Hydrogeological Assessment

FINAL REPORT

Forever Homes Inc.

Project Name:
168 Meadowlily Road South,
London, Ontario

Project Number:
LON-23006227-A0

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Date Submitted:
June 4, 2024

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Date Submitted:

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Executive Summary

EXP Services Inc. (EXP) was retained by Forever Homes Inc. (Client) to carry out a hydrogeological assessment and prepare a report relating to the proposed development at 168 Meadowlily Road South in London, Ontario, hereinafter referred to as the 'Site'. The overall Site size is approximately 8.3 hectares. It is understood that the overall development may consist of a medium density residential development with multiple build forms including low rise cluster town houses, mid rise apartments, high rise apartments, parkland and street widening with newly established infrastructure (municipal servicing, paved access roads and parking lots.

The objective of the hydrogeological study is to examine the hydrogeological characteristics of the Site by reviewing the Ministry of the Environment, Conservation and Parks (MECP) Water Well Records (WWR), reviewing the soil and groundwater information provided from a series of sampled boreholes and monitoring wells, compiling an annual water balance, completing regular groundwater monitoring to assess seasonal fluctuations; and assess the 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 this potential for impact.

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

- The Site is within the Upper Thames River watershed and the Dorchester Corridor sub-watershed. The Meadowlily Woods Environmentally Significant Area (ESA) is mapped north of the Site, in the wooded area. There are no wetlands mapped within the property boundary;

- According the Natural Heritage Constraints Analysis Memo completed by NRSI (2022) there are several drainage features just north of the Site, some of which are likely to convey runoff north towards the Thames River. These features are not mapped on Site, however one of these features is mapped as a regulated land by the UTRCA which encroaches the northern property boundary;

- A total of eleven (11) boreholes (BH1-BH11) were advanced throughout the entire Site. Four (4) boreholes (BH/MW1, BH/MW4, BH/MW9, and BH/MW11) were completed as groundwater monitoring wells. Boreholes were advanced to depths ranging from 5.0 to 11.1 m below ground surface (bgs);

- Groundwater levels ranged from dry conditions noted in all four (4) wells to 1.32 m bgs at monitoring well BH/MW9 screened to a depth of 6.1 m bgs. Groundwater elevations ranged from dry conditions at all four (4) wells to 281.42 m amsl at BH/MW11. The highest groundwater elevations were observed at monitoring well BH/MW11 which is situated at the highest ground surface elevation. All four (4) monitoring wells are screened in clayey silt till and therefore recovery to static groundwater levels took several months, from installation in fall 2022 to spring 2023;

- The horizontal groundwater flow on Site is interpreted to be from a topographic high in the southeast portion of the Site to the northwest portion of the Site;

- Single well response tests (SWRT) were performed on two (2) selected monitoring wells on Site (BH9/MW and BH11/MW) to evaluate the hydraulic characteristics of the screened overburden. Based on these tests, the estimated hydraulic conductivities for the clayey silt till was 10^{-10} m/s in both wells;

- A total of three (3) soil samples collected from boreholes were selected for grain size distribution analysis testing. Based on the grain size analyses, the hydraulic conductivity was calculated to be 10^{-11} to 10^{-10} m/s in the clayey silt till;

- Groundwater quality samples were collected for analysis of general chemistry parameters from monitoring wells BH9/MW and BH11/MW on May 19, 2023. No parameters exceeded the ODWQS MAC guidelines for any sampled monitoring wells.

- Based on the MECP WWR, there are no water supply wells within a 500 m radius of the Site that are installed into the shallow overburden (<10 m below ground surface);

- The monitoring wells remain on Site. When the wells are no longer required, they should be decommissioned in accordance with O. Reg. 903; and,

- Short term impacts to the shallow groundwater may occur during construction, where excavations crossing the shallow groundwater require construction dewatering.

<u>Recommendations</u>

- The pre- to post-development Site-wide water balance calculations indicates that post-development condition will maintain 46% of the pre-development infiltration volumes. Consideration should be given to implementing Low Impact Development (LID) strategies to improve the post-development infiltration volumes.
- Final servicing and finished floor depths/elevations have not been provided at this time. A detailed assessment of dewatering requirements can be completed at the detailed design stage, if required.

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Tables (in text)

Drawings (Appendix A)

1. Introduction and Background

1.1 Background

EXP Services Inc. (EXP) was retained by Forever Homes Inc. (Client) to carry out a hydrogeological assessment and prepare a report relating to the proposed development at 168 Meadowlily Road South in London, Ontario, hereinafter referred to as the 'Site' (**Appendix A**, **Drawing 1**). The overall Site size is approximately 8.3 hectares. It is understood that the overall development may consist of a medium density residential development with multiple build forms including low rise cluster town houses, mid rise apartments, high rise apartments, parkland and street widening with newly established infrastructure (municipal servicing, paved access roads and parking lots). The proposed development plan (dated May 15, 2024) is included in **Appendix B**.

The objective of the hydrogeological study is to examine the hydrogeological characteristics of the Site by reviewing the Ministry of the Environment, Conservation and Parks (MECP) Water Well Records (WWR), reviewing the soil and groundwater information provided from a series of sampled boreholes and monitoring wells across the Site, compiling an annual water balance, completing regular groundwater monitoring to assess seasonal fluctuations; and assess the 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 this potential for impact.

It is understood that the hydrogeological investigation and water balance assessment will be submitted for review and approval by the City of London as part of the Draft Plan of Subdivision 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 development 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 not subject to this regulation, as the Site does not contain a water feature.

1.2 Terms of Reference and Scope of Work

A scoping meeting was held on August 31st, 2022 between EXP and the City of London's Hydrogeologist. The purpose of the meeting was to discuss the current site conditions and EXP's approach for the hydrogeological assessment. The scope of work and general direction of the hydrogeological assessment were generally determined prior to the initiation of the fieldwork. The UTRCA indicated via email communication on August 23, 2022 that given there are no wetlands or other surface water features on Site, the review of this report is deferred to the City of London's hydrogeologist.

A Geotechnical Investigation was also completed for the Site by EXP and submitted under separate cover (EXP project number LON-22019965-A0). The 2022 Geotechnical investigation included the advancement of eleven (11) boreholes (BH1 - BH11). The borehole logs are included in **Appendix C**. Information from the geotechnical study will be incorporated into this report, where appropriate.

The purpose of the Hydrogeological Assessment was to examine the subsoil and groundwater conditions at the Site, by advancing a series of boreholes completed as monitoring wells illustrated on **Drawing 2** and reviewing information provided in the Geotechnical Investigation (EXP, 2022) as well as previous investigations completed in the vicinity of the Site.

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 (where available) including Site plans, previous reports, geological maps, geological cross sections, groundwater level information, borehole logs, and MECP WWR.
2. Field Program:
    a. Installation of monitoring wells was carried out as part of this Hydrogeological Site Assessment work. Additional field testing consisted of returning to the monitoring wells to obtain groundwater level measurements for the purposes of characterizing the shallow groundwater conditions at the Site.
    b. Single well response tests (SWRT) were completed on selected wells to characterize the hydrogeological conditions at the Site;
    c. Water quality sampling of groundwater was completed and submitted for laboratory analysis; and,
3. Data Evaluation: Evaluation of the available field and laboratory data, preliminary assessment of the dewatering requirements, and potential dewatering effects on the surrounding environment, as applicable.
4. Water Balance: Preparation of an annual site-wide water balance assessment evaluating pre-development and post-development conditions.
5. Reporting: This task consisted of preparing this hydrogeological assessment report, reviewed by a Professional Geoscientist (P. Geo.) with a license to practice in Ontario.

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

2. Methodology

2.1 Borehole Drilling and Monitoring Well Installations

A total of eleven (11) boreholes (BH1-BH11) were advanced between September 1 and September 8, 2022, as part of the Geotechnical Investigation throughout the entire Site (EXP, 2022). Four (4) boreholes (BH/MW 1, BH/MW4, BH/MW9, and BH/MW11) were completed as groundwater monitoring wells. The locations of the boreholes and monitoring wells are presented on **Drawing 2**. Borehole drilling and monitoring well installation was completed under the technical supervision of EXP. The locations and depths of the boreholes were determined based on the proposed development plan provided to EXP. Boreholes were advanced to depths ranging from 5.0 to 11.1 m below ground surface (bgs).

The boreholes were completed using a track-mounted drill rig and standard 21 cm (8") over-drill (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 soil samples were submitted for laboratory testing that included moisture content and gradation analysis. Copies of the 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 on **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.

Table 1 – Monitoring Well Construction Details

Well ID	Ground Surface Elevation (m amsl)	Borehole Completion Depth (m bgs)	Screen Interval (m bgs)	Screened Strata
BH1/MW	276.60	9.60	3.96 - 5.49	Clayey Silt Till
BH4/MW	281.50	6.60	4.57 - 6.10	Clayey Silt Till
BH9/MW	282.50	6.60	4.57 - 6.10	Clayey Silt Till
BH11/MW	283.90	11.1	4.81 - 6.33	Clayey Silt Till

Notes: 1. m amsl denotes metres above mean sea level.
2. Elevations were surveyed with a Trimble on September 2022.

2.2 Well Development and Groundwater Sampling

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.

Groundwater quality samples were collected for analysis of groundwater quality from monitoring wells BH9/MW and BH11/MW on May 19, 2023. Groundwater chemistry results are presented and discussed in **Section 4.5**.

2.3 Long-Term Groundwater and Surface Water Elevation Monitoring

Water level monitoring in all monitoring wells installed on Site was completed on a regular basis from installation in September 2022 until June 2023. Additional monitoring of wells was completed in February 2024. Measurements were manually collected using a battery-signal water level tape.

2.4 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 SWRT within the installed monitoring wells. The second method involves a calculated estimation of hydraulic conductivity based on soil sample particle size analysis.

2.4.1 Single Well Response Tests

SWRT were completed on monitoring locations BH9/MW and BH11/MW between February 1 and February 6, 2024, to evaluate the hydraulic characteristics of the screened overburden material. The test method consisted of pumping a volume of water from the wells in order to induce an immediate water level response. The water level response was monitored using an electronic data logger until static or near-static levels were reached.

The results from the SWRTs were analyzed using the mathematical solution by Hvorslev (1951) for an unconfined aquifer as provided in the software AQTESOLV ™ Pro v. 4.5. Hvorslev (1951) was selected as the analytical method since research has shown that the Hvorslev analysis typically results in higher K estimates compared to 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 small values from slug tests, largely due to inadequate development of the wells that are slugged (Butler and Healy, 1998). Butler (1998) states the "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 deemed to be inherently better or more potentially true than smaller values (Ismael, 2016).

Assumptions in the Hvorslev method for estimating K are:

- The aquifer has infinite aerial extent;
- The aquifer is homogeneous and uniformly thick;
- 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.

2.4.2 Grain Size Analysis

A total of three (3) soil samples were selected for grain size analyses from boreholes completed onsite in October 2022. Due to the nature of the Site soils, estimated hydraulic conductivity (K) values were determined using the Kaubisch methodology.

3. Site Description and Geologic Setting

3.1 Site Location and Description

The Site is located at 168 Meadowlily Road South in London, Ontario (**Drawing 1**). The subject area is currently in agricultural use. At the central south end of the Site, there is a grassed and treed area where a residence used to be present. The Site is generally bounded by a woodlot and residence to the north, Meadowlily Road South to the west, Commissioners Road East to the south, and a public sports park to the east (**Drawing 2**). The Meadowlily Woods Environmentally Significant Area (ESA) is mapped north of the Site, in the wooded area.

3.2 Topography and Drainage

The Site is in an agricultural land use setting. The topography is characterized by low to moderate relief ranging from a topographic high of approximately 285 m above mean sea level (amsl) in the southeast corner of the Site to a topographic low of 279 m amsl in the northwest corner of the Site sloping gradually to the norther towards the Upper Thames River. The Site is within the Upper Thames River watershed and the Dorchester Corridor sub-watershed (Natural Resources Solutions Inc; NRSI, 2022). There are no wetlands mapped within the property boundary. According the Natural Heritage Constraints Analysis Memo completed by NRSI (2022) there are several drainage features just north of the Site, some of which are likely to convey runoff north towards the Thames River. These features are not mapped on Site, however one of these features is mapped as a regulated land by the UTRCA which encroaches the northern property boundary. A drainage feature is also mapped west of Meadowlily Road South but is not likely to receive runoff from the Site.

3.3 Site Geology

3.3.1 Bedrock Geology

The Site is underlain by limestone, dolostone and shale of the Dundee Formation (OGS, 2011; **Drawing 3**). This formation consists of 60 to 160 feet (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 (OGS, 1978) indicates the bedrock surface at an elevation in the range of 213 m to 221 m amsl. The bedrock surface generally slopes to the southwest in this area. Review of (MECP) WWR within 500 m of the Site (**Appendix E**) indicates three (3) wells within 500 m of the Site intersect bedrock at depths of approximately 35 m to 64 m bgs. These depths equate to bedrock elevations of about 210 m to 220 m, which is generally consistent with the bedrock topography mapping. Bedrock was not encountered during the drilling work completed as part of this investigation.

3.3.2 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 Mount Elgin Ridges physiographic region and a till moraine physiographic landform. Mapping of the physiographic regions and landforms of the Site and surrounding area are provided on **Drawing 4** and **Drawing 5**, respectively.

Surficial geological mapping by the Ontario Geological Survey (OGS, 2010) shows the Site is mapped as a clay to silt-textured till derived from glaciolacustrine deposits or shale (**Drawing 6**). North of the Site are river and delta glaciofluvial deposits and modern alluvial deposits.

3.3.3 Site Specific Surficial Geology

A total of eleven (11) boreholes (BH1-BH11) were advanced between September 1 and September 8, 2022, as part of the Geotechnical Investigation throughout the entire Site (EXP, 2022). Four (4) boreholes (BH/MW 1, BH/MW4, BH/MW9, and BH/MW11) were completed as groundwater monitoring wells. The locations of the boreholes are provided in **Drawing 2** and borehole logs are provided in **Appendix C**.

Overall, the shallow stratigraphy at the Site is relatively homogenous consisting predominantly of clayey silt till. Generalized geological cross sections through the Site, as shown in **Drawing 2**, are provided in **Drawings 7** and **8**.

As shown in cross section A-A’ (**Drawing 7**) extending northwest to southeast, the shallow soils are generally homogenous, consisting of clayey silt till across all boreholes examined. Sandy silt overlies the till in BH1/MW and BH11/MW and fill overlies the till at BH10. All boreholes shown were terminated within the clayey silt till with the exception of BH1/MW which was terminated in silt underlying the till.

As shown in cross section B-B’ (**Drawing 8**) extending southwest to northeast, the shallow soils are generally homogenous, consisting of clayey silt till. A thin surficial layer of sandy silt was observed overlying the till at BH4/MW and BH8. All boreholes shown were terminated within the clayey silt till.

4. Hydrogeologic Setting

In addition 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 WWR within 500 m 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 Stratford Till 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.

On a regional scale, the deep overburden aquifer flow direction is reported to be towards the south-southwest (Dillon and Golder, 2004).

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, which generally ranges in thickness between 40 and 70 m 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 and Surface Water Elevations

4.2.1 Monitoring Wells

Manual water levels in the monitoring wells have been collected regularly between September 2022 and June 2023. Additional water level monitoring was completed in February 2024. Details of the water levels are summarized in **Appendix F**.

Overall, groundwater levels ranged from dry conditions noted in all four (4) wells to 1.32 m bgs at monitoring well BH/MW9 screened to a depth of 6.1 m bgs. Groundwater elevations ranged from dry conditions at all four (4) wells to 281.42 m amsl at BH/MW11. The highest groundwater elevations were observed at monitoring well BH/MW11 which is situated at the highest ground surface elevation. All four (4) monitoring wells are screened in clayey silt till and therefore recovery to static groundwater levels took several months, from installation in fall 2022 to spring 2023.

4.3 Hydraulic Gradients and Groundwater Flow

Groundwater flow on Site was interpreted based on high groundwater elevations collected on February 6, 2024. The interpreted shallow groundwater flow direction within the clayey silt till unit is illustrated on **Drawing 9**.

The clayey silt till unit present at the Site is interpreted to represent an aquitard unit beneath the Site. In general, the groundwater flow direction across aquitards is primarily vertical (Cherry, et. al., 2006). Therefore, the predominant groundwater flow direction in the till unit is anticipated to be downward with the horizontal component likely following topography. The horizontal flow on Site is interpreted to be from a topographic high in the southeast portion of the Site to the northwest portion of the Site. The horizontal hydraulic gradient across the Site will vary due to the range in topography and resulting range in groundwater elevations. The hydraulic gradient is found to be approximately 0.03 m/m across the Site.

4.4 Hydraulic Conductivity

SWRT were performed on two (2) selected monitoring wells on Site (BH9/MW and BH11/MW) to evaluate the hydraulic characteristics of the screened overburden. The results of the tests are summarized in **Table 2**, and the calculations are presented in **Appendix G**. The results provide information regarding the hydraulic conductivity of the soils surrounding the well screen.

Based on these tests, the estimated hydraulic conductivities for the clayey silt till was 10^{-10} m/s in both wells. The results are consistent with literature values of hydraulic conductivities for till ranging from 10^{-6} to 10^{-12} m/s (Table 2.2, Freeze and Cherry; 1979).

A total of three (3) soil samples collected from boreholes were selected for grain size distribution analysis testing. Based on the grain size analyses, the hydraulic conductivity was calculated to be 10^{-11} to 10^{-10} m/s in the clayey silt till. The results are summarized in **Table 2** below, and are shown graphically in **Appendix D.**

Table 2 – Hydraulic Conductivity Results

Sample ID	Lithology	Hydraulic Conductivity (m/s)
Grain Size Analyses		
BH2 S2 (0.8 - 1.2 m bgs)	Clayey Silt Till	10^{-10} to 10^{-11}
BH4 S5 (4.6 - 5.0 m bgs)	Clayey Silt Till	10^{-10} to 10^{-11}
BH9 S2 (0.8 - 1.2 m bgs)	Clayey Silt Till	10^{-10} to 10^{-11}
SWRT Analyses		
BH9/MW (4.6 – 6.1 m bgs)	Clayey Silt Till	10^{-10}
BH11/MW (4.6 – 6.1 m bgs)	Clayey Silt Till	10^{-10}

4.5 Water Quality Results

Groundwater quality samples were collected for analysis of general chemistry parameters from monitoring wells BH9/MW and BH11/MW on May 19, 2023. Water quality tables are presented in **Appendix H** and laboratory Certificates of Analysis results are provided in **Appendix I.**

The groundwater quality results were compared to the Ontario Drinking Water Quality Standards (ODWQS) Maximum Acceptable Concentrations (MAC; O. Reg. 169/03). Since the groundwater on Site is not planned for use as drinking water, these guidelines are used for comparison's sake only. As demonstrated in the tabulated results in **Appendix H**, no parameters exceeded the ODWQS MAC guidelines for any sampled monitoring wells.

5. Site-Wide Water Balance Assessment

5.1 Background Information

The water balance assessment for the Site was completed in accordance with the recommendations included 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 water balance calculations have been completed based on the areas drawn from the Proposed Development Plan, provided in **Appendix B**. EXP should be retained to review the water balance should the proposed development plan change.

5.2 Pre-development Conditions

The current total Site area is 8.30 hectares (83,000 m^2). At the central south end of the Site, there is a grassed and treed area where a residence used to be present. The land is generally characterized by low to moderate relief. The Site is generally bounded by a woodlot and residence to the north, Meadowlily Road South to the west, Commissioners Road East to the south, and a public sports park to the east. The Meadowlily Woods Environmentally Significant Area (ESA) is north of the Site, in the wooded area.

5.3 Proposed Post-Development Conditions

The proposed development plan is to consist of a medium density residential development with multiple build forms including townhouses, stacked townhouses, and low-rise apartments with newly established infrastructure (municipal servicing, paved access roads and parking lots). It is understood only minor grading will occur at the Site.

5.4 Thornthwaite-Mather Water Balance

The water balance is based on estimates for a typical annual period, as an expression of the mean annual precipitation, change in groundwater storage, evapotranspiration, surficial run-off, and infiltration. The relationship in these factors can be balanced, as shown in the following equation:

Mean Annual Precipitation - Change in Groundwater Storage - Evapotranspiration = Runoff + Infiltration

where:`

- Total annual precipitation (983.73 mm/yr) is based on data provided by Environment Canada, based on the 30-year average data for climate normals, using local weather station information (London International Airport, ON).

- Long term changes in groundwater storage are assumed to be negligible (i.e. no significant groundwater pumping or withdrawal from the aquifer). Seasonal changes are expected to balance out over the course of a full year.

- 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. The evapotranspiration values are obtained using the method described by Thornthwaite and Mather (1957) but are sourced from Environment Canada Data using values for water holding capacity derived from Table 3.1 of the MOE Stormwater Management Planning and Design Manual (MOE, 2003).

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.

Infiltration rates and soil moisture capacities were determined using values presented in Table 3.1 of the MOE Stormwater Management Planning and Design Manual (MOE, 2003) based on site topography, vegetative cover, and the interpreted hydrologic soil group based on the results of the drilling program. The weighted values based on the Site conditions are presented in the calculation sheets provided in **Appendix J-1** and **J-2.**

Localized infiltration rates will vary based on factors such as the soils 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. The Site is currently covered with moderately rooted crops. Impervious surfaces are considered to be negligible across the Site in the pre-development condition.

Hydrologic Soil Groups of the Site were estimated based on the near surface soils encountered in boreholes advanced on the Site by EXP as part of the geotechnical investigation. The near surface soils typically comprised topsoil and occasionally a thin layer of sandy silt overlying clayey silt till. The near surface soils are classified as a CD-Type Hydrologic Soil Group (HSG). These soils have a low rate of water transmission.

Based on the present and estimated future vegetation cover, topography, and soils on the Site, the infiltration factor in the pre- and post-development environment has been given values ranging from 0.5 to 0.6 for the pervious areas. These values can be seen in the water balance calculation spreadsheet presented in **Appendix J-3.**

Evapotranspiration values were determined using the method described by Thornthwaite and Mather (1957). It is common practice and an accepted method by most Conservation Authorities to provide estimates of surplus using the Thornthwaite and Mather approach, where surplus is estimated based on precipitation minus evapotranspiration (Steenhuis and Van Der Molen, 1986). The distribution of runoff and infiltration from the surplus water is determined from the infiltration factor for the Site.

5.5 Water Balance Analysis

Table 4 summarizes the pre- and post-development water balance calculations for the entire Site. Calculation worksheets are provided in **Appendix J**.

Table 3: Summary of Preliminary Water Balance Estimates

	Pre Development	Post Development	Difference	% Maintained
Estimated Runoff (m^3/year)	17,627	55,607	37,979.80	315%
Estimated Infiltration (m^3/year)	17,627	8,155	-9,471.9	46%

Based on the above, the proposed development maintains 46% of the pre-development infiltration volume. Therefore, the use of secondary infiltration (LIDs) would be required in order to increase post-development infiltration volumes.

At this time, it is recommended that clean rooftop runoff be directed to grassy areas to increase the infiltration volumes across the Site. Details regarding total rooftop area for increasing the overall infiltration targets for the Site will be provided during the Detailed Design stage of the project.

5.6 Secondary Infiltration Opportunities

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 includes maintaining the hydrologic cycle, protecting water quality, and preventing increased erosion and flooding.

The following list provides some mitigation measures which may be taken into consideration, during the detailed design stage of the development. These measures may include secondary infiltration by directing and capturing clean runoff water from impervious surfaces into landscaped areas where existing infiltration capacity can be utilized. More specifically, considerations may include but not limited to the following:

- Increased topsoil depth throughout yard and green space areas to reduce runoff. In general, a runoff reduction up to 30% may be possible in areas where increased topsoil thicknesses are utilized depending on final topsoil thickness, storm duration and intensity;
- Collection of clean rooftop runoff into side yard and rear yard swales and/or vegetative filter strips, which can be directed to infiltration trenches to promote infiltration;
- Installation of linear bioswales to collect and promote infiltration;
- Planting of trees and bushes;
- Installing soakaway areas;
- Implementing rainwater harvesting (i.e. to re-use in toilet flushing and irrigation, etc.);

- Installing green roof technologies;
- Using filters/bio-retention (i.e. islands, parking areas, etc.);
- Installing absorbent landscaping; and,
- Installing oil/grit separators.

As discussed above, these mitigation measures are provided for information purposes only and inclusion in this report does not necessarily mean each of these methods are or will be proposed at the Site. In the event infiltration facilities are a proposed LID as part of the detailed Site design, in-situ infiltration testing will be completed once the proposed locations and design details (i.e. base elevations) are known.

It is noted that water quality will need to be accounted for in the design of any mitigation measure to account for potential impacts from contaminate sources such as winter maintenance on roads and parking lots. In addition, the shallow groundwater condition will also need to be considered in any infiltration facility design. In the event infiltration facilities are proposed, only "clean" runoff from landscaped/pervious surfaces and/or rooftop runoff should be directed toward these facilities.

6. Sourcewater Protection Considerations

6.1 Significant Groundwater Recharge Areas (SGRA)

Groundwater recharge is largely controlled by soil conditions, and typically occurs in upland areas.

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.

An assessment report for the Upper Thames River Source Protection Area was completed by the Thames-Sydenham and Region Source Protection Committee. As defined by the *Clean Water Act (2006)* and identified by the Thames-Sydenham and Region Source Protection Committee, the Site is generally located outside of a SGRA.

Upon review of the SGRA mapping, the tree line at the north and east border of the Site has been mapped as being within a SGRA. The surficial soils encountered in the drilling program were generally low permeability clayey silt till deposits, occasionally with a thin sandy silt deposit at surface. The developable area of the Site should not be considered within a SGRA.

6.2 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:

1. Intrinsic susceptibility index (ISI).

2. Aquifer vulnerability index (AVI).

3. Surface to aquifer advection time (SAAT).

4. 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.

The Thames-Sydenham and Region Source Protection Committee has determined, using the ISI method, that the Site is not located within HVA areas.

7. Impact Assessment

7.1 Water Well Users

A search of the Ontario MECP WWR database was completed using a buffer of 500 m from the Site. This resulted in the identification of 22 records.

Water uses in the area include the following:

- Water Supply Wells (5 wells) used for domestic, public and livestock purposes;
- Test Hole (5 wells);
- Observation Wells (8 well);
- Abandoned (3 well); and,
- Unknown use (1 wells)

The approximate locations of identified wells are shown on **Drawing 10**, with the MECP WWR Summary provided in **Appendix E**.

Domestic water supply in the local area wells are generally drawing from the confined intermediate sand and gravel aquifer or from the bedrock aquifer. The water supply wells within 500 m of the Site are screened at a depth ranging from 38.1 m to 64 m bgs. There are no shallow water supply wells within 500 m. As a result, the potential of impact to the private well water supply is expected to be low.

Monitoring wells have been installed as part of this investigation to assess stabilized groundwater conditions in this portion of the Site. Prior to the Site grading work, and when the monitoring wells are determined to be no longer required, the wells will need to be properly decommissioned by a licensed well contractor in accordance with Ontario Regulation 903.

7.2 General Comments

During construction, short term impacts to nearby natural features may occur, particularly where vegetation on nearby land is stripped and area grading works is completed.

The following recommendations are provided to help minimize impact to natural features in the vicinity of 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.

7.3 Groundwater Separation and Preliminary Construction Dewatering Considerations

Based on the low permeability surficial soils found at the site, construction dewatering rates are expected to be minimal for basement/servicing with a typical foundation depth of 3.5 m bgs. A more detailed assessment of dewatering requirements can be completed at the detailed design stage, if required, once Site grading, finished floor and servicing elevations are known.

In the event construction dewatering is required, collected water from excavations should be discharged a sufficient distance away from the excavated area to prevent the discharge water from returning to the excavation. Sediment control measured should be provided at the discharge point of the dewatering system. Groundwater discharge options may include:

- The municipal storm sewer system; groundwater chemistry will be required to adhere to storm sewer criteria outlined in the City of London Waste Discharge By-Law (WM-16); or

- The municipal sanitary sewer system; groundwater chemistry will be required to adhere to sanitary sewer criteria outlined in the City of London Waste Discharge By-Law (WM-16).

Approval for the selected discharge option is required from the City of London prior to commencing dewatering activities.

8. 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 by authored by Mr. Nicolas Sabo, M.E.S., B.Sc. Mr. Sabo has more than 10 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. He obtained his Bachelor's degree in Natural Resources Management (Environmental Major) from the University of Guelph and obtained his Masters in Environmental Studies from York University.

This report was peer-reviewed by Ms. Hagit Blumenthal M.Sc., P.Geo. Ms. Blumenthal has experience in conducting hydrogeological assessments. Ms. Blumenthal is a hydrogeologist and environmental geoscientist with more than 10 years' experience in the environmental field, and is a licensed Professional Geoscientist (P.Geo.) in Ontario. She obtained a Master of Science (M.Sc.) in 2010 from the University of Waterloo and has worked in the Hydrogeological and Environmental fields since then.

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10. 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 regard 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

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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 – Proposed Development Plan

Appendix C – Borehole Logs

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Appendix D – Grain Size Analyses

Appendix E – MECP Water Well Record Summary

Appendix F – Water Levels

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Appendix G – Single Well Response Test Data

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Appendix H – Water Quality Tables

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Appendix I – Laboratory Chain of Analysis

Appendix J – Site-Wide Water Balance Assessment

Appendix K – Limitations and Use of Report

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.

RELIANCE ON INFORMATION PROVIDED

The evaluation and conclusions contained in the Report are based on conditions in evidence at the time of site inspections and information provided to EXP by the Client and others. The Report has been prepared for the specific site, development, building, design or building assessment objectives and purpose as communicated by the Client. EXP has relied in good faith upon such representations, information and instructions and accepts no responsibility for any deficiency, misstatement or inaccuracy contained in the Report as a result of any misstatements, omissions, misrepresentation or fraudulent acts of persons providing information. Unless specifically stated otherwise, the applicability and reliability of the findings, recommendations, suggestions or opinions expressed in the Report are only valid to the extent that there has been no material alteration to or variation from any of the information provided to EXP.

STANDARD OF CARE

The Report has been prepared in a manner consistent with the degree of care and skill exercised by engineering consultants currently practicing under similar circumstances and locale. No other warranty, expressed or implied, is made. Unless specifically stated otherwise, the Report does not contain environmental consulting advice.

COMPLETE REPORT

All documents, records, data and files, whether electronic or otherwise, generated as part of this assignment form part of the Report. This material includes, but is not limited to, the terms of reference given to EXP by its client ("Client"), communications between EXP and the Client, other reports, proposals or documents prepared by EXP for the Client in connection with the site described in the Report. In order to properly understand the suggestions, recommendations and opinions expressed in the Report, reference must be made to the Report in its entirety. EXP is not responsible for use by any party of portions of the Report.

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Where EXP has submitted both electronic file and a hard copy of the Report, or any document forming part of the Report, only the signed and sealed hard copy shall be the original documents for record and working purposes. In the event of a dispute or discrepancy, the hard copy shall govern. Electronic files transmitted by EXP have utilize specific software and hardware systems. EXP makes no representation about the compatibility of these files with the Client's current or future software and hardware systems. Regardless of format, the documents described herein are EXP's instruments of professional service and shall not be altered without the written consent of EXP.

Legal Notification