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Hydrologic Impact Study

Wildpine Trails

J.L.Richards
ENGINEERS · ARCHITECTS · PLANNERS

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1.0 Introduction

1.1 Purpose

J.L. Richards & Associates Ltd (JLR) has been retained by Latitude Homes Inc (LHI) to prepare this Hydrological Impact Study (HIS) in support of the site plan application for the development known as Wildpine Trails at 37 Wildpine Court in Ottawa.

The need for an HIS is triggered by the location of the development being within a 30 metres setback from a wetland. The setback was jointly agreed upon between the biologists from the Mississippi Valley Conservation Authority (MVC) and Kilgour & Associates Limited (KAL). The Hydrological Impact Study is, therefore, a requirement of application approval by the MVC and City of Ottawa. The HIS is required to identify the impact, if any, to the wetland and identify, if required, any proposed mitigation measures necessary to minimize the impacts to the wetland.

This HIS should be read in conjunction with the Environmental Impact Statement for the site prepared by KAL.

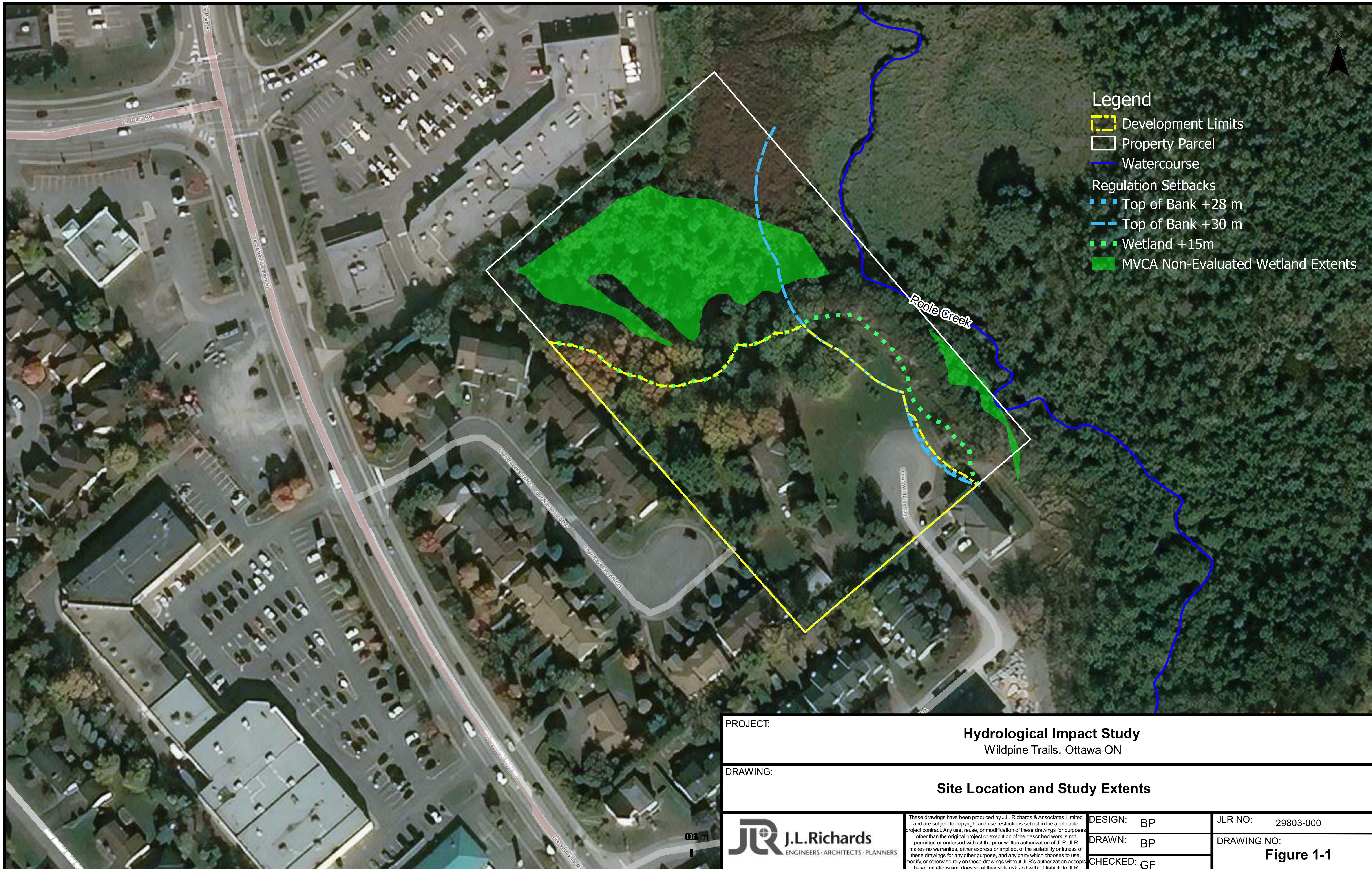
1.2 Site Description

The Wildpine Trails development site is approximately 2 hectares and bounded by existing residential properties on Wildpine Court and Ravenscroft Court to the south and west respectively, a shopping plaza to the northwest and Poole Creek and the Stittsville Wetland Complex to the northeast and east.

Located on the site is a gravelled cul-de-sac turning area connected along the southern boundary to Wildpine Court, a single detached residential property with separate garage and shed buildings. Around the residential property and turning area is an open lawn area but the majority of the site is forested.

Part of the site is within the regulated floodplain of Poole Creek and/or the regulated limits of the non-evaluated wetland. The HIS will focus on the water balance on the extent of the site which can potentially be subject to development and that will potentially impact the operation of the wetland.

The development site as a whole and study extents, referred to as 'the site' for this report, are shown in Figure 1-1.



PROJECT:

Hydrological Impact Study

Wildpine Trails, Ottawa ON

DRAWING:

Site Location and Study Extents

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2.0 Existing Conditions

2.1 Land Cover

The current site is divided into two (2) distinct land cover areas. The northern portion of the site is predominately forested with deciduous trees while the southern portion has open lawn space, a gravelled turning area and a single storey residential building with separate garage and shed. Given that the site has been in this condition since at least 1991, according to available aerial photography, then the current site land cover will be considered as existing condition.

2.2 Soil Conditions

EXP Geotechnical Engineers visited the site to undertake geotechnical investigations. Between visits in December 2020 and May 2021, 18, test holes have been dug across the site including 4 boreholes and 12 test pits. Groundwater levels were recorded when observed during each of the visits and infiltration testing was undertaken at five (5) locations during the visit in May 2021. The testing was consistent with the recommendations of the CVC/TRCA's publication entitled "Low Impact Development – Stormwater Management Planning and Design Guide, 2010". A report was prepared by EXP detailing the soil conditions and infiltration testing of the site.

A 100mm to 300mm deep topsoil was encountered at ground surface across the majority of the site. Fill was found across all of the site, beneath the topsoil or at the surface, in a layer 1 to 3 metres thick. The fill was generally organic with cobbles, boulders, topsoil and tree roots found in all test holes with some construction debris found in some of the test pits.

Parts of the site, mainly to the north and east, had an organic silty sand to sandy silt layer composed of decayed wood and topsoil. The organics layer had depths ranging from 2 to 4 metres below the existing grade. This material was classed as organic silty sand to sandy silt (SM to ML) under the Unified Soil Classification System (USCS).

To the north and the east of the site, the material underlying the organics layer is a sandy silt (ML) with trace to some gravel extending to depths of 5 to 6 metres. The organics layer is not present in the south and west of the site which has glacial till underlying the fill. The glacial till layer extends to depths of 4 to 6 metres or deeper. The glacial till can be classified as silty sand with gravel (SM).

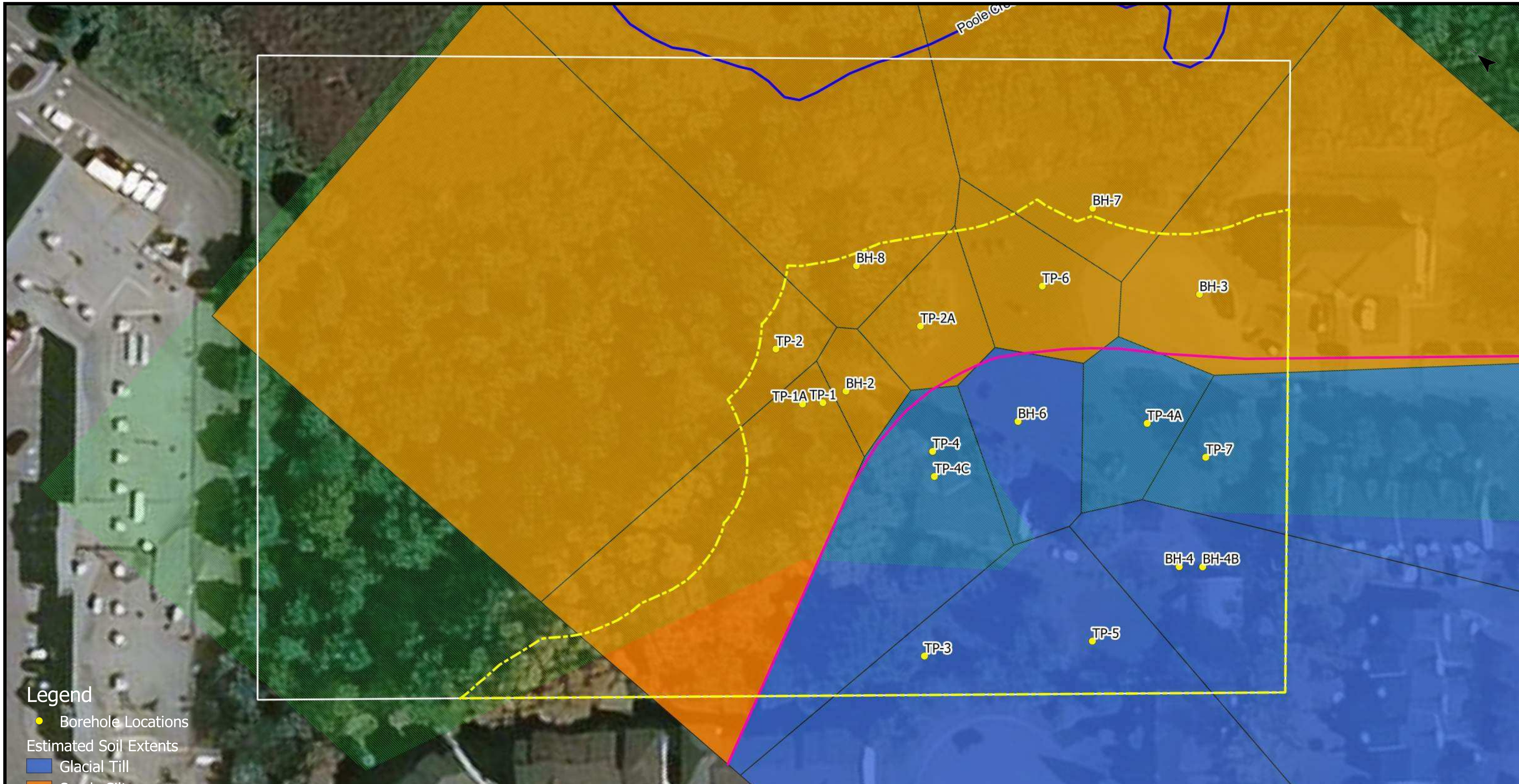
A summary of the soil parameters and values used for the water budget analysis is provided in Table 2-1. The approximate extents of each soil type for the purposes of the water budget assessment was based on Voronoi polygons around each testhole location is shown on Figure 2-1.

The infiltration rates listed in Table 2-1 are as per the measurements taken by EXP in May 2021 and are selected based on representation of the soil type and location within the site.

Table 2-1: Soils Summary

Soil Type	Moisture Content (%)	Organic Content (%)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Infiltration Rate (mm/hr)
Organics	89.4	14.4	0	59	34	7	131

<table>
<tr><th>Soil Type</th><th>Moisture Content (%)</th><th>Organic Content (%)</th><th>Gravel (%)</th><th>Sand (%)</th><th>Silt (%)</th><th>Clay (%)</th><th>Infiltration Rate (mm/hr)</th></tr>
<tr><td>Sandy Silt</td><td>-</td><td>-</td><td>0</td><td>36</td><td>59</td><td>5</td><td>14</td></tr>
<tr><td>Glacial Till</td><td>-</td><td>-</td><td>39</td><td>48</td><td colspan="2">13</td><td>300</td></tr>
</table>



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Hydrological Impact Study

Wildpine Trails, Ottawa ON

DRAWING:

Soils Mapping

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2.3 Topography and Drainage

The site has two (2) topography zones. The area to the south and west is a shelf gently sloping towards the northeast. Along the south and east, there is a steeper sloped section going towards either Poole Creek at the eastern edge and the Stittsville Wetland Complex to the north east and east. The highest point of the site is at the connection point with Ravenscroft Court to the west.

The topography is shown in Figure 2-2 with the drainage divide between Poole Creek and the Wetland Complex to the north-east.

2.4 Groundwater

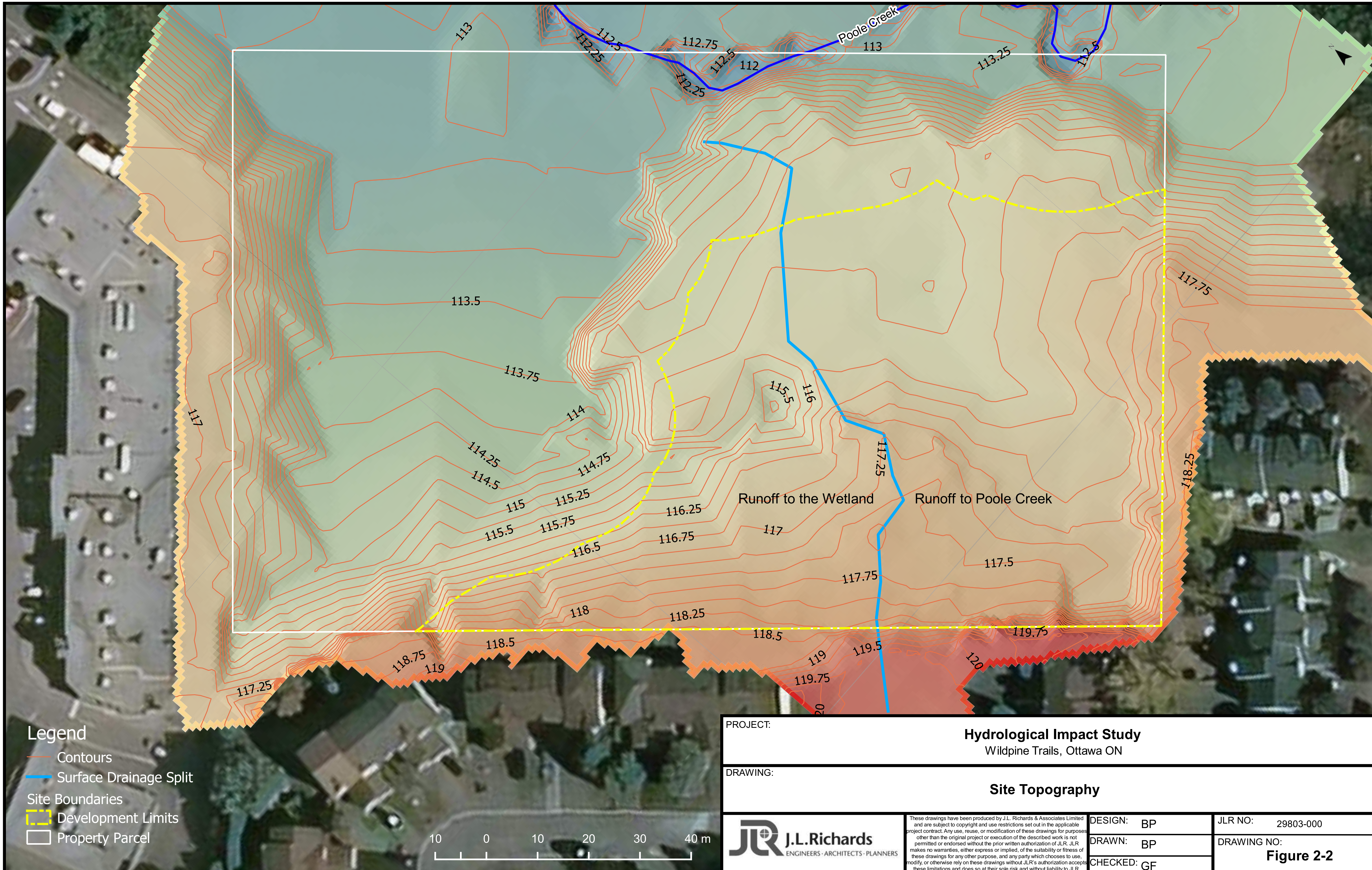
Groundwater measurements were recorded when observed by EXP in each of the test holes during both visits in December 2020, recorded 25 days later in January 2021 and May 2021. Figure 2-3 shows the recorded groundwater measurements at each of the test holes as well as the approximate groundwater contours which can be developed from these elevations and the approximate divide in groundwater gradient to Poole Creek and the Wetland Complex.

It should be noted that where groundwater conditions were recorded in December/January and May there was no significant difference in levels indicating that they are relatively steady during the year.

2.5 Poole Creek

In May 2020, Marshall Macklin Monaghan submitted the Upper Poole Creek Subwatershed Study to the Township of Goulbourn. Although the extents of the study are to the north of the site (i.e., upstream each), the report provides some characterization of the watercourse. It is one of the few cold or cool water streams in the region; however, temperature impacts have been felt from increased stormwater management ponds in the subwatershed. The headwaters of the stream originate from wetlands while along the stream urban runoff from Stittsville contributes to the flow.

The development guidelines in the Subwatershed Study recommends for enhanced water quality protection which is equivalent to an 80% TSS removal and no quantity control is required for flooding or erosion is required except to meet sewer capacities.



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Hydrological Impact Study

Wildpine Trails, Ottawa ON

DRAWING:

Site Topography

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Poole Cre
BH-7
112.39 m
BH-8
112.99 m
TP-6
113.16 m
BH-3
113.38 m
BH-2
113.3 m
TP-1A
113.57 m
TP-1
112.07 m
BH-6
113.89 m
TP-4A
113.85 m
BH-4
114.02 m
Legend
Testhole with Groundwater Elevation Recorded
Groundwater Split
Groundwater Contours
Site Boundaries
Development Limits
Property Parcel
10 0 10 20 30 40 m
PROJECT:
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Groundwater Elevations
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Figure 2-3

3.0 Proposed Conditions

The Wildpine Trails site will be developed to include public right of ways (ROWs), townhouses and a private lane with townhouses under a condominium corporation. The development will consist of 29 properties sited in six (6) blocks.. The public ROW will be in an 'L' shape connecting Ravenscroft Court to Wildpine Court while the private lane will extent from close to the apex of the 'L' towards the wetland site.

As per the MVCA requirements, agreed with the developer, development may extend up to a 15-metre setback from the wetland delineation or up to 28 to 30 metres of the Top of Bank of the channel of Poole Creek. These setbacks were agreed between the MVCA, the developer and the biologist.

The layout of the future development is shown in Figure 3-1.

3.1 Grading and Drainage

The site is intended to be graded to an approximate elevation of 118 metres to match the existing grading at the connections with Wildpine Court and Ravenscroft Court. Three (3) sags are envisioned to collect drainage, one each on the two (2) public ROW and one along the private lane. These street sags will have catchbasins connected to the minor system. Major overland flow will generally drain towards the connection with Wildpine Court as it is the low point.

At the end of the private laneway, the grading will slope down to meet the existing ground at the 15-metre setback to the wetland. Since no earthworks are to take place on the inside of the 15-metre setback, the elevation at the setback line will be maintained at around 116.5 metres.

The rear yards of the properties backing onto the Poole Creek channel will be graded towards Poole Creek. All other rear yards will be collected and directed to the minor system either via rear yard pots into the minor system or overland flow to one of the street sags. Two (2) properties at the end of the private laneway may have rear yards draining into the wetland area due to existing topography and to limit earthworks within the forested area to the north-west.

3.2 Stormwater Management

The stormwater management solution will consist of two (2) separate systems. The primary system consists of an Etobicoke Exfiltration System (EES) which accommodates frequent flows for infiltration, supplemented by a conventional piped sewer system and a perched outlet to the wetland via a control orifice and level spreader. Additional underground storage will also be required to maintain post-development flows to the wetland to pre-development levels.

The EES will consist of twin 200 mm diameter perforated pipes surrounded by a 600 mm deep by 900 mm clear stone envelope under the storm sewer on the private lane. The EES will be connected to the manhole at the intersection and will be graded to the north-west along the private laneway. A connection to the manhole at the north-west end of the private lane will be capped but to allow for exfiltration and will also be used for clean out during maintenance of the system. A total of 14 m^3 of storage is available in the EES while the combined storage of infiltrated runoff to 116.2 metre elevation is 17 m^3, consisting of the EES, manhole and sewer storage below the outlet to the wetland.

The perched outlet to the wetland is via a 200 mm diameter control orifice at 116.2 metres and a level spreader at 116.5 metres which is positioned at the lowest elevation to allow spill without earthworks required within 15 metres of the wetland. The level spreader will ensure that any flows discharging via the perched outlet will mimic the spread of shallow overland flow to the wetland in the pre-development condition.

Additional underground storage is located to the north of the north-west end of the private right-of-way and consists of 60m³ of storage tanks between the elevations of 116.2 metres and 117.0 metres. Below these elevations discharges are required to go via the outlet to the wetland to achieve pre-development flow rates while storage above 117 metres increases the head on the outlet orifice so that discharges are beyond the allowable release rate in the large events.

No controls, other than a reduced contributing area, are proposed for areas draining to Poole Creek which is consistent with the Upper Poole Creek Subwatershed Study (MMM 2000) although the site is downstream and outside of the limits of the Upper Poole Creek Subwatershed. The catchment draining to Poole Creek consists only of clean water runoff from roofs and rear yards and the drainage area has been limited to an extent whereby the post-development drainage from the smaller catchment is comparable to the pre-development runoff. By not providing controls, the runoff consists of sheet flow to the creek along the channel banks and is similar to pre-development conditions. No point discharges to Poole Creek is proposed which in turn means that no erosion potential is being created.

3.2.1 Water Quality

Water Quality control is required for the runoff from the public ROW and private laneway and front yards facing the ROW. Surface runoff from these catchments is all collected via street catch basins which in turn is connected to the minor system and the EES. The drainage area to the EES is 0.57 ha at an average imperviousness of 55%.

According to Table 3.2 of the MECP SWM Planning and Design Manual storage of 30 m^3/ha is required to provide 80% TSS removal for lands with an average imperviousness of 55%, which means that for the EES drainage area storage of up to 17 m^3 is required to be infiltrated. The combined storage of the EES and runoff captured in the minor system to drain to the EES is 17 m^3 which is that required to provide 80% TSS removal. Therefore, the EES on its own meets the enhanced protection level and no further water quality controls are required.

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Hydrological Impact Study
Wildpine Trails, Ottawa ON

DRAWING:

Future Development Configuration

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4.0 Water Balance

4.1 Approach and Methodology

An understanding of the water budget within the study area can be gained through the use of a continuous hydrological model, as recommended by the Toronto and Region Conservation Authority (TRCA). Based on their publication entitled "Stormwater Management Criteria, TRCA, August 2012", the use of a continuous model such as Qualhymo or PCSWMM is recommended (refer to Table 2-1 of the aforementioned publication).

PCSWMM will be used for this study and the model includes simplified groundwater and snowmelt modules which allow the continuous simulation of the water budget including the elements of evapotranspiration, the water table and snowfall and snowmelt.

A parameter by parameter description of the hydrological inputs to the model is contained in Appendix A. Model input mapping is shown in Figure 4-1.

4.2 Model Inputs

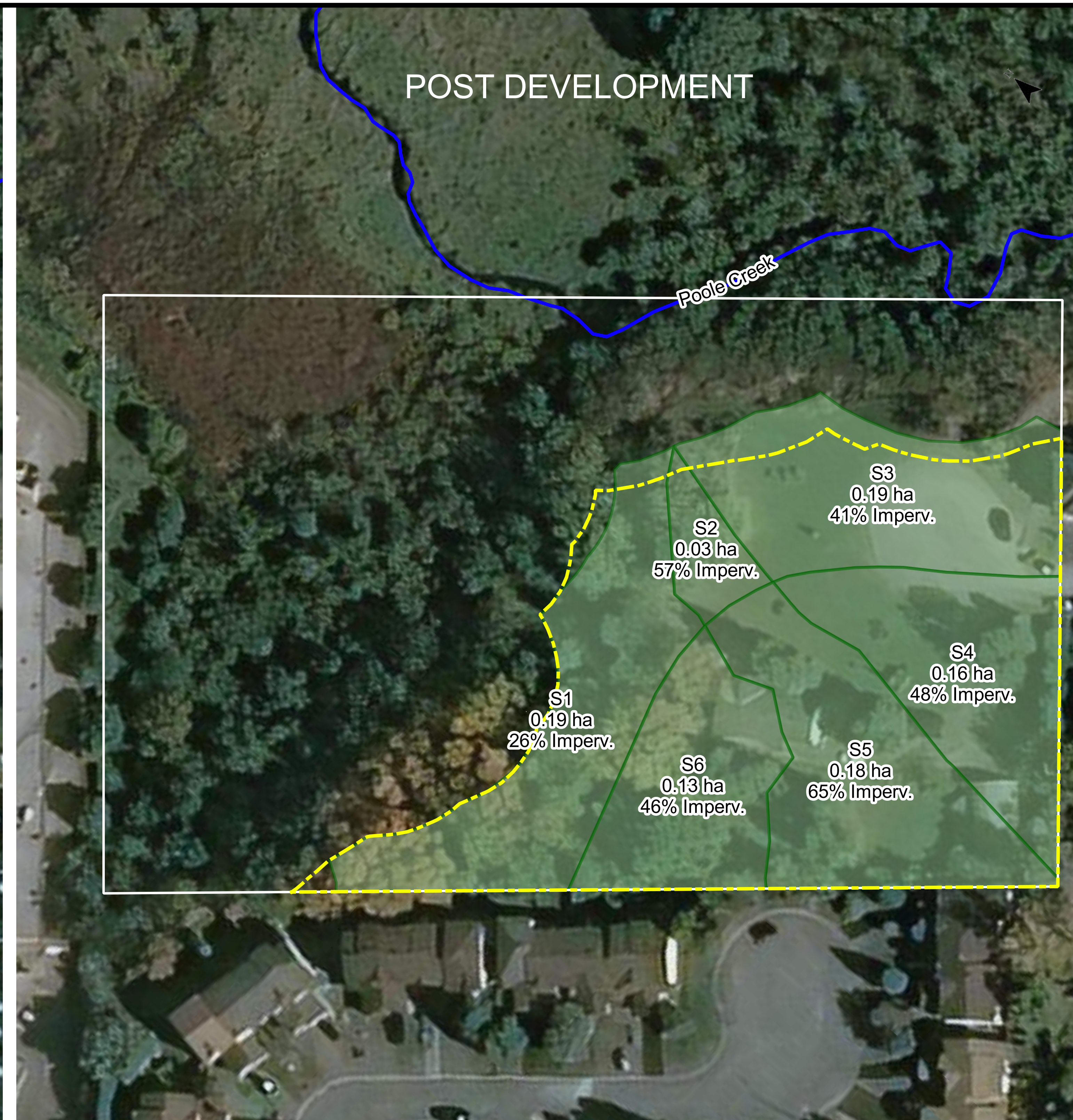
4.2.1 Land Cover

Under the pre-development condition, the land cover has been taken as current conditions with the level of impervious set based on the cover set out in Table 4-1. Under post-development conditions, the land cover is predominately impervious surfaces due to the road and property construction.

Table 4-1: Model Land Cover Inputs

Land Cover Type	Impervious (%)	Routed to Pervious (%)	Pre-Development Area (ha)	Pre-Development Area (%)	Post Development Area (ha)	Post Development Area (%)
Grassed	0	-	0.38	43	0.34	39
Forest	0	-	0.37	42	0.14	16
Gravel	75	100	0.08	9		
Roof	100	100	0.06	7		
Roof	100	50			0.21	24
Street	100	0			0.11	12
Driveway	100	0			0.08	9
TOTAL			0.89	100	0.89	100

The average impervious under the pre-development condition is 14% while under the post development condition the average imperviousness across the site, including the areas draining to Poole Creek, increases to 45%. The area contributing flow to the EES has an impervious slightly higher than the average at 55% impervious.



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Hydrological Impact Study

Wildpine Trails, Ottawa ON

DRAWING:

Pre and Post Development Model Schematics (Long Term Continous Simulation)

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DRAWING NO: **Figure 4-1**

4.2.2 Topography, Soils and Groundwater

The model has been delineated into six (6) subcatchments based on the overland flow directions, groundwater flow and soils divides. It has been assumed that the organics is present in the north-east of the site and is consistent with the divide between the glacial till and underlying sandy silts. Under the pre-development conditions, it is assumed that the organics are present across the site; however, under post-development the organics have been removed and the underlying sandy silts are the governing soil group within the disturbed areas.

Groundwater levels in the aquifers are based on the average groundwater elevation across the subcatchment. The SWMM 5.0 engine analyzes groundwater flow for each subcatchment independently. It represents the subsurface region beneath a subcatchment as consisting of an unsaturated upper zone that lies above a lower saturated zone. The elevation of the lower saturated zone, the water table, varies in time depending on the rates of inflow and outflow of the lower saturated zone. The flow to the lower saturated zone is controlled by percolation, which is dictated by the soils data. The upper unsaturated soil zone receives water via infiltration from surface runoff. Evapotranspiration occurs from the upper unsaturated zone and can occur from the lower saturated zone depending on root depth. If the water table, or elevation of the lower saturated zone, reaches the surface level then as the soil becomes saturated, infiltration will be declining to a point where it will no longer occur.

Soil parameters are described in Appendix A and are consistent with the soil types and infiltration rates summarized from the geotechnical report in Section 2.2.

4.2.3 Climate Data

The continuous simulation model input precipitation is from the Environment Canada weather stations at Ottawa International Airport and the Experimental Farm in Ottawa. Over thirty (30) years of hourly data, between January 1, 1960 and October 31, 1990, is used in the model with the average annual rainfall during the period being 844 mm/year. Maximum and minimum daily temperatures from the same weather stations and time period are also entered into the model.

The model simulates evaporation based on average monthly rates from Environment Canada Monthly Normals for the same stations.

Snowmelt is an additional mechanism by which runoff may be generated in a continuous simulation model. The current SWMM implementation utilizes the Canadian SWMM snowmelt routines with extensions for long term continuous modelling.

Snowfall rates are determined directly from hourly precipitation data by using a pre-set temperature: snowfall will occur when the temperature is below the pre-set point and rainfall when above. Snowmelt is handled differently by the SWMM engine depending on the occurrence of rainfall. During rain on snowmelt events, the model takes into account the rainfall intensity and the air temperature as well as the saturation vapour pressure. When snowmelt occurs without any rainfall, the snowmelt is linearly proportional to the air temperature, which varies with the user supplied melt coefficients.

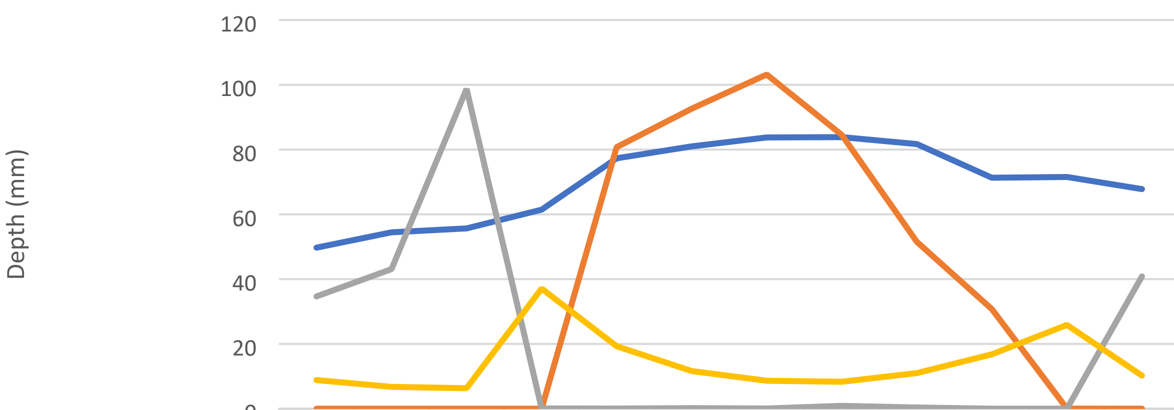
For the pre-development model, it has been assumed that all snow occurs on pervious land cover and there is no snow removal or grit operations. The post-development model assumes that the roads are cleared, and snow hauled off site.

4.3 Model Results

4.3.1 Pre-Development

The water budget results for the pre-development condition across the site are shown in Figure 4-2 and Table 4-2.

Figure 4-2: Pre-Development Continuous Simulation Monthly Average Results



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rainfall	50	54	56	61	77	81	84	84	82	71	72	68
Evapotranspiration	0	0	0	0	81	93	103	85	52	31	0	0
Runoff	35	43	99	0	0	0	0	1	0	0	0	41
Infiltration	9	7	6	37	19	12	9	8	11	17	26	10

Table 4-2: Pre-Development Continuous Simulation Annual Average Results

Water Budget Component	Annual Average Depth (mm)	Percent of Water Budget (%)
Rainfall	840	100
Evapotranspiration	443	53
Runoff	219	26
Infiltration	171	20

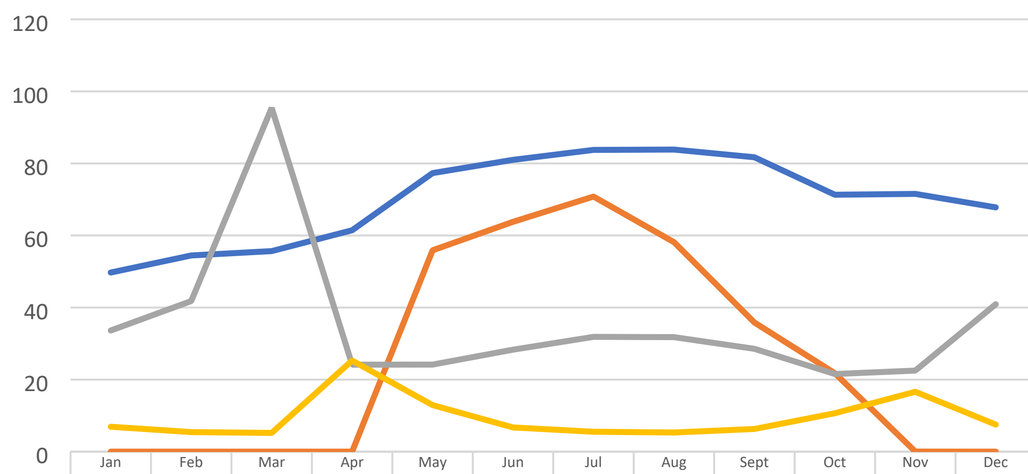
The Evapotranspiration component includes evaporation from the surface as well as transpiration from the vegetation in uptake of moisture through the soil in the upper and lower zones.

Infiltration includes only surface infiltration into the soil zone and excludes any infiltrated runoff that is then subject to transpiration.

4.3.2 Post Development

Under the post-development condition, with no mitigation measures, the water balance simulation results for the site is shown in Figure 4-3 and Table 4-3. The post-development scenario includes removal of the organics on the development land area to the north of the site as well as applying a 2.5 factor reduction factor to the infiltration rates in the development extents as per Credit Valley Conservation Authority LID guidance to allow for increased compaction as a result of earthworks and construction. This approach is conservative as it reduces the effectiveness of the infiltration.

Figure 4-3: Post Development (no mitigation) Continuous Simulation Average Monthly Results



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rainfall	50	54	56	61	77	81	84	84	82	71	72	68
Evapotranspiration	0	0	0	0	56	64	71	58	36	22	0	0
Runoff	34	42	95	24	24	28	32	32	29	22	22	41
Infiltration	7	5	5	25	13	7	6	5	6	11	17	8

Table 4-3: Post Development (no mitigation) Continuous Simulation Annual Average Results

Water Budget Component	Annual Average Depth (mm)	Percent of Water Budget (%)
Rainfall	840	100
Evapotranspiration	306	36
Runoff	425	51
Infiltration	114	14

The impact of the increased impervious surface results is an increase in runoff on average of 206 mm per year while infiltration rates is reduced by an average of 57 mm per year. Mitigation measures are, therefore, required to increase overall infiltration from the site.

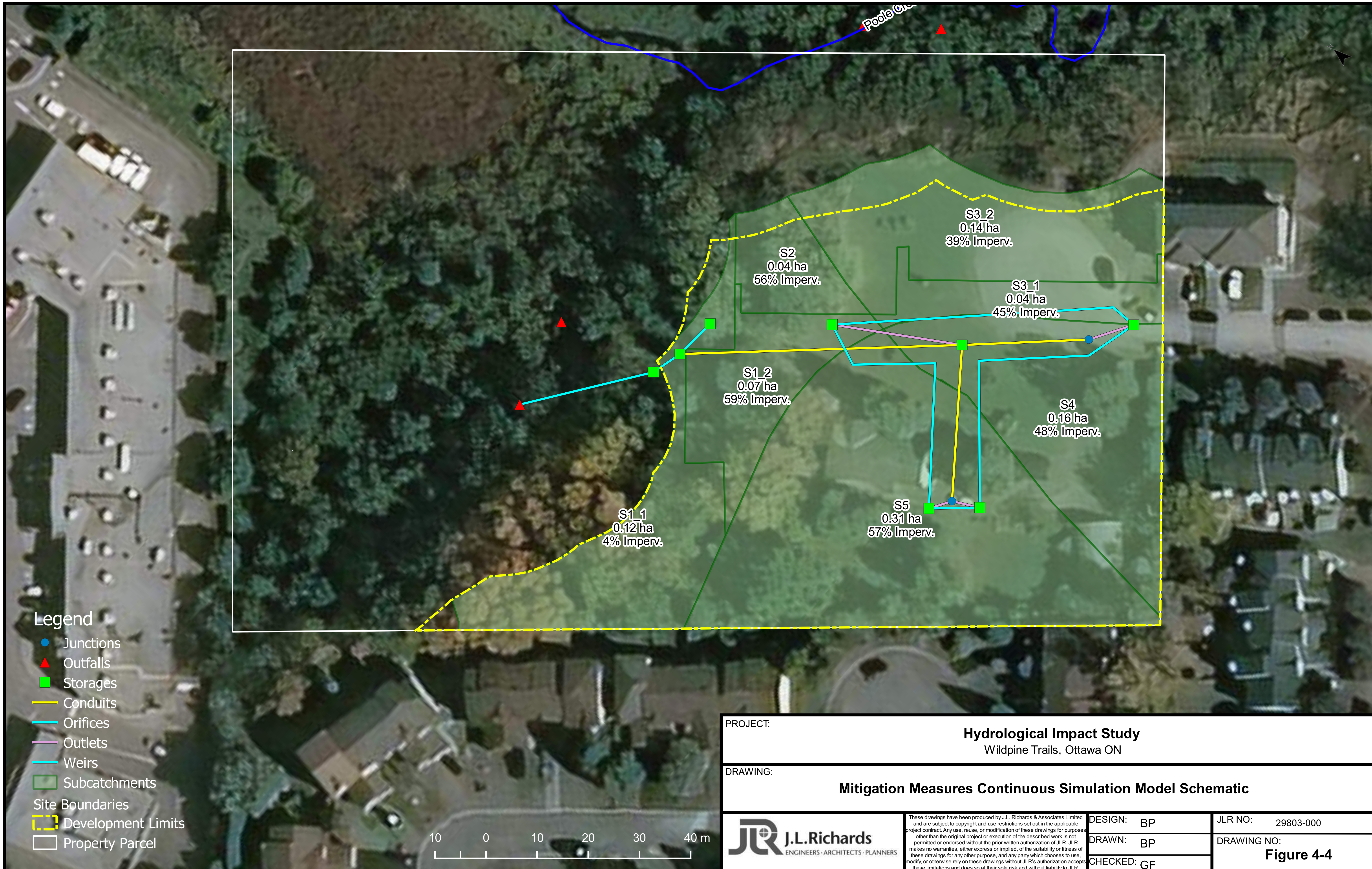
4.4 Mitigation Modelling

4.4.1 Model Inputs

The long-term continuous simulation model of the mitigation measures across the site is similar to the pre- and post-development models except that:

- As per the post-development model (no mitigation), it is assumed that the organics layer has been removed across the development extents and the underlying sandy silt layer is the critical soil component
- The subcatchments have been divided further to delineate areas which drain to the EES and areas which drain either to Poole Creek or directly to the wetland.
- The runoff from areas draining to the EES are directly connected to the upstream EES manhole to facilitate the model runtime. Since all the flow within the catchments draining to the EES is captured by the EES and does not overflow to adjoining catchments, this approach is suitable.

The model schematic with the mitigation measures included is shown in Figure 4-4.



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Hydrological Impact Study

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DRAWING:

Mitigation Measures Continuous Simulation Model Schematic

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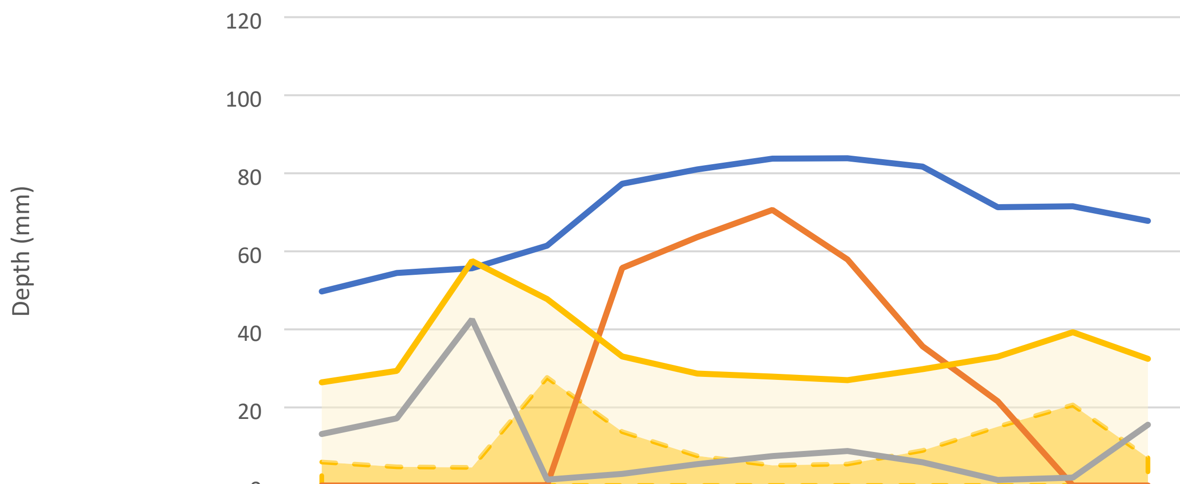
DRAWING NO: **Figure 4-4**

4.4.2 Mitigation Water Budget Results

The results for the water budget continuous simulation with the mitigation measures in place are shown in Figure 4-5 and Table 4-4 below.

Figure 4-5: Post Development (with mitigation) Continuous Simulation Average Monthly Results



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
EES Infiltration	20	25	53	20	19	21	23	21	21	18	19	25
Ground Infiltration	6	5	5	28	14	8	5	5	9	15	21	7
Rainfall	50	54	56	61	77	81	84	84	82	71	72	68
Evapotranspiration	0	0	0	0	56	64	71	58	36	22	0	0
Runoff	13	17	43	2	3	5	8	9	6	1	2	16
Infiltration	26	29	58	48	33	29	28	27	30	33	39	32

Table 4-4: Post Development (with mitigation) Continuous Simulation Annual Average Results

Water Budget Component	Annual Average Depth (mm)	Percent of Water Budget (%)
Rainfall	840	100
Evapotranspiration	305	36
Runoff	124	15
Infiltration	412	49
└ Ground Infiltration	127	15
└ EES Infiltration	285	34

The simulation results have shown that the mitigation measures are found to increase the infiltration capacity of the site to above pre-development levels and reduce runoff and to closely mimic the pre-development rates.

4.4.3 Operation of Mitigation Measures

The mitigation measures were simulated with a 25 mm design storm to assess operation of the system during a water quality event. Water levels in a water quality event surcharge the EES and enter the traditional storm sewer; however, no flow outlets via the perched outlet would occur and, therefore, all runoff would be captured and subsequently infiltrated. The drawdown during the 25 mm event is completed within 12 hours.

The simulation results in the 1:100 year 3-hour Chicago storm event show that the EES would drawdown within 24 hours.

5.0 Impacts

5.1 Groundwater Conditions

Groundwater, when encountered in the boreholes, was recorded at elevations of around 113.5 metres or approximately 1 metre below the proposed EES installation depth. As such, it is not anticipated that the EES will adversely impact groundwater in the area as this system is perched by about 1 metre. Infiltration rates with the mitigation measures in place are such that recharge of groundwater will be maintained to pre-development levels.

5.2 Wetland Impacts

The mitigation measures have been proposed to, and are shown in the modelling to achieve, pre-development runoff to the wetland and maintain infiltration rates for groundwater to the wetland. Any runoff to the wetland from the development is via a control orifice upstream of a level spreader. The level spreader is located up to 15 metres from the wetland in line with the offset requirements. The level spreader is intended to disperse the overland flow and dissipate the energy of flows through the control orifice.

With the proposed measures in place it is anticipated that there will be no measurable changes to the operation of the wetland.

5.3 Environmental Impacts

The site has maintained a 15-metre buffer to the wetland and the stormwater management measures have been predominantly kept within the development area and are outside of any treed areas. The approach is consistent with the Environmental Impact Statement and, therefore, there should be no measurable environmental impacts on the wetland.

6.0 Summary

The proposed development at Wildpine Trails will result in increased runoff and reduced infiltration in the water budget for the site. However, the long term continuous simulation modelling has shown that the mitigation measures proposed in the stormwater management for the site, including the EES and outlet control, will increase infiltration beyond what is currently experienced and impact on the wetland will be minimal.

This report has been prepared for the exclusive use of Latitude Homes Inc, for the stated purpose, for the named facility. Its discussions and conclusions are summary in nature and cannot be properly used, interpreted or extended to other purposes without a detailed understanding and discussions with the client as to its mandated purpose, scope and limitations. This report was prepared for the sole benefit and use of Latitude Homes Inc and may not be used or relied on by any other party without the express written consent of J.L. Richards & Associates Limited.

J.L. RICHARDS & ASSOCIATES LIMITED

Prepared by:

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Appendix A

Hydrological Input Parameters

PCSWMM Hydrologic Model Parameters

The following sets out a description of each of the parameters used in the continuous simulation modelling for the water balance assessment. Any differences from the below at any of the specific elements are noted in the description in the model.

The continuous simulation is different from the event modelling for the servicing assessment and the parameters values described below do not necessarily reflect the event modelling.

Only those elements which impact the soil infiltration affect the continuous simulation model and to save run time the continuous simulation model has much of the sewer network and major system network removed. The pond is maintained in the continuous simulation model as it is intended to provide addition infiltration into the soils and groundwater table as a post development mitigation measure.

1.0 Subcatchments

1.1 General Parameters

Parameter	Units	Description / Values
Name	-	Subcatchments are numbered sequentially with the prefix ‘S’.
Tag	-	No tags have been used for the subcatchments.
Rain Gauge	-	The 30 year data was used from Environment Canada weather stations at Ottawa Macdonald-Cartier International Airport and the Experimental Farm.
Outlet	-	The downstream major system node to which the subcatchment overland flow drains.
Area	ha	The area is calculated internally by PCSWMM and the value varies.
Width / Flow Length	m	Under the pre-development condition the width is the area of the catchment divided by the measured runoff flow path. Under post development the developed catchments representing predominately residential land uses have the width parameter set at 225 m/ha as per the OSDG. Where the catchments are for non-residential land uses the width is the area of the catchment divided by the runoff flow path.

Parameter	Units	Description / Values
Slope	%	Under the pre-development condition the slope is set at the average slope on the DEM underlying the catchment. In the post development condition the developed catchments have the slope set at 3%.
Imperv	%	The percent impervious is area weighted based on the following percent impervious for the various land uses: **Land Cover** — **Impervious (%)** Open Space — 0 Gravel — 75 Roof — 100 ROW — 100
N Imperv	-	A constant of 0.013 is selected as the Manning's N for impervious surfaces such as roads, sidewalk and parking areas. The value is representative of smooth impervious surface as per Table 3-5 of the EPA Storm Water Management Model Reference Manual Vol I – Hydrology (EPA, 2016).
N Perv	-	A constant of 0.25 is selected as the Manning's N for pervious areas. The value is representative of light to tense turf land cover as per Table 3-5 of the EPA Storm Water Management Model Reference Manual Vol I – Hydrology (EPA, 2016).
DStore Imperv	mm	A constant of 1.57 mm is used as the impervious depression storage as per the OSDG Section 5.4.5.4.
DStore Perv	mm	A constant of 4.67 mm is used as the impervious depression storage as per the OSDG Section 5.4.5.4.
Zero Imperv	%	Not applied.
Subarea Routing	-	The constant 'PERVIOUS' is entered to simulate the subarea of impervious surface, such as the rear part of roofs, which may flow over pervious areas prior to discharging to the outlet of the subcatchment.

<table>
<tr><th>Parameter</th><th>Units</th><th>Description / Values</th></tr>
<tr><td>Percent Routed</td><td>%</td><td>The percentage of impervious area which is routed across the pervious area. The percentages are area weighted in PCSWMM based on the following impervious types:

Land Cover | Percent Routed
Open Space | 100
Gravel | 100
Roof | 50
ROW | 0</td></tr>
<tr><td>Infiltration</td><td>-</td><td>The Horton infiltration methodology is used, consistent with the City’s OSDG. The Maximum Infiltration Rate for the Horton coefficients are as per the results of the EXP field testing of soil infiltration rates. The Minimum Infiltration Rate is taken from Akan 1993 for each of the soil types. The following values were used for each of the identified soil types:

Soil Type | Max. Infiltration Rate (mm/hr) | Min. Infiltration Rate (mm/hr) | Decay Constant (hr⁻¹)
Organics | 131 | 11.4 | 4.14
Sandy Silt | 14 | 3.8 | 4.14
Glacial Till | 300 | 7.6 | 4.14

For the post development conditions the values have been reduced by a factor of 2.5 as per guidance from the Credit Valley Conservation Authority and Toronto and Region Conservation Authority Low Impact Development Stormwater Management Planning and Design Guide Appendix C. The Guide states that a safety correction factor of 2.5 should be applied where there is a ratio between the mean measured infiltration rates of 1 or less. The safety factor represents the potential loss of infiltration due to compaction during construction and gradual accumulation of fine sediments over the lifespan of the BMP.</td></tr>
<tr><td>Infiltration Pattern</td><td>-</td><td>An infiltration pattern has been applied to the subcatchments so that there is no infiltration during the months of January, February, March or December when average temperatures are below freezing and the ground is considered impervious as it is frozen. During the other months full infiltration is simulated.</td></tr>
</table>

The parameters Curb Length, LID Controls and Erosion are not used in the model.

1.2 Snowmelt

Parameter	Units	Description / Values
Dividing Temperature	°C	The temperature below which precipitation will fall as snow. Generally accepted as being 0°C. Value: 0
Snow Capture Factor	Fraction	It is assumed that the data from Environment Canada has captured all snowfall in the gauges. This factor can be used to increase snowfall where the gauges may not be accurate. Value: 1.0
ATI Weight	Fraction	Applied over the entire subwatershed, the ATI weighting factor is an indication of the thickness of the surface layer of snow. A low value will indicate a thicker surface layer with weighting to temperatures over the previous week while a value closer to 0.5 will indicate a normal surface layer. The lower the ATI Weight the snow will cool and warm more slowly. A value of 0.5 has been found to give reasonable results in watersheds and has been used here. Value: 0.5
Negative Melt Ratio	Fraction	The effect of the heat transfer during non-melt periods and the standard value is used. Value 0.6
Elevation above MS	m	The elevation will affect atmospheric pressure for the melt calculations. Value: 113
Latitude	°	The latitude will dictate the sunrise and sunset times in temperature calculations. Value: 45.0
Longitude Correction	minutes	Used to correct for in separation of the position of site versus the meridian of the standard time zone. This will have negligible effects. Value: 0

Parameter	Units	Description / Values
Melt Coefficients	mm/hr /°C	The Melt Coefficient has been taken from the AES snowmelt equations for southern Ontario (MNR Technical Guide Flooding Hazard Limit, 2002). The AES equations have a melt coefficient of 3.66 mm/day/°C for mean daily air temperatures. This equates to 0.1525 mm/hr/°C. Value: 0.153
Base Temperature	°C	The base temperature at which the snowpack will melt has been assumed as 0°C. A lower value could be used for rooftops where there will be heat transfer through the roof. Value: 0
Fraction Free Water Capacity	Fraction	Since snow is considered a porous medium some of the melt water may be contained within the snow pack. The fraction of the free water capacity is the fraction of the snow pack void space which will retain meltwater. This fraction is normally less than 0.1 and 0.05 has been used here to represent a deep snowpack. A value of 0.25 may represent a shallow slush layer. Value: 0.05
Initial Snow Depth	mm	The initial snow depth on the site is considered as zero. Value: 0
Initial Free Water	mm	Since there is no initial snow depth the initial free water has also been considered as zero. Value: 0
Depth at 100% Cover	mm	The snowmelt model assumes that there will always be a depth of snow above which there will be 100% coverage of the snow, even in areas which may be affected by shading, drifting of topography. Typical depths are 25 mm to 100 mm. Since the area is relatively open with limited shading then the lower end of the value range has been used. Value: 25

Parameter	Units	Description / Values
Fraction of impervious area that is plowable	fraction	It is assumed that for the developed areas where the 'future' snow pack is used that 20% of impervious areas will be plowed. Value: 0.2 For the area that is plowable the following parameters are applied: Depth at which snow removal begins (mm) 25.4 Fraction transferred out of the watershed 0.8 Fraction transferred to the impervious area 0.1 Fraction transferred to the pervious area 0.1 Fraction transferred into immediate melt 0.0 Faction moved to another subcatchment 0.0
Areal Depletion	Fraction	The areal depletion curve represents the area of snow cover for depths of the snow less than the depth at 100% coverage. Natural areal depletion curves are suggested by the software and are used here.

1.3 Groundwater

Used in the continuous simulation modelling only.

Parameter	Units	Description / Values
Aquifer Name	-	Name of the aquifer representing soil conditions. Three aquifers have been created to define the different soil types present in the site, approximated from Tables II, III, and IV in the Geotechnical Report by EXP. **Aquifer** / **Clay (%)** / **Sand (%)** / **Texture Class** Organics / 7 / 59 / Sandy Loam Sandy Silt / 5 / 36 / Silty Loam Glacial Till / 13 / 48 / Loam Texture Classes were taken from the SPAW Calculator texture class for the split of clay and sand components.
Receiving Node	-	Name of the receiving node for groundwater outflow to baseflow. This is based on the groundwater subwatershed delineation.

Parameter	Units	Description / Values
Surface Elevation	m	Elevation of the ground surface for the subcatchment was averaged from the surface DEM and varied per subcatchment.
Coefficients		The coefficients were set for the saturated groundwater zone to represent a storage reservoir where outflow is linear proportional to the water table depth without surface water interaction. The groundwater equation used is: $f_G = A1\ (d_L - h^*) - A2(h_{sw} - h^*)$ Where: f_G = groundwater flow dL = depth of the lower saturated subsurface zone h_{sw} = height of surface water above the bottom of the groundwater zone h* = height of bed of surface water above the groundwater zone $A1 = A2 = K_s/2L^2$ Where K_s = Soil saturated hydraulic conductivity L = Length of midpoint of catchment to the surface water channel
Surface Water Depth	m	Water surface elevation depths in relation to the catchment location and varies with subcatchment.
Initial Elevation	m	Initial elevation of the water table as per the EXP Geotechnical Investigations. Values vary per catchment.
		All other parameters used as per the receiving node or aquifer

1.4 Aquifer

Used in the continuous simulation modelling only.

Parameter	Units	Description / Values
Porosity	Fraction	The following values were used for the volumetric water content of the soil at saturation (i.e. volume of water per total volume): **Aquifer** / **Texture Class** / **Porosity** Organics / Sandy Loam / 0.453 Sandy Silt / Silty Loam / 0.501 Glacial Till / Loam / 0.463 *(Source: Table 4-7, (Rossman & Huber, 2016))*

Parameter	Units	Description / Values
Wilting Point	Fraction	This is soil moisture contact at which plants cannot obtain sufficient moisture from the soil to meet transpiration requirements and they will die. It is roughly equivalent to the moisture content of soil at 15 atmospheres. The following values were used: **Aquifer** / **Texture Class** / **Wilting Point** Organics / Sandy Loam / 0.115 Sandy Silt / Silty Loam / 0.100 Glacial Till / Loam / 0.079 *(Source: SPAW Calculator)*
Field Capacity	Fraction	Considered to be the amount of water a well-drained soil holds after free water has drained off. The following values were used: **Aquifer** / **Texture Class** / **Field Capacity** Organics / Sandy Loam / 0.267 Sandy Silt / Silty Loam / 0.318 Glacial Till / Loam / 0.187 *(Source: SPAW Calculator)*
Conductivity	mm/hr	Within the Aquifer Parameters, the soil saturated conductivity is a governing parameter of the percolation rate between the upper unsaturated soil layer and the lower saturated soil layer. This is not the same as any permeability rate used for the surface infiltration. The values have been selected from the SPAW calculator and are: **Aquifer** / **Texture Class** / **Conductivity** Organics / Sandy Loam / 115 Sandy Silt / Silty Loam / 126 Glacial Till / Loam / 3.7 *(Source: SPAW Calculator)*
Conductivity Slope	-	Conductivity slope measures the rate at which a soil's hydraulic conductivity decreases with decreasing moisture content. **Aquifer** / **Texture Class** / **Conductivity Slope** Organics / Sandy Loam / 18.7 Sandy Silt / Silty Loam / 15.9 Glacial Till / Loam / 28.9
Tension Slope		Used for backward compatibility in the software and not used in this model

Parameter	Units	Description / Values
Upper Evaporation Factor	Fraction	This factor determines the fraction of available subsurface evaporation rate used in the upper subsurface zone (compared to the lower subsurface zone). A higher evaporation rate is associated with looser soils, lower water table elevations and shallow root zones. It was assumed that in all soils 80% of the available subsurface evaporation would be used in the upper zone due to the depth of the water table. **Value: 0.8**
Lower Evaporative Depth	m	The depth of the lower subsurface zone which can be used for evapotranspiration should be approximate to the expected average depth of root penetration. This does not impact this type of model but the following values were used: **Aquifer** / **Texture Class** / **Lower Evaporative Depth** Organics / Sandy Loam / 2.3 Sandy Silt / Silty Loam / 5.2 Glacial Till / Loam / 3.7 *(Source: Shah et al 2007 from EPA 2015)*
Lower Groundwater Loss Rate	mm/hr	This is the rate of percolation from the lower subsurface zone to a deep aquifer and is approximate to the rate at which the water table elevation will drop over a prolonged dry period. The saturated hydraulic conductivity of a compacted clay soil was used in all cases however it does not affect the model. **Value: 0.004**
Bottom Elevation	m	Taken as the average refusal or testhole depth from the EXP geotechnical investigations. **Value: varies**
Unsaturated Zone Moisture		The moisture content of the unsaturated upper subsurface zone at the start of the simulation. Cannot be less than the wilting point and cannot be more that porosity. Assumed to be field capacity at the start of the simulation. **Aquifer** / **Texture Class** / **Unsaturated Zone Moisture** Organics / Sandy Loam / 0.267 Sandy Silt / Silty Loam / 0.318 Glacial Till / Loam / 0.187

2.0 Storage Nodes

In the mitigation measures continuous simulation model the storage nodes have been assigned seepage parameters to simulate the exfiltration of the stored runoff to the underlying soils. The seepage parameters are set up as per the Green Ampt infiltration methodology used in SWMM for seepage at storage nodes and pipes.

Only the water balance parameters have been listed below, other parameters are as per the physical representation of the storage at the node.

Parameter	Units	Description / Values
Storage Curve and Curve Name	-	The tabular storage curve type has been selected and the curve developed to allow the equivalent area of the void space of the EES at the bottom of the curve and then the curve reduces to the base area of a typical manhole above a depth of 600mm (the proposed depth of the EES). The storage curve is set up to allow storage of the void space in the EES.
Suction Head	mm	The following values were used for the capillary suction head (i.e. volume of water per total volume): **Aquifer** / **Texture Class** / **Porosity** Organics / Sandy Loam / 0.453 Sandy Silt / Silty Loam / 0.501 Glacial Till / Loam / 0.463 *(Source: Table 4-7, (Rossman & Huber, 2016))*
Conductivity	mm/hr	The soil saturated conductivity in the Green Ampt Equation is a governing parameter of the percolation rate between the upper unsaturated soil layer and the lower saturated soil layer. This is not the same as any permeability rate used for the surface infiltration. The values have been selected from the SPAW calculator and are: **Aquifer** / **Texture Class** / **Conductivity** Organics / Sandy Loam / 115 Sandy Silt / Silty Loam / 126 Glacial Till / Loam / 3.7 *(Source: SPAW Calculator)*
Initial Deficit	Fraction	Difference between porosity and initial moisture content. Set as the assumed moisture content of the unsaturated upper subsurface zone at the start of the simulation.

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