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HYDROGEOLOGICAL REPORT

Proposed Townhouse Development
910 Veterans Drive
Barrie, Ontario

Prepared For: 2528286 Ontario Inc.
Type of Document: Final Report
Reference Number: 19-1004A
Prepared By: Alexander Winkelmann, P.Eng
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1 Introduction

Central Earth Engineering Inc. (CEE) was retained by 2528286 Ontario Inc. c/o Innovative Planning Solutions to complete a hydrogeological investigation and report for 910 Veterans Drive in the City of Barrie. The site is bounded by Veterans Drive to the east, a residential property to the south and agricultural land to the north and west. A site location plan is provided as Figure 1. The existing property is approximately 90 metres long (north to south) and 80 metres wide (east to west). The property currently contains a single family detached residential dwelling with a detached shed and garage, with much of the site consisting of manicured lawn with some mature trees.

CEE was provided with the following for the property for review:

- "*Concept Plan 'A', 53 Units, Veteran's Drive and McKay Rd, Salem Secondary Plan*", File 18-769, dated March 20, 2019 by Innovative Planning Solutions.
- "*910 Veterans Drive, City of Barrie 53 Unit Back to Back Townhouse Development Functional Servicing & Storm Water Management Brief*", Project No. 18-11393B, dated March 28th, 2019, by Pinestone Engineering Ltd.

Based on our review of the provided drawings and reports, it is proposed to demolish the existing residential buildings on site and construct four blocks of back to back townhouses for a total of 53 units. The townhouses will be 3 to 4 storeys high. A 12-metre-wide road will run north-south through the centre of the property and exit into the proposed low-density residential development that will eventually surround the site. Though the drawings show an 8-metre-wide road, it is understood that the most recent Draft Plan of Subdivision indicates that a 12-metre-wide road is required. Due to the proposed grading surrounding the site in other adjacent subdivisions, it is likely that approximately 3 metres of filling will be required to raise grades to match, though the exact amount of filling may change slightly during detailed design. Based on our correspondence, the townhomes will not have any underground basement levels (i.e. they will be slab-on-grade) and the depth for site servicing will be of typical depth for similar developments.

This revision (Revision 1, dated August 16, 2019) is prepared to address comments provided by both the Lake Simcoe Region Conservation Authority and the City of Barrie. Further details on the exact comments/questions and are responses are provided in the following letter report: "*Response to Geotechnical and Hydrogeological Comments Proposed 56 Unit Townhouse Development 910 Veterans Drive, Barrie, Ontario*", Reference No. 19-1004A, dated August 16, 2019, by Central Earth Engineering Inc.

2 Site Setting

2.1 Physiography, Surficial and Bedrock Geology

The site is located within the physiographic area denoted as the Peterborough Drumlin Field (Chapman & Putnam, 1984). Based on surficial and bedrock geology mapping of the site by the Ontario Geological Survey, the surficial geology consists of stony, sandy silt to silty sand-textured till on Paleozoic terrain. Near the site, the surficial geology consists of ice-contact stratified deposits (sand and gravel, minor silt, clay and till). At depth, limestone bedrock of the Lindsay Formation is present.

2.2 Topography and Drainage

Topographic mapping by the MNRF and County of Simcoe show the site and surrounding area is generally flat, with a geodetic elevation near 310 metres. The topography gradually slopes to the southeast to Elevation 300 metres over approximately 850 metres.

This site is in the Lovers Creek subwatershed, which is part of the Lake Simcoe watershed. The Ontario Flow Assessment Tool (OFAT) by MNRF shows the site drains to the southeast into a tributary of Lovers Creek, about 650 metres southeast of the site. The tributary flows into Lovers Creek, which generally flows north and outlets into Kempenfelt Bay of Lake Simcoe.

It is understood that the post-development drainage direction will change and all run-off will be directed to the southwest corner of the site towards a storm water management pond located within the larger adjacent residential development. The proposed change in drainage area will not affect the water balance calculations included in this report but will need to be addressed in the storm water management report that will be prepared for the site by others.

2.3 MOECC Well Records

Ministry of the Environment and Climate Change water well records were obtained within 300 metres of the site area to assess the general nature of the ground water resource in near vicinity of the site, and historical/current uses of wells in the area. Nine (9) well records were found, and a summary of the data obtained from this review is presented below. The approximate well locations are shown on Figure 3.

One (1) of the wells within 300 metres of the site has been abandoned, with the remaining eight (8) either still in use, or not in use but have not been formally abandoned yet. The wells were originally installed for domestic drinking water supply with one of the wells installed for monitoring purposes. The boreholes for the wells were generally advanced to depths of 40 to 58 metres below grade, and the wells were screened where ground water was encountered around 35 to 57 metres below grade. One well record indicates the borehole was advanced to 14 metres below grade and ground water was encountered at a depth of 13 metres. Water levels from these well records generally provide information for deeper aquifers and may not accurately reflect shallower water levels near the site.

The stratigraphic descriptions within monitoring wells are typically inaccurate due to the methodology in which they are determined (observations of cuttings and no consistency between descriptions of soil between different drillers). Though this is the case, an overall sense of the deep stratigraphy can be determined by looking at commonalities between most stratigraphic descriptions and where the wells were terminated in an aquifer. In the area surrounding the site, the well records generally indicate that “sands” extend to depths of greater than 58 metres below grade. Some zones of “clay” were noted in some locations.

It is expected that the private, domestic drinking water wells are still in use in the 300-metre radius because the area is not serviced by municipal water.

2.4 Nearby Boreholes by Other Consultants

Three (3) boreholes with monitoring well installations were advanced within 300 metres of the site by Golder Associates in 2016. The borehole locations are shown on Figure 3.

BH16-4 was advanced to a depth of 11 metres below grade. It encountered a 200 mm thick topsoil layer, underlain by silty sand to 1.4 metres below grade, underlain by silty clay to 2.1 metres below grade, underlain by silt sand to sand that extended beyond the vertical depth of investigation at a depth of 11 metres. BH16-14 encountered 150 mm of topsoil underlain by silty sand to silt and sand glacial till that extended beyond the vertical depth of investigation at 5 metres below grade. BH16-16 encountered 130 mm if topsoil underlain by silty sand that extended beyond the vertical depth of investigation at 5 metres below grade.

The boreholes were dry upon completion of drilling. Monitoring wells were installed in the boreholes, summarized below.

Monitoring Well	Depth of Screen (m)	Strata Screened	Ground Water Level on May 4, 2016	
			Depth (m)	Elev. (m)
BH16-4	9.1 to 10.6	Silty sand to sand	Dry	
BH16-14	3.0 to 4.5	Silt & Sand Glacial Till	Not measured	
BH16-16	3.0 to 4.5	Silty sand	Dry	

Monitoring wells installed by Golder Associates about 1 km west of the site encountered ground water at about 2 to 4 metres below existing grade, however, they were installed near a marshy area which is likely a ground water recharge zone.

2.5 Visual Inspection of Site

The site is currently developed with a residential dwelling, two detached garages, a shed, and a paved driveway. The northern and western property edges are vegetated with mature coniferous trees, and the remaining property is partially vegetated with grass lawn and partially vegetated with mature deciduous, coniferous trees, and some shrubs. A shallow drainage swale runs along the eastern property limit, parallel to Veterans Drive.

Based on our preliminary visual estimates, it appears the following hard cover and soft cover surfaces exist:

- Hard Cover (5%):
  - Paved driveway: 2%
  - Buildings: 3%
- Soft Cover (95%):
  - Lawn: 46%
  - Trees/Shrubs: 49%

In general, surface drainage occurs as sheet drainage across the site, but channelized flow is expected in the drainage swale along Veterans Drive.

2.6 Regulatory Requirements

2.6.1 Source Water Protection

The following documents should be used in determination of the regulatory requirements when it comes to maintaining hydrogeological function at this site:

- "*Lake Simcoe Protection Plan*", dated July 2009, by MOECC, MNR & LSRCA.
- "*Approved South Georgian Bay Lake Simcoe Source Protection Plan*", dated January 26, 2015, by LSRCA.
- *"Lake Simcoe Protection Plan Water Budget Policy for LSPP 4.8-DP and 6.40-DP,"* dated November 2018, by LSRCA.

The Lake Simcoe Protection Plan (LSPP) Designated Policy (DP) 6.36 builds on the Provincial Policy Statement (PPS) and *Clean Water Act, 2006*, to define a Significant Groundwater Recharge Area (SGRA). The definition from the LSPP is below.

- *"6.36-DP: A significant groundwater recharge are is an area identified,*
  - *as a significant groundwater recharge area by any public body for the purposes of implementing the PPS;*
  - *as a significant groundwater recharge area in the assessment report required under the Clean Water Act, 2006, for the Lake Simcoe and Couchiching/Black River Source Protection Area; or*
  - *by the LSRCA in partnership with MOE and MNR as an ecologically significant groundwater recharge area in accordance with the guidelines developed under policy 6.37."*

Based on Simcoe County and LSRCA mapping, the site is located in the following areas:

- Significant Groundwater Recharge Area (SGRA): The site is not located within a SGRA (Figure 4A);
- Wellhead Protection Area (WHPA): The site is located within a WHPA classified as Q2 (Figure 4B); and
- Highly Vulnerable Aquifer (HVA): The site is located within an HVA (Figure 4C).

"Lake Simcoe Protection Plan Water Budget Policy for LSPP 4.8-DP and 6.40-DP," (by LSRCA, dated November 2018) Section 6.0 describes the policy hierarchy for water balance required for Lake Simcoe Watershed. The policies from most to least stringent are described below:

1. Source Protection Plan Land Use Policy (SPP LUP) 12: *"Planning Approval Authorities shall only permit new major development (excluding single detached residential, barns and non-commercial structures that are accessory to an agricultural operation) in a WHPA-Q2 where the activity would be a significant drinking water threat, where it can be demonstrated through the submission of a hydrogeological study that the existing water balance can be maintained through the use of best management practices such as low impact development. Where necessary, implementation and maximization of off-site recharge enhancement within the same WHPA-Q2 to compensate for any predicted loss of recharge from the development."*
2. Designated Policy (DP) 6.40: "*Outside of the Oak Ridges Moraine area, an application for major development within a significant groundwater recharge area (SGRA) shall be accompanied by an*

environmental impact study that demonstrates that the quality and quantity of groundwater in these areas and the function of the recharge areas will be protected, improved or restored."

3. Designated Policy (DP) 4.8 d): *"An application for major development shall be accompanied by a stormwater management plan that demonstrates: through an evaluation of anticipated changes in the water balance between pre-development and post-development, how such changes shall be minimized."*

The proposed development is within a WHPA-Q2, therefore SPP LUP-12 applies. Due to the residential nature of the proposed development, no significant contaminating activities are expected to occur as per O.Reg 287/07 under the Clean Water Act, 2006 which prescribes 21 threats (with the exception of Threat 20: An activity that reduces the recharge of an aquifer). As the development is not within an SGRA as defined by the LSPP, DP-6.40 does not apply and an environmental impact study is not required. The proposed development at the site is considered a major development by the Lake Simcoe Protection Plan (LSPP) since more than 500 m^2 of impervious surface (buildings, parking lot) will be created. As the development is considered a "major" development, DP-4.8 also applies. As such, infiltration based low impact development measures are required to match pre and post-development water balances. This would also ensure that the requirements within SPP LUP-12 are met.

Based on Table 2 in "*Lake Simcoe Protection Plan Water Budget Policy for LSPP 4.8-DP and 6.40-DP*," infiltration-based practices are permitted for low-density residential land for impervious (paved) areas. It is noted that runoff from vegetated areas and rooftops are always permitted and runoff from pollution hotspots are never permitted

In addition, the following policy will also apply at the site: *"Phosphorous Offsetting Policy",* dated September 2017, by LSRCA. Section 4.4 Phosphorous Offsetting Policies in the above document discusses the applicable policies, including that the application for a major development *"… shall be accompanied by a Preliminary Phosphorous Budget as part of an overall Functional Servicing Report or Preliminary Stormwater Management Report."* Phosphorous offsetting must be carried out as part of the stormwater management report to be completed for the site by others. Some additional details are provided in Section 5.4.3 of this report.

2.6.2 Temporary Groundwater Dewatering

The volume of water entering the excavation will be based on both ground water infiltration and precipitation events. Construction dewatering is governed by the following regulations:

- Ontario Water Resources Act, R.S.O. 1990, C. O.40;
- O. Reg. 387/04: Water Taking and Transfer; and
- O. Reg. 63/16: Registrations Under Part II.2 of the Act - Water Taking

Based on the regulations, the following dewatering limits and requirements are as follows:

- <u>Construction Dewatering less than 50,000 L/day:</u> The takings of both ground water and storm water does not require a hydrogeological report nor a Permit to Take Water (PTTW) from the Ministry of the Environment, Conservation and Parks (MECP).
- <u>Construction Dewatering greater than 50,000 L/day and less than 400,000 L/day:</u> The taking of ground water and/or storm water requires a hydrogeological report and registration to the Environmental Activity Sector Registry (EASR) but does not require a Permit to Take Water (PTTW) from the Ministry of the Environment, Conservation and Parks (MECP).

- Construction Dewatering greater than 400,000 L/day: The taking of ground water and/or storm water requires a hydrogeological report and requires a Category 3 Permit to Take Water (PTTW) from the Ministry of the Environment, Conservation and Parks (MECP).

3 Procedures and Methodology

Prior to the commencement of drilling activities, the locations of underground utilities including natural gas, electrical, telephone, water, etc. were marked out by public and private utility locating companies. The fieldwork for the drilling program was carried out on February 11, 2018. A total of three boreholes (Borehole 1 through 3) were advanced on site by Drilltech Drilling using a track-mounted drill rig. To advance the boreholes, continuous flight solid stem augers and standard soil sampling equipment was utilized. All samples were collected as per ASTM D1586 to assess the strength characteristics of the substrate.

The boreholes were advanced to 6.6 metres below existing grade (Elev. 94.3 to 93.52 metres). The horizontal locations were laid out in the field by Central Earth Engineering prior to the drilling operations and were spread evenly across the site. Geodetic elevation measurement of the ground surface of the borehole were measured based off a temporary benchmark chosen by CEE with an assumed Elev. 100.00 metres (centre line of road at centre of driveway to 910 Veterans Dr.) using a laser level. GPS measurements measured with a handheld GPS unit and referenced to the NAD 83 geodetic datum.

The field staff examined and classified characteristics of the soils encountered in the boreholes, including the presence of fill materials, made groundwater observations during and upon completion of the drilling, recorded observations of borehole construction, and processed the recovered samples. Soil sampling was conducted at regular intervals for the full depth of the borehole. The boreholes were backfilled upon completion. All recovered soil samples were logged in the field, carefully packaged and transported to the laboratory for more detailed examination and classification. In the laboratory, the samples were classified as to their visual and textural characteristics. Stabilized groundwater levels were measured in the three installed monitoring wells on February 13 and March 7, 2019.

4 Subsurface Conditions

4.1 General Overview

The detailed soil profiles encountered in the boreholes are indicated on the attached borehole logs in Appendix A. The borehole locations are shown on both an existing aerial photograph and the proposed site plan on Figures 2A and 2B, respectively. A generalized subsurface profile showing site-specific boreholes is provided as Figure 5. The results of geotechnical laboratory testing carried out on selected soil samples are provided in Appendix B.

It should be noted that the conditions indicated on the borehole logs are for specific locations only and can vary between and beyond the borehole locations. It should be noted that the soil boundaries indicated on the borehole logs are inferred from non-continuous sampling and observations during drilling. These boundaries are intended to reflect approximate transition zones and should not be interpreted as exact planes of geological change.

In addition, the descriptions provided in the borehole logs are inferred from a variety of factors, including: visual observations of the soil samples retrieved, laboratory testing, measurements prior to and after drilling, and the drilling process itself (speed of drilling, shaking/grinding of the augers, etc.). The passage of time also may result in changes in conditions interpreted to exist at locations where sampling was conducted.

4.2 Stratigraphy

All the boreholes encountered a nominal surficial topsoil layer ranging in thickness between 150 to 600 mm. Underneath the surficial topsoil layer, all three boreholes encountered a sand and silt glacial till deposit with some gravel and trace clay that extended beyond the vertical extent of the investigation for Boreholes 1 and 2 (Elev. 94.2 to 93.6 metres) and to a depth of 3.1 metres below existing grade in Borehole 3 (Elev. 97.9 metres). The glacial till stratum was noted to contain a higher silt content in Boreholes 1 and 2 at a depth of 4.6 metres below existing grade (Elev. 95.6 and 96.2 metres, respectively). The deposit was noted to be brown in color and generally in a moist in-situ state.

SPT "N" Values measured in the deposit ranged between:

- 0 to 1.2 metres below existing grade: 6 to 37 blows per 300 mm of penetration.
- 1.2 to 6.6 metres below existing grade: 33 blows per 300 mm to greater than 50 blows per 150 mm of penetration.

Base on the above information the upper 1.2 metres has a loose to dense relative density, while below 1.2 metres below existing grade the sand and silt glacial till deposit has a dense to very dense relative density.

In Borehole 3 below the sand and silt glacial till deposit a deposit of fine sand with some silt, trace clay and trace gravel was encountered at 3.1 metres below existing grade (Elev. 97.9 metres) and extended to 6.1 metres (Elev. 94.8 metres). The deposit was noted to be brown and moist. SPT "N" Values obtained in the deposit were greater than 50 blows per 150 mm of penetration indicating a very dense relative density. Below the fine sand deposit, the same sand and silt glacial till stratum that was present above the fine sand deposit was encountered at 6.1 metres below existing grade (Elev. 94.8 metres) and extended beyond the depth of the investigation at 6.6 metres below existing grade (Elev. 94.4 metres). The glacial till deposit was noted to be brown and moist. SPT "N" Values obtained in the deposit was greater than 50 blows per 150 mm of penetration indicating a very dense relative density.

4.3 Ground Water

It is noted that no groundwater was encountered in the three monitoring wells installed on site. The ground water is significantly deep in this area of Barrie, and the components of the hydrogeological report that require ground water level measurements (i.e. ground water levels and flow direction, ground water chemical quality, single head response tests, etc.) are not considered warranted for the type of development proposed.

4.3.1 Ground Water Levels

Unstabilized ground water level measurements and cave measurements were taken upon completion of drilling of each borehole. These measurements provide a rough estimate of the possible excavation and temporary ground water control constructability considerations that may arise. All three boreholes were dry upon completion of drilling.

Monitoring wells were installed in each borehole consisting of 50 mm diameter PVC piping with 1.5 metre slotted screens. Well sand was used to backfill around the screens, and they were sealed with bentonite. The monitoring wells were noted to be dry on both February 13 and March 7, 2019. A summary of the groundwater level measurements is presented below.

Monitoring Well	Screened Location		Strata Screened	Ground Water Level on February 13, 2019		Ground Water Level on March 7, 2019	
	Depth (m)	Local Elev. (m)		Depth (m)	Local Elev. (m)	Depth (m)	Local Elev. (m)
1	4.6 to 6.1	95.5 to 94.0	Silt & Sand (Glacial Till)	Dry		Dry	
2	4.6 to 6.1	96.2 to 94.7	Silt & Sand (Glacial Till)	Dry		Dry	
3	4.7 to 6.2	96.2 to 94.7	Fine Sand	Dry		Dry	

Based on the results of the water levels and the moisture contents of the soil within the boreholes, the prevailing ground water table is expected to relatively deep and beyond 6.2 metres below existing grade (beyond local Elevation 94.0 metres). The well records within a 300-metre radius encountered water at a depth of 35 metres or more below grade, however these levels generally reflect deeper aquifer levels and not shallower water levels. It is expected that the static ground water table is likely between 10 to 15 metres below existing grade.

Subsequent monthly monitoring ground water level readings were conducted until June 25, 2019, with details provided in the following report: "*Monthly Water Level Readings, Proposed 56 Unit Townhouse Development, 910 Veterans Drive, Barrie, Ontario*", Reference No. 19-1004A, dated August 6, 2019, by Central Earth Engineering. No ground water was noted in any of the monitoring wells during this monitoring, and therefore the seasonal high ground water level is also considered to be beyond 6.2 metres below existing grade (beyond local Elevation 94.0 metres) as the monitoring was conducted during the spring months.

The monitoring wells are recommended to be decommissioned following MOECC Ontario Regulation 903 once they are no longer in use and prior to development.

4.3.2 Permeability and Infiltration

Rising head tests could not be completed at the site because the monitoring wells were dry. The hydraulic conductivities of site soils were estimated from grain size distribution curves (as provided in Appendix B). According to Freeze and Cherry (1979), the typical hydraulic conductivity of the strata investigated are:

- Silt and Sand Glacial Till: 10^{-7} m/s to 10^{-8} m/s
- Sand, Some Silt: 10^{-4} m/s to 10^{-5} m/s

Determination of percolation rate are based on the "*Ontario Ministry of Municipal Affairs and Housing (OMMAH), Supplementary Guidelines to the Ontario Building Code 1997. SG-6 Percolation Time and Soil Descriptions, 1997*". The near surface soils at this site would be characterized as an M.L. under the Unified Soil Classification System. Based on this document and the soil type, the estimated percolation rate for the near surface soils would be 20 mins/cm (infiltration rate of 30 mm/hr). Grain size analysis is not typically sufficiently accurate and in-situ percolation testing using a Guelph Permeameter may be required in the vicinity of any proposed infiltration based Low Impact Development facilities to more accurately determine the percolation rate for detailed design.

It is noted that the grade of the site will be raised by approximately 3 metres. Based on this, infiltration based Low Impact Development measures will likely be within imported soils and should only be tested once confirmation of the material make up of soils being brought to site have been confirmed. In-situ percolation testing using a Guelph Permeameter of the native underlying soils may not be necessary.

4.3.3 Baseline Groundwater Chemical Testing

No groundwater was encountered within the monitoring wells. As such, no baseline chemical testing was conducted.

5 Discussion and Analysis

5.1 Proposed Development Plan

CEE was provided with the following for the property for review:

- "*Concept Plan 'A', 53 Units, Veteran's Drive and McKay Rd, Salem Secondary Plan*", File 18-769, dated March 20, 2019 by Innovative Planning Solutions.
- "*910 Veterans Drive, City of Barrie 53 Unit Back to Back Townhouse Development Functional Servicing & Storm Water Management Brief*", Project No. 18-11393B, dated March 28th, 2019, by Pinestone Engineering Ltd.

Based on our review of the provided drawings and reports, it is proposed to demolish the existing residential buildings on site and construct four blocks of back to back townhouses for a total of 53 units. The townhouses will be 3 to 4 storeys high. A 12-metre-wide road will run north-south through the centre of the property and exit into the proposed low-density residential development that will eventually surround the site. Though the drawings show an 8-metre-wide road, it is understood that the most recent Draft Plan of Subdivision indicates that a 12-metre-wide road is required. Due to the proposed grading surrounding the site in other adjacent subdivisions, it is likely that approximately 3 metres of filling will be required to raise grades to match, though the exact amount of filling may change slightly during detailed design. Based on our correspondence, the townhomes will not have any underground basement levels (i.e. they will be slab-on-grade) and the depth for site servicing will be of typical depth for similar developments.

5.2 Ground Water Control Methodology

5.2.1 Temporary Construction Ground Water Control

The volume of water entering the excavation will be based on both ground water infiltration and precipitation events. As excavations are expected to be above the prevailing ground water table, there should be limited ground water control issues present. During times of high precipitation, some water may collect at the base of the excavation. Local sumps placed at the base of the excavation can typically control groundwater seepage in this scenario.

As per O.Reg. 63/16, as construction dewatering will be less than 50,000 L/day, the takings of both ground water and storm water does not require a hydrogeological report nor a Permit to Take Water (PTTW) from the Ministry of the Environment, Conservation and Parks (MECP).

As no groundwater will be taken as part of the construction activities due to the depth of the seasonally high groundwater table, no temporary drawdown of the groundwater table will occur that would adversely effect the groundwater quantity of neighbouring properties that utilize drinking water wells as the source of their potable water.

5.2.2 Building Permanent Drainage

Where possible, the ground surface should be sloped on a positive grade away from the proposed townhouses to promote surface water run-off and to reduce groundwater infiltration adjacent to underground levels and foundations. To minimize infiltration of surface water, the upper 150 mm of backfill should comprise compacted relatively impervious soil material, where possible.

Perimeter drainage at the foundation level is not required, provided that the underside of concrete slab is at least 200 mm above the prevailing grade of the site and the surrounding surfaces slope away from the building at a gradient of at least 2 percent. For the portions of the slab below prevailing grade, and for any pits or chambers made below grade level, perimeter drainage or waterproofing is required.

It is noted that City of Barrie engineering standards require that there be at least a 0.5 metre separation between the seasonal high groundwater level and the invert of the proposed floor slabs of the building. It is noted that:

- All monitoring wells were measured to be dry during the spring months, indicating that the seasonally high groundwater level is beyond 6 metres below existing grade;
- Grade is to be raised by approximately 3 metres;
- The buildings are currently proposed to be slab-on-grade buildings.

Based on the above, there is therefore a minimum of 9 metres (or more) of grade separation between the seasonally high groundwater level and the invert of the proposed floor slabs.

5.3 Water Balance

5.3.1 Water Balance Components

A water balance is an accounting of the water resources within a given area. The water balance equates the precipitation (P) over a given area to the summation of the change in ground water storage (S), evapotranspiration/evaporation (ET), surface water runoff (R) and infiltration (I) using the following equation:

$$\mathrm{P} = S + I + ET + R$$

The components of the water balance vary in space and time and depend on climatic conditions as well as the soil and land cover conditions (i.e., rainfall intensity, land slope, soil hydraulic conductivity and vegetation). For example, runoff occurs at a higher percentage during periods of snowmelt when the ground is frozen or during intense rainfall events.

Precise measurement of the water balance components is difficult, and as such, approximations and simplifications are made to characterize the water balance of a property. Field observations of the drainage conditions, land cover and soil types, groundwater levels and local climatic records are important inputs to the water balance calculations.

- Precipitation (P): For the purposes of approximating the annual precipitation at this site, the monthly rainfall between 1981 and 2010 was used based on data Government of Canada historical weather data for the Barrie WPCC weather station (Climate ID 6110557 – 44.38 N, Longitude 79.69 W, Elevation 229 metres).
- Storage (S): Although there are groundwater storage gains and losses on a short-term basis, the net change in groundwater storage on a long-term basis is assumed to be zero.
- Evapotranspiration/Evaporation (PET): The evapotranspiration and evaporation components vary based on the characteristics of the land surface cover (i.e., type of vegetation, soil moisture conditions, perviousness of surfaces, etc.). Potential evapotranspiration refers to the water loss from a vegetated surface to the atmosphere under conditions of an unlimited water supply. Evaporation occurs from a hard surface (such as flat rooftops, asphalt, etc.).
- Water Surplus (R + I): The difference between the mean precipitation and evapotranspiration is referred to as the water surplus. The water surplus is divided into two parts: as surface or overland runoff (R) and the infiltration into the surficial soil (I). The infiltration is comprised of two end member components: one component that moves vertically downward to underlying aquifers (referred to as percolation, deep infiltration or net recharge) and a second component that moves laterally through the near surface soil profile or shallow soils as interflow that re-emerges locally to surface (i.e., as runoff) at some short distance and time following precipitation.

5.3.2 Approach and Methodology

The analytical approach to calculate the water balance involves monthly soil-moisture balance calculations to determine the pre-development (based on existing land use) infiltration volumes. The detailed water balance calculations are provided in Appendix E, which are summarized in this and subsequent sections of the report. The following assumptions were used as part of the soil-moisture balance calculations:

- A soil moisture balance approach assumes that soils do not release water as potential recharge while a soil moisture deficit exists.
- During wetter periods, any excess of precipitation over evapotranspiration first goes to restore soil moisture. Considering the nature of the predominantly cohesionless near surface soils in the area and grassed lawn, a soil moisture storage capacity of 150 mm was used.
- Once the soil moisture deficit is overcome, any further excess water can then pass through the soil as infiltration and either become interflow (indirect runoff) or recharge (deep infiltration).

Monthly potential evapotranspiration calculations accounting for latitude, climate and the actual evapotranspiration and water surplus components of the water balance based on the monthly precipitation and soil moisture conditions was calculated. The MOECC SWM Planning and Design Manual (2003) methodology for calculating total infiltration based on topography, soil type and land cover was used, and a corresponding infiltration factor was calculated. The water surplus was multiplied by the infiltration factor to determine both the pre-existing and post-condition annual volumes for run-off and infiltration for the property.

A post-development water balance scenario was also calculated based on the proposed land development plan. Based on the proposed development plan provided to CEE, it was estimated that there would be an increase to approximately 85% of the ground surface being covered in hard surfaces such as buildings, roads or driveways.

It is noted that the infiltration and runoff values presented in Appendix E are estimates only. Single values are used for the water balance calculations, but it is important to understand that infiltration rates are dependent upon the hydraulic conductivity of the surficial soils which may vary over several orders of magnitude. As such, the margins of error for the calculated infiltration and runoff component values are potentially quite large. These margins of error are recognized, but for the purposes of this assessment, the numbers used in the water balance calculations are considered reasonable estimates based on the site-specific conditions and useful for comparison of pre- to post-development conditions.

5.3.3 Pre and Post Water Balance

The pre-development water balance calculations based on the existing land use considering 5% hard cover and 95% soft cover of the site. The pre-development average annual infiltration volume on the property was calculated to be about 1,745 m^3/year and the total runoff volume from the property was calculated to be about 725 m^3/year.

Based on the proposed development plan, a post-development water balance was calculated considering an increase in hard cover from 5% to 85% which would consider the townhouses, sidewalks, roadways and driveways being constructed at this site. The post-development average annual infiltration volume on the property was calculated to be about 275 m^3/year and the total runoff volume from the property was calculated to be about 5,025 m^3/year.

These calculations suggest that, without mitigation such as low impact development measures, the proposed development will increase the surface water runoff volume by about 7 times and reduce shallow infiltration to about 15%. The potential impacts of these changes and recommended mitigation measures are discussed below.

5.4 Recommended Mitigation Measures

5.4.1 Runoff Quantity

Urban development of an area affects the natural water balance. The most significant difference is the addition of impervious surfaces as a type of surface cover (i.e., roads, parking lots, driveways, and rooftops). Impervious surfaces prevent infiltration of water into the soils and the removal of the vegetation reduces the evapotranspiration component of the natural water balance. The evaporation component from impervious surfaces is relatively minor (estimated to be 15% of precipitation) compared to the evapotranspiration component that occurs with vegetation in this area (up to two thirds of precipitation). So, the net effect of the urbanization of the site is that most of the precipitation that falls onto impervious surfaces increases the surplus water resulting in more direct runoff from developed areas and reduced natural infiltration.

In conjunction with increased run-off, there is a reduction in infiltration to the shallow groundwater system. A reduction in infiltration can potentially lead to a lowering of the local water table and reduce the potential for this seasonal water table intersection and discharge.

Methods which do not necessarily increase infiltration rate, but decrease the volume and concentration of surface water run-off can be considered at this site:

- Increasing the topsoil thickness by about two times the normal thickness (up to 30 cm) to retain more water in storage; and
- Implementation of rainwater harvesting which intercepts, diverts and stores roof runoff (i.e. cisterns) for future use.

5.4.2 Mitigation Measures for Maintaining Infiltration

The increases in surface water runoff that will occur with urban development and mitigation of the potential impacts to the local water table due to reduction of infiltration may be minimized by using appropriate stormwater management and using low impact development (LID) measures to promote infiltration. These measures can be implemented on-site, or within the larger residential development that this site will be integrated into to the west where more land space may be available to build these LID measures.

The basic premise for low impact development is to try to minimize changes to runoff and infiltration. As outlined in the MOECC SWMP Design Manual (2003) and Low Impact Development Stormwater Management Planning and Design Guide published by the CVC and TRCA (2010), there are a suite of techniques that may be considered to promote infiltration and reduce runoff. In order to maintain ground water function at the site the following typical LID measures can be considered as part of typical site developments:

- Collection of run-off from the building rooftops and redirection to grass areas and overland flow. It must be demonstrated that there will be a minimum 5 metre flow path over pervious areas to allow this mitigation method to be effective;
- Provision of gentle slopes in open areas or along drainage ditches in order to allow time for water infiltration.
- Construction of engineered infiltration measures such as soakaway pits, infiltration galleries or bioswales (subsurface infiltration methods can only be considered in areas where there is sufficient soil permeability and depth to water table to accommodate the systems within the unsaturated zone); and
- Construction of grass channels or filter strips which allow infiltration, discharge at a lower rate and direct roof runoff to overland flow.

Implementation of LID measures will not only allow for infiltration of the surface water into the near-surface groundwater regime but allow for increase in natural filtration of surficial run-off, prevent sedimentation transport and potential erosion, and help reduce flooding by increasing the transit time for water on the site. These types of LID techniques promote natural infiltration by providing additional water volumes in the pervious areas. This is particularly effective in the summer months, when natural infiltration would not generally occur because the additional water overcomes the natural soil moisture deficit.

It is understood that stormwater from the roof areas and pervious areas for the site will be infiltrated, and details will be provided by others in a stormwater management report for the site (by others). This includes demonstrating through plans and sections (including all dimensions, materials used and including the seasonal high groundwater level) how this infiltration deficit will be mitigated. In addition, the stormwater management report will need to include calculations to demonstrate that the LID facilities will be adequately sized both volumetrically and for area to allow completed drawdown within a 24 to 48 hours time period.

As it is a requirement of maintaining the same levels of infiltration post construction, no appreciable change in the groundwater table elevation should occur over the long-term condition. As such, the no adverse effects to the groundwater quantity of neighbouring properties that utilize drinking water wells as the source of their potable water.v

5.4.3 Groundwater Quality

Depending on land use, runoff from urban developments may contain a variety of dilute contaminants such as suspended solids, chloride from road salt, oil and grease, metals, pesticide residues, bacteria and viruses. For groundwater, generally except for the dissolved constituents such as nitrogen and salt, most contaminants are attenuated by filtration during groundwater flow through the soils.

The potential for effects on groundwater quality from infiltration in the proposed development area is expected to be limited due to the residential nature of the site and will not effect local drinking water wells in the vicinity of the site. Any potential changes to the shallow groundwater quality are not expected to influence the surface water quality in the flow to either Lake Simcoe or the minor watercourses further south considering the limited groundwater discharge volumes.

Phosphorous removal will need to be addressed in the stormwater management report to be prepared for the site by others. *"LSRCA Technical Guidelines for Stormwater Management Submissions"* (dated September 1, 2016, by LSRCA) states that 80% removal of annual Total Phosphorous is required and provides a list of typical phosphorous removal rates for various stormwater management best management practices. LID measures are recommended for this site to maintain the pre to post development water balance. LID's used in a treatment train approach remove phosphorous, and some typical removal rates are 60% for infiltration trenches, 65% for vegetated filter strips, and 87% for perforated pipe infiltration / exfiltration system based on the LSRCA guidelines.

6 Limitations and Conclusion

6.1 Limitations

The investigation and comments are necessarily on-going as new information of underground conditions becomes available. More specific information with respect to the conditions between samples, or the lateral and vertical extent of materials may become apparent during excavation operations. The interpretation of the borehole information must, therefore, be validated during excavation operations. Consequently, during the future development of the property, conditions not observed during this investigation may become apparent. Should this occur, Central Earth Engineering should be contacted to assess the situation and additional testing and reporting may be required.

Central Earth Engineering should be retained for a general review of the final design drawings and specifications to verify that this report has been properly interpreted and implemented. If not accorded the privilege of making this review, Central Earth Engineering will assume no responsibility for interpretation of the recommendations in the report. For example, it should be appreciated that modifications to bearing levels may be required if unforeseen subsoil conditions are revealed after the excavation is exposed to full view or if final design decisions differ from those assumed in this report.

The comments given in this report are intended only for the guidance of the design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc. could be 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.

This report was prepared by Central Earth Engineering for the account of 2528286 Ontario Inc. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Central Earth Engineering accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this project.

6.2 Conclusion

It is recognized that municipal/regional governing bodies, in their capacity as the planning and building authority under Provincial statues, will make use of and rely upon this report, cognizant of the limitations thereof, both as are expressed and implied.

We trust this report is complete within our terms of reference, and the information presented is sufficient for your present purposes. If you have any questions, or when we may be of further assistance, please do not hesitate to contact our office.

Yours Truly,

Central Earth Engineering Inc.

Alexander Winkelmann, P.Eng.
President

Figures

SITE LOCATION PLAN

BOREHOLE LOCATION PLANS

MECP & OTHER WELL LOCATION PLAN

REGULATORY MAPPING

GENERALIZED SUBSURFACE PROFILE

Appendix A –

BOREHOLE LOGS

Appendix B –

GEOTECHNICAL LABORATORY DATA

Appendix C –

GOLDER BOREHOLE LOGS

Appendix D –

MOECC WATER WELL RECORDS

Appendix E –

WATER BALANCE ANALYSIS