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February 14, 2023

Via: Email (mrogato@blackthorncorp.ca)

Mr. Paul Bigioni
c/o Mr. Maurizio Rogato (Blackthorn Development Corp.)
869547 Ontario Inc.
25 Buggey Lane
Ajax ON L1Z 1X4

Dear Mr. Bigioni/Mr. Rogato:

Re: Water Balance Assessment
Frisque Lands, 3225 Fifth Concession Road, Pickering, Ontario
Project No.: 300056041.0000

R.J. Burnside & Associates Limited (Burnside) was retained by Blackthorn Development Corp. on behalf of Mr. Paul Bigioni to complete a detailed water balance assessment to support the engineering design work for a proposed residential development located on the northeast corner of Fifth Concession and Sideline 4 in the City of Pickering (herein referred to as the subject lands; Figure 1). We understand the subject lands consist of approximately 18 ha of vacant land with a municipal address of 3225 Fifth Concession Road (3225 Balsam Road/Sideline 4), Pickering, Ontario. The subject lands are bounded by Balsam Road/Sideline 4 to the west, natural heritage areas to the west, north and east, and a golf course (Deer Creek Golf & Banquet Facility) to the south (Figure 2). The subject lands consist of vacant/undeveloped lands that are zoned for residential use.

Carruthers Creek bisects the subject lands and flows in a southerly direction. Access to the west side of the subject lands is via Balsam Road/Sideline 4 and access to the east side is via Dexshire Drive/Fifth Concession Road (Figure 2). The subject lands are located in the jurisdiction of the Toronto and Region Conservation Authority (TRCA), with a small portion of the subject lands east of Carruthers Creek mapped within the Central Lake Ontario Conservation Authority (CLOCA).

A Preliminary Hydrogeological Site Assessment of the subject lands was prepared by GeoPro Consulting Limited (GeoPro) in 2017 to characterize the physical setting, soil and groundwater conditions. Development plans are moving forward, and Burnside has been asked to provide water balance calculations to determine the potential development impacts to the infiltration volume of the subject lands based on the latest development concept. Candevcon East Limited (CDC) has designed the stormwater management strategy for the proposed development, as detailed in the Stormwater Management Report (2023). The water balance calculations provide input to CDC for the design of Low Impact Development (LID) measures to be incorporated into the stormwater management plans.

Presented below is a summary of the physical setting of the subject lands based on the Preliminary Hydrogeological Site Assessment (GeoPro, 2017) and the detailed water balance assessment based on the proposed development plan, land use breakdown and area imperviousness values provided by CDC. Discussion regarding water balance mitigation measures is also provided.

1.0 Drainage and Topography

The subject lands are located within the Carruthers Creek subwatershed, West Lake Ontario Shoreline watershed, which drains to Lake Ontario approximately 11 km south.

Topography across the subject lands is rolling to hilly, sloping gently to the west on the east side of Carruthers Creek, and sloping gently to the south on the west side of Carruthers Creek. The valleys along Carruthers Creek are steeply to very steeply sloping. Elevations range from approximately 139 masl in the northeast corner and 137 masl in the northwest corner of the subject lands to 124 masl at the lowest point along Carruthers Creek (Figure 3).

2.0 Soil and Groundwater Conditions

The subject lands are situated within and near the northern boundary of the Iroquois Plain physiographic region, as described by Chapman and Putnam (1984) as the old shore of Lake Ontario, formerly Lake Iroquois. The South Slope physiographic region is located just north of the subject lands, consisting of mainly till plains, drumlinized in some areas, on the southern slope of the Oak Ridges Moraine. Regional surficial geology mapping published by the Ontario Geological Survey (2010) shows the east side of the subject lands as silty to sandy till and the west side as coarse textured glaciolacustrine deposits, with the Carruthers Creek valley mapped as modern alluvial deposits (Figure 4).

Hydrogeological and geotechnical investigations completed on the subject lands include the following drilling and test pit advancements:

- Six boreholes (BH101 to BH107) with depths to 5.0 m below ground surface (mbgs) (GeoPro, 2021).
- Seven boreholes (BH1 to BH7) with depths of 2.7 mbgs to 29.6 mbgs, all of which were completed as monitoring wells to permit measurement of groundwater levels (GeoPro, 2017).
- Six test pits (TP1 to TP6) with depths of 3.0 mbgs to 3.3 mbgs (V.A. Wood, 2016).
- Ten test pits (TP1 to TP10) were hand dug to depths of 0.5 mbgs (GeoPro, 2017).

The findings of the drilling and test pitting programs identified predominantly silty sand to fine sandy silt underlying 0.2 m to 0.7 m of topsoil/fill material to depth up to 11.7 m west of Carruthers Creek. Below 11.7 m are alternating deposits of sand/silt till and clayey silt till to depths of 28.4 mbgs where the weathered shale bedrock is encountered at BH7. East of Carruthers Creek, deposits of sandy silt till and clayey silt till were encountered up to depths of 7.8 m underlying 0.7 m to 1.1 m of topsoil/fill material. A 1.0 m to 1.6 m thick layer of silty sand/fine sandy silt was encountered at BH4 and BH5. Gravelly sand was identified in BH5 from 6.9 mbgs to 8.1 mbgs.

Hydraulic conductivity estimates prepared by GeoPro included estimates from grainsize analyses and single well response tests. The hydraulic conductivity estimates from grainsize analyses of 27 soil samples ranged from 1.7×10^{-8} cm/s to 9.2×10^{-4} cm/s. The hydraulic conductivity estimates from single well response tests ranged from 2.1 x 10^{-5} cm/s to 2.1 x 10^{-4} cm/s for wells screened within the fine sand and silt to fine sandy silt west of Carruthers Creek and 2.5 x 10^{-6} cm/s to 1.5 x 10^{-4} cm/s for wells screened within the sand/silt till and clayey silt till east of Carruthers Creek. It is noted that the wells installed east of Carruthers Creek were screened across various soil lithologies including thin layers of sand resulting in higher hydraulic conductivities than expected for till. A hydraulic conductivity of 3.2 x 10^{-4} cm/s was estimated at the interface between the sandy silt till and weathered shale bedrock. The hydraulic conductivity results suggest that the soils have a low to moderate permeability. Corresponding infiltration rates (and percolation times) ranged from 17 mm/hour to 50 mm/hour (12 min/cm to 35 min/cm) on the west side of the subject lands and from 12 mm/hour to 33 mm/hour (18 min/cm to >50 min/cm) on the east side of the subject lands.

A preliminary single well pumping test was completed by GeoPro in monitoring well BH7 in 2017, which included a step-drawdown test and a 55-minute constant rate pumping test with recovery monitoring. BH7 is screened at the till-weathered shale interface from 28.1 mbgs to 29.6 mbgs. The well was pumped at up to 7.8 L/min during the step test (drawdown 14.2 m) and 5.75 L/min (drawdown 11.8 m) for the constant rate test. GeoPro estimated the transmissivity of BH7 between 1.2 x 10^{-6} m^2/s and 3.7 x 10^{-6} m^2/s with a storativity of 0.024.

Preliminary groundwater monitoring data (GeoPro, 2017) identified groundwater levels between 0.27 and 1.72 mbgs within the shallow overburden aquifer across the subject lands. Artesian conditions were identified in BH7, screened at the till-weathered shale interface, with groundwater measured at 0.63 m to 0.65 m above grade.

3.0 Water Balance Calculations

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

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

where:

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

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

Precipitation (P)

The long-term average annual precipitation for the area is 872 mm based on data from the Environment Canada Oshawa WPCP climate station (Station 6155878: 43° 52’00” N, 78°

50’00” W, elevation 83.80 masl, located 16.6 km southeast of the subject lands) for the period between 1981 and 2010. Average monthly records of precipitation and temperature from this station have been used for the water balance component calculations in this study (refer to the attached Tables A-1 through A-6).

Storage (S)

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

Evapotranspiration (ET) / Evaporation (E)

Evapotranspiration and evaporation components vary based on the characteristics of the land surface cover (i.e., type of vegetation, soil moisture conditions, perviousness of surfaces, etc.). Potential evapotranspiration (PET) refers to the water loss from a vegetated surface to the atmosphere under conditions of an unlimited water supply. The actual rate of evapotranspiration (AET) is often less than the PET under dry conditions (i.e., during the summer when there is a soil moisture deficit). In this report, the monthly PET and AET have been calculated using a soil-moisture balance approach, using average temperature data and climate information adjusted to the local latitude (Tables A-1 through A-6).

Water Surplus (R + I)

The difference between the mean annual P and the mean annual ET is referred to as the water surplus. Part of the water surplus travels across the surface of the soil as surface or overland runoff and the remainder infiltrates the surficial soil.

The infiltration is comprised of two end member components: one component that moves vertically downward to the groundwater table (typically referred to as percolation, infiltration or net recharge) and a second component that moves laterally through the shallow soils (referred to as interflow) that re-emerges locally to surface (i.e., as runoff) at some short time following cessation of precipitation. As opposed to the “direct” component of surface runoff that occurs overland during precipitation or snowmelt events, shallow interflow becomes an “indirect” component of runoff. The interflow component of infiltration is not accounted for in the water balance equation cited above since it is often difficult to distinguish between interflow and deeper recharge. For the purposes of the water balance presented herein, total potential infiltration volumes are calculated.

3.1 Existing Conditions

Water balance calculations were completed using a soil-moisture balance approach, which assumes that soils do not release water as potential recharge while a soil moisture deficit exists. During wetter periods, any excess of precipitation over evapotranspiration first goes to restore soil moisture. Once the soil moisture deficit is overcome, any further excess water can then pass through the soil as infiltration.

Due to predominantly different surficial soils on the west and east sides of the subject lands, different soil moisture storage capacity estimates were used for each area. For the sandy loam soils on the west side of the subject lands a soil moisture storage capacity of 150 mm was selected for undeveloped pasture/shrub lands (Table A-1) and 300 mm was selected for wooded lands (Table A-2). For the sandy silt till soils on the east side of the subject lands a soil moisture storage capacity of 250 mm was selected for undeveloped pasture/shrub lands (Table A-4) and 400 mm was selected for wooded lands (Table A-5). Tables A-1, A-2, A-4 and A-5 detail the monthly potential evapotranspiration calculations accounting for latitude and climate, and the actual evapotranspiration and water surplus components of the water balance based on the monthly precipitation and soil moisture conditions.

The SWM Planning and Design Manual (MOE, 2003) methodology for calculating total infiltration based on topography, soil type and land cover was used and a corresponding runoff component was calculated for the soil moisture storage conditions.

The monthly water balance calculations show that a water surplus is generally available from December to May (Tables A-1, A-2, A-4 and A-5), depending on soil and vegetation type. Infiltration occurs during periods when there is sufficient water available to overcome the soil moisture storage requirements. In winter climates, frozen conditions affect when the actual infiltration will occur, however, the monthly balance calculations show the potential volumes available for this water balance component. The monthly calculations are summed to provide estimates of the annual water balance component values (Tables A-1, A-2, A-4 and A-5). The average annual infiltration under the existing land use conditions is estimated to range from 187 mm/year to 200 mm/year for pasture/shrub and wooded lands respectively on the west side of the subject lands, and from 133 mm/year to 147 mm/year for pasture/shrub and wooded lands respectively on the east side of the subject lands.

As summarized on Table A-7, the total area of the subject lands is about 17.9 ha. The water balance component values from Tables A-1, A-2, A-4 and A-5 were used to calculate the average annual volume of infiltration under existing conditions. Based on these component values, the average pre-development infiltration volume is estimated to be about 30,600 m^3/year (Table A-7).

3.2 Potential Development Impacts to Water Balance

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 limit infiltration of water into the soils and the removal of the vegetation removes the evapotranspiration component of the natural water balance. The evaporation component from impervious surfaces is relatively minor (estimated to be about 10% to 20% of precipitation) compared to the evapotranspiration component that occurs with vegetation in this area (about 69% of precipitation in the study area). So, the net effect of the construction of impervious surfaces is that most of the precipitation that falls onto impervious surfaces becomes surplus water and direct runoff. The natural infiltration components (interflow and recharge) are reduced.

Water balance calculations of the potential water surplus for impervious areas are shown at the bottom of Table A-1. Assuming an evaporation from impervious surfaces of 15% of precipitation (131 mm), the remaining 85% of the precipitation that falls on impervious surfaces is assumed to become runoff (741 mm/year).

It is noted that the proposed development will be serviced by municipal water supply, so there will be no impact on the water balance and local groundwater quantity conditions related to any on-site groundwater supply pumping.

3.3 Post-Development Infiltration With No LID Measures

In order to assess the potential development impact on the water balance, the post-development infiltration volumes have been calculated for the subject lands on Table A-7. These calculations assume no LID measures are in place and thus represent a 'worst-case scenario' of potential development impacts on the water balance. These calculations allow for the quantification of an infiltration target for LID design to maintain the natural water balance conditions.

The total areas for the proposed land uses have been estimated based on the proposed development concept and the infiltration and runoff components for the post-development land uses have been calculated based on topography, soil type and land cover as shown on Tables A-3 and A-6 for the west and east sides of the subject lands, respectively.

Comparison of the pre-development and post-development infiltration (with no LID) volumes shows that development has the potential to reduce the natural infiltration across the subject lands by approximately 1,300 m^3/year, or 4% (Table A-7). In order to match the pre-development infiltration volume, the difference between the pre- and post-development conditions becomes a useful "infiltration target" for the LID measures. It is noted that with the wide margins of error associated with this type of analysis, this infiltration deficit volume is considered only as a reasonable estimate that is suitable as a target or guide for the LID strategy design, and not an exact value that must be met.

3.4 Water Balance Mitigation Strategies

CDC has designed the stormwater management system for the proposed development, as detailed in the Stormwater Management Report (CDC, 2023). To minimize changes to the water balance, best management practices and LID measures are proposed for the subject lands including the following:

- Extra depth topsoil has been proposed across the development. This is a measure intended to 'hold on' to more stormwater, to delay runoff and allow more opportunity for infiltration to occur. It is noted that extra depth topsoil is not a LID measure that is quantified in the water balance calculations.

- The rear half of roofs for single house lots (3,516 m^2) will be disconnected and directed to rear lawn areas. Directing the extra water to pervious areas maximizes the potential for infiltration in these areas. As per the estimation provided in the Low Impact Development Stormwater Management Planning and Design Guide (CVC and TRCA, 2010), and the type of surficial soils encountered on the subject lands, it is assumed that where rear roof areas are directed to pervious areas, 50% of the roof runoff will infiltrate in the pervious areas located in sandy soil (west of Carruthers Creek) and 25% of the roof runoff will infiltrate in the pervious areas located in till soils (east of Carruthers Creek).

3.5 Post-Development Infiltration With LID Measures in Place

Table A-8 outlines the calculations made for the subject lands with LID measures in place. Comparing the pre-development infiltration volume to the post-development infiltration volume with LID measures in place, the water balance is maintained. This shows the significant benefit of the proposed LID measures in increasing recharge volumes within the developed area (Table A-8).

We trust this is the information you require at this time. If you have questions, please do not hesitate to call.

Yours truly,

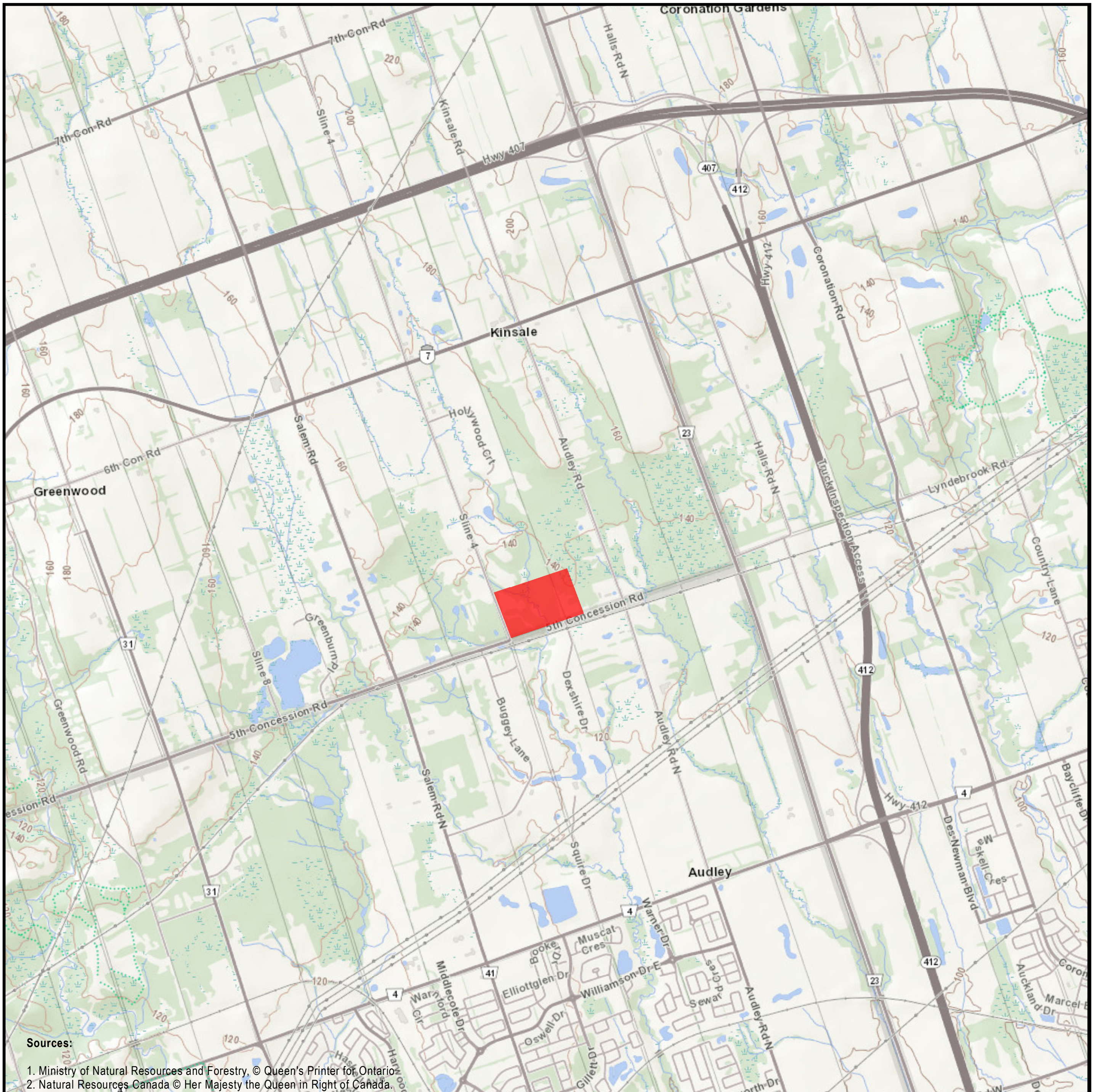
R.J. Burnside & Associates Limited

Angela Mason, M.Sc., P.Geo.
Hydrogeologist
AM:cl

Travis Mikel, P.Geo.
Senior Hydrogeologist

Enclosure(s)

cc: Andrea Keeping, P.Eng., Candevcon East Limited (enc.) (Via: Email (akeeping@candevcon.com))



LEGEND

SUBJECT LANDS

0 250 500 1,000 1,500 2,000 2,500
Metres

N

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FRISQUE LANDS
PICKERING, ONTARIO

WATER BALANCE ASSESSMENT

Figure Title:

SITE LOCATION

Drawn	Checked	Date	Figure No.
SK	AM	FEBRUARY 2023	1
Scale		Project No.	
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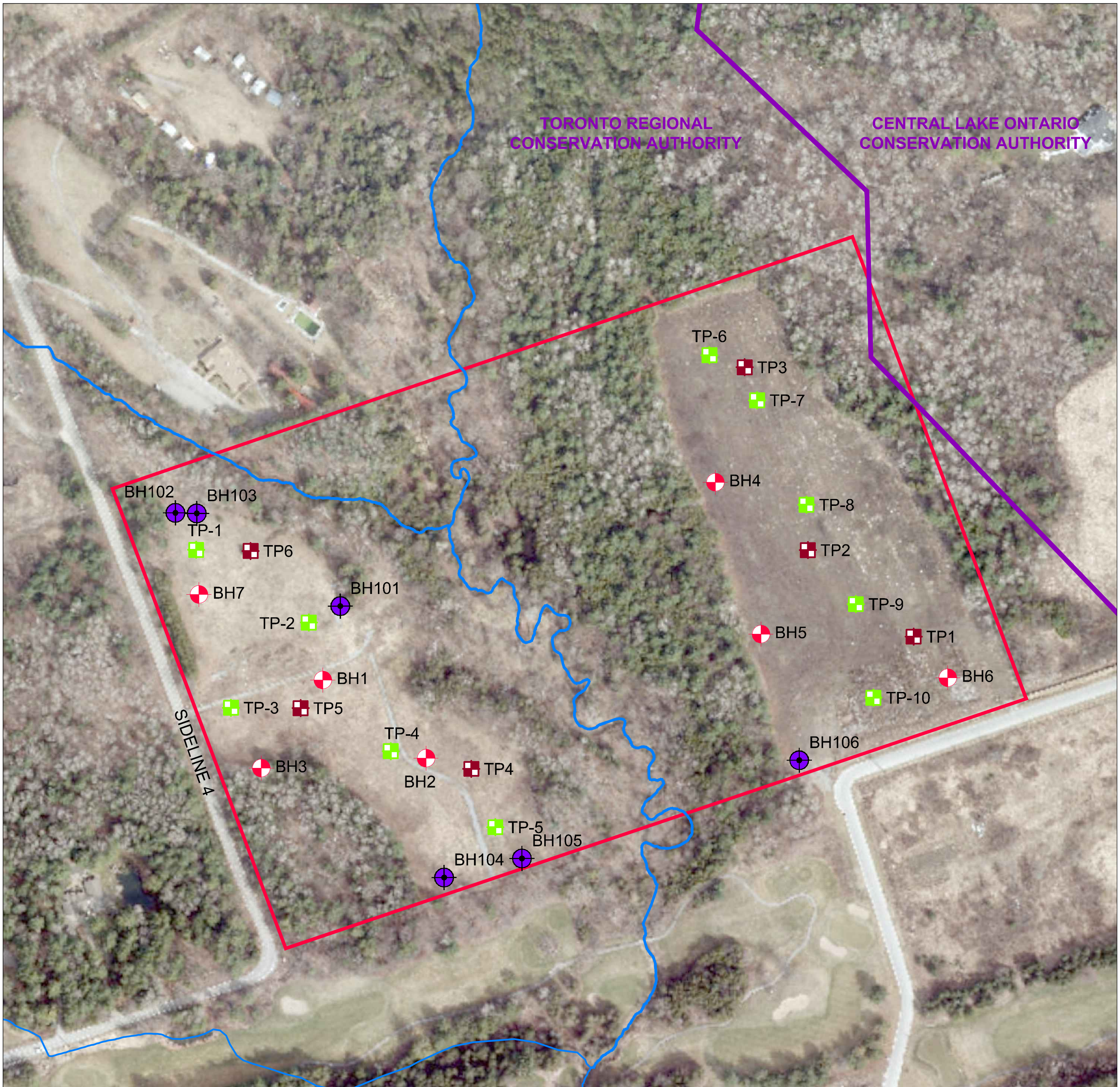
Path:Nigel/Shared Work Areas/ A:\056041 Frisque Lands\06_GIS\056041 Site Location.mxd Date Saved: Sunday, November 20, 2022



LEGEND

- SUBJECT LANDS
- WATERCOURSE
- CONSERVATION AUTHORITY BOUNDARY
- MONITORING WELL (GeoPro, 2017)
- TEST PIT (VA WOOD, 2017)
- TEST PIT (GeoPro, 2017)
- BOREHOLE (GeoPro, 2022)

0 25 50 100 150 200 250 300

Metres

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WATER BALANCE ASSESSMENT

Figure Title

SITE PLAN

Drawn	Checked	Date	Figure No.
SK	AM	FEBRUARY 2023	2
Scale		Project No.	
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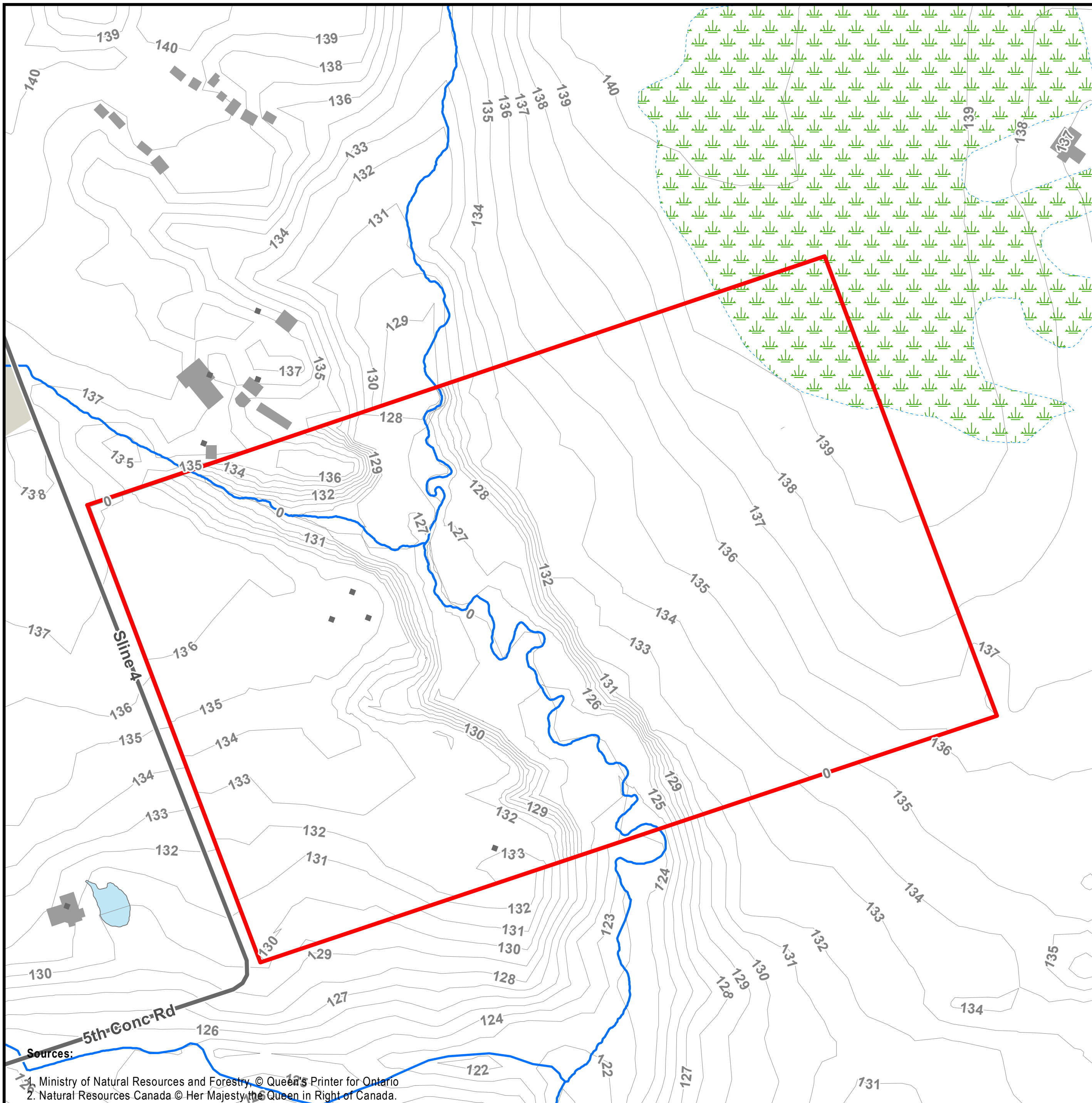
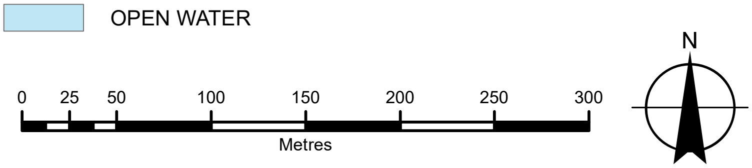
File: Nigel/Shared Work Area/ A:\056041 Frisque Lands\02_Production\056041 Site Plan.dwg Date Plotted: February 2, 2023 - 11:25 AM



LEGEND

- SUBJECT LANDS
- CONTOUR (1m intervals - masl)
- BUILDING
- ROADWAY
- WATERCOURSE - PERMANENT
- WATERCOURSE - INTERMITTENT
- WETLAND
- OPEN WATER



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PICKERING, ONTARIO

WATER BALANCE ASSESSMENT

Figure Title:

TOPOGRAPHY AND DRAINAGE

Drawn	Checked	Date	Figure No.
SK	AM	FEBRUARY 2023	3
Scale		Project No.	
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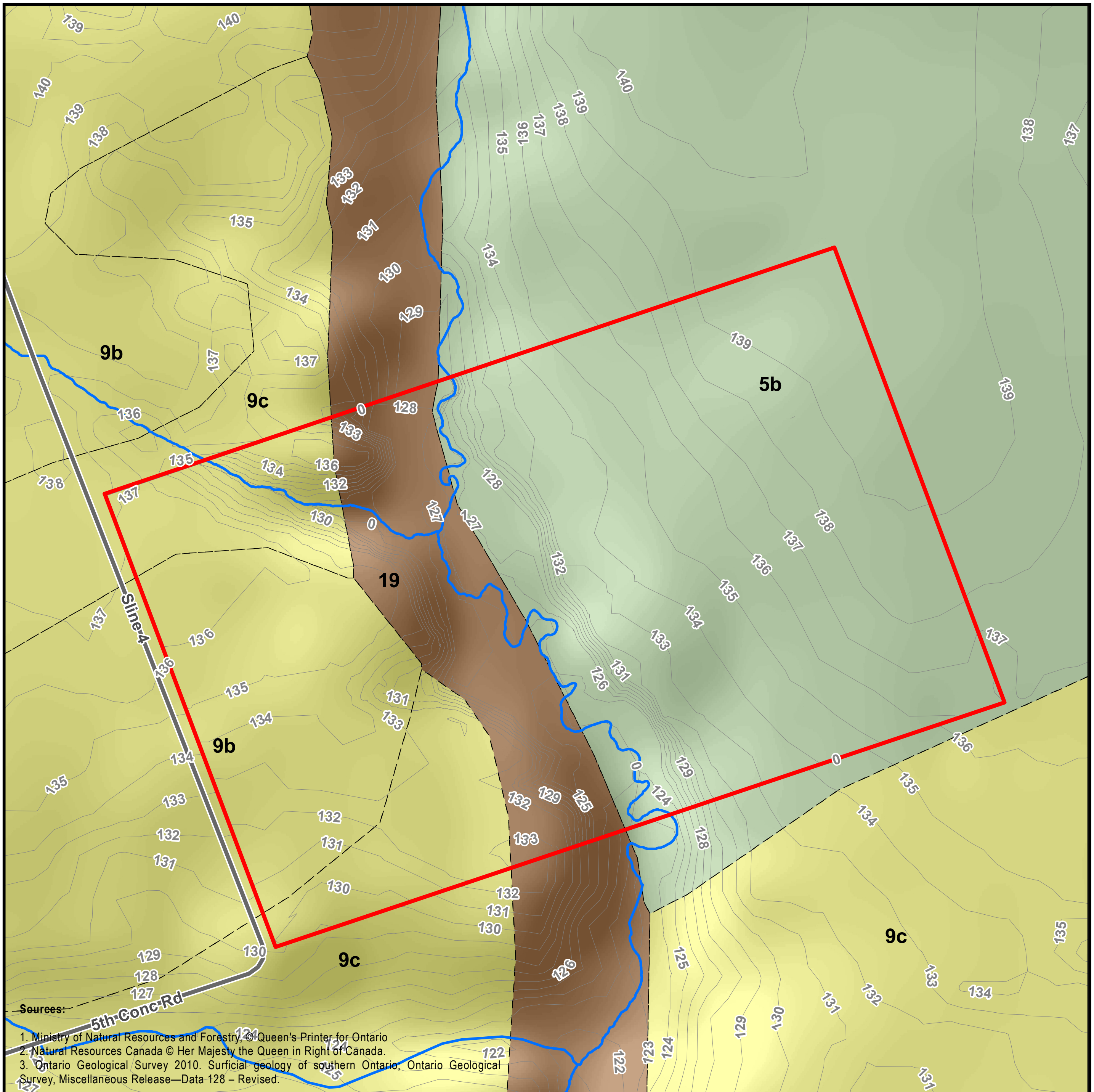

LEGEND

- SUBJECT LANDS
- CONTOUR (1m intervals - masl)
- ROADWAY
- WATERCOURSE
- 5b: Till: Stone-poor, carbonate-derived silty to sandy till
- 9b: Coarse-textured glaciolacustrine deposits: Littoral-foreshore deposits
- 9c: Coarse-textured glaciolacustrine deposits: Foreshore-basinal deposits
- 19: Modern alluvial deposits

0 25 50 100 150 200 250 300
Metres

N

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WATER BALANCE ASSESSMENT

Figure Title:

SURFICIAL GEOLOGY

Drawn	Checked	Date	Figure No.
SK	AM	FEBRUARY 2023	4
Scale		Project No.	
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TABLE A-1

Pre-Development Monthly Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 150 mm (pasture and shrubs in sandy loam soils)

Precipitation data from Oshawa WPCP Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-4.80	-3.60	0.40	6.60	12.30	17.60	20.60	20.00	15.90	9.50	4.20	-1.20	**8.1**
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.02	1.52	3.91	6.72	8.53	8.16	5.76	2.64	0.77	0.00	**38.0**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	1.36	29.28	57.92	85.79	101.94	98.69	76.75	43.64	17.84	0.00	**513**
Adjusting Factor for U (Latitude 43^{o} 40' N)	0.81	0.82	1.02	1.13	1.27	1.29	1.3	1.2	1.04	0.95	0.8	0.76	
Adjusted Potential Evapotranspiration PET (mm)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	66	57	54	73	79	74	73	77	94	70	85	71	**872**
Potential Evapotranspiration (PET)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
P - PET	66	57	53	40	5	-37	-59	-41	14	29	71	71	**267**
Change in Soil Moisture Storage	0	0	0	0	0	-37	-59	-41	14	29	71	24	**0**
Soil Moisture Storage max 150 mm	150	150	150	150	150	113	54	13	27	56	126	150	
Actual Evapotranspiration (AET)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
Soil Moisture Deficit max 150 mm	0	0	0	0	0	37	96	137	123	94	24	0	
Water Surplus - available for infiltration or runoff	66	57	53	40	5	0	0	0	0	0	0	47	**267**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	49	42	40	30	4	0	0	0	0	0	0	35	**200**
Potential Direct Surface Water Runoff (independent of temperature)	16	14	13	10	1	0	0	0	0	0	0	12	**67**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	872	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	131	mm/year											
P-PE (surplus available for runoff from impervious areas)	741	mm/year											

Assume January storage is 100% of Soil Moisture Storage

Soil Moisture Storage (pasture/shrubs in fine sandy loam) 150 mm <-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003

*MOE SWM infiltration calculations		
topography - rolling land	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - silty sand (open sandy loam)	0.4	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - cultivated lands	0.15	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.75**	

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

TABLE A-2

Pre-Development Monthly Water Balance Components

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

Precipitation data from Oshawa WPCP Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-4.80	-3.60	0.40	6.60	12.30	17.60	20.60	20.00	15.90	9.50	4.20	-1.20	**8.1**
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.02	1.52	3.91	6.72	8.53	8.16	5.76	2.64	0.77	0.00	**38.0**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	1.36	29.28	57.92	85.79	101.94	98.69	76.75	43.64	17.84	0.00	**513**
Adjusting Factor for U (Latitude 43^{o} 40' N)	0.81	0.82	1.02	1.13	1.27	1.29	1.3	1.2	1.04	0.95	0.8	0.76	
Adjusted Potential Evapotranspiration PET (mm)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	66	57	54	73	79	74	73	77	94	70	85	71	**872**
Potential Evapotranspiration (PET)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
P - PET	66	57	53	40	5	-37	-59	-41	14	29	71	71	**267**
Change in Soil Moisture Storage	0	0	0	0	0	-37	-59	-41	14	29	71	24	**0**
Soil Moisture Storage max 300 mm	300	300	300	300	300	263	204	163	177	206	276	300	
Actual Evapotranspiration (AET)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
Soil Moisture Deficit max 300 mm	0	0	0	0	0	37	96	137	123	94	24	0	
Water Surplus - available for infiltration or runoff	66	57	53	40	5	0	0	0	0	0	0	47	**267**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	49	42	40	30	4	0	0	0	0	0	0	35	**200**
Potential Direct Surface Water Runoff (independent of temperature)	16	14	13	10	1	0	0	0	0	0	0	12	**67**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	872	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	131	mm/year											
P-PE (surplus available for runoff from impervious areas)	741	mm/year											

Assume January storage is 100% of Soil Moisture Storage
Soil Moisture Storage (mature forests in fine sandy loam) 300 mm <-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003

*MOE SWM infiltration calculations

topography - rolling to hilly land	0.15	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - silty sand (open sandy loam)	0.4	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - wooded lands	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.75**	

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

TABLE A-3

Post-Development Monthly Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 75 mm (urban lawns in sandy loam soils) - graded

Precipitation data from Oshawa WPCP Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-4.80	-3.60	0.40	6.60	12.30	17.60	20.60	20.00	15.90	9.50	4.20	-1.20	**8.1**
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.02	1.52	3.91	6.72	8.53	8.16	5.76	2.64	0.77	0.00	**38.0**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	1.36	29.28	57.92	85.79	101.94	98.69	76.75	43.64	17.84	0.00	**513**
Adjusting Factor for U (Latitude 43^{o} 40' N)	0.81	0.82	1.02	1.13	1.27	1.29	1.3	1.2	1.04	0.95	0.8	0.76	
Adjusted Potential Evapotranspiration PET (mm)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	66	57	54	73	79	74	73	77	94	70	85	71	**872**
Potential Evapotranspiration (PET)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
P - PET	66	57	53	40	5	-37	-59	-41	14	29	71	71	**267**
Change in Soil Moisture Storage	0	0	0	0	0	-37	-38	0	14	29	32	0	**0**
Soil Moisture Storage max 75 mm	75	75	75	75	75	38	0	0	14	43	75	75	
Actual Evapotranspiration (AET)	0	0	1	33	74	111	111	77	80	41	14	0	**543**
Soil Moisture Deficit max 75 mm	0	0	0	0	0	37	75	75	61	32	0	0	
Water Surplus - available for infiltration or runoff	66	57	53	40	5	0	0	0	0	0	38	71	**329**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	49	42	40	30	4	0	0	0	0	0	29	53	**247**
Potential Direct Surface Water Runoff (independent of temperature)	16	14	13	10	1	0	0	0	0	0	10	18	**82**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	872	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	131	mm/year											
P-PE (surplus available for runoff from impervious areas)	741	mm/year											

Assume January storage is 100% of Soil Moisture Storage

Soil Moisture Storage (urban lawns in fine sandy loam) 75 mm <-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003

*MOE SWM infiltration calculations

topography - rolling, graded	0.25	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - silty sand (open sandy loam)	0.4	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - urban lawns	0.1	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.75**	

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

TABLE A-4

Pre-Development Monthly Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 250 mm (pasture and shrubs in silt to sandy silt till soils)

Precipitation data from Oshawa WPCP Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-4.80	-3.60	0.40	6.60	12.30	17.60	20.60	20.00	15.90	9.50	4.20	-1.20	**8.1**
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.02	1.52	3.91	6.72	8.53	8.16	5.76	2.64	0.77	0.00	**38.0**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	1.36	29.28	57.92	85.79	101.94	98.69	76.75	43.64	17.84	0.00	**513**
Adjusting Factor for U (Latitude 43^{o} 40' N)	0.81	0.82	1.02	1.13	1.27	1.29	1.3	1.2	1.04	0.95	0.8	0.76	
Adjusted Potential Evapotranspiration PET (mm)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	66	57	54	73	79	74	73	77	94	70	85	71	**872**
Potential Evapotranspiration (PET)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
P - PET	66	57	53	40	5	-37	-59	-41	14	29	71	71	**267**
Change in Soil Moisture Storage	0	0	0	0	0	-37	-59	-41	14	29	71	24	**0**
Soil Moisture Storage max 250 mm	250	250	250	250	250	213	154	113	127	156	226	250	
Actual Evapotranspiration (AET)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
Soil Moisture Deficit max 250 mm	0	0	0	0	0	37	96	137	123	94	24	0	
Water Surplus - available for infiltration or runoff	66	57	53	40	5	0	0	0	0	0	0	47	**267**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	36	31	29	22	3	0	0	0	0	0	0	26	**147**
Potential Direct Surface Water Runoff (independent of temperature)	30	25	24	18	2	0	0	0	0	0	0	21	**120**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	872	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	131	mm/year											
P-PE (surplus available for runoff from impervious areas)	741	mm/year											

Assume January storage is 100% of Soil Moisture Storage

Soil Moisture Storage (pasture/shrubs in silt loam)	250 mm	<-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003
*MOE SWM infiltration calculations		
topography - rolling land	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - silt to sandy silt till (medium combinations of clay and loam)	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - cultivated lands	0.15	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.55**	
Latitude of site (or climate station)	44 ^{O} N	

TABLE A-5

Pre-Development Monthly Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 400 mm (wooded lands in silt to sandy silt till soils)

Precipitation data from Oshawa WPCP Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-4.80	-3.60	0.40	6.60	12.30	17.60	20.60	20.00	15.90	9.50	4.20	-1.20	**8.1**
Heat index: $i = (t/5)^{1.514}$	0.00	0.00	0.02	1.52	3.91	6.72	8.53	8.16	5.76	2.64	0.77	0.00	**38.0**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	1.36	29.28	57.92	85.79	101.94	98.69	76.75	43.64	17.84	0.00	**513**
Adjusting Factor for U (Latitude 43^{o} 40' N)	0.81	0.82	1.02	1.13	1.27	1.29	1.3	1.2	1.04	0.95	0.8	0.76	
Adjusted Potential Evapotranspiration PET (mm)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	66	57	54	73	79	74	73	77	94	70	85	71	**872**
Potential Evapotranspiration (PET)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
P - PET	66	57	53	40	5	-37	-59	-41	14	29	71	71	**267**
Change in Soil Moisture Storage	0	0	0	0	0	-37	-59	-41	14	29	71	24	**0**
Soil Moisture Storage max 400 mm	400	400	400	400	400	363	304	263	277	306	376	400	
Actual Evapotranspiration (AET)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
Soil Moisture Deficit max 400 mm	0	0	0	0	0	37	96	137	123	94	24	0	
Water Surplus - available for infiltration or runoff	66	57	53	40	5	0	0	0	0	0	0	47	**267**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	36	31	29	22	3	0	0	0	0	0	0	26	**147**
Potential Direct Surface Water Runoff (independent of temperature)	30	25	24	18	2	0	0	0	0	0	0	21	**120**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	872	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	131	mm/year											
P-PE (surplus available for runoff from impervious areas)	741	mm/year											

Assume January storage is 100% of Soil Moisture Storage

Soil Moisture Storage (mature forests in silt loam) 400 mm <-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003

*MOE SWM infiltration calculations

topography - rolling to hilly land	0.15	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - silt to sandy silt till (medium combinations of clay and loam)	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - wooded lands	0.2	<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.55**	

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

TABLE A-6

Post-Development Monthly Water Balance Components

Based on Thornthwaite's Soil Moisture Balance Approach with a Soil Moisture Retention of 125 mm (urban lawns in silt to sandy silt till soils) - graded

Precipitation data from Oshawa WPCP Climate Station (1981 - 2010)

Potential Evapotranspiration Calculation	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Average Temperature (Degree C)	-4.80	-3.60	0.40	6.60	12.30	17.60	20.60	20.00	15.90	9.50	4.20	-1.20	**8.1**
Heat index: i = $(t/5)^{1.514}$	0.00	0.00	0.02	1.52	3.91	6.72	8.53	8.16	5.76	2.64	0.77	0.00	**38.0**
Unadjusted Daily Potential Evapotranspiration U (mm)	0.00	0.00	1.36	29.28	57.92	85.79	101.94	98.69	76.75	43.64	17.84	0.00	**513**
Adjusting Factor for U (Latitude 43^o 40' N)	0.81	0.82	1.02	1.13	1.27	1.29	1.3	1.2	1.04	0.95	0.8	0.76	
Adjusted Potential Evapotranspiration PET (mm)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
COMPONENTS	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**YEAR**
Precipitation (P)	66	57	54	73	79	74	73	77	94	70	85	71	**872**
Potential Evapotranspiration (PET)	0	0	1	33	74	111	133	118	80	41	14	0	**605**
P - PET	66	57	53	40	5	-37	-59	-41	14	29	71	71	**267**
Change in Soil Moisture Storage	0	0	0	0	0	-37	-59	-29	14	29	71	12	**0**
Soil Moisture Storage max 125 mm	125	125	125	125	125	88	29	0	14	43	113	125	
Actual Evapotranspiration (AET)	0	0	1	33	74	111	133	106	80	41	14	0	**593**
Soil Moisture Deficit max 125 mm	0	0	0	0	0	37	96	125	111	82	12	0	
Water Surplus - available for infiltration or runoff	66	57	53	40	5	0	0	0	0	0	0	59	**279**
Potential Infiltration (based on MOE metholodogy*; independent of temperature)	36	31	29	22	3	0	0	0	0	0	0	32	**153**
Potential Direct Surface Water Runoff (independent of temperature)	30	25	24	18	2	0	0	0	0	0	0	27	**126**
IMPERVIOUS AREA WATER SURPLUS													
Precipitation (P)	872	mm/year											
Potential Evaporation (PE) from impervious areas (assume 15%)	131	mm/year											
P-PE (surplus available for runoff from impervious areas)	741	mm/year											

Assume January storage is 100% of Soil Moisture Storage

Soil Moisture Storage (urban lawns in silt loam)	125	mm	<-- See "Water Holding Capacity" values in Table 3.1, MOE SWMPDM, 2003
*MOE SWM infiltration calculations			
topography - rolling, graded	0.25		<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
soils - silt to sandy silt till (medium combinations of clay and loam)	0.2		<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
cover - urban lawns	0.1		<-- Infiltration Factors from the bottom section of Table 3.1, MOE SWMPDM, 2003
Infiltration factor	**0.55**		
Latitude of site (or climate station)	44 ^{O} N		

TABLE A-7

Land Use**	Soil Type	Approx. Land Area (m^2)**	Estimated Impervious Fraction for Land Use**	Estimated Impervious Area (m^2)	Runoff from Impervious Area* (m/a)	Runoff Volume from Impervious Area (m^3/a)	Estimated Pervious Area (m^2)	Runoff from Pervious Area* (m/a)	Runoff Volume from Pervious Area (m^3/a)	Infiltration from Pervious Area* (m/a)	Infiltration Volume from Pervious Area (m^3/a)	Total Runoff Volume (m^3/a)	Total Infiltration Volume (m^3/a)
Frisque Lands Water Balance - Existing Conditions and Post-Development with No Mitigation													
Existing Land Use													
Undeveloped Pasture / Shrub Lands (West)	Sandy Loam	58,500	0.00	0	0.741	0	58,500	0.067	3,902	0.200	11,706	3,902	11,706
Wooded Lands (West)	Sandy Loam	22,100	0.00	0	0.741	0	22,100	0.067	1,474	0.200	4,422	1,474	4,422
Undeveloped Pasture / Shrub Lands (East)	Sandy Silt Till	61,600	0.00	0	0.741	0	61,600	0.120	7,396	0.147	9,039	7,396	9,039
Wooded Lands (East)	Sandy Silt Till	36,800	0.00	0	0.741	0	36,800	0.120	4,418	0.147	5,400	4,418	5,400
TOTAL PRE-DEVELOPMENT		**179,000**	**-**	**0**		**0**	**179,000**	**-**	**17,190**	**-**	**30,568**	**17,190**	**30,568**
Post-Development Land Use													
Open Space & Buffer Area (Pasture/Shrub - West)	Sandy Loam	32,500	0.00	0	0.741	0	32,500	0.067	2,168	0.200	6,503	2,168	6,503
Wooded Lands (West)	Sandy Loam	22,100	0.00	0	0.741	0	22,100	0.067	1,474	0.200	4,422	1,474	4,422
Residential Lots & Roadways ** (West)	Sandy Loam	26,000	0.26	6,760	0.741	5,011	19,240	0.082	1,583	0.247	4,748	6,593	4,748
Open Space & Buffer Area (Pasture/Shrub - East)	Sandy Silt Till	27,300	0.00	0	0.741	0	27,300	0.120	3,278	0.147	4,006	3,278	4,006
Wooded Lands (East)	Sandy Silt Till	36,800	0.00	0	0.741	0	36,800	0.120	4,418	0.147	5,400	4,418	5,400
Residential Lots & Roadways ** (East)	Sandy Silt Till	34,300	0.20	6,860	0.741	5,085	27,440	0.126	3,445	0.153	4,211	8,530	4,211
TOTAL POST-DEVELOPMENT		**179,000**	**-**	**13,620**	**-**	**10,095**	**165,380**	**-**	**16,366**	**-**	**29,291**	**26,461**	**29,291**
% Change from Pre to Post												154	4
Effect of development (with no mitigation)												1.5 times increase	4% reduction in infiltration
To balance pre- to post infiltration target (m^3/a)=													**1,277**

* figures from Tables A-1 through A-6

** data provided by CDC

34200 60,200

60,300 59300

TABLE A-8

Frisque Lands Water Balance - Existing Conditions and Post-Development with Mitigation (with LIDs)

Land Use	Soil Type	Approx. Land Area (m^2)**	Estimated Impervious Fraction for Land Use**	Estimated Impervious Area (m^2)	Runoff from Impervious Area* (m/a)	Runoff Volume from Impervious Area (m^3/a)	Estimated Pervious Area (m^2)	Runoff from Pervious Area* (m/a)	Runoff Volume from Pervious Area (m^3/a)	Infiltration from Pervious Area* (m/a)	Infiltration Volume from Pervious Area (m^3/a)	Total Runoff Volume (m^3/a)	Total Infiltration Volume (m^3/a)
Existing Land Use													
Undeveloped Pasture / Shrub Lands (West)	Sandy Loam	58,500	0.00	0	0.741	0	58,500	0.067	3,902	0.200	11,706	3,902	11,706
Wooded Lands (West)	Sandy Loam	22,100	0.00	0	0.741	0	22,100	0.067	1,474	0.200	4,422	1,474	4,422
Undeveloped Pasture / Shrub Lands (East)	Sandy Silt Till	61,600	0.00	0	0.741	0	61,600	0.120	7,396	0.147	9,039	7,396	9,039
Wooded Lands (East)	Sandy Silt Till	36,800	0.00	0	0.741	0	36,800	0.120	4,418	0.147	5,400	4,418	5,400
TOTAL PRE-DEVELOPMENT		**179,000**	**-**	**0**		**0**	**179,000**	**-**	**17,190**	**-**	**30,568**	**17,190**	**30,568**
Post-Development Land Use													
Open Space & Buffer Area (Pasture/Shrub - West)	Sandy Loam	32,500	0.00	0	0.741	0	32,500	0.067	2,168	0.200	6,503	2,168	6,503
Wooded Lands (West)	Sandy Loam	22,100	0.00	0	0.741	0	22,100	0.067	1,474	0.200	4,422	1,474	4,422
Residential Lots (West) – Front Roof, Driveway and Pervious areas	Sandy Loam	24,130	0.20	4,890	0.741	3,624	19,240	0.082	1,583	0.247	4,748	5,207	4,748
Residential Lots (West) – Rear Roof to grass (assume 50% of runoff volume infiltrates[a])	Sandy Loam	1,870	1.00	1,870	0.741	1,386	0	0.082	0	0.247	0	693	693
Open Space & Buffer Area (Pasture/Shrub - East)	Sandy Silt Till	27,300	0.00	0	0.741	0	27,300	0.120	3,278	0.147	4,006	3,278	4,006
Wooded Lands (East)	Sandy Silt Till	36,800	0.00	0	0.741	0	36,800	0.120	4,418	0.147	5,400	4,418	5,400
Residential Lots (East) – Front Roof, Driveway and Pervious areas	Sandy Silt Till	32,654	0.16	5,214	0.741	3,865	27,440	0.126	3,445	0.153	4,211	7,310	4,211
Residential Lots (East) – Rear Roof to grass (assume 25% of runoff volume infiltrates[a])	Sandy Silt Till	1,646	1.00	1,646	0.741	1,220	0	0.126	0	0.153	0	915	305
TOTAL POST-DEVELOPMENT		**179,000**	**-**	**13,620**	**-**	**10,095**	**165,380**	**-**	**16,366**	**-**	**29,291**	**25,463**	**30,289**
% Change from Pre to Post												148	1
Effect of development (with mitigation)												1.5 times increase	Maintains infiltration
To balance pre- to post infiltration target (m^3/a)=													**279**

* figures from Tables A-1 through A-6

** data provided by CDC

[a] based on estimation in the LID SWM Planning and Design Guide (CVC & TRCA, 2010) for hydrologic groups A, B, C & D