Hydrogeological Assessment
620 Lockhart Road

Mattamy (Lockhart) Limited
Barrie, Ontario

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R.J. Burnside & Associates Limited
292 Speedvale Avenue West Unit 20
Guelph ON   N1H 1C4 CANADA

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R.J. Burnside & Associates Limited

Report Prepared By:

PROFESSIONAL GEOSCIENTIST
8/July/2021
STEPHANIE L. CHARITY
PRACTISING MEMBER
1796
ONTARIO

Stephanie Charity, P.Geo.
Hydrogeologist
SC:cl

Report Reviewed By:

PROFESSIONAL GEOSCIENTIST
8/July/2021
DWIGHT J. SMIKLE
PRACTISING MEMBER
1293
ONTARIO

Dwight Smikle, M.Sc., P.Geo.
Senior Hydrogeologist
DS:cl

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1.0 Introduction

R.J. Burnside & Associates Limited (Burnside) has been retained by Mattamy (Lockhart) Limited to complete a hydrogeological assessment of the lands known as 620 Lockhart Road, Barrie in support of a draft plan of subdivision. The Mattamy lands, herein referred to as the subject lands are located north of Lockhart Road 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. The Hewitt's Creek SPA includes lands bounded by Lockhart Road to the south, Sideroad 20 to the east, Mapleview Drive and Big Bay Point Road to the north (Figure 1). In 2016, a Subwatershed Impact Study (SIS) of the Hewitt's SPA was completed for the Hewitt's Creek Landowners Group (Burnside, 2016). The SIS evaluated the hydrogeological setting of the Hewitt's SPA, including the subject lands at a regional scale. The SIS forms the baseline information that the current study seeks to build upon in support of the draft plan application.

1.1 Scope of Work

The scope of work completed for the hydrogeological study was developed to build upon the more regional work completed for the SIS (Burnside, 2016) and to address requirements for hydrogeological studies in support of draft plan approval. The scope of work included completion of the following tasks:

The scope of the hydrogeological assessment involved a review of available regional information as well as the completion of site-specific investigations as described below:

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 and the well locations are plotted on Figure 8. 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 and assess potential impacts to the local private wells from development of the subject lands.

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. Wells installed as part of geotechnical investigation were included in the monitoring program. The locations of the monitoring wells 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 hydraulic conductivity. Single well response tests were completed at 4 groundwater monitoring wells (MW1, MW3d, MW4 and MW5) in May 2021. 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 from January 2021 to June 2021. Automatic water level recorders (dataloggers) were installed in three monitoring wells to document the range of groundwater fluctuations and the response of aquifers to precipitation events (MW3d, MW4 and BH20-4). 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. Water quality review and testing: Water quality data was collected from selected monitoring wells to typify the groundwater quality in the vicinity of the subject lands. Groundwater samples were collected in 2021 from MW3d and MW4. The water samples were submitted to a qualified 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 E.

7. Water balance calculations: Pre and post-development water balance calculations have been completed to assess the groundwater infiltration volumes across the study area. The local climate data and detailed water balance calculations are provided in Appendix F.

8. 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 the majority of the subject lands is located in the Lovers Creek subwatershed. A small portion of the subject lands, the northeast corner is located in the Hewitt's Creek subwatershed (Figure 3). The topography of the subject lands is gently rolling and slopes to the west and southwest. The highest elevation is located at the northeast corner of the subject lands at approximately 272 meters above sea level (masl). The lowest portion of the subject lands is located in the southwest corner at Lockhart Road at an elevation of approximately 253 masl. There are no watercourses on the subject lands.

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. The drumlins through the region are comprised of highly calcareous till (Chapman & Putnam, 1984).

The overburden 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 of silty to sandy glacial till, ice contact stratified sediments of sand and gravel and glaciolacustrine deposits of silty and clay in the southwest 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 Hydrostratigraphy

The sediments found at surface within a study area will influence groundwater occurrence and flow. Within the subject lands, the surficial sediments are overburden sediments of glacial origin. The overburden has 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 areas (aquifers) and finer-grained less permeable areas (aquitards) of varying thicknesses. The basic hydrostratigraphic sequence that was modelled in the regional studies (AquaResource, 2011) consists of four main aquifer areas (A1-A4) and four main aquitards (C1 to C4) with a confining layer (UC) over the uppermost aquifer (A1).

A description of the interpreted regional hydrostratigraphic framework is provided below (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. The upper confining layer has been mapped as coarse-grained lacustrine deposits which are part of a regionally extensive sand plain (LSRCA, 2012). Regional studies such as the AquaResource (2011) report indicate that the confining layer (UC) is patchy in the area of the study area.
- A1 – Represents the uppermost aquifer. Frequently exists as a surficial unconfined aquifer. It is generally associated with coarse grained glacial and interglacial sediments mapped as ice contact stratified drift. The majority of the local domestic wells are completed within this area. The upper aquifer A1 is reported to be present throughout the larger Barrie area, and has been interpreted to occur extensively in the study area.
- 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.

2.4 Local Stratigraphy

Eighteen geotechnical boreholes were completed on the subject lands in 2020 by DS Consultants Limited (DSCL) (logs provided in Appendix B and locations shown on Figure 5). 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 and monitoring wells (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. Where appropriate, the interpretations of the cross-sections was aided by the knowledge gained from the SIS.

The cross-sections illustrate that the subject lands are underlain by sandy silt to silty sand till with a thickness of 5 to 10 m (Figures 6 and 7). Underlying the till layer is a sand layer that is interpreted to form the local aquifer where supply wells are completed. In the northeast portion of the subject lands the sand layer is unconfined (Figure 6).

3.0 Hydrogeology

3.1 Hydraulic Conductivity

In order to predict aquifer responses and groundwater movement it is important to understand the hydrogeological properties of the subsurface materials encountered at a particular site. Hydraulic conductivity is a measure of the ability of soils to transmit groundwater. High hydraulic conductivity means that groundwater is easily transmitted, while a low hydraulic conductivity is associated with low potential for groundwater transmission. There are various methods that can be used to assess soil hydraulic conductivity, and different methods are suitable for different circumstances. Grainsize data and soil characteristics 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. These methods have been used to estimate the hydraulic conductivity of the soils encountered in the study area as discussed below.

3.1.1 Grainsize Analysis

Grainsize analysis from the geotechnical report (DSCL, 2020) were reviewed in order to obtain estimates of hydraulic conductivity. 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, the approximation is still considered useful for finer grained materials to provide a general indication of the range of the hydraulic conductivity values. Hydraulic conductivity values were derived empirically using the Hazen method for four samples collected during borehole drilling on the subject lands. The grainsize distribution graphs are provided in Appendix C and the calculated hydraulic conductivity values are provided in Table 1.

Table 1: Summary of Grainsize Analyses

Sample ID	Depth of Sample (mbgs)	Soil Classification	% Fines	Estimated Hydraulic Conductivity (cm/s)
BH20-1 SS4	2.3	Silty Sand Till	37	1.2×10^{-5}
BH20-3 SS3	1.5	Silty Clay	98	na
BH20-5 SS3	1.5	Silty Sand Till	42	5.3×10^{-6}
BH20-6 SS3	1.5	Silty Sand Till	48	2.3×10^{-6}
BH20-9 SS5	3.1	Silty Sand Till	42	5.3×10^{-6}

3.1.2 Single Well Response Tests

To assess the in-situ hydraulic conductivity of the sediments, single well response tests (bail-down tests) were conducted at monitoring wells MW1, MW4, MW5 and MW3d (BH20-9). The results from the tests were plotted (Appendix C) 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)
MW1	6.1 – 7.6	Silty Sand Till	2.7×10^{-6}
MW4	6.3 – 7.8	Silty Sand Till	1.4×10^{-5}
MW5	6.3 – 7.8	Silty Sand Till	4.3×10^{-8}
MW3d	5.6 – 7.1	Silty Sand	1.4×10^{-5}

*metres below ground surface

3.1.3 Hydraulic Conductivity Discussion

Grainsize analyses results indicate that the silty sand till sediments can range from 37% to 48% fines and the silty clay layer encountered at BH20-3 had 98% fines. The greater amount 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. The hydraulic conductivities estimated from the grainsize analyses for the dominant sediment type, silty sand till ranges between 10^{-5} to 10^{-6} cm/sec. The single well response test analyses resulted in similar hydraulic conductivities ranging from 10^{-5} to 10^{-6} cm/sec. The hydraulic conductivity measured at MW5 (4.3×10^{-8} cm/sec) was very low due to the till sediments being very dense.

3.2 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 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 generally located at elevations between 245 and 255 masl and generally in excess of 5 m below grade across the subject lands. The locations of the MECP water well records are shown on Figure 8. As a condition of draft plan approvals for other developments in the Hewitt's SPA, the City of Barrie has required that a well survey and monitoring of domestic wells should take place. This condition requires that domestic wells within 300 m of individual properties be evaluated for impacts due to construction. On behalf of the Hewitt's Landowners Group, Burnside has undertaken a well survey of all lands within the Hewitt's SPA and is currently implementing a monitoring and mitigation plan for domestic wells. The Burnside monitoring and mitigation plan has been approved by the City of Barrie. Participation in the Landowners Group would allow the Burnside study to be utilized for the subject lands.

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).

3.3 Water Level Monitoring Results

Groundwater levels were monitored at eight monitoring wells across the subject lands in order to gain information on groundwater distribution and fluctuations. Groundwater levels were monitored between January 2021 and June 2021. Additional groundwater monitoring is ongoing in order to obtain four seasons of monitoring, however the data that is available at the time of report preparation is being provided at this time. 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-Oro Climate Station (Climate Station ID#6117700)) which is the closest station with daily precipitation values for 2021.

In addition to the manual water level measurements recorded at each location, automatic water level recorders (loggers) collected hourly water level data at MW3, BH20-4 and MW4. 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 January 2021 to June 2021, groundwater elevations in the monitoring wells ranged from 252.7 masl to 264.3 masl. The period from January to June is typically expected to be the period during which the seasonal groundwater high is encountered and therefore this period is considered to be the most critical to understanding the potential for impacts due to high water table conditions.

- 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. Seasonal variations tend to be less in sandy sediments such as observed on the subject lands. Seasonal variation observed at the monitoring wells during the period of monitoring January to June ranged from 0.2 m at MW2 to 1.1 m at MW5 (Figures D-1 to D-8, Appendix D).

- MW1, MW3d, MW5 and BH20-3 are screened in a silty sand till that overlies the regional sand aquifer. Water levels at these wells were measured 0 to 2 m below surface (Figure D-1, D-3, D-5 and D-6, Appendix D). At MW5 and BH20-3 there is a confining lens of silty clay resulting in potentiometric (pressure) heads that are near or above grade (Figure D-5 and Figure D-6, Appendix D).

- MW2 located at the topographic high in the northeast corner of the subject lands is screened in the unconfined regional sand aquifer at a depth of 9.9 m. Groundwater levels at MW2 ranged from 8.9 m to 9.1 m bgs and are reflective of unconfined conditions in this area of the subject lands (Figure D-2, Appendix D).

- Continuous water level data at MW3d, MW4 and BH20-4 are plotted against precipitation to determine if there is a correlation between changes in water level and the occurrence of precipitation events (Figures D-3, D-4 and D-7, Appendix D). The logger data shows correlation between water levels and large precipitation events (>20 mm) such as seen on March 26, 2021 and April 11, 2021. The impact on water levels differs between wells. At MW3d, the response is immediate while the response at BH20-4 appears to be more gradual and delayed. The wells are completed in the silty sand till layer which functions as a poor aquifer and the response to precipitation is interpreted to be due to fracturing of the till layer.

3.4 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 2021) 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. Shallow groundwater flows on the subject lands is interpreted to be west and southwest.

3.5 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.

The monitoring of groundwater levels in the nested wells MW3s/d was intended to assist with the determination of vertical hydraulic gradients and thereby to assist with the evaluation of groundwater recharge or discharge conditions on the subject lands. Downward gradients calculated MW3s/d confirm that recharge conditions occur in this area (Figure D-3, Appendix D).

3.6 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). Figure 10 indicates that SGRAs are mapped in the northeast portion of the subject lands. Boreholes in this area and groundwater monitoring at MW2 indicate that this area is sandy and unconfined and supports the interpretation that recharge occurs in this area.

Ecologically Significant Groundwater Recharge Areas (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. Within the LSRCA jurisdiction, 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.

Figure 10 shows the LSRCA mapping of ESGRAs on the subject lands. Within the subject lands, areas mapped as ESRGAs are generally located in the southwest corner and along Lockhart Road and the north east portion of the subject lands (Figure 10). 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 to low hydraulic conductivity have a limited potential to move significant quantities of groundwater.

Higher recharge is expected in the northeast portion of the subject lands where sands were encountered at surface.

3.7 Aquifer Vulnerability

Aquifer vulnerability refers to the susceptibility of the aquifer to potential contamination. Some degree of protection for groundwater quality from natural and human impacts is provided by the soil above the water table. The degree of protection is dependent upon the depth to the water table (for unconfined aquifers) or the depth of the aquifer (for confined aquifers) and the type of soil above the water table or aquifer. As these two properties vary over any given area, the degree of protection or vulnerability of the groundwater to contamination also varies.

The aquifer vulnerability for the subject lands was mapped in the Lakes Simcoe and Couchiching-Black River SPA Part 1 Approved Assessment Report, Lake Simcoe Region Conservation Authority, 2015. The approach used by the LSRCA to create a regional vulnerability map using the aquifer vulnerability index (AVI) method. Using water well records for the area to determine the soil types and depths to aquifer an AVI was calculated for each delineated aquifer to produce a map of regional groundwater vulnerability. The high aquifer vulnerability mapping for the subject lands is provided in Figure 11. Most of the subject lands is mapped with a high vulnerability.

Depending on land use, runoff from urban developments may contain a variety of dilute contaminants such as suspended solids, chloride from road salt, oil and grease, metals, pesticide residues, bacteria and viruses. For groundwater, generally, with the exception of the dissolved constituents such as nitrogen and salt, most contaminants are attenuated by filtration during groundwater transport through the soils. The potential for effects on local groundwater quality from infiltration in the urban areas is therefore expected to be limited. It is noted from the geological cross-sections (Figures 6 and 7) that a layer of sandy silt till overlies the surficial sand aquifer that local wells are screened in. This layer will provide some protection to the underlying sand aquifer.

3.8 Water Quality

3.8.1 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 May 14, 2021 at two groundwater monitoring wells (MW3d and MW4). 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 E-1, Appendix E and discussed below.

- The results showed that the water generally met the Ontario Drinking Water Quality Standards (ODWQS) except for total hardness, alkalinity, turbidity and nitrate.
- Both samples exceeded the ODWQS for total hardness (100 mg/L) with values of 354 mg/L (MW3d) and 301 mg/L (MW4). 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. Exceedances in alkalinity are also related to dissolved calcium.
- Elevated nitrate was detected in both samples with values of 11.8 mg/L (MW3s) and 19.4 mg/L (MW4). Nitrate in shallow groundwater is typical of areas where agricultural activities are present such as the subject lands. Both samples exceed the ODWQS for nitrate, 10 mg/L and indicate that the groundwater has been impacted from agricultural activities in the vicinity of the subject lands.
- The results show that the groundwater samples met the Provincial Water Quality Objectives with the exception of total phosphorus at both wells and zinc at MW3d.
- Total phosphorus in the samples was 0.05 mg/L in MW3d and 1.46 mg/L in MW4 which exceeds the Provincial Water Quality Objective of 0.03 mg/L. Elevated phosphorus is another indication of impacts to the groundwater from agricultural activities in the vicinity of the subject lands.
- Zinc at MW3d was reported at a concentration of 0.034 mg/L which is slightly higher than the PWQO of 0.03 mg/L.

4.0 Water Balance

A water balance assessment is required in order to assess potential land development impacts on the local groundwater conditions. The water balance completed for this study 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 F.

4.1 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). 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 a property. 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 groundwater balance components for the subject lands are discussed below:

Precipitation (P)

The long-term average annual precipitation for the area of the subject lands is 933 mm 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 6 km northeast of the subject lands. Average monthly records of precipitation and temperature from this station have been used for the water balance calculations in this study (Appendix F).

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 and not considered for the calculations.

Evapotranspiration (ET)

Evapotranspiration and evaporation components vary based on the characteristics of the land surface cover (i.e., type of vegetation, 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.

Water Surplus (R + I)

The difference between the mean annual P and the mean annual ET is referred to as the water surplus. 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 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.

4.2 Approach and Methodology

The analytical approach to calculate the water balance utilized for this assessment 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 used for the areas where the land cover was predominantly short to moderate-rooted vegetation in the fields and agricultural areas (Table F-1, Appendix F). A soil moisture storage capacity of 75 mm was used to represent the post-development vegetation which will be dominantly urban lawn (Table F-2, Appendix F). Tables F-1 to F-2 in Appendix F 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 F-3 in Appendix F.

4.3 Water Balance Component Values

The detailed monthly calculations of the water balance components are provided in Tables F-1 and F-2 in Appendix F. For these calculations, it has been assumed that sandy loam soils are representative for the subject lands for estimating the soil infiltration factor. The calculations show that a water surplus is generally available from November to May (see Figure F-1). 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 F-1 and F-2, Appendix F). A summary of these values is provided in Table 3.

Table 3: Water Balance Component Values

Water Balance Component	Agricultural Lands	Urban Lawn
Average Precipitation	933 mm/year	933 mm/year
Actual Evapotranspiration	593 mm/year	555 mm/year
Water Surplus	340 mm/year	378 mm/year
Infiltration	204 mm/year	227 mm/year
Runoff	136 mm/year	151 mm/year

4.4 Pre-Development Water Balance (Existing Conditions)

The pre-development water balance calculations are presented in Table F-3 in Appendix F. As summarized on Table F-3, the total area of the subject lands is about 27.9 ha. The water balance component values from Table F-1 and Table F-2 were used to calculate the average annual volume of infiltration across the subject lands. Based on these component values, the pre-development infiltration volume for the subject lands is calculated to be about 56,900 m^3/year (Table F-3, Appendix F).

4.5 Potential Urban Development Impacts to Water Balance

It is recognized that the urban development of an area affects the natural water balance. The most significant difference is 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 area of the subject lands. 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 F-1 in Appendix F. There is an evaporation component from impervious surfaces and this is typically estimated to be between about 10% and 20% of the total precipitation. 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.

4.6 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 F-3 in Appendix F. The land use areas and the associated percentage imperviousness were based on the current design layout provided by the design engineers.

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 F-1 and Table F-2 in Appendix F. In summary from these appendix tables, the average calculated post-development infiltration volume (without mitigation) is about 27,900 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 from 56,900 m^3/year to 27,900 m^3/year, i.e., a reduction of about 29,000 m^3/year or 51%. These calculations assume no low impact development (LID) measures for stormwater management are in place.

4.7 Mitigation Measures

The use of Low Impact Development (LID) measures for stormwater management can be used to mitigate the potential impacts of development on the water balance. The overall deficit in groundwater infiltration post-development has been estimated to be 29,000 m^3/year (see Table F-3 in Appendix F). To mitigate the loss of infiltration on the subject lands an infiltration gallery is proposed in the park block. Calculations completed as part of the Functional Servicing Report indicate that the infiltration gallery will result in an additional 31,865 m^3/year of infiltration.

5.0 Development Considerations

5.1 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.

5.2 Groundwater Control in Foundations

The City of Barrie requires 0.5 m separation between foundations and seasonal high groundwater levels. It is expected that in some areas of the subject lands where shallow groundwater conditions exist this separation may not be achieved during the seasonal groundwater high conditions. From discussions with the design engineers it is understood that a gravity drain with connection to the sewer will be installed at 0.5 m below the foundation in areas where groundwater control is required. At this elevation the drain will function to divert groundwater from the area of the foundation and will maintain the required 0.5 m separation between seasonal groundwater high and the underside of foundations.

5.3 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).

5.4 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.

6.0 References

AquaResource et al. 2011. City of Barrie Tier Three Water Balance and Local Area Risk Assessment Groundwater Flow Model, AquaResource, Golder and IWC, 2011.

Burnside, 2016. Hewitt's Secondary Plan Area Hydrogeological Assessment, Hewitt's Landowners Group, R.J. Burnside & Associates Limited, June 2016.

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Ontario Ministry of the Environment, Storm Water Management Planning and Design Manual, March 2003.

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Ontario Ministry of the Environment, Conservation and Parks, Water Well Records.

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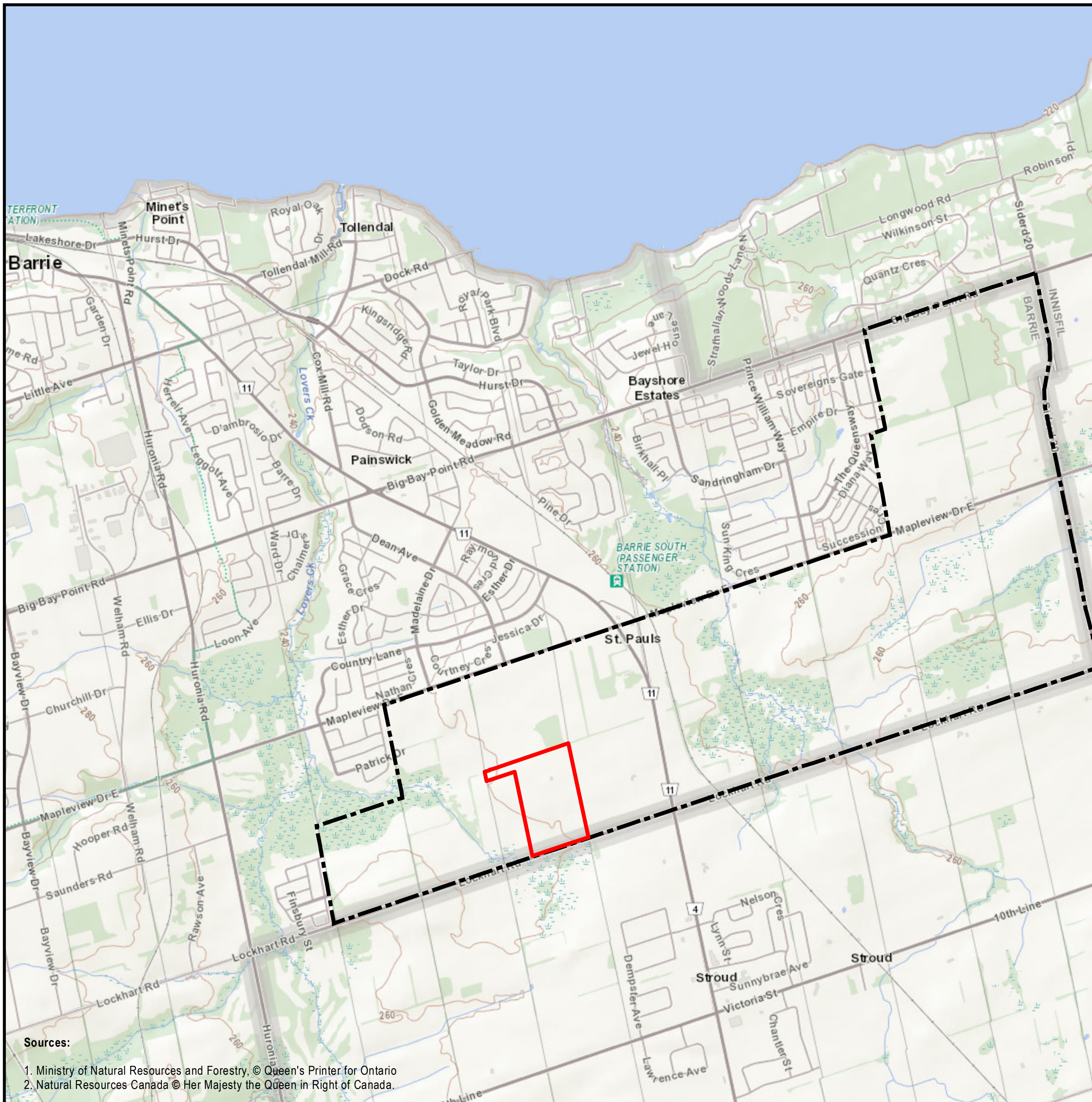
Figures



LEGEND

SUBJECT LANDS

HEWITTS SECONDARY PLAN AREA

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

Metres

N

BURNSIDE

Client / Report

MATTAMY (LOCKHART) LIMITED
BARRIE, ONTARIO

HYDROGEOLOGICAL ASSESSMENT

Figure Title:

SITE LOCATION

Drawn	Checked	Date	Figure No.
SK	SC	July 2021	1
Scale		Project No.	
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File Path: Nigel/Shared Work Areas/0520992 Mattany Lockhart/06_GIS/052092 Site Location.mxd

LEGEND

SUBJECT LANDS
WATERCOURSE
DRAINAGE DITCH
MONITORING WELL (DS CONSULTANTS, 2020)

0 50 100 200 300 400
Metres

N

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HYDROGEOLOGICAL ASSESSMENT

Figure Title

MONITORING LOCATIONS

Drawn	Checked	Date	Figure No.
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Scale		Project No.	
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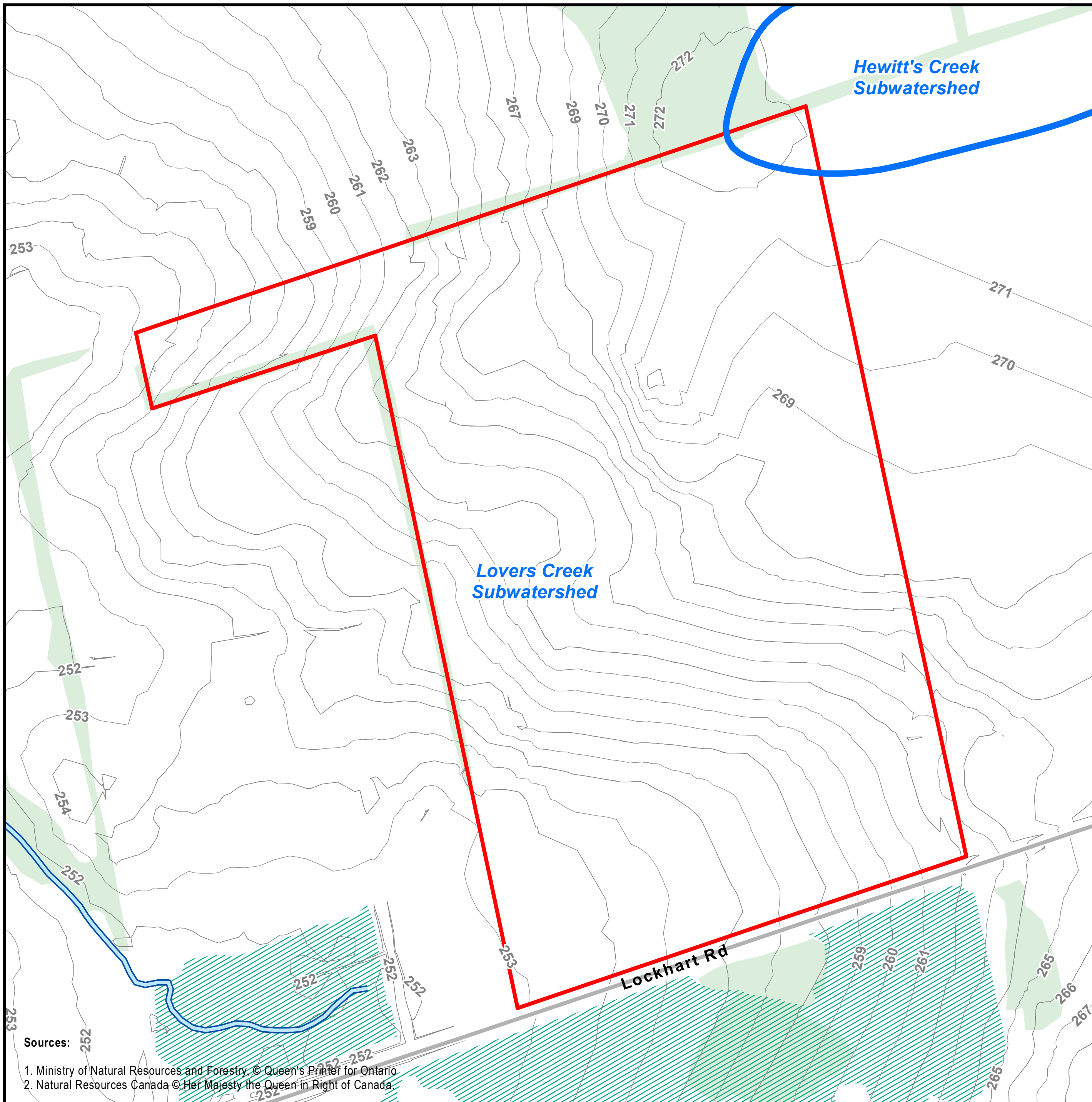

Sources:

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

LEGEND

- SUBJECT LANDS
- SUBWATERSHED BOUNDARY
- ROADWAY
- WATERCOURSE
- CONTOUR (1m intervals - masl)
- WETLAND
- WOODED AREA

0 25 50 100 150 200 250 300 350 400

Metres

N

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HYDROGEOLOGICAL ASSESSMENT

Figure Title:

TOPOGRAPHY AND DRAINAGE

Drawn	Checked	Date	Figure No.
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File Path: Nigel/Shared Work Areas/0520992 Mattany Lockhart/06_GIS/052092 Topography & Drainage.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. Ontario Geological Survey 2010. Surficial Geology of Southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 128 - Revision.

LEGEND

- SUBJECT LANDS
- ROADWAY
- WATERCOURSE
- 5b: Till: Stone-poor, carbonate-derived silty to sandy till
- 6: Ice-contact stratified deposits - sand and gravel
- 8a: Fine-textured glaciolacustrine deposits: clay and silt, massive-well laminated

0 50 100 200 300 400
Metres

N

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HYDROGEOLOGICAL ASSESSMENT

Figure Title:

SURFICIAL GEOLOGY

Drawn	Checked	Date	Figure No.
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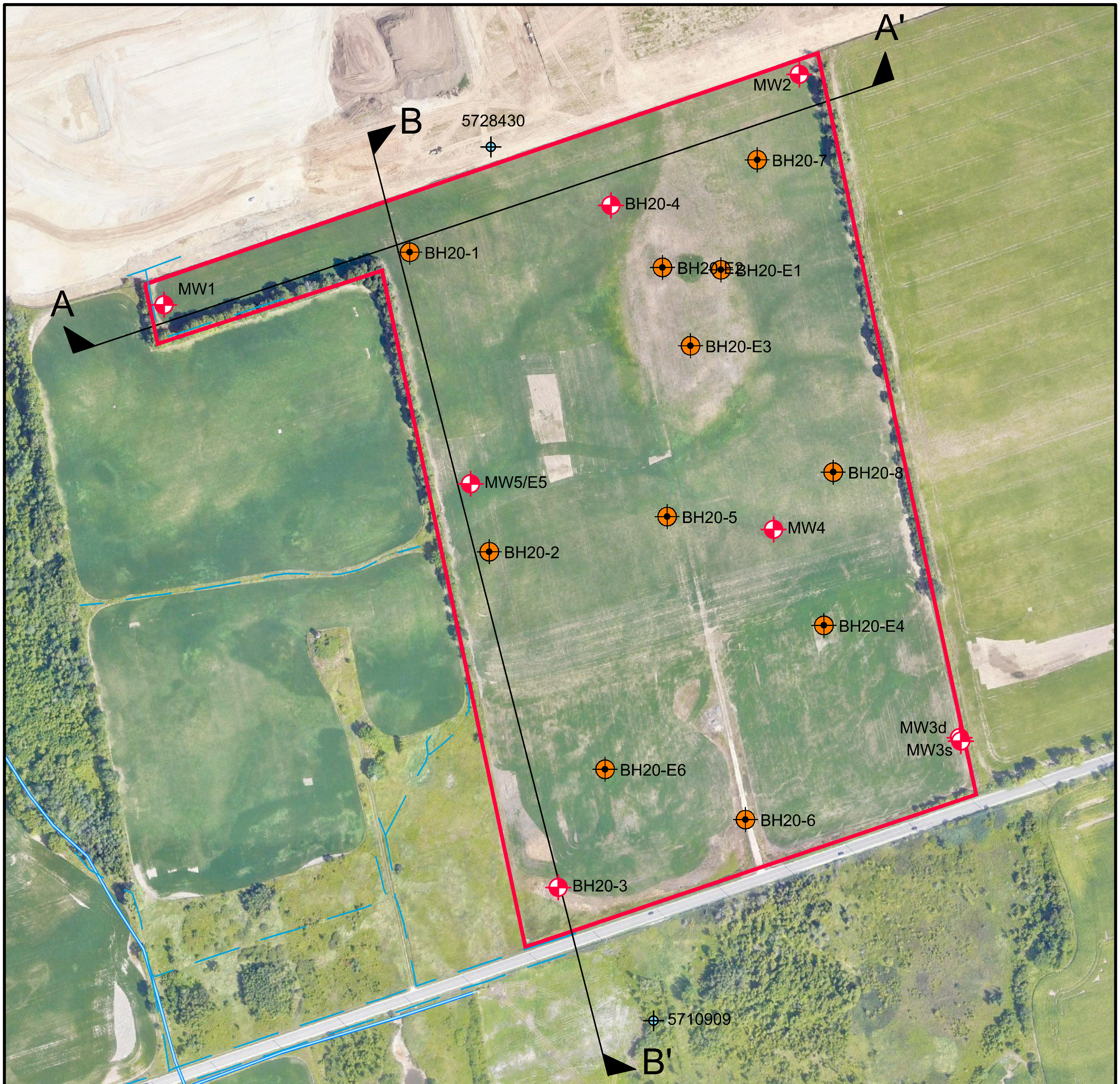

LEGEND

SUBJECT LANDS

WATERCOURSE

MONITORING WELL (DS, 2020)

BOREHOLE (DS, 2020)

MECP WELL RECORD LOCATION

A A' CROSS-SECTION LOCATION KEY

0 100 200 400 600

Metres

N

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HYDROGEOLOGICAL ASSESSMENT

Figure Title

BOREHOLE, WELL AND CROSS-SECTION LOCATION PLAN

Drawn	Checked	Date	Figure No.
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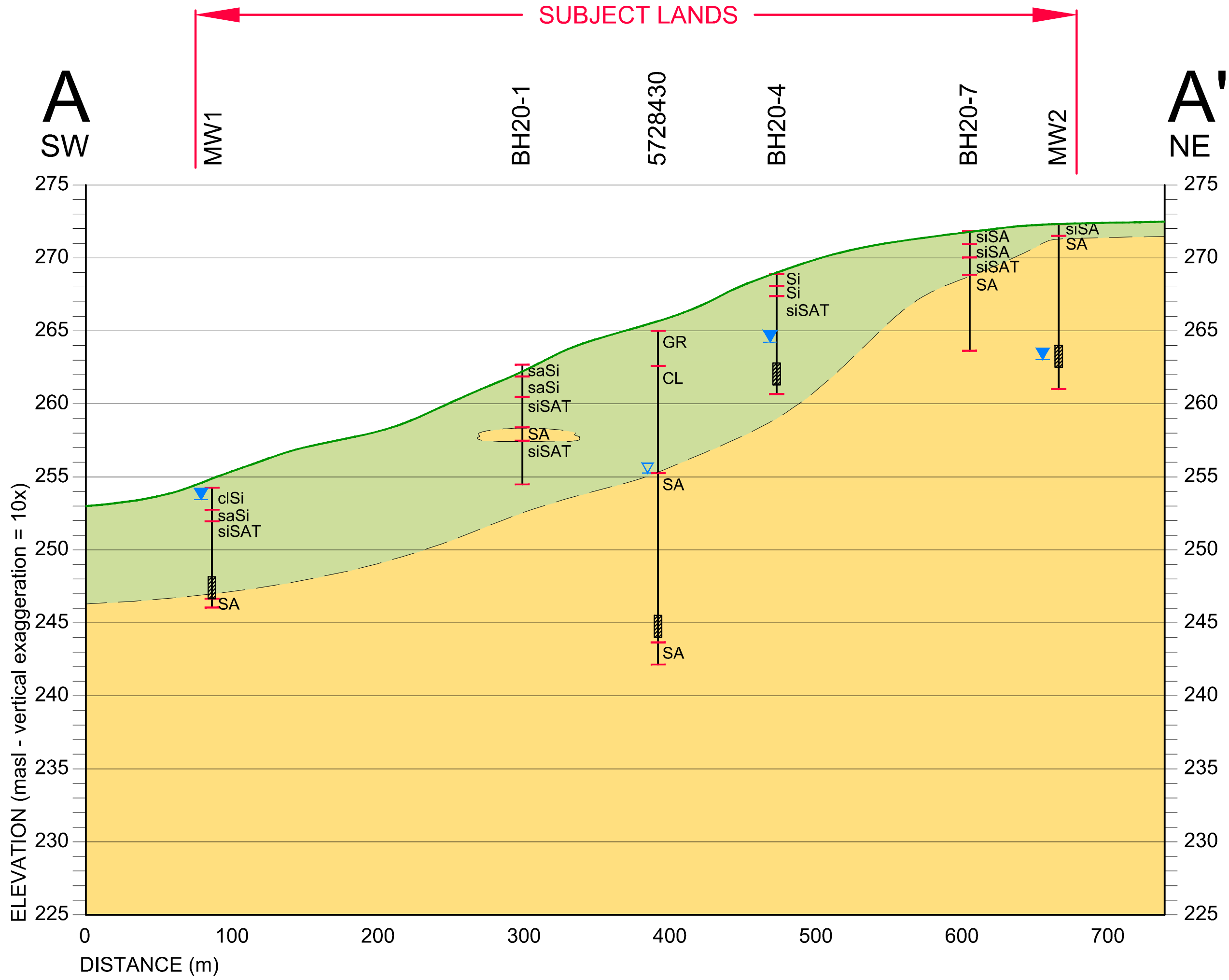

LEGEND

BH1	WELL NUMBER / ID	si	SILTY
	EXISTING GROUND PROFILE	sa	SANDY
	GEOLOGICAL CONTACT	cl	CLAYEY
	MEASURED WATER LEVEL (March, 2021)	TS	TOPSOIL
	STATIC WATER LEVEL (MECP WELL RECORD)	PRDG	PREDUG
	WELL SCREEN	T	TILL
	INTERPRETED STRATIGRAPHY	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.
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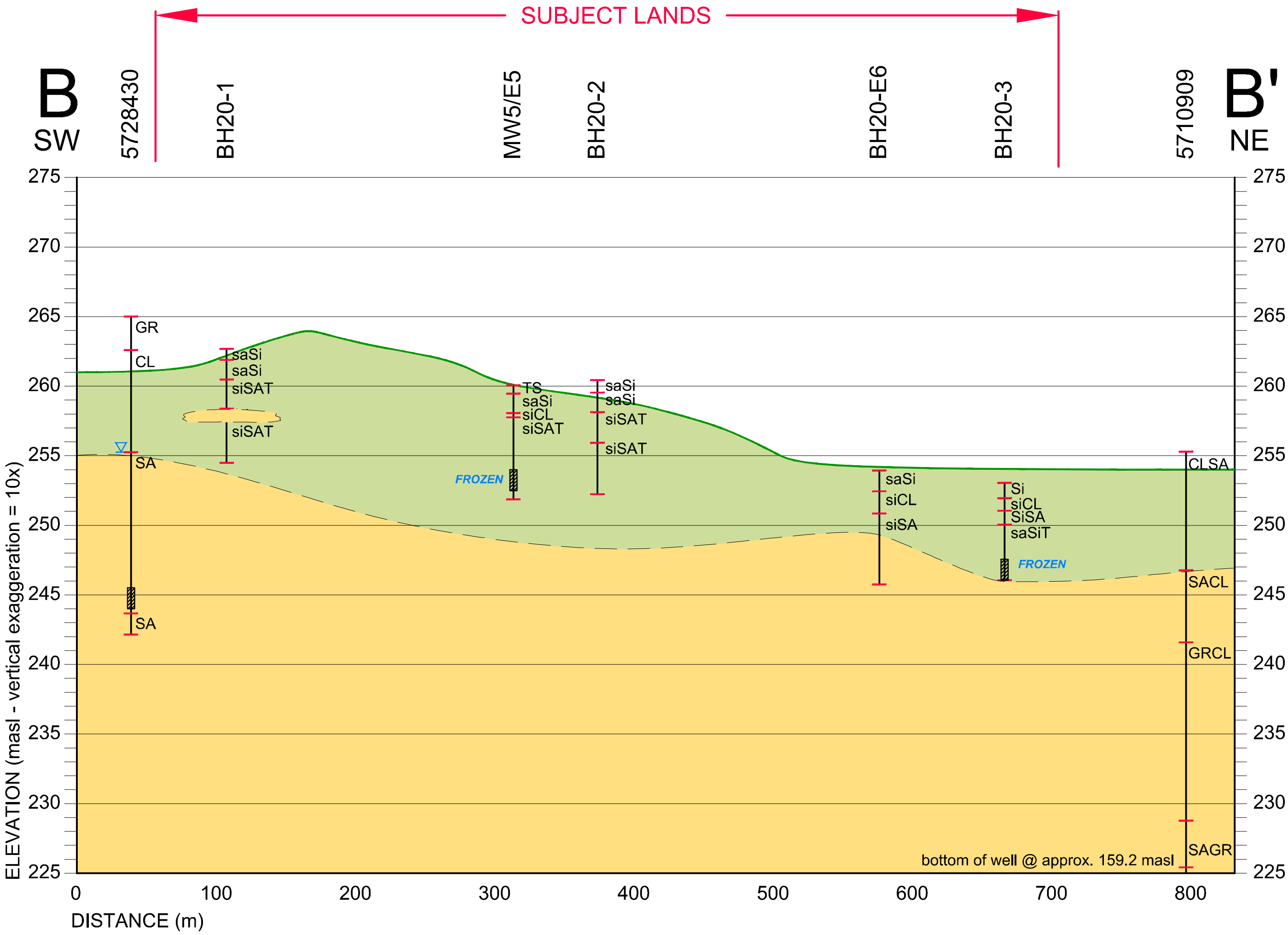

LEGEND

BH1	WELL NUMBER / ID
	EXISTING GROUND PROFILE
	GEOLOGICAL CONTACT
	MEASURED WATER LEVEL (March, 2021)
	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 B-B'

Drawn	Checked	Date	Figure No.
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Scale		Project No.	
1:6,000		300052092	

File Name:Nigel\Shared Work Areas\052092 Mattamy Lockhart\02_Production\ 052092 HG Study Drawing Set.dwg Date Plotted: July 2, 2021 - 11:05 AM

LEGEND

SUBJECT LANDS

BUFFER (500m)

MECP WELL USE:

- WATER SUPPLY
- ABANDONED - SUPPLY
- ABANDONED - OTHER
- UNKNOWN

0 50 100 200 300 400 500 600 700
Metres

N

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BARRIE, ONTARIO

HYDROGEOLOGICAL ASSESSMENT

Figure Title:

MECP WELL RECORD LOCATION

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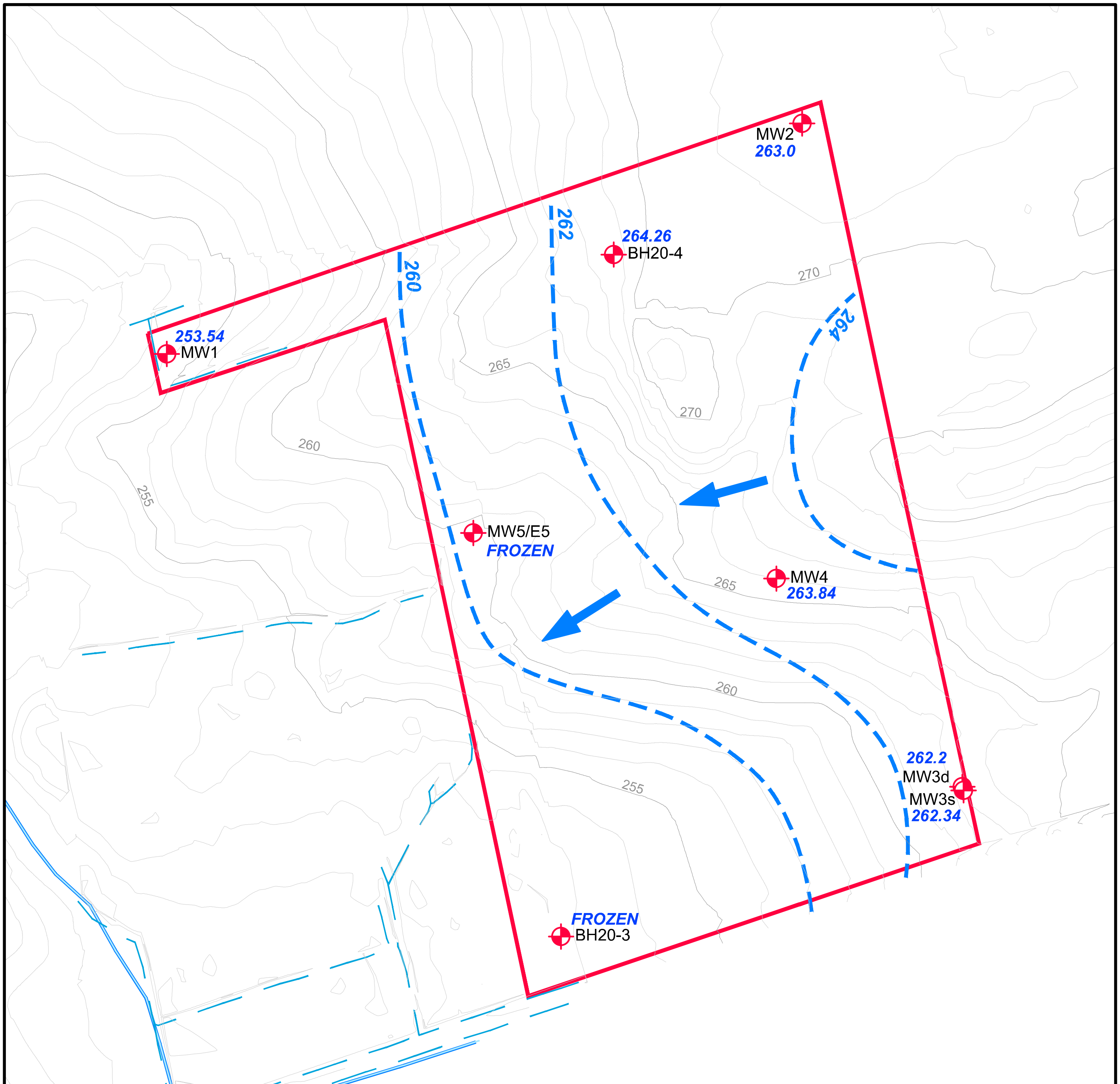

LEGEND

- SUBJECT LANDS
- WATERCOURSE
- MONITORING WELL (RJB, 2014)
- MONITORING WELL (SOIL ENG., 2019)
- INTERPRETED GROUNDWATER CONTOUR (masl)
- 263.84 MEASURED WATER LEVEL (MARCH, 2021)
- INTERPRETED GROUNDWATER FLOW DIRECTION

0 100 200 400 600

Metres

N

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INNISFIL, ONTARIO

HYDROGEOLOGICAL ASSESSMENT

Figure Title

INTERPRETED GROUNDWATER FLOW

Drawn	Checked	Date	Figure No.
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Scale		Project No.	
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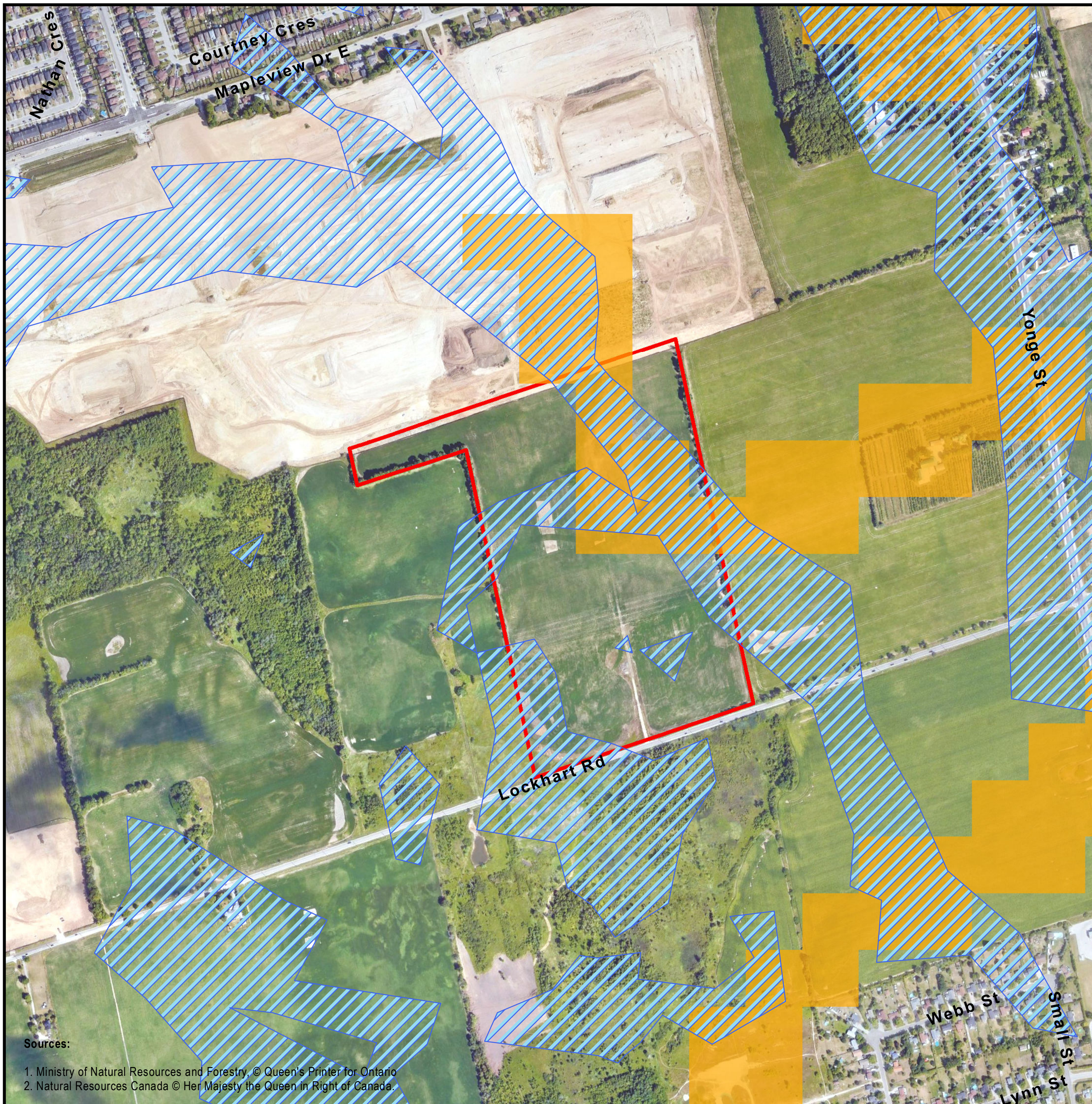

LEGEND

SUBJECT LANDS

ECOLOGICALLY SIGNIFICANT GROUNDWATER RECHARGE AREAS (ESGRA, LSRCA)

SIGNIFICANT GROUNDWATER RECHARGE AREAS (SGRA, LSRCA)

0 50 100 200 300 400 500 600 700
Metres

N

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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.	
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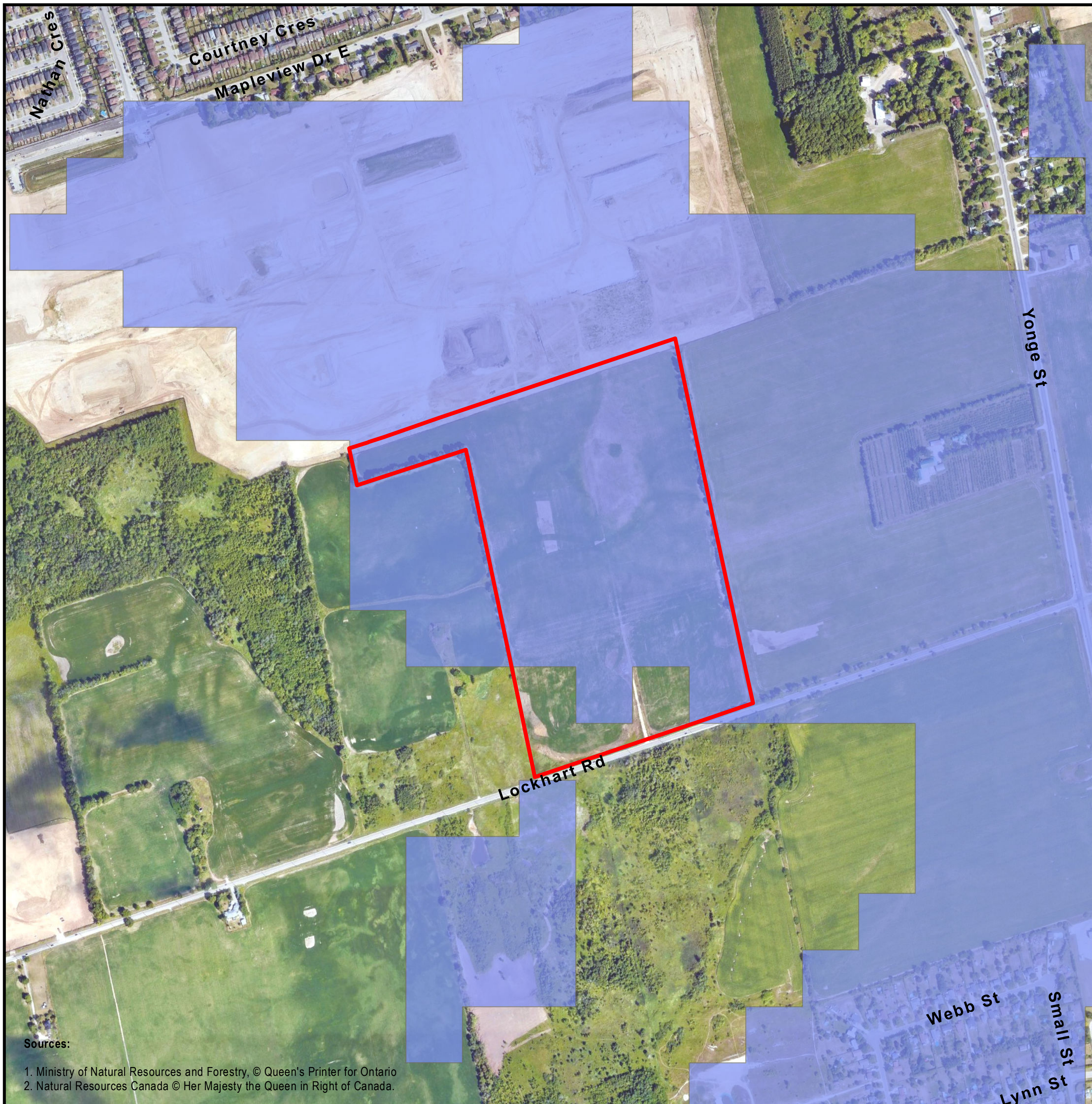

LEGEND

SUBJECT LANDS

HIGH AQUIFER VULNERABILITY

0 50 100 200 300 400 500 600 700

Metres

N

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BARRIE, ONTARIO

HYDROGEOLOGICAL ASSESSMENT

Figure Title:

AQUIFER VULNERABILITY

Drawn	Checked	Date	Figure No.
SK	SC	July 2021	11
Scale		Project No.	
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File Path: Nigel/Shared Work Areas/0520992 Mattany Lockhart/06_GIS/052092 Aquifer Vulnerability.mxd

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Appendix A

MECP Well Records

Appendix A

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 10 014	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 10 015	17 609760 4909924 W	2008/03 1663	43.3			NU		7104796 (Z77794) A	
INNISFIL TOWNSHIP CON 10 015	17 609760 4909924 W	2007/03 1663	5			NU		7104795 (Z77795) A	
INNISFIL TOWNSHIP CON 10 015	17 609732 4909940 W	1962/10 2514	6	FR 0054	35/57/5/1:0	ST DO	0057 3	5701273 ()	PRDG 0037 BRWN CLAY MSND GRVL 0054 MSND 0060
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	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
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
INNISFIL TOWNSHIP CON 11 015	17 609376 4910783 L	2004/04 2513	6.28	FR 0085	36/55/2/1:0	DO	0086 6	5738721 (Z00199) A000103	BRWN SAND SILT STNS 0014 YLLW SAND 0062 BLUE SAND SILT CLAY 0085 GREY SAND SILT CMTD 0092
INNISFIL TOWNSHIP CON 11 015	17 609376 4910783 L	2004/04 2513				NU		5738722 (Z00200) A000104 A	
INNISFIL TOWNSHIP CON 11 015	17 609400 4911050 W	2011/02 2513				NU		7168649 (Z103439) _NO_TAG A	
INNISFIL TOWNSHIP CON 11 015	17 609564 4910423 W	1979/04 3203	6 5	FR 0060	30/75/2/6:10	DO	0080 3	5716067 ()	PRDG 0030 PRDR 0060 BRWN SAND CLAY 0064 GREY SAND CLAY LYRD 0083 GREY CLAY 0092
INNISFIL TOWNSHIP CON 11 015	17 609427 4911085 W	2017/12 7626						7308492 (C39439) A235213 P	
INNISFIL TOWNSHIP CON 11 015	17 609614 4910663 W	1968/09 4608	30	FR 0025	26///:	DO		5705828 ()	BRWN CLAY STNS 0020 MSND 0036

TOWNSHIP CON LOT	UTM	DATE CNTR	CASING DIA	WATER	PUMP TEST	WELL USE	SCREEN	WELL	FORMATION
INNISFIL TOWNSHIP CON 11 015	17 609575 4910893 W	1967/01 4608	30	FR 0035	35//2/:	DO		5701419 ()	BRWN CLAY 0035 MSND 0050
INNISFIL TOWNSHIP CON 11 015	17 609572 4910457 W	1965/08 2514	6	FR 0043	30/52/3/2:30	ST DO	0052 3	5701415 ()	PRDG 0033 MSND CLAY 0043 MSND 0055 FSND 0058
INNISFIL TOWNSHIP CON 11 015	17 609379 4910783 L	1999/03 2513	6	FR 0064	26/58/9/1:0	DO	0060 6	5734439 (195331)	LOAM 0001 YLLW SAND 0004 YLLW SILT 0018 YLLW SAND 0027 YLLW SAND SILT CLAY 0052 YLLW SAND 0064 YLLW CLAY 0064

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

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

4. Water Detail

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

BURNSIDE

[THE DIFFERENCE IS OUR PEOPLE]

Appendix B

Borehole Logs

LOG OF BOREHOLE BH20-1

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: See Drawing 1 N 4910499.315 E 608729.072

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Sep/09/2020

REF. NO.: 20-231-400
ENCL NO.: 2

ELEV (m) DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	WATER CONTENT (%)	METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
262.7						
262.6 / 0.2	**TOPSOIL:** 150mm					
	SANDY SILT: trace clay, some organic, brown, moist, loose, disturbed material	1	SS	6		
261.9 / 0.8	**SANDY SILT:** trace clay, trace gravel, brown, moist, compact	2	SS	11		
		3	SS	18		
260.5 / 2.2	**SILTY SAND TILL:** with gravel, trace clay, grey, moist, compact	4	SS	39		6 57 29 8
		5	SS	32		
						grinding
258.4 / 4.3	**SAND:** sand seam, some gravel, trace silt, saturated, dense	6	SS	40		wet spoon, saturated sand layer
257.5 / 5.2	**SILTY SAND TILL:** with gravel, trace clay, grey, wet, very dense	7	SS	80		
						grinding
		8	SS	>100		
254.5 / 8.2	**END OF BOREHOLE:**					

Notes:
1) Water level at 3.2m below grade at the completion of drilling.
2) Cave-in to 4.6m upon completion

Column headings also printed: STRATA PLOT; GROUND WATER CONDITIONS; ELEVATION (262, 261, 260, 259, 258, 257, 256, 255); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L, WATER CONTENT (%) 10 20 30; POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3)

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity ○ ^{8}=3% Strain at Failure

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LOG OF BOREHOLE BH20-2

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: See Drawing 1 N 4910243.586 E 608797.335

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Sep/10/2020

REF. NO.: 20-231-400
ENCL NO.: 3

(m) ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	WATER CONTENT (%)	METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
260.4						
260.2 / 0.2	**TOPSOIL:** 150mm					
	SANDY SILT: disturbed, some organic, brown, moist, loose	1	SS	7	~21	
259.5 / 0.9	**SANDY SILT:** trace gravel, brown, moist, compact	2	SS	16	~11	
	Some gravel, moist, sand seams	3	SS	12	~10	
258.1 / 2.3	**SILTY SAND TILL:** some gravel, trace clay, grey, moist, dense	4	SS	43	~10	
		5	SS	53	~6	
	Wet sand layer at 3.7m					
255.9 / 4.5	**SILTY SAND TILL:** some gravel, trace clay, grey, wet, very dense	6	SS	61	~8	
		7	SS	57	~8	
		8	SS	43	~8	wet spoon
252.2 / 8.2	**END OF BOREHOLE:** Notes: 1) Water level at 3.7m below grade at the completion of drilling. 2) cave-in at 7.3m below grade upon completion					

Column headings also printed: STRATA PLOT; GROUND WATER CONDITIONS; ELEVATION (260, 259, 258, 257, 256, 255, 254, 253); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) 10 20 30; POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3).

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity ○ ^{8}=3% Strain at Failure

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: See Drawing 1 N 4909956.586 E 608856.231

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Sep/10/2020

REF. NO.: 20-231-400
ENCL NO.: 4

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	WATER CONTENT (%) (approx.)	METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
253.1						W. L. 253.4 m Jan 11, 2021		
252.9 / 0.2	**TOPSOIL:** 230mm					W. L. 253.3 m Sep 30, 2020		
	SILT: with fine sand, brown, moist to wet, loose, weathered	1	SS	9			~14	
252.0 / 1.1	**SILTY CLAY:** trace sand, brown to grey, very moist, firm to stiff	2	SS	6		252	~18	
		3	SS	12			~25	0 2 32 66
251.1 / 2.0	**SILT AND SAND:** fine sand, trace gravel, trace clay, grey, wet, compact	4	SS	13	Bentonite	251	~10	
250.1 / 3.0	**SANDY SILT TILL:** with gravel, trace clay, grey, wet, loose to compact	5	SS	11		250	~10	
						249		
		6	SS	9		248	~10	wet spoon
					Filter Pack			
		7	SS	29	Slotted Pipe	247	~6	
246.1 / 7.0	**END OF BOREHOLE:**							~~Grinding on~~ boulder, Auger refusal

Notes:
1) 50mm dia. monitoring well installed upon completion.
2) Water level Reading:

Date:	Water Level (mbgl):
Sept 30, 2020	-0.17
Jan 11, 2021	-0.31

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100
SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 40 60 80 100
PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30
POCKET PEN. (Cu) (kPa) NATURAL UNIT WT (kN/m^3)

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES + 3, × 3: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

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LOG OF BOREHOLE BH20-4

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: See Drawing 1 N 4910539.485 E 608901.801

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Sep/09/2020

REF. NO.: 20-231-400
ENCL NO.: 5

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	WATER CONTENT (%) (approx.)	METHANE AND GRAIN SIZE DISTRIBUTION (%)
269.0 / 0.0	**TOPSOIL:** 250mm					
0.3	**SILT:** disturbed material, trace sand, some organic, brown, moist, loose	1	SS	6	~20	
268.2 / 0.8	**SILT:** some sand, trace gravel, trace clay, brown, moist, loose	2	SS	7	~10	
267.5 / 1.5	**SILTY SAND TILL:** some gravel, trace clay, grey, moist, dense to very dense	3	SS	32	~10	
		4	SS	58	~7	
		5	SS	68	~7	
		6	SS	>100	~6	
		7	SS	>100	~6	grinding
		8	SS	>100	~7	
260.8 / 8.2	**END OF BOREHOLE:**					

Ground water conditions: Bentonite; W. L. 263.9 m Jan 11, 2021; W. L. 263.3 m Sep 30, 2020; Filter Pack; Slotted Pipe

END OF BOREHOLE:
Notes:
1) 50mm dia. monitoring well installed upon completion.
2) Water level Reading:

Date:	Water Level (mbgl):
Sept 30, 2020	5.69
Jan 11, 2021	5.11

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED; + FIELD VANE & Sensitivity; ● QUICK TRIAXIAL; × LAB VANE
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L
POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3)

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity; ○ ^{8}=3% Strain at Failure

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LOG OF BOREHOLE BH20-5

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: See Drawing 1 N 4910273.423 E 608949.757

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Sep/10/2020

REF. NO.: 20-231-400
ENCL NO.: 6

(m) ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	ELEVATION	METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
265.2						
265.0 0.2	**TOPSOIL:** 150mm **SILT:** trace organics, trace sand, brown, moist, loose, weathered	1	SS	7	265	
264.4 0.8	**SANDY SILT:** trace gravel, grey, moist, loose	2	SS	9	264	
263.7 1.5	**SILTY SAND TILL:** with gravel, trace clay, grey, moist, compact to very dense	3	SS	10	263	12 46 33 9
		4	SS	36	262	
		5	SS	32	261	grinding
	wet, sand seams	6	SS	57	260	grinding
	saturated	7	SS	45	259	wet spoon
					258	grinding
257.0 8.2		8	SS	>100	257	
	END OF BOREHOLE: Notes: 1) Water level at 3.4m below grade at completion of drilling. 2) No cave-in upon completion.					

STRATA PLOT · GROUND WATER CONDITIONS · DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 · SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100 · PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L · WATER CONTENT (%) 10 20 30 · POCKET PEN. (Cu) (kPa) · NATURAL UNIT WT (kN/m^3)

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

LOG OF BOREHOLE BH20-6

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: See Drawing 1 N 4910014.013 E 609016.963

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Sep/11/2020

REF. NO.: 20-231-400
ENCL NO.: 7

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	WATER CONTENT (%)	METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
256.5 / 0.0	**SAND AND GRAVEL FILL:** brown, compact, moist	1	SS	11		
		2	SS	13		
255.3 / 1.2	**TOPSOIL:** 200mm, black, moist					
255.1 / 1.4	**SILTY SAND TILL:** trace gravel, trace clay, brown, moist to wet, loose	3	SS	8		3 49 37 11
	Grey, with gravel, wet	4	SS	4		
		5	SS	6		
	compact below 3.8m	6	SS	13		spoon refusal on boulder
251.8 / 4.7	**SANDY SILT:** with gravel, some clay, grey, compact, wet	7	SS	21		
250.4 / 6.1	**SILTY SAND:** some to trace gravel, sand seams at 6.4m, brown, saturated, compact to very dense	8	SS	20		
	grey	9	SS	>100		cobble in spoon
		10	SS	>100		
246.7 / 9.8	**END OF BOREHOLE:**					

Notes:
1) Water level at 1.5m during drilling.
2) No cave-in upon completion.

Column headings: SOIL PROFILE; STRATA PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION (256, 255, 254, 253, 252, 251, 250, 249, 248, 247); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3)

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES
+3, ×3: Numbers refer to Sensitivity
○ 8=3% Strain at Failure

LOG OF BOREHOLE BH20-7

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: See Drawing 1 N 4910578.452 E 609026.09

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Sep/09/2020

REF. NO.: 20-231-400
ENCL NO.: 8

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	WATER CONTENT (%) (approx.)
271.9					
271.8 / 0.2	**TOPSOIL:** 150mm **SILTY SAND:** disturbed, trace organics, trace gravel, brown, moist, loose	1	SS	4	
271.0 / 0.9	**SILTY SAND:** trace gravel, brown, moist, loose to compact	2	SS	6	
270.1 / 1.8	**SILTY SAND TILL:** with gravel, trace clay, grey, moist, compact to dense	3	SS	18	
		4	SS	39	
268.9 / 3.0	**SAND:** trace gravel, trace cobbles, brown, moist, very dense	5	SS	68	
		6	SS	>100	
		7	SS	79	
		8	SS	>100	
263.7 / 8.2	**END OF BOREHOLE:** Notes: 1) Borehole dry during drilling. 2) No cave-in upon completion.				

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION (271, 270, 269, 268, 267, 266, 265, 264); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10 20 30); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

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LOG OF BOREHOLE BH20-8

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: See Drawing 1 N 4910311.883 E 609091.492

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Sep/10/2020

REF. NO.: 20-231-400
ENCL NO.: 9

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	METHANE AND GRAIN SIZE DISTRIBUTION (%)
268.5					
268.3 / 0.0	**TOPSOIL:** 200mm				
0.2	**SANDY SILT:** some organics, trace gravel, brown, moist, loose, weathered	1	SS	5	
267.6 / 0.9	**SILTY SAND TILL:** with gravel, trace clay, grey, moist, compact small seam of red sand at 1.2m	2	SS	16	
	dense	3	SS	31	
		4	SS	41	
		5	SS	62	
	seam of red sand	6	SS	81	
	saturated	7	SS	>100	intense grinding (likely boulder) wet spoon
260.9 / 7.6	**SAND:** some gravel, grey, saturated, dense	8	SS	35	
260.3 / 8.2	**END OF BOREHOLE:**				

Notes:
1) Water at depth of 4.6m at completion of drilling.
2) Cave-in at 6.6m upon completion

Column headings: SOIL PROFILE; SAMPLES; STRATA PLOT; GROUND WATER CONDITIONS; ELEVATION; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100); PLASTIC LIMIT w_P, NATURAL MOISTURE CONTENT w, LIQUID LIMIT w_L; WATER CONTENT (%) (10 20 30); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); GR SA SI CL

Elevation scale: 268, 267, 266, 265, 264, 263, 262, 261

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity; ○ ^{8}=3% Strain at Failure

LOG OF BOREHOLE BH20-9

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: See Drawing 1 N 4910084.417 E 609199.788

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Sep/11/2020

REF. NO.: 20-231-400
ENCL NO.: 10

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	WATER CONTENT (%)	METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
263.0 / 0.0 (262.8 / 0.2)	**TOPSOIL:** 150mm **SANDY SILT:** with gravel, some cobble, some clay, brown, wet, loose, weathered	1	SS	4		
262.1 / 0.9	**SANDY SILT:** some gravel, trace clay, brown, wet, loose to compact	2	SS	10		
		3	SS	8		
260.5 / 2.4	**SILTY SAND:** Brown, trace gravel, compact, saturated	4	SS	12		
260.0 / 3.0	**SILTY SAND TILL:** trace gravel, trace clay, grey, wet, loose to dense	5	SS	5		10 48 33 9
		6	SS	15		
		7	SS	46		
256.9 / 6.1	**SILTY SAND:** trace gravel and cobbles, interbedded with sand and silt, brown, wet, very dense	8	SS	60		
255.4 / 7.6	**SANDY SILT:** Grey, with gravel, wet, very dense	9	SS	>100		spoon bouncing
254.8 / 8.2	**END OF BOREHOLE:**					

Groundwater conditions: W. L. 262.2 m Sep 30, 2020; Bentonite; Filter Pack; Slotted Pipe

Notes:
1) 50mm dia. monitoring well installed upon completion.
2) Water level Reading:

Date:	Water Level (mbgl):
Sept 30, 2020	0.73
Jan 11, 2021	0.63

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION; DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); METHANE AND GRAIN SIZE DISTRIBUTION (%)

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES + 3 , × 3 : Numbers refer to Sensitivity ○ ε=3% Strain at Failure

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LOG OF BOREHOLE BH20-E1

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: N 4910484.333 E 608995.132

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Dec/03/2020

REF. NO.: 20-231-400
ENCL NO.: 11

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	WATER CONTENT (%)	METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
270.0 / 0.0								
269.9 / 0.1	**TOPSOIL:** 75mm							
	SAND: some organic, brown, moist, loose, disturbed material	1	SS	7				
	some gravel, possible fill	2	SS	9		269		
268.5 / 1.5	**SANDY SILT:** trace gravel, with sand seams, grey, wet, compact	3	SS	15		268		clayey glob in tip of spoon, possible fill
		4	SS	13				
266.9 / 3.1	**SILTY SAND TILL:** some gravel, moist, dense	5	SS	29		267		
266.3 / 3.7	**END OF BOREHOLE:**							

Notes:
1) Borehole remained open at the completion of drilling.

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30
POCKET PEN. (Cu) (kPa) | NATURAL UNIT WT (kN/m^3)

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

DS CONSULTANTS LTD.

LOG OF BOREHOLE BH20-E2

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: N 4910486.773 E 608945.472

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Dec/03/2020

REF. NO.: 20-231-400
ENCL NO.: 12

(m) ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS / 0.3 m	WATER CONTENT (%)
270.6 / 0.0	**TOPSOIL:** 300mm				
270.3 / 0.3	**SAND:** some gravel, some organic, dark brown, moist, loose, fill	1	SS	6	~17
269.7 / 0.9	**CLAYEY SILT:** with organics and wood, dark brown, wet, soft, fill	2	SS	5	55
268.8 / 1.8	**SAND:** trace gravel, grey, wet, dense	3	SS	5	~23
		4	SS	29	~7
267.6 / 3.1	**SANDY SILT TILL:** trace gravel, trace cobble, grey, moist, dense	5	SS	37	~10
267.0 / 3.7	**END OF BOREHOLE:**				

Notes:
1) Borehole remained open at the completion of drilling.

Column headings: SOIL PROFILE; STRATA PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10 20 30); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Elevation scale: 270, 269, 268, 267

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity ○ ε=3% Strain at Failure

DS CONSULTANTS LTD.

LOG OF BOREHOLE BH20-E3

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: N 4910419.047 E 608969.214

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Dec/03/2020

REF. NO.: 20-231-400
ENCL NO.: 13

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
270.6							
270.3 / 0.0	**TOPSOIL:** 300mm						
0.3	**SAND:** trace organic, brown, moist, loose, disturbed	1	SS	7		270	
269.7 / 0.9	**SAND:** some gravel, trace cobble, brown, moist, compact to dense	2	SS	16			cobble in tip of spoon
	gravelly at 1.5m	3	SS	17		269	
		4	SS	23		268	
	layered	5	SS	30		267	
266.9 / 3.7	**END OF BOREHOLE:** Notes: 1) Borehole remained open upon completion of drilling.						

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): O UNCONFINED; + FIELD VANE & Sensitivity; ● QUICK TRIAXIAL; × LAB VANE; 20 40 60 80 100
PLASTIC LIMIT w_P — NATURAL MOISTURE CONTENT w — LIQUID LIMIT w_L
WATER CONTENT (%): 10 20 30
POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m^3)

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity; O ε=3% Strain at Failure

DS CONSULTANTS LTD.

LOG OF BOREHOLE BH20-E4

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: N 4910180.413 E 609083.344

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Dec/04/2020

REF. NO.: 20-231-400
ENCL NO.: 14

(m) ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" BLOWS/0.3 m	NATURAL MOISTURE CONTENT w (%)
261.6 0.0	**TOPSOIL:** 300mm	1	SS	6	
261.3 0.3	**SANDY SILT:** trace gravel, trace clay, brown, wet, loose				
		2	SS	7	
		3	SS	11	
		4	SS	6	
	compact below 3m	5	SS	12	
257.0 4.6	**SILTY SAND TILL:** tracee gravel, grey, wet, very dense	6	SS	50	
256.5 5.2	**END OF BOREHOLE:**				

Column headings: SOIL PROFILE; STRATA PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION (261, 260, 259, 258, 257); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity ○ ^{8}=3% Strain at Failure

LOG OF BOREHOLE BH20-E6

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: N 4910057.43 E 608896.02

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Dec/04/2020

REF. NO.: 20-231-400
ENCL NO.: 16

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	WATER CONTENT (%)
254.0					
253.9 / 0.1	**TOPSOIL:** 100mm **SANDY SILT:** brown to grey, wet, compact	1	SS	6	
		2	SS	12	
252.5 / 1.5	**SILTY CLAY:** grey, wet, soft	3	SS	7	
	sand seams below 2.3m	4	SS	8	
251.0 / 3.1	**SILTY SAND:** trace gravel, grey, saturated, loose	5	SS	11	
		6	SS	6	
		7	SS	6	
	some gravel below 7.6m	8	SS	9	
245.8 / 8.2	**END OF BOREHOLE:**				

Column headings: SOIL PROFILE; SAMPLES; GROUND WATER CONDITIONS; ELEVATION (254–246); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH (kPa): O UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity   O ^{8}=3% Strain at Failure

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LOG OF BOREHOLE MW1

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: N 4910454.565 E 608519.325

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Dec/02/2020

REF. NO.: 20-231-400
ENCL NO.: 17

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	WATER CONTENT (%) / REMARKS
254.1 / 0.0	**TOPSOIL:** 300mm	1	SS	6	W. L. 253.6 m Jan 11, 2021	
253.8 / 0.3	**CLAYEY SILT:** some sand, trace gravel, brown, moist to wet, soft	2	SS	3	Bentonite	
252.6 / 1.5	**SANDY SILT:** trace gravel, trace clay, brown, wet, loose	3	SS	10		
251.8 / 2.3	**SILTY SAND TILL:** trace gravel, brown to grey, wet, dense to very dense	4	SS	31		
		5	SS	>100		
		6	SS	>100		
		7	SS	>100	Filter Pack, Slotted Pipe	grinding through boulder at 6.9m
246.5 / 7.6	**SAND:** trace gravel, grey, wet, very dense	8	SS	>100		
245.9 / 8.2	**END OF BOREHOLE:**					

Notes:
1) 50mm dia. monitoring well installed upon completion.
2) Water level Reading:

Date:	Water Level (mbgl):
Jan 11, 2021	0.49

Column headings: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH (kPa): O UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10 20 30); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m³); METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL; ELEVATION 254–246.

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: +3, ×3: Numbers refer to Sensitivity; O ε=3% Strain at Failure

LOG OF BOREHOLE MW2

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: N 4910651.555 E 609062.995

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Dec/03/2020

REF. NO.: 20-231-400
ENCL NO.: 18

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
272.1						
272.0 / 0.2	**TOPSOIL:** 150mm					
	SILTYY SAND: some organics, trace gravel, brown, moist, loose, disturbed	1	SS	5		
271.3 / 0.8	**SAND:** trace gravel, brown, moist, dense to very dense	2	SS	34		
		3	SS	47		
		4	SS	53		
		5	SS	70	Bentonite	
		6	SS	72		
		7	SS	80		
		8	SS	>100	Filter Pack	
	wet below 9.1m	9	SS	52	W. L. 263.1 m Jan 11, 2021	
					Cave-in	
260.8 / 11.3		10	SS	17		wet sand caving-in

END OF BOREHOLE:
Notes:
1) 50mm dia. monitoring well installed upon completion.
2) Water level Reading:

Date:	Water Level (mbgl):
Jan 11, 2021	8.97

Column headings: SOIL PROFILE; SAMPLES; STRATA PLOT; ELEVATION (272, 271, 270, 269, 268, 267, 266, 265, 264, 262, 261); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH (kPa) ○ UNCONFINED + FIELD VANE & Sensitivity ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100; PLASTIC LIMIT W_P NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L; WATER CONTENT (%) 10 20 30; POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3)

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES + 3, × 3: Numbers refer to Sensitivity ○ 8=3% Strain at Failure

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LOG OF BOREHOLE MW3

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: N 4910081.23 E 609200.298

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Dec/04/2020

REF. NO.: 20-231-400
ENCL NO.: 19

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	GROUND WATER CONDITIONS	ELEVATION	METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
263.0 / 262.9 0.1	**TOPSOIL:** 50mm						
	SILT: some sand, some org, trace gravel, brown, moist, loose, disturbed	1	SS	4			
262.2 / 0.8	**SILT:** some sand, trace clay, trace gravel, brown, wet, compact	2	SS	13	W. L. 262.2 m Jan 11, 2021		
261.5 / 1.5	**SANDY SILT:** Brown, trace gravel, wet, compact	3	SS	12		261	wet spoon
	clayey and soft below 2.5m	4	SS	12			
		5	SS	7	Filter Pack	260	
259.0 / 4.0	**SAND:** trace gravel, grey, wet, very dense	6	SS	73	Slotted Pipe	259	
258.1 / 4.9	**SILTY SAND TILL:** Grey, trace gravel, wet, very dense					258	
257.8 / 5.2	**END OF BOREHOLE:**						

Notes:
1) 50mm dia. monitoring well installed upon completion.
2) Water level Reading:

Date:	Water Level (mbgl):
Jan 11, 2021	0.83

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100
SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE: 20 40 60 80 100
PLASTIC LIMIT W_P — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L
WATER CONTENT (%): 10 20 30
POCKET PEN. (Cu) (kPa)
NATURAL UNIT WT (kN/m^3)

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3, \times^3$: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

LOG OF BOREHOLE MW4

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: N 4910262.152 E 609040.767

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Dec/04/2020

REF. NO.: 20-231-400
ENCL NO.: 20

ELEV (m) / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS/0.3 m	WATER CONTENT (%)
266.3 / 0.0	**TOPSOIL:** 300mm				
266.0 / 0.3	**SILTY CLAY:** trace sand, redish brown, moist, soft	1	SS	7	
265.5 / 0.8	**SANDY SILT:** trace gravel, trace clay, brown, moist to wet, loose to compact	2	SS	7	
		3	SS	21	
264.0 / 2.3	**SILTY SAND TILL:** trace gravel, grey, moist to wet, very dense	4	SS	62	
		5	SS	50	
		6	SS	>100	
		7	SS	>100	
		8	SS	80	
258.1 / 8.2	**END OF BOREHOLE:**				

Groundwater conditions: W. L. 263.7 m Jan 11, 2021; Filter Pack; Slotted Pipe

Column headings: SOIL PROFILE; STRATA PLOT; SAMPLES; GROUND WATER CONDITIONS; ELEVATION (266, 265, 264, 263, 262, 261, 260, 259); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH (kPa): O UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); METHANE AND GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

Notes:
1) 50mm dia. monitoring well installed upon completion.
2) Water level Reading:

Date:	Water Level (mbgl):
Jan 11, 2021	2.57

DS SOIL LOG 20-231-400 MATTAMY, 620 LOCKHART ENVIRO.GPJ DS.GDT 21/1/13

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES $+^3, \times^3$: Numbers refer to Sensitivity; O ^{8}=3% Strain at Failure

LOG OF BOREHOLE MW5/E5

PROJECT: Geotechnical Investigation
CLIENT: Mattamy Homes
PROJECT LOCATION: 620 Lockhart Road, Barrie, Ontario
DATUM: Geodetic
BOREHOLE LOCATION: N 4910301.466 E 608781.543

DRILLING DATA
Method: Solid Stem Auger
Diameter: 150mm
Date: Dec/03/2020

REF. NO.: 20-231-400
ENCL NO.: 15

(m) ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	"N" BLOWS / 0.3 m	GROUND WATER CONDITIONS	METHANE AND GRAIN SIZE DISTRIBUTION (%)
260.0 / 0.0	**TOPSOIL:** 600mm	1	SS	4	W. L. 259.5 m Jan 11, 2021	
259.4 / 0.6	**SANDY SILT:** trace to some gravel, brown and grey, wet, loose to dense	2	SS	7		
		3	SS	30		
258.0 / 2.0	**SILTY CLAY:** trace sand, grey, wet, stiff					
257.7 / 2.3	**SILTY SAND TILL:** trace gravel, trace clay, grey, wet, compact to very dense	4	SS	14	Bentonite	wet spoon
		5	SS	20		
	very dense below 3.7m					
		6	SS	>100		spoon bouncing
		7	SS	>100	Filter Pack, Slotted Pipe	
251.8 / 8.2		8	SS	>100		

END OF BOREHOLE:
Notes:
1) 50mm dia. monitoring well installed upon completion.
2) Water level Reading:

Date:	Water Level (mbgl):
Jan 11, 2021	0.55

Column headings: STRATA PLOT; ELEVATION (259, 258, 257, 256, 255, 254, 253, 252); DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH (kPa): ○ UNCONFINED, + FIELD VANE & Sensitivity, ● QUICK TRIAXIAL, × LAB VANE (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (10, 20, 30); POCKET PEN. (Cu) (kPa); NATURAL UNIT WT (kN/m^3); GR SA SI CL

GROUNDWATER ELEVATIONS
Measurement 1st 2nd 3rd 4th

GRAPH NOTES: $+^3$, $\times^3$: Numbers refer to Sensitivity; ○ ε=3% Strain at Failure

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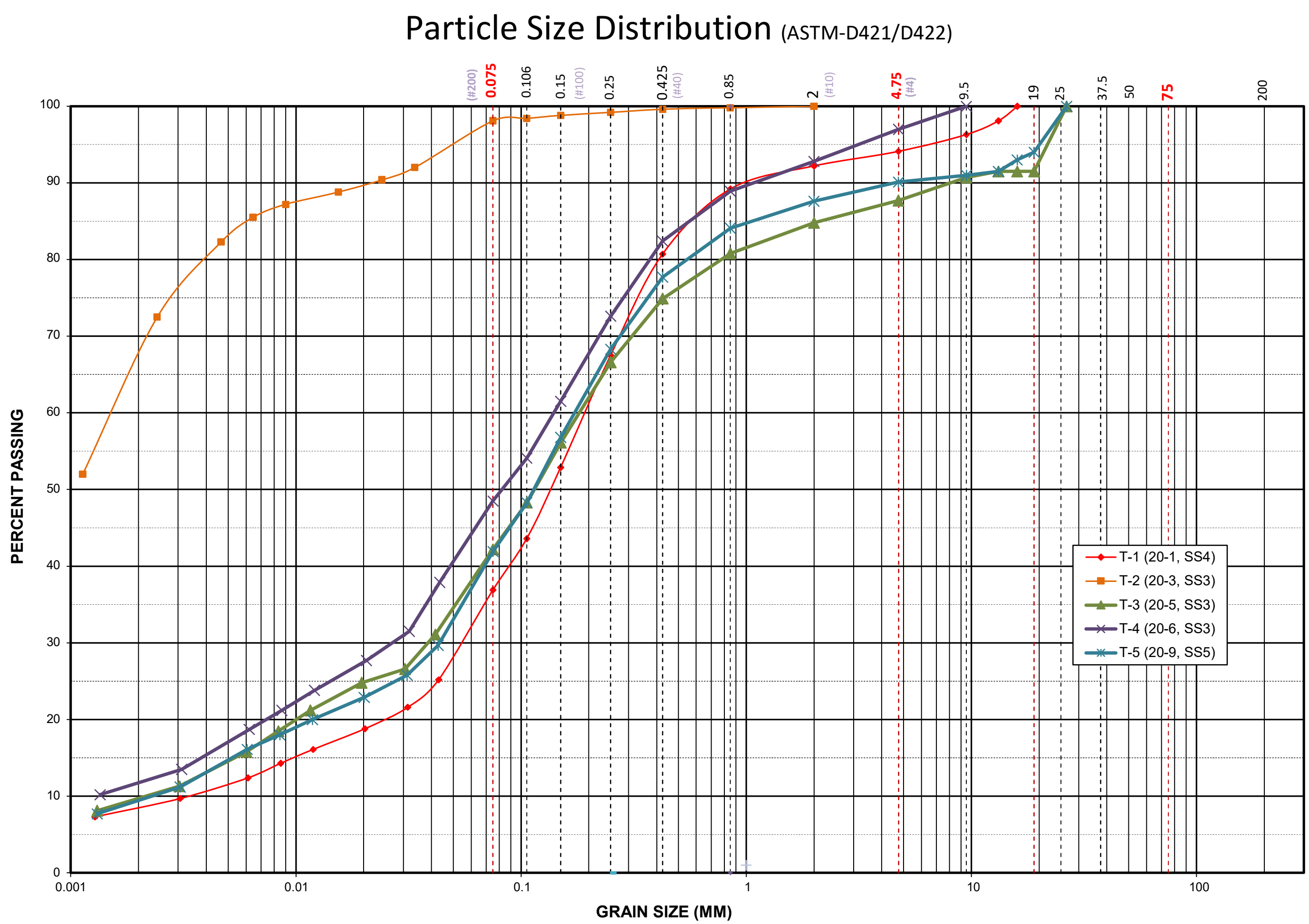
Appendix C

Hydraulic Conductivity

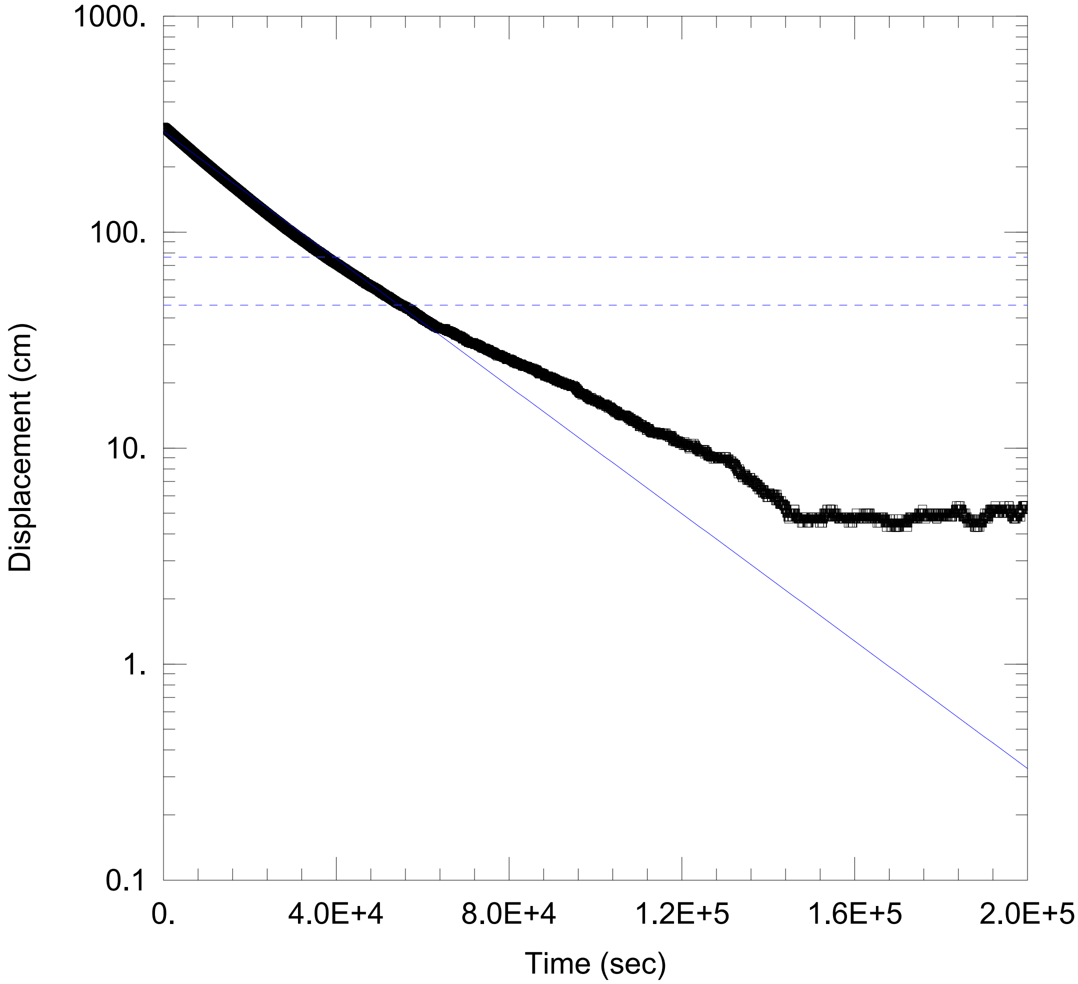
Appendix C



Silt and Clay		Sand			Gravel		Cobble +
Clay	Silt	Fine	Medium	Coarse	Fine	Coarse	

Specification and Comments:

DS CONSULTANTS LTD. 6221 Highway 7, Unit 16 Vaughan, Ontario, L4H 0K8 Telephone: (905) 264-9393 www.dsconsultants.ca	Project:	Geotechnical Investigation, 620 Lockhart Rd.	Tested by :	Matt
	Project No.:	20-231-400	Date:	Sept-30-2020
	Client:	Mattamy Homes	Figure No.:	12



HYDRAULIC CONDUCTIVITY TEST AT MW1- SCREENED IN SILTY SAND TILL

PROJECT INFORMATION

Company: R.J Burnside & Associates Ltd.
Project: 300052092
Location: 620 Lockhart Road, Barrie
Test Well: MW1
Test Date: May 11, 2021

AQUIFER DATA

Saturated Thickness: 695. cm
Anisotropy Ratio (Kz/Kr): 1.

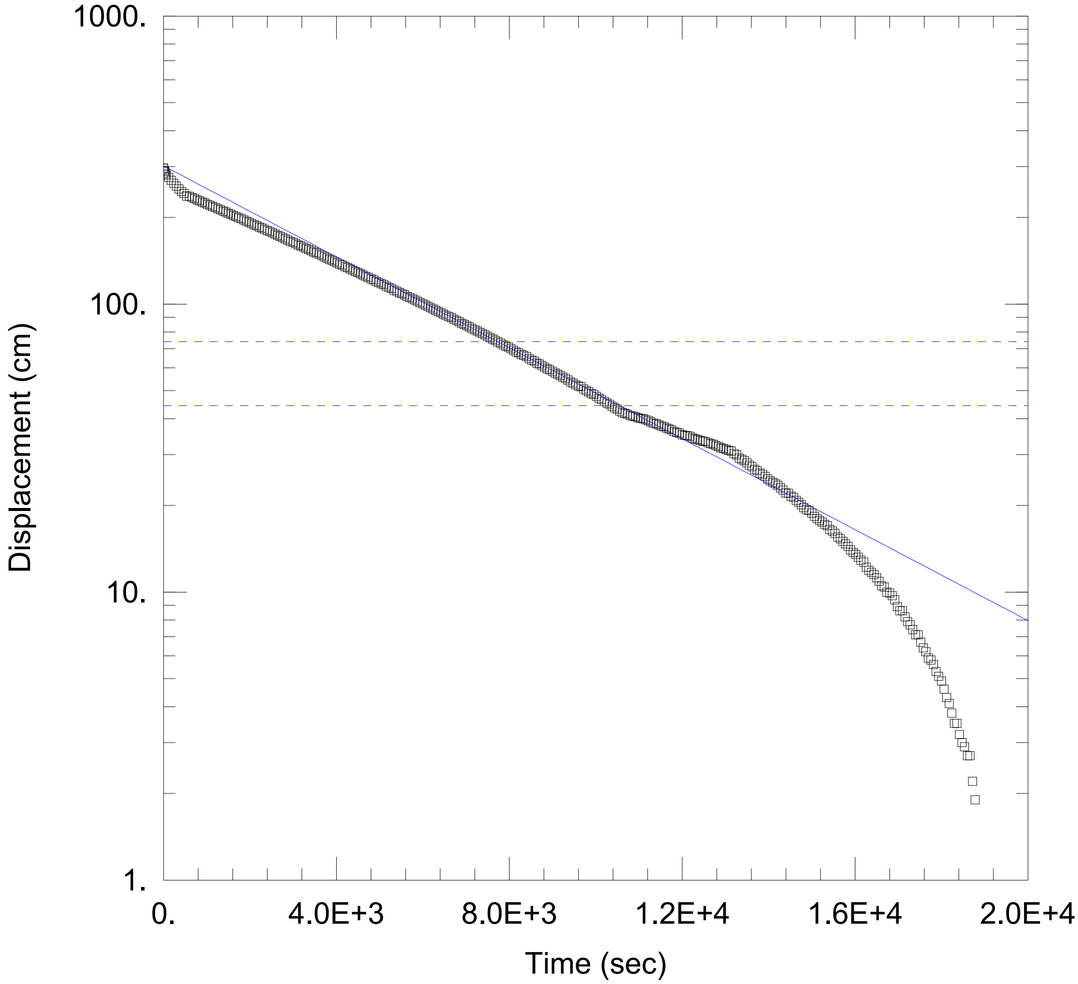
WELL DATA (MW1)

Initial Displacement: 306. cm
Total Well Penetration Depth: 695. cm
Casing Radius: 2.54 cm
Static Water Column Height: 695. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 2.657E-6 cm/sec
y0 = 292.1 cm



HYDRAULIC CONDUCTIVITY TEST AT MW3D- SCREENED IN SILTY SAND

PROJECT INFORMATION

Company: R.J Burnside & Associates Ltd.
Project: 300052092
Location: 620 Lockhart Road, Barrie
Test Well: MW3d
Test Date: May 11, 2021

AQUIFER DATA

Saturated Thickness: 639. cm
Anisotropy Ratio (Kz/Kr): 1.

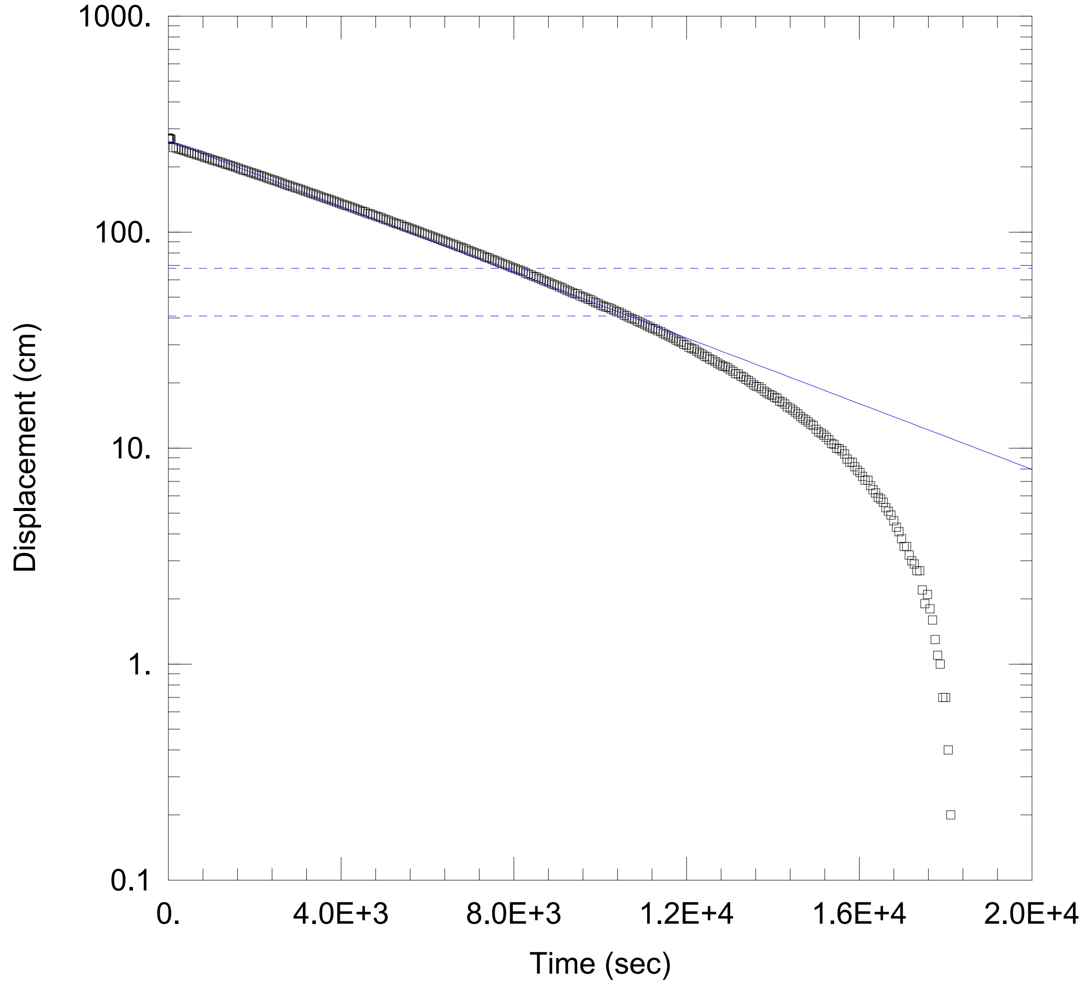
WELL DATA (MW3d)

Initial Displacement: 296. cm
Total Well Penetration Depth: 639. cm
Casing Radius: 2.54 cm
Static Water Column Height: 639. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 1.422E-5 cm/sec
y0 = 301.8 cm



HYDRAULIC CONDUCTIVITY TEST AT MW4- SCREENED IN SILTY SAND TILL

PROJECT INFORMATION

Company: R.J Burnside & Associates Ltd.
Project: 300052092
Location: 620 Lockhart Road, Barrie
Test Well: MW4
Test Date: May 11, 2021

AQUIFER DATA

Saturated Thickness: 518. cm
Anisotropy Ratio (Kz/Kr): 1.

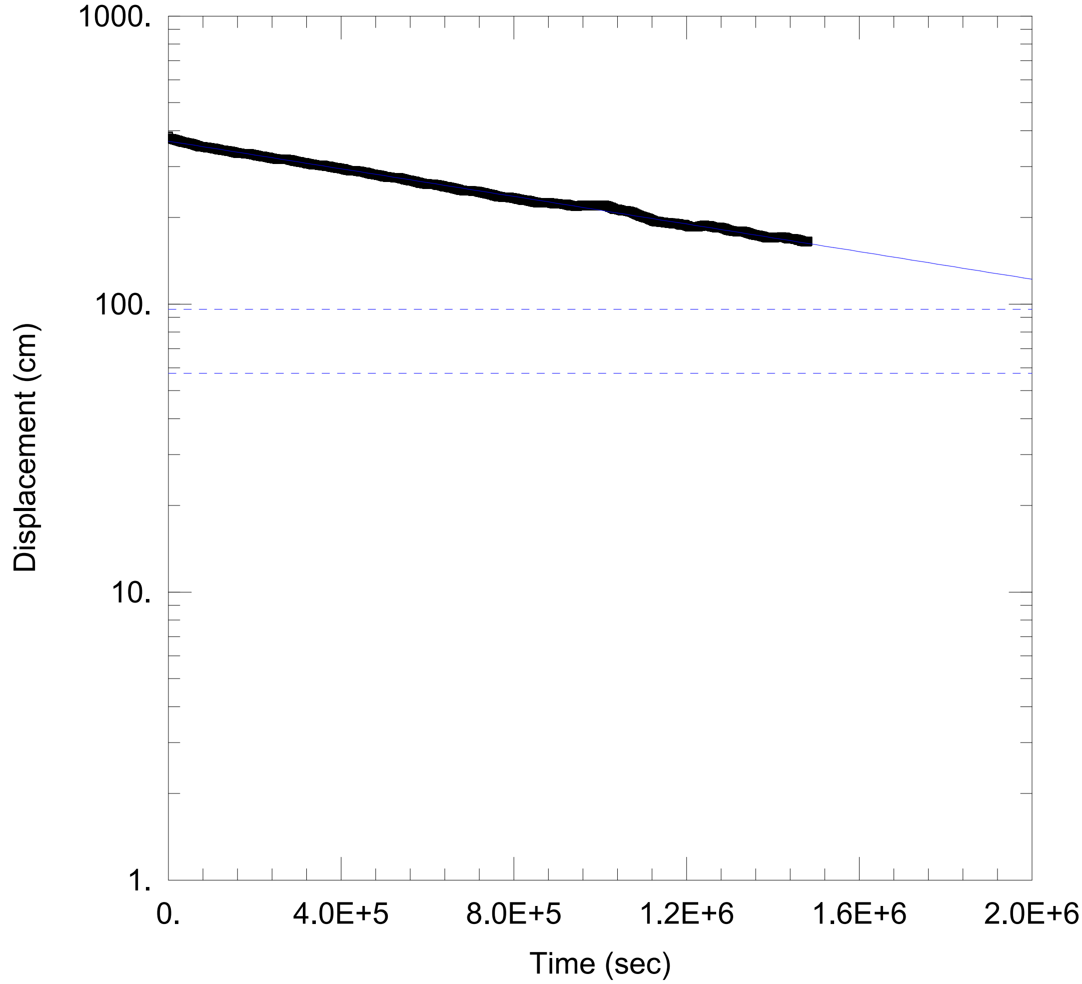
WELL DATA (MW4)

Initial Displacement: 272. cm
Total Well Penetration Depth: 518. cm
Casing Radius: 2.54 cm
Static Water Column Height: 518. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined
Solution Method: Hvorslev

K = 1.37E-5 cm/sec
y0 = 264.3 cm



HYDRAULIC CONDUCTIVITY TEST AT MW5 - SCREENED IN SILTY SAND TILL

PROJECT INFORMATION

Company: R.J Burnside & Associates Ltd.
Project: 300052092
Location: 620 Lockhart Road, Barrie
Test Well: MW5
Test Date: May 11, 2021

AQUIFER DATA

Saturated Thickness: 830. cm

Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (MW5)

Initial Displacement: 383. cm
Total Well Penetration Depth: 830. cm
Casing Radius: 2.54 cm

Static Water Column Height: 830. cm
Screen Length: 152. cm
Well Radius: 7.62 cm

SOLUTION

Aquifer Model: Unconfined

Solution Method: Hvorslev

K = 4.32E-8 cm/sec

y0 = 367.7 cm

BURNSIDE

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Appendix D

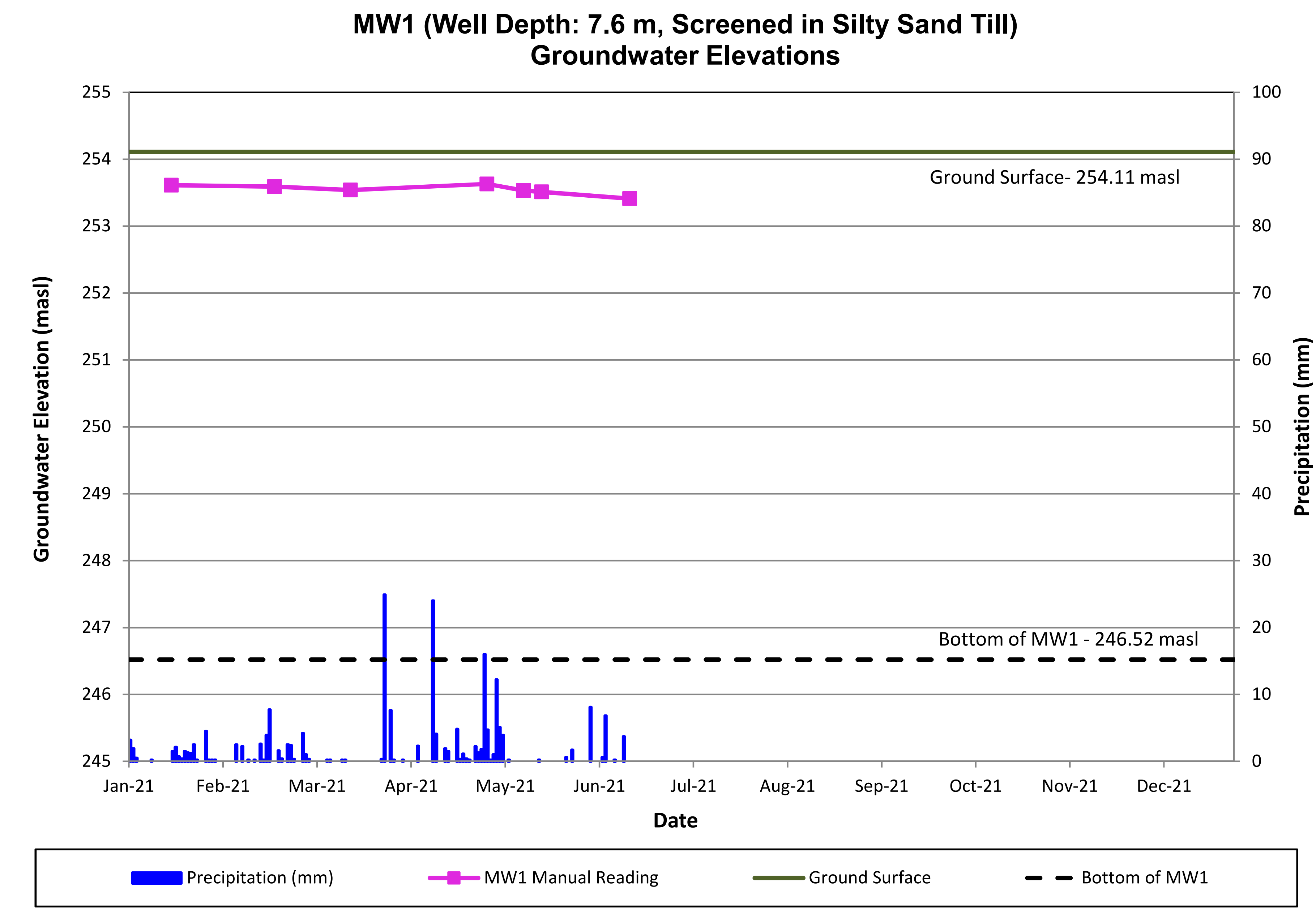
Groundwater Levels

Appendix D

Table D-1
Groundwater Elevations

Well	Well Depth (mbgs)	Ground Surface Elevation (masl)	January 15, 2021		February 18, 2021		March 15, 2021		April 29, 2021		May 17, 2021		June 15, 2021	
			Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)	Water Level (mbgs)	Water Elevation (masl)
MW1	7.59	254.11	0.50	253.61	0.52	253.59	0.57	253.54	0.48	253.63	0.60	253.51	0.70	253.41
MW2	9.88	272.05	9.01	263.04	9.01	263.04	9.05	263.00	8.96	263.09	8.96	263.09	9.05	263.00
MW3s	4.58	263.01	1.03	261.98	0.87	262.14	0.67	262.34	0.66	262.35	0.74	262.27	0.92	262.09
MW3d	7.08	263.00	0.47	262.53	0.54	262.46	0.80	262.20	0.92	262.08	1.05	261.95	1.23	261.77
MW4	7.78	266.30	2.60	263.70	2.57	263.73	2.46	263.84	2.69	263.61	2.68	263.62	2.91	263.39
MW5	7.80	260.02	0.42	259.60	Frozen	Frozen	Frozen	Frozen	-0.12	260.14	-	-	0.64	259.38
BH20-3	7.00	253.10	Frozen	Frozen	Frozen	Frozen	Frozen	Frozen	-0.21	253.31	0.30	252.80	0.37	252.73
BH20-4	6.31	269.00	5.17	263.83	5.05	263.95	4.74	264.26	5.35	263.65	5.23	263.77	5.74	263.26

'-' denotes data unavailable
mbgs - metres below ground surface
masl - metres above sea level


MW1 (Well Depth: 7.6 m, Screened in Silty Sand Till)
Groundwater Elevations
Ground Surface- 254.11 masl
Bottom of MW1 - 246.52 masl
Groundwater Elevation (masl)
Precipitation (mm)
Date
255
254
253
252
251
250
249
248
247
246
245
100
90
80
70
60
50
40
30
20
10
0
Jan-21
Feb-21
Mar-21
Apr-21
May-21
Jun-21
Jul-21
Aug-21
Sep-21
Oct-21
Nov-21
Dec-21
Precipitation (mm)
MW1 Manual Reading
Ground Surface
Bottom of MW1

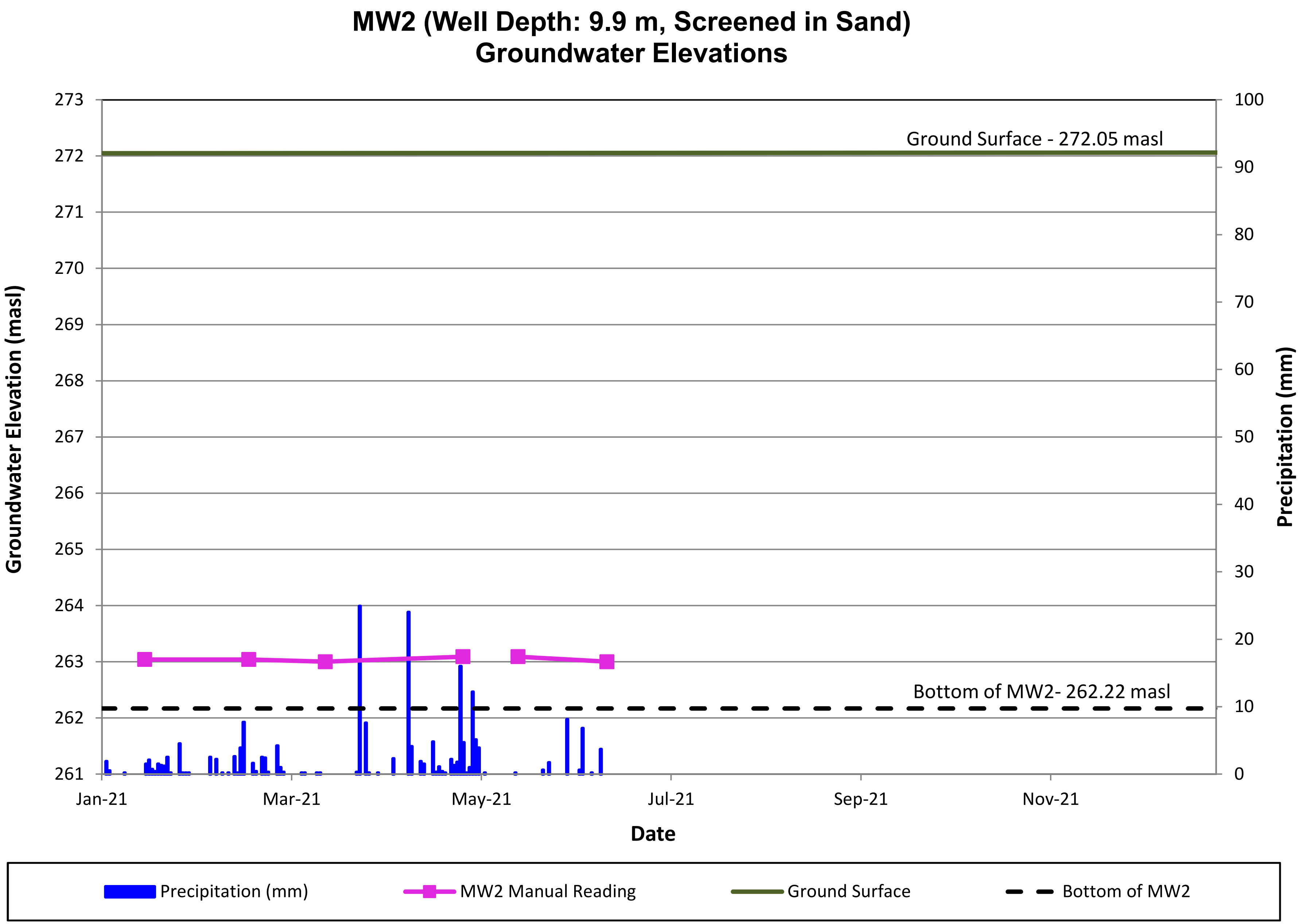


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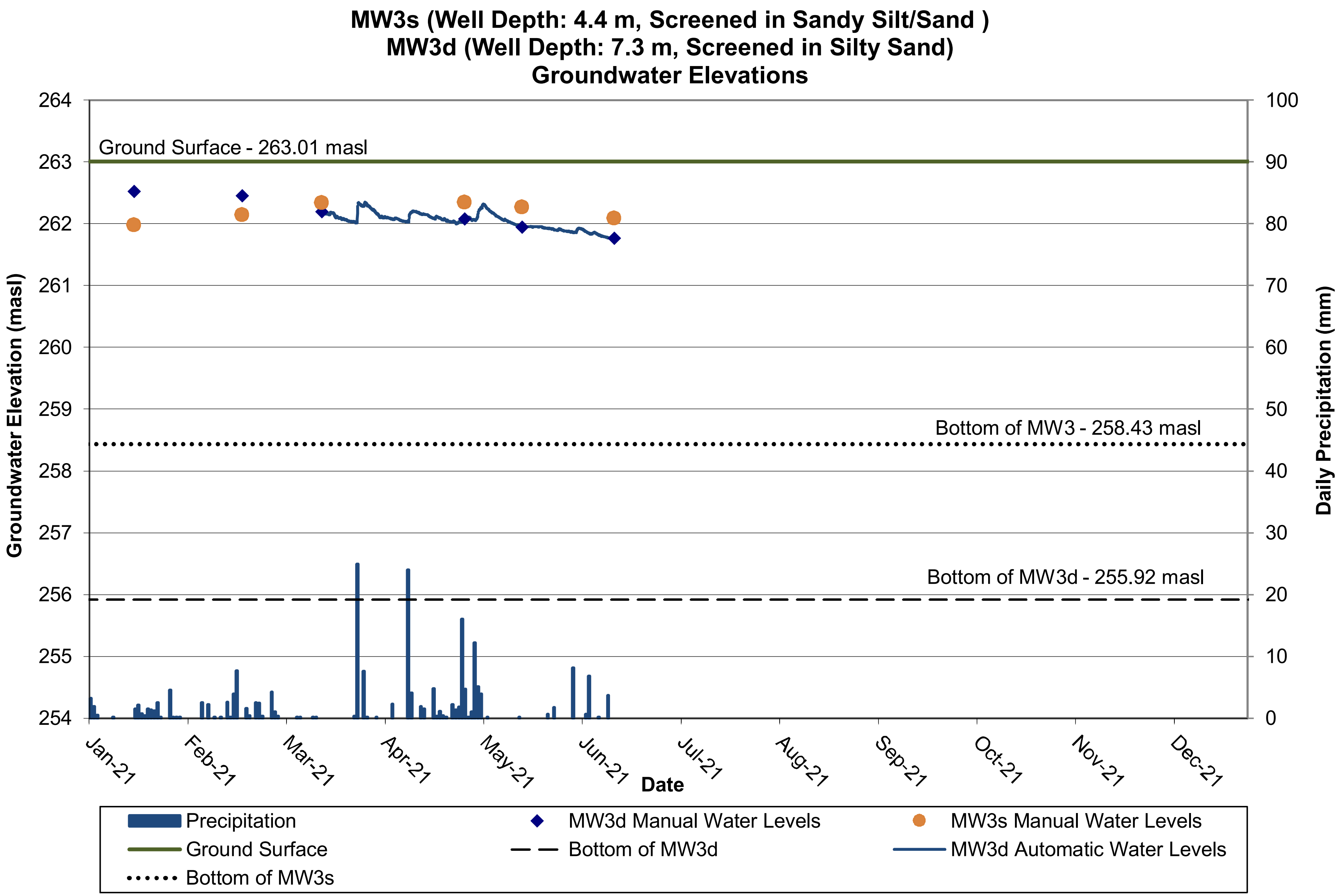
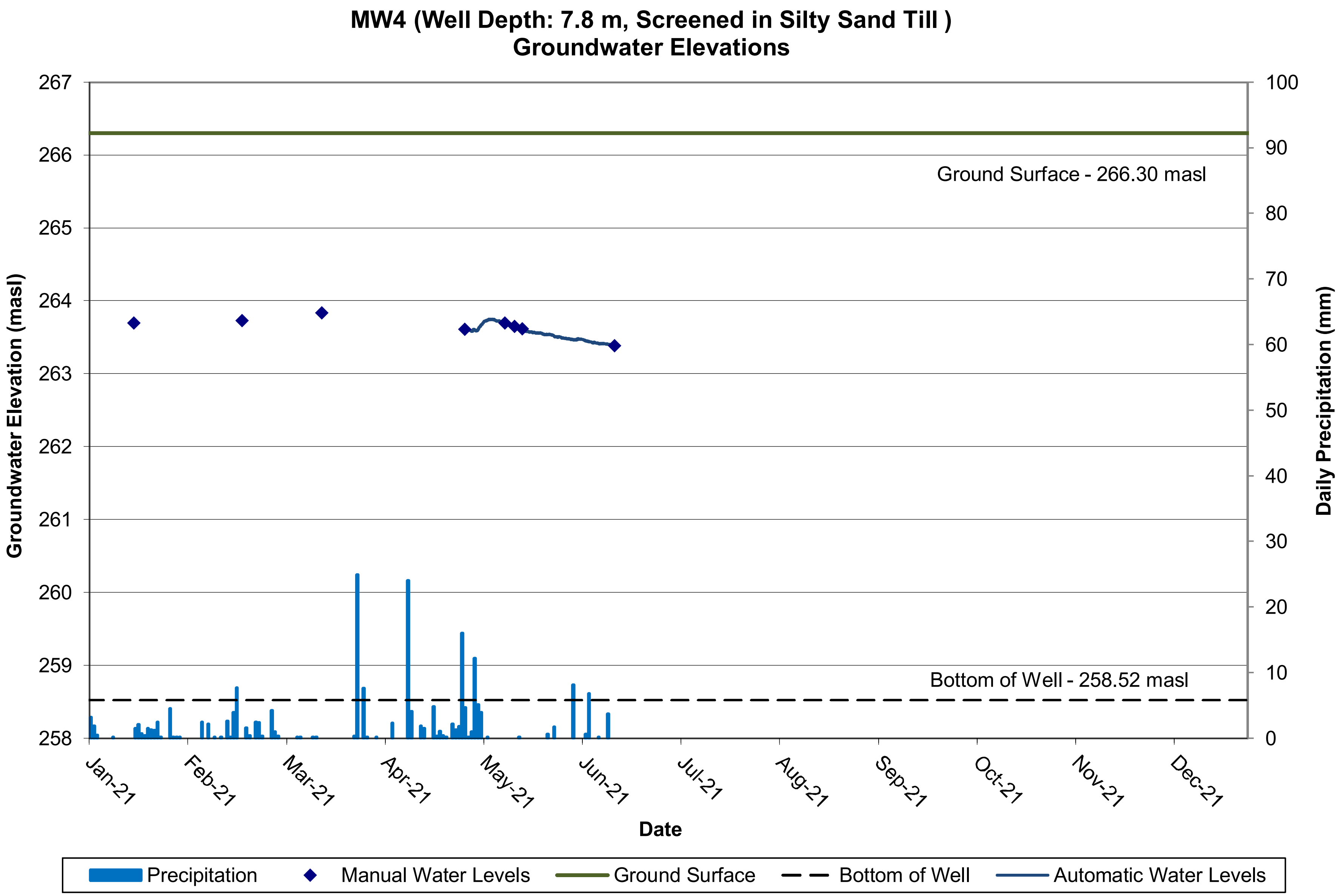
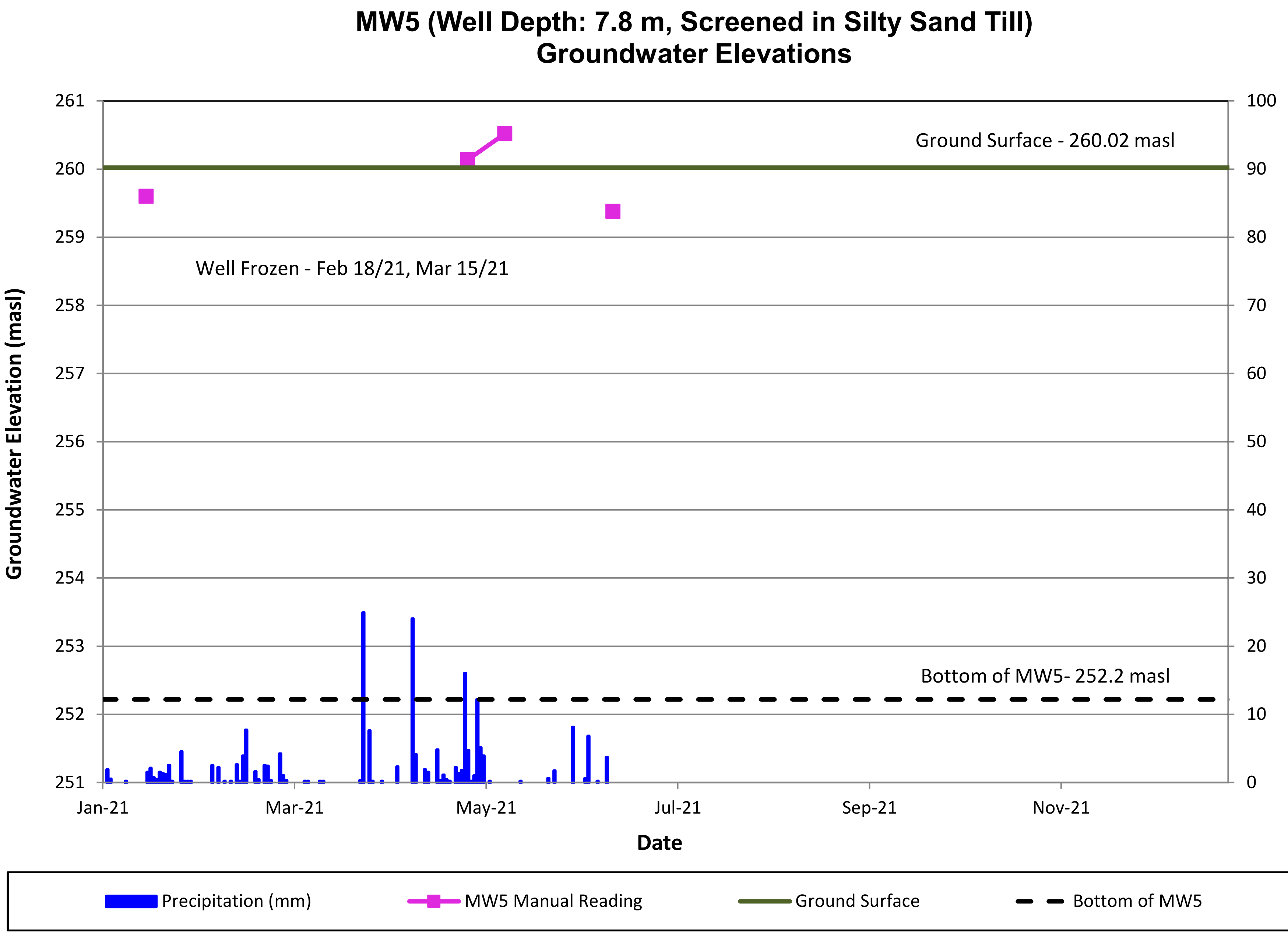
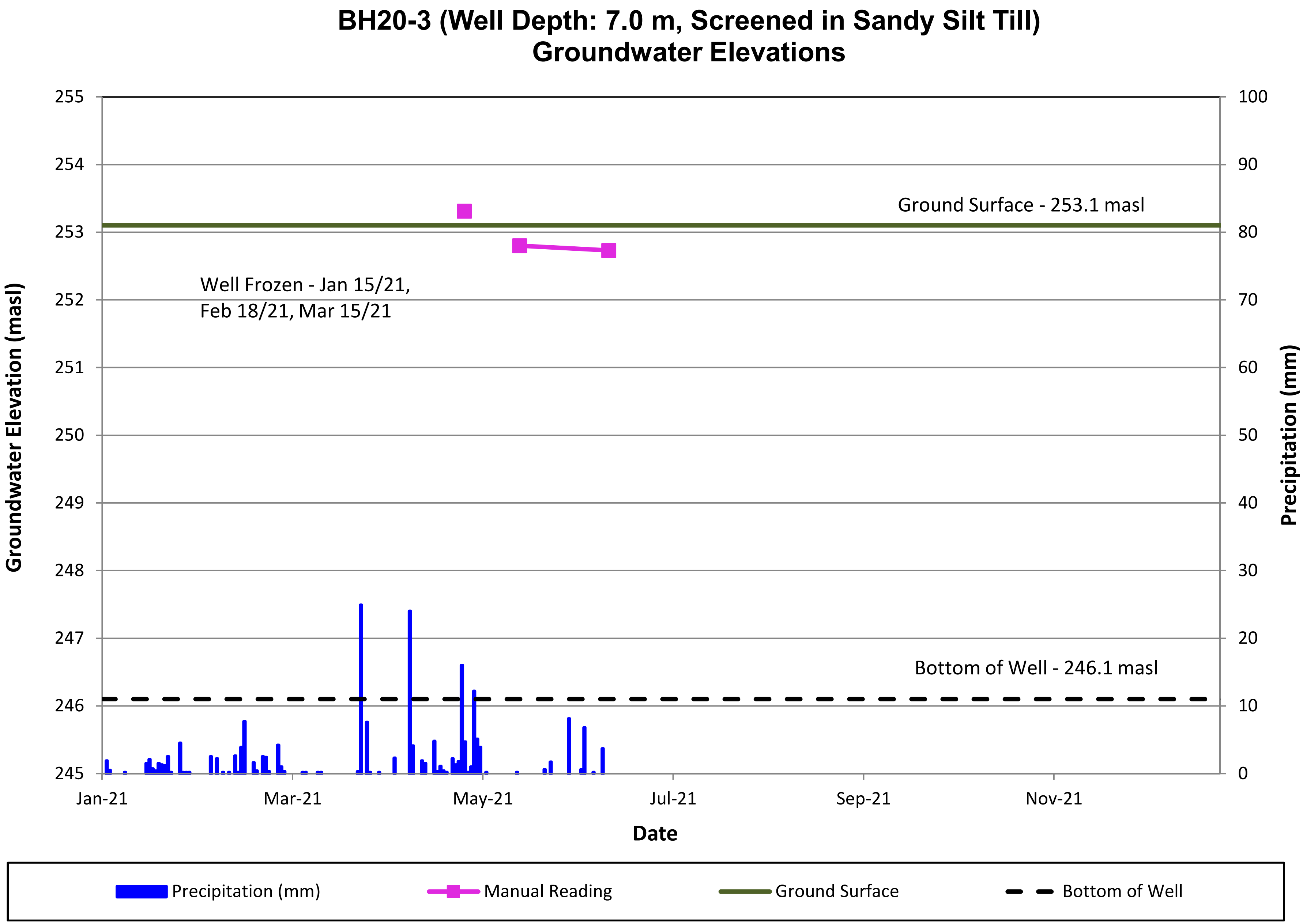
Figure D-2

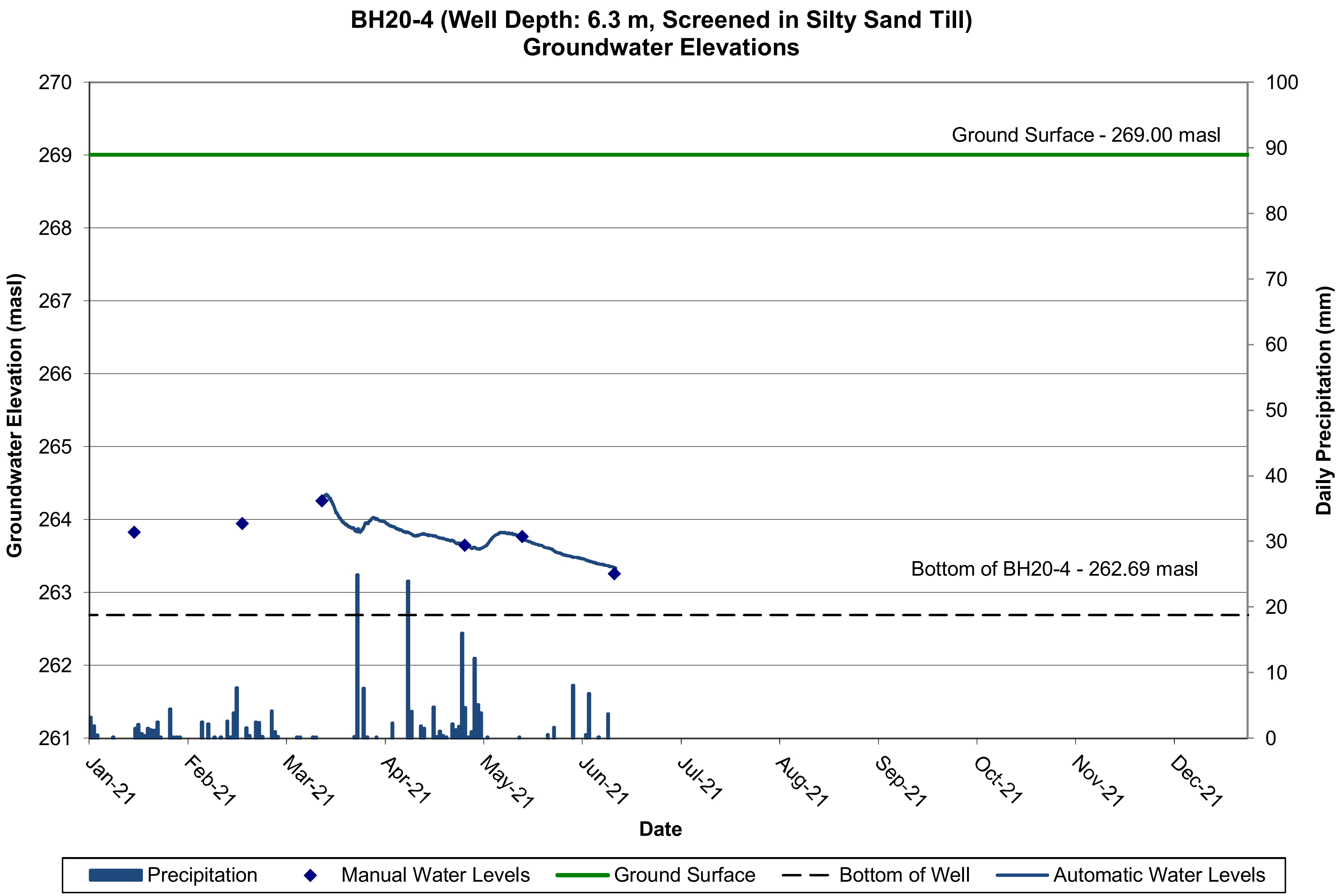


MW3s (Well Depth: 4.4 m, Screened in Sandy Silt/Sand)
MW3d (Well Depth: 7.3 m, Screened in Silty Sand)
Groundwater Elevations
Ground Surface - 263.01 masl
Bottom of MW3 - 258.43 masl
Bottom of MW3d - 255.92 masl
Groundwater Elevation (masl)
Daily Precipitation (mm)
264
263
262
261
260
259
258
257
256
255
254
100
90
80
70
60
50
40
30
20
10
0
Jan-21
Feb-21
Mar-21
Apr-21
May-21
Jun-21
Jul-21
Aug-21
Sep-21
Oct-21
Nov-21
Dec-21
Date
Precipitation
MW3d Manual Water Levels
MW3s Manual Water Levels
Ground Surface
Bottom of MW3d
MW3d Automatic Water Levels
Bottom of MW3s


MW4 (Well Depth: 7.8 m, Screened in Silty Sand Till)
Groundwater Elevations
Groundwater Elevation (masl)
Daily Precipitation (mm)
267
266
265
264
263
262
261
260
259
258
100
90
80
70
60
50
40
30
20
10
0
Ground Surface - 266.30 masl
Bottom of Well - 258.52 masl
Jan-21
Feb-21
Mar-21
Apr-21
May-21
Jun-21
Jul-21
Aug-21
Sep-21
Oct-21
Nov-21
Dec-21
Date
Precipitation
Manual Water Levels
Ground Surface
Bottom of Well
Automatic Water Levels


MW5 (Well Depth: 7.8 m, Screened in Silty Sand Till)
Groundwater Elevations
Ground Surface - 260.02 masl
Well Frozen - Feb 18/21, Mar 15/21
Bottom of MW5- 252.2 masl
261
260
259
258
257
256
255
254
253
252
251
100
90
80
70
60
50
40
30
20
10
0
Groundwater Elevation (masl)
Precipitation (mm)
Jan-21
Mar-21
May-21
Jul-21
Sep-21
Nov-21
Date
Precipitation (mm)
MW5 Manual Reading
Ground Surface
Bottom of MW5


BH20-3 (Well Depth: 7.0 m, Screened in Sandy Silt Till)
Groundwater Elevations
Groundwater Elevation (masl)
Precipitation (mm)
255
254
253
252
251
250
249
248
247
246
245
100
90
80
70
60
50
40
30
20
10
0
Ground Surface - 253.1 masl
Well Frozen - Jan 15/21, Feb 18/21, Mar 15/21
Bottom of Well - 246.1 masl
Jan-21
Mar-21
May-21
Jul-21
Sep-21
Nov-21
Date
Precipitation (mm)
Manual Reading
Ground Surface
Bottom of Well



BH20-4 (Well Depth: 6.3 m, Screened in Silty Sand Till)
Groundwater Elevations
Groundwater Elevation (masl)
Daily Precipitation (mm)
270
269
268
267
266
265
264
263
262
261
100
90
80
70
60
50
40
30
20
10
0
Ground Surface - 269.00 masl
Bottom of BH20-4 - 262.69 masl
Jan-21
Feb-21
Mar-21
Apr-21
May-21
Jun-21
Jul-21
Aug-21
Sep-21
Oct-21
Nov-21
Dec-21
Date
Precipitation
Manual Water Levels
Ground Surface
Bottom of Well
Automatic Water Levels

Appendix E

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Appendix E

Water Quality

Table E-1
Groundwater Quality

Monitoring Well					MW3d	MW4
Date Sampled					**14-May-21**	**14-May-21**
Parameter	**Unit**	**RDL**	**ODWQS**	**PWQO**		
Electrical Conductivity	µS/cm	2			607	550
pH	pH Units	NA	(6.5-8.5)	(6.5-8.5)	7.8	7.87
Saturation pH (Calculated)					6.33	6.58
Langelier Index (Calculated)					1.47	1.29
Total Hardness (as CaCO3) (Calcul	mg/L	0.5	(80-100)		**354**	**301**
Total Dissolved Solids	mg/L	30	500		354	403
Alkalinity (as CaCO3)	mg/L	2	(30-500)		**2030**	**1270**
Bicarbonate (as CaCO3)	mg/L	2			2030	1270
Carbonate (as CaCO3)	mg/L	2			< 2	< 2
Hydroxide (as CaCO3)	mg/L	2			< 2	< 2
Fluoride	mg/L	0.06	1.5		< 0.06	0.12
Chloride	mg/L	1	250		48	32
Nitrate as N	mg/L	0.06	10.0		**11.8**	**19.4**
Nitrite as N	mg/L	0.03	1.0		<0.03	<0.03
Bromide	mg/L	0.3			<0.3	<0.3
Sulphate	mg/L	10	500		15	<10
Phosphate (total reactive)	mg/L	0.03			<0.03	0.05
Ammonia+Ammonium (N)	mg/L	0.04			<0.04	<0.04
Total Phosphorus	mg/L	0.03		0.03	0.05	1.46
Total Organic Carbon	mg/L	0.5			1	1
Colour	TCU	3	5		24	8
Calcium	mg/L	0.01			117	100
Magnesium	mg/L	0.001			15.3	12.2
Sodium	mg/L	0.01	20 (200)		7.17	5.92
Potassium	mg/L	0.009			1.51	2.32
Aluminum	mg/L	0.001	0.1	0.075	0.019	0.004
Antimony	mg/L	0.0009	0.006		< 0.0009	< 0.0009
Arsenic	mg/L	0.0002	0.025	1	< 0.0002	< 0.0002
Barium	mg/L	0.00002	1		0.08243	0.01243
Beryllium	mg/L	0.000007			< 0.000007	< 0.000007
Boron	mg/L	0.002	5	2	0.007	0.008
Cadmium	mg/L	0.000003	0.005	0.0002	0.000003	0.000003
Chromium	mg/L	0.00008	0.05	0.009	0.00123	0.00037
Cobalt	mg/L	0.000004			0.00005	0.000039
Copper	mg/L	0.0002	1	0.005	0.0006	0.0004
Iron	mg/L	0.007	0.3	0.3	0.022	0.007
Lead	mg/L	0.00009	0.01	0.001	< 0.00009	< 0.00009
Manganese	mg/L	0.00001	0.05		0.00363	0.00348
Mercury	mg/L	0.00001	0.001	0.0002	< 0.00001	< 0.00001
Molybdenum	mg/L	0.00004		0.04	0.00027	0.00211
Nickel	mg/L	0.0001		0.025	0.0012	0.0018
Selenium	mg/L	0.00004	0.01	0.01	0.00032	0.00009
Silver	mg/L	0.00005		<0.002	< 0.00005	< 0.00005
Strontium	mg/L	0.00002			0.257	0.258
Thallium	mg/L	0.000005		0.0003	< 0.000005	< 0.000005
Tin	mg/L	0.00006			0.00009	0.00009
Titanium	mg/L	0.00005			0.00113	0.00017
Tungsten	mg/L	0.00002			< 0.00002	0.00008
Uranium	mg/L	0.000002	0.02	0.005	0.000442	0.000118
Vanadium	mg/L	0.00001	3		0.00065	0.00089
Zinc	mg/L	0.002	5	0.03	0.034	0.006
Zirconium	mg/L	0.002			< 0.002	< 0.002

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 F

Water Balance

Appendix F

WATER BALANCE CALCULATIONS
Mattamy (Lockhart) Limited
620 Lockhart Road
Barrie, ON
PROJECT No.300052092

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TABLE F-1

Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 150 mm (moderately-rooted vegetation in sandy 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^{o} 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 150 mm	150	150	150	150	150	121	64	37	53	92	150	150	
Actual Evapotranspiration (AET)	0	0	0	28	75	114	135	117	77	38	9	0	**593**
Soil Moisture Deficit max 150 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)	50	37	35	20	5	0	0	0	0	0	13	44	**204**
Potential Direct Surface Water Runoff (independent of temperature)	33	25	23	13	3	0	0	0	0	0	9	29	**136**
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	150	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 loam	0.4		<-- 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	**0.6**		
Latitude of site (or climate station)	44 ^{O} N.		

WATER BALANCE CALCULATIONS
Mattamy (Lockhart) Limited
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PROJECT No.300052092

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TABLE F-2

Post-Development Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 75 mm (urban lawn in sandy 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^{o} 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	-46	0	17	39	19	0	**0**
Soil Moisture Storage max 75 mm	75	75	75	75	75	46	0	0	17	56	75	75	
Actual Evapotranspiration (AET)	0	0	0	28	75	114	123	90	77	38	9	0	**555**
Soil Moisture Deficit max 75 mm	0	0	0	0	0	29	75	75	58	19	0	0	
Water Surplus - available for infiltration or runoff	83	62	58	34	8	0	0	0	0	0	60	74	**378**
Potential Infiltration (based on MOE methodology*; independent of temperature)	50	37	35	20	5	0	0	0	0	0	36	44	**227**
Potential Direct Surface Water Runoff (independent of temperature)	33	25	23	13	3	0	0	0	0	0	24	29	**151**
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 75 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 loam	0.4	<-- 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	**0.6**	

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

WATER BALANCE CALCULATIONS
Mattamy (Lockhart) Limited
620 Lockhart Road
Barrie, ON
PROJECT No.300052092

TABLE F-3

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												
Open Space /Agricultural	279,300	0.00	0	0.793	0	279,300	0.136	37,953	0.204	56,930	37,953	56,930
TOTAL PRE-DEVELOPMENT	**279,300**		**0**		**0**	**279,300**		**37,953**		**56,930**	**37,953**	**56,930**
Post-Development Land Use (with no LID measures in place)												
Residential	160,500	0.50	80,250	0.793	63,635	80,250	0.151	12,134	0.227	18,201	75,769	18,201
Park	25,200	0.05	1,260	0.793	999	23,940	0.151	3,620	0.227	5,430	4,619	5,430
Roads (ROW)	93,600	0.80	74,880	0.793	59,377	18,720	0.151	2,830	0.227	4,246	62,208	4,246
TOTAL POST-DEVELOPMENT	**279,300**		**156,390**		**124,012**	**122,910**		**18,584**		**27,876**	**142,596**	**27,876**
% Change from Pre to Post											376	51
Effect of development (with no mitigation)											3.7 times increase in runoff	51% reduction of infiltration

** figures from Tables F-1 and F-2.

To balance pre- to post-,
the infiltration target (m^3/a)= **29,054**

Figure F-1
Pre-Development Monthly Site Water Balance

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