REPORT

Water Balance Report
Bradford Highlands Golf Course Redevelopment

Submitted to:

Bradford Highlands Joint Venture
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Submitted by:

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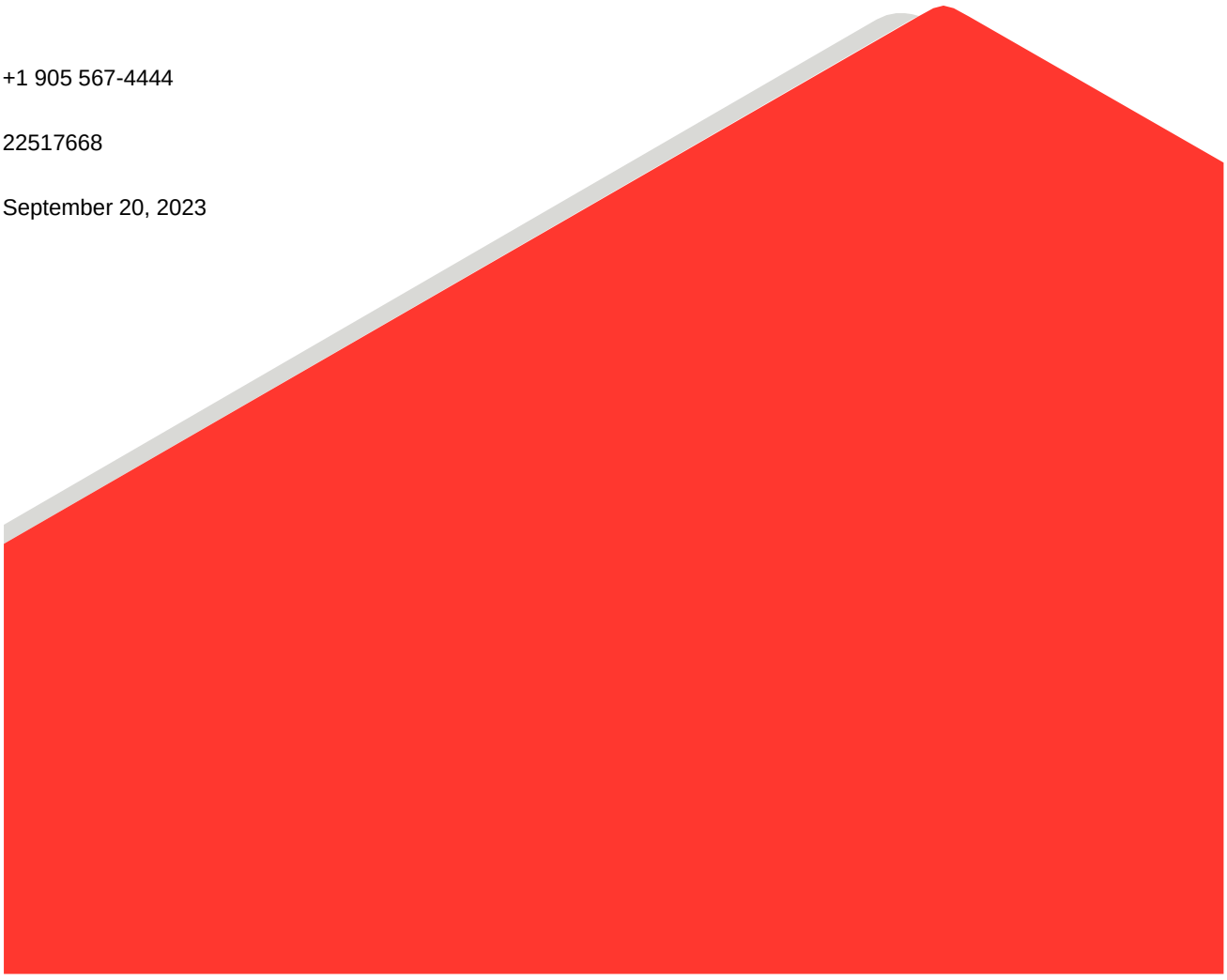

Distribution List

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1.0 INTRODUCTION

Bayview Bradford Highlands Joint Venture Inc. ('Bayview' the 'Client') has retained WSP to produce geotechnical, hydrogeological and environmental reports to accompany the Client's application for Draft Plan approval for the proposed redevelopment of the Bradford Highlands Golf Course in Bradford, Ontario (the Site). The purpose of this report is to present the water balance analysis for the pre-development and proposed post-development conditions.

2.0 BACKGROUND

The proposed residential development, hereafter referred to as the Site, is located southeast of the intersection of Concession Road 6 and Brownlee Drive, in the Town of Bradford, Ontario (Figure 1). The site was previously the location of the Bradford Highlands Golf Club; this water balance assessment is focused on the 87.7 ha proposed for the new development.

The proposed development falls within the Lake Simcoe watershed and within the jurisdiction of the Lake Simcoe Region Conservation Authority (LSRCA). The southwestern Site area flows directly to the Holland River which then discharges to Lake Simcoe. The remainder of the Site first discharges to existing drainage features which connect to the Holland River east of the Site.

A water balance assessment was carried out to compare pre- and post-development water balance conditions, including estimates of average annual infiltration and runoff volumes from the site. All assumed areas and land uses were based on the drainage area information provided in the "Stormwater Management Report, Bradford Highlands Residential Subdivision" prepared by KSGS Engineering Corp. (KSGS, 2023).

3.0 METHODOLOGY

The water balance assessment was based on meteorological data from the Meteorological Service of Canada Thornthwaite water budgets (Egbert MOE, Ontario between 1989 to 2016), watershed boundaries, land use data and the existing soil types.

Water balance calculations are based on the following equation:

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

Where:

P = precipitation;

S = change in groundwater storage;

ET = evapotranspiration;

R = surface runoff; and

I = infiltration (groundwater recharge).

Short-term or seasonal changes in soil moisture storage (S) occur during dry conditions in the summer months and relatively saturated conditions in the winter and spring. Long-term changes (e.g., year to year) in soil moisture storage are generally small and have been assumed to be zero.

Precipitation data collected at the Environment Canada (EC) Egbert MOE monitoring station (1989 to 2016) indicated a mean annual precipitation (P) of 786 mm/yr. Evapotranspiration (ET) refers to water losses from soil surfaces to the atmosphere. The term combines evaporation (i.e., water lost from the soil surface) and transpiration (i.e., water lost to plants and trees) because of the difficulties involved in separating these processes. Potential ET refers to the loss of water from a vegetated surface to the atmosphere under conditions of an unlimited water supply. The actual rate of ET is typically less than the potential rate under dry conditions (e.g., during the summer months when there is a soil moisture deficit). The mean annual potential ET for the area in question is approximately 607 mm/year based on data (Thornthwaite water budget for Egbert meteorological station) provided by Environment Canada (EC).

Annual water surplus is the difference between the annual P and the annual actual ET and represents the total amount of water, the sum of surface runoff (R) and infiltration (I), that would flow from the catchment area on an annual basis. On a monthly basis, surplus water remains after actual evapotranspiration has been removed from the sum of rainfall and snow-melt and maximum soil storage is exceeded. Maximum soil storage is quantified using a water holding capacity (WHC) specific to the soil type and land use and conceptually represents the difference in water content between the field capacity and the wilting point. The total water surplus is calculated by summing the surplus available from each WHC within the watershed. Tables following the text of this report include the EC water budget for Egbert EC information, considered for the water balance assessment.

Infiltration rates were estimated using the Ontario Ministry of Environment (MECP) Stormwater Management Planning and Design (SWM) Manual (2003). There are three factors which are considered in estimating the fraction of the total annual surplus that infiltrates beyond the surficial soil layer, the factors are topography, soil type and ground cover. The sum of the fractions representing each of these characteristics establishes the total percentage of surplus, which can be infiltrated in areas with sufficient downward gradient. Wetlands and water bodies are assumed to have an upward or negligible downward gradient, resulting in all surpluses being contained in these areas, which provide increased evaporation and limited infiltration.

3.1 Land-Use Scenarios

The site was assessed based on a single 87.7 ha catchment, reflecting the land use mapping provided in the KSGS Stormwater Management Report. The water balance analysis was completed for two scenarios:

- Pre-development examined the existing drainage patterns and mapped land uses on the study area.
- Post-development considering mitigation measures (i.e., Low Impact Development (LID) features) proposed in the stormwater management report.

Based on the borehole logs from the WSP Hydrogeological report (WSP, 2022), the soils below the topsoil layer within the footprint under pre-development conditions were generally silty clay to clayey silt. WHC and infiltration factors for the various land uses were taken from the MOE SWM Manual (MOE, 2003).

Pre-Development Land Uses

The pre-development land use for the Site is shown in Table 1. The pre-development Site reflects the recent golf-course land use.

- Forested areas were assigned a WHC of 400 mm and infiltration factor of 0.6
- Golf course areas were assigned a WHC of 100 mm and an infiltration factor of 0.4
- Undeveloped areas (i.e., areas that are neither forested nor landscaped golf course areas) were assumed as pastures and shrub areas and assigned a WHC of 250 mm and infiltration factor of 0.5

Table 1: Pre-Development Land Use

Land Use	Area (ha)	Soil	Water Holding Capacity (mm)	Infiltration Coefficient			
				Slope Factor	Soil Factor	Vegetation Factor	Total
Forest	1.7	Clay Loam	400	0.2	0.2	0.2	0.6
Pasture/Shrub	4.9	Clay Loam	250	0.2	0.2	0.1	0.5
Golf Course	81.1	Clay Loam	100	0.1	0.2	0.1	0.4

Post-Development Land Uses

The post-development land use for the site is shown in Table 2. The post-development Site reflect a mix of residential and park land uses, which has been further divided into landscaped (urban lawn), paved, roof, and pond areas.

- Landscaped areas were assigned a WHC of 100 mm and infiltration factor of 0.4
- Paved and roof areas were assumed to lose 10% of annual precipitation as evaporation, with the remainder assumed as runoff (based on guidance in from the Ontario Conservation Authorities “Hydrogeological Assessment Submissions (Ontario CAs, 2013)), with no infiltration
- Pond areas were assumed to always have water available at surface for evaporation, and the annual surplus was thus assumed as annual precipitation minus potential evaporation with no infiltration

Table 2: Post-Development Land Use

Land Use	Area (ha)	Soil	Water Holding Capacity (mm)	Infiltration Coefficient			
				Slope Factor	Soil Factor	Vegetation Factor	Total
Landscaped	49.1	Clay Loam	100	0.1	0.2	0.1	0.4
Paved	18.7	Clay Loam	(90% Precip) [1]	-	-	-	-
Roof[3]	17.1	Clay Loam	(90% Precip) [1]	-	-	-	-
Pond	2.7	Clay Loam	(Precip-PET)[2]	-	-	-	-

[1] 90% of the total precipitation is available as surplus for impervious areas based on Ontario CAs 2013

[2] Surplus for open water areas assumed as Precipitation minus Potential Evapotranspiration

[3] Includes roof area directed towards infiltration Low Impact Development features discussed below

Low Impact Development

As part of the land uses described above, the current development plan proposes to collect and infiltrate the first 45 mm of collected rainfall from 1.9 ha of rooftops (as described in the Draft Stormwater Management Report (KSGS Engineering Corp., 2023). The runoff capture and infiltration for these features was estimated by taking the daily precipitation at the Egbert station for the available period of record (2001 to 2021), estimating daily rainfall (assumed as precipitation on days when the mean temperature was above zero), subtracting an initial 1 mm initial abstraction, and assuming the capture of up to 45 mm for any assumed rainfall above that 1 mm amount. The results suggested that a system designed to thus capture and infiltrate the first 45 mm of runoff event would provide approximately 505.8 mm/yr infiltration for that area.

4.0 RESULTS

Results from the pre-development and post-development scenarios are described below.

4.1 Pre-Development Scenario

Results from the pre-development scenario are shown in Table 3 below. Of the 689,000 m^3/yr precipitation over the Site, 473,000 m^3/yr is lost as evapotranspiration, with the remaining 211,000 m^3/yr surplus being divided into 86,000 m^3/yr infiltration and 125,000 m^3/yr runoff.

4.2 Post-Development Scenario

Results from the pre-development scenario are shown in Table 4 below. The precipitation is the same as the pre-development scenario, however the increase in hard surfaces results in decreased evapotranspiration losses and increase in surplus to 379,000 m^3/yr (an increase of 168,000 m^3/yr or 80% compared to the pre-development scenario). Despite the infiltration features (which provide 9,000 m^3/yr infiltration), the increase in hard surfaces likewise results in a decrease in post-development infiltration to 57,000 m^3/yr (a decrease of 29,000 m^3/yr or 34% compared to the pre-development scenario). The post-development runoff meanwhile increases to 322,000 m^3/yr (197,000 m^3/yr or 158% above pre-development conditions).

Table 3: Pre-Development Water Balance Results

Land Use	Area (ha)	WHC (mm)	Precipitation		Actual Evap.		Surplus		Infiltration		Runoff	
			(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)
Forest	1.7	400	786	13,000	605	10,000	177	3,000	106	2,000	71	1,000
Pasture/Shrub	4.9	250	786	39,000	593	29,000	192	9,000	96	5,000	96	5,000
Golf Course / Urban Lawn	81.1	100	786	637,000	536	434,000	245	199,000	98	79,000	147	119,000
Total	87.7			689,000		473,000		211,000		86,000		125,000

Table 4: Post-Development Water Balance Results

Land Use	Area (ha)	WHC (mm)	Precipitation		Actual Evap.		Surplus		Infiltration		Runoff	
			(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)	(mm/yr)	(m^3/yr)
Landscaped	49.1	100	786	386,000	536	263,000	245	120,000	98	48,000	147	72,000
Paved Road	18.7	(90% Precip)[1]	786	147,000	79	15,000	707	133,000	0	0	707	133,000
Roof	15.2	(90% Precip)[1]	786	120,000	79	12,000	707	108,000	0	0	707	108,000
Roof to Infiltration	1.9	(90% Precip)[1]	786	15,000	79	1,000	707	13,000	506	9,000	202	4,000
Pond	2.7	(Precip-PET)[2]	786	21,000	607	16,000	179	5,000	0	0	179	5,000
Total	87.7			689,000		**307,000**		**379,000**		**57,000**		**322,000**

[1] 90% of the total precipitation is available as surplus for impervious areas based on Ontario CAs 2013

[2] Surplus for open water areas assumed as Precipitation minus Potential Evapotranspiration

5.0 CONCLUSIONS

The water balance assessment for the pre-development and post-development scenarios for the Bradford Highlands Site demonstrates that the proposed development will result in a 34% decrease in average annual infiltration and 158% increase in average annual runoff from the Site. These changes take into account the proposed infiltration features for the site, assuming the designs capture the stated 45 mm runoff from the 1.9 ha of rooftop area.

Signature Page

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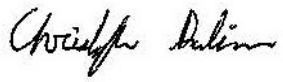

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Water Resources Engineer

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Principal, Senior Water Resources Engineer

CD/DK/KMM/mp

REFERENCES

KSGS Engineering Corp., “Stormwater Management Report, Bradford Highlands Residential Subdivision. Town of Bradford West Gwillimbury”, July 2023.

Ontario Ministry of the Environment (MECP), “Stormwater Management Planning and Design Manual”, 2003.

WSP, “Preliminary Hydrogeological Assessment, Proposed Residential Subdivision, Bradford Highlands Golf Course”, October 2022.

FIGURE

LEGEND

- APPROXIMATE SITE BOUNDARY
- APPROXIMATE MNR NATURAL HERITAGE BOUNDARY

0 100 200
1:6,000 METRES

REFERENCE(S)

BASE DATA - MNR LIO, OBTAINED 2015

PRODUCED BY GOLDER ASSOCIATES LTD UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2017

BOREHOLE LOCATION SURVEY: RADY-PENTEK & EDWARD SURVEYING LTD., JULY 28, 2016

PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

BASE IMAGERY SOURCE: SIMCOE COUNTY GIS, 2016

CLIENT
BRADFORD HIGHLAND JOINT VENTURE

PROJECT
WATER BALANCE ASSESSMENT
BRADFORD HIGHLANDS GOLF COURSE

TITLE
PRE-DEVELOPMENT FIGURE

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-02-22
PREPARED	SB
DESIGN	SB
REVIEW	
APPROVED	

PROJECT No. 1543120 | CONTROL | Rev. | FIGURE 1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

0 25 mm

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