEROUS
FSND	FINE SAND
GNIS	GNEISS
GRNT	GRANITE
GRSN	GREENSTONE
GRVL	GRAVEL
GRWK	GREYWACKE
GVLY	GRAVELLY
GYPS	GYPSUM
HARD	HARD
HPAN	HARDPAN
IRFM	IRON FORMATION
LIMY	LIMY
LMSN	LIMESTONE
LOAM	TOPSOIL
LOOS	LOOSE
LTCL	LIGHT-COLOURED
LYRD	LAYERED
MARL	MARL
MGRD	MEDIUM-GRAINED
MGVL	MEDIUM GRAVEL
MRBL	MARBLE
MSND	MEDIUM SAND
MUCK	MUCK
OBDN	OVERBURDEN
PCKD	PACKED
PEAT	PEAT
PGVL	PEA GRAVEL
PORS	POROUS
PRDG	PREVIOUSLY DUG
PRDR	PREV. DRILLED
QRTZ	QUARTZITE
QSND	QUICKSAND
QTZ	QUARTZ
ROCK	ROCK
SAND	SAND
SHLE	SHALE
SHLY	SHALY
SHRP	SHARP
SHST	SCHIST
SILT	SILT
SLTE	SLATE
SLTY	SILTY
SNDS	SANDSTONE
SNDY	SANDYOAPSTONE
SOFT	SOFT
SPST	SOAPSTONE
STKY	STICKY
STNS	STONES
STNY	STONEY
THIK	THICK
THIN	THIN
TILL	TILL
UNKN	UNKNOWN TYPE
VERY	VERY
WBRG	WATER-BEARING
WDFR	WOOD FRAGMENTS
WTHD	WEATHERED

2. Core Color

Code	Description
WHIT	WHITE
GREY	GREY
BLUE	BLUE
GREN	GREEN
YLLW	YELLOW
BRWN	BROWN
RED	RED
BLCK	BLACK
BLGY	BLUE-GREY

3. Well Use

Code	Description
DO	Domestic
ST	Livestock
IR	Irrigation
IN	Industrial
CO	Commercial
MN	Municipal
PS	Public
AC	Cooling And A/C
NU	Not Used
OT	Other
TH	Test Hole
DE	Dewatering
MO	Monitoring
MT	Monitoring TestHole

4. Water Detail

Code	Description
FR	Fresh
SA	Salty
SU	Sulphur
MN	Mineral
UK	Unknown
GS	Gas
IR	Iron

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Appendix B

Borehole Logs

Appendix B

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 1

FIGURE NO.: 1

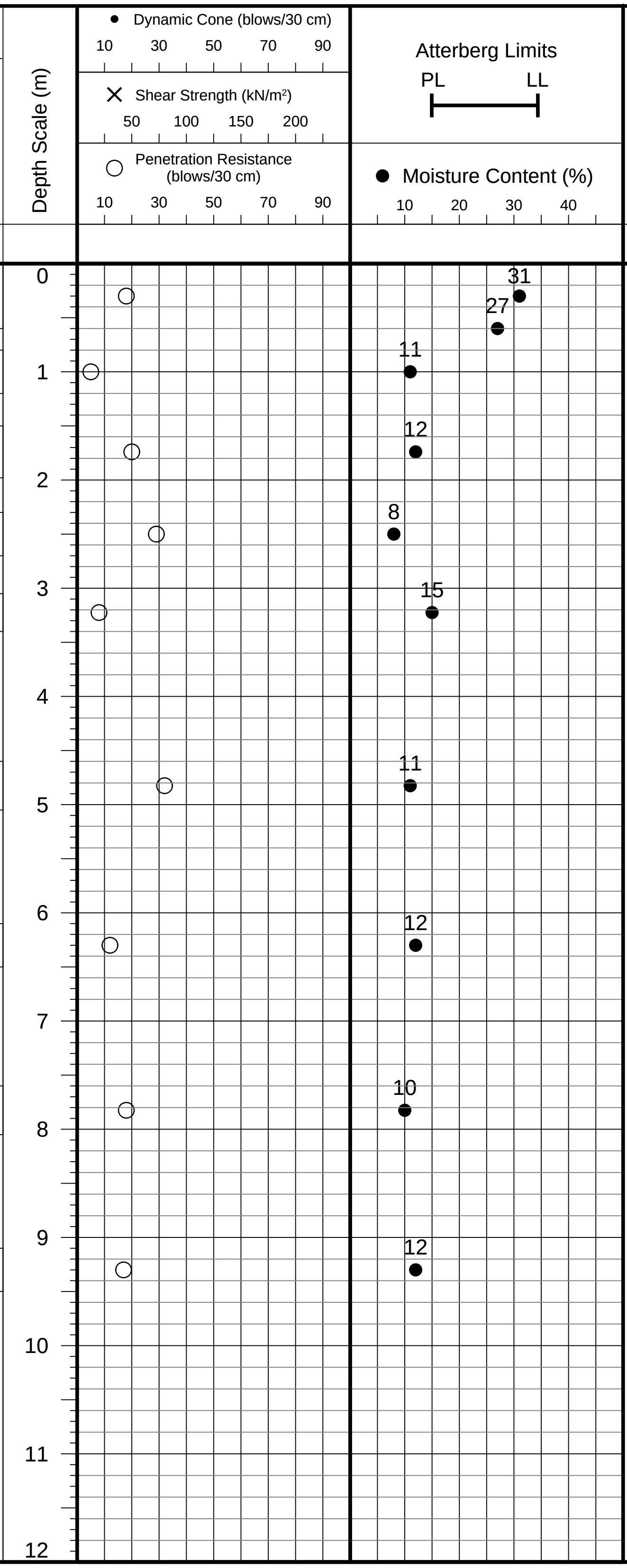
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 4, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
253.0	Ground Surface			
0.0	**PLOUGHED SOIL** brown sandy silt with topsoil inclusions Frost	1A 1B	DO	18
252.3 0.7	Brown, loose to compact **SILTY SAND TILL** some clay, trace of gravel occ. sand seams and layers, cobbles and boulders	2 3 4	DO DO DO	5 20 29
250.1 2.9	Brown, loose to dense **SAND** well graded some gravel, some to silty occ. silt and clay seams below 6 m	5 6 7	DO DO DO	8 32 12
245.8 7.2	Brown, compact **SILTY SAND TILL** some clay, trace gravel occ. cobbles and boulders	8 9	DO DO	18 17
243.5 9.5	**END OF BOREHOLE**			



WATER LEVEL

W.L @ EL. 251.8 m on completion

Cave-in @ El. 251.2 m

Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: BH/MW 2

FIGURE NO.: 2

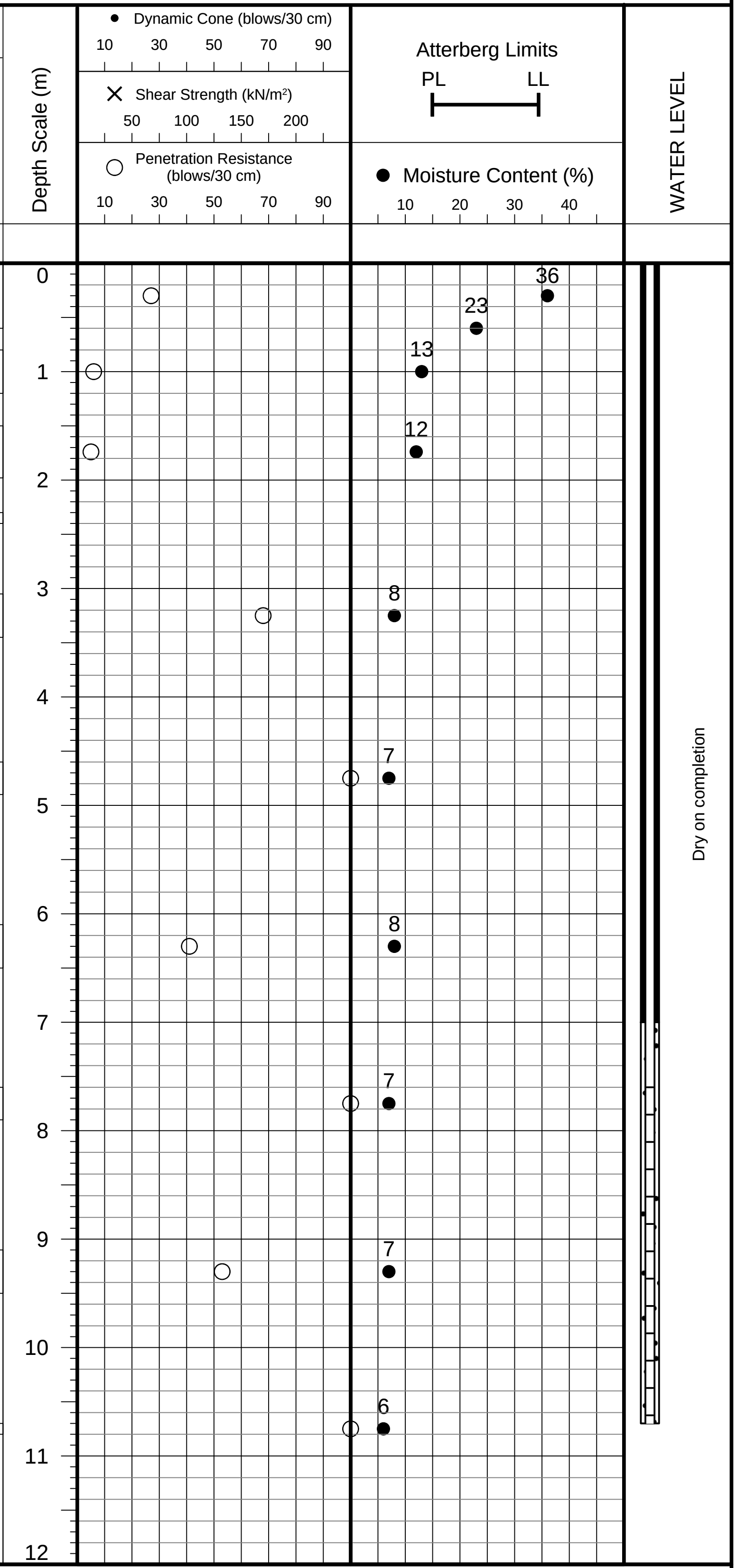
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 1, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
259.6	Ground Surface			
0.0	**PLOUGHED SOIL** brown sandy silt with topsoil inclusions Frost	1A 1B	DO	27
258.9 0.7	**EARTH FILL** brown sandy silt some clay and gravel, some organic inclusions	2	DO	6
		3	DO	5
257.4 2.2	Very dense **SILTY SAND TILL** trace to some clay, trace gravel occ. cobbles and boulders	4		50/NP
		5	DO	68
	brown grey	6	DO	50/15
		7	DO	41
		8	DO	50/15
	Installed 50mm Ø monitoring well to 10.7 m 3.0 m screen from 7.6 to 10.7 m Sand backfill from 7.0 to 10.7 m Bentonite seal from 0.0 to 7.0 m Provided with a 4x4 steel casing	9	DO	53
		10	DO	50/15
248.8 10.8	**END OF BOREHOLE**			



Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 3

FIGURE NO.: 3

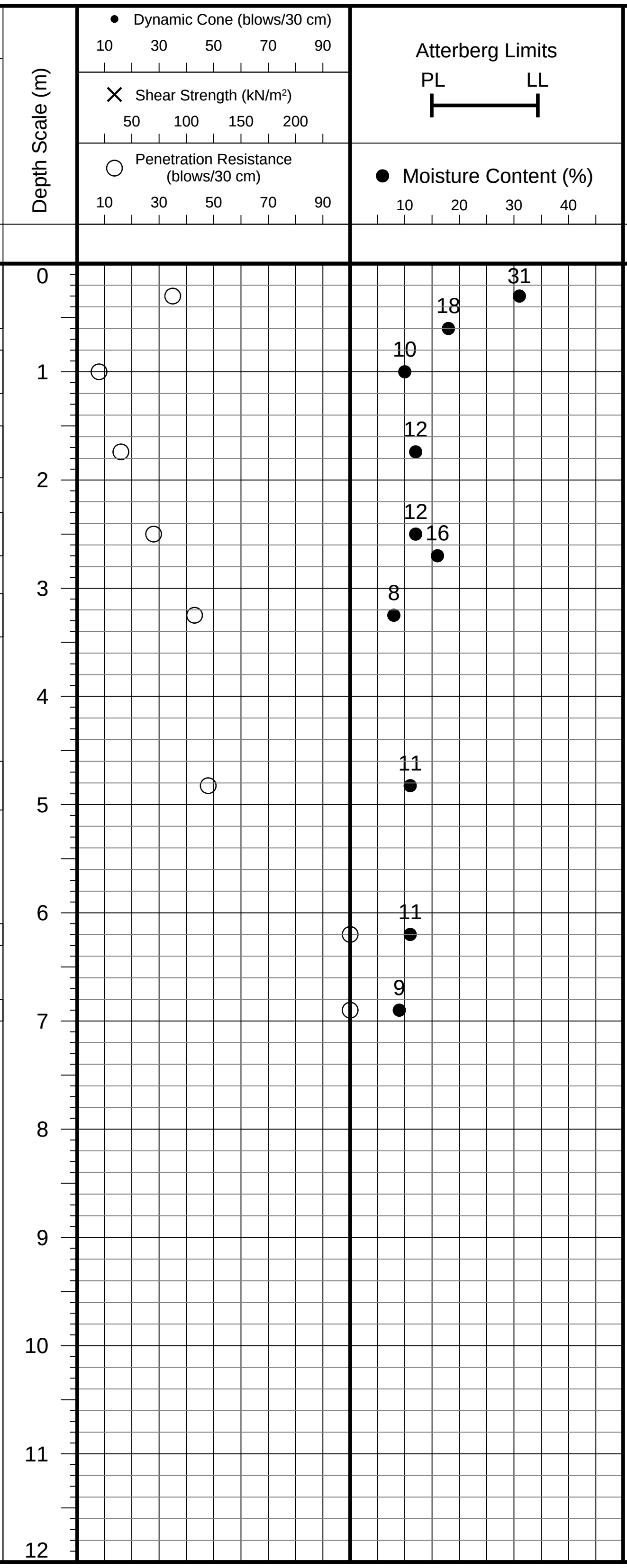
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 4, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES		
		Number	Type	N-Value
262.8	Ground Surface			
0.0	**PLOUGHED SOIL** brown sandy silt with topsoil inclusions Frost	1A 1B	DO	35
262.1 0.7	Brown, loose to very dense **SILTY SAND TILL** trace of clay and gravel occ. sand and clay layers, cobbles and boulders	2	DO	8
		3	DO	16
		4A 4B	DO	28
		5	DO	43
		6	DO	48
		7	DO	50/15
		8	DO	60/15
255.8 7.0	**END OF BOREHOLE**			



WATER LEVEL

W.L @ EL. 258.8 m on completion

Cave-in @ El. 258.2 m

Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 4

FIGURE NO.: 4

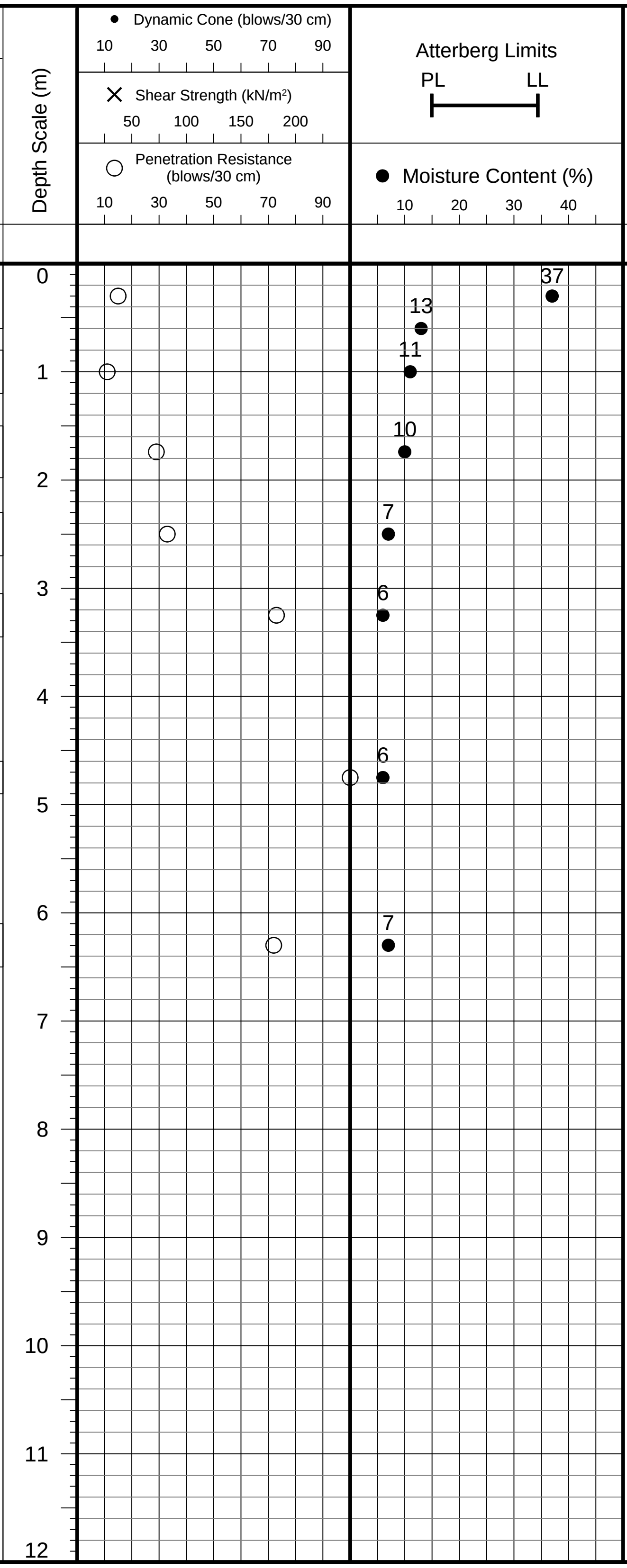
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 4, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
258.5	Ground Surface			
0.0	**38 cm TOPSOIL**	1A 1B	DO	15
	Compact to very dense Frost **SILTY SAND TILL** trace to some clay, trace gravel occ. cobbles and boulders	2	DO	11
		3	DO	29
	brown grey	4	DO	33
		5	DO	73
		6	DO	50/15
		7	DO	72
251.6 6.9	**END OF BOREHOLE** **Refusal to augering on propable boulder**			



WATER LEVEL

▽ W.L @ EL. 252.4 m on completion

Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 5

FIGURE NO.: 5

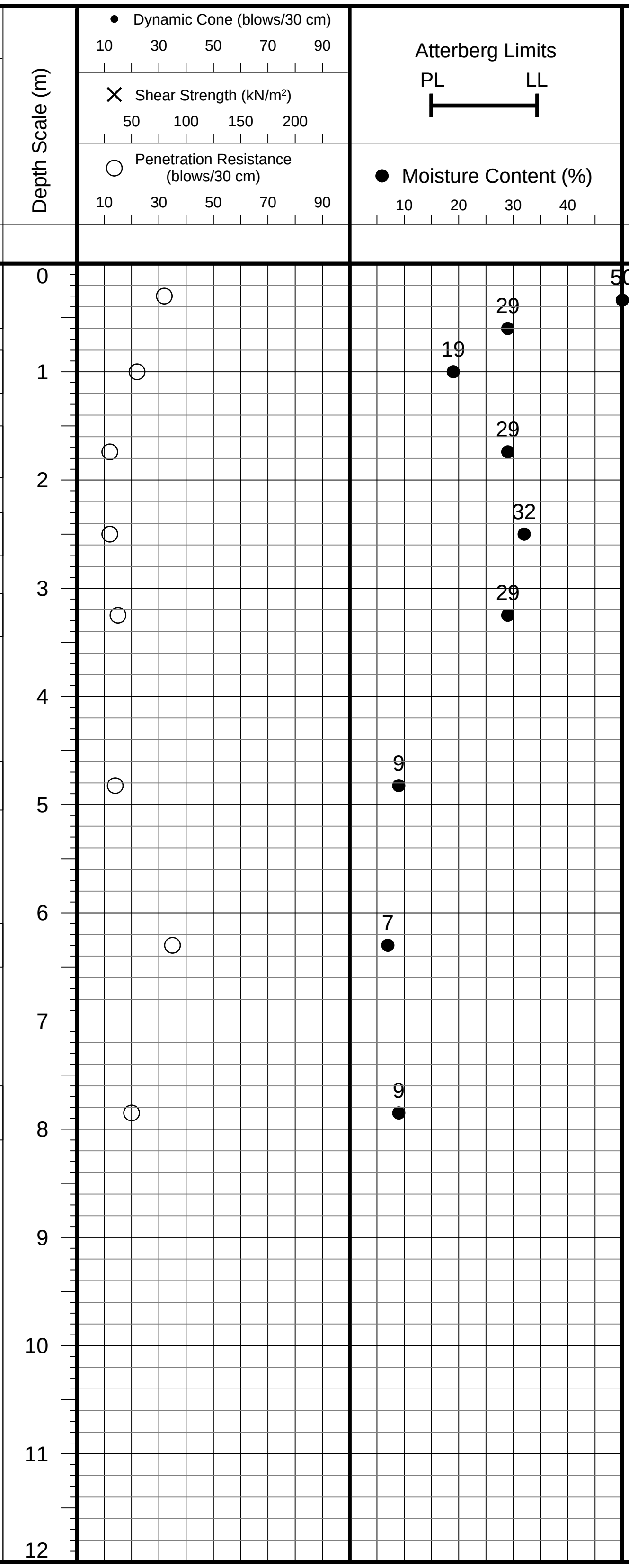
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 5, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	WATER LEVEL
254.9	Ground Surface				
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	32	
254.2 0.7	**EARTH FILL** brown sand and clay scattered topsoil	2	DO	22	
253.7 1.2	Brown, stiff **SILTY CLAY** occ. sand seams	3	DO	12	
		4	DO	12	
		5	DO	15	
251.4 3.5	Grey, compact to dense **SILTY SAND TILL** trace to some clay, trace gravel occ. cobbles and boulders	6	DO	14	
		7	DO	35	▽ W.L @ EL. 247.9 m on completion
		8	DO	20	
246.8 8.1	**END OF BOREHOLE**				



JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 6

FIGURE NO.: 6

PROJECT DESCRIPTION: Proposed Residential Development

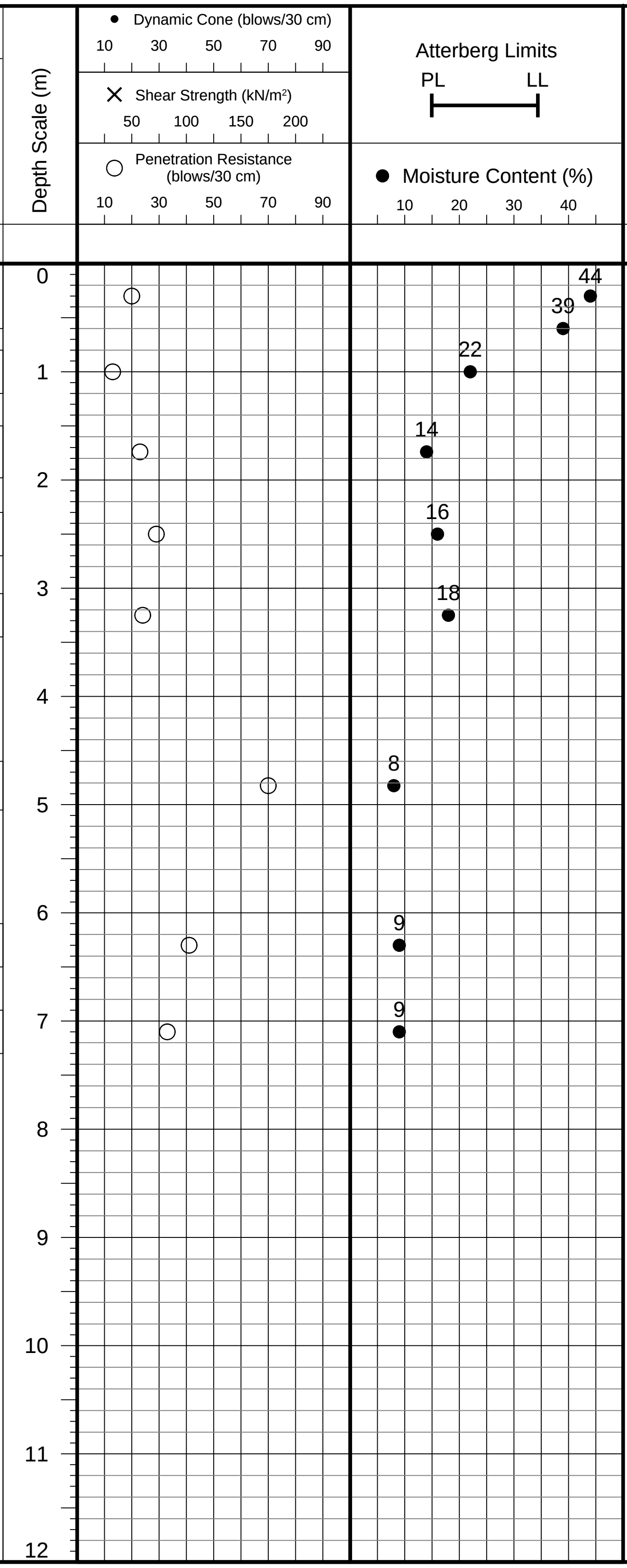
METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 5, 2019

El. (m) Depth (m)	SOIL DESCRIPTION
253.3	Ground Surface
0.0	**PLOUGHED SOIL** brown sandy silty with topsoil inclusions Frost
252.6 0.7	Brown, stiff **SILTY CLAY** occ. sand seams
251.9 1.4	Brown, compact **SILTY SAND TILL** trace of clay and gravel occ. sand layers, cobbles and boulders
251.1 2.2	Brown, compact **SAND** fine to medium grained, some silt trace of fine gravel
249.3 4.0	Dense to very dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders brown grey
246.0 7.3	**END OF BOREHOLE**

SAMPLES		
Number	Type	N-Value
1A 1B	DO	20
2	DO	13
3	DO	23
4	DO	29
5	DO	24
6	DO	70
7	DO	41
8	DO	33



WATER LEVEL

W.L @ EL. 250.9 m on completion
Cave-in @ El. 250.7 m

Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 7

FIGURE NO.: 7

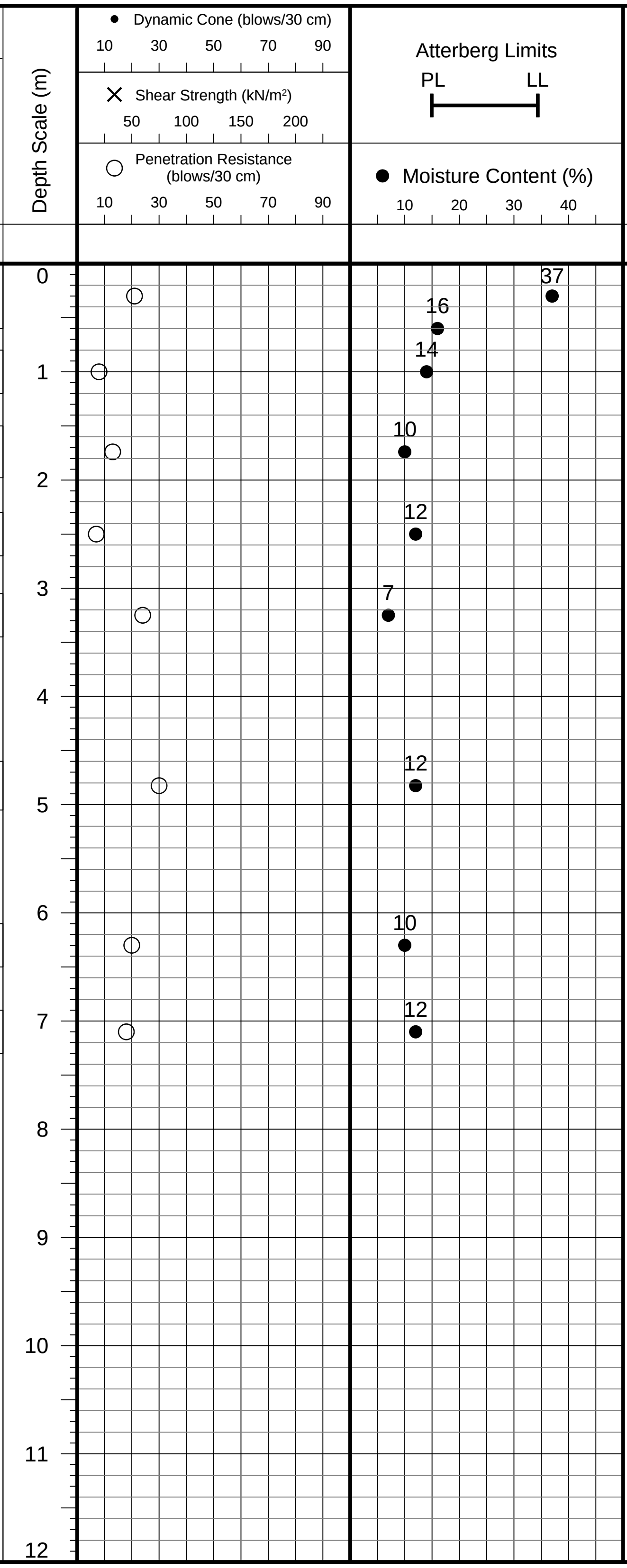
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 28, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
252.6	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand with topsoil inclusions Frost	1A 1B	DO	21
251.9 0.7	**EARTH FILL** brown to grey silty clay some sand and gravel trace organics	2	DO	8
		3	DO	13
		4	DO	7
249.8 2.8	Brown, compact **SILTY SAND TILL** trace to some clay, trace gravel occ. sand seams and layers, cobbles and boulders	5	DO	24
		6	DO	30
		7	DO	20
245.9 6.7	Grey, compact **SAND** fine to medium grained trace of gravel and clay	8	DO	18
245.3 7.3	**END OF BOREHOLE**			



WATER LEVEL

W.L @ EL. 249.6 m on completion
Cave-in @ El. 249.3 m

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: BH/MW 8

FIGURE NO.: 8

PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

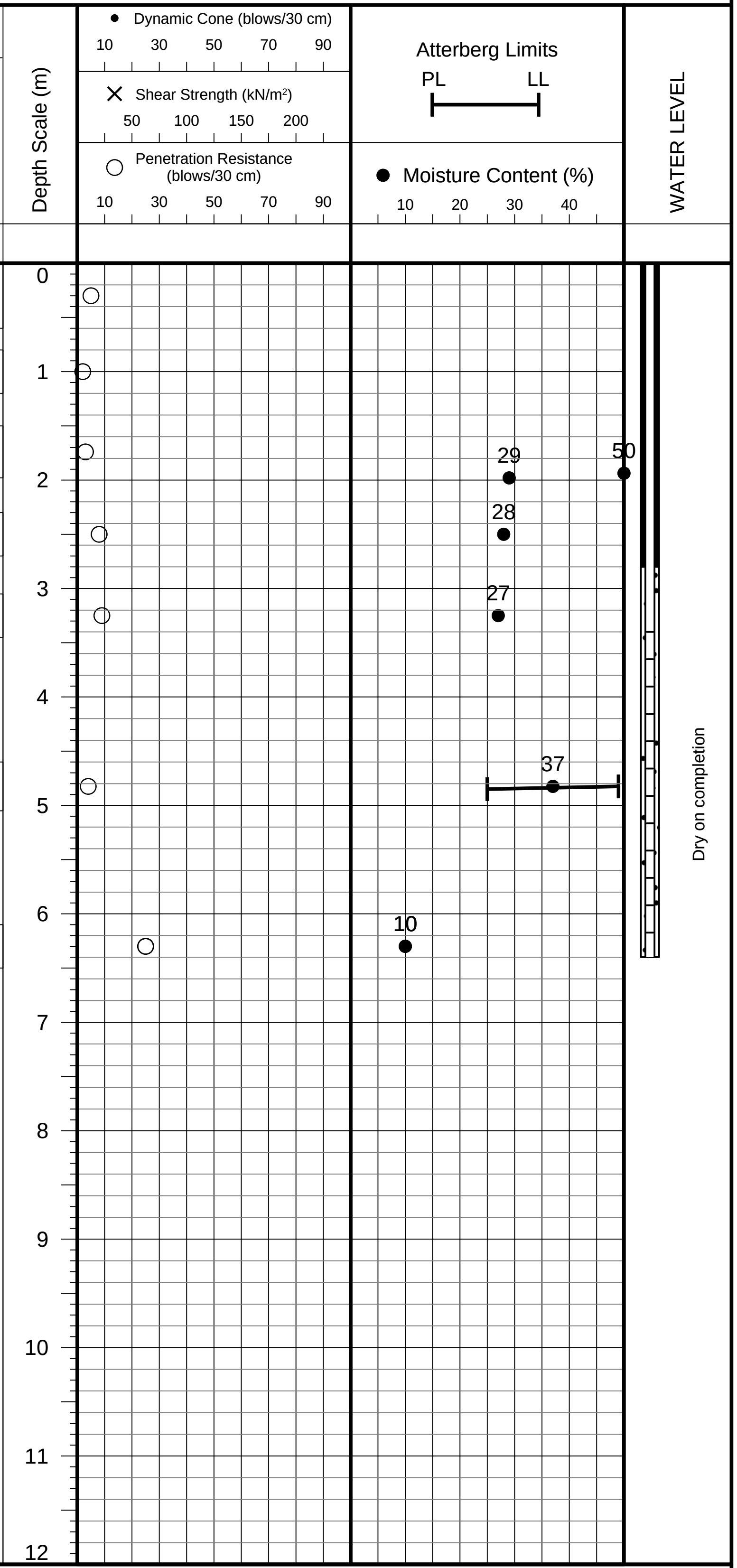
PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 5, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES		
		Number	Type	N-Value
252.4	Ground Surface			
0.0	**TOPSOIL AND PEAT** occ. wood chips	1	DO	5
		2	DO	2
250.7 1.7	Grey, soft to stiff **SILTY CLAY** occ. sand seams and layers	3A 3B	DO	3
		4	DO	8
		5	DO	9
		6	DO	4
246.4 6.0	Grey, compact **SILTY SAND TILL** trace clay and gravel occ. cobbles and boulders	7	DO	25
245.9 6.5				

END OF BOREHOLE

Installed 50mm Ø monitoring well to 6.4 m
3.0 m screen from 3.4 to 6.4 m
Sand backfill from 2.8 to 6.4 m
Bentonite seal from 0.0 to 2.8 m
Provided with a 4x4 steel casing



Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 9

FIGURE NO.: 9

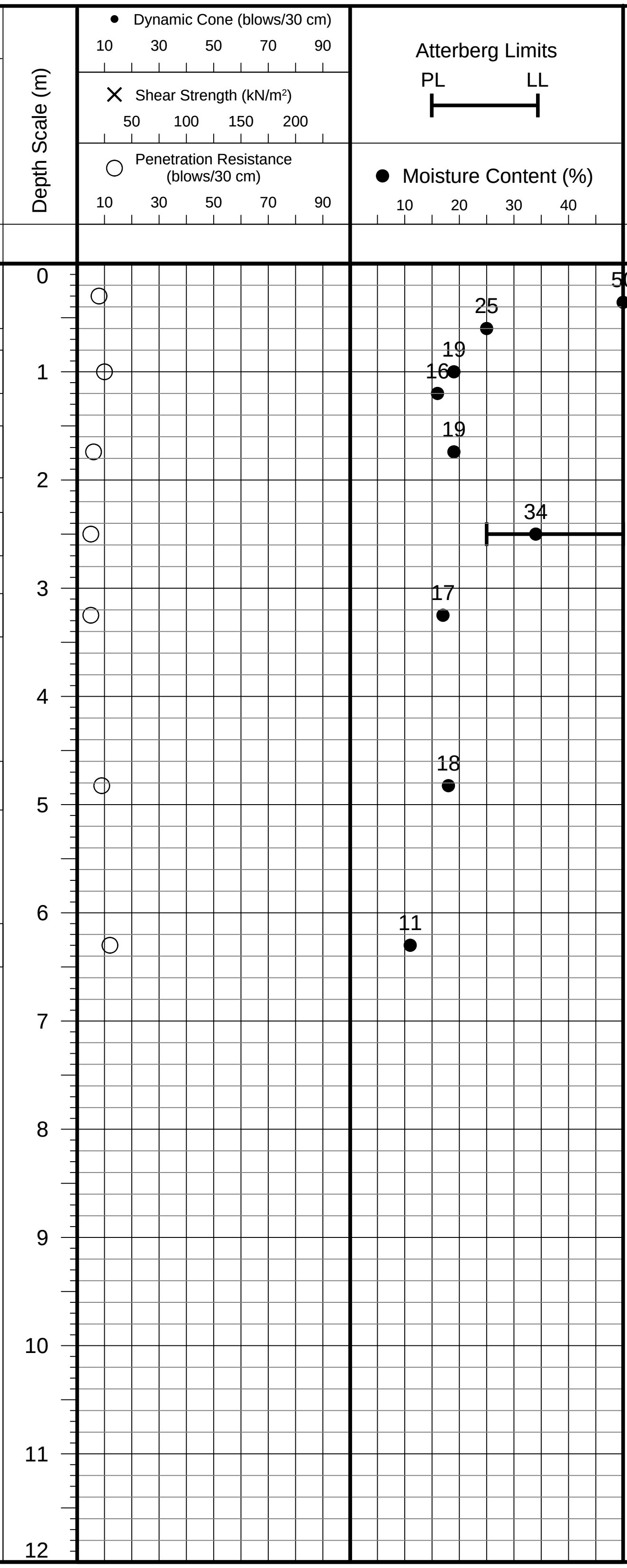
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: March 5, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	WATER LEVEL
252.6	Ground Surface				
0.0	**30 cm TOPSOIL** Brown, loose **SAND** weathered fine grained, some silt	1A 1B	DO	8	
251.7 0.9	Firm to stiff **SILTY CLAY** occ. sand seams and layers — brown/grey	2A 2B	DO	10	
		3	DO	6	
		4	DO	5	
		5	DO	5	
248.6 4.0	Grey, stiff **SILTY CLAY TILL** trace of gravel occ. sand seams and layers, cobbles and boulders	6	DO	9	Dry on completion
		7	DO	12	
246.1 6.5	**END OF BOREHOLE**				



JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: BH/MW 10

FIGURE NO.: 10

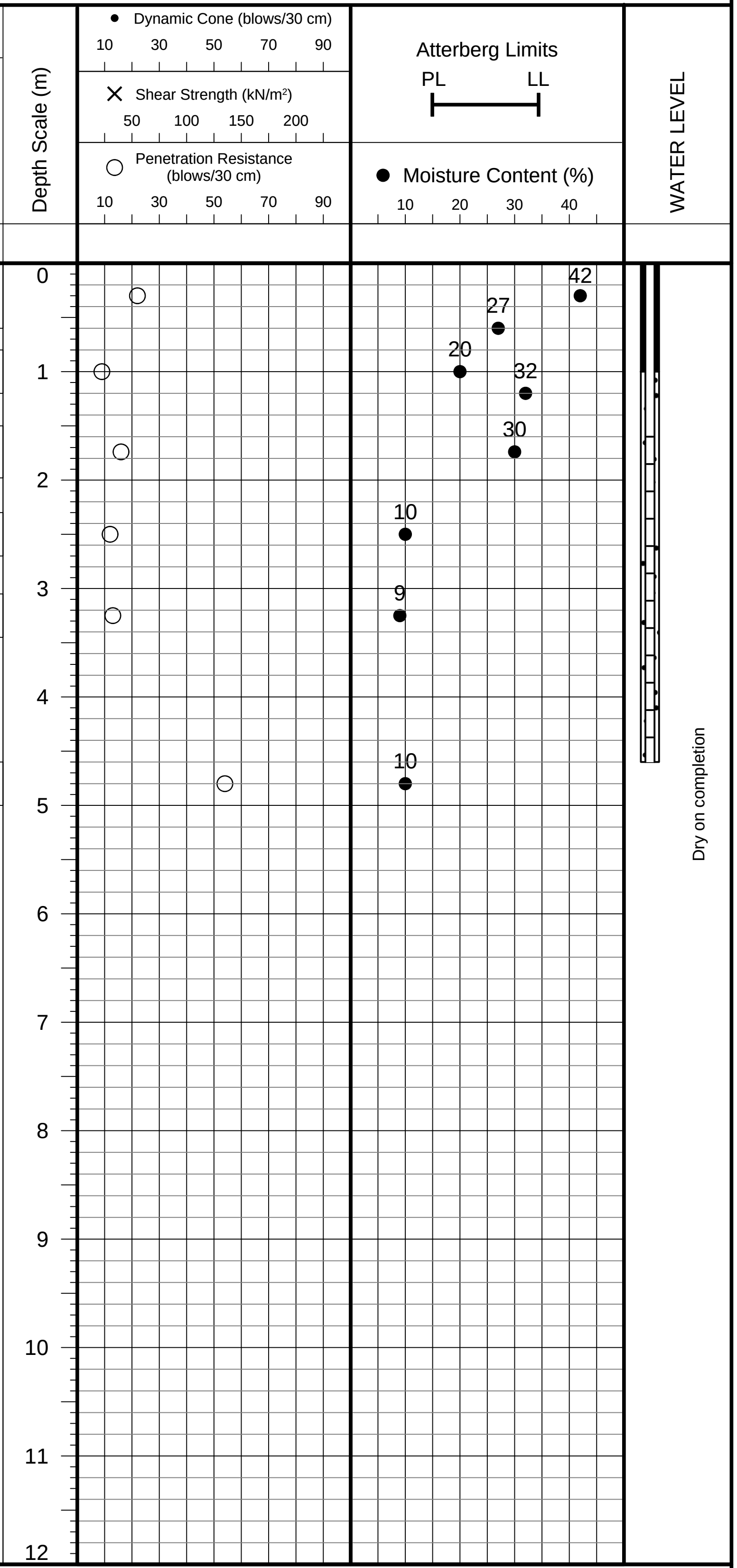
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 26, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
252.1	Ground Surface			
0.0	**PLOUGHED SOIL** brown sand and silt with topsoil inclusions _ _Frost_	1A 1B	DO	22
251.2 0.9	Brown, very stiff **SILTY CLAY** occ. sand seams and layers	2A 2B	DO	9
		3	DO	16
250.0 2.1	Grey, compact to very dense **SILTY SAND TILL** trace to some clay, trace gravel occ. cobbles and boulders	4	DO	12
		5	DO	13
		6	DO	54
247.1 5.0	**END OF BOREHOLE** Installed 50mm Ø monitoring well to 4.6 m 3.0 m screen from 1.6 to 4.6 m Sand backfill from 1.0 to 4.6 m Bentonite seal from 0.0 to 1.0 m Provided with a 4x4 steel casing			



Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 11

FIGURE NO.: 11

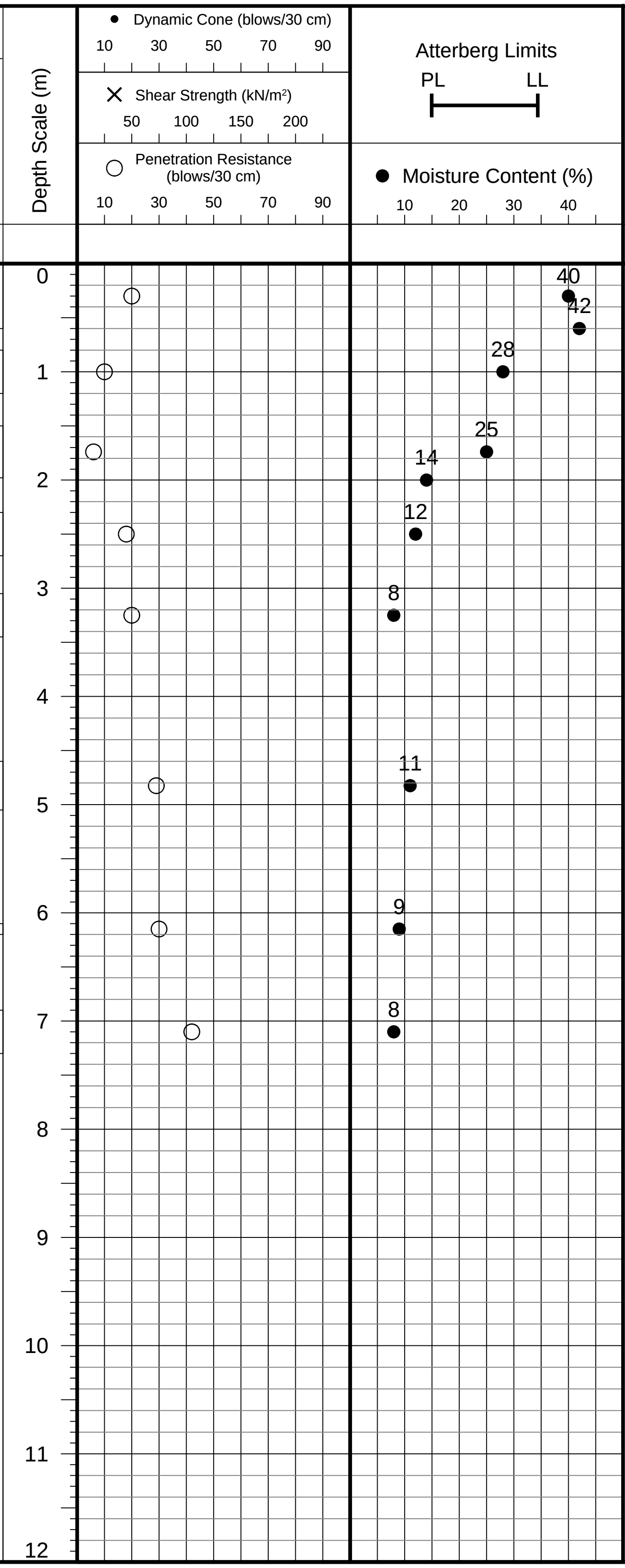
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 26, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
252.1	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand with topsoil inclusions Frost	1A 1B	DO	20
251.4 0.7	Brown, compact **SILTY CLAY** occ. sand seams and layers	2	DO	10
		3A 3B	DO	6
250.3 1.8	Grey, loose to dense **SILTY SAND TILL** trace of gravel, some clay occ. sand seams and layers, cobbles and boulders	4	DO	18
		5	DO	20
		6	DO	29
	boulder	7	DO	30/NP
		8	DO	42
244.8 7.3	**END OF BOREHOLE**			



WATER LEVEL

W.L @ EL. 247.8 m on completion

Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: BH/MW 12

FIGURE NO.: 12

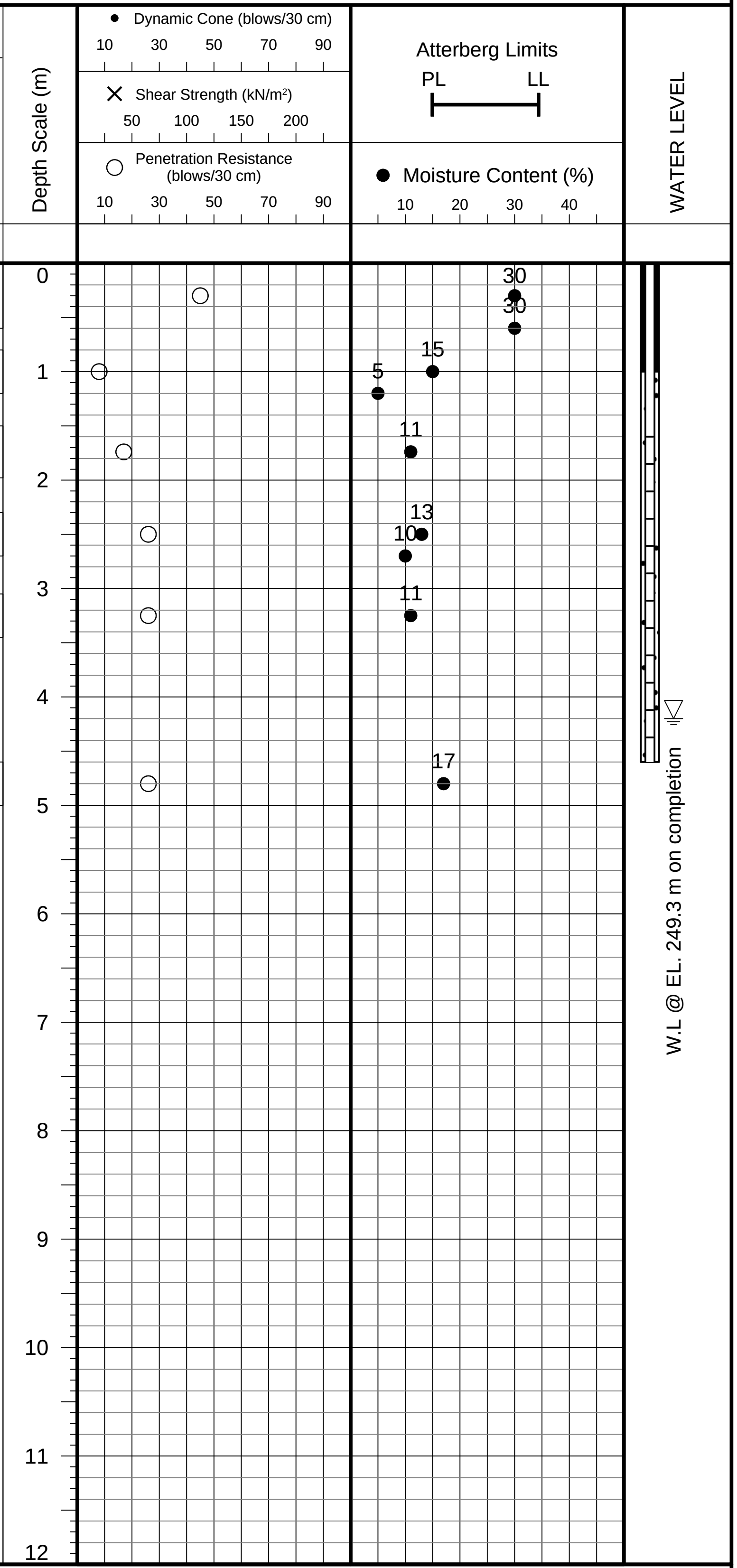
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 27, 2019

		SAMPLES		
El. (m) Depth (m)	SOIL DESCRIPTION	Number	Type	N-Value
253.5	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand with topsoil inclusions _ _Frost	1A 1B	DO	45
252.5 1.0	Brown, loose to compact **SILTY SAND TILL** trace of clay, some gravel occ. sand layers, cobbles and boulders	2A 2B	DO	8
		3	DO	17
		4A 4B	DO	26
		5	DO	26
249.5 4.0	Brown, compact **SAND** fine to medium grained, some silt to silty	6	DO	26
248.5 5.0	**END OF BOREHOLE** Installed 50mm Ø monitoring well to 4.6 m 3.0 m screen from 1.6 to 4.6 m Sand backfill from 1.0 to 4.6 m Bentonite seal from 0.0 to 1.0 m Provided with a 4x4 steel casing			



JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 13

FIGURE NO.: 13

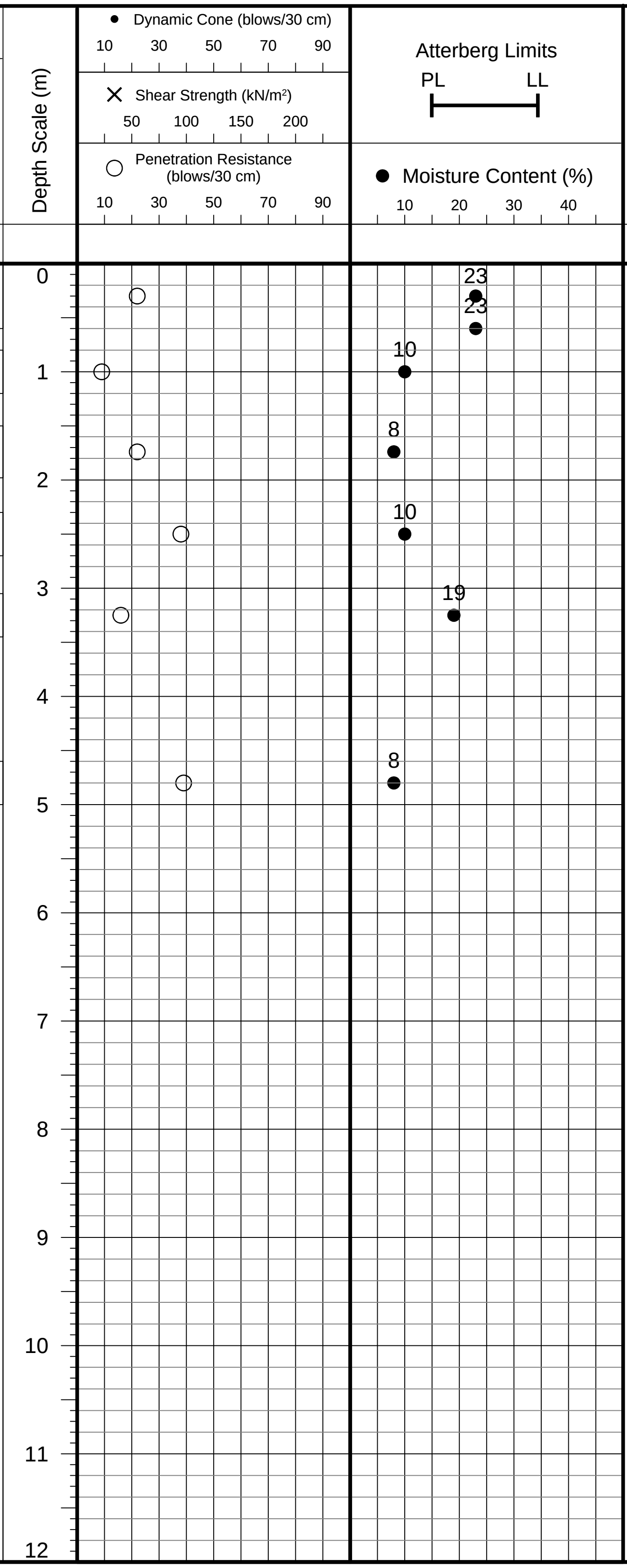
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 27, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES		
		Number	Type	N-Value
252.1	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	22
251.4 0.7	Brown, loose to dense **SILTY SAND TILL** trace of clay and gravel occ. sand layers, cobbles and boulders	2	DO	9
		3	DO	22
249.6 2.5	Brown, compact **SAND** fine to medium grained trace of gravel occ. cobbles	4	DO	38
		5	DO	16
248.3 3.8	Brown, dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders	6	DO	39
247.1 5.0	**END OF BOREHOLE**			



WATER LEVEL

W.L @ EL. 248.9 m on completion

Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 14

FIGURE NO.: 14

PROJECT DESCRIPTION: Proposed Residential Development

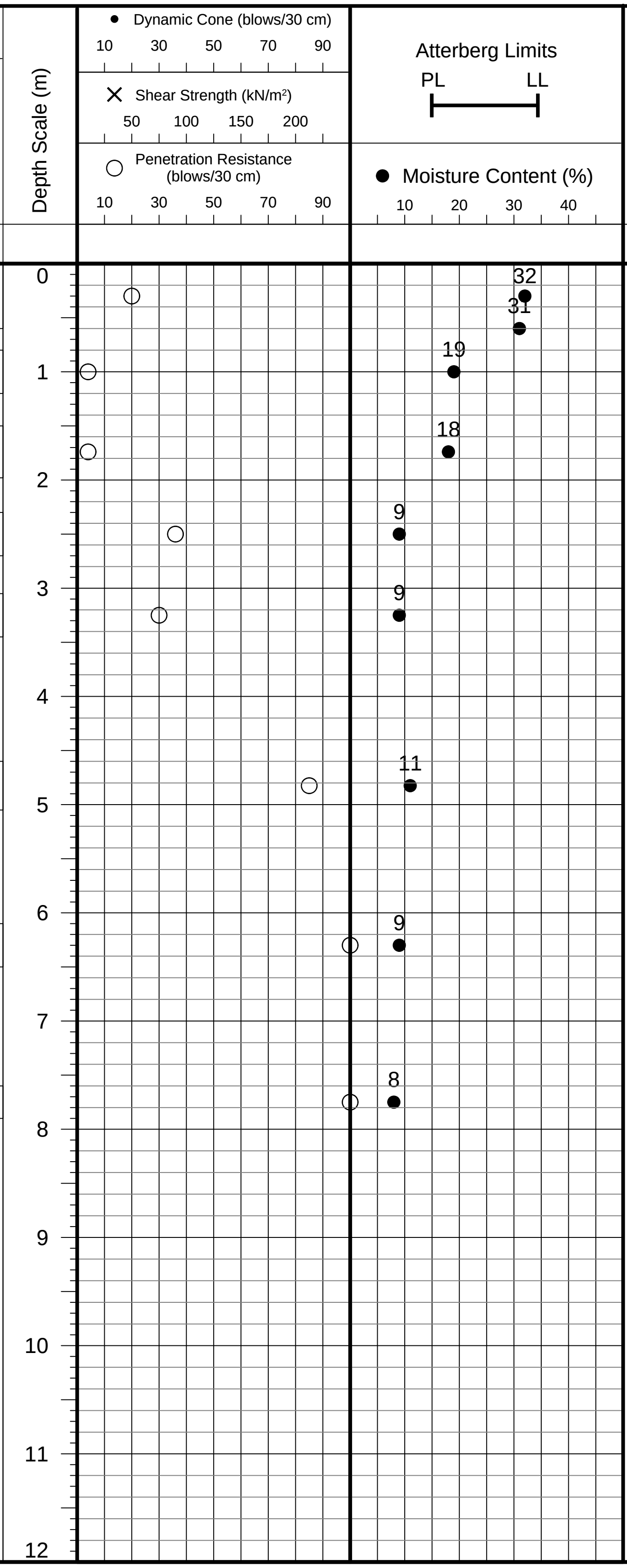
METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 27, 2019

El. (m) Depth (m)	SOIL DESCRIPTION
250.5	Ground Surface
0.0	**PLOUGHED SOIL** brown silty sand Frost
249.8 0.7	**EARTH FILL** brown sand and clay scattered topsoil
248.4 2.1	Brown, dense to very dense **SILTY SAND TILL** trace to some clay, trace gravel occ. sand layers, cobbles and boulders
242.6 7.9	**END OF BOREHOLE**

SAMPLES		
Number	Type	N-Value
1A 1B	DO	20
2	DO	4
3	DO	4
4	DO	36
5	DO	30
6	DO	85
7	DO	50/15
8	DO	55/15



WATER LEVEL

∇ W.L @ EL. 248.1 m on completion

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: BH/MW 15

FIGURE NO.: 15

PROJECT DESCRIPTION: Proposed Residential Development

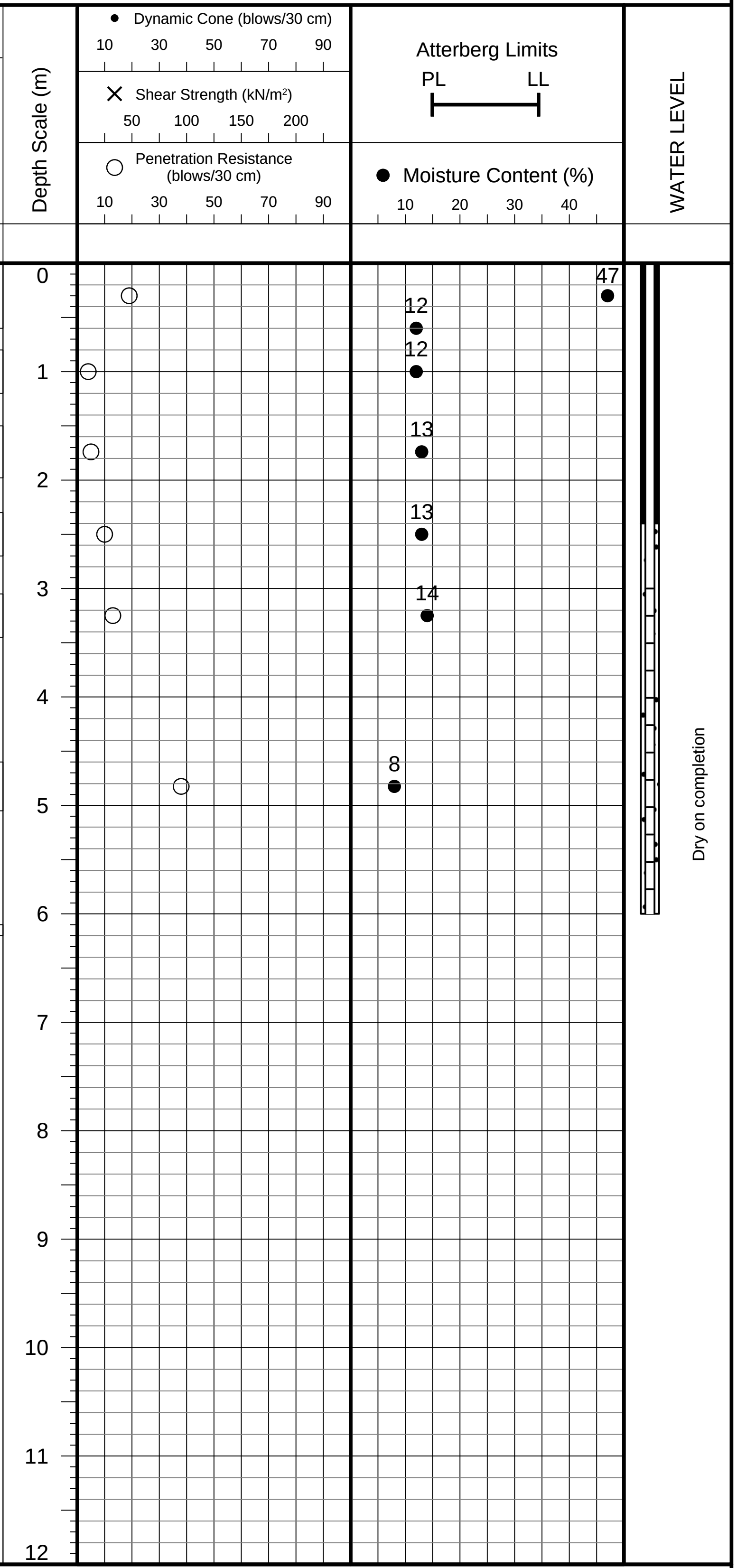
METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 28, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
251.5	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	19
250.8 0.7	Brown, dense to very dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders	2	DO	4
		3	DO	5
		4	DO	10
		5	DO	13
		6	DO	38
		7	DO	50/NP
245.1 6.4	**END OF BOREHOLE** **Refusal to augering on probable boulder**			

Installed 50mm Ø monitoring well to 6.0 m
3.0 m screen from 3.0 to 6.0 m
Sand backfill from 2.4 to 6.0 m
Bentonite seal from 0.0 to 2.4 m
Provided with a 4x4 steel casing



Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 16

FIGURE NO.: 16

PROJECT DESCRIPTION: Proposed Residential Development

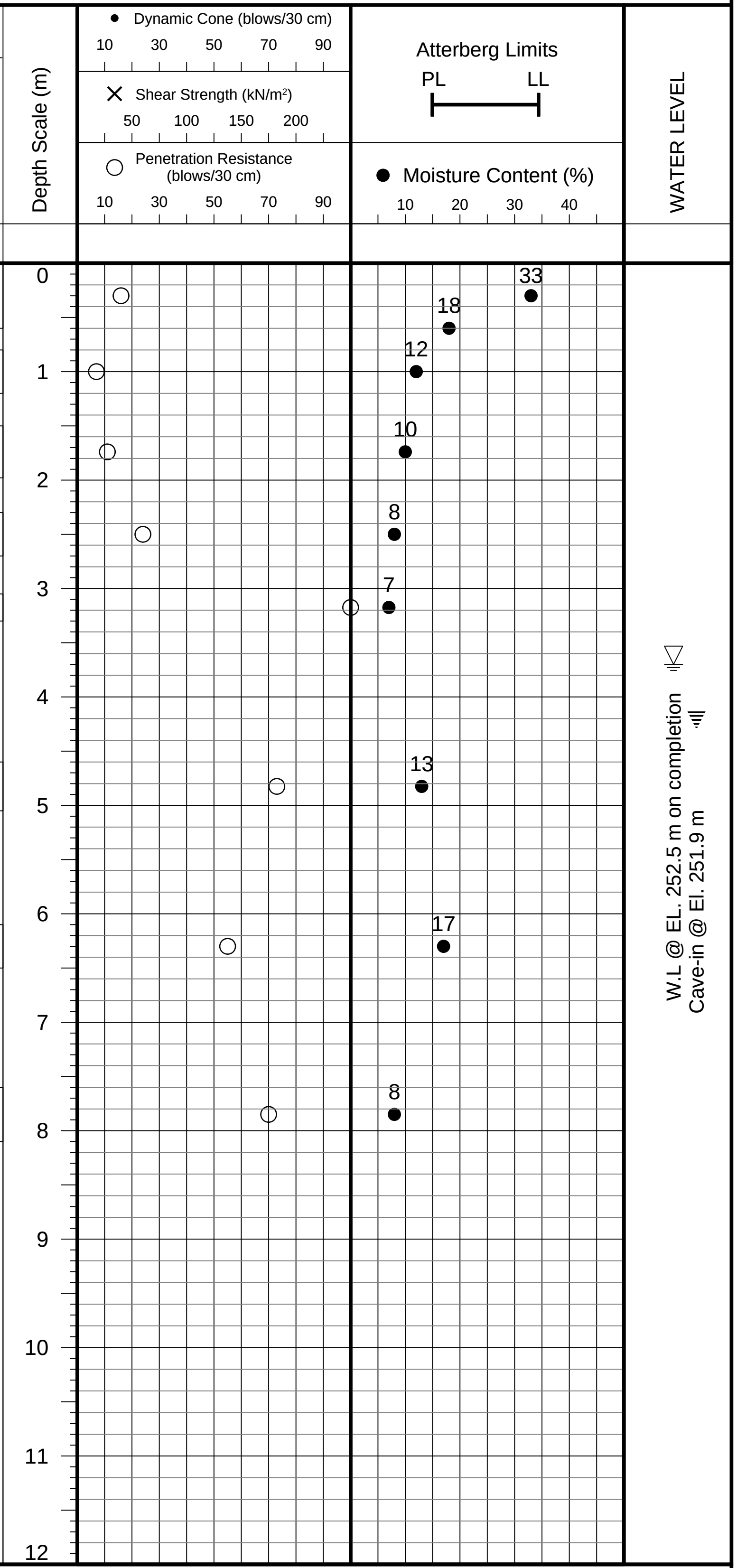
METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 28, 2019

El. (m) Depth (m)	SOIL DESCRIPTION
256.2	Ground Surface
0.0	**PLOUGHED SOIL** brown silty sand Frost
255.5 0.7	**EARTH FILL** brown sand and clay scattered topsoil
254.5 1.7	Brown, compact to very dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders
252.3 3.9	Brown, very dense **SAND** fine to medium grained trace of gravel occ. cobbles
249.2 7.0	Brown, very dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders
248.1 8.1	**END OF BOREHOLE**

SAMPLES		
Number	Type	N-Value
1A 1B	DO	16
2	DO	7
3	DO	11
4	DO	24
5	DO	50/15
6	DO	73
7	DO	55
8	DO	70



W.L @ EL. 252.5 m on completion
Cave-in @ El. 251.9 m

Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 17

FIGURE NO.: 17

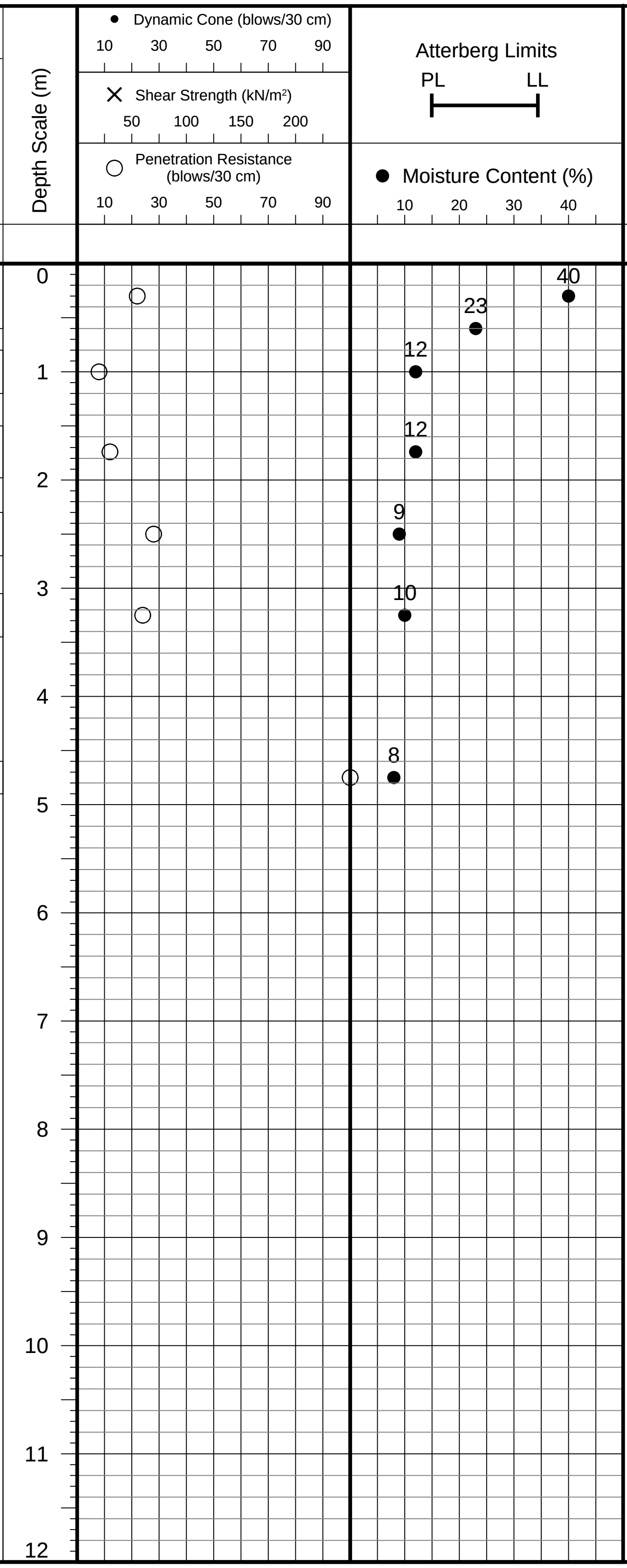
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 28, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
254.9	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	22
254.2 0.7	Brown, loose to very dense **SILTY SAND TILL** trace of clay and gravel occ. sand layers, cobbles and boulders	2	DO	8
		3	DO	12
		4	DO	28
		5	DO	24
		6	DO	50/15
250.0 4.9	**END OF BOREHOLE**			



WATER LEVEL

W.L @ EL. 252 m on completion
Cave-in @ El. 251.9 m

Soil Engineers Ltd.

JOB NO.: 1901-S077 **LOG OF BOREHOLE NO.: 18** **FIGURE NO.:** 18

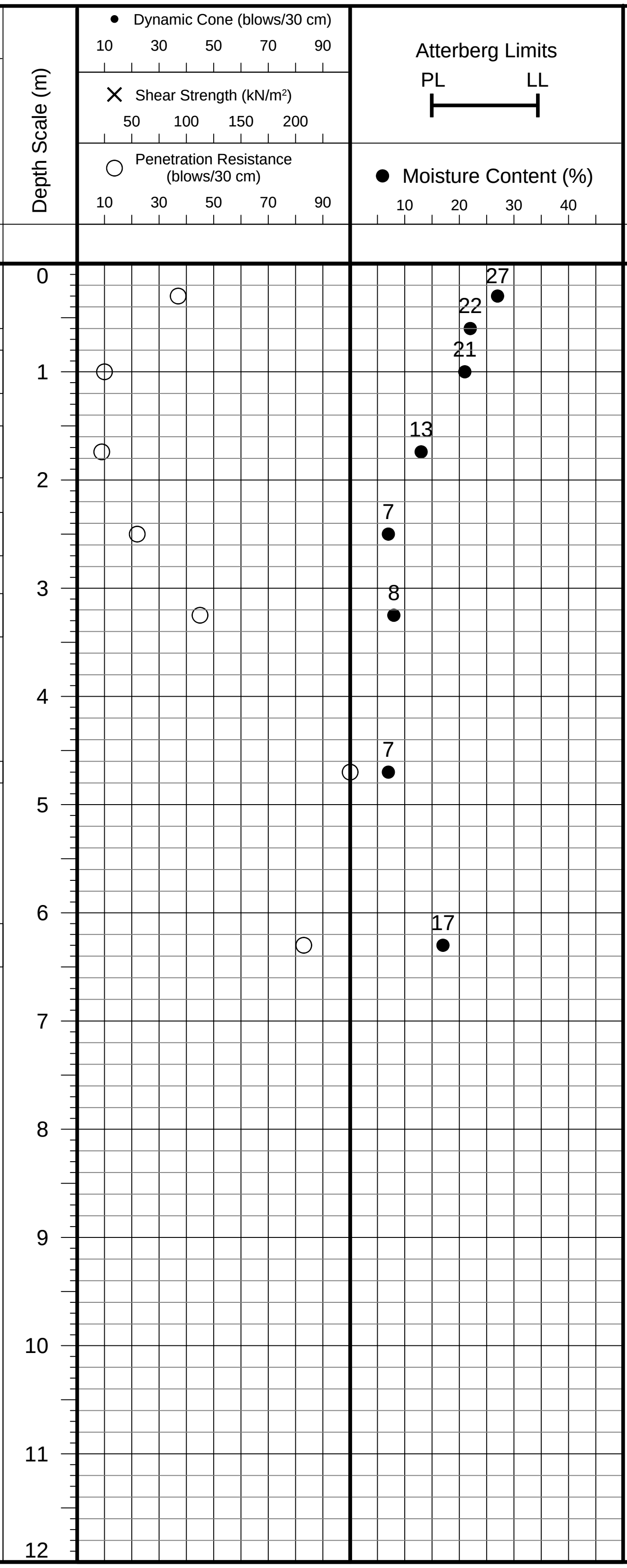
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 26, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
256.1	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	37
255.4 0.7	**EARTH FILL** brown sand and clay scattered topsoil	2	DO	10
		3	DO	9
254.0 2.1	Brown, compact to very dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders	4	DO	22
		5	DO	45
		6	DO	50/15
250.6 5.5	Brown, very dense **SAND** well graded, some silt trace of gravel	7	DO	83
249.6 6.5	**END OF BOREHOLE**			



WATER LEVEL

▽

W.L @ EL. 250.6 m on completion

Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: BH/MW 19

FIGURE NO.: 19

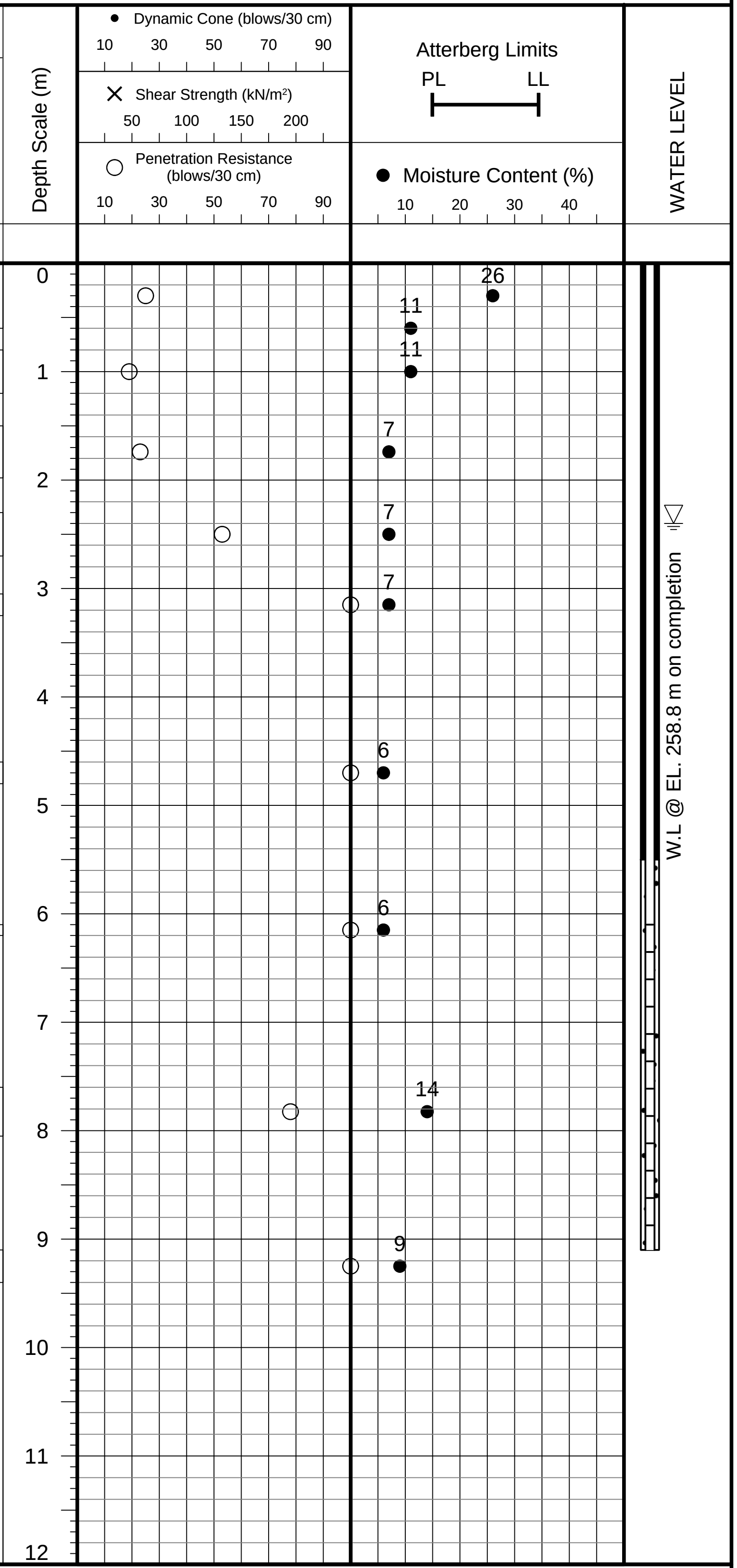
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 26, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value
261.2	Ground Surface			
0.0	**35 cm TOPSOIL**	1A 1B	DO	25
	EARTH FILL brown sand and clay scattered topsoil Frost			
260.1 1.1		2	DO	19
	Brown, compact to very dense **SILTY SAND TILL** trace of clay, some gravel occ. sand layers, cobbles and boulders	3	DO	23
		4	DO	53
		5	DO	50/15
		6	DO	70/15
		7	DO	50/10
254.2 7.0	Brown, very dense **SAND** fine to medium grained trace of gravel, some silt	8	DO	78
251.8 9.4		9	DO	50/15
	END OF BOREHOLE Installed 50mm Ø monitoring well to 9.1 m 3.0 m screen from 6.1 to 9.1 m Sand backfill from 5.5 to 9.1 m Bentonite seal from 0.0 to 5.5 m Provided with a 4x4 steel casing			



JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 20

FIGURE NO.: 20

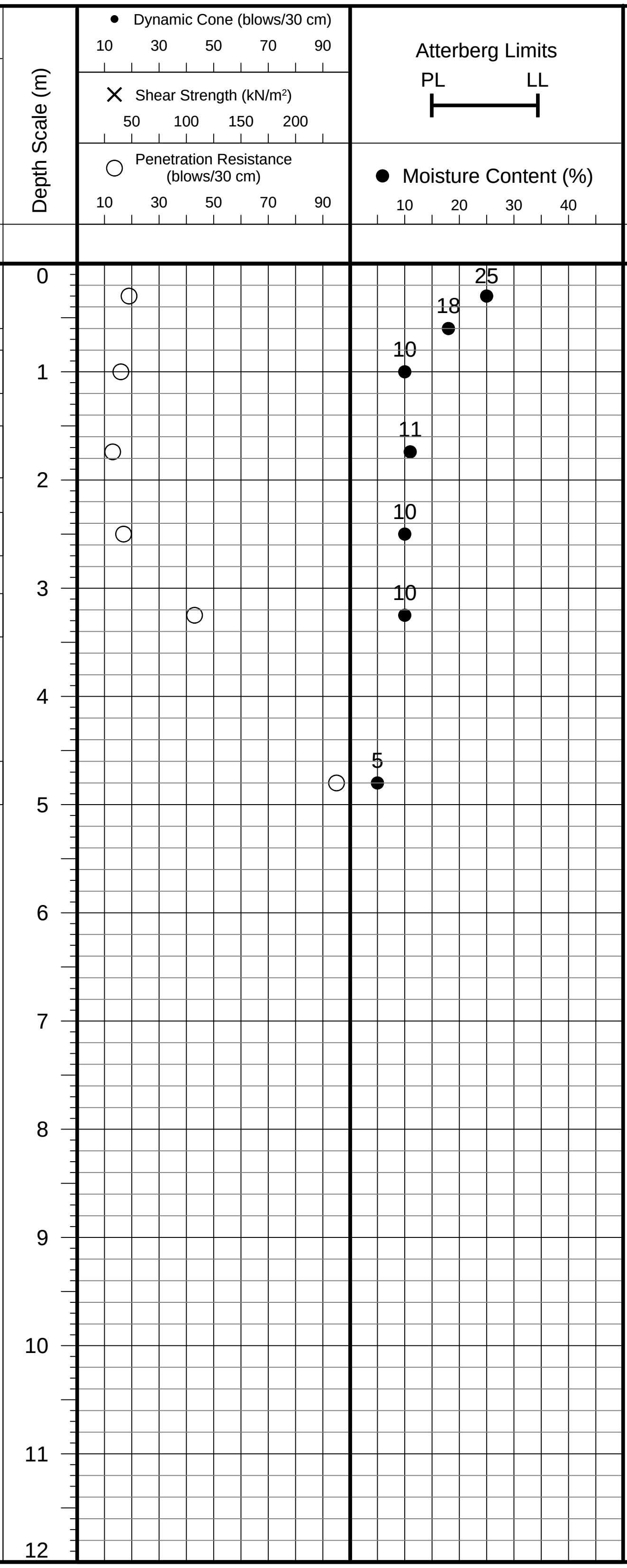
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 19, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	Moisture Content (%)	WATER LEVEL
264.6	Ground Surface					
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	19	25 18	Dry on completion
263.9 0.7	**EARTH FILL** brown sandy silt, some clay occ. organic inclusions	2	DO	16	10	
263.2 1.4	Brown, compact to dense **SILTY SAND TILL** trace of clay and gravel occ. pockets of sand, cobbles and boulders	3	DO	13	11	
		4	DO	17	10	
		5	DO	43	10	
260.6 4.0	Brown, very dense **SAND** well graded some silt and gravel occ. cobbles	6	DO	95	5	
259.6 5.0	**END OF BOREHOLE**					



Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 21

FIGURE NO.: 21

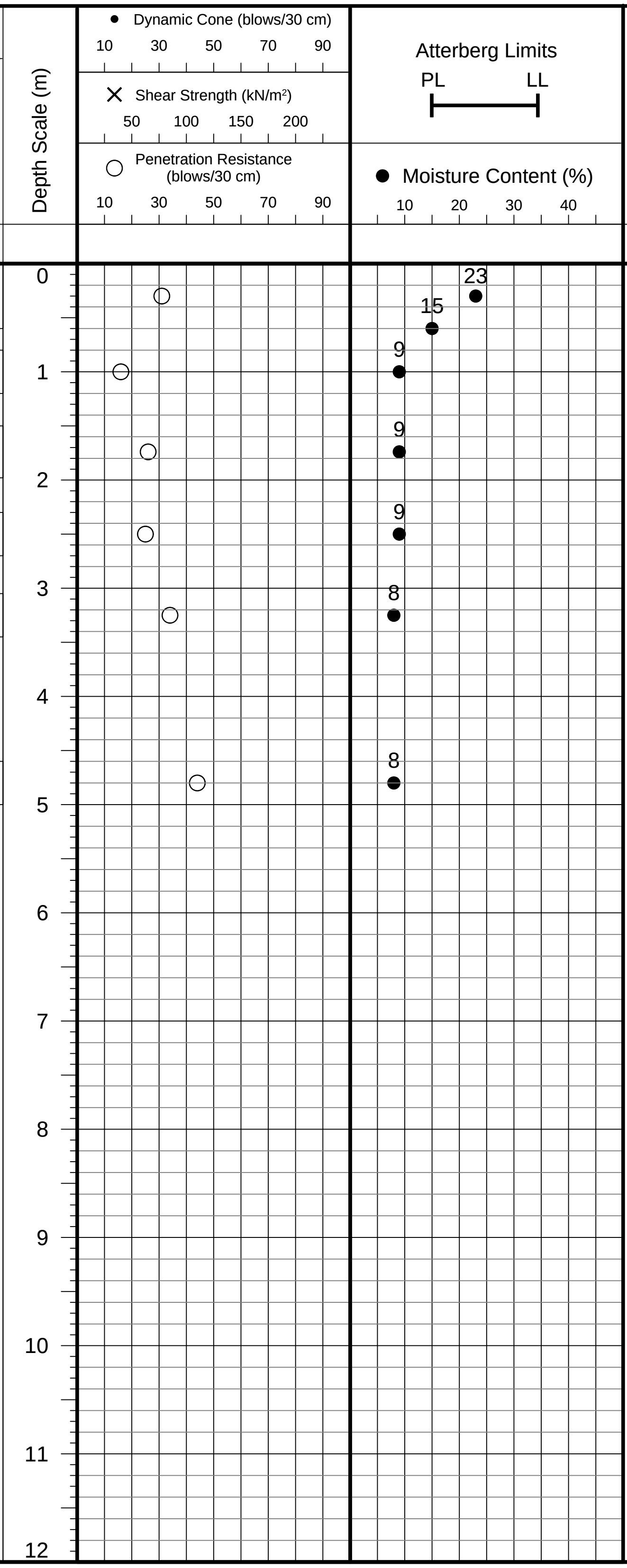
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 19, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	Type	N-Value	WATER LEVEL
259.5	Ground Surface				
0.0	**25 cm TOPSOIL** Brown, compact to dense Frost **SILTY SAND TILL** trace clay and gravel occ. cobbles and boulders	1A 1B	DO	31	Dry on completion
		2	DO	16	
		3	DO	26	
		4	DO	25	
		5	DO	34	
		6	DO	44	
254.5 5.0	**END OF BOREHOLE**				



Soil Engineers Ltd.

JOB NO.: 1901-S077

LOG OF BOREHOLE NO.: 22

FIGURE NO.: 22

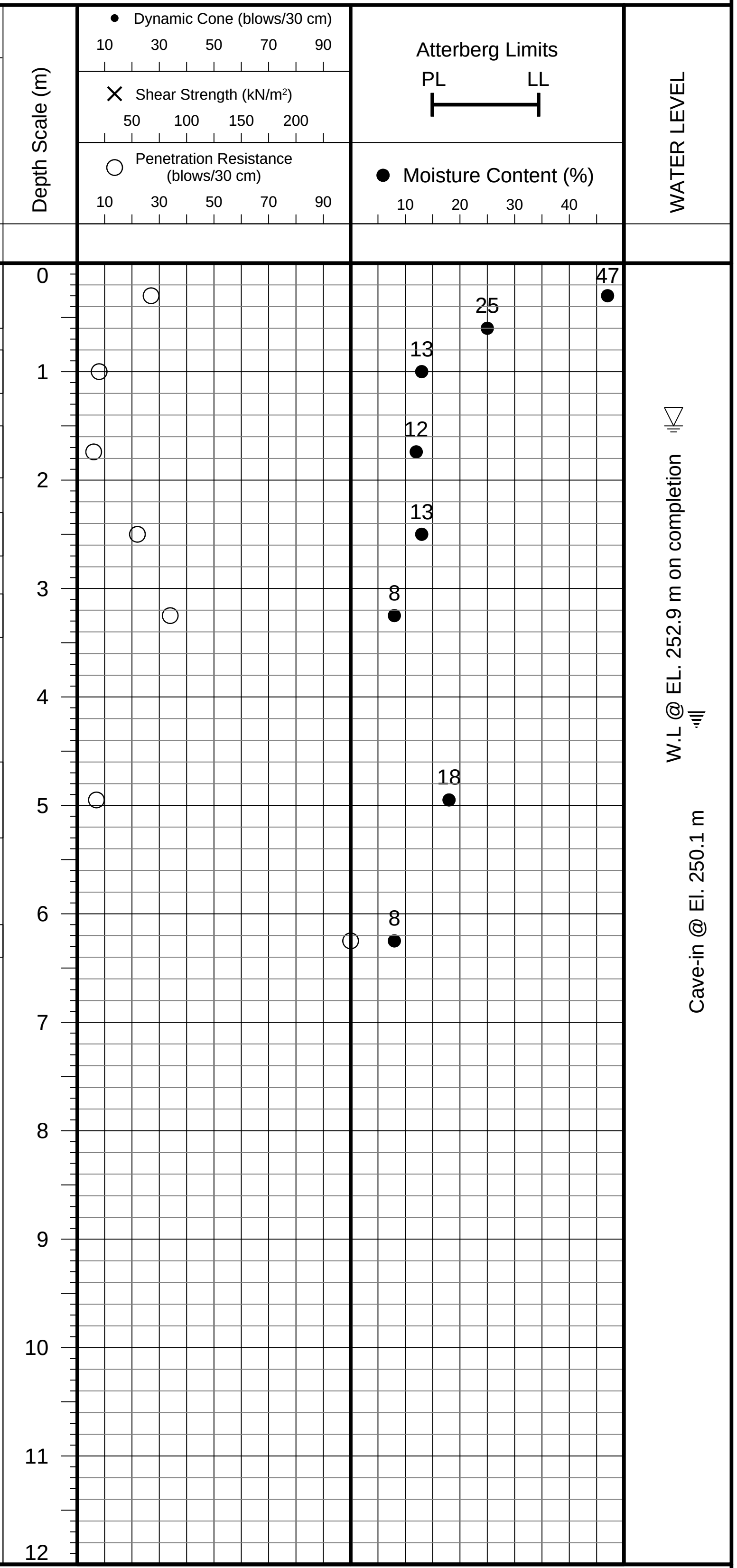
PROJECT DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger
Hollow Stem

PROJECT LOCATION: Lockhart Road, City of Barrie

DRILLING DATE: February 26, 2019

El. (m) Depth (m)	SOIL DESCRIPTION	SAMPLES Number	SAMPLES Type	SAMPLES N-Value
254.4	Ground Surface			
0.0	**PLOUGHED SOIL** brown silty sand Frost	1A 1B	DO	27
253.7 0.7	Brown, loose to dense **SILTY SAND TILL** trace to some clay occ. cobbles and boulders	2	DO	8
		3	DO	6
		4	DO	22
		5	DO	34
250.2 4.2	Brown, loose **SAND (disturbed)** fine to medium grained, some silt	6	DO	7
248.9 5.5	Brown, very dense **SILTY SAND TILL** trace of clay and gravel occ. cobbles and boulders	7	DO	50/15
248.0 6.4	**END OF BOREHOLE**			



W.L @ El. 252.9 m on completion

Cave-in @ El. 250.1 m

Soil Engineers Ltd.

JOB NO.: 1610-S022

LOG OF BOREHOLE NO.: 19

FIGURE NO.: 19

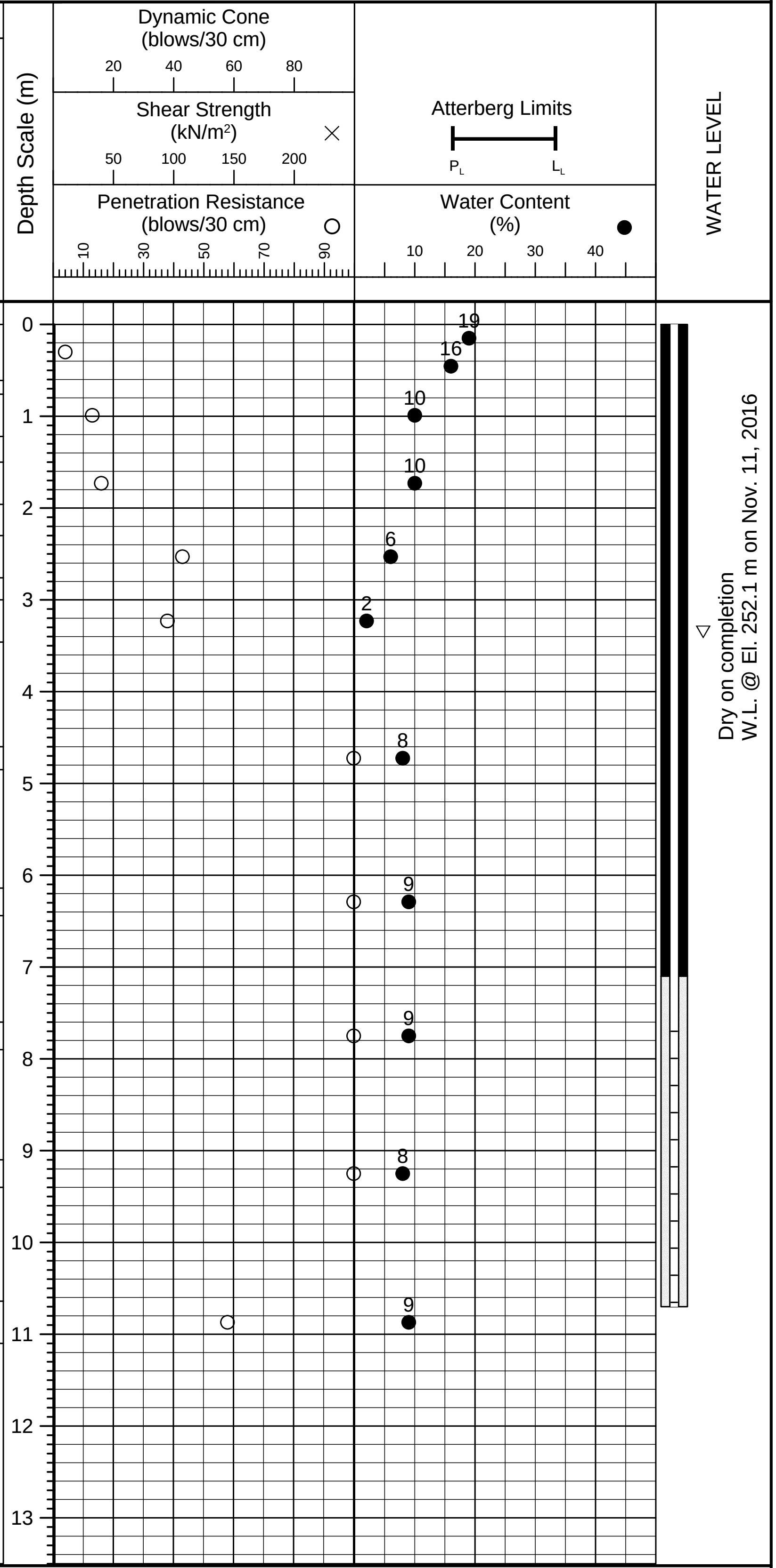
JOB DESCRIPTION: Proposed Residential Development

METHOD OF BORING: Flight-Auger

JOB LOCATION: South of Mapleview Drive, West of Goodwin Drive, City of Barrie

DRILLING DATE: October 21, 2016

El. (m) Depth (m)	SOIL DESCRIPTION		SAMPLES Number	Type	N-Value
255.5	Ground Surface				
0.0	**23 cm TOPSOIL**		1A	DO	4
	Dark brown **PLOUGHED SOIL** mixed with topsoil		1B		
254.7 0.8	Brown, compact **SILTY SAND TILL** a trace to some clay, a trace of gravel occ. wet sand and silt seams and layers, cobbles and boulders		2	DO	13
		weathered			
			3	DO	16
253.2 2.3	Brown, dense	boulder	4	DO	43
	SAND well-graded, gravelly occ. silt seams and layers	with gravel and cobbles	5	DO	38
250.9 4.6	Very dense		6	DO	50/10
	SILTY SAND TILL		7	DO	50/15
			8	DO	50/15
	a trace to some clay, a trace of gravel occ. wet sand and silt seams and layers, cobbles and boulders		9	DO	50/15
		brown grey			
244.4			10	DO	58
11.1	**END OF BOREHOLE** Installed 50 mm Ø monitoring well to 10.7 m Completed with 3.0 m screen Sand backfill from 7.7 m to 10.7 m Bentonite seal from 0.0 m to 7.7 m Provided with a protective monument steel casing				



SOIL ENGINEERS LTD.

LOG OF DRILLING OPERATIONS

MW12

BURNSIDE

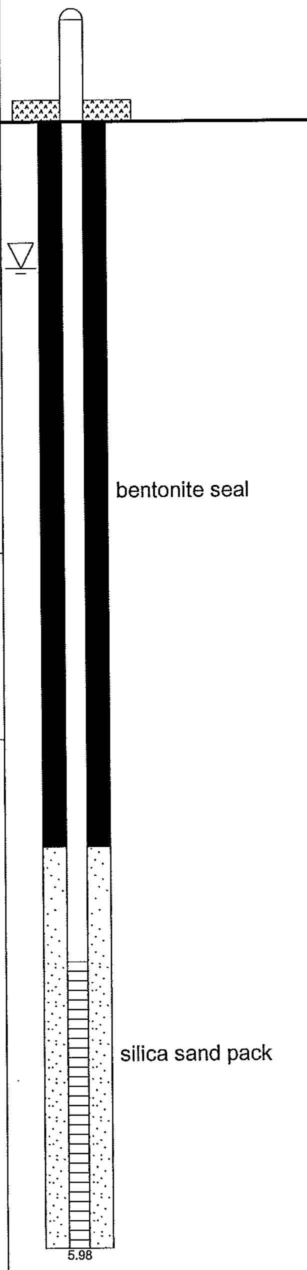
R.J. Burnside & Associates Limited
292 Speedvale Avenue West, Guelph, Ontario N1H 1C4
telephone (519) 823-4995 fax (519) 836-5477

Page 1 of 1

Client: **Hewitt's Creek Landowners Group**	Project Name: **Hewitt's Secondary Plan Area**	Logged by: **K. Churcher**
Project No.: **300033110**	Location: **Barrie, ON**	Ground (m amsl): **255.90**
Drilling Co.: **Lantech Drilling**	Date Started: **3/24/2014**	Static Water Level Depth (m): **0.78**
Drilling Method: **Hollow Stem Auger**	Date Completed: **3/24/2014**	Sand Pack Depth (m) : **3.85 - 5.98**

Surface Elevation (m): 255.90

Depth (m)	Stratigraphic Description
	TOPSOIL
0.76	SILTY SAND, fine grained, some clay, firm, cohesive, moist, brown, medium plasticity, rusty brown mottling throughout - becoming more wet
2.29	CLAYEY SILT, some fine sand, firm, cohesive, moist, brown, medium plasticity, slow dilatency
3.28	SILTY SAND, medium to fine grained, some clay, wet, semi-loose, cohesive, gray - some small gravel - gravel becoming larger
6.40	



SAMPLE Num.	Type	Int.	N.Val.
1	SS	☒	10
2	SS	☒	9
3	SS	☒	12
4	SS	☒	14
5	SS	☒	8
6	SS	☒	31
7	SS	☒	27

Depth Scale (ft) (m): 1.0, 5.0, 2.0, 3.0, 10.0, 4.0, 15.0, 5.0, 6.0, 20.0

Prepared By: **K. Churcher** Checked By: **D. Smikle** Date Prepared: **4/14/2014**

This borehole log was prepared for hydrogeological and/or environmental purposes and does not necessarily contain information suitable for a geotechnical assessment of the subsurface conditions. Borehole data requires interpretation by R. J. Burnside & Associates Limited personnel before use by others.

LEGEND	MONITORING WELL DATA	SAMPLE TYPE
▼ Water found @ time of drilling	Pipe: **51 mm dia. PVC**	AC Auger Cutting; SS ☒ Split Spoon
▽ Static Water Level - 6/9/2014	Screen: **51 mm dia. PVC #10 slot**	CS Continuous; AR ▨ Air Rotary
		RC Rock Core; WC Wash Cuttings

BHLOG GUELPH P:\GINT\PROJECTS\300 JOBS\300033110 BARRIE\300033110 BARRIE - KIM'S.GPJ TEMPLATE.GDT 11/10/15

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[THE DIFFERENCE IS OUR PEOPLE]

Appendix C

Grainsize and Hydraulic Conductivity

Appendix C

BURNSIDE

[THE DIFFERENCE IS OUR PEOPLE]

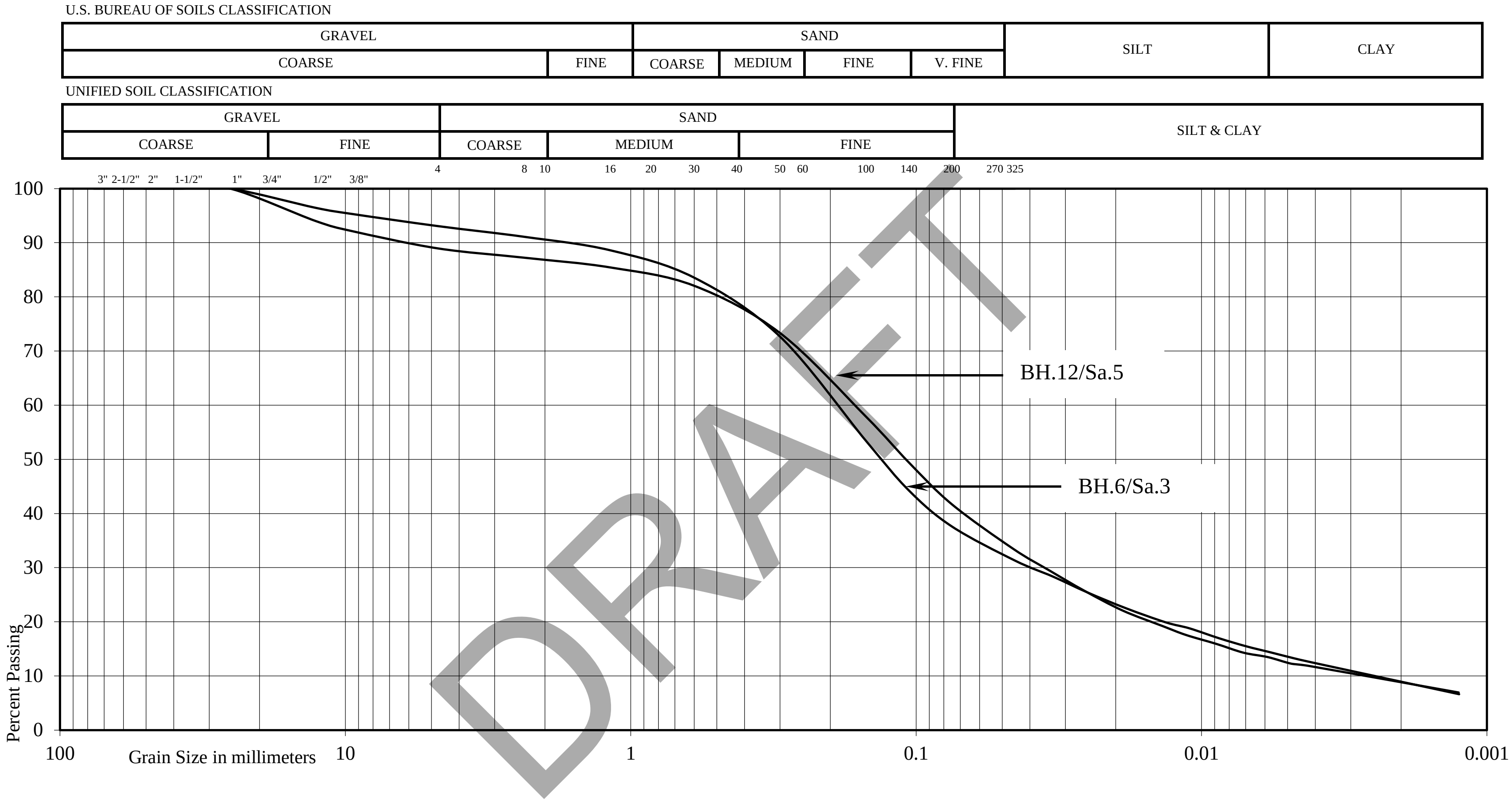
Appendix C-1

Grainsize Analysis

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1901-S077



Project: Proposed Residential Development

Location: Lockhart Road, City of Barrie

Borehole No:	6	12
Sample No:	3	5
Depth (m):	1.7	3.3
Elevation (m):	251.6	250.2

BH./Sa.	6/3	12/5
Liquid Limit (%) =	-	-
Plastic Limit (%) =	-	-
Plasticity Index (%) =	-	-
Moisture Content (%) =	14	11
Estimated Permeability (cm./sec.) =	10^{-6}	10^{-3}

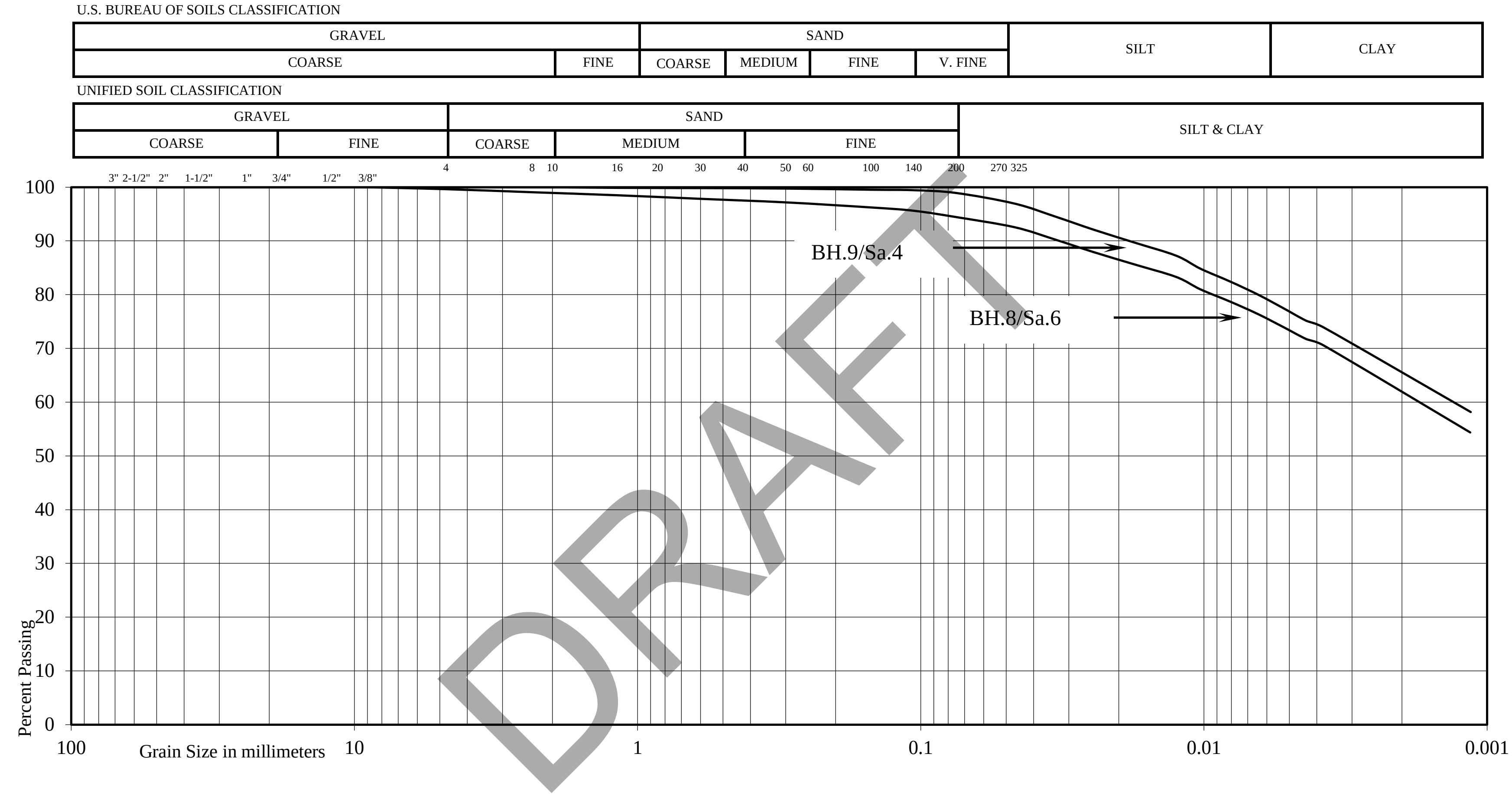
Classification of Sample [& Group Symbol]: SILTY SAND TILL, a trace to some gravel, a trace of clay

Figure: 23

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1901-S077



Project: Proposed Residential Development
Location: Lockhart Road, City of Barrie

Borehole No:	8	9
Sample No:	6	4
Depth (m):	4.8	2.5
Elevation (m):	247.6	250.1

BH./Sa.	8/6	12/5
Liquid Limit (%) =	49	-
Plastic Limit (%) =	25	-
Plasticity Index (%) =	24	-
Moisture Content (%) =	37	11
Estimated Permeability (cm./sec.) =	>10^{-7}	>10^{-7}

Classification of Sample [& Group Symbol]: SILTY CLAY, traces of sand and fine sand

Figure: 24

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

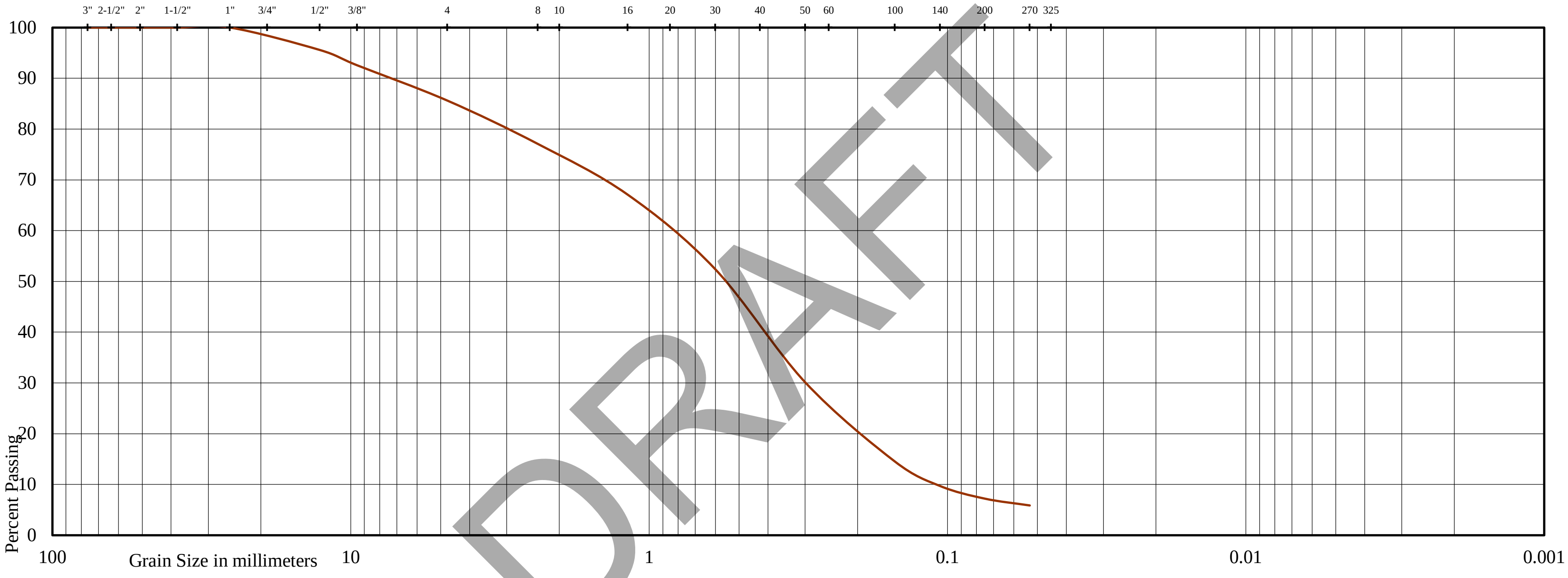
Reference No: 1901-S077

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 Residential Development

Location: Lockhart Road, City of Barrie

Liquid Limit (%) = -

Plastic Limit (%) = -

Borehole No: 1

Plasticity Index (%) = -

Sample No: 5

Moisture Content (%) = 15

Depth (m): 3.3

Estimated Permeability

Elevation (m): 249.7

(cm./sec.) = 10^{-3}

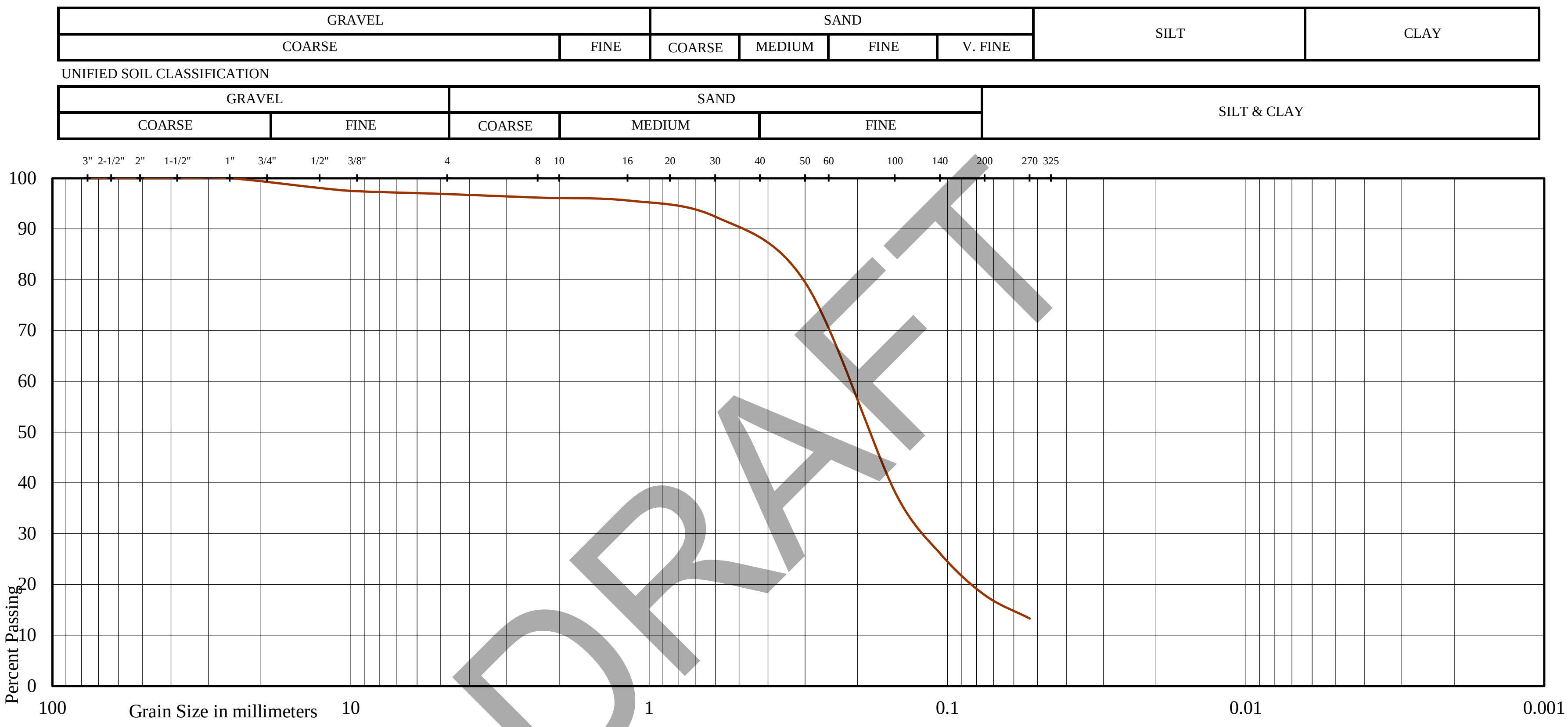
Classification of Sample [& Group Symbol]: SAND, well graded, some gravel and a trace of silt

Figure: 25

Soil Engineers Ltd.

GRAIN SIZE DISTRIBUTION

Reference No: 1901-S077



Project: Proposed Residential Development

Location: Lockhart Road, City of Barrie

Borehole No: 19

Sample No: 8

Depth (m): 7.8

Elevation (m): 253.4

Liquid Limit (%) = -

Plastic Limit (%) = -

Plasticity Index (%) = -

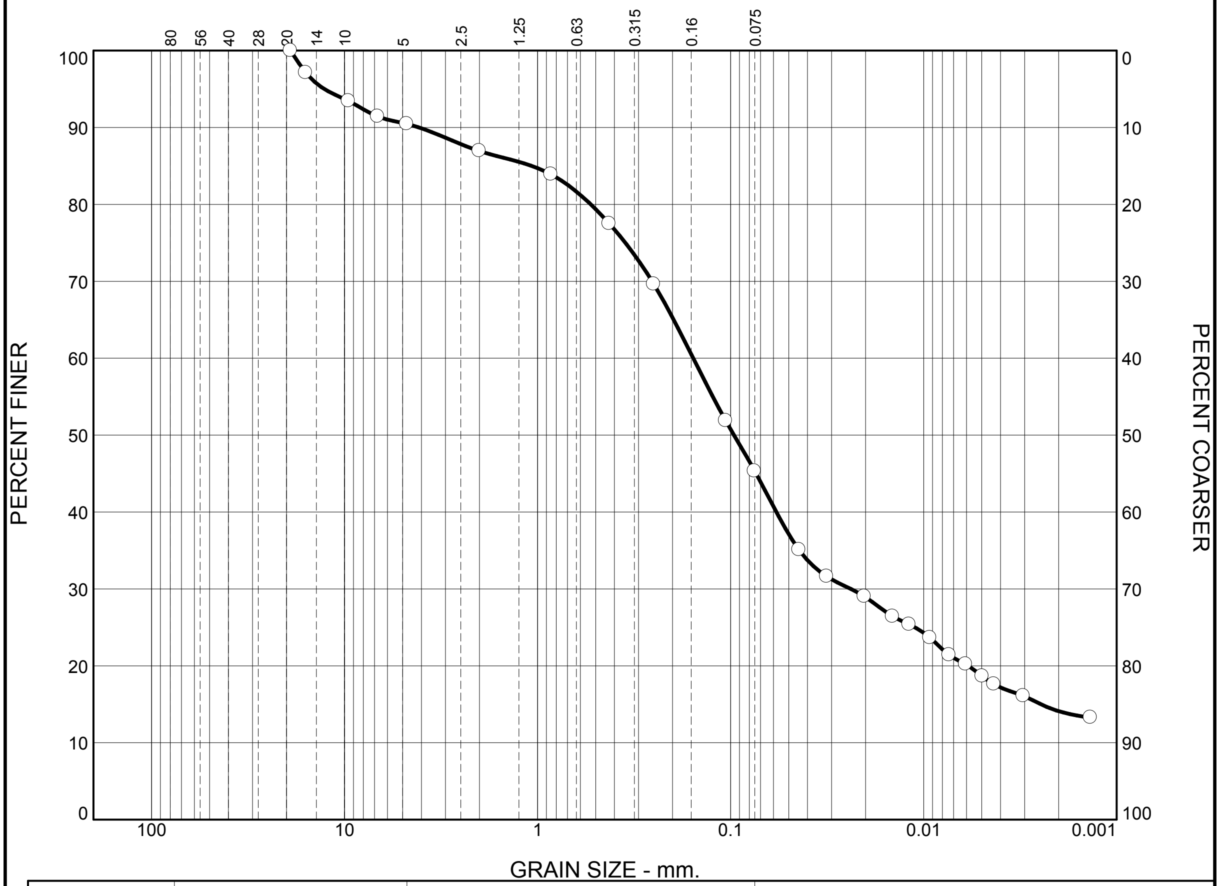
Moisture Content (%) = 14

Estimated Permeability (cm./sec.) = 10^{-4}

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

Figure: 26

Grain Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○	0	0	10	3	10	32	31	14

☒	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○			1.0715	0.1562	0.0961	0.0238	0.0025			

Material Description	USCS	AASHTO
○ SILTY SAND, some clay, trace to some gravel		

Project No. 15-041 **Client:** R.J. Burnside & Associates Limited

Project: Burnside File 300033110

Barrie East

○ **Depth:** 15-17 **Sample Number:** MW12 SS6

Remarks:

alston associates inc.
consulting engineers

Figure 13

Tested By: YM/JM **Checked By:** JB

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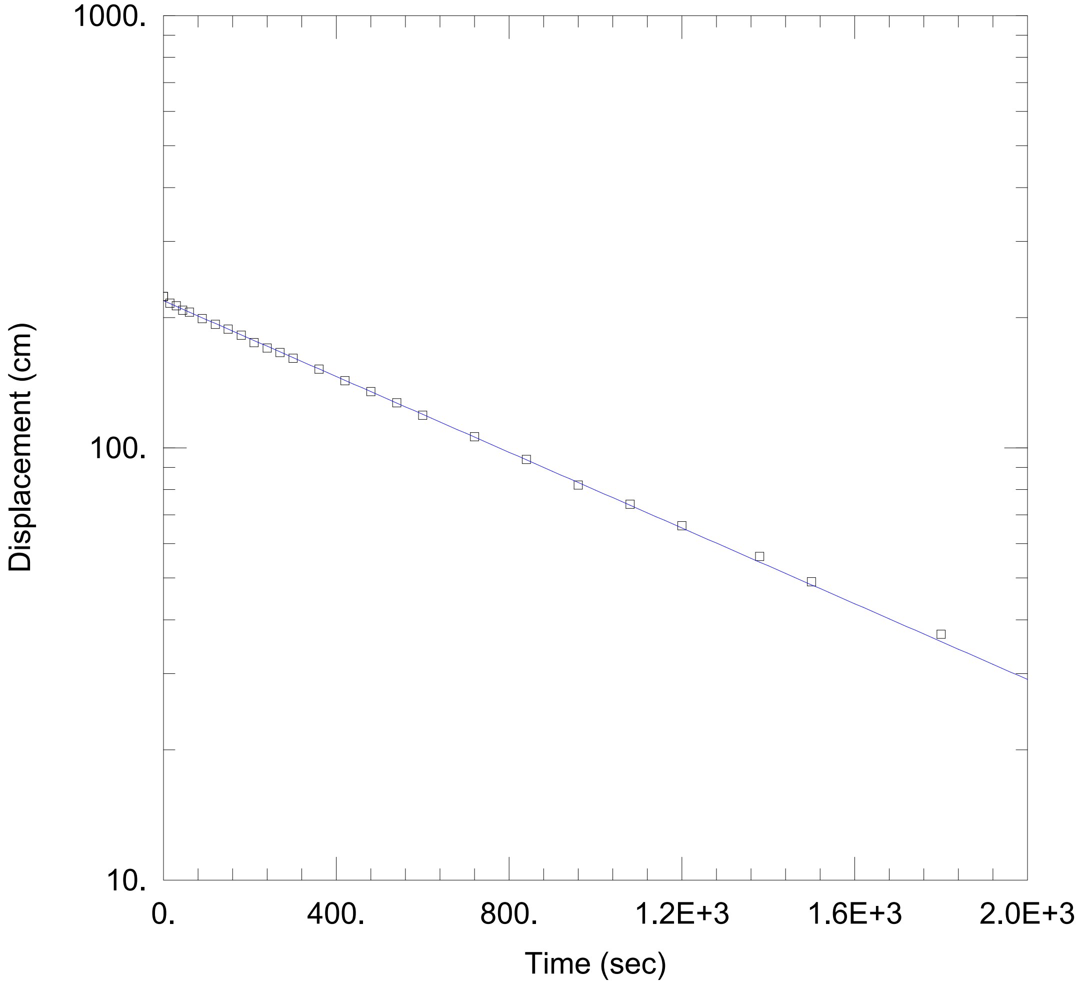
Appendix C-2

Hydraulic Conductivity



HYDRAULIC CONDUCTIVITY TEST AT BH2 "SCREENED IN SILTY SAND TILL"

PROJECT INFORMATION

Company: R.J Burnside & Associates Limi
Project: 300043818
Location: Barrie
Test Well: BH2
Test Date: August 26, 2019

AQUIFER DATA

Saturated Thickness: 743. cm
Anisotropy Ratio (Kz/Kr): 1.

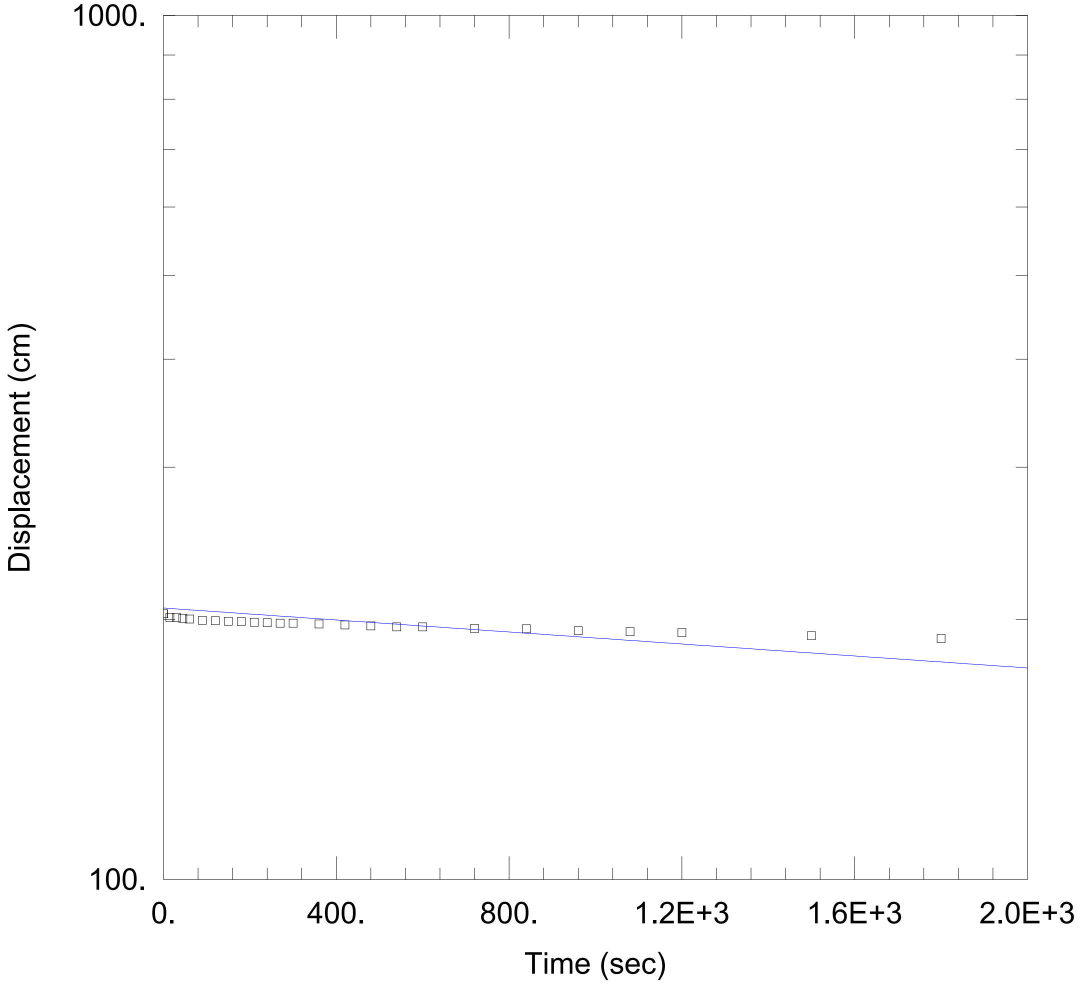
WELL DATA (BH2)

Initial Displacement: 224. cm
Total Well Penetration Depth: 743. cm
Casing Radius: 2.54 cm
Static Water Column Height: 743. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 7.892E-5 cm/sec
y0 = 218.8 cm



HYDRAULIC CONDUCTIVITY TEST AT BH8 "SCREENED IN SILTY CLAY/SILTY SAND TILL"

PROJECT INFORMATION

Company: R.J Burnside & Associates Limi
Project: 300043818
Location: Barrie
Test Well: BH8
Test Date: August 26, 2019

AQUIFER DATA

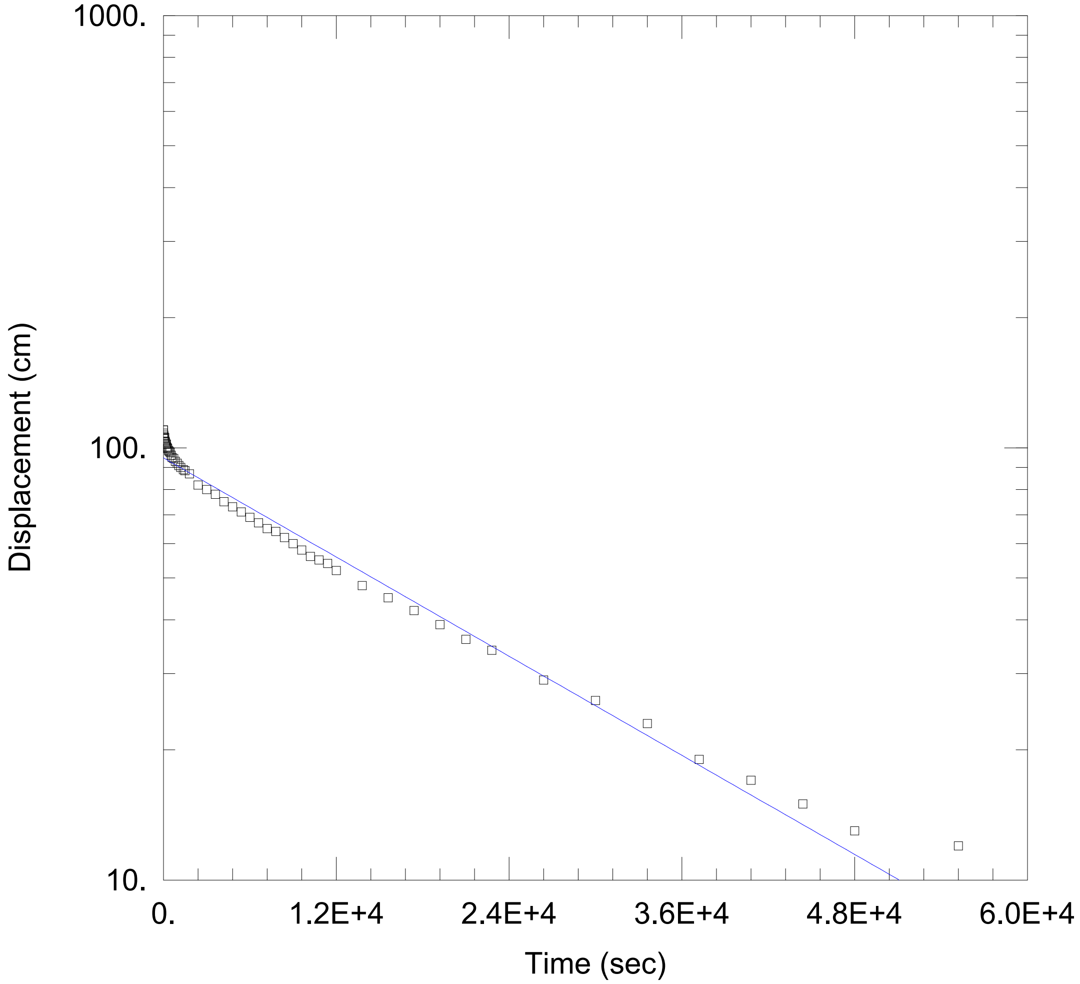
Saturated Thickness: 552. cm
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH8)

Initial Displacement: 203. cm
Total Well Penetration Depth: 552. cm
Casing Radius: 2.54 cm
Static Water Column Height: 552. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 6.251E-6 cm/sec
y0 = 206.1 cm



HYDRAULIC CONDUCTIVITY TEST AT BH10 "SCREENED IN SILTY CLAY/SILTY SAND TILL"

PROJECT INFORMATION

Company: R.J Burnside & Associates Limi
Project: 300043818
Location: Barrie
Test Well: BH10
Test Date: August 29, 2019

AQUIFER DATA

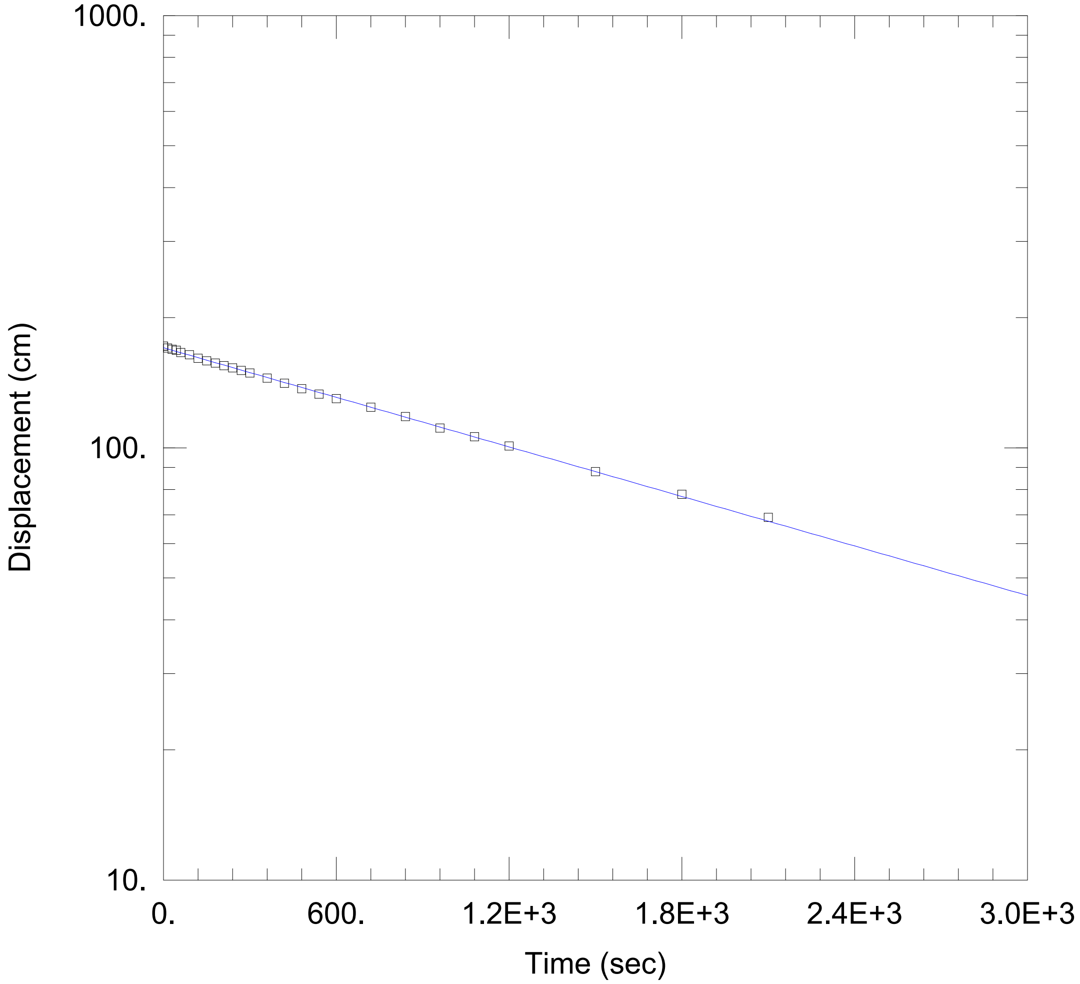
Saturated Thickness: 276. cm
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH10)

Initial Displacement: 110. cm
Total Well Penetration Depth: 276. cm
Casing Radius: 2.54 cm
Static Water Column Height: 276. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev
K = 3.443E-6 cm/sec
y0 = 94.71 cm



HYDRAULIC CONDUCTIVITY TEST AT BH15 "SCREENED IN SILTY SAND TILL"

PROJECT INFORMATION

Company: R.J Burnside & Associates Limi
Project: 300043818
Location: Barrie
Test Well: BH15
Test Date: August 26, 2019

AQUIFER DATA

Saturated Thickness: 517. cm
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (BH15)

Initial Displacement: 172. cm
Total Well Penetration Depth: 517. cm
Casing Radius: 2.54 cm
Static Water Column Height: 517. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 3.443E-5 cm/sec
y0 = 170.3 cm

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Appendix D

Groundwater Level Data

Appendix D

Table D-1
Groundwater Elevations

	Well Depth (mbgl)	Ground Surface Elevation (masl)	11-Apr-2019		11-Jun-2019		25-Jun-2019		31-Jul-2019	
			Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)
LI-BH2	**9.84**	**259.60**	0.94	258.66	-	-	0.87	258.73	1.73	257.87
LI-BH8	**6.04**	**252.40**	-0.79	253.19	-	-	-0.74	253.14	0.09	252.31
LI-BH10	**4.44**	**252.10**	0.08	252.02	-	-	0.44	251.66	1.33	250.77
LI-BH12	**4.60**	**253.50**	1.26	252.24	-	-	0.40	253.10	2.07	251.43
LI-BH15	**6.24**	**251.50**	0.05	251.45	-	-	-0.07	251.57	0.51	250.99
LI-BH19	**9.08**	**261.20**	7.20	254.00	-	-	5.88	255.32	6.54	254.66
LM-BH19	**10.89**	**255.50**	2.46	253.04	-	-	2.17	253.33	3.13	252.37
MW12	**5.98**	**255.90**	Frozen	Frozen	-	-	0.71	255.19	1.40	254.50
LM-PZ1s	**1.27**	**251.00**	-	-	-	-	0.09	250.91	-	-
LM-PZ1d	**1.81**	**251.00**	-	-	-	-	0.03	250.97	-	-
LI-PZ2s	**1.13**	**246.50**	-	-	0.71	245.79	-	-	0.43	246.07
LI-PZ2d	**1.70**	**246.50**	-	-	-0.11	246.61	-	-	0.22	246.28
LI-PZ3s	**0.96**	**252.00**	-	-	0.42	251.58	0.03	251.97	-0.71	252.71
LI-PZ3d	**1.91**	**252.00**	Frozen	Frozen	-0.59	252.59	-0.58	252.58	-0.43	252.43

"-" denotes data unavailable

Table D-1
Groundwater Elevations

	Well Depth (mbgl)	Ground Surface Elevation (masl)	26-Aug-2019		25-Sep-2019		25-Oct-2019		22-Nov-2019	
			Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)
LI-BH2	**9.84**	**259.60**	2.39	257.21	2.87	256.73	2.94	256.66	1.74	257.86
LI-BH8	**6.04**	**252.40**	0.49	251.91	4.13	248.27	0.55	251.86	-0.51	252.91
LI-BH10	**4.44**	**252.10**	1.69	250.41	1.95	250.15	1.46	250.64	0.13	251.97
LI-BH12	**4.60**	**253.50**	2.60	250.90	2.90	250.60	2.79	250.71	1.93	251.57
LI-BH15	**6.24**	**251.50**	1.07	250.43	1.04	250.47	0.70	250.80	0.17	251.33
LI-BH19	**9.08**	**261.20**	6.78	254.42	7.71	253.49	8.12	253.08	8.21	252.99
LM-BH19	**10.89**	**255.50**	3.83	251.67	4.44	251.06	4.69	250.81	4.13	251.37
MW12	**5.98**	**255.90**	1.92	253.98	2.16	253.74	1.61	254.29	0.43	255.47
LM-PZ1s	**1.27**	**251.00**	0.79	250.21	-	-	0.30	250.70	0.02	250.98
LM-PZ1d	**1.81**	**251.00**	0.90	250.10	-	-	0.25	250.75	-0.08	251.08
LI-PZ2s	**1.13**	**246.50**	0.78	245.72	0.85	245.65	0.53	245.97	0.18	246.32
LI-PZ2d	**1.70**	**246.50**	0.55	245.95	1.66	244.84	0.47	246.03	0.10	246.40
LI-PZ3s	**0.96**	**252.00**	0.39	251.61	0.69	251.31	-0.01	252.01	-0.14	252.14
LI-PZ3d	**1.91**	**252.00**	-0.24	252.24	0.13	251.87	0.13	251.87	-0.10	252.10

"-" denotes data unavailable

Table D-1
Groundwater Elevations

	Well Depth (mbgl)	Ground Surface Elevation (masl)	17-Dec-2019		23-Jan-2020		27-Feb-2020		26-Mar-2020	
			Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)
LI-BH2	**9.84**	**259.60**	-	-	0.44	259.16	0.79	258.81	0.16	259.44
LI-BH8	**6.04**	**252.40**	-	-	Frozen	Frozen	-0.76	253.16	Flowing	Flowing
LI-BH10	**4.44**	**252.10**	0.18	251.92	0.46	251.64	Frozen	Frozen	0.09	252.01
LI-BH12	**4.60**	**253.50**	1.39	252.11	1.06	252.44	1.61	251.89	0.84	252.66
LI-BH15	**6.24**	**251.50**	0.31	251.19	0.02	251.48	0.13	251.37	-0.20	251.70
LI-BH19	**9.08**	**261.20**	7.98	253.22	6.47	254.73	6.37	254.83	5.50	255.70
LM-BH19	**10.89**	**255.50**	-	-	0.87	254.63	2.25	253.25	1.34	254.16
MW12	**5.98**	**255.90**	0.46	255.44	0.53	255.37	0.59	255.31	0.32	255.58
LM-PZ1s	**1.27**	**251.00**	-	-	Frozen	Frozen	Frozen	Frozen	-0.18	251.18
LM-PZ1d	**1.81**	**251.00**	-	-	Frozen	Frozen	Frozen	Frozen	-0.14	251.14
LI-PZ2s	**1.13**	**246.50**	-	-	0.04	246.46	0.12	246.38	0.00	246.50
LI-PZ2d	**1.70**	**246.50**	-	-	Frozen	Frozen	0.11	246.39	-0.08	246.58
LI-PZ3s	**0.96**	**252.00**	-0.10	252.10	Frozen	Frozen	Frozen	Frozen	-0.09	252.09
LI-PZ3d	**1.91**	**252.00**	-0.18	252.18	Frozen	Frozen	Frozen	Frozen	-0.34	252.34

"-" denotes data unavailable

Table D-1
Groundwater Elevations

	Well Depth (mbgl)	Ground Surface Elevation (masl)	23-Apr-2020		27-Nov-2020		16-Dec-2020	
			Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)
LI-BH2	**9.84**	**259.60**	1.56	258.04	0.87	258.73	0.42	259.18
LI-BH8	**6.04**	**252.40**	Frozen	Frozen	Flowing	Flowing	Frozen	Frozen
LI-BH10	**4.44**	**252.10**	0.51	251.59	0.07	252.03	0.14	251.96
LI-BH12	**4.60**	**253.50**	1.34	252.16	1.16	252.34	0.90	252.60
LI-BH15	**6.24**	**251.50**	-0.05	251.55	0.05	251.45	0.07	251.43
LI-BH19	**9.08**	**261.20**	5.69	255.51	7.33	253.87	7.04	254.16
LM-BH19	**10.89**	**255.50**	1.79	253.71	2.65	252.85	1.56	253.94
MW12	**5.98**	**255.90**	0.53	255.37	0.30	255.60	0.38	255.52
LM-PZ1s	**1.27**	**251.00**	-0.19	251.19	-0.20	251.20	Frozen	Frozen
LM-PZ1d	**1.81**	**251.00**	-0.14	251.14	-0.40	251.40	Frozen	Frozen
LI-PZ2s	**1.13**	**246.50**	0.05	246.45	Dry	Dry	Frozen	Frozen
LI-PZ2d	**1.70**	**246.50**	0.06	246.44	Dry	Dry	Frozen	Frozen
LI-PZ3s	**0.96**	**252.00**	-0.05	252.05	-0.40	252.40	Frozen	Frozen
LI-PZ3d	**1.91**	**252.00**	-0.16	252.16	-0.37	252.37	Frozen	Frozen

"-" denotes data unavailable

LI-BH2 (Well Depth: 9.8 m, Screened in Silty Sand Till)
Groundwater Elevations

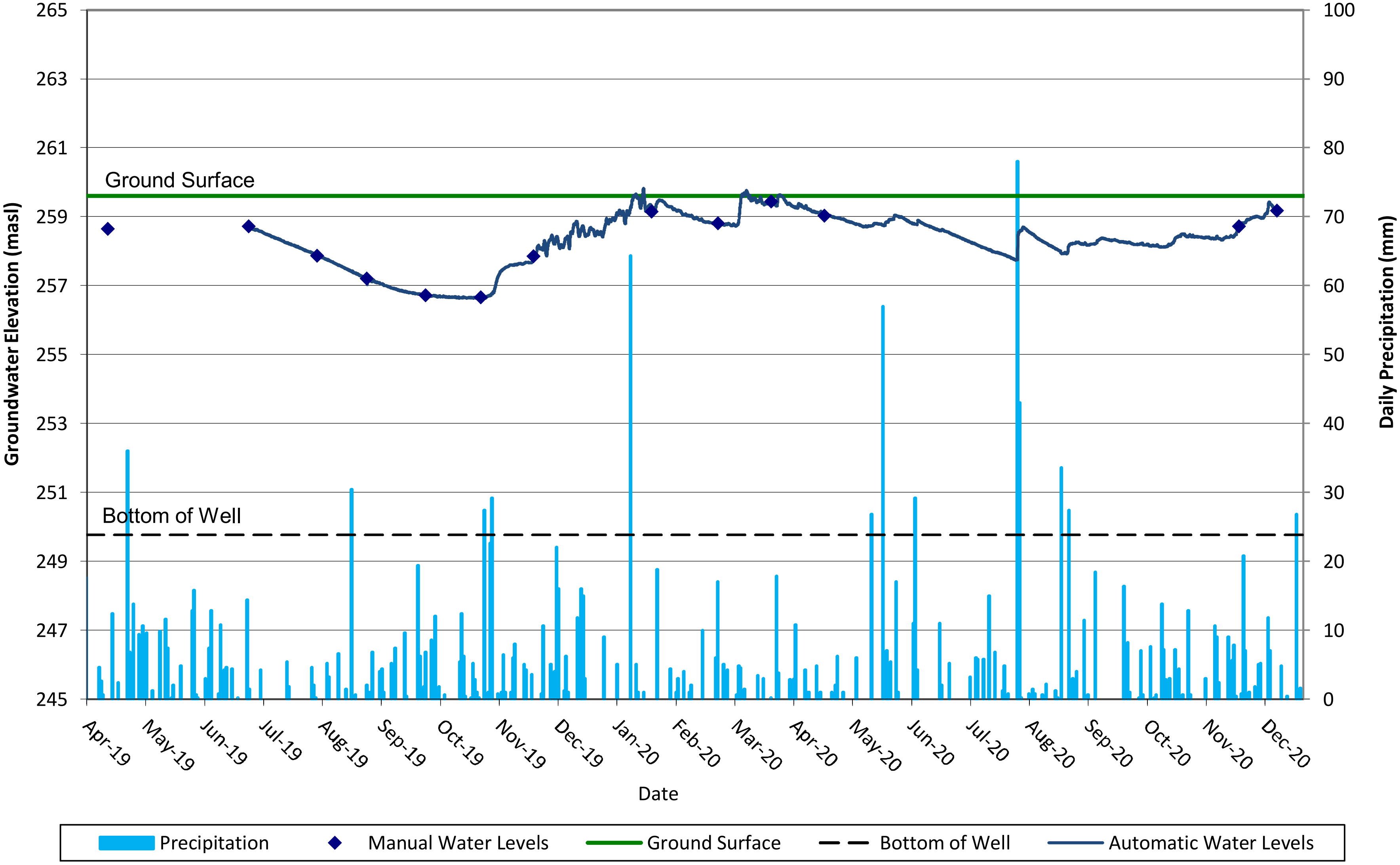

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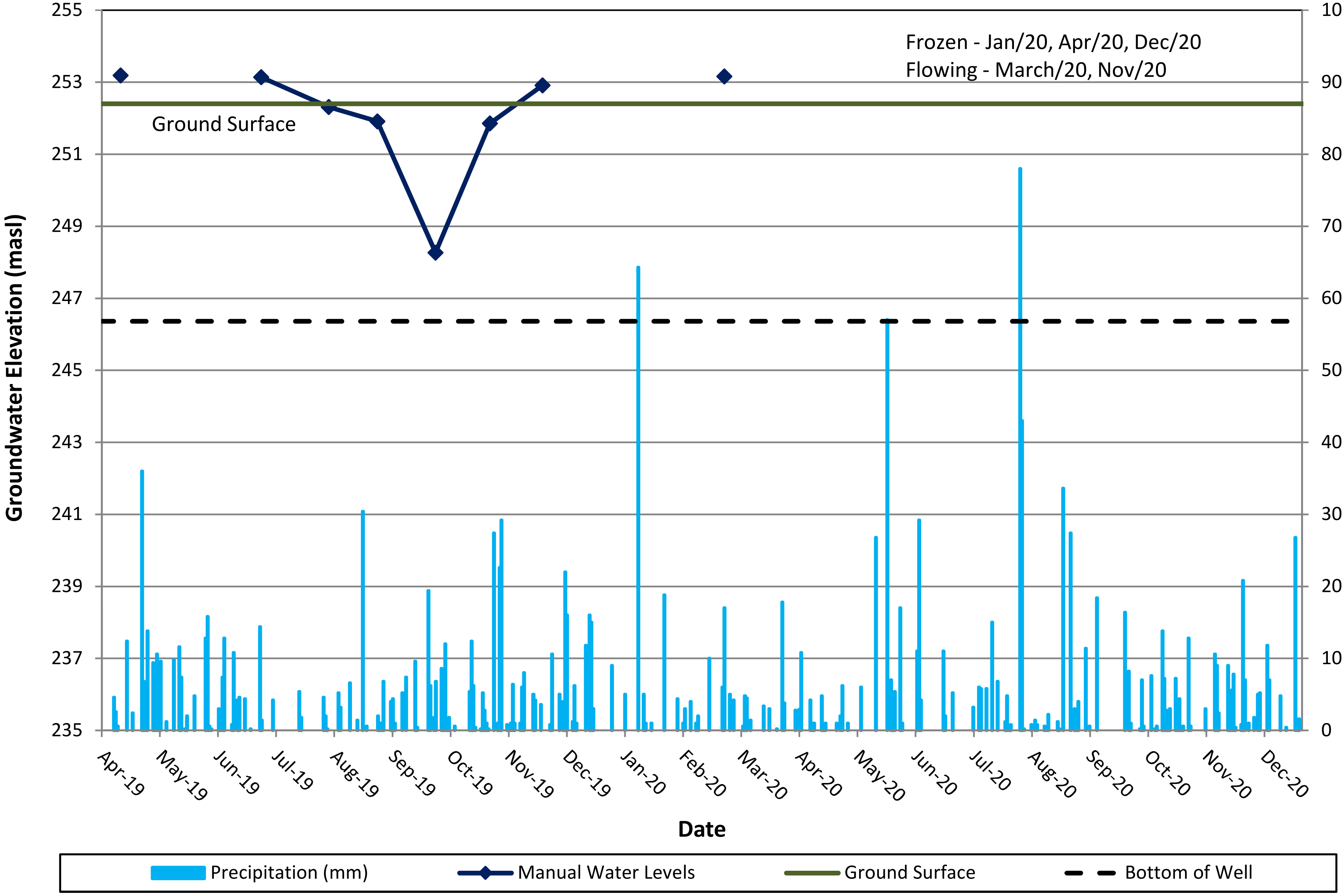
Figure D-1

LI-BH8 (Well Depth: 6.0 m, Screened in Silty Clay/Silty Sand Till)
Groundwater Elevations



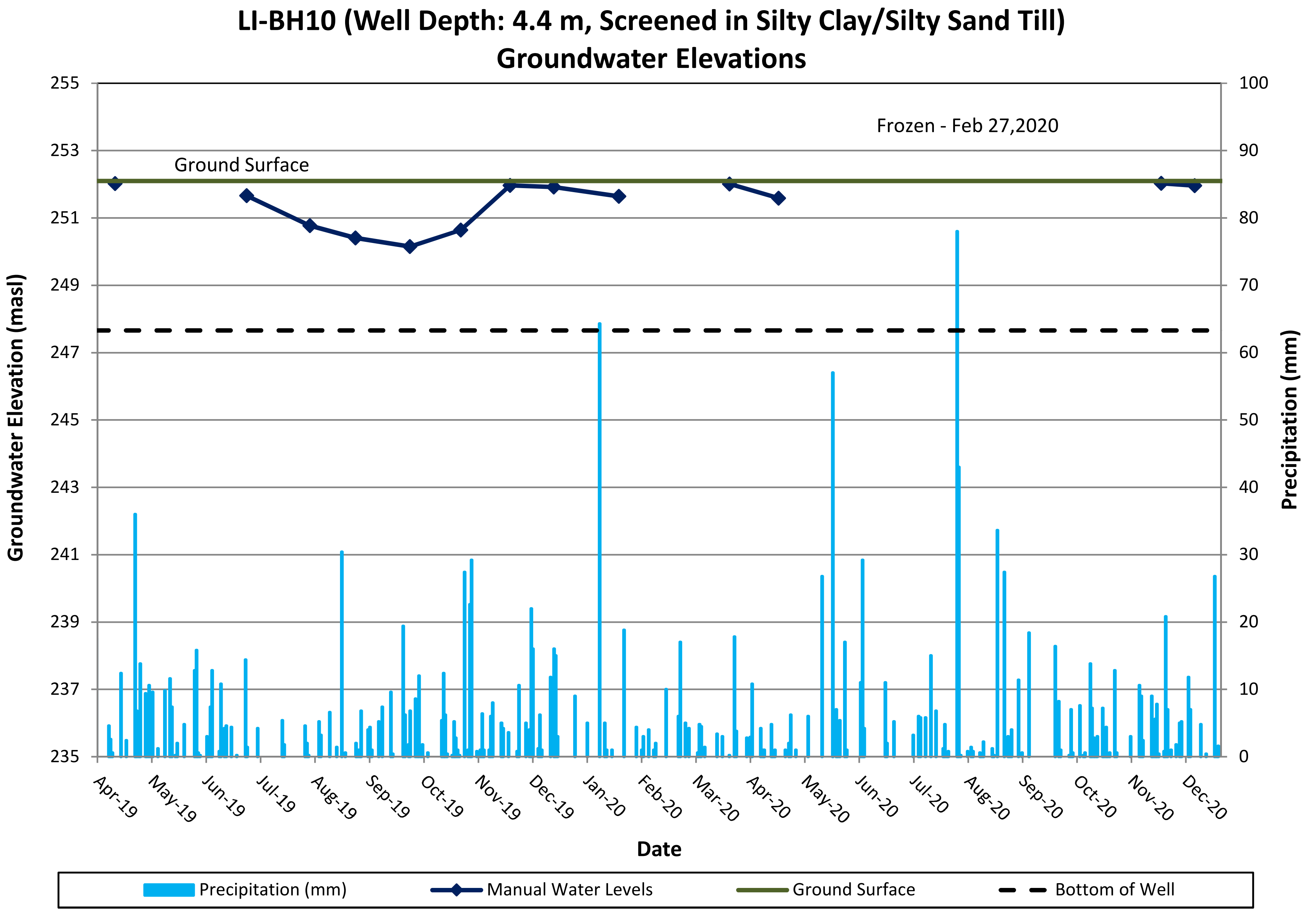

LI-BH10 (Well Depth: 4.4 m, Screened in Silty Clay/Silty Sand Till)
Groundwater Elevations
Frozen - Feb 27,2020
Ground Surface
Groundwater Elevation (masl)
255
253
251
249
247
245
243
241
239
237
235
Precipitation (mm)
100
90
80
70
60
50
40
30
20
10
0
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
Date
Precipitation (mm)
Manual Water Levels
Ground Surface
Bottom of Well

Figure D-3

LI-BH12 (Well Depth: 4.6 m, Screened in Silty Sand Till/Sand)
Groundwater Elevations

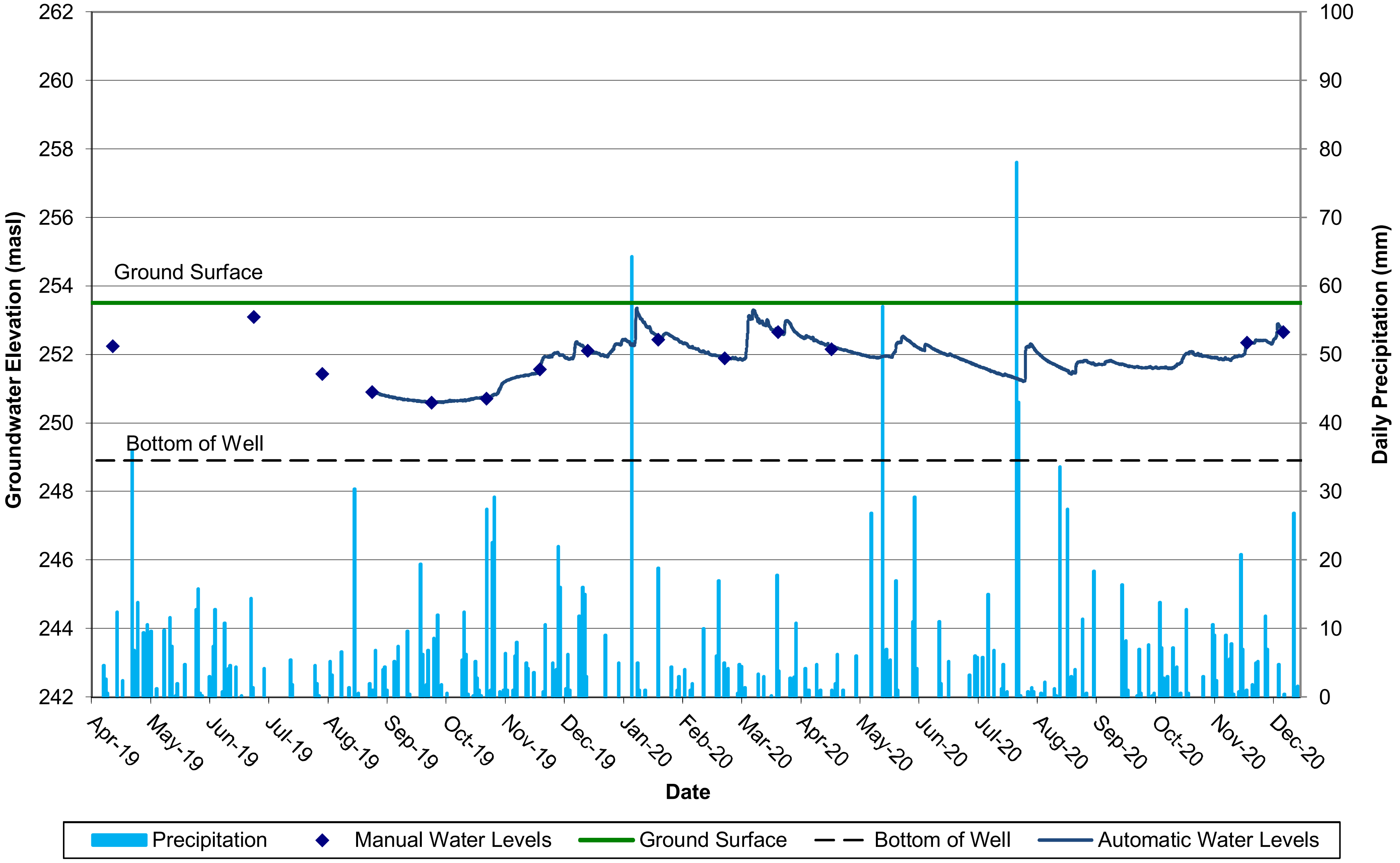


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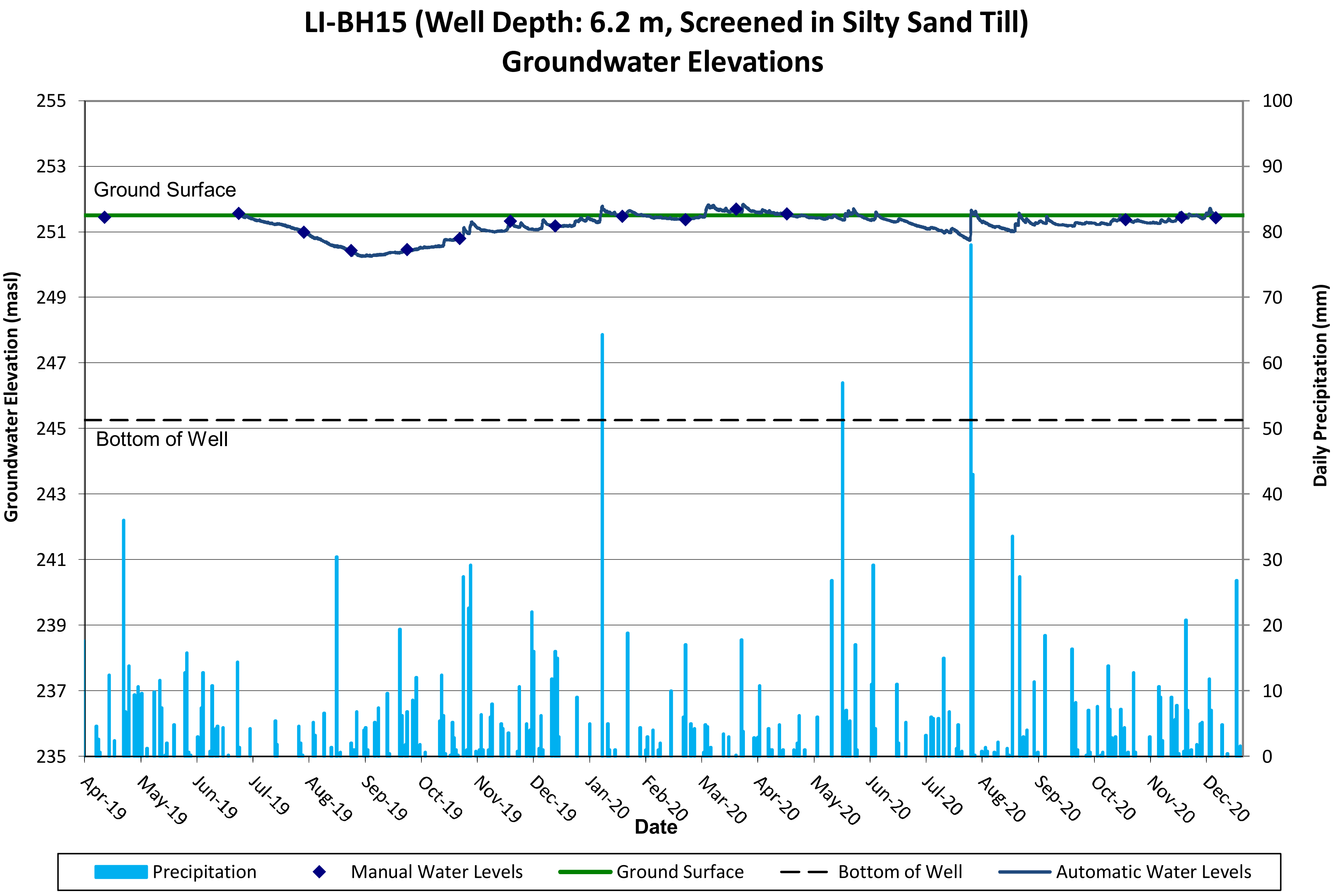
Figure D-4


LI-BH15 (Well Depth: 6.2 m, Screened in Silty Sand Till)
Groundwater Elevations
Ground Surface
Bottom of Well
Groundwater Elevation (masl)
Daily Precipitation (mm)
255
253
251
249
247
245
243
241
239
237
235
100
90
80
70
60
50
40
30
20
10
0
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
Date
Precipitation
Manual Water Levels
Ground Surface
Bottom of Well
Automatic Water Levels

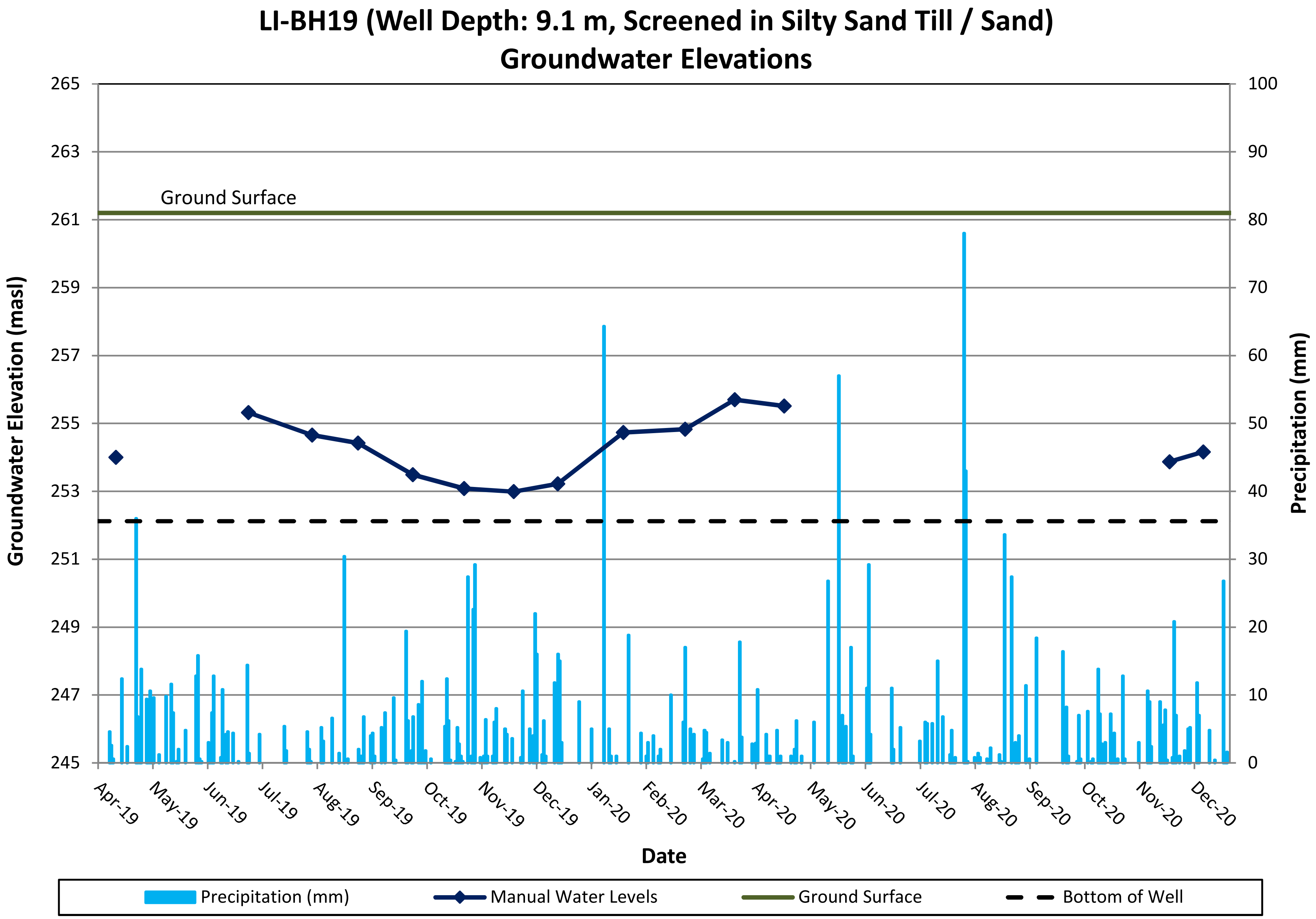


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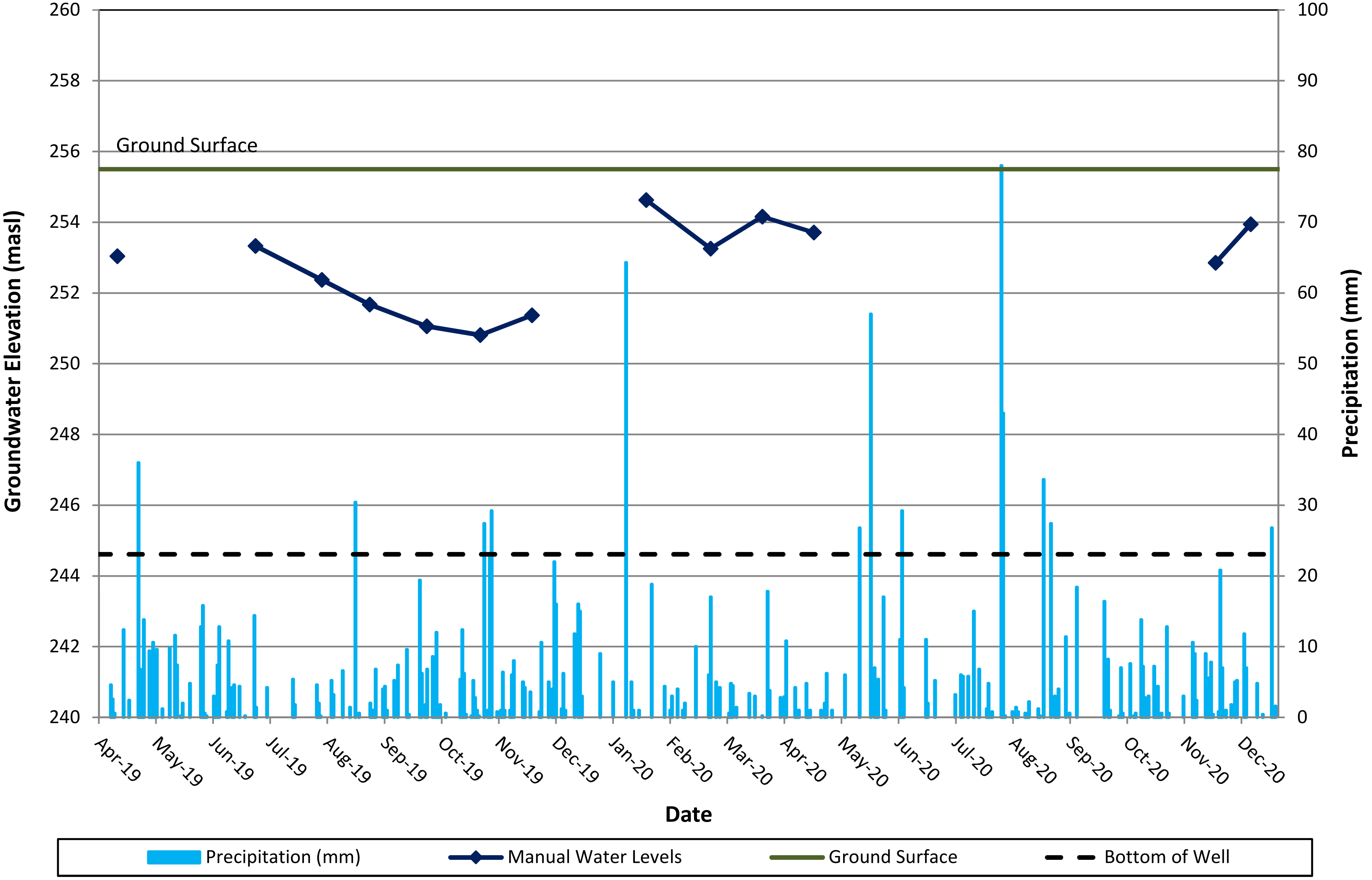
Figure D-6

LM-BH19 (Well Depth: 10.9 m, Screened in Silty Sand Till)
Groundwater Elevations



MW12 (Well Depth: 6.0 m, Screened in Silty Sand)
Groundwater Elevations

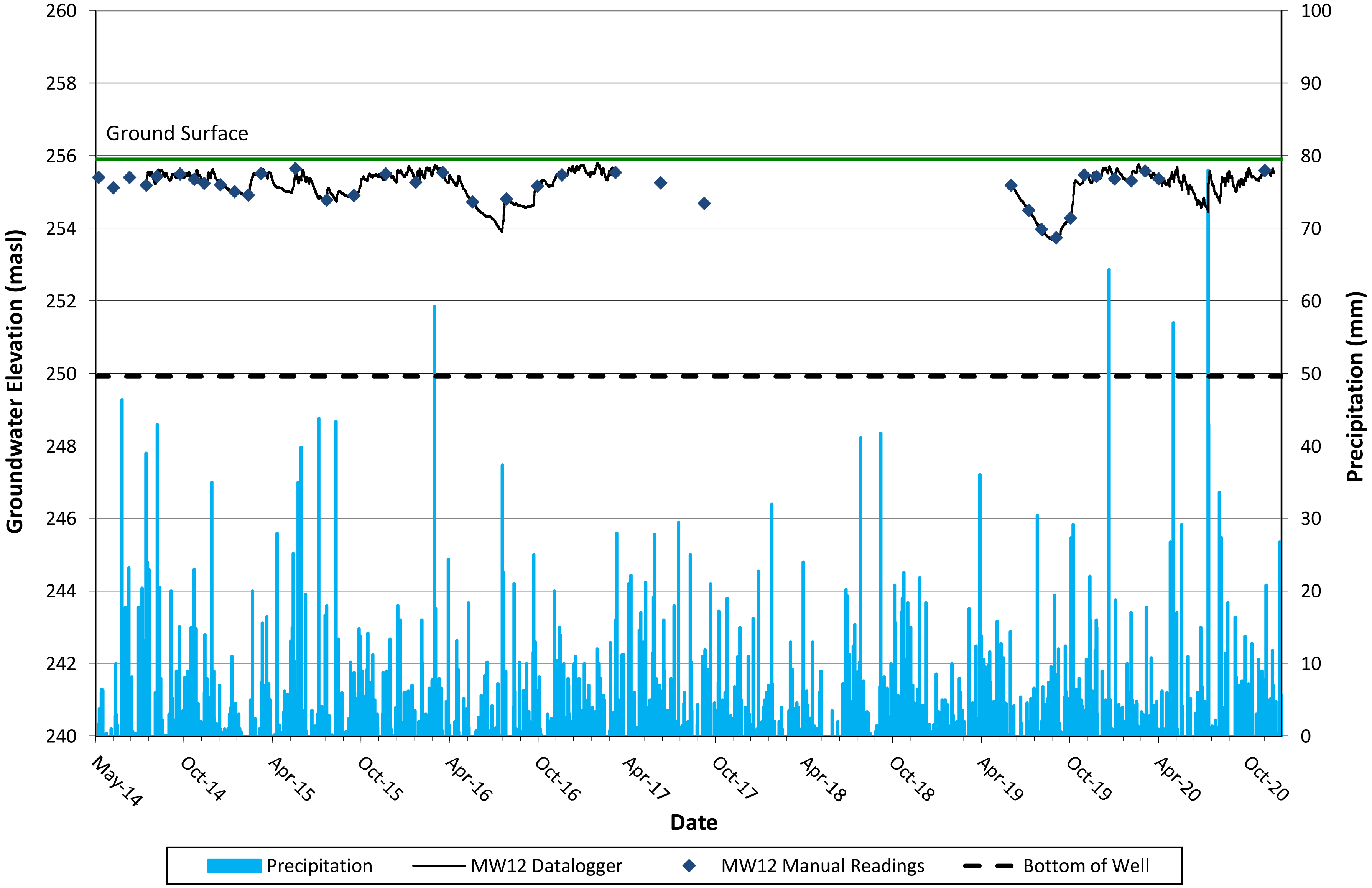


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Figure D-8

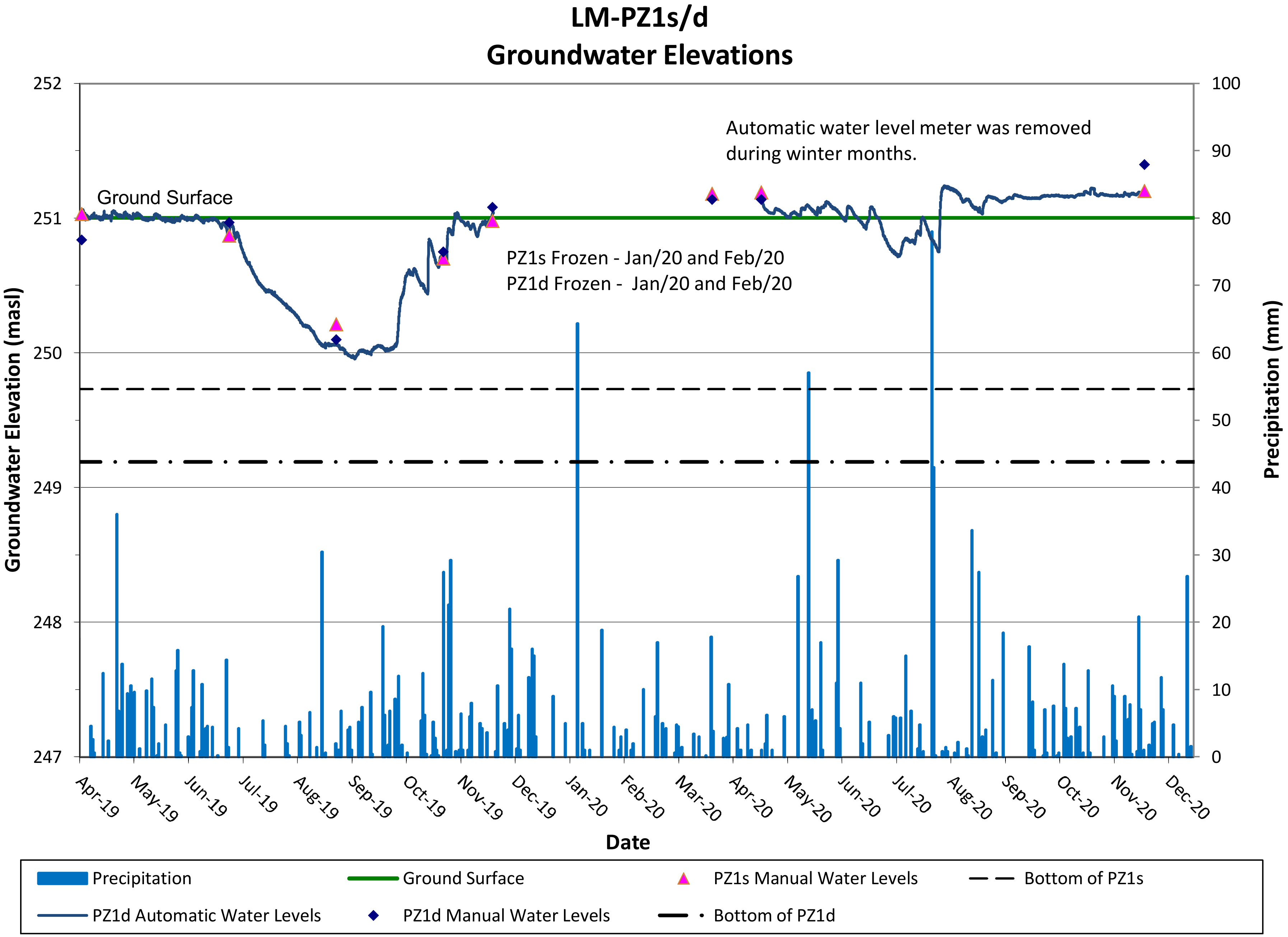
LM-PZ1s/d
Groundwater Elevations
Groundwater Elevation (masl)
Precipitation (mm)
252
251
250
249
248
247
100
90
80
70
60
50
40
30
20
10
0
Ground Surface
Automatic water level meter was removed during winter months.
PZ1s Frozen - Jan/20 and Feb/20
PZ1d Frozen - Jan/20 and Feb/20
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
Date
Precipitation
Ground Surface
PZ1s Manual Water Levels
Bottom of PZ1s
PZ1d Automatic Water Levels
PZ1d Manual Water Levels
Bottom of PZ1d

Figure D-9

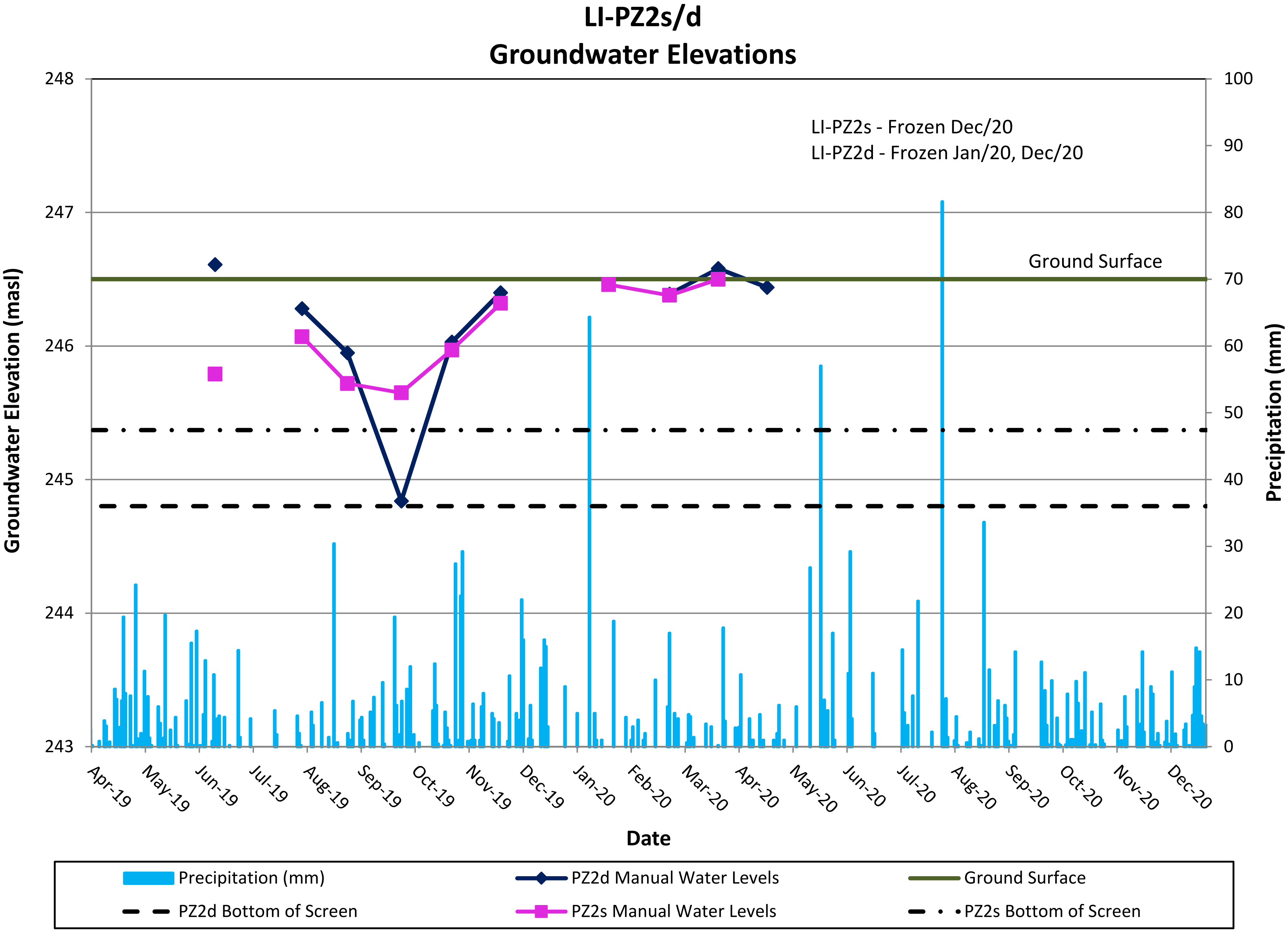
LI-PZ2s/d
Groundwater Elevations
LI-PZ2s - Frozen Dec/20
LI-PZ2d - Frozen Jan/20, Dec/20
Ground Surface
Groundwater Elevation (masl)
248
247
246
245
244
243
Precipitation (mm)
100
90
80
70
60
50
40
30
20
10
0
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
Date
Precipitation (mm)
PZ2d Manual Water Levels
Ground Surface
PZ2d Bottom of Screen
PZ2s Manual Water Levels
PZ2s Bottom of Screen

Figure D-10

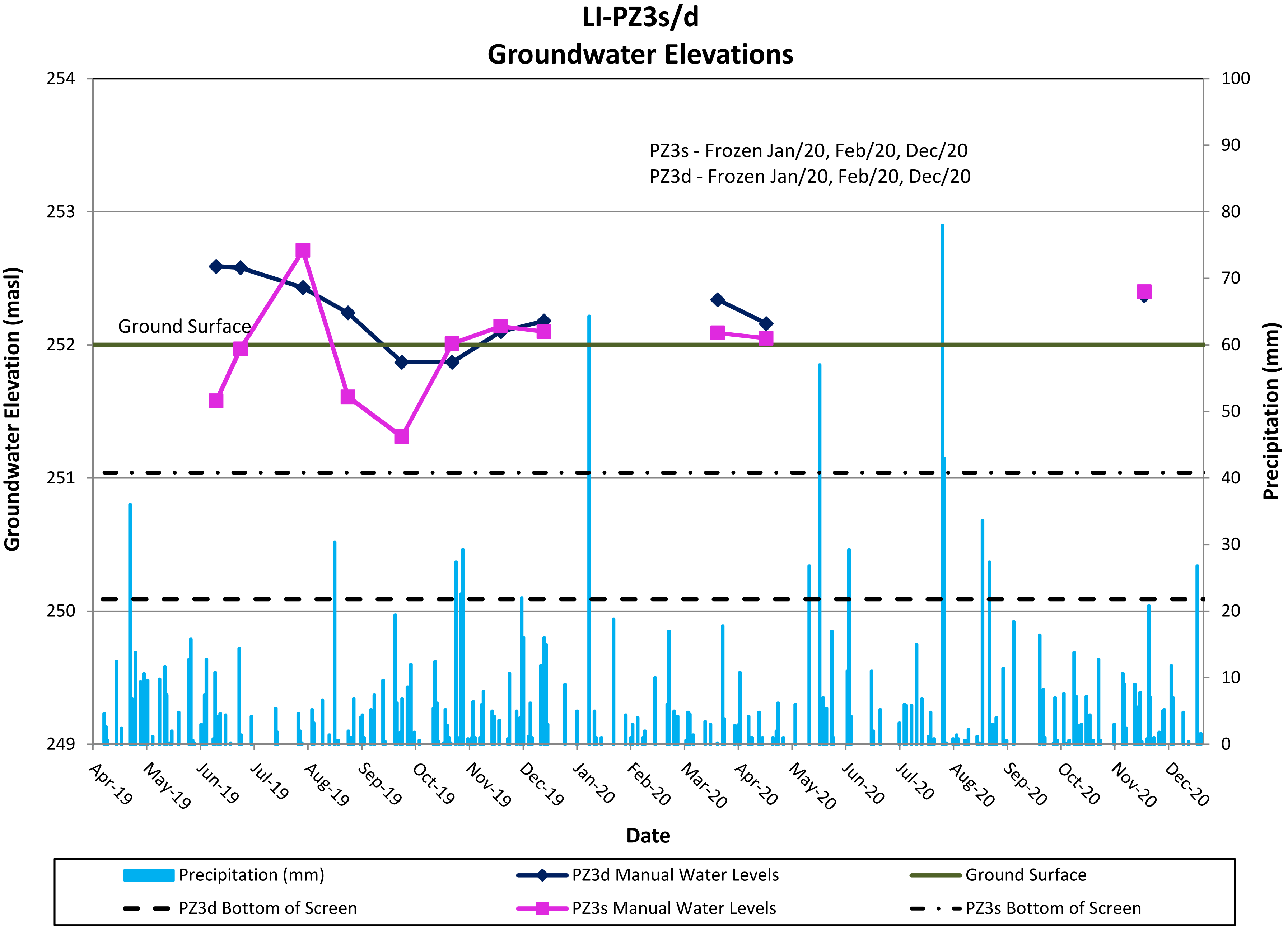
LI-PZ3s/d
Groundwater Elevations
PZ3s - Frozen Jan/20, Feb/20, Dec/20
PZ3d - Frozen Jan/20, Feb/20, Dec/20
Ground Surface
Groundwater Elevation (masl)
Precipitation (mm)
254
253
252
251
250
249
100
90
80
70
60
50
40
30
20
10
0
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
Aug-20
Sep-20
Oct-20
Nov-20
Dec-20
Date
Precipitation (mm)
PZ3d Manual Water Levels
Ground Surface
PZ3d Bottom of Screen
PZ3s Manual Water Levels
PZ3s Bottom of Screen

Figure D-11

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Appendix E

Surface Water Data

Appendix E

Table E-1
Surface Water Flow

Date	Days since rain:	Monitoring Location	
		SS2	SS3
7-May-14	3	-	7.3
9-Jun-14	6	1.9	1.4
10-Jul-14	2	6.8	6.1
13-Aug-14	0	0.7	<0.5
4-Sep-14	1	8	14.4
22-Oct-14	1	22.3	22.3
20-Nov-14	0	8.6	17.6
10-Dec-14	0	12.9	12.4
12-Jan-15	0	Frozen	7
11-Feb-15	0	Frozen	Partially Frozen
11-Mar-15	5	Snow Covered	Snow Covered
6-Apr-15	1	21.9	15.6
16-Jun-15	0	44.5	45.5
19-Aug-15	0	127.1	Too deep to measure
14-Oct-15	0	2.9	2
18-Dec-15	0	30	10.2
18-Feb-16	0	Partially Frozen and Snow Covered	Partially Frozen and Snow Covered
13-Apr-16	2	37.9	17.2
14-Jun-16		3.3	2.6
22-Aug-16	0	8.8	5.4
25-Oct-16	1	17.8	9.4
14-Dec-16	0	Partially Frozen and Snow Covered	5.3
3-Apr-17	2	20.6	4.4
5-Jul-17	3	2.8	Minimal Flow
3-Oct-17	2	5.1	Minimal Flow
25-Jun-19	0	Minimal Flow	-
31-Jul-19	1	Minimal Flow	Standing Water
26-Aug-19	0	Standing Water	Dry
26-Sep-19	0	Dry	Dry
25-Oct-19	0	4	Minimal Flow
22-Nov-19	1	64.5	Channel to Large to enter
17-Dec-19	1	Frozen	Frozen
23-Jan-20	2	Frozen	Frozen
27-Feb-20	0	Partially Frozen	Partially Frozen
26-Mar-20	0	31.4	30.6
23-Apr-20	3	19.8	13.4
16-Dec-20		Partially Frozen and Snow Covered	Partially Frozen and Snow Covered

Notes:
"<0.5" minimal flow not measureable with equipment (estimated)
"-" not measured

Table E-2
Surface Water Levels at Staff Gauges

Date	Staff Gauge	
	SG-2	SG-3
9-May-14	0.13	0.26
9-Jun-14	Dry	0.192
10-Jul-14	Dry	0.3
13-Aug-14	Dry	0.24
4-Sep-14	Dry	0.35
22-Oct-14	0.13	0.38
20-Nov-14	Frozen @ 0.13	0.32
10-Dec-14	Frozen @ 0.14	0.32
12-Jan-15	Frozen @ 0.15	0.3
11-Feb-15	Frozen @ 0.15	0.315
11-Mar-15	Frozen @ 0.15	Snow Covered
6-Apr-15	0.13	0.48
6-Jun-15	Damp Ground	0.69
19-Aug-15	Dry, pooled water throughout wetland	0.96
14-Oct-15	Dry	0.48
18-Dec-15	0.06	0.57
18-Feb-16	Frozen @ 0.08	0.78
13-Apr-16	0.06	0.73
14-Jun-16	Dry	0.64
22-Aug-16	Dry	0.68
26-Oct-16	Dry	0.72
14-Dec-16	Dry	0.74
3-Apr-17	0.01	0.27
5-Jul-17	Dry	0.08
3-Oct-17	Dry	0.11
25-Jun-19	N/A	0.2
31-Jul-19	Dry	0.1
26-Aug-19	Dry	Dry
26-Sep-19	Dry	Dry
25-Oct-19	Dry	0.18
22-Nov-19	0.4	0.1
17-Dec-19	Frozen	N/A
23-Jan-20	Frozen & Snow Covered	Frozen & Snow Covered
27-Feb-20	0.25	Frozen
26-Mar-20	0.22	0.05
23-Apr-20	0.23	0.05
16-Dec-20	Frozen & Snow Covered	Frozen & Snow Covered

Notes:
mags - meters above ground surface

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Appendix F

Water Quality

Table F-1
Groundwater Quality

Monitoring Well					**LI-BH2**	**LI-BH15**
Date Sampled					**29-Aug-19**	**29-Aug-19**
Parameter	**Unit**	**RDL**	**ODWQS**	**PWQO**		
Electrical Conductivity	µS/cm	2			583	587
pH	pH Units	NA	(6.5-8.5)	(6.5-8.5)	7.69	7.79
Saturation pH (Calculated)					7.05	7.09
Langelier Index (Calculated)					0.64	0.7
Total Hardness (as CaCO3) (Calcu	mg/L	0.5	(80-100)		**264**	**255**
Total Dissolved Solids	mg/L	20	500		332	304
Alkalinity (as CaCO3)	mg/L	5	(30-500)		246	232
Bicarbonate (as CaCO3)	mg/L	5			246	232
Carbonate (as CaCO3)	mg/L	5			<5	<5
Hydroxide (as CaCO3)	mg/L	5			<5	<5
Fluoride	mg/L	0.05	1.5		<0.05	<0.05
Chloride	mg/L	0.10	250		15.3	5.39
Nitrate as N	mg/L	0.05	10.0		5.87	8.92
Nitrite as N	mg/L	0.05	1.0		<0.05	<0.05
Bromide	mg/L	0.05			<0.05	<0.05
Sulphate	mg/L	0.10	500		21.8	8.83
Ortho Phosphate as P	mg/L	0.10			<0.10	<0.10
Ammonia as N	mg/L	0.02			0.04	0.04
Total Phosphorus	mg/L	0.02		0.03	<0.02	<0.02
Total Organic Carbon	mg/L	0.5			1	1.1
Colour	TCU	5	5		<5	<5
Turbidity	NTU	25	5		**126000**	**392**
Calcium	mg/L	0.05			74.7	81.2
Magnesium	mg/L	0.05			18.8	12.7
Sodium	mg/L	0.05	20 (200)		4.6	3.73
Potassium	mg/L	0.05			2	1.16
Aluminum	mg/L	0.004	0.1	0.075	0.008	0.008
Antimony	mg/L	0.003	0.006		<0.003	<0.003
Arsenic	mg/L	0.003	0.025	1	<0.003	<0.003
Barium	mg/L	0.002	1		0.048	0.039
Beryllium	mg/L	0.001			<0.001	<0.001
Boron	mg/L	0.010	5	2	0.025	0.013
Cadmium	mg/L	0.001	0.005	0.0002	<0.001	<0.001
Chromium	mg/L	0.003	0.05	0.009	<0.003	<0.003
Cobalt	mg/L	0.001			<0.001	0.001
Copper	mg/L	0.003	1	0.005	<0.003	<0.003
Iron	mg/L	0.010	0.3	0.3	<0.010	<0.010
Lead	mg/L	0.001	0.01	0.001	<0.001	<0.001
Manganese	mg/L	0.002	0.05		<0.002	0.003
Mercury	mg/L	0.0001	0.001	0.0002	<0.0001	<0.0001
Molybdenum	mg/L	0.002		0.04	<0.002	<0.002
Nickel	mg/L	0.003		0.025	<0.003	<0.003
Selenium	mg/L	0.004	0.01	0.01	<0.004	<0.004
Silver	mg/L	0.002		<0.002	<0.002	<0.002
Strontium	mg/L	0.005			0.234	0.187
Thallium	mg/L	0.006		0.0003	<0.006	<0.006
Tin	mg/L	0.002			<0.002	<0.002
Titanium	mg/L	0.002			<0.002	<0.002
Tungsten	mg/L	0.010			<0.010	<0.010
Uranium	mg/L	0.002	0.02	0.005	<0.002	<0.002
Vanadium	mg/L	0.002	3		<0.002	<0.002
Zinc	mg/L	0.005	5	0.03	<0.005	<0.005
Zirconium	mg/L	0.004			<0.004	<0.004

ODWQS - Ontario Drinking Water Quality Standards

RDL - Reported Detection Limit

PWQS - Provincial Water Quality Standards

Bold indicates an exceedence of the ODWQS

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Appendix G

Water Balance

WATER BALANCE CALCULATIONS
Lockhart Innisfil Investments Limited
Barrie, ON

PROJECT No.300043818

TABLE G-1

Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 200 mm (moderately-rooted vegetation in sandy clay loam soils)

Precipitation data from Barrie WPCC Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-7.7	-6.6	-2.1	5.6	12.3	17.9	20.8	19.7	15.3	8.7	2.7	-3.5	**6.9**
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.00	1.19	3.91	6.90	8.66	7.97	5.44	2.31	0.39	0.00	**36.8**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	0.00	25.18	58.76	88.02	103.48	97.59	74.33	40.47	11.47	0.00	**499**
Adjusting Factor for U (Latitude 44° 20' N)	0.81	0.82	1.02	1.13	1.27	1.29	1.3	1.2	1.04	0.95	0.8	0.76	
Adjusted Potential Evapotranspiration PET (mm)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
WATER BALANCE COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	83	62	58	62	82	85	77	90	94	78	89	74	**933**
Potential Evapotranspiration (PET)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
P - PET	83	62	58	34	8	-29	-57	-27	17	39	80	74	**340**
Change in Soil Moisture Storage	0	0	0	0	0	-29	-57	-27	17	39	58	0	**0**
Soil Moisture Storage max 200 mm	200	200	200	200	200	171	114	87	103	142	200	200	
Actual Evapotranspiration (AET)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
Soil Moisture Deficit max 200 mm	0	0	0	0	0	29	86	113	97	58	0	0	
Water Surplus - available for infiltration or runoff	83	62	58	34	8	0	0	0	0	0	22	74	**340**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	37	28	26	15	3	0	0	0	0	0	10	33	**153**
Potential Direct Surface Water Runoff (independent of temperature)	45	34	32	19	4	0	0	0	0	0	12	40	**187**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	933	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	140	mm/year											
P-PE (surplus available for runoff from impervious areas)	793	mm/year											

Assume January storage is 100% of Soil Moisture Storage
Soil Moisture Storage 200 mm <-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003

*MOE SWM infiltration calculations

topography - hilly	0.1	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - sandy clay loam	0.25	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - predominantly cultivated land	0.1	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.45**	

Latitude of site (or climate station) 44 ° N.

WATER BALANCE CALCULATIONS
Lockhart Innisfil Investments Limited
Barrie, ON

PROJECT No.300043818

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TABLE G-2

Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 300 mm (wooded areas in sandy clay loam soils)

Precipitation data from Barrie WPCC Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-7.7	-6.6	-2.1	5.6	12.3	17.9	20.8	19.7	15.3	8.7	2.7	-3.5	**6.9**
Heat index: i = (t/5)$^{1.514}$	0.00	0.00	0.00	1.19	3.91	6.90	8.66	7.97	5.44	2.31	0.39	0.00	**36.8**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	0.00	25.18	58.76	88.02	103.48	97.59	74.33	40.47	11.47	0.00	**499**
Adjusting Factor for U (Latitude 44° 20' N)	0.81	0.82	1.02	1.13	1.27	1.29	1.3	1.2	1.04	0.95	0.8	0.76	
Adjusted Potential Evapotranspiration PET (mm)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
WATER BALANCE COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	83	62	58	62	82	85	77	90	94	78	89	74	**933**
Potential Evapotranspiration (PET)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
P - PET	83	62	58	34	8	-29	-57	-27	17	39	80	74	**340**
Change in Soil Moisture Storage	0	0	0	0	0	-29	-57	-27	17	39	58	0	**0**
Soil Moisture Storage max 400 mm	400	400	400	400	400	371	314	287	303	342	400	400	
Actual Evapotranspiration (AET)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
Soil Moisture Deficit max 400 mm	0	0	0	0	0	29	86	113	97	58	0	0	
Water Surplus - available for infiltration or runoff	83	62	58	34	8	0	0	0	0	0	22	74	**340**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	45	34	32	19	4	0	0	0	0	0	12	40	**187**
Potential Direct Surface Water Runoff (independent of temperature)	37	28	26	15	3	0	0	0	0	0	10	33	**153**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	933	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	140	mm/year											
P-PE (surplus available for runoff from impervious areas)	793	mm/year											

Assume January storage is 100% of Soil Moisture Storage

Soil Moisture Storage	400 mm	<-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003

*MOE SWM infiltration calculations

topography - hilly land	0.1	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - sandy clay loam	0.25	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - woodlands	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.55**	

Latitude of site (or climate station) 44 ° N.

WATER BALANCE CALCULATIONS
Lockhart Innisfil Investments Limited
Barrie, ON

PROJECT No.300043818

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TABLE G-3

Post-Development Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 100 mm (urban lawn in sandy clay loam soils)

Precipitation data from Barrie WPCC Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-7.7	-6.6	-2.1	5.6	12.3	17.9	20.8	19.7	15.3	8.7	2.7	-3.5	**6.9**
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.00	1.19	3.91	6.90	8.66	7.97	5.44	2.31	0.39	0.00	**36.8**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	0.00	25.18	58.76	88.02	103.48	97.59	74.33	40.47	11.47	0.00	**499**
Adjusting Factor for U (Latitude 44° 20' N)	0.81	0.82	1.02	1.13	1.27	1.29	1.3	1.2	1.04	0.95	0.8	0.76	
Adjusted Potential Evapotranspiration PET (mm)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
WATER BALANCE COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	83	62	58	62	82	85	77	90	94	78	89	74	**933**
Potential Evapotranspiration (PET)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
P - PET	83	62	58	34	8	-29	-57	-27	17	39	80	74	**340**
Change in Soil Moisture Storage	0	0	0	0	0	-29	-57	-14	17	39	44	0	**0**
Soil Moisture Storage max 100 mm	100	100	100	100	100	71	14	0	17	56	100	100	
Actual Evapotranspiration (AET)	0	0	0	28	75	114	135	104	77	38	9	0	**580**
Soil Moisture Deficit max 100 mm	0	0	0	0	0	29	86	100	83	44	0	0	
Water Surplus - available for infiltration or runoff	83	62	58	34	8	0	0	0	0	0	35	74	**353**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	37	28	26	15	3	0	0	0	0	0	16	33	**159**
Potential Direct Surface Water Runoff (independent of temperature)	45	34	32	19	4	0	0	0	0	0	20	40	**194**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	933	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	140	mm/year											
P-PE (surplus available for runoff from impervious areas)	793	mm/year											

Assume January storage is 100% of Soil Moisture Storage

Soil Moisture Storage	100 mm	<-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003

*MOE SWM infiltration calculations

topography - hilly land	0.1	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - sandy clay loam	0.25	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - urban lawn	0.1	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.45**	

Latitude of site (or climate station) 44 ^{O} N.

WATER BALANCE CALCULATIONS
Lockhart Innisfil Investments Limited
Barrie, ON

PROJECT No.300043818

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TABLE G-4

Water Balance for Pre- and Post-Development Land Use Conditions (with no SWM/LID measures in place)

Land Use Description	Approx. Land Area* (m^2)	Estimated Impervious Fraction for Land Use*	Estimated Impervious Area (m^2)	Runoff from Impervious Area** (m/a)	Runoff Volume from Impervious Area (m^3/a)	Estimated Pervious Area (m^2)	Runoff from Pervious Area** (m/a)	Runoff Volume from Pervious Area (m^3/a)	Infiltration from Pervious Area** (m/a)	Infiltration Volume from Pervious Area (m^3/a)	Total Runoff Volume (m^3/a)	Total Infiltration Volume (m^3/a)
Pre-Development Land Use												
Woodland/Wetland	146,800	0.00	0	0.793	0	146,800	0.153	22,442	0.187	27,429	22,442	27,429
Open Space /Agricultural	371,400	0.00	0	0.793	0	371,400	0.187	69,394	0.153	56,777	69,394	56,777
TOTAL PRE-DEVELOPMENT	**518,200**		**0**		**0**	**518,200**		**91,835**		**84,205**	**91,835**	**84,205**
Post-Development Land Use (with no LID measures in place)												
Single Residential	136,000	0.70	95,200	0.793	75,490	40,800	0.194	7,921	0.159	6,481	83,411	6,481
Townhouse	23,500	0.75	17,625	0.793	13,976	5,875	0.194	1,141	0.159	933	15,117	933
Roads	93,000	0.65	60,450	0.793	47,935	32,550	0.194	6,320	0.159	5,171	54,254	5,171
Reserves and Widenings	9,600	0.65	6,240	0.793	4,948	3,360	0.194	652	0.159	534	5,600	534
Stormwater Management	92,200	0.50	46,100	0.793	36,556	46,100	0.194	8,950	0.159	7,323	45,506	7,323
Environmental Protection	163,900	0.00	0	0.793	0	163,900	0.153	25,056	0.187	30,624	25,056	30,624
TOTAL POST-DEVELOPMENT	**518,200**		**225,615**		**178,905**	**292,585**		**50,040**		**51,065**	**228,944**	**51,065**
% Change from Pre to Post											249	39
Effect of development (with no mitigation)											2.5 times increase in runoff	39% reduction of infiltration

* data provided by Jones Consulting July 2021

** figures from Tables G-1, G-2 and G-3.

To balance pre- to post-,
the infiltration target (m^3/a)= **33,140**

R.J. Burnside & Associates Limited