Hydrogeological Assessment

FINAL REPORT

Kilbourne Developments Inc.

Project Name:
Hydrogeological Assessment
Kilbourne Lands
London, Ontario

Project Number:
LON-21008854-A0

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Date Submitted:
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Executive Summary

EXP Services Inc. (EXP) was retained by **Kilbourne Developments Inc.** to conduct a hydrogeological assessment for the proposed subdivision of lands located along the east side of Bostwick Road, between Southdale Road West and Wharncliffe Road South, in London, Ontario, hereinafter referred to as the 'Site'. These lands were formerly known as the 'McPerl Lands' and are now referred to as the 'Kilbourne Lands'. The development plan for the Site includes a combination of low to medium/high density residential blocks, medium density/commercial blocks, open space blocks, park blocks, stormwater management blocks, and associated roads and servicing.

The objectives of the hydrogeological study were to examine the hydrogeological characteristics of the Site by collecting soil and groundwater information provided from a series of sampled boreholes, monitoring wells and piezometers; reviewing the Ministry of the Environment, Conservation and Parks (MECP) Water Well Records (WWR) to identify private water well users in the area; collecting multiple years of groundwater and surface water elevations to identify seasonal variations across the Site; completing monthly feature-based water balances for the required features, and assessing the surface water and natural heritage features on the property. The assessment provides comments pertaining to potential impacts on hydrogeological conditions at the Site and provides recommendations and design/construction measures, where applicable, to mitigate the potential for impact.

It is understood that the hydrogeological assessment will be submitted for review and approval by the City of London and the Upper Thames River Conservation Authority (UTRCA).

Based on the results of the hydrogeological assessment, the following findings are presented:

- The Site is situated within the Dingman Creek subwatershed;

- The Site is bisected by the Thornicroft Drain (the Drain) which originates at Southdale Road and flows south through the Site. There are two (2) tributaries which flow from the west into the Drain through the Site. The City of London classifies the Thornicroft Drain as a Significant Valleyland. A portion of the Drain is mapped as an Unevaluated Wetland. Lands adjacent to the Drain include Significant Woodlands, Unevaluated Vegetation Patches, Valleyland features, and a warehousing complex;

- An ecological study completed by Natural Resource Solutions Inc. (NRSI) identified three (3) primary wetland features on Site (the Northern Woodlot Wetlands, the Central Thornicroft Drain Wetland and the Southern Tributary Wetlands). The natural features on site will be maintained with the exception of the Southern Tributary Wetlands which will be relocated nearby;

- The Drain and associated natural features on Site are regulated lands of the UTRCA;

- Drainage from the Site is primarily via overland flow with minor seepage into the shallow subsurface with the exception of the Thornicroft Drain which is a groundwater recharging feature. Runoff generally follows topography towards the valleyland associated with the Thornicroft Drain. The Drain then flows south through the Site and connects with Dingman Creek near Highway 402;

- The Site is covered with a low-permeability clayey silt or silty clay till (aquitard) underlain by an extensive silty sand / sandy silt and sand stratum (aquifer);

- A Significant Groundwater Recharge Area (SGRA) is mapped at the northern portion of the Site associated with the woodland, along the Thornicroft Drain and in the south portion of the Site. A Highly vulnerable Aquifer (HVA) is mapped in the southern portion of the Site. Based on the presence of a relatively thick (9.5 m) surficial aquitard unit in the southern portion of the Site, it is our opinion that the lands in the southern portion (aside from those in the immediate vicinity of the Thornicroft Drain), where clayey silt till is the surficial geological unit, should not be characterized as an SGRA or HVA;

- A total of twenty-one (21) domestic groundwater supply wells are located within a 500 m radius of the Site. These wells were installed at depths of 7.9 m to 35.1 m below ground surface (bgs) with the majority screened predominantly between 10 and 20 m bgs;

- Groundwater elevations within the monitoring wells were cyclical, showing similar seasonal fluctuations with some degree of response to precipitation events. Seasonal high elevations were generally observed in the spring months;

- Overall, surface water elevations within surface water (SW) Stations 2 to 4 remained generally constant throughout the monitoring period with some response to precipitation events. Groundwater elevations within the piezometers were generally lower than surface water indicating the Drain is likely being predominantly fed by surface water and is a groundwater recharging feature. Groundwater elevations in the piezometers show a similar cyclical pattern to groundwater elevations in the monitoring wells with higher elevations in the late fall to early spring. Similar seasonal trends were observed in SW Stations 6-8 and 10.

- Based on grain size analysis, the hydraulic conductivity of the dominant clayey silt till soils at the Site in the range of 10^{-9} to 10^{-11} m/s. The estimated hydraulic conductivities for the silty sand to sand based on grain size analyses and single well response tests (SWRTs) range from 5.1×10^{-7} m/s to 8.2×10^{-5} m/s; and,

- The monitoring wells on Site have been maintained for ongoing study past the completion of this report. When the wells are no longer required, they should be decommissioned in accordance with O. Reg. 903.

Table of Contents

Appendices

Tables (in text)

Drawings (Appendix A)

1. Introduction and Background

1.1 Background

EXP Services Inc. (EXP) was retained by **Kilbourne Developments Inc.** to conduct a hydrogeological study for the proposed subdivision of lands located along the east side of Bostwick Road, between Southdale Road West and Wharncliffe Road South, in London, Ontario, hereinafter referred to as the 'Site' (**Appendix A, Drawing 1**). These lands were formerly known as the 'McPerl Lands' and are now referred to as the 'Kilbourne Lands'. The development plan for the Site includes a combination of low to medium/high density residential blocks, medium density/commercial blocks, open space blocks, park blocks, stormwater management blocks, and associated roads and servicing. The proposed Draft Plan of Subdivision, dated December 22, 2023, is provided in **Appendix B**.

It is noted that the lands immediately north of the Site located at 3080 Bostwick Road, London, are also owned by the Client and EXP is currently undertaking a hydrogeological investigation of this property. Hydrogeological information collected by EXP from these northern lands have been incorporated into the assessment of the Site, where relevant.

The Site is bisected by the Thornicroft Drain (the Drain) which extends north-south through the Site. Map 5 (Natural Heritage) of the City of London Official Plan classifies the section of the Thornicroft Drain bisecting the Site as a Significant Valleyland. Additionally, Unevaluated Wetland are also shown on Map 5 to be located along a portion of the Drain. An ecological study was completed for the Site by Natural Resource Solutions Inc. (NRSI) which categorized the ecological land classifications (ELCs) for the Site. The wetlands on Site were evaluated and mapped by NRSI. Overall, there are three (3) primary wetland features on Site (the northern woodlot wetlands, the central Thornicroft Drain wetland and the southern tributary wetland), as shown on **Drawing 2**. The natural features on Site will be maintained post-development with the exception of the southern tributary wetland which will be relocated nearby. The development design will incorporate the requirements relevant to the Thornicroft Drain as outlined in the Dingman Creek Subwatershed Stormwater Servicing Study.

The objectives of the hydrogeological study were to examine the hydrogeological characteristics of the Site by collecting soil and groundwater information provided from a series of sampled boreholes, monitoring wells and piezometers; reviewing the Ministry of the Environment, Conservation and Parks (MECP) Water Well Records (WWR) to identify private water well users in the area; collecting multiple years of groundwater and surface water elevations to identify seasonal variations across the Site; completing monthly feature-based water balances for the required features, and assessing the surface water and natural heritage features on the property. The assessment provides comments pertaining to potential impacts on hydrogeological conditions at the Site and provides recommendations and design/construction measures, where applicable, to mitigate the potential for impact.

It is understood that the hydrogeological study will be submitted for review and approval by the City of London and the Upper Thames River Conservation Authority (UTRCA) as part of the Draft Plan Approval for the proposed development. The study design and report have been compiled in accordance with the City of London Design Specification & Requirements Manual (2019) as well as the Conservation Authority Guidelines for Hydrogeological Assessments (2013).

The UTRCA administers a regulation made under Section 28 of the Conservation Authorities Act, known as Development, Interference with Wetlands and Alterations to Shorelines and Watercourses (O.Reg. 157/06). The regulation was approved by the Minister of Natural Resources and Forestry on May 4, 2006. This regulation allows the UTRCA to ensure that proposed developments and other activities have regard for natural hazard features. The UTRCA implements the regulation by issuing Section 28 permits for works in or near watercourses, valleys, wetlands, or shorelines, when required.

Property owners must obtain permission and/or a letter of clearance from the local Conservation Authority before beginning any development, site alteration, construction, or placement of fill within the regulated area. Permits are also required for any wetland interference, or for altering, straightening, diverting or interfering in any way with the existing channel of a creek, stream or river. It is EXP's understanding that the Site is subject to this regulation, and requires a Section 28 permit, as the Site contains wetland features.

1.2 Terms of Reference and Scope of Work

The current investigation was carried out in general accordance with Proposal P18-278, dated August 2, 2018. The investigation was authorized by Mr. David Ailles of York Developments, on behalf of Kilbourne Developments Inc. An additional surface water monitoring program of the Thornicroft Drain and tributaries on Site was completed separately in accordance with the scope of work outlined in EXP proposal, dated July 5, 2019 and addressed to Ali Soufan of York Developments.

A geotechnical investigation was completed in February 2019, in conjunction with the hydrogeological investigation and included advancing eight (8) boreholes and twenty (20) test pits on Site. The geotechnical investigation was completed under a separate cover (EXP, 2019). Subsoil and groundwater information from the previously completed geotechnical investigations prepared by EXP in 2019 was used to assist in the preparation of this report.

The scope of work for the Hydrogeological Assessment consisted of the following tasks:

1. Desktop Study: This task consisted of a review of existing information including Site plans, previous reports, geological maps, geological cross sections, groundwater level information, borehole logs, and MECP WWR.

2. Field Program: Drilling of eight (8) boreholes (BH501-BH508) was carried out in November 2018 as part of the preliminary field program in conjunction with the 2019 Geotechnical Investigation, with monitoring wells installed in all the boreholes including nested monitoring wells in three (3) locations (BH502/MW-A/B, BH505/MW-A/B and BH506/MW-A/B). An additional borehole was advanced and installed as a monitoring well in June 2019 (BH509/MW). A total of seven (7) surface water (SW) stations were installed in July 2019 to allow for analysis of the surface water features on the Site. SW Stations 9 and 10 were installed in June 2020 and SW Stations 11 and 12 were installed in March 2022. Water levels were measured, groundwater samples were collected, and single well response tests (SWRTs) were completed for the purposes of characterizing the hydrogeological conditions at the Site and seasonal variability.

3. Data Evaluation: Evaluation of the collected field and laboratory data, preliminary assessment of the potential dewatering requirements, and potential dewatering effects on the surrounding environment, as applicable.

4. Water Balance: Preparation of monthly feature-based water balance assessments for the required features evaluating pre- and post-development conditions.

5. Reporting: This task consisted of preparing this hydrogeological assessment report, reviewed by a Professional Engineer (P. Eng.) or Professional Geoscientist (P. Geo.) licensed to practice in Ontario.

Reference is made to **Appendix K** of this report, which contains further information necessary for the proper interpretation and use of this report.

1.3 Proposed Development and Stormwater Management Strategies

The proposed development will contain mixed low to medium/high density residential/commercial properties with local servicing installed to standard depths of approximately 2 to 4 m below grade. The Draft Plan of Subdivision is provided in **Appendix B**. The development will also include park and open space areas, stormwater management (SWM) facilities, as well as interior roadways and sidewalks.

A Drainage and Floodlines Future Conditions Report was prepared by Matrix Solutions Inc. in June 2022 (Matrix, 2022). A map of the proposed storm drainage areas is provided in **Appendix B**. A Stormwater Management (SWM) report was also completed by Stantec Consulting Ltd., dated July 5, 2024 (Stantec, 2024).

As outlined in the SWM report (Stantec 2024), the development and some external lands are proposed to be serviced by four (4) dry SWM facilities. Water quality treatment to remove 80% of total suspended solids (TSS) is to be provided to the runoff from the proposed development prior to being discharged to the Thornicroft Drain. The proposed water quality treatment strategy will be selected and developed as detailed design progresses and may involve a combination of Low Impact Development (LID) measures in boulevards, Etobicoke Exfiltration Systems, and oil/grit separators (OGS).

Opportunities to implement infiltration measures across the site will be examined at detailed design but will include potential quality treatment measures mentioned above along with possibly introducing infiltration in the SWM facilities as well (Stantec, 2024).

The relocated southern tributary wetland will not be connected to any proposed storm infrastructure or stormwater management pond and will instead be graded into the valleylands and connected to the floodplain where it will be sustained naturally at the south end of the Site.

2. Methodology

2.1 Borehole Drilling and Monitoring Well Installations

The borehole drilling program for the Site was completed in November 2018 with additional drilling completed in June 2019. In total, drilling included the completion of nine (9) boreholes across the Site with installation of monitoring wells in all boreholes (BH501/MW-BH509/MW). Nested monitoring wells were completed in three (3) locations (BH502/MW-A/B, BH505/MW-A/B and BH506/MW-A/B). Borehole drilling and monitoring well installations were completed between November 6 and November 14, 2018, and on June 27, 2019 under the technical supervision of EXP. The location and depth of the boreholes was based on the proposed development plan which was provided to EXP and locations of significant natural features. Boreholes were advanced to depths ranging from 5.0 and 15.7 m below ground surface (bgs).

The boreholes were completed using a track-mounted drill rig and standard 21 cm (8") OD hollow stem auger drilling techniques with split spoon sampling. During the drilling, the stratigraphy in the boreholes was examined and logged in the field by EXP technical personnel. Representative samples of the soils found in the boreholes were submitted for laboratory testing that included moisture content and gradation. Copies of the field borehole logs are provided in **Appendix C**. Copies of the soil gradation analyses are included in **Appendix D**.

All wells were constructed from 5.1 cm (2") diameter, schedule 40, polyvinyl chloride (PVC), flush-threaded casing. The appropriate number of risers were coupled with screen sections via threaded joints to construct the well. The well screens consisted of PVC pipe with 0.010-inch factory-generated slots. A summary of the well installation details is provided in **Table 1**, with the well locations shown in **Drawing 2**.

A primary filter pack consisting of Silica Sand was placed around the well screen in the borehole and extended above the top of the well screen. Hole Plug, a swelling Bentonite clay that forms an effective barrier to the vertical movement of fluids when installed in a borehole, was used as a seal above the filter pack.

All monitoring wells were surveyed in September 2019 using a SOKKIA GPS survey unit. The ground surface and top of pipe elevations are included in **Table 1** below.

Table 1 – Monitoring Well Construction Details

Well ID	Ground Surface Elevation (m amsl)	Top of Standpipe Elevation (m amsl)	Borehole Completion Depth (m bgs)	Screen Interval (m bgs)	Screened Strata
BH501/MW	271.88	272.66	8.1	6.1-7.6	Sand
BH502/MW-A	273.15	273.86	12.2	10.7-12.2	Sand
BH502/MW-B	273.14	273.86	7.6	6.1-7.6	Silty Sand
BH503/MW	271.82	272.82	8.1	6.1-7.6	Sandy Silt / Sand
BH504/MW	267.33	268.18	5.0	3.1-4.6	Sand
BH505/MW-A	268.59	269.40	14.2	12.2-13.7	Sand
BH505/MW-B	268.64	269.42	7.6	6.1-7.6	Silty Sand
BH506/MW-A	266.65	267.46	15.7	13.7-15.2	Sand
BH506/MW-B	266.71	267.48	7.6	6.1-7.6	Sand
BH507/MW	263.89	264.64	7.6	6.1-7.6	Sand
BH508/MW	264.13	264.88	12.6	10.7-12.2	Sand
BH509/MW	266.59	267.41	9.6	7.0-8.5	Silty Sand

Notes: 1. m amsl denotes metres above mean sea level.
2. m bgs denotes metres below ground surface.

2.2 Surface Water and Piezometer Installations

A total of seven (7) SW stations were established at the Site in July 2019 (SW Stations 2 through 8). SW Stations 9 and 10 were installed in June 2020, and SW Stations 11 and 12 were installed in March 2022. A total of three (3) stations (SW Station 2 to SW Station 4) were installed within the Thornicroft Drain. SW Station 5 was installed within a pond in Bob's Golf Range and east of Thornicroft Drain. West of the Thornicroft Drain, SW Stations 6 and 7 were installed within the North Tributary in the Significant Woodland and SW Station 8 was installed within the South Tributary to the Thornicroft Drain. Two (2) stations (SW Stations 9 and 10) were installed within headwater drainage features immediately east of the Drain, as part of the Headwater Drainage Feature Analysis Study completed by NRSI. In March 2022, SW Stations 11 and 12 were installed within the southern tributary wetland which will be relocated and compensated further to the south end of the Site. All stations are presented on **Drawing 2**. A staff gauge or piezometer, or a combination of both, were installed at each station. **Table 2** below outlines the installation details located at each station.

All stations were installed in locations identified as having, or potentially having, seasonal surface water or potential shallow groundwater flow. The staff gauges (SGs) were installed at SW Stations 2 to 5 within standing surface water bodies and fixed to a T-post that had been pounded into the ground approximately 1.0 m deep. The piezometers were also installed to a depth of approximately 1.0 m, adjacent to the surface features, where shallow groundwater may be present. The piezometers were installed with a 6-inch Solinst drive point end (6-inch screen length). The

Solinst drive point piezometer ends have a stainless steel, 50 mesh cylindrical filter screen, within a ¾" (20mm) stainless steel drive-point body. The stations were surveyed using a SOKKIA GPS survey unit.

Table 2 – Surface Water and Piezometer Station Details

Station ID	Location	Monitoring Equipment	ID	Datalogger
SW Station 2	Thornicroft Drain	Piezometer Staff Gauge	P2 SG2	No Yes
SW Station 3	Thornicroft Drain	Piezometer Staff Gauge	P3 SG3	No Yes
SW Station 4	Thornicroft Drain	Piezometer Staff Gauge	P4 SG4	No Yes
SW Station 5	Golf Course Pond	Staff Gauge	SG5	Yes
SW Station 6	North Tributary	Piezometer	Tributary 1	No
SW Station 7	North Tributary	Piezometer	Tributary 2	No
SW Station 8	South Tributary	Piezometer	Tributary 3	No
SW Station 9	Headwater Feature TDT10-1	Piezometer	P6 TDT10-1	No
SW Station 10	Headwater Feature TDT7-1	Piezometer	P7	No
SW Station 11	Southern tributary wetland	Piezometer	P11	Yes
SW Station 12	Southern tributary wetland	Piezometer	P12	No

2.3 Well Development and Groundwater Sampling

Monitoring wells were developed after installation. The wells were developed to:

- remove fine soil particles adjacent to the well screen that may otherwise interfere with water quality analyses;
- restore the groundwater properties that may have been disturbed during the drilling process;
- improve the hydraulic communication between the well and the geologic materials; and,
- remove water, if any, added during the drilling process.

Wells were generally developed by removing a minimum of ten (10) times the volume of water contained in the well casing (casing volume) where possible using rigid high-density polyethylene (HDPE) tubing fitted with Waterra™ inertial pumps.

After appropriate well development, groundwater samples were collected for analysis of groundwater quality. Samples were collected from monitoring wells on November 26, 2018, and April 11, 2019, to establish baseline water quality and assess seasonal variability.

Prior to collecting groundwater samples for chemical analysis during each sampling event, the stagnant water in the well was purged to allow groundwater representative of the aquifer to enter the well. A minimum of three (3) casing volumes of water was removed ("purged") from each well immediately prior to sampling.

Monitoring wells were purged using either a peristaltic pump or rigid high-density polyethylene (HDPE) tubing fitted with Waterra™ inertial pumps that are dedicated to each monitoring well. Water samples were collected by direct transfer of groundwater from the Waterra™ pumping system to appropriate pre-labelled containers, with filtering and preservation as appropriate, before submission to Bureau Veritas Laboratories (previously Maxxam Analytical) in London, Ontario, for chemical analysis. The samples were submitted for analysis of dissolved metals, cations and anions, nitrogen species (nitrate, nitrite, and ammonia), phosphate and chloride.

2.4 Surface Water Sampling

Surface water quality samples were collected from the Drain adjacent to BH507/MW on November 26, 2018, and April 11, 2019, and from SW Stations 2-4 on September 22, 2019, December 13, 2019, April 27, 2020, and August 26, 2020. Surface water quality samples were collected from SW Station 5 on September 22, 2019, and April 27, 2020.

All samples were submitted for analysis of dissolved and total metals, cations and anions, nitrogen species (nitrate, nitrite, and ammonia), phosphate and chloride.

2.5 Long-Term Groundwater Elevation Monitoring

Monthly groundwater elevations have been collected from monitoring wells BH501/MW-BH508/MW since installation in November 2018 and from monitoring well BH509/MW since installation in June 2019 until May 2024. Monthly Surface water elevations were collected from SW Stations 2-8 from August 2019 to October 2022, from SW Stations 9 and 10 from June 2020 to October 2022, and from SW Stations 11 and 12 since May 2022. Measurements have been manually collected using a battery-signal water level tape. The groundwater and surface water monitoring at the Site ceased as of May 2024.

Water level dataloggers were installed in monitoring wells BH501/MW, BH502/MW-A/B, BH505/MW-A/B and BH506/MW-A/B as well as in staff gauges SG1 to SG5 and P11 in SW Station 11 to assist in the evaluation of groundwater and surface water elevations and influence of precipitation on water levels. An additional logger was placed at surface and used for barometric compensation. Dataloggers collected measurements every 24 hours. The dataloggers at BH506/MW-A and B malfunctioned in September 2021 and June 2022 respectively. Until May 2024, monitoring at these two wells was completed manually.

2.6 Hydraulic Conductivity Testing

Hydraulic conductivity estimates for the soils were determined using two methods. The first method is applicable to saturated soils at depth and involves single well recovery tests (SWRTs) within the installed monitoring wells (**Appendix E**). The second method involves a calculated estimation of hydraulic conductivity based on soil sample particle size analysis (**Appendix D**). The two methods used for this study area are described in the following subsections.

2.6.1 Single Well Response Tests (SWRTs)

Single well response tests (SWRTs) were completed on BH501/MW, BH502/MW-B, BH505/MW-B and BH507/MW to evaluate the hydraulic characteristics of the screened overburden. The test method consisted of an initial purging of the well and subsequent monitoring the rise in the water level in the well over time.

The mathematical solution by Hvorslev (1951) was used to interpret the data and involved matching a straight-line solution to water-level displacement data collected during the recovery test. The time required for the water level in the well to reach 37% of the initial change (T_o) is determined from the plot, and used in the following equation to estimate the hydraulic conductivity (K);

$$\mathbf{K\ (m/s) = [r^2 \ln(L/R)] / [2\ L\ T_o]}$$

where: r is the radius of the well casing;
R is the radius of the well screen; and,
L is the length of the well screen.

Hvorslev (1951) was selected as the analytical method since research has shown that the Hvorslev analysis typically results in higher K estimates compared to several other analytical methods, including Bouwer and Rice (1976), and Dagan (1978) (Ismael, 2016). Ismael (2016) also states:

> *Larger K values typical of pump tests are generally known to be superior to smaller values from slug tests, largely due to inadequate development of wells that are slugged (Butler and Healy, 1998). Butler (1998) says that "the hydraulic-conductivity estimate obtained from a slug test should virtually always be viewed as a lower bound on the hydraulic conductivity of the formation in the vicinity of the well." That is why larger K values are considered to be inherently better or more potentially true than smaller values*.

Assumptions in the Hvorslev method for estimating K are:

- The aquifer has infinite aerial extent;
- The aquifer is homogeneous and of uniform thickness;
- The tested well is fully or partially penetrating;
- Flow to the well is quasi-steady-state (storage is negligible); and
- Water is injected into or discharged from the well instantaneously.

2.6.2 Grain Size Analyses

A total of five (5) soil samples were selected for grain size distribution analysis. Due to the nature of the soils at the Site, estimated hydraulic conductivity (K) values were determined using different methods depending on the soil sample characteristics including the Kaubisch, Hazen, Beyer, Kozeny-Carman, or Puckett methodologies.

3. Site Description and Geologic Setting

3.1 Site Location and Description

The Site is located along the east side of Bostwick Road, between Southdale Road West and Wharncliffe Road South, in London, Ontario. The Site is approximately 85 ha in size and currently consists of open space, a golf course, agricultural land, and warehousing (**Drawing 1**). The Site is bounded predominantly by agricultural lands to the west, open space, woodlot and a commercial development to the north, commercial land to the east, and agricultural and commercial lands to the south.

3.2 Topography and Drainage

The existing topography at the Site is generally undulating and sloping towards the Thornicroft Drain which runs north-south transecting the Site. Elevations at the Site range from a topographic high of approximately 275 m amsl located in the northwest portion of the Site and a topographic low of approximately 262 m amsl at the southern portion of the drain. The Site is located in the Dingman Creek subwatershed.

Drainage from the Site is primarily via overland flow with minor seepage into the shallow subsurface with the exception of the Thornicroft Drain which is a groundwater recharging feature. Runoff generally follows topography towards the valleyland associated with the Thornicroft Drain which originates at Southdale Road as primarily stormwater runoff, draining the development area to the north of Southdale Road. The Drain then flows south through the Site and connects with Dingman Creek near Highway 402. The total length of the Drain within the Site is roughly 1.8 km. There are two (2) tributaries which flow from the west into the Drain through the Site. **Drawing 2** shows the monitoring stations, as well as the natural feature designations along the Drain and within the surrounding area. The City of London classifies the Thornicroft Drain as a Significant Valleyland throughout the Site and also classifies a portion of the Drain as an Unevaluated Wetland. Adjacent lands next to the Drain include Significant Woodlands, Unevaluated Vegetation Patches and Valleyland features. The Drain and associated natural features on Site are also regulated lands of the UTRCA (**Drawing 3**).

3.3 Wetlands and Ecology

The ecology of the Site has been studied by NRSI, and a detailed study was completed summarizing the ecological findings (NRSI, 2021). NRSI has provided a drawing of the ecological land classifications present throughout the Site, included in **Appendix B**. The following provides a brief discussion of the ecology of the property in order to provide context between the surface and shallow groundwater environment at the Site.

The ELC as completed by NRSI, defines the following:

- SWD2-2 wetland within the northern woodlot (Green Ash Mineral Deciduous Swamp Type);
- FOD6-5 and FOD7-4 within the northern woodlot (Fresh - Moist Sugar Maple - Hardwood Deciduous Forest Type and Fresh - Moist Black Walnut Lowland Deciduous Forest Type);
- MAM2-2/SWD4-1 wetland adjacent to the Thornicroft Drain just south of SW Station 2 (Reed-canary Grass Mineral Meadow Marsh Type/ Willow Mineral Deciduous Swamp Type);
- MAM2-2 wetland within the southern portion of Thornicroft Drain (Reed-canary Grass Mineral Meadow Marsh Type); and,

- FOD6-5 and FOD7-3 and CUS1 at the southern portion of the Site (Fresh - Moist Sugar Maple - Hardwood Deciduous Forest Type, Fresh - Moist Willow Lowland Deciduous Forest Type, and Mineral Cultural Savannah Ecosite).

Groundwater indicator species were observed within the unevaluated wetlands throughout the Site and included the following:

- Sensitive Fern (Onoclea sensibilis)
- Perfoliate Thoroughwort (Eupatorium perfoliatum)
- Spotted Joe-pye-weed (Eutrochium maculatum)
- Spotted Touch-me-not (Impatiens capensis)
- Pussy Willow (Salix discolor)

Overall, NRSI identified three (3) primary wetland features on Site (the northern woodlot wetlands, the central Thornicroft Drain wetland and the southern tributary wetland). The natural features on site are planned to be maintained with the exception of the southern tributary wetland which will be relocated further to the south.

3.4 Site Geology

3.4.1 Bedrock Geology

The Site is underlain by limestone, dolostone and shale of the Dundee Formation (OGS, 2011). This formation consists of 18 to 49 m of light brown, medium-grained with some minor chert (Hewitt, 1972), and is part of the Algonquin Arch, which forms a ridge along the southwestern Ontario peninsula between the Michigan Basin (to the northwest) and the Appalachian Basin (to the southwest). Bedrock is generally not exposed in the area.

Review of bedrock topography mapping (**Drawing 4**; OGS, 1978) indicates the bedrock surface is at an elevation of approximately 200 m amsl at the Site and the overburden thickness is up to approximately 75 m. The bedrock surface generally slopes to the south or southwest in this area.

3.4.2 Overburden Geology

The physiography of Southwestern Ontario was altered significantly by the glacial and interglacial periods that took place throughout the Quaternary period. The overburden deposits which are present in the study area were formed by numerous glacial events during the late Wisconsinan glacial stage approximately 10,000 to 23,000 years before present. There were two distinct glacial lobes present in Southwestern Ontario during this period. The Huron Lobe advanced from Lake Huron southwards, and the Erie Lobe advanced from the northeast, receding to the east.

During the advancement of the glacial ice sheets, bedrock and unconsolidated sediments were eroded. During the recession of the glaciers, the eroded materials were deposited in lakes, rivers and along spillways, contributing to the present configuration of moraines, abandoned spillways, drumlins, eskers, abandoned shorelines, and various still-water sediment deposits.

Deposits in the area can be contributed to the Port Bruce Stadial period. In the London area, a series of east-west recessional and end moraines were formed, along with the Port Stanley Till Plain. Deposition of the basal portion of the Port Stanley Till was formed during the initial advance of the Erie Lobe. Overlying till was deposited during subsequent cycles of advance and retreat, resulting in silt and sand layering within the till plain.

The surficial deposits were mapped and categorized into several physiographic regions by Chapman and Putnam (1984). The Site is located within the physiographic region known as the Mount Elgin Ridges (**Drawing 5**). The Site is located on undrumlinized till plains with a spillway located to the south and west and a till moraine to the north (**Drawing 6**).

Surficial geology mapping (OGS, 2010) indicates the surficial soils at the Site consist of clay to silt textured till across most of the Site with coarse-textured glaciolacustrine deposits consisting of sand, gravel, minor silt and clay along the southern property boundary (**Drawing 7**).

3.4.3 Site Specific Surficial Geology

In conjunction with the Preliminary Geotechnical Investigation for the Site (EXP, 2019), nine (9) boreholes and twenty (20) test pits were completed by EXP. The locations of the boreholes and test pits are provided in **Drawing 2**. The boreholes were terminated at depth ranging from 5.0 and 15.7 m below existing grade. Borehole and test pit logs are provided in **Appendix C**.

Generalized stratigraphic cross sections through the Site, as shown on **Drawing 8**, are provided as **Drawings 9** to **Drawing 11**. As shown on the geological cross-sections, the surficial geology is generally characterized by a low permeability clayey silt/silty clay till layer across the Site, with small pockets of silt, or fill at surface of some boreholes and a few minor silt/sandy silt lenses within the till noted west of the Site. The clayey silt/silty clay till layer is underlain by thin and discontinuous layer of silt/sandy silt. The clayey silt/silty clay till and silt layer are underlain by an extensive sand/silty sand/sandy silt unit noted across the area. The detailed stratigraphy encountered in the boreholes is summarized below. It is noted that the boundaries of the soil indicated on the borehole logs are inferred from non-continuous sampling and observations during drilling. These boundaries are intended to reflect transition zones and should not be interpreted as exact planes of geological change.

Generally, topsoil is found across the Site at surface. Fill material was encountered beneath the topsoil in boreholes BH506/MW to BH508/MW to a maximum depth of 1.7 m bgs and consisted of loose sandy silt with some organics. All other boreholes encountered clayey silt till, clayey silt, or clayey sandy silt beneath the topsoil at depths ranging from 3.0 m to 10.0 m bgs, except for BH509/MW which had gravel present. Beneath the till, sand/silty sand/sandy silt was encountered in all boreholes. The sand/silty sand/sandy silt was encountered at depths ranging from 1.0 m to 15.7 m bgs and was underlain by till in BH508/MW and BH509/MW.

3.4.4 Hydrostratigraphic Interpretation

Based on the encountered geology, groundwater, and surface water elevations observed at the Site, it is interpreted that the investigated subsurface comprises two distinct hydrostratigraphic units: a silt/clayey silt till/silty clay till which is interpreted to be an aquitard unit and an underlying silty sand/sandy silt/sand aquifer unit.

An aquitard is defined as a less-permeable bed within a stratigraphic sequence (Freeze and Cherry, 1979) and can store water and slowly transmit water from one aquifer to another (Fetter, 2001). A perched water table is likely to be present within this aquitard unit, as evidenced by the shallow groundwater measurements collected from piezometers interpreted to be installed within the surficial till.

The silty sand/sandy silt/sand unit underlying the clayey silt till is interpreted to be an aquifer unit beneath the Site. The water table in the underlying sand aquifer is unconfined in the northern portion of the Site and confined in the southern portion of the Site. Based on the boreholes advanced across the Site, it appears the surficial till unit pinches out towards the Thornicroft Drain and the sand unit may daylight along the drain in some areas.

4. Hydrogeologic Setting

In additional to the groundwater information collected from the monitoring wells installed at the Site, the following documents were reviewed to gain an understanding of the hydrogeological conditions in the area:

- Dillon Consulting Limited and Golder Associates Ltd. Middlesex-Elgin Groundwater Study, Final Report, submitted to Middlesex and Elgin Counties, dated July 2004, henceforth referred to as the Middlesex-Elgin Groundwater Study;
- Goff, K and D.R. Brown, 1981. Ground-Water Resources – Summary. Thames River Basin Water Management Study Technical Report. Ontario Ministry of the Environment, Water Resources Report 14;
- Thames-Sydenham and Region Source Protection Committee. 2011. Upper Thames River Source Protection Area, Approved Updated Assessment Report. 12 August; and,
- MECP Water Well Records (WWR) within 500 m of the perimeter of the Site.

4.1 Regional Aquifer

Goff and Brown (1981) described the potential for four regional aquifers in the study area; shallow unconfined overburden aquifer, intermediate and deep confined aquifers and a bedrock aquifer.

4.1.1 Overburden Aquifers

The uppermost shallow and unconfined overburden aquifer was described as consisting of lacustrine or glacio-fluvial sands that may, in some locations, be overlain by lower permeability silts and clays. Regionally, the shallow aquifer is generally associated with the Caradoc Sand Plain and glacial deposits and are typically less than 15 m in thickness. Shallow overburden aquifers are discontinuous in nature and are expected to be linked more directly to precipitation and recharge compared to the intermediate and deep overburden aquifers.

Intermediate depth (15 to 30 m bgs) and deep overburden aquifers (>30 m bgs) aquifers generally consist of saturated sand and gravel deposits in the overburden and are very discontinuous in nature due to the heterogeneous nature of glacial deposits. Sand and gravel layers are present in the Port Stanley and Catfish Creek glacial till sheets. The intermediate depth and deep overburden aquifers are generally confined by overlying silt, clay and glacial till deposits which limit vertical migration of shallow groundwater.

Locally, shallow groundwater flow is expected to follow the local topography, and generally drain towards Dingman Creek, to the southwest of the Site. On a regional scale, the deep overburden aquifer flow direction is reported to be towards the south-southwest (Dillon and Golder, 2004).

Based on the well record information reviewed for this investigation (discussed below), the occurrence of shallow overburden water supply wells in the immediate vicinity of the Site is low.

4.1.2 Bedrock Aquifer

The bedrock aquifer is contained within limestone of the Dundee Formation. The water quality is generally good with elevated levels of iron, sodium and chloride in some wells. As with the intermediate and deep overburden aquifers, the bedrock aquifer is confined by the overlying till material within overburden that is up to approximately 75 m thick in the vicinity of the Site. Wells extending into the shallow fractured bedrock (up to about 3 m) are typically considered to be hydraulically connected to the overlying sand and gravel deposits that are present at the bedrock-overburden interface.

Flow direction in the deeper confined aquifer(s) and regional groundwater system has not been assessed as part of this investigation. However, as part of the Middlesex-Elgin Groundwater Study (Dillon and Golder, 2004), groundwater flow within the deeper aquifer is generally in a south-southwest direction towards Lake Erie.

4.2 Site Specific Groundwater Elevations and Flow

Monthly water levels are provided in **Appendix F**. Dataloggers were installed in seven (7) selected monitoring wells (monitoring wells BH501/MW, BH502/MW-A/B, BH505/MW-A/B, BH506/MW, and BH507/MW) in December 2018 to provide continuous groundwater elevation monitoring. Results are presented in **Appendix F**. Manual measurements generally correlate well with datalogger results.

4.2.1 Monitoring Well Hydrographs

Overall, the shallowest groundwater levels (less than 2 m bgs) were noted in monitoring wells BH507/MW and BH509/MW ranging from 3.09 m (BH509/MW) to 1.44 m bgs (BH507/MW). These are shallow wells located at the southern portion of the Site. The deepest groundwater levels were noted in BH502/MW-A (deep) ranging from 8.20 m to 7.47 m bgs. This well was installed in the northern portion of the Site in a topographic high relative to the other wells.

The hydrograph from monitoring well BH501/MW screened in sand from 6.1 to 7.6 m bgs, shows a cyclical pattern of elevations fluctuating over a range of up to 1 m with some direct response to rain events. Seasonal low elevations occur between June and October/November and peak elevations occur in the spring approximately between March and May. In 2022 peak elevations were also observed in late fall and winter (October to January). Groundwater elevations at this well ranged from 266.80 m to 267.85 m amsl corresponding to groundwater levels of 5.08 to 4.03 m bgs.

The hydrograph for the nested monitoring wells BH502/MW-A (deep) screened in sand from 10.7 – 12.2 m and BH502/MW-B (shallow) screened in silty sand from 6.1 – 7.6 m, shows a similar cyclical pattern in both the shallow and deep wells with seasonal low elevations between June and October/November and peak elevations in the spring approximately between March and May. In 2022 peak elevations were also observed in late fall and winter (October to January). Both wells show some response to rain events, however, a direct response to precipitation is more prominent in the shallow monitoring well BH502/MW-B. Groundwater elevations were consistently higher in the shallow monitoring well BH502/MW-B suggesting a downward vertical gradient and recharge conditions. Groundwater elevations at BH502/MW-A ranged from 264.86 m to 265.89 m amsl corresponding to groundwater levels of 8.29 to 7.26 m bgs. Groundwater elevations at BH502/MW-B ranged from 266.86 m to 268.97 m amsl corresponding to groundwater levels of 6.28 to 4.17 m bgs.

The hydrograph for the nested monitoring wells BH505/MW-A (deep) screened in sand from 12.2 – 13.7 m and BH505/MW-B (shallow) screened in silty sand from 6.1 – 7.6 m, shows a similar cyclical pattern in both the shallow and deep wells with seasonal low elevations between June and October/November and peak elevations in the spring approximately between March and May. In 2022 peak elevations were also observed in late fall and winter (October to January). Both wells show a direct response to precipitation events. Groundwater elevations were consistently higher in the shallow monitoring well BH505/MW-B suggesting a downward vertical gradient and recharge conditions. However, overall groundwater elevations in both BH505/MW-A and BH505/MW-B were similar, suggesting they are screened in hydraulically connected material. Groundwater elevations at BH505/MW-A ranged from 264.00 m to 264.90 m amsl corresponding to groundwater levels of 4.59 to 3.69 m bgs. Groundwater elevations at BH505/MW-B ranged from 264.03 m to 264.97 m amsl corresponding to groundwater levels of 4.61 to 3.67 m bgs.

The hydrograph for the nested monitoring wells BH506/MW-A (deep) screened in sand from 13.7 – 15.2 m and BH506/MW-B (shallow) screened in sand from 6.1 – 7.6 m, shows relatively consistent groundwater elevations in both the shallow and deep wells with minimal seasonal fluctuations. Seasonal low elevations were observed between June and October/November and peak elevations in the spring approximately between March and May. In 2022 peak elevations were also observed in late fall and winter (October to January). Both wells show a direct response to precipitation events. Groundwater elevations were almost identical between the shallow and deep wells at BH506/MW indicating these wells are screened within hydraulically connected soils with little to no vertical hydraulic gradient. This observation is consistent with the borehole log indicating these wells are screened within the same sand layer. Groundwater elevations at BH506/MW-A ranged from 263.63 m to 264.62 m amsl corresponding to groundwater levels of 3.02 to 2.03 m bgs. Groundwater elevations at BH506/MW-B ranged from 263.73 m to 264.61 m amsl corresponding to groundwater levels of 2.98 to 2.10 m bgs.

Overall, groundwater elevations within the monitoring wells were cyclical, showing similar seasonal variations with some degree of response to precipitation events. Seasonal high elevations were generally observed in the spring months.

4.2.2 Surface Water Station Hydrographs

Manual water level measurements were collected monthly from August 2019 to October 2022 at SW Stations 2-8, and from July 2020 to October 2022 for SW Stations 9 and 10. SW stations 11 and 12 were installed in March 2022 with manual measurements collected monthly since May 2022. The manual measurements collected from each of the surface water monitoring stations across the Site are provided in **Appendix F**.

To supplement the monthly manual measurements, dataloggers were installed at surface water staff gauge locations SG1, SG2, SG3, SG4, SG5 and P11. The dataloggers were programmed to collect daily measurements which were then downloaded during each monthly site visit. Hydrographs presenting the datalogger information collected from SW Stations 2, 3, 4, 5 and 11 are presented in **Appendix F** and are discussed in detail below.

Station 2 Hydrograph

Surface water Station 2 is located near the southern boundary of the Woodlot, within the Thornicroft Drain (see **Drawing 2**).

The SW Station 2 hydrograph shows surface water elevations generally respond to major precipitation events. Surface water elevations ranged from 267.44 m to 268.56 m amsl, for a total range of 1.1 m recorded at this SW station. The manual water levels collected monthly at staff gauge SG2 align with the datalogger data. After the June 2020 monitoring event, the datalogger was dislodged from the staff gauge due to debris and the data was found to be unreliable until it was re-connected during the next monthly visit on June 29, 2020. This gap in data is indicated on the hydrograph. Similarly unreliable data was found between May and June, 2021.

Also presented in the SW Station 2 hydrograph are the manual groundwater measurements collected from piezometer P2. Groundwater elevations within the piezometer were highest in September 2019 and from January to May 2020, and lowest from June to August 2020. The groundwater elevations collected in P2 ranged from 266.88 m to 267.41 m amsl, for a total documented range of 0.5 m in groundwater elevations collected at this station. These elevations correspond with groundwater levels of 0.56 m to 0.03 m bgs. Although groundwater elevations at this piezometer were close to ground surface at 267.44 amsl, flowing artesian conditions at this piezometer were not observed. This piezometer was destroyed in September 2020.

Groundwater levels in P2 were generally below the surface water levels suggesting Thornicroft Drain is a groundwater recharging feature at this location.

Station 3 Hydrograph

Surface water Station 3 is located just south of the confluence with the Southern Tributary, as shown on **Drawing 2**.

The SW Station 3 hydrograph also shows surface water elevation data generally responds to precipitation events. Surface water elevations ranged from 264.69 m to 265.75 m amsl, for a total range of 1.1 m recorded at this SW station. The manual water levels collected at staff gauge SG3 align with the data collected on the dataloggers.

Also presented in the SW Station 3 hydrograph are the manual groundwater measurements collected from piezometer P3. Groundwater levels in the piezometer indicate a cyclical seasonal pattern with elevated groundwater levels above ground surface predominantly in winter and spring corresponding with spring freshet. Lower groundwater levels were observed in the summer and fall. Groundwater elevations ranged from approximately 264.35 m to 265.32 m amsl, for a total documented range of 1.0 m in groundwater elevations collected at this station. These elevations correspond with groundwater levels of 0.22 m bgs to 0.75 m ags.

Groundwater levels in P3 were generally below the surface water levels suggesting Thornicroft Drain is a groundwater recharging feature with the exception of springtime when the spring freshet results in above ground levels and discharge conditions into the Drain. During this time the Drain receives both surface water runoff and discharge contribution.

Station 4 Hydrograph

Surface water Station 4 is located at the southern reach of Thornicroft Drain, as shown on **Drawing 2**.

The SW Station 4 hydrograph also shows surface water data generally responds to major precipitation events. Surface water elevations ranged from approximately 260.38 m to 261.53 m amsl, for a total range of 1.2 m recorded at this SW station. The manual water levels collected at staff gauge SG4 align with the data collected on the dataloggers. Also presented in the SW Station 4 hydrograph are the manual groundwater elevations from piezometer P4.

Groundwater levels in P4 indicate flowing artesian conditions ranging in elevations from 260.27 m to 261.39 m amsl, for a total documented range of 1.1 m in groundwater elevations collected at this station. These elevations correspond with groundwater levels of 0.03 m to 1.15 m ags. Groundwater levels were generally higher than the surface water levels. Confined aquifer conditions were noted in monitoring wells BH507/MW and BH508/MW located in the southern portion of the Site similar to SW Station 4. The pressurized confined aquifer may daylight in at the drain in this area resulting in the observed flowing artesian discharge conditions.

Station 5 Hydrograph

Surface water Station 5 was installed into a pond in Bob's Golf Range, as shown on **Drawing 2**. Only a staff gauge, SG5, was installed into this feature.

The SW Station 5 hydrograph also shows some response of surface water levels to major precipitation events. Dry conditions were observed during the October 2019 and June 2020 monitoring events. Surface water elevations ranged from approximately 266.80 m to 267.87 m amsl, for a total range of 1.1 m documented at this SW station. The manual water levels collected at staff gauge SG5 align with the data collected on the dataloggers. The datalogger could not be retrieved at this location since October 2020, however manual measurements have continued.

Stations 6, 7, and 8

Surface water Stations 6 and 7 are located within the North Tributary in the Significant Woodland, as shown in **Drawing 2**. Groundwater levels in both of the piezometers in SW Stations 6 and 7 indicate a cyclical seasonal pattern with elevated groundwater levels predominantly in winter and spring and lower groundwater levels in the summer and fall. Flowing artesian conditions were observed in the winter and spring. The groundwater elevations collected in the piezometer in SW Station 6 ranged from 269.61 m to 270.34 m amsl, for a total documented range of 0.7 m in groundwater elevations collected at this station. These elevations correspond to groundwater levels of 0.67 m bgs to 0.06 m ags. The groundwater elevations collected in the piezometer in SW Station 7 ranged from 267.24 m to 268.49 m amsl, for a total documented range of 1.3 m in groundwater elevations collected at this station. These elevations correspond with groundwater levels of 1.07 m bgs and 0.18 m ags.

There was no surface water present at these locations (i.e. dry surface water conditions) in the summer and early fall.

Surface water Station 8 is located in the South Tributary to the Thornicroft Drain. Similarly to other stations, groundwater levels at this location indicate a cyclical seasonal pattern with elevated groundwater levels predominantly in winter and spring and lower groundwater levels in the summer and fall. Flowing artesian conditions were not observed at this location. The groundwater elevations collected in the piezometer in SW Station 8 ranged from 264.25 m to 264.98 m amsl, for a total documented range of 0.7 m in groundwater elevations collected at this station. These elevations correspond with groundwater levels of 0.91 m and 0.18 m bgs. There was no surface water present at this location (i.e. dry surface water conditions) in the summer and early fall.

Stations 9 and 10

These SW stations consist of piezometers installed into the shallow soil, within the appropriate drainage corridors.

SW Station 9 is located within the Headwater Drainage Feature TDT10-1 mapped by NRSI (2019). The shallow groundwater readings within the piezometer at this location were found to be dry during the July 2020 monitoring event and from August to October 2022. Between September 2020 and August 2022, the shallow groundwater elevations have remained fairly consistent ranging from 268.52 m to 269.09 m amsl, for a total documented range of 0.6 m in groundwater elevations collected at this station. These elevations correspond with groundwater levels of 0.45 m bgs and 0.12 m ags. The highest groundwater elevation measured at SW Station 9 was in November 2021. No surface water was present surrounding piezometer 9, except in November 2020, January and November 2021.

SW Station 10 is located within the Headwater Drainage Feature TDT7-1 mapped by NRSI (2019). Groundwater levels at this location indicate a cyclical seasonal pattern with elevated groundwater levels predominantly in winter and spring and lower groundwater levels in the summer and fall. Groundwater elevations ranged from 267.49 m to 268.28

m amsl, for a total documented range of 0.8 m in groundwater elevations collected at this station. These elevations correspond with groundwater levels of 0.77 m bgs and 0.02 m ags. The highest levels noted were in October 2021. No surface water has been present surrounding piezometer 10 since installation in June 2020.

Stations 11 and 12

Surface water Stations 11 and 12 were installed within the southern tributary wetland. Groundwater levels in the piezometer in SW Station 11 were relatively constant since installation in March 2022 ranging between 262.92 m (dry) and 263.36 m amsl, for a total documented range of 0.4 m in groundwater elevations collected at this station. These elevations correspond with groundwater levels of 0.3 m bgs and 0.14 m ags. Dry conditions were noted through much of the monitoring period. Flowing artesian conditions were noted in early spring (March 2022). There was no surface water present at this location (i.e. dry surface water conditions) since installation.

Dry conditions were also noted at SW Station 12 through much of the monitoring period. Measured groundwater elevations here ranged from 264.89 m and 265.24 m amsl, for a range of 0.4 m. These elevations correspond with groundwater levels of 0.36 m and 0.01 m bgs. There was no surface water present at this location (i.e. dry surface water conditions) since installation.

Overall, surface water elevations within SW Stations 2 to 4 remained generally constant throughout the monitoring period with some response to precipitation events. Groundwater elevations within the piezometers were generally lower than surface water indicating the Drain is likely being predominantly fed by surface water and is a groundwater recharging feature. Groundwater elevations in the piezometers show a similar cyclical pattern to groundwater elevations in the monitoring wells with higher elevations in the late fall to early spring.

4.2.3 Hydraulic Gradients and Groundwater Flow

A total of three (3) nested groundwater well sets were installed on Site. The groundwater elevations collected from the nested well pairs during the monitoring period are tabulated in **Appendix F**.

The groundwater elevations collected in the nested wells BH502/MW-A/B and BH505/MW-A/B indicate that the vertical hydraulic gradient is consistently downwards throughout the monitoring period, due to the shallow well having higher groundwater elevations than the deeper well. A minor upward vertical gradient was noted in BH505/MW-A/B in August and September 2021 following significant rain events. Groundwater elevations in the nested monitoring well BH506/MW-A/B were nearly identical between the shallow and deep wells as both were screened within the same sand unit. As a result, there is little to no vertical hydraulic gradient in these nested monitoring wells.

As stated previously, the surficial silt/clayey silt till unit represents an aquitard unit beneath the Site. Completion of water table mapping within aquitards is typically not practical since the head in the well is dependent on the screened interval and depth more than location (Midwest Geosciences Group, 2018). As such, mapping the water table within aquitards can result in many peaks and closed depressions that do not represent the water table. Since the predominant groundwater flow direction in aquitards is vertical, water table mapping may not be representative of groundwater flow paths in aquitards (Midwest Geosciences Group, 2018).

In general, the groundwater flow direction across an aquifer is horizontal while groundwater flow across aquitards is primarily vertical (Cherry, et. at., 2006). Therefore, the predominant groundwater flow direction in the silt/clay silt till unit is anticipated to be downward with the horizontal component likely following topography, as shown on **Drawing 12a**.

A groundwater flow direction interpretation for the sand aquifer unit was created based on measurements collected from selected monitoring wells and surface water monitoring stations on February 9, 2022. As shown on **Drawing 12b**, the groundwater flow direction in the sand aquifer unit is interpreted to be southerly.

4.3 Wetlands Hydroperiod Assessments

The hydroperiod of a wetland is defined as the length of time and portion of the year a wetland holds ponded water (Tarr and Babbitt) and the TRCA (2018) states "The hydroperiod of a wetland is the seasonal pattern of water level fluctuation".

The three wetland features at the Site were assessed for their hydroperiods, discussed below.

Northern Woodlot Wetlands

Surface water monitoring station SW 6 was installed in the vicinity of the northernmost wetland within the Northern Woodlot Wetlands area and is considered to represent both wetlands in this area. SW Station 6 consisted of a piezometer that was monitored monthly between August 2019 to October 2022. Both inside (groundwater) and outside (surface water) measurements were collected throughout the monitoring period at this location.

Based on water level measurements and field observations, the wetlands in the northern woodlot appear to start retaining surface water in the fall and winter with maximum free surface water levels generally reached in the late winter/early spring before becoming dry in the summer. These correspond with elevated groundwater levels above ground surface in the spring which likely represent a perched water table. Based on the monitoring data, these wetlands are fed by seasonal groundwater discharge and runoff and there appears to be no significant sustained year-round ponded water within these features.

Google Earth imagery was not used in the assessment of the wetlands within the northern woodlot due to the forested cover which limits the ability to observe standing water at ground surface.

Central Thornicroft Wetland

Surface water monitoring station SW 10 was installed in the vicinity of the Central Thornicroft Wetland and consisted of a piezometer that was monitored monthly between June 2020 and October 2022. Both inside (groundwater) and outside (surface water) measurements were collected throughout the monitoring period at this location.

Based on water level measurements and field observations, no ponded water was observed at this location during the monitoring period. Historical aerial images were reviewed as part of the assessment of this feature using Google Earth. The aerial imagery review did not identify ponded water in the delineated wetland area aside from the Thornicroft Drain which transects this feature. It is noted that due to the forested cover in areas of this feature, the ability to identify surface water ponding on the aerial imagery was limited. Groundwater levels at this location were at or above ground surface in winter and spring indicating this feature is seasonally fed by groundwater discharge from a shallow perched system.

Based on the above assessment, there appears to be no sustained year-round ponded water within this feature.

Southern Tributary Wetlands

The southern tributary wetlands are comprised of two wetland areas, one smaller are located near the Thornicroft Drain, and one larger wetland located further from the drain. Surface water monitoring station SW 11 was installed in the smaller wetland while surface water monitoring station SW 12 was installed in the larger wetland. Both monitoring stations consisted of a piezometer that was monitored monthly between May 2022 to May 2024. Both inside (groundwater) and outside (surface water) measurements were collected throughout the monitoring period at these locations.

Based on water level measurements and field observations, no ponded water was observed at these locations during the monitoring period. Historical aerial images were reviewed as part of the assessment of these features using Google Earth. The aerial imagery review did not identify ponded water in the delineated wetland areas. It is noted that due to some forest cover, the ability of identify surface water ponding on the aerial imagery may be limited. Groundwater levels at this location were at or above ground surface in the spring indicating this feature is seasonally fed by groundwater discharge from a shallow perched system.

Based on the above assessment, there appears to be no sustained year-round ponded water within these features.

4.4 Hydraulic Conductivity

Single well recovery tests (SWRTs) were performed on four (4) monitoring wells (BH501/MW, BH502/MW-B, BH505/MW-B and BH507/MW) to evaluate the hydraulic characteristics of the screened overburden. The results of the tests are summarized in **Table 4**, and the semi-log plots of normalized drawdown versus time are provided in **Appendix E.**

Based on these tests, the estimated hydraulic conductivities for silty sand are 3.1 x 10^{-6} m/s (BH505/MW-B) and 8.4 x 10^{-6} m/s (BH502/MW-B) and the hydraulic conductivities for sand are 5.1 x 10^{-7} m/s (BH507/MW) and 8.2 x 10^{-5} m/s (BH501/MW). These results are generally consistent with literature values for their respective lithologies reported by Freeze and Cherry (1979).

The hydraulic conductivity of the clayey silt till unit was estimated based on a grain size analysis of a sample collected from BH501/MW at 1.5-2.7 m bgs. Based on the grain size analysis, the hydraulic conductivity of the clayey silt till unit was estimated to be between 1x10^{-9} and 1x10^{-11} m/s,

Table 4 – Hydraulic Conductivity (K) Testing Results

Sample ID	Lithology	Hydraulic Conductivity (K) (m/s)
Grain Size Analyses		
BH501/MW (1.5-2.7 m bgs)	Clayey Silt Till	10^{-9} - 10^{-11}
Single Well Response Tests		
BH501/MW	Sand	8.2 x 10^{-5}
BH502/MW-B	Silty Sand	8.4 x 10^{-6}
BH505/MW-B	Silty Sand	3.1 x 10^{-6}
BH507/MW	Sand	5.1 x 10^{-7}

4.5 Water Quality Results

4.5.1 Groundwater Quality

Groundwater samples were collected from monitoring wells on November 26, 2018, and April 11, 2019, to document baseline water quality and assess seasonal variability. A summary of the groundwater analytical results and Certificates of Analyses are provided in **Appendix G** and **Appendix H**, respectively.

The groundwater quality results were compared to the Ontario Drinking Water Standards, Objectives and Guidelines (ODWQS) (O.Reg. 169/03) maximum allowable concentrations (MAC). Since the groundwater on site is not planned for use as drinking water, the ODWQS MAC are used for comparison's sake only. In comparison to these guidelines, groundwater was found to meet all of the ODWQS for most sampling events, except for uranium which was above the ODWQS guideline (20 ug/L) in well BH507/MW on April 11, 2019, with a concentration of 21 ug/L.

4.5.2 Surface Water Quality

Surface water quality samples were collected from the Drain adjacent to BH507/MW on November 26, 2018, and April 11, 2019, and from SW Stations 2-4 on September 22, 2019, December 13, 2019, April 27, 2020, and August 26, 2020. Surface water quality samples were collected from SW Station 5 on September 22, 2019, and April 27, 2020, only. All surface water samples were analyzed for general chemistry parameters and were compared to the Provincial Water Quality Objectives (PWQO, MOEE, 1994). The surface water quality results identified some exceedances for metals and a single exceedance for pH at SW Station 5 in September 2019. A summary of the surface water analytical results , and Certificates of Analyses are included in **Appendix G** and **Appendix H**, respectively.

Sampling results indicate exceedances of the PWQO guideline for total aluminum (75 ug/L) and total iron (300 ug/L) in all surface water stations. The PWQO guideline for total cobalt (0.9 ug/L) was exceeded in the Drain adjacent to BH507/MW and in SW Stations 3 and 4. The PWQO guideline for total copper (5 ug/L) and total zinc (20 ug/L) was exceeded in the Drain adjacent to BH507/MW and in SW Station 3. Other exceedances include total lead (in SW Station 3) and total vanadium (in the Drain adjacent to BH507/MW and SW Station 3).

4.5.3 Water Quality Interpretations

The water quality results were plotted on Piper and Schoeller Diagrams, provided as **Drawings 13** and **14a-c,** respectively.

The Piper Diagram plots most groundwater quality results within the calcium-magnesium bicarbonate type waters, with only the results from BH501/MW and BH507/MW plotting on the boundary with mixed type waters or no dominant type waters. Surface water quality results plot within the sodium-chloride type water indicating chloride impact (i.e. road salt) within SW Stations 2-4 within the Thornicroft Drain. The development lands to the north direct stormwater flow to the Thornicroft Drain, including salt impacted road runoff. The salt-related concentrations trend from highest to located from north to south further indicating the source of the impacts is the residential development to the north.

SW Station 5 differs in composition compared to the Thornicroft Drain stations as it does not show salt impacted water quality and is similar to the groundwater samples.

The Schoeller Diagrams have been separated into major and minor ion components for each sampling event. Variable sodium and chloride concentrations were noted in November 2018 and April 2019 within the monitoring wells and the Drain adjacent to BH507/MW, with the highest sodium and chloride concentrations noted in the Drain adjacent to BH507/MW and within BH501/MW likely due to salt impacted road runoff. In SW Stations 2-5, the major ion concentrations were similar except for SW Station 5 which shows lower chloride and sodium concentrations in comparison to SW Stations 2-4 in September 2019, and SW Station 4 which had a lower sulphate concentration during the same sampling event. The minor ions show similar concentrations across all locations and sampling events.

5. Feature-Based Water Balance Assessments

The feature-based monthly water balance assessments were completed in accordance with the recommendations indicated in the guidance document “Hydrogeological Assessment Submissions: Conservation Authority Guidelines to Support Development Applications” (Conservation Ontario, 2013), and using appropriate site condition values obtained from Table 3.1 of the MOE Stormwater Management Planning and Design Manual (MOE, 2003). The results of the water balances, based on the Draft Plan of Subdivision dated December 22, 2023, are provided in **Appendix I**.

The water balance accounts for all water in and out-flows in the hydrologic cycle. Precipitation (P) falls as rain and snow. It can then run off towards wetlands, ponds, lakes, and streams (R), infiltrate into the ground (I), or evaporate from surface water and vegetation (ET). When long-term average values of P, R, I, and ET are used, then minimal or no net change to groundwater storage (ΔS) is assumed.

The annual water balance can be stated as follows:

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

Where:

P = precipitation (mm/year)

ET = evapotranspiration (mm/year)

R = runoff (mm/year)

I = Infiltration (mm/year)

ΔS = change in groundwater storage (taken as zero) (mm/year)

5.1 Precipitation and Evapotranspiration

The annual total precipitation used for this water balance (1011 mm/yr) is based on data provided by Environment Canada, based on the 30 year average data for climate normals, using the nearest local weather station information (London CS ID 6144478, located approximately 15.7 km northeast of the Site). In this detailed monthly water balance, precipitation as rain and snow are both considered. Snow storage and resulting snow melt in the winter and early spring months is considered as part of the evapotranspiration volumes.

Evapotranspiration combines evaporation and transpiration and refers to the water lost to the atmosphere. The rate of evapotranspiration is a function of the water holding capacity of the soil and varies with soil and vegetation type and amount of impermeable surface cover.

Monthly evapotranspiration volumes were calculated using the monthly water balance graphical interface created by the U.S. Geological Survey (USGS), Open-File report 2007-1088 (McCabe and Markstrom, 2007). This interface uses the principles outlined by Thornthwaite and Mather (1957) and permits the user to easily modify water balance parameters and provide useful estimates of water balance components for a specified location.

The difference between the annual precipitation and the annual evapotranspiration represents the surplus water which is available for infiltration and surface run-off. Distribution of the surplus water to infiltration is based on an infiltration factor based on site conditions for topography, cover vegetation and soil.

5.2 Infiltration and Runoff

The soil water holding capacities and infiltration rate were determined using values presented in Table 3.1 of the MOE Stormwater Management Planning and Design Manual (MOE, 2003) based on the vegetative cover and the hydrologic soil group. The weighted values based on the Site conditions are presented in the calculation sheets provided in **Appendix I**.

Localized infiltration rates will vary based on factors such as the saturated hydraulic conductivity of surface soils, land slope, rainfall intensity, relative soil moisture at the start of a rainfall event, and type of cover on the ground surface.

Based on soil mapping by the Ministry of Agriculture, Food and Rural Affairs the surficial soils are predominantly C-type soils (silt loam) throughout the majority of the Site and B-type soils (fine sandy loam) along the Thornicroft Drain (silt and sand loam). Based on borehole logs from the Site, the soil cover is predominantly clayey silt till (C-type soil). For the water balance analysis, soil moisture capacities for B and C-type soils were utilized.

Feature-based water balance assessments were completed on the three (3) primary wetland features on Site (the Northern Woodlot Wetlands-Catchment A, the Central Thornicroft Drain wetland-Catchment B and the Southern Tributary Wetlands-Catchment C). These existing wetlands are presented in **Appendix I**. All three wetland features have portions of their catchments proposed for development.

The water balance completed for the catchments A and B excludes the areas of these wetlands themselves as these wetlands will be maintained post-development. Given that the Southern Tributary Wetlands are proposed to be relocated, the area of this wetland was included in the calculations and only pre-development conditions are provided for this catchment (catchment C). The percent imperviousness in post-development is based on Table E-3 in the Dingman Creek Storm Servicing Study EA (Aquafor Beech, 2020). In addition, the percent imperviousness for the SWM blocks was assumed to be 50%. Road runoff was excluded in the post-development calculations as only clean runoff may be directed to natural features.

Feature-based water balance calculations have been completed for each of the three (3) wetland features and are provided in **Appendix I**. Pre- and Post-Development Catchment Area figures are also provided in **Appendix I** as **Figures I-1** and **I-2**, respectively. **Table 5** provides a summary of the feature-based water balance calculations.

Table 5 – Summary of Feature-Based Water Balance Estimates

	Pre-Development	Post-Development	% Maintained
Northern Woodlot Wetlands (Catchment A)			
Estimated Runoff (m^3/year)	32,196	22,691	70%
Estimated Infiltration (m^3/year)	13,576	9,591	71%
Central Thornicroft Drain Wetland (Catchment B)			
Estimated Runoff (m^3/year)	29,659	9,521	32%
Estimated Infiltration (m^3/year)	9,818	2,738	28%
Southern Tributary Wetland (Catchment C)			
Estimated Runoff (m^3/year)	20,479	N/A	N/A
Estimated Infiltration (m^3/year)	6,668	N/A	N/A

As shown, the post-development condition is estimated to maintain 70% of runoff to the Northern Woodlot Wetlands. These wetlands are interpreted to be primarily maintained by surface runoff with limited groundwater contribution seasonally in the spring, and are dry in the summer. It is acknowledged that the predicted post-development runoff volume may not be sufficient to maintain the current function of the Northern Woodlot Wetlands. Mitigation measures to increase the post-development runoff volume to this area are being considered, including the direction of some stormwater runoff from the development block immediately north of these features (Block 7) on the 3080 Bostwick development property, also owned by the client, and potentially the redirection of runoff from development blocks across the proposed Bradley Avenue extension, south of these features within the Site.

The post-development condition is estimated to maintain 32% of runoff to the Central Thornicroft Wetland. This wetland is also interpreted to be primarily maintained by surface runoff with limited groundwater contribution seasonally. No ponded water was observed during the monitoring period of this feature, aside from the section of the Thornicroft Drain transecting this feature. It is acknowledged that the predicted post-development runoff volume may not be sufficient to maintain the current function of the Central Thornicroft Wetland. Mitigation measures to increase the post-development runoff volume to this area are being considered, including directing clean roof-top runoff from nearby residential blocks, altering post-development grades to increase the catchment area, and/or directing runoff from the nearby stormwater management pond to the feature.

The mitigation measures listed above are not exhaustive and options are currently being explored with both the ecological and stormwater management consultants. The water balance will be updated at the focussed design studies stage to include the proposed mitigation measured for the Northern Woodlot Wetlands and Central Thornicroft Wetland.

Given that the Thornicroft Drain transects this wetland, it is interpreted that the Thornicroft Drain is also contributing to maintaining this wetland feature. Since the Thornicroft Drain will remain present post-development, it is anticipated that the Thornicroft Drain will continue to contribute to maintaining this feature under the post-development condition. Therefore, the proposed condition is not anticipated to impact the current function of this feature.

5.3 Low Impact Development (LID) Practices

Low Impact Development (LID) is a stormwater management strategy that seeks to mitigate the impacts of increased runoff and stormwater pollution by managing runoff as close to its source as possible (TRCA, 2010). Effective management of stormwater is critical to the continued health of our streams, rivers, lakes, fisheries and terrestrial habitats. The primary objectives of stormwater management include maintaining the hydrologic cycle, protecting water quality, and preventing increased erosion and flooding. A relatively common LID strategy is the implementation of secondary infiltration where clean runoff is directed to surface or subsurface infiltration facilities.

It is noted that the majority of the Site is not located within a Significant Groundwater Recharge Area (SGRA) and the Conservation Authority Guidelines (June, 2013) state that professional judgement should be used in determine post-development infiltration targets in areas outside of SGRAs. Given that the majority of the Site is underlain by clayey silt till at ground surface, the implementation of secondary infiltration facilities at the Site may be limited.

If secondary infiltration measures are being considered as part of the post-development design, in-situ infiltration testing within/in the vicinity of the proposed locations will be required.

6. Groundwater Separation and Preliminary Construction Dewatering Considerations

Daily construction water takings between 50,000 L/day and 400,000 L/day require registration on the Environmental Activity and Sector Registry (EASR) in accordance with Ontario Regulation 63/16. Where construction dewatering volumes are anticipated to exceed 400,000 L/day, a Category 3 Permit to Take Water (PTTW) approved by the MECP is required in accordance with Sections 34 and 98 of the Ontario Water Resources Act R.S.O. 1990 and the Water Taking and Transfer Regulation O. Reg. 387/04.

Groundwater can be found close to surface during seasonal high conditions, typically in late winter and spring months. Construction excavations will likely encounter shallow groundwater in the surficial till unit. Excavations terminated in this upper till unit are not anticipated to have a significant ingress of groundwater due to the low hydraulic conductivity of these shallow soils.

In the event construction excavations are proposed to extend into the underlying sand aquifer unit, significant dewatering may be required. The volume of water requiring management depends on the depth of excavation into this unit and whether groundwater control methods will be used during construction.

It is noted that artesian conditions are present in certain areas of the Site (i.e. the sand aquifer unit is pressurized, and the potentiometric surface of this unit extends above the top of the sand unit into the overlying clayey silt till). A hydrostatic uplift assessment may be required to assess the potential for base heave of excavations terminated in the clayey silt till where an artesian condition is present in the sand aquifer.

A detailed assessment of dewatering requirements can be completed at the detailed design stage once foundation and servicing elevations are finalized.

7. Source Water Protection Considerations

7.1 Significant Groundwater Recharge Areas (SGRA)

Groundwater recharge is largely controlled by soil conditions, and typically occurs in upland areas. The groundwater flow direction has been identified as flowing in a southern direction.

As defined in the Clean Water Act (2006), an area is a significant groundwater recharge area if,

1. the area annually recharges water to the underlying aquifer at a rate that is greater than the rate of recharge across the whole of the related groundwater recharge area by a factor of 1.15 or more; or

2. the area annually recharges a volume of water to the underlying aquifer that is 55% or more of the volume determined by subtracting the annual evapotranspiration for the whole of the related groundwater recharge area from the annual precipitation for the whole of the related groundwater recharge area.

Areas in the north portion of the Site associated with the woodlot, along the Thornicroft Drain, and in the southern portion of the Site are mapped as within an SGRA which was assessed through the Upper Thames River Assessment Report (August 12, 2011, Amended July 2023), shown on **Drawing 15**. Section 4.5 (Significant Groundwater Recharge Areas) of the Assessment Report states that professional judgement is allowed in the determination of areas deemed to exhibit significant recharge or not. Additionally, Section 4.5.1 (Uncertainty of SGRA) states that recharge is a difficult parameter to estimate and the resulting SGRA in the model has a degree of uncertainty.

The predicted annual recharge volume in the north portion of the Site from the UTRCA modelling is 339.6 mm/yr. Borehole locations BH501/MW and BH502/MW-A/B are located in the vicinity of the delineated northern SGRA in the UTRCA model. Surficial clayey silt till was encountered at both locations with thicknesses of 2.7 m and 0.7 m, respectively. Given the relatively thinner till sequence at these locations, there is higher potential for increased surface water infiltration and the designation of these lands as SGRA is considered appropriate. Additionally, the monitoring completed at the surface water monitoring stations along the Thornicroft Drain indicate this feature is primarily a groundwater recharging feature. As such, the designation of the lands in the vicinity of the Thornicroft Drain as SGRA is also considered appropriate.

The predicted annual recharge volume in the south portion of the Site from the UTRCA modelling is 427.6 mm/yr, with smaller areas of 278.0 mm/yr. Borehole location BH508/MW and TP520 are located within the area mapped as an SGRA in the southern portion of the Site. A 9.5 m thick sequence of stiff to hard clayey silt till was encountered at BH508/MW and the till was also encountered at TP520 which was advanced to a depth of 6.1 m bgs within the clayey silt till. Based on the presence of a thick aquitard unit in the southern portion of the Site, it is our opinion that the lands in the southern portion (aside from those in the immediate vicinity of the Thornicroft Drain), where clayey silt till is the surficial geological unit, should not be characterized as an SGRA and lower post-development infiltration maintenance would be appropriate.

7.2 Highly Vulnerable Aquifers (HVA)

The susceptibility of an aquifer to contamination is a function of the susceptibility of its recharge area to the infiltration of contaminants. As defined in the *Clean Water Act (2006)*, the vulnerability of groundwater within a source protection area shall be assessed using one or more of the following groundwater vulnerability assessment methods:

3. Intrinsic susceptibility index (ISI).
4. Aquifer vulnerability index (AVI).
5. Surface to aquifer advection time (SAAT).
6. Surface to well advection time (SWAT).

In the Thames-Sydenham and Region, HVAs were mapped using the ISI method. The ISI method is an indexing approach using existing provincial Water Well Information System (WWIS) database. The ISI method is described in detail in the MECP's Technical Terms of Reference (2001). However, in short, the ISI method is a scoring system that takes into consideration the unique hydrogeologic conditions at a particular location. The scores are determined using a combination of the saturated thickness of each unit and an index number related to the soil type, and as such, the scores reflect the susceptibility of the aquifer to contamination.

As defined in the MECP's 2001 Technical Rules,

- an area having an ISI score of less than 30 is considered to be an area of high vulnerability;
- an area having an ISI score greater than or equal to 30, but less than or equal to 80, is considered to be an area of medium vulnerability; and,
- an area having an ISI score of greater than 80 is considered to be an area of low vulnerability.

As defined by the Clean Water Act (2006) and identified by the Thames-Sydenham and Region Source Protection Committee, a HVA is mapped in the southern portion of the Site and has a vulnerability score of 6 (**Drawing 16**).

The area of the Site delineated as a HVA coincides with borehole location BH508/MW and TP520. As previously discussed, there is a relatively thick (9.5 m) sequence of surficial till in this area of the Site. Based on the presence of a thick aquitard unit in the southern portion of the Site, it is our opinion that the lands in the southern portion (aside from those in the immediate vicinity of the Thornicroft Drain), where clayey silt till is the surficial geological unit, should not be characterized as an HVA.

8. Impact Assessment

8.1 MECP Water Well Records

A search of the Ontario MECP WWR database resulted in the identification of 160 well records within approximately 500 m of the Site boundary (**Drawing 17**). The monitoring wells installed on the Site have not been included in the drawing.

Water uses in the area include the following:

- Monitoring/test holes/observation wells (58 wells);
- domestic water use (21 wells with 1 well also used as public);
- unknown or other (20 wells);
- Public (2 wells);
- Water Supply with use unknown (1 well);
- irrigation (2 wells);
- commercial (7 wells);
- industrial (18 wells with 1 well also used as domestic);
- livestock (6 wells with 4 wells also used as domestic);
- abandoned (25 wells).

The approximate locations of identified wells are shown on **Drawing 17**, with the MECP WWR Summary provided in **Appendix J**.

8.2 Water Well Users

Potable wells in the area are typically sourced from intermediate to deep sand and gravel and bedrock aquifers which are generally confined below low permeability silty clay overburden. Domestic water supply wells in the area are screened at depths ranging from 7.9 m to 57.3 m bgs with the majority of them screened predominantly between 10 and 20 m bgs. Three water supply wells (MECP WWR Well ID 4103487, 4103502 and 4104949) were installed at shallow depths (< 10 mbgs). These wells were installed between 1952 and 1970 and are likely no longer in use. In addition, a review of google street view imagery indicated there are fire hydrants in the vicinity suggesting the area is connected to the municipal water supply system. As a result, the proposed development is not expected to impact water supply wells in the vicinity of the Site.

Excavations terminated in the silty clay till found across the Site are not anticipated to significantly impact the deep water supply wells since the till unit will limit both the vertical and horizontal zone of influence due to the lower permeability of the founding soils.

Further assessment of excavations terminated in the sand aquifer unit would be required once the final servicing/foundation elevations are known. Services may extent into this unit in the central and northern areas of the Site. Any temporary construction dewatering operations which may be required to deal with groundwater seepage from the overburden soils are not expected to cause long-term impacts to the intermediate and deep overburden and bedrock aquifers supplying the water supply wells near the Site.

Monitoring wells have been installed at the Site as part of the Site investigations to document stabilized groundwater conditions. Prior to the Site grading work, and when the monitoring wells are determined to be no longer required, the wells should be properly decommissioned in accordance with Ontario Regulation 903. Decommissioning a well which is no longer in use helps to ensure the safety of those in the vicinity of the well, prevents surface water infiltration into an aquifer via the well, prevents the vertical movement of water within a well, conserves aquifer yield and hydraulic head and can potentially remove a physical hazard.

8.3 Surface Water Features

Based on the proposed Draft Plan of Subdivision (**Appendix B**) the majority of the surface water features will be maintained on Site including the Thornicroft Drain, the Northern Woodlot Wetlands and the Central Thornicroft Drain Wetland. It is proposed that a SWM Block will be developed at the location of the southern tributary wetland and the wetland will be compensated for in block 83 at the south end of the Site. In order to maintain the surface water features on site, buffer areas are proposed including 30 m buffer areas surrounding the Thornicroft Drain, the Northern Woodlot Wetlands and the Central Thornicroft Drain Wetland and a 15 m buffer surrounding the relocated southern tributary wetland.

Based on a multi-year groundwater and surface water monitoring as part of this hydrogeological investigation Thornicroft Drain is primarily surface runoff fed and the area is generally interpreted as a groundwater recharging feature; therefore, maintaining runoff to the natural features on Site is recommended.

In general, surface water features are considered as being vulnerable to contamination from surface construction activities. During construction, short term impacts to surface water features may be anticipated, particularly where vegetation on nearby land is stripped and area grading works are underway.

The following comments are provided with recommendations to help minimize impact to surface water features observed at the site:

- During the site grading work, suitable sedimentation controls will be required to help control and reduce the turbidity of run-off water which may flow towards the surface water features;
- A Best Management Practice (BMP) and spill contingency plan (including a spill action response plan) should be in place for fuel handling, storage and onsite equipment maintenance activities to minimize the risk of contaminant releases as a result of the proposed construction activities;
- Re-establishing vegetative cover in disturbed areas following the completion of the construction work;
- Limit the use of commercial fertilizers in landscaped areas which border a habitat feature; and,
- Limit the use of salts or other additives for ice and snow control on the roadways and parking areas.

8.4 Water Quality Monitoring Considerations

There are a number of items which can be considered during construction and for the future residential development which can assist in maintaining groundwater and surface water quality. The following comments are provided for consideration, but are not intended as an exhaustive list in this regard:

- In the event imported materials are required to restore onsite excavations, or to raise grades in portions of the Site, analytical testing of the imported material will be required as per the Excess Soil Regulation (Ontario Regulation 406/19);Contractors working at the Site should ensure that construction equipment is in good working order. Equipment operators should have spill-prevention kits, where appropriate; and

- Chemical application in landscaped and grassed areas should be limited. Consideration may be given to using grass varieties which are heartier and require less extensive watering or fertilizers.

Consideration may be given to carrying out additional water quality testing during construction, where construction activities are in close proximity to surface water features.

Monitoring stations to assess post-development changes to water quality may be considered; however, the specific purpose and long-term responsibility for servicing and maintenance of the monitoring stations would need to be established.

9. Qualifications of Assessors

EXP Services Inc. provides a full range of environmental services through a full-time Earth and Environmental Services Group. EXP's Environmental Services Group has developed a strong working relationship with clients in both the private and public sectors and has developed a positive relationship with the Ontario MECP. Personnel in the numerous branch offices form part of a large network of full-time dedicated environmental professionals in the EXP organization.

This report was authored by Ms. Kassandra Wallace, B.B.R.M. Ms. Wallace has more than 7 years' experience in the environmental consulting industry that includes conducting hydrogeological assessments for various types of development projects, Phase One and Phase Two Environmental Site Assessments, and remediation projects. She obtained her Bachelor's degree in Bio-Resource Management (Environmental Management Major) from the University of Guelph and obtained her Ontario College Graduate Certificate in Environmental Engineering Applications from Conestoga College.

This report was reviewed by Ms. Heather Jaggard, M.Sc., P.Geo. Ms. Jaggard is a hydrogeologist and environmental geoscientist with more than 12 years in the environmental field and is a licensed Professional Geoscientist (P.Geo.) in Ontario. She obtained a Master's of Science (M.Sc.) in 2012 from Queen's University in Kingston, and is a Qualified Person (QP) registered with the Ontario MECP. She has worked in the Hydrogeological and Environmental fields since that time. In her professional career, Ms. Jaggard has completed numerous hydrogeological assessments and modelling works for land development sites. Environmental site assessments and preparation of submissions for PTTW have been part of her routine assignments.

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11. General Limitations

The information presented in this report is based on a limited investigation designed to provide information to support an assessment of the current environmental conditions within the subject property. The conclusions and recommendations presented in this report reflect Site conditions existing at the time of the investigation. Consequently, during the future development of the property, conditions not observed during this investigation may become apparent. Should this occur, EXP Services Inc. should be contacted to assess the situation, and the need for additional testing and reporting. EXP has qualified personnel to provide assistance in regards to any future geotechnical and environmental issues related to this property.

Our undertaking at EXP, therefore, is to perform our work within limits prescribed by our clients, with the usual thoroughness and competence of the engineering profession. It is intended that the outcome of this investigation assist in reducing the client's risk associated with environmental impairment. Our work should not be considered 'risk mitigation'. No other warranty or representation, either expressed or implied, is included or intended in this report.

The comments given in this report are intended only for the guidance of design engineers. The number of test holes required to determine the localized underground conditions between test holes affecting construction costs, techniques, sequencing, equipment, scheduling, etc. would be much greater than has been carried out for design purposes. Contractors bidding on or undertaking the works should in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

EXP Services Inc. should be retained for a general review of the final design and specifications to verify that this report has been properly interpreted and implemented. If not afforded the privilege of making this review, EXP Services Inc. will assume no responsibility for interpretation of the recommendations in this report

This report was prepared for the exclusive use of **Kilbourne Developments Inc.** and may not be reproduced in whole or in part, without the prior written consent of EXP, or used or relied upon in whole or in part by other parties for any purposes whatsoever. Any use which a third party makes of this report, or any part thereof, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. EXP Services Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

We trust this report is satisfactory for your purposes. Should you have any questions, please do not hesitate to contact this office.

Appendix A – Drawings

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Appendix B – Development Plan and Ecology Drawings

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Appendix C – Borehole and Test Pit Logs

Appendix D – Grain Size Analyses

Appendix E – Single Well Response Tests

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Appendix F – Water Levels and Hydrographs

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Appendix G – Water Quality Data

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Appendix H – Laboratory Analytical Results and Chain of Custody

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Appendix I – Feature-Based Water Balance Assessment

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Appendix J – MECP Water Well Record Summary

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Appendix K – Limitations and Use of Report

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LIMITATIONS AND USE OF REPORT

BASIS OF REPORT

This report ("Report") is based on site conditions known or inferred by the geotechnical investigation undertaken as of the date of the Report. Should changes occur which potentially impact the geotechnical condition of the site, or if construction is implemented more than one year following the date of the Report, the recommendations of EXP may require re-evaluation.

The Report is provided solely for the guidance of design engineers and on the assumption that the design will be in accordance with applicable codes and standards. Any changes in the design features which potentially impact the geotechnical analyses or issues concerning the geotechnical aspects of applicable codes and standards will necessitate a review of the design by EXP. Additional field work and reporting may also be required.

Where applicable, recommended field services are the minimum necessary to ascertain that construction is being carried out in general conformity with building code guidelines, generally accepted practices and EXP's recommendations. Any reduction in the level of services recommended will result in EXP providing qualified opinions regarding the adequacy of the work. EXP can assist design professionals or contractors retained by the Client to review applicable plans, drawings, and specifications as they relate to the Report or to conduct field reviews during construction.

Contractors contemplating work on the site are responsible for conducting an independent investigation and interpretation of the test pit results contained in the Report. The number of test pits necessary to determine the localized underground conditions as they impact construction costs, techniques, sequencing, equipment and scheduling may be greater than those carried out for the purpose of the Report.

Classification and identification of soils, rocks, geological units, contaminant materials, building envelopment assessments, and engineering estimates are based on investigations performed in accordance with the standard of care set out below and require the exercise of judgment. As a result, even comprehensive sampling and testing programs implemented with the appropriate equipment by experienced personnel may fail to locate some conditions. All investigations or building envelope descriptions involve an inherent risk that some conditions will not be detected. All documents or records summarizing investigations are based on assumptions of what exists between the actual points sampled. Actual conditions may vary significantly between the points investigated. Some conditions are subject to change over time. The Report presents the conditions at the sampled points at the time of sampling. Where special concerns exist, or the Client has special considerations or requirements, these should be disclosed to EXP to allow for additional or special investigations to be undertaken not otherwise within the scope of investigation conducted for the purpose of the Report.

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