HALIFAX REGIONAL MUNICIPALITY FUTURE SERVICED COMMUNITIES – HIGHWAY 102 WATERSHED AND STORMWATER MANAGEMENT STUDY

April 16, 2025

Prepared for:
Halifax Regional Municipality

Prepared by:
Stantec Consulting Ltd.

Project Number:
160410459

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1 Introduction

The 2006 Halifax Municipal Planning Strategy (Regional Plan) provides guiding principles on the development of future settlement in the Halifax Regional Municipality (HRM) until 2031. Land development within a watershed has the potential to negatively impact the biophysical environment, therefore the Regional Plan requires that prior to undertaking secondary municipal planning or considering amendments to existing secondary plans, HRM must complete watershed studies to aid in municipal planning. The assessment of study areas and watershed studies are intended to provide solutions and recommendations to existing issues or potential impacts due to future development, identify measures to improve or maintain water quality of water bodies within the watershed, and to mitigate the potential impact that future development may exert on these natural environments.

The areas being studied as part of this project are the remaining Future Serviced Communities identified for development by the Regional Municipal Planning Strategy (Regional Plan) and the Road to Economic Prosperity for African Nova Scotian Communities. Sandy Lake, Highway 102 West Corridor and Morris Lake had not yet undergone the comprehensive neighbourhood planning process outlined by the Regional Plan and a fourth area, Westphal was added for consideration of future serviced development through the African Nova Scotian Road to Economic Prosperity Action Plan.

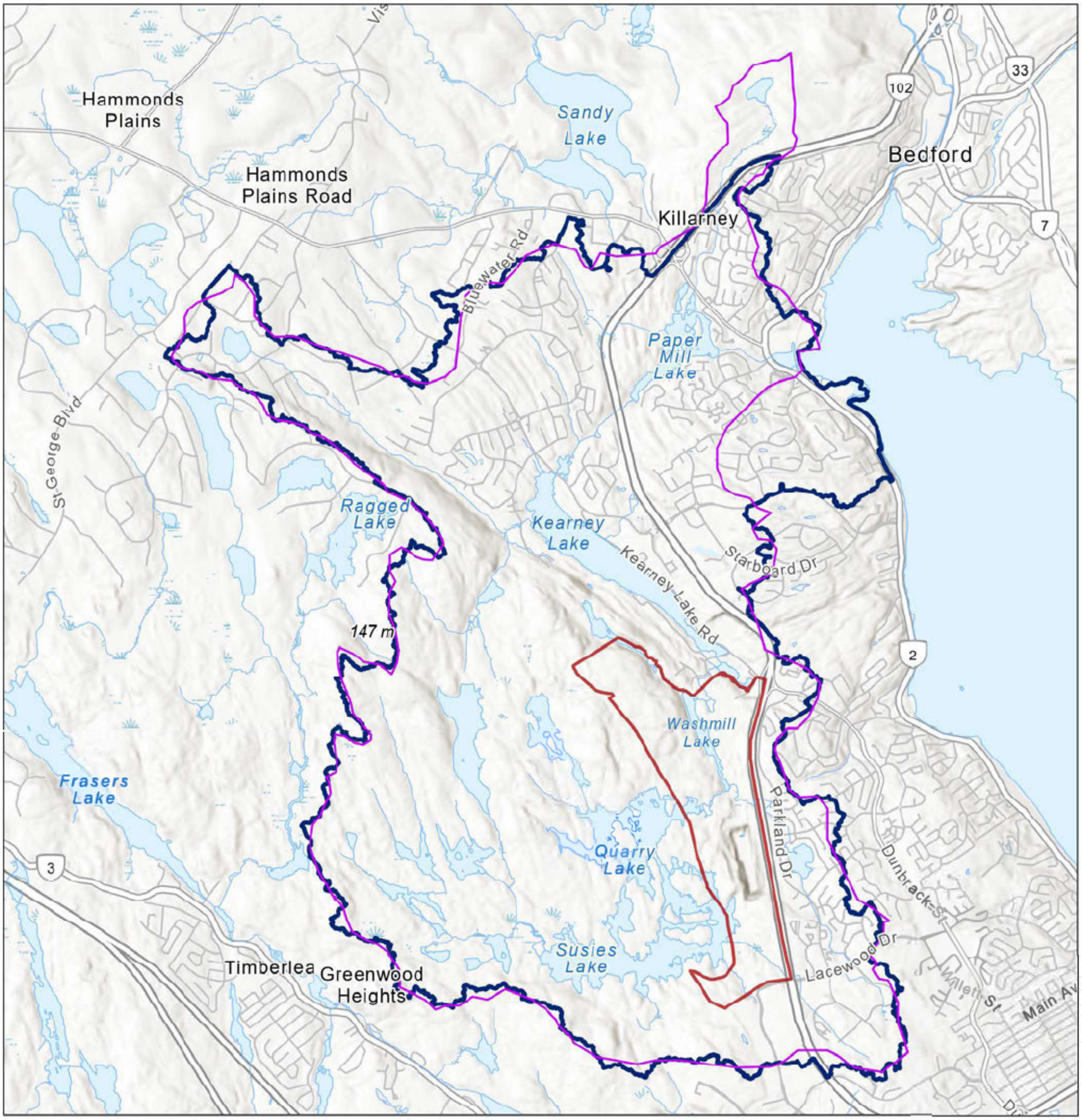
This study was prepared in conjunction with the Land Suitability Analysis (Stantec 2024) of the Highway 102 West Corridor Study Area. Additionally, further background conditions on the site can be found within the suite of studies prepared for the Highway 102 Future Serviced Community, which include:

- Development Scenarios Report – Highway 102 (Stantec 2023)
- Highway 102 Transportation Study (Stantec 2024)
- Highway 102 Water Servicing Plan – Draft Report (Stantec 2024)

1.1 Background

The Highway 102 study area (HSA) watershed is located within the Kearney Run Watershed (1EJ-5) in the Halifax Regional Municipality (HRM), in Bedford, Nova Scotia (NS) (**Figure 1.1**), with commercial and residential land use in the surrounding areas. Bayers Lake business park borders the HSA to the south, Clayton Park West development area borders to the east, and Kearney Lake borders to the north. Portions of Quarry and Susies Lake, and the entirety of Washmill Lake are included in the HSA. The HSA watershed has a drainage area of approximately 36.23 km^2 (3,623 ha). Runoff within the watershed flows from the west into Washmill Lake and from the south-east into Susies Lake, which ultimately discharge into Kearney Lake, and eventually into the Bedford Basin in Halifax Harbour.

Washmill Lake is included within a series of lakes that make up the Birch Cove Lakes Area (Porter Dillon 1996). Washmill Lake has a surface area of 78.5 ha and a mean depth of 2.5 m for an estimated volume of 19.3×10^6 m^3 (AECOM 2013). Washmill Lake receives flow from Quarry Lake and Susies Lake to the southwest and Charlies Lake to the north and then discharges into Kearney Lake. There is a dam located at the discharge point of Quarry Lake which reduces flows entering Washmill Lake (AECOM 2013).



Legend

- Study Area
- Lidar De1ineated Watershed Boundary
- Kearney Run Watershed (1EJ-5)
- Watercourse
- Waterbody

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Project Location
Halifax Regional Municipality,
Nova Scotia

Prepared by AC on 2024-04-18

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Halifax Regional Municipality
Future Serviced Communities

Figure No.
1.1

Title
Project Location

Notes
1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Stantec; Halifax Regional Municipality, Government of Nova Scotia
3. Background: Esri

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2 Watershed Study

The objective of this watershed study is to determine water quality impacts to sensitive or natural receptors within or downstream of the HSA. The focus of this study is on sourcing and quantifying contaminant loadings of total phosphorus (TP), fecal coliforms and sediment due to impacts of land-use change to the HSA and its contributing watershed area from proposed development scenarios. These specific contaminants were selected because of their documented adverse effects on waterbodies throughout the HRM.

In this study, contaminant loading models for three land development scenarios (developer-requested, low-density, high-density) were evaluated to understand the potential water quality effects resulting from each scenario; a fourth scenario (aerial land-use scenario) incorporates the same housed population as the developer-requested scenario; however, this scenario covers 20% less land area compared to the developer-requested scenario. The areal land-use scenario was evaluated to assess impacts of development on the watershed when forested area is conserved within the watershed. The outcome of the study is to provide a number of recommendations for the planning, design, and implementation of new developments that will help to maintain existing water quality.

Water samples collected were intended to support the Highway 102 Watershed Study and the sampling program conducted may not be of sufficient duration or frequency to establish pre-development conditions. For areas where new or additional development could adversely impact watercourses, the Halifax Regional Municipal Planning Strategy mandates the completion of watershed or sub-watershed studies before undertaking secondary planning strategies. Developers must assess potential risks to water sources and establish monitoring programs to evaluate changes in water quality and quantity. This involves confirming parameters to be measured, determining sampling locations and frequency, and establishing baseline data prior to development.

Water samples from waterbodies with the HSA were collected monthly between April and November 2023. Samples from flowing waterbodies (streams, rivers) were collected by hand using laboratory supplied bottles and preserved according to laboratory protocols. Samples from lakes or ponds were collected from a boat using a low-flow peristaltic pump. When using a peristaltic pump standard precautions were followed to minimize aeration and preserve the integrity of the sample. The pump was operated at a controlled, low-flow rate. The tubing intake was weighted to rest at the sample depth and above the lake bottom, reducing the risk of pulling sediment into the sample or introducing bubbles. Tubing remained submerged and sealed throughout the sample collection to minimize contact with atmospheric air. Sufficient sample was drawn through the tubing to ensure a representative sample was collected. The sample was collected in laboratory supplied bottles and preserved according to laboratory protocols

2.1 Surface Water Quality Observations

Data collection was completed by Stantec Consulting Ltd. (Stantec) monthly between April and November 2023 and was used in conjunction with the historical water quality data collected intermittently since 1980 to characterize surface water quality in the HSA. Field monitoring of water quality was conducted at select locations across the HSA including in-lake, deep zone, watercourses, lake inlet, and lake outlets (Stantec 2024a).

The captured data was used as a comparison tool for contaminant models as well as a measure of baseline water quality in Washmill Lake.

Table 2.1 is a summary of the surface water quality data sources collected within the HSA. A description of local water quality and summary of the 2023 Stantec water quality results can be found in the *Highway 102 Land Suitability Analysis* (Stantec 2024a) and water quality monitoring results are in **Appendix A**.

Contaminant models were developed to assess key parameters that are particularly sensitive to changes in land use within a watershed, such as when forested land is developed to residential or commercial use. Probable causes of water quality impacts may be identified by examining changes to these key parameter concentrations. Total P, fecal coliform (represented by *E. coli*), and sediment were identified as key parameters to assess changes in trophic level/nutrients, water clarity, and anthropogenic inputs. A description of existing condition results of parameters that may affect the internal loading of the lake including pH, dissolved oxygen (DO), temperature, and conductivity is provided in **Section 2.1.4**.

Table 2.1: Historical Water Quality Data Sources

Data Source	Sampling Location	Period of Record	Number of Samples	Month of Sampling Events	Parameters Sampled
Department of Fisheries and Oceans (DFO)	Susies Lake	1980, 1991, 2000, 2021	1 per site per year sampled for a total of 4 per site	January, March, and April	Alkalinity, Aluminum, Ammonia, Arsenic, Calcium, Chloride, Chlorophyll-a, Color, Conductivity, Copper, Dissolved Organic Carbon, Iron, Magnesium, Manganese, Nitrate, pH, Potassium, Silica, Sodium, Sulphate, Total nitrogen, Total Phosphorous, Zinc
AECOM	Washmill Lake, Quarry Lake	2006-2011	11 – Washmill 4 – Quarry	June, December, April, August	Total Suspended Solids, Total Phosphorous, Total coliform, *E. coli,* Nutrients, Inorganics
Porter Dillon	Susies Lake, Quarry Lake, Washmill Lake	1994-1995	4 per site per year for a total of 24 samples	Once per season (Winter, Spring, Summer, Fall)	General Chemistry, metals, Chlorophyll-a, Total Phosphorous, Chloride
HRM Lake Watchers	Susies Lake	2021 and 2022	Twice per year	Once in Spring and once in summer	Color, *E. coli,* Total Phosphorous, Chlorophyll-a, Chloride, total metals
Stantec	HSA – 8 locations across the study area including Washmill Lake, Washmill Lake Deep Zone, Quarry Lake outlet, Little Belchers pond outlet, Little Fox Brook, Washmill Lake outlet, and three tributaries to Susies Lake	2023	8 per site for a total of 64 samples	Monthly from April to November	Total phosphorus, Dissolved chloride, Turbidity, Colour, Total suspended solids, and *E. coli* (counts).

2.1.1 TOTAL PHOSPHORUS

Phosphorus (P) is a common water quality parameter associated with the growth and proliferation of algae and aquatic vegetation in freshwater bodies. It is typically considered a limiting nutrient in natural freshwater systems, indicating it is not as readily available in comparison with other nutrients required for plant growth. The level of biological productivity within a lake is defined by the trophic level of the lake (**Table 2.2**). Lakes can naturally transition to a higher trophic level by accumulating nutrients (such as P) over thousands of years (Anderson 2002). In urbanized watersheds, however, the influence of human activities can cause an increase in P loading to waterbodies, contributing to an overabundance of vegetation and algae growth in a process called cultural eutrophication (Anderson 2002).

Table 2.2: Total Phosphorus Trigger Ranges for Canadian Lakes and Rivers (CCME 2004)

Trophic Status	Total Phosphorus (mg/L)
Ultra-oligotrophic	<0.004
Oligotrophic	0.004 to 0.010
Mesotrophic	0.010 to 0.020
Meso-eutrophic	0.020 to 0.035
Eutrophic	0.035 to 0.100
Hyper-eutrophic	>0.100

Total P levels in HSA are presented in **Figure 2.1** grouped by lake with water quality results presented in **Appendix A**. Total P for Washmill Lake ranged from below the detection limit (0.004 mg/L) to 0.010 mg/L with an average value of 0.006 mg/L using the 1994 to 2023 dataset. The majority of the samples were taken during the spring. The median TP concentration for Washmill Lake was found to be 0.004 mg/L, which is classified as oligotrophic (0.004 to 0.010 mg/L). The AECOM (2013) preliminary watershed study of the Birch Cove Area Lakes assessed data from 2006 to 2012 and also identified Washmill Lake as oligotrophic with a median concentration of 0.008 mg/L.

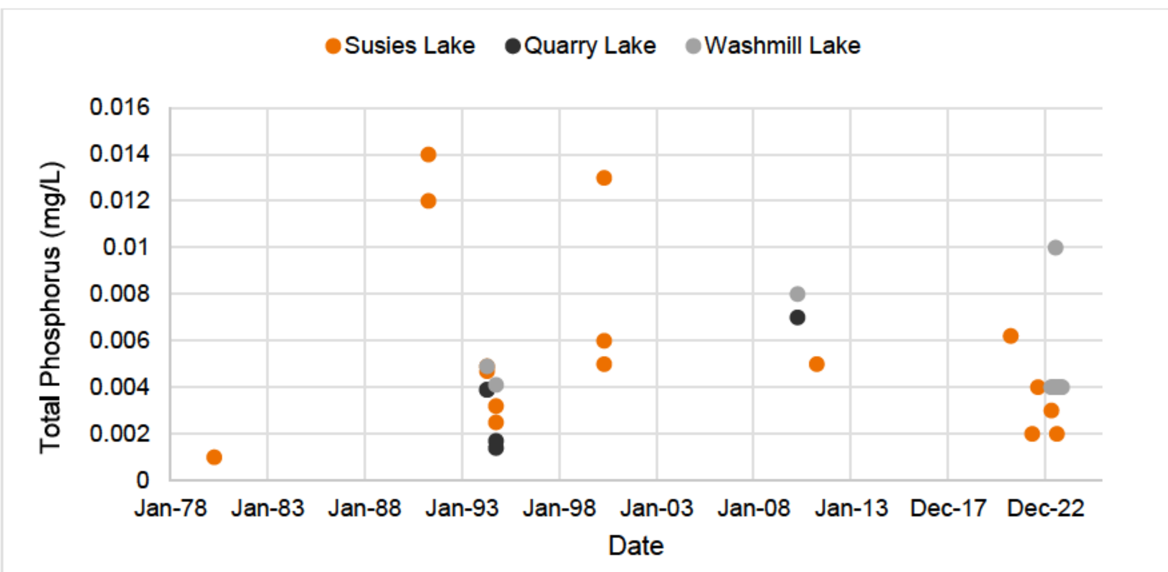

Figure 2.1: HSA Total Phosphorus Concentration (mg/L)

2.1.1.1 Internal Loading

Internal P loading is the process by which P trapped in the sediment of a lake becomes resuspended in the water column (Søndergaard 2003). During periods of increased external loading of a lake system, organic and inorganic P can become trapped in the sediment. The increased loading of P within the lake during the internal loading process often leads to eutrophication and deterioration of the ecosystem health such as an increase in cyanobacterial blooms, dissolved oxygen depletion, turbid water, and poor aquatic habitat. Factors that can influence P solubility and release back into the water column include redox reactions (P sorbed onto iron (III) compounds is released as iron (III) is reduced to iron (II)), resuspension of sediment, temperature, pH, chemical diffusion, microbial processes, and mineralization (Søndergaard 2003).

Anthropogenic watershed runoff is the primary source of external P loading into a lake (James 2016). Without the implementation of low-impact development (LID) or mitigation measures, runoff from the surrounding watershed can result in the deposition of P-rich sediment in lake basins.

2.1.2 FECAL COLIFORM

E. coli is a species of coliform bacteria of fecal origin, referred to as a fecal coliform bacteria. It is commonly used as a fecal indicator bacteria, denoting the potential presence of fecal matter containing pathogens and an associated risk to human health. Although there are other species of bacteria within the fecal coliform family, *E. coli* and fecal coliform are considered analogous in this report for the purposes of modelling. In urbanized watersheds, presence of *E. coli* in recreational waters may come from wild or domestic animals in proximity to a waterbody, stormwater runoff and domestic wastewater discharge represent additional human-related sources of *E. coli.*

Summary statistics for coliform levels in the HSA are presented in **Table 2.3** with water quality results presented in **Appendix A**. Fecal coliforms and *E. coli* concentrations were measured in the HSA area lakes in 2010, during the AECOM (2013) study and as part of the Stantec study (2024a). The mean value of total coliform was 385 CFU/100 mL while *E. coli* levels were lower with a mean value of 57 CFU/100 mL. The maximum total coliform concentration (700 CFU/100 mL) was observed in Washmill Lake during the July 17, 2023, sampling event. Potential sources of fecal coliform within the HSA watershed include runoff from the nearby commercial zones, human fecal sources from recreation and developed land use within the watershed, wildlife and avian.

Table 2.3: Coliform Water Quality Statistics for the HSA

Parameter	n	Mean	Median	Max	Min
Total Coliforms (CFU/100 mL)	8	385	300	700	120
E. coli (CFU/100 mL)	19	57.5	54	100	20

2.1.3 TOTAL SUSPENDED SOLIDS

Sediment carried in water has a variety of effects on water quality and is commonly measured as Total Suspended Solids (TSS) (mg/L) (Environment Canada n.d.). Sediment is associated with clarity of water and can decrease the penetration of light which has the potential to impact the health and survival of fish and other aquatic life. Additionally, sediment plays a role in the transport and fate of pollutants in water as contaminants can attach to sediment particles and be transported and deposited in other areas. The CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME CWQG-FAL) for suspended sediments is a maximum increase of 25 mg/L from background levels for short term exposures (e.g., 24 hours), and a maximum average increase of 5 mg/L from background levels for long term exposures (e.g., between 24 hours and 30 days) (CCME 1999).

Construction and land development projects accelerate the transport of sediment by exposing large areas of soil to rain and runoff within a watershed. Without implementation of erosion and sediment control measures, there is a risk of the degradation or destruction of fish habitat and impact to users of the lake or waterbody for recreational use.

Summary statistics for TSS concentrations in the HSA are presented in **Table 2.4** and **Appendix A**. TSS concentrations are low in Washmill Lake with a median value of 1 mg/L and a maximum value of

2.8 mg/L. The low TSS concentrations suggest that Washmill Lake is not substantially affected by urban runoff or erosion within the watershed. TSS concentrations above CCME CWQG-FAL values can negatively impact aquatic life by reducing light penetration and water clarity, thus altering fish habitat conditions (CCME 1999).

Table 2.4: Total Suspended Solids Water Quality Statistics for the HSA

Parameter	n	Mean	Median	Max	Min
Total Suspended Solids (mg/L)	9	1.15	1.0	2.8	<1

2.1.4 BASELINE IN SITU WATER QUALITY

Baseline *in situ* water quality profiles of Washmill Lake were collected between April and November 2023. The results from the monitoring are presented in **Appendix A**, and a comprehensive description of water quality for the HSA is presented in the Land Suitability Analysis (Stantec 2024a). The following section describes the results of the water quality profiles of the maximum depth of Washmill Lake for parameters that may affect the nutrient loading of the lake, including pH, DO, temperature, and conductivity. Due to available equipment throughout the study period, the water quality parameters were measured at water depths of up to 4.0 m, with the exception of April, October, and November when maximum depth of the lake was able to be reached (6.0 m) using a sample from a low-flow peristaltic pump. The use of different methods (direct sonde profiling vs. peristaltic pump sampling) is not expected to result in substantial differences in water quality values considering the measurements were taken every meter at discrete depths and the sampling procedures in Section 2.0 were in place.

The pH of Washmill Lake ranged between 6.02 to 7.40, with an average value of 6.74 throughout the 2023 monitoring period. These values represent neutral pH, and the mean pH value is within the CCME CWQG-FAL guideline range (6.5 to 9.0). Conductivity in Washmill Lake ranged between 0.121 to 0.255 mS/cm. The maximum conductivity value of 0.255 mS/cm was observed in May.

DO profiles of Washmill Lake were measured throughout the 2023 monitoring period. DO and temperature readings are presented in Figure 1.3; it should be noted that while temperature readings were taken in October, the DO probe experienced a malfunction, and DO readings were not collected during the October monitoring event. The DO values for Washmill Lake reach a minimum of 3.40 mg/L during the August monitoring event at a depth of 6 m below surface. The July and August sampling events had the lowest average DO concentrations with values of 6.2 mg/L, each. The CCME CWQG-FAL for DO is 6.0 mg/L for early life stage aquatic life and 5.50 mg/L for other life stages. The lake would not be considered to be anoxic during these months as DO is not entirely depleted, however hypoxic conditions are present as DO is reduced at depths below 4 m. This increases the potential for internal loading of P within the water column as anoxic conditions can induce the release of sediment-bound P (Deeds et. al. 2021).

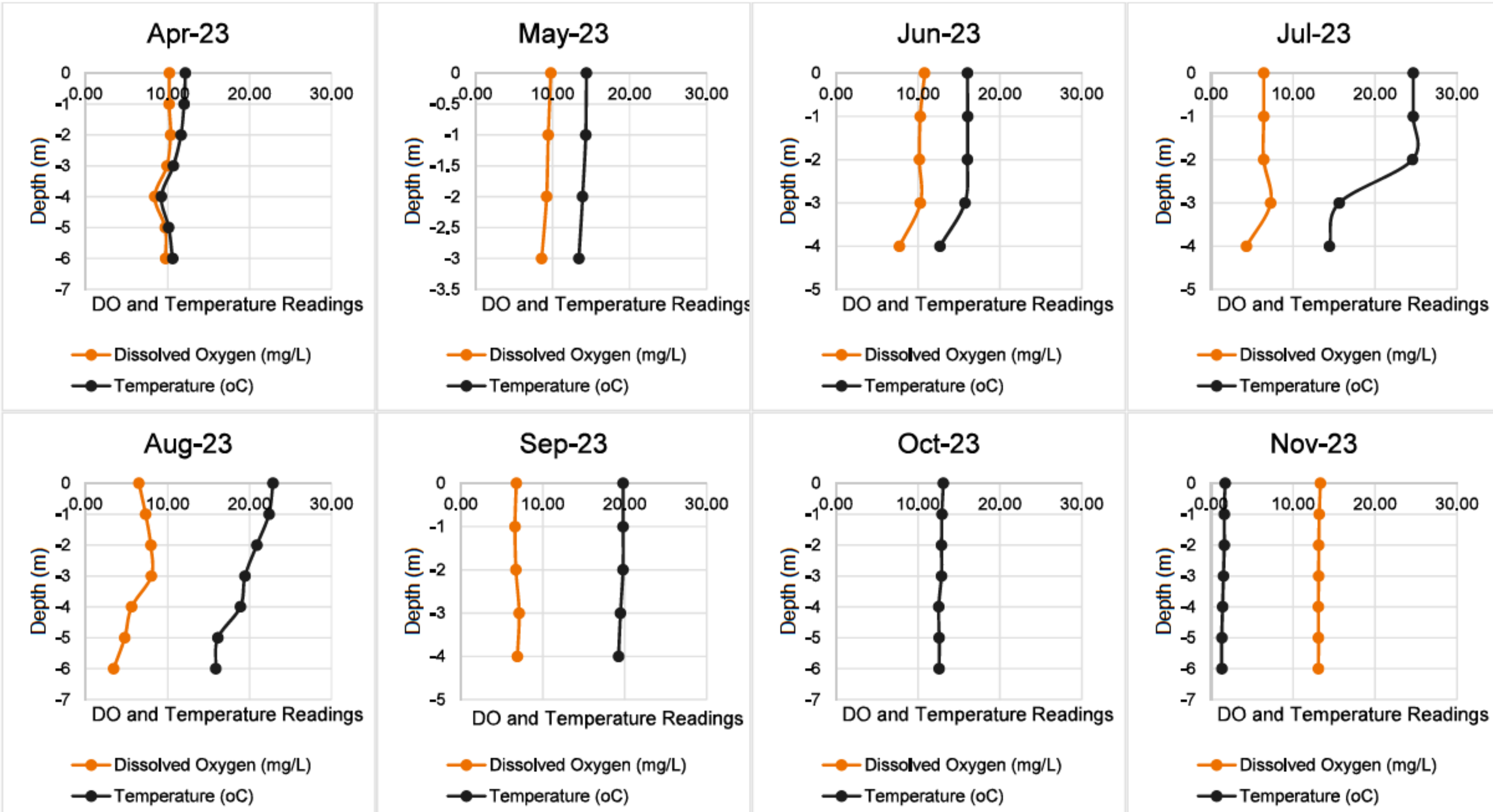

Figure 2.2: **Dissolved Oxygen and Temperature Profiles of Washmill Lake**

3 Water Quality Assessment

3.1 Watershed Delineation

Watershed delineation was completed using provincial LiDAR data (Halifax) to delineate the sub-watershed area contributing to the HSA and outfall points of interest. Watercourse and waterbody GIS data was provided through the Nova Scotia Topographic Database. Land uses for the watershed were derived from Nova Scotia Department of Natural Resources and Renewables Forestry Layer as well as the zoning boundary layer from HRM. The results of the land use assessment are presented in **Figure 3.1** and **Figure 3.2**.

The dominant land use within the HSA Watershed is forested (50%) followed by medium-density residential (11%). The current land uses within the HSA include two large inactive gravel pits from a historic quarrying operation.

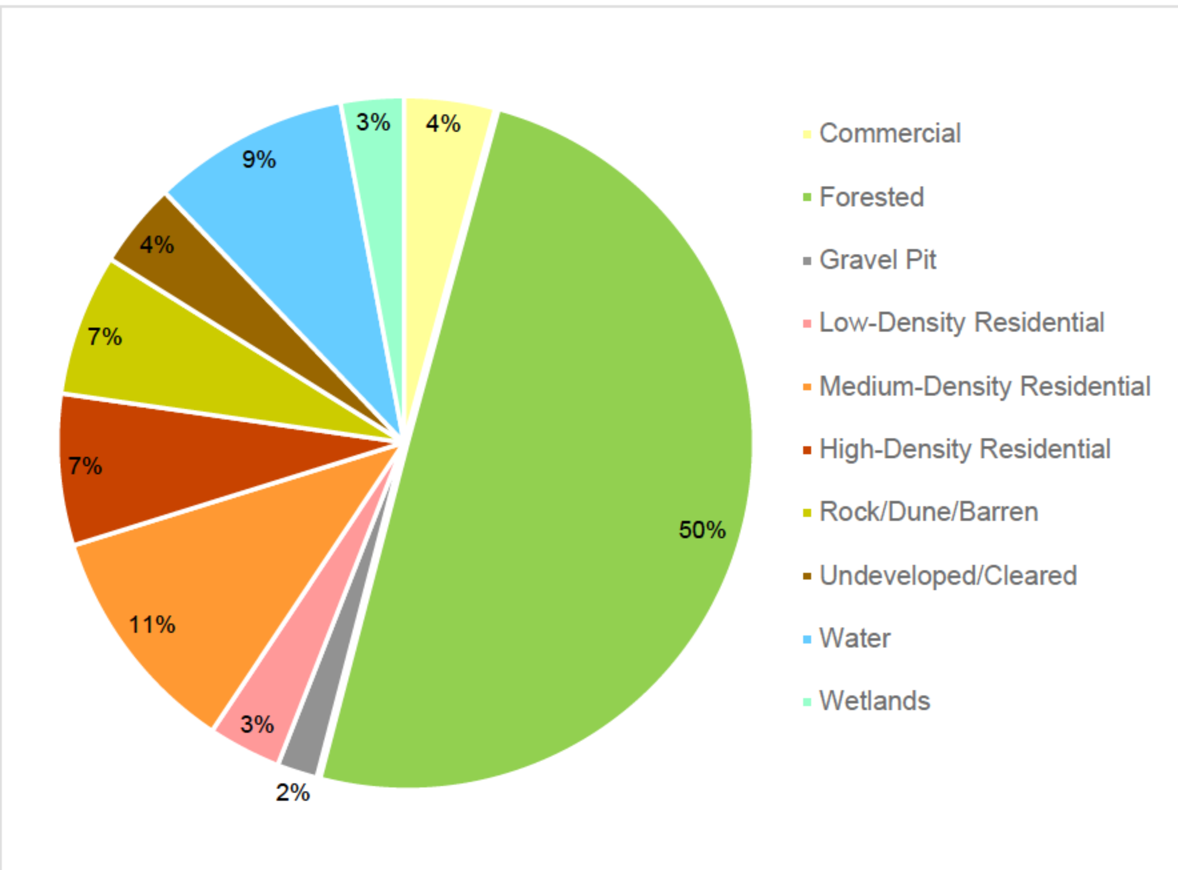

Figure 3.1: Existing HSA Watershed Land Use Breakdown

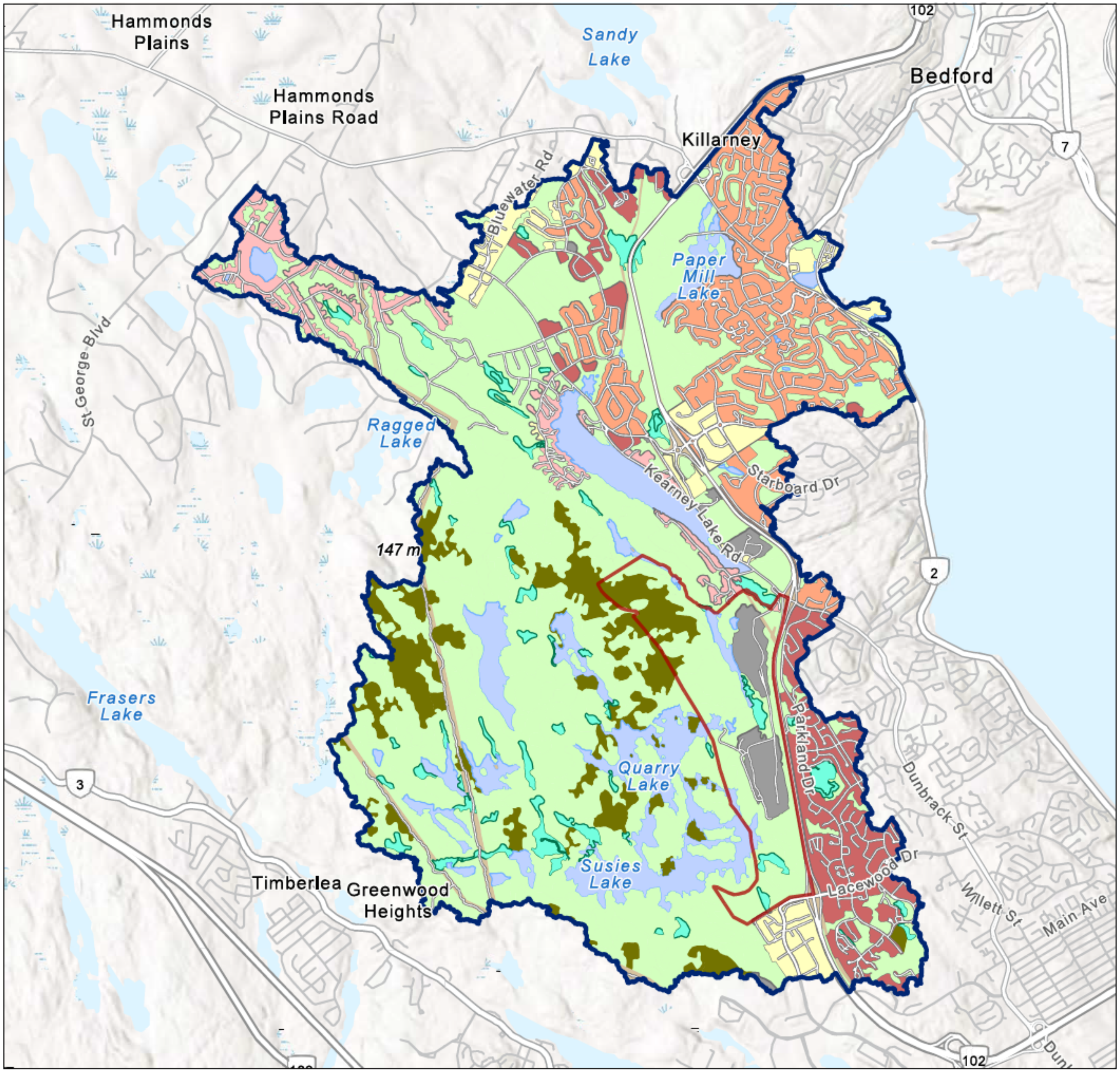

Figure No.
3.2
Title
HSA - Land USe

Client/Project 160410459
Halifax Regional Municipality
Future Serviced Communities

Project Location
Halifax Regional Municipality,
Nova Scotia

Prepared by AC on 2024-04-15

N

0 1 2 km

(At original document size of 8.5x11)
1:60,000

Legend

- Study Area
- Watershed Boundary
- Road

Land Use

- High Density Residential
- Medium Density Residential
- Low Density Residential
- Commercial
- Gravel Pit
- Rock/Dune/Barren
- Forested
- Undeveloped/Grassed
- Waterbody
- Wetlands

Notes
1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Stantec; Halifax Regional Municipality, Government of Nova Scotia (DNR)
3. Background: Esri

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3.2 Climate

Climate normal data were used for an estimate of the annual rainfall in the study area. The Environment Canada Halifax Stanfield International Airport Climate Station (Climate ID: 8202249) data from 1991 to 2020 were used. This station is located approximately 20 km from the HSA and is the closest climate station to the study area with complete 30 years of climate normals data. For the thirty-year data period, the annual precipitation is 1,393.3 mm per year.

Table 3.1: Climate Normals Data – Halifax Stanfield International Airport (ID: 8202249)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	78.6	70.7	89.0	90.4	108.2	89.8	86.7	90.5	107.3	139.2	145.4	106.8	1,202.4
Precipitation (mm)	125.9	111.0	120.2	106.4	109.7	89.8	86.7	90.5	107.3	139.8	159.1	146.9	1,393.3
Temperature (°C)	-5.7	-5.2	-0.9	4.5	10.1	15.2	19.2	19.2	15.2	9.2	3.8	-1.9	6.9

Annual precipitation amounts for 2023 were 13% higher than the climate normal with a total annual precipitation of 1,575.2 mm. Large precipitation events during the months of June and July caused flooding events within the adjacent Sackville River Watershed and surrounding areas. It should also be noted that the early spring months of 2023 were unusually dry, which caused wildfires to spread during the months of May and early June.

As historical data is the input for calculating climate normals for a particular site, there is limited applicability of climate normals data to assess the future climate conditions. The Climate Atlas of Canada's online tool (Prairie Climate Center 2019) was used to generate projected climate change precipitation and temperature data for the Municipality of Halifax. This online data portal provides downscaled data projections of temperature and precipitation from an ensemble of 24 different climate models. Projected climate changes in temperature and precipitation associated with the Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathway 8.5 (RCP8.5) scenario over a 30-year time horizon were selected. The RCP8.5 scenario was chosen as it represents greenhouse gas emissions continuing to be released at current rates, i.e., a High Carbon climate future. The RCP8.5 scenario reflects an intermediate stabilization scenario for the emission of greenhouse gases, in which radiative forcing is stabilized at approximately 8.5 Watts per metre squared (IPCC 2020). Results of the climate change projections are found in **Table 3.2**.

Quantity and timing of precipitation on a watershed have the capacity to influence runoff volumes within the watershed. As precipitation trends increase, as shown in **Table 3.2**, greater runoff volumes are expected within the watershed; timing of these precipitation events have the potential to cause increased flooding events, changes to lake turnover rates, or sedimentation events within watersheds (Qiu et.al. 2021).

Table 3.2: Climate Change Projections – Halifax (RCP8.5) (Prairie Climate Center 2019)

Parameter	Period	1991-2020 Climate Normals	2021-2050			2051-2080		
			Low	Mean	High	Low	Mean	High
Total Precipitation (mm)	annual	1393.3	1280	1519	1781	1324	1571	1849
Mean Temperature (°C)	annual	6.9	7.5	8.6	9.9	9.2	10.6	12.1

3.3 Development Scenarios

The HSA is being studied for future residential and commercial development. The focus of future development in the HSA is on lands owned by the B.D. Stevens Group and the Annapolis Group. The two landowners declared their intention to undertake a major development in the HSA prior to HRM issuing the Request for Proposals (RFP) for the Future Serviced Communities project (Stantec 2023b). The developments proposed, extend beyond the HSA (as shown in **Figure 3.3** and **Figure 3.4**), however only the proposed developments within the HSA were considered in this analysis. Four development scenarios were considered by Stantec (2023b) to assess changes in annual contaminant loads in this study. Details on each of the development scenarios being evaluated by HRM are provided in the *Development Scenarios – Highway 102 West Corridor* (Stantec 2023).

Table 3.3 provides a breakdown of the land use changes to the HSA watershed for each development scenario based on the scenarios proposed for the HSA (Stantec 2023). **Sections 3.3.1**, **3.3.2**, **3.3.3,** and **3.3.4** provide summary descriptions of each development scenario. It should be noted that for the low-density and high-density (developer-requested) development scenarios, the primary change is the number of units considered and does not necessarily reflect a difference in total affected area within the HSA. As per **Table 3.3,** the areal land use scenario maintains the greatest forested area compared to existing conditions, while the low density, developer-requested (high-density), and medium density scenarios maintain second/third (tie) and fourth-most forested area, respectively.

As the initial scenarios (low-, medium-, and high-density) were not significantly different from one another in terms of land cover differences, the areal land-use scenario was included to demonstrate the impact of a reduction in developed area. The density scenarios reflect population density rather than the density of proposed development across the landscape.

Table 3.3: Development Scenarios Land Use Changes

Land Use Type	Existing Land Uses (ha)	Low-Density Scenario (ha)	Mid-Density Scenario (ha)	Developer Requested Scenario (ha)	Aerial Land Use Scenario (ha)
A - Commercial	150.7	151.1	152.3	152.9	152.4
B – Low Density Residential (LDR)	121.3	274.7	124.1	121.3	121.3
C - Medium Density Residential (MDR)	385.9	385.9	406.6	409.4	404.7
D - High Density Residential (HDR)	251.5	251.5	379.6	379.6	354.0
E- Rock/Dune/Barren	235.6	235.6	235.6	235.6	235.6
F - Forested	1772.9	1588.3	1588.9	1588.3	1619.1
G - Undeveloped/Grass	141.3	141.3	141.3	141.3	141.3
H - Road	65.3	96.1	96.1	96.1	96.1
I - Wetland	104.6	104.6	104.6	104.6	104.6
J – Gravel Pit	67.2	67.2	67.2	67.2	67.2
K - Water	327.4	327.4	327.4	327.4	327.4
Developed Land	1,041.9	1,226.5	1,225.9	1,226.5	1,195.7
Undeveloped Land	2,581.8	2,397.2	2,397.8	2,397.2	2,428
Note: Developed Land is the sum of A, B, C, D, H and J; undeveloped land is the sum of E, F, G, I and K					

3.3.1 LOW-DENSITY SCENARIO

A Low-Density scenario will utilize low and medium-low density housing typologies, such as single detached dwellings, townhouses, and low-rise apartments. The primary difference between the developer-requested scenario and the low-density scenario is the capacity of the units within the development (i.e., smaller population inhabiting this area). The low-density scenario proposes to have an estimated population of 3,419 with a population density of 22 persons per hectare (Stantec 2023). There are no new multi-unit dwellings proposed in this scenario within the HSA.

3.3.2 MEDIUM-DENSITY SCENARIO

The Medium-Density scenario creates a higher unit density compared to the low-density scenario, while not utilizing as many multi-unit dwellings as the developer-requested high-density scenario. This approach accommodates low, medium-low, and medium-high density housing typologies, such as single detached, duplex, townhouse, low-rise residential, multi-family medium density buildings, as well as mixed-use buildings adding up to a 233% density increase compared to the Low-Density scenario. The medium-density scenario proposes to have an estimated population of 11,397 with a population density of 74 persons per hectare (Stantec 2023).

3.3.3 DEVELOPER REQUESTED SCENARIO

The developer requested scenario is considered to be the high-density scenario and explores the proposed intentions of key developers that own lands within the Study Area. B.D. Stevens Group and Annapolis Group have communicated their intentions to develop land within the HSA to accommodate residential and commercial/office uses. At this time, the following conceptual plans of B.D Stevens Group and Annapolis group were available (**Figure 3.3** and **Figure 3.4**) and were used as the basis of the developer-requested scenario. The proposed developments in **Figure 3.4** which are considered in this study include only the orange (mixed-use) areas. The developer-requested scenario proposes to have an estimated population of 21,326 with a population density of 139 persons per hectare (Stantec 2023). The primary dwelling type in this scenario is multi-unit housing with an estimated 10,500 units of the multi-unit unit type. Please note that Quarry Lake was the name presented in the B.D. Stevens concept plan (**Figure 3.3)** and is distinct from Quarry Lake adjacent to Susie's Lake shown in **Figure 1.1.** The quarry pit was not reclassified as a waterbody for the water quality assessment as future use of the quarry lands is still under consideration, and creating a lake within the pit would require approvals at the municipal, provincial, and federal levels. This would necessitate a more detailed assessment at that time including lake circulation, water balance and groundwater modelling. For the purposes of the watershed study retaining the land use as a 'gravel pit' provide a more conservative approach. Additional discussion on 'Quarry Lake' is provided in Section 8.5.1 as it relates to stormwater.

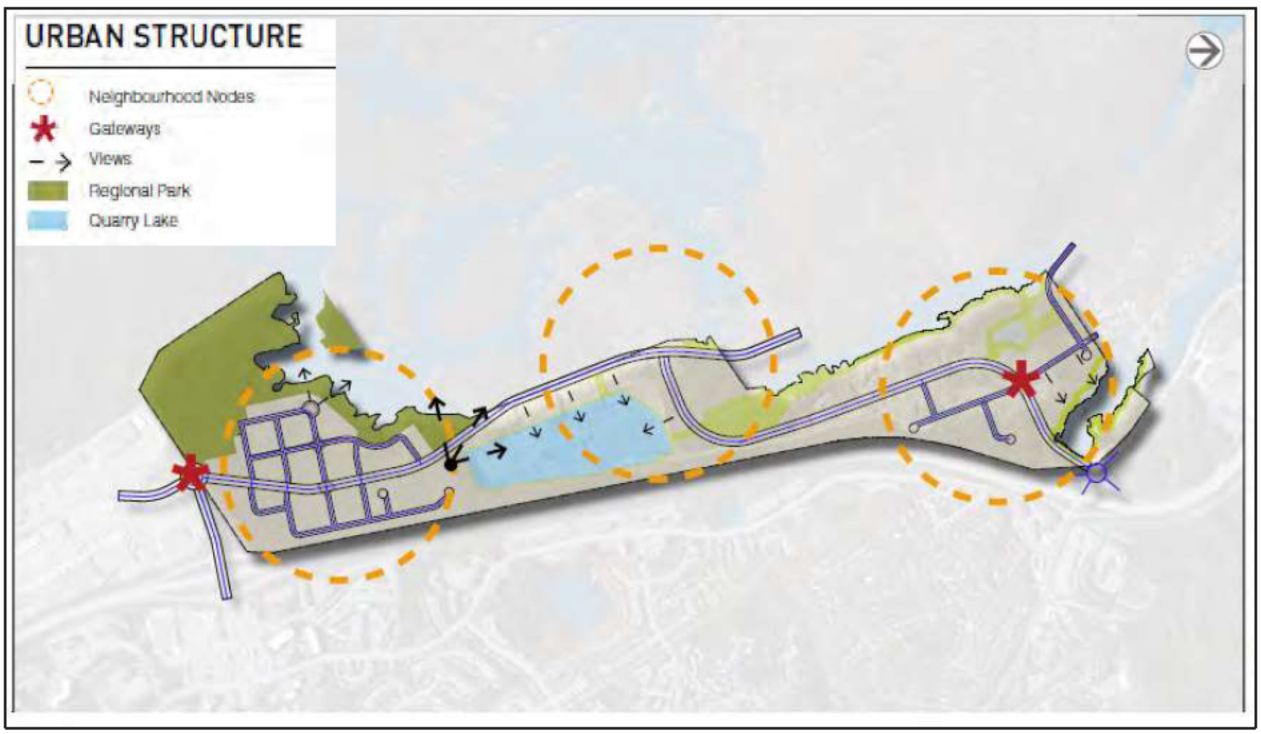


Figure 3.3: B.D. Stevens Concept Plan (Stantec 2023)

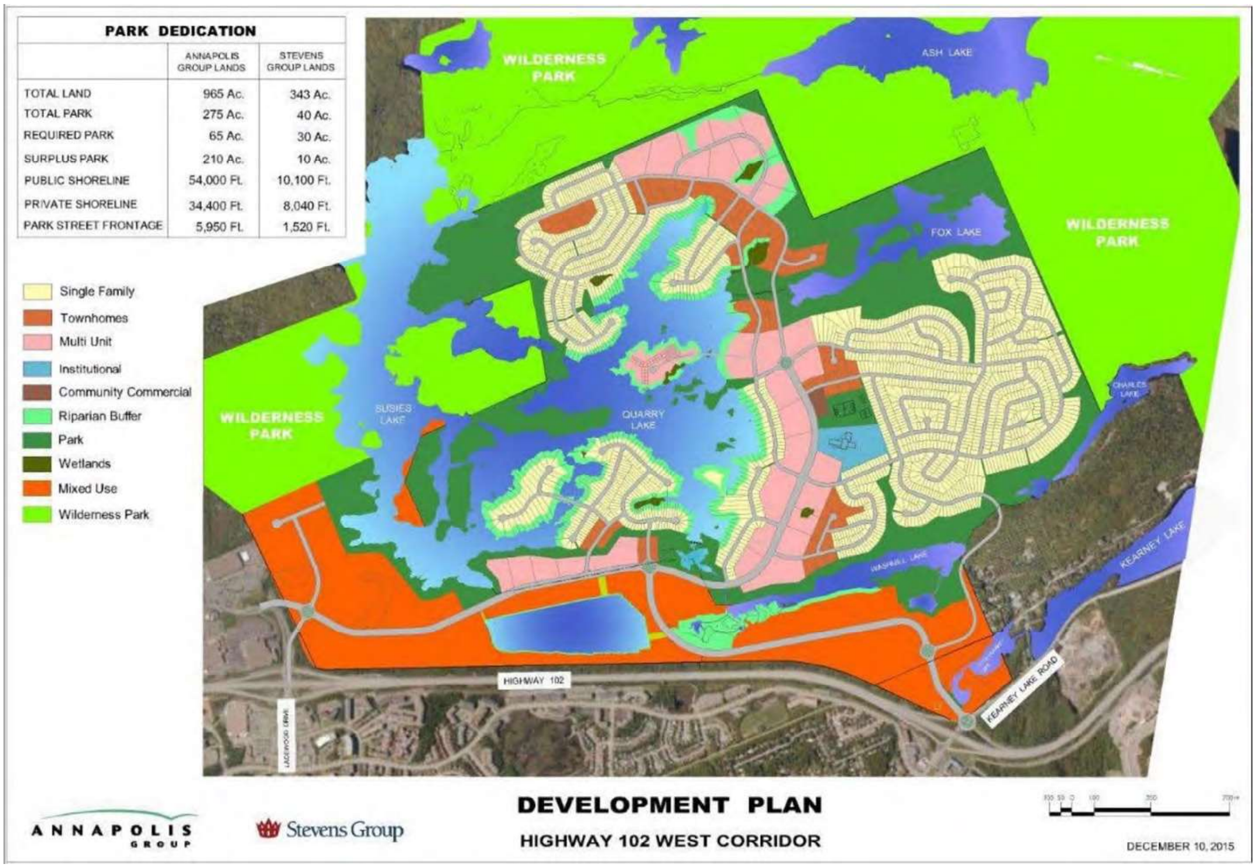


Figure 3.4: Annapolis Group Concept Plan (Stantec 2023)

3.3.4 AREAL LAND-USE SCENARIO

The areal land-use scenario incorporates the same housed population as the developer requested scenario, however this scenario covers 20% less residential, commercial, and industrial land area compared to the developer requested scenario. This scenario was evaluated to assess impacts of development on the watershed when forested area is conserved within the watershed. The areal land-use scenario proposes to have an estimated population of 21,326.

3.4 Storm-Event Model

Rainfall event-based contaminant load modeling is useful in design of appropriate stormwater treatment system for a Project area. A rainfall event-based contaminant load model uses literature-based contaminant concentration values derived for specific land uses to determine a stormwater contaminant load for a single precipitation event. Event mean concentration (EMC) data is derived from sampling runoff from specific land uses over the duration of a storm event. It is used for the purposes of modeling as it represents an average contaminant concentration generated over the duration of an event.

For the rainfall-event based model, the event-associated contaminant export load is calculated using the following formula:

$$P_{Event} = \sum R\, x A_{LU} x EMC_{LU} x RC_{LU} x 0.001$$

Where:

P_{Event} = total contaminant load on an event basis, kg or CFU

R = rainfall depth associated with selected precipitation event, mm

A_{LU} = area associated with a specific land use, m^2

EMC_{LU} = contaminant event mean concentrations associated with a specific land use, mg/L or CFU/100 mL

RC_{LU} = rainfall runoff coefficient associated with a specific land use, unitless

To determine the volume of runoff discharging from each land use during the rain event, a hydrologic model was developed for the HSA Stormwater Management Plan (Stantec 2024b) using PCSWMM (Computational Hydraulics Inc. of Guelph, Ontario, CA) to firstly estimate the runoff from the HSA watershed. The 2-yr 24-hr Chicago design storm was used as it is one of the design storms in the Highway 102 Stormwater Management Plan (Stantec 2024b). Land use-based curve numbers (CN) were selected for use with the SCS method of rainfall runoff estimation (**Table 3.4**) (Stantec 2024b). Initial abstraction of 1.5 mm accounts for depression storage, interception and infiltration occurring before runoff begins and was estimated for pervious land use areas as per United States Department of Agriculture (USDA) 1986. When the total watershed runoff volume was determined, runoff for each land use was estimated using the formula provided above, with the runoff coefficients (RC) given in **Table 3.4**. The hydrologic model results were then used to validate the runoff volumes from the rain-event based model.

Table 3.4: Summary of Land Use Runoff Parameters

Land Use	Curve Number[1]	Runoff Coefficient[1]
Commercial	92	0.85
Gravel Pit	85	0.68
Forested/Rock/Dune/Barren	60	0.14
Undeveloped/Grass	67	0.20
High-Density Residential	85	0.75
Medium-Density Residential	72	0.75
Low-Density Residential	68	0.65
Road	98	0.90
Water	99	0.99
Wetlands	99	0.99

[1] McCuen 1998

3.4.1 PARAMETER SELECTION FOR PRECIPITATION EVENT BASED PHOSPHORUS MODEL

EMC TP data were sourced for the land use distribution found within the studied watershed. As there is limited availability of local data, EMC values were taken from commonly referenced literature sources and are given in **Table 3.5** below.

Table 3.5: Total Phosphorous Event Mean Concentrations for Select Land Use

Land Use	Total Phosphorous Event Mean Concentration (mg/L)
Commercial	0.30[1]
Forested	0.15[2]
Gravel Pit	0.30[1]
Undeveloped/Grass	0.12[2]
Low-Density Residential	0.22[2]
Medium-Density Residential	0.36[2]
High-Density Residential	0.45[2]
Rock/Dune/Barren	0.19[2]
Road	0.62[2]
Wetlands	0.10[1]
Water	n/a

[1] CH2M HILL 1993; [2] Pitt and MacLean 1986; [3] USEPA 2001

3.4.2 PARAMETER SELECTION FOR PRECIPITATION EVENT BASED FECAL COLIFORM LOADING MODEL

EMC fecal coliform data were sourced for the land use distribution found within the studied watersheds, as presented in **Table 3.6**. Data is given in units of CFU/100 mL, which refers to the number of colony forming units (CFU) of bacteria per 100 mL of sample volume. Fecal coliform EMC values were used as there is limited available data for land use associated *E. coli* concentrations. These values are considered comparable to *E. coli* concentrations for the purpose of this study. Where available, data were taken from a study conducted by Theriault and Duchesne (2012) on fecal coliform loading in urban watersheds in Quebec. Commonly referenced literature sources were used for the remaining EMC values. Barnhart et al. (nd) found higher bacteria counts in runoff from residential areas and attributed loadings to wildlife rather than domestic animals with variation in bacterial loadings from specific land uses thought to be due to the transient nature of the wildlife sources. Differences in EMC values between forest and undeveloped/grassed areas may also be attributed to differences in runoff volumes from the specific land uses. A forested site would have substantial wildlife use but minimal runoff volume comparison with a grassed site. As noted in the USEPA Preliminary Data Summary of Urban Stormwater Best Management Practices (1999), literature values for land use-based fecal coliform EMCs vary greatly between studies and show a strong trend of seasonal fluctuation.

Table 3.6: Fecal Coliform Event Mean Concentrations for Select Land Uses

Land Use	Fecal Coliform Event Mean Concentration (CFU/100 mL)
Commercial Development	4,500[1]
Gravel Pit	4,500[2]
Forest/Rock/Dune/Barren/Wetlands	500[2]
Undeveloped/Grassed	10,365[3]
High-Density Residential	7,750[1]
Medium-Density Residential	7,750[1]
Low-Density Residential	7,750[1]
Road	1,400[2]
Water	n/a

[1] Theriault and Duchesne 2012; [2] CH2M HILL1993; [3] Burnhart *et al.* nd

3.4.3 PARAMETER SELECTION FOR PRECIPITATION EVENT BASED SEDIMENT LOADING MODEL

The precipitation event-based sediment loading was calculated using the Modified Universal Soil Loss Equation (MUSLE) (Haan 1982). MUSLE is a storm-based application of the Revised Universal Soil Loss Equation (RUSLE) and uses the volume of storm event runoff (m^3) and peak discharge (Q_p) to calculate the rainfall factor (R_w). Sediment loading (A) is then calculated using the following equation:

$$A = R_w \times K \times LS \times C \times P$$

Where:

- A is the potential, long term average annual erosion loss (tonnes ha^{-1} $year^{-1}$)
- R_w is the MUSLE *rainfall factor* (MJ mm ha^{-1} $hour^{-1}$)
- K is the *soil erodibility factor* (tonnes hour MJ^{-1} mm^{-1})
- LS is the *slope length and steepness factor* (dimensionless)
- C is the *cropping management factor* (dimensionless)
- P is the support practice factor (dimensionless)

Table 3.7 provides the input parameters used to calculate the MUSLE precipitation event sediment load for the HSA watershed. The MUSLE land use categories include Undisturbed Forest Land (Forested and Wetland), Roads (Roads), Disturbed Forest Land (Rock/Dune/Barren and Undeveloped/Grass), Urban (High Density Development, Medium Density Development, Low Density Development, Commercial, Gravel Pit).

Table 3.7: MUSLE Input Parameters

Input	Value	Assumptions	MUSLE Source
Rainfall Factor (Rw)	87.4	Calculated using the volume of runoff in m^3 and peak discharge	Haan 1982
Soil Erodibility Factor (K) (tonnes h MJ-1 mm-1)	0.017	Dominant soil type in the area is gravelly sandy loam till (Halifax/Danesville soils); Table K-1	Wall et al. 2002, p56
Slope length and Steepness Factor (LS)			
General Forest Cover	1.79	General Forest cover is average slope across the watershed and average flow length (8% slope, 250 m length)	Wall et al. 2002 Table LS-1
Roads (Paved and Gravel)	2.64	Roads and Transmission lines use the maximum slope and flow length in watershed, (12.8% slope, 100 m length)	Wall et al. 2002 Table LS-2
Urban Areas	0.09	Areas prepared for residential / commercial development have minimal slope and average flow length of 250 m	Wall et. al. 2002 Table LS-3
Cropping Management Factor (C)			
Undisturbed Forest Land	0.001	Forested land natural condition with duff at least 5 cm deep	Table C-6 Wall et. al 2002
Roads (Paved and Gravel)	0.07		Table C-8 Wall et al 2002
Disturbed forested Land	0.04		Table C-7 Wall et. al 2002
Urban areas	0.17	Urban land use C-Factor	Ramlal (2007), HECL 2012
Support Management Factor (P)	1	No management practices	Wall et al. 2002

3.5 Annual Loading Model

Annual contaminant loading models use land use-based contaminant loading rates to determine the contaminant load derived from a watershed on an annual basis (Brylinsky 2004). As the annual rainfall amount is inherently integrated into the land use-based contaminant loading rates, the use of local data is most accurate. In the absence of local data, literature values are used. For the annual loading model, the estimated annual contaminant load is calculated using the following formula:

$$Load_{Annual} = \sum LR_{LU} \; x \; A_{LU}$$

Where:

$Load_{Annual}$ = total contaminant load on an annual basis, kg/year or CFU/100mL·year^{-1}

LR_{LU} = areal contaminant loading rate associated with a specific land use, phosphorus (g/m^{2}·year^{-1}) or *E. coli* (CFU/100mL/m^{2}·year^{-1})

A_{LU} = area associated with a specific land use, m^{2}

3.5.1 PARAMETER SELECTION FOR ANNUAL PHOSPHORUS LOADING MODEL

Land use based areal loading P data were sourced for the land use distribution found within the studied watershed. Where possible, parameters were selected from the Nova Scotia-focused study conducted by Brylinsky (2004) and are indicated with an asterisk (*). Selected parameters are presented in **Table 3.8**.

Table 3.8: Area-based Phosphorous Loading Rates for Select Land Uses

Land Use	Phosphorous Loading Rate (g/m^{2}·yr)
Commercial*	0.0202[2]
Forested*	0.0024[1]
Gravel Pit	0.020[2]
Low-Density Residential*	0.025[1]
Medium-Density Residential*	0.030[1]
High-Density Residential*	0.035[1]
Rock/Dune/Barren	0.010[3]
Undeveloped/Grass*	0.015[2]
Water*	n/a
Wetland*	0.0024[1]
Roads	0.035[2]

[1]Waller and Hart 1986; [2] Reckhow *et al.* 1980; [3] MDEP 2000, * - indicates loading rate from Brylinsky (2004)

3.5.2 LAKE SYSTEM MODEL

In addition to the annual loading model, the lake system model provides an estimate of the P balance within Washmill Lake. It considers P lake inputs from atmospheric deposition, surface runoff, and contributing waterbodies and provides an estimate of in-lake P concentration after accounting for P sedimentation and surface outflow. The estimated in-lake P concentration can then be compared to measured P concentration values.

The lake system model is taken from the widely accepted *User's Manual for Prediction of Phosphorus Concentration in Nova Scotia Lakes* (Brylinsky 2004). The model described by Brylinsky (2004) is a mass-balance approach, using the Vollenweider equation, as follows:

$$PV = \frac{M/V}{\left(\frac{Q}{V}\right) + \sigma}$$

Where:

PV = Total mass of phosphorus in lake (g)

P = Lake phosphorus concentration (g/m^3)

V = Lake volume (m^3)

t = time

M = Annual mass of phosphorus input to lake (g/year)

Q = Annual volume of water outflow from lake (m^3/year)

σ = Sedimentation coefficient (/year)

Brylinsky (2004) proposes a series of physical, hydraulic, and water-quality-based parameters to determine the total mass of phosphorous in the studied lake. A full table of model parameters and results is presented in **Appendix B**. A summary of select lake system model parameters are given in **Table 3.9**, below.

Table 3.9: Summary of Select Lake System Model Parameters

Parameter	Abbrev.	Value	Units	Source
Annual Unit Precipitation	Pr	1.396	m/yr	Estimated using climate normals data
Annual Unit Lake Evaporation	Ev	0.52	m/yr	Calculated using Thornthwaite (1948) method
Annual Unit Hydraulic Runoff - Developed	Ruv	1.10	m/yr	Brylinsky (2004)
Annual Unit Atmospheric P Deposition	Da	0.0173	g P m^2/yr	Brylinsky (2004)
Phosphorus Retention Coefficient	v	12.40	n/a	Brylinsky (2004)

3.5.2.1 Lake Evapotranspiration

Potential Evapotranspiration (PET) was calculated using the Thornthwaite Method (Thornthwaite 1948) and the average annual temperature shown in **Table 3.1**. For the lakes, actual evapotranspiration (ET) is considered equivalent to the sum of monthly PET multiplied by the area of the lake. The annual ET loss is estimated to be 516 mm/year.

3.5.3 PARAMETER SELECTION FOR ANNUAL FECAL COLIFORM LOADING MODEL

As there is limited areal-loading data available for land use associated fecal coliform loading, event mean concentration (EMC) values were used to determine the annual loading of fecal coliform from the studied watershed. Using the climate normal average annual precipitation value of 1396.2 mm (Section 1.3), the event-based loading method was used to calculate the fecal coliform loading associated with the annual depth of rainfall. Input parameters are presented in **Table 3.10** below. Due to limited available data, fecal coliform loading from wetlands and partially cleared forest land uses were assumed to be similar to forest land use. Similarly, fecal coliform loading from institutional land use was assumed to be similar to commercial development land use.

Table 3.10: Area-based Fecal Coliform Loading Rates for Select Land Uses

Land Use	Fecal Coliform Loading Rate (CFU/ha·yr)
Commercial/Gravel Pit	5.59E+11
Forest/Rock/Dune/Barren	4.27E+11
Undeveloped/Grass	9.77E+09
High-Density Residential	3.47E+11
Medium-Density Residential	8.12E+11
Low-Density Residential	8.12E+11
Roadway	7.03E+11

3.5.4 PARAMETER SELECTION FOR ANNUAL SEDIMENT LOADING MODEL

The sediment loading model was completed using the RUSLE tailored for application in Canada (RUSLEFAC) by Wall et. al. (2002). The RUSLEFAC model is a commonly used empirical equation for estimating soil loss from water erosion for a variety of land uses and the approach used in this study is specifically for use in Canada, including regional specific input parameter value tables. Only the area undergoing change in land use is considered in this model. The annual soil loss in tonnes/ha/year is calculated using the RUSLEFAC equation, presented below:

$$Annual\ Average\ Soil\ Loss\ (A) = R \times K \times LS \times C \times P$$

Where:

A	is the potential, long term average annual erosion loss (tonnes ha^{-1} $year^{-1}$)
R	is the *rainfall factor* (MJ mm ha^{-1} $hour^{-1}$)
K	is the *soil erodibility factor* (tonnes hour MJ^{-1} mm^{-1})
LS	is the *slope length and steepness factor* (dimensionless)
C	is the *cropping management factor* (dimensionless)
P	is the support practice factor (dimensionless)

Table 3.11 summarizes the inputs, assumptions, and sources used for the RUSELFAC calculations. The RUSLEFAC land use categories include undisturbed forest land (Forested and Wetland), Roads (Roads), Disturbed Forest Land (Rock/Dune/Barren and Undeveloped/Grass), Urban (High Density Development, Medium Density Development, Low Density Development, Commercial, Gravel Pit).

Table 3.11: RUSELFAC Input Parameters

Input	Value	Assumptions	RUSLEFAC Source
Rainfall Factor (R) (MJ mm ha-1 hour-1)	1790	Table R-1 - Erosivity index and monthly distribution (%) for sites in the Prairie Region and Eastern Canada	Wall et al. 2002, p. 44
Soil Erodibility Factor (K) (tonnes h MJ-1 mm-1)	0.017	Dominant soil type in the area is gravelly sandy loam till (Halifax/Danesville soils); Table K-1	Wall et al. 2002, p56
Slope length and Steepness Factor (LS)			
General Forest Cover	1.79	General Forest cover is average slope across the watershed and average flow length (8% slope, 250 m length)	Wall et al. 2002 Table LS-1
Roads (Paved and Gravel)	2.64	Roads and Transmission lines use the maximum slope and associated flow length in watershed, (12.8% slope, 125 m length))	Wall et al. 2002 Table LS-2
Urban Areas	0.09	Areas prepared for Residential / commercial development have minimal slope and average flow length of 250 m	Wall et. al. 2002 Table LS-3
Cropping Management Factor (C)			
Undisturbed Forest Land	0.001	Forested land natural condition with duff at least 2 inches deep	Table C-6 Wall et. al 2002
Roads (Paved and Gravel)	0.07		Table C-8 Wall et al 2002
Disturbed forested Land	0.04		Table C-7 Wall et al 2002
Urban areas	0.17	Urban Land use C-Factor	Ramlal (2007), HECL 2012
Support Management Factor (P)	1	No management practices	Wall et al. 2002

4 Water Quality Modeling Results

4.1 Storm-Event Model

4.1.1 PHOSPHOROUS

Precipitation event-based TP loading was completed for a design storm event with a 2-year return period, 24-hour duration precipitation depth occurring over the studied watershed. Resultant TP loading for the existing conditions, low-density, medium-density, areal land use, and developer requested (high-density) are listed in **Table 4.1**. When compared to the annual phosphorous load, the event-based TP loading is approximately 20% of the annual load for each scenario, including existing condition. Compared to the existing conditions TP loading, the development scenarios result in an increase of TP loading of 11%, 19%, 19% and 17% for the low-, medium-, developer-requested (high-density) and areal land-use scenarios, respectively. The developer-requested (high-density) and medium-density scenarios are predicted to have the greatest increase in TP loading due to the amount of high-density housing and roads within the watershed; the additional change in land use to high density residential (e.g., impervious surfaces for parking lots and building size) increases the TP loading.

Table 4.1: Predicted P Loading to HSA for Existing Condition during Storm Event

Development Scenario	Land Use	Area (ha)	P Loading (kg)	Land Use Percentage	P Load Percentage
Existing Conditions	Commercial	150.7	8.9	4.2%	11.4%
	Forested	1772.9	5.3	48.9%	6.8%
	Gravel Pit	67.2	3.1	1.9%	4.0%
	Low-Density Residential	121.3	3.9	3.3%	5.0%
	Medium-Density Residential	385.9	24.0	10.6%	30.5%
	High Density Residential	251.5	19.5	6.9%	24.9%
	Rock/Dune/Barren	235.6	1.5	6.5%	1.9%
	Undeveloped/Grass	141.3	0.6	3.9%	0.8%
	Water	327.4	-	9.0%	-
	Wetland	104.6	2.6	2.9%	3.3%
	Road	65.3	9.1	1.8%	11.6%
	Total	3623.7	**78.5**	**100.0%**	**100.00%**
Low-Density Scenario	Commercial	151.1	9.0	4.2%	10.3%
	Forested	1588.3	4.8	43.8%	5.5%
	Gravel Pit	67.2	3.1	1.9%	3.6%

Development Scenario	Land Use	Area (ha)	P Loading (kg)	Land Use Percentage	P Load Percentage
	Low-Density Residential	274.7	8.9	7.6%	10.2%
	Medium-Density Residential	385.9	24.0	10.6%	27.5%
	High Density Residential	251.5	19.5	6.9%	22.4%
	Rock/Dune/Barren	235.6	1.5	6.5%	1.7%
	Undeveloped/Grass	141.3	0.6	3.9%	0.7%
	Water	327.4	-	9.0%	
	Wetland	104.6	2.6	2.9%	3.0%
	Road	96.1	13.4	2.7%	15.4%
	Total	3623.7	**87.3**	**100.0%**	**100.0%**
Medium-Density Scenario	Commercial	152.3	9.0	4.2%	9.6%
	Forested	1588.9	4.8	43.8%	5.1%
	Gravel Pit	67.2	3.1	1.9%	3.3%
	Low-Density Residential	124.1	4.0	3.4%	4.3%
	Medium-Density Residential	406.6	25.2	11.2%	26.9%
	High Density Residential	379.6	29.5	10.5%	31.4%
	Rock/Dune/Barren	235.6	1.5	6.5%	1.6%
	Undeveloped/Grass	141.3	0.6	3.9%	0.6%
	Water	327.4	-	9.0%	
	Wetland	104.6	2.6	2.9%	2.8%
	Road	96.1	13.4	2.7%	14.3%
	Total	3623.7	**93.7**	**100.0%**	**100.0%**
Developer Requested (High-Density) Scenario	Commercial	152.9	9.1	4.2%	9.66%
	Forested	1588.3	4.8	43.8%	5.08%
	Gravel Pit	67.2	3.1	1.9%	3.33%
	Low-Density Residential	121.3	3.9	3.3%	4.20%
	Medium-Density Residential	409.4	25.4	11.3%	27.10%
	High Density Residential	379.6	29.5	10.5%	31.41%
	Rock/Dune/Barren	235.6	1.5	6.5%	1.55%
	Undeveloped/Grass	141.3	0.6	3.9%	0.63%
	Water	327.4	-	9.0%	

Development Scenario	Land Use	Area (ha)	P Loading (kg)	Land Use Percentage	P Load Percentage
	Wetland	104.6	2.6	2.9%	2.76%
	Road	96.1	13.4	2.7%	14.28%
	Total	3623.9	**93.8**	**100.00%**	**100.00%**
Areal Land Use Scenario	Commercial	152.4	9.0	4.2%	9.86%
	Forested	1619.1	4.9	44.7%	5.30%
	Gravel Pit	67.2	3.1	1.9%	3.41%
	Low-Density Residential	121.3	3.9	3.3%	4.30%
	Medium-Density Residential	404.7	25.1	11.2%	27.44%
	High Density Residential	354.0	27.5	9.8%	30.00%
	Rock/Dune/Barren	235.6	1.5	6.5%	1.59%
	Undeveloped/Grass	141.3	0.6	3.9%	0.65%
	Water	327.5	-	9.0%	-
	Wetland	104.7	2.6	2.9%	2.83%
	Road	96.1	13.4	2.7%	14.63%
	Total	3623.7	**91.6**	**100.00%**	**100.00%**

4.1.2 FECAL COLIFORM

Precipitation event-based fecal coliform loading was completed for a design storm event with a 2-year return period, 24-hour duration precipitation depth occurring over the studied watershed, with results given in **Table 4.2**. From existing conditions, this represents an increase in fecal coliform load of 12.0%, 13%, 13%, and 10% for the low-density, medium-density, developer-requested (high-density), and areal-land use scenarios, respectively. For all development scenarios, including existing conditions, the greatest FC annual loads are attributed to medium-density residential development land use (approximately 38%). This is due to the high volume of medium density development in all scenarios (including existing conditions) resulting in the greatest impact overall.

Table 4.2: Predicted Fecal Coliform Loading to HSA during Storm Event

Development Scenario	Existing Condition Land Use	Area (ha)	FC Loading (CFU)	Land Use Percentage	FC Load Percentage
Existing Conditions	Commercial	150.66	1.41E+12	4.2%	11.0%
	Gravel Pit	67.20	4.69E+11	1.9%	3.6%
	Forest/ Rock/Dune/Barren/ Wetland	2113.11	2.11E+11	58.3%	1.6%
	Undeveloped/Grass	141.28	6.59E+11	3.9%	5.1%
	High-Density Residential	251.54	3.36E+12	6.9%	26.2%
	Medium-Density Residential	385.90	5.16E+12	10.6%	40.2%
	Low-Density Residential	121.31	1.39E+12	3.3%	10.8%
	Roadway	65.30	1.87E+11	1.8%	1.5%
	Water	327.45	-	9.0%	-
	Total	**3623.74**	**1.28E+13**	**100.0%**	**100.0%**
Low-Density Scenario	Commercial	151.08	1.41E+12	4.2%	9.9%
	Gravel Pit	67.20	5.21E+10	1.9%	0.4%
	Forest/ Rock/Dune/Barren/ Wetland	1928.58	1.93E+11	53.2%	1.4%
	Undeveloped/Grass	141.28	6.59E+11	3.9%	4.6%
	High-Density Residential	251.54	3.36E+12	6.9%	23.6%
	Medium-Density Residential	385.90	5.16E+12	10.6%	36.2%
	Low-Density Residential	274.67	3.14E+12	7.6%	22.0%
	Roadway	96.06	2.76E+11	2.7%	1.9%
	Water	327.45	-	9.0%	-
	Total	**3623.74**	**1.43E+13**	**100.0%**	**100.0%**
Medium-Density Scenario	Commercial	152.26	1.42E+12	4.2%	9.8%
	Gravel Pit	67.20	5.21E+10	1.9%	0.4%
	Forest/ Rock/Dune/Barren/ Wetland	1929.20	1.93E+11	53.2%	1.3%
	Undeveloped/Grass	141.28	6.59E+11	3.9%	4.5%
	High-Density Residential	379.56	5.07E+12	10.5%	34.9%

Development Scenario	Existing Condition Land Use	Area (ha)	FC Loading (CFU)	Land Use Percentage	FC Load Percentage
	Medium-Density Residential	406.60	5.44E+12	11.2%	37.4%
	Low-Density Residential	124.14	1.42E+12	3.4%	9.8%
	Roadway	96.06	2.76E+11	2.7%	1.9%
	Water	327.45	-	9.0%	
	Total	**3623.74**	**1.45E+13**	**100.0%**	**100.0%**
Developer Requested (High-Density) Scenario	Commercial	152.89	1.43E+12	4.2%	9.8%
	Gravel Pit	67.20	5.21E+10	1.9%	0.4%
	Forest/ Rock/Dune/Barren/ Wetland	1928.58	1.93E+11	53.2%	1.3%
	Undeveloped/Grass	141.28	6.59E+11	3.9%	4.5%
	High-Density Residential	379.56	5.07E+12	10.5%	34.9%
	Medium-Density Residential	409.43	5.47E+12	11.3%	37.6%
	Low-Density Residential	121.31	1.39E+12	3.3%	9.5%
	Roadway	96.06	2.76E+11	2.7%	1.9%
	Water	327.45	-	9.0%	
	Total	**3623.74**	**1.45E+13**	**100.0%**	**100.0%**
Areal Land-Use Scenario	Commercial	152.44	1.42E+12	4.2%	10.1%
	Gravel Pit	67.20	5.21E+10	1.9%	0.4%
	Forest/ Rock/Dune/Barren/ Wetland	1959.33	1.96E+11	54.1%	1.4%
	Undeveloped/Grass	141.28	6.59E+11	3.9%	4.7%
	High-Density Residential	353.95	4.73E+12	9.8%	33.5%
	Medium-Density Residential	404.72	5.41E+12	11.2%	38.3%
	Low-Density Residential	121.31	1.39E+12	3.3%	9.8%
	Roadway	96.06	2.76E+11	2.7%	2.0%
	Water	327.45	-	9.0%	-
	Total	**3623.74**	**1.41E+13**	**100.0%**	**100.0%**

4.1.3 SEDIMENT

The total event-based soil loss load (tonnes) for each development scenario is presented in **Table 4.3**. Low-density, medium-density, and developer-requested scenarios had approximately the same increase in sediment load from existing conditions. The areal land-use scenario had a storm-based sediment load which was approximately 0.5 tonnes lower than the three development scenarios. The increased urban area in the three development conditions compared to the areal land-use scenario accounts for the slight increase in event-based sediment load. These values represent no mitigation or management condition, therefore with the implementation of standard erosion and sedimentation controls, these values would be expected to decrease. The low, medium-, and high-density development scenarios represent a sediment load increase of 11% when compared to existing conditions (74.5 tonnes). The areal land-use scenario represents a sediment load increase of 9% when compared to existing conditions (74.5 tonnes). The predicted increase in sediment load to the watershed is attributed to the increased amount of impervious/residential area within the watershed due to development.

Table 4.3: Event-Based Sediment Loading Results

Development Condition	Land Use	A (tonnes/ha)	Area (ha)	Total Storm Event Load (tonnes)
Existing Condition	Forest General (Non-Disturbed)	0.0025	1877.5	74.5
	Roads	0.1745	65.3	
	Disturbed Forest Land	0.0997	376.9	
	Urban	0.0213	976.6	
Low-Density Scenario	Forest General (Non-Disturbed)	0.0025	1693.0	82.6
	Roads	0.1745	96.1	
	Disturbed Forest Land	0.0997	376.9	
	Urban	0.0213	1130.4	
Medium-Density Scenario	Forest General (Non-Disturbed)	0.0025	1693.6	82.6
	Roads	0.1745	96.1	
	Disturbed Forest Land	0.0997	376.9	
	Urban	0.0213	1129.8	
Developer Requested (High-Density) Scenario	Forest General (Non-Disturbed)	0.0025	1693.0	82.6
	Roads	0.1745	96.1	
	Disturbed Forest Land	0.0997	376.9	
	Urban	0.0213	1130.4	
Areal Land-Use Scenario	Forest General (Non-Disturbed)	0.0025	1723.7	82.1
	Roads	0.1745	96.1	
	Disturbed Forest Land	0.0997	376.9	
	Urban	0.0213	1099.6	

4.2 Annual Watershed Loading Model

Modelling was completed to predict changes in land use associated contaminant loadings for the four proposed development scenarios. Models were completed for TP, FC, and sediment using methods described in **Section 3**.

4.2.1 PHOSPHORUS

The annual TP loading from the 1,768 Ha HSA watershed is listed in **Table 4.4**. When compared to existing conditions, there is an increase TP loading of 11% for the low-density scenario, 15% for the medium-density and developer-requested (high-density) scenarios, and 13% for the areal land-use scenario. The existing condition annual TP load corresponds to an annual loading rate of 0.0108 gm $P/m^2 \cdot yr$. This loading rate is similar to the P export loading rates measured by Scott et. al. (2000) for a watershed in Halifax as presented in Brylinsky (2004).

Table 4.4: HSA Predicted Annual P Loading for the Selected Development Scenarios

Development Scenario	Land Use	Area (ha)	Annual P Loading (kg/year)	Land Use Percentage	P Load Percentage
Existing Condition	Commercial	150.7	30.4	4.2%	7.8%
	Forested	1772.9	42.5	48.9%	10.9%
	Gravel Pit	67.2	13.4	1.9%	3.4%
	Low-Density Residential	121.3	30.3	3.3%	7.8%
	Medium-Density Residential	385.9	115.8	10.6%	29.6%
	High-Density Residential	251.5	88.0	6.9%	22.5%
	Rock/Dune/Barren	235.6	23.6	6.5%	6.0%
	Undeveloped/Grass	141.3	21.2	3.9%	5.4%
	Water	327.4	0.0	9.0%	0.0%
	Wetlands	104.6	2.5	2.9%	0.6%
	Roads	65.3	22.9	1.8%	5.9%
	Grand Total	**3623.7**	**390.7**	**100%**	**100.0%**
Low-Density Condition	Commercial	151.1	30.5	4.2%	7.0%
	Forested	1588.3	38.1	43.8%	8.8%
	Gravel Pit	67.2	13.4	1.9%	3.1%
	Low-Density Residential	274.7	68.7	7.6%	15.8%
	Medium-Density Residential	385.9	115.8	10.6%	26.6%
	High-Density Residential	251.5	88.0	6.9%	20.2%
	Rock/Dune/Barren	235.6	23.6	6.5%	5.4%
	Undeveloped/Grass	141.3	21.2	3.9%	4.9%
	Water	327.4	0.0	9.0%	0.0%
	Wetlands	104.6	2.5	2.9%	0.6%
	Roads	96.1	33.6	2.7%	7.7%
	Grand Total	**3623.7**	**435.4**	**100.0%**	**100.0%**
Medium-Density Scenario	Commercial	152.3	30.8	4.2%	6.8%
	Forested	1588.9	38.1	43.8%	8.5%
	Gravel Pit	67.2	13.4	1.9%	3.0%
	Low-Density Residential	124.1	31.0	3.4%	6.9%
	Medium-Density Residential	406.6	122.0	11.2%	27.2%
	High-Density Residential	379.6	132.8	10.5%	29.6%
	Rock/Dune/Barren	235.6	23.6	6.5%	5.2%
	Undeveloped/Cleared	141.3	21.2	3.9%	4.7%
	Water	327.4	0.0	9.0%	0.0%
	Wetlands	104.6	2.5	2.9%	0.6%

Development Scenario	Land Use	Area (ha)	Annual P Loading (kg/year)	Land Use Percentage	P Load Percentage
	Roads	96.1	33.6	2.7%	7.5%
	Grand Total	**3623.7**	**449.1**	**100%**	**100.0%**
Developer Requested (High-Density) Condition	Commercial	152.9	30.9	4.2%	6.9%
	Forested	1588.3	38.1	43.8%	8.5%
	Gravel Pit	67.2	13.4	1.9%	3.0%
	Low-Density Residential	121.3	30.3	3.3%	6.7%
	Medium-Density Residential	409.4	122.8	11.3%	27.3%
	High-Density Residential	379.6	132.8	10.5%	29.6%
	Rock/Dune/Barren	235.6	23.6	6.5%	5.2%
	Undeveloped/Grass	141.3	21.2	3.9%	4.7%
	Water	327.4	0.0	9.0%	0.0%
	Wetlands	104.6	2.5	2.9%	0.6%
	Roads	96.1	33.6	2.7%	7.5%
	Grand Total	**3623.7**	**449.3**	**100%**	**100.0%**
Areal Land-Use Scenario	Commercial	152.4	30.8	4.2%	7.0%
	Forested	1619.1	38.9	44.7%	8.8%
	Gravel Pit	67.2	13.4	1.9%	3.0%
	Low-Density Residential	121.3	30.3	3.3%	6.9%
	Medium-Density Residential	404.7	121.4	11.2%	27.6%
	High-Density Residential	354.0	123.9	9.8%	28.2%
	Rock/Dune/Barren	235.6	23.6	6.5%	5.4%
	Undeveloped/Grass	141.3	21.2	3.9%	4.8%
	Water	327.4	0.0	9.0%	0.0%
	Wetlands	104.6	2.5	2.9%	0.6%
	Roads	96.1	33.6	2.7%	7.6%
	Grand Total	**3623.7**	**439.6**	100%	100.0%

Figure 4.1 presents the land use breakdown of TP loading for each development scenario. High- and medium-density residential areas account for approximately 50% of annual loading within the watershed for the selected development conditions. Of the proposed development scenarios, the low-density scenario has the lowest annual TP load (435.4 kg P/yr), with the areal land use scenario having 439.6 kg P/yr; this is attributable to the amount of medium and high-density residential area compared to the other scenarios. Despite the medium-density development scenario having a smaller population and fewer high-rise apartments, the developer-requested (high-density) and medium-density annual TP loading rates are similar (449.3 kg P/yr and 449.1 kg P/yr, respectively).

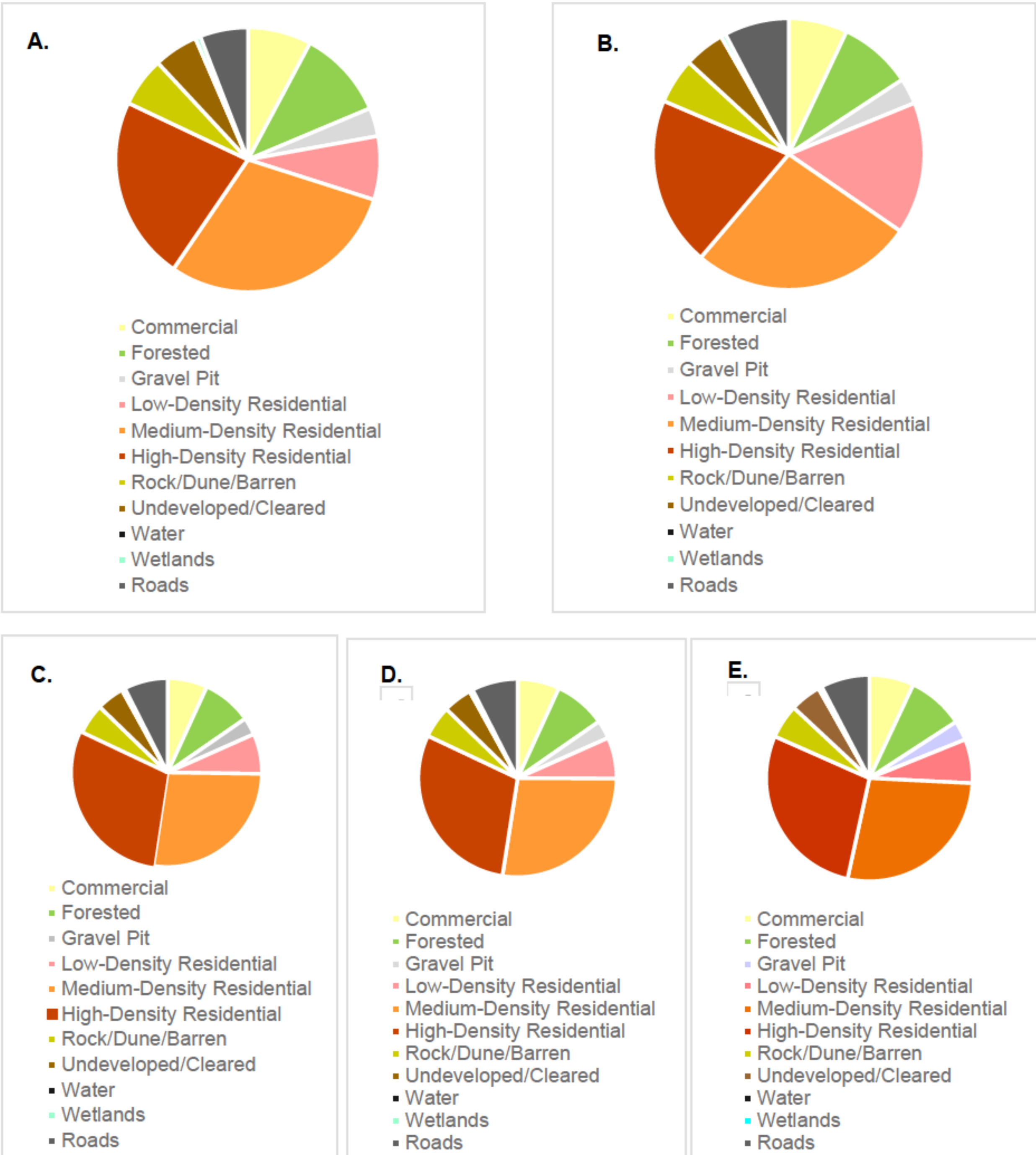


Figure 4.1: TP Loading - Existing Conditions (A) Low-Density (B) Medium-Density (C) Developer-Requested (High-Density) (D), and Areal Land-Use (E)

4.2.2 FECAL COLIFORM

The annual fecal coliform loading from the HSA watershed is approximately 7.96E+14, 9.07E+14, 9.22E+14, 9.23E+14 and 8.98E+14 CFU/year for the existing conditions, low-density, medium-density, developer-requested (high-density), and areal land-use scenarios, respectively (**Table 4.5**). Over half of the annual loading is generated from medium- and high-density residential land use types within the watershed for the selected development scenarios. Forested areas account for between 53-58% of the land use within the watershed and contribute 2-3% of the annual fecal coliform loading whereas high-density residential areas account between 7-11% of the overall area and contribute approximately 25-35% of the annual load.

Table 4.5: Predicted Annual Fecal Coliform Loading to HSA the Selected Development Scenarios

Development Scenario	Land Use	Area (ha)	Annual FC Loading (CFU/year)	Land Use Percentage	FC Load Percentage
Existing Condition	Commercial Development	150.7	8.42E+13	4.2%	10.6%
	Gravel Pit	67.2	2.87E+13	1.9%	3.6%
	Forested/ Rock/Dune/Barren/ Wetland	2113.1	2.07E+13	58.3%	2.6%
	Undeveloped/Grass	141.3	4.91E+13	3.9%	6.2%
	High-Density Residential	251.5	2.04E+14	6.9%	25.7%
	Medium-Density Residential	385.9	3.13E+14	10.6%	39.4%
	Low-Density Residential	121.3	8.53E+13	3.3%	10.7%
	Roadway	65.3	1.02E+13	1.8%	1.3%
	Water	327.4		9.0%	0.0%
	Grand Total	**3623.7**	**7.96E+14**	**100.00%**	**100.00%**
Low-Density Condition	Commercial Development	151.1	8.45E+13	4.2%	9.3%
	Gravel Pit	67.2	2.87E+13	1.9%	3.2%
	Forested/Rock/Dune/Barren/ Wetland	1928.5	1.88E+13	53.2%	2.1%
	Undeveloped/Grass	141.3	4.91E+13	3.9%	5.4%
	High-Density Residential	251.5	2.04E+14	6.9%	22.5%
	Medium-Density Residential	385.9	3.13E+14	10.6%	34.5%
	Low-Density Residential	274.7	1.93E+14	7.6%	21.3%
	Roadway	96.1	1.50E+13	2.7%	1.7%
	Water	327.4		9.0%	0.0%
	Grand Total	**3623.7**	**9.07E+14**	**100.00%**	**100.00%**
Medium-Density Condition	Commercial Development	152.3	8.51E+13	4.2%	9.2%
	Gravel Pit	67.2	2.87E+13	1.9%	3.1%
	Forested/Rock/Dune/Barren/ Wetland	1929.1	1.89E+13	53.2%	2.0%

Development Scenario	Land Use	Area (ha)	Annual FC Loading (CFU/year)	Land Use Percentage	FC Load Percentage
	Undeveloped/Grass	141.3	4.91E+13	3.9%	5.3%
	High-Density Residential	379.6	3.08E+14	10.5%	33.4%
	Medium-Density Residential	406.6	3.30E+14	11.2%	35.8%
	Low-Density Residential	124.1	8.73E+13	3.4%	9.5%
	Roadway	96.1	1.50E+13	2.7%	1.6%
	Water	327.4		9.0%	0.0%
	Total	**3623.7**	**9.22E+14**	**100.00%**	**100.00%**
Developer-Requested (High-Density) Condition	Commercial Development	152.9	8.55E+13	4.2%	9.3%
	Gravel Pit	67.2	2.87E+13	1.9%	3.1%
	Forested/Rock/Dune/Barren/ Wetland	1928.6	1.88E+13	53.2%	2.0%
	Undeveloped/Grass	141.3	4.91E+13	3.9%	5.3%
	High-Density Residential	379.6	3.08E+14	10.5%	33.4%
	Medium-Density Residential	409.4	3.32E+14	11.3%	36.0%
	Low-Density Residential	121.3	8.53E+13	3.3%	9.2%
	Roadway	96.1	1.50E+13	2.7%	1.6%
	Water	327.5		9.0%	0.0%
	Total	**3623.7**	**9.23E+14**	**100.00%**	**100.00%**
Areal Land-Use Scenario	Commercial Development	152.4	8.52E+13	4.2%	9.5%
	Rock/Dune/Barren	67.2	2.87E+13	1.9%	3.2%
	Forest/Rock/Dune/Barren/ Wetland	1959.3	1.91E+13	54.1%	2.1%
	Undeveloped/Grass	141.3	4.91E+13	3.9%	5.5%
	High-Density Residential	354.0	2.87E+14	9.8%	32.0%
	Medium-Density Residential	404.7	3.28E+14	11.2%	36.6%
	Low-Density Residential	121.3	8.53E+13	3.3%	9.5%
	Roadway	96.1	1.50E+13	2.7%	1.7%
	Water	327.5		9.0%	0.0%
	Total	**3623.7**	**8.98E+14**	**100.00%**	**100.00%**

4.2.3 SEDIMENT

The estimated total annual sediment loss load (tonnes/year) for each development scenario are presented in **Table 4.6**. For the existing conditions, the total annual loading rate is 1,359.6 tonnes/year, with no mitigation measures in place. Three of the development scenarios had similar annual sediment loading rates at approximately 1,496 tonnes/year. The areal land-use scenario had the lowest annual sediment load of 1,492.1 tonnes/year. As similar amounts of area are planned to be developed for the three scenarios it is expected that they will have similar loading rates as the developed area classified as "urban" and summed as one land use category. The increase in sediment load from existing conditions is estimated to be 10%.

Table 4.6: Predicted Annual Sediment Loading to HSA for the Selected Development Scenarios

Development Condition	Land Use	Sediment Loading (tonnes/ha/yr)	Area (ha)	Total Annual Load (tonnes/yr)
Existing Condition	Forest General (Non-Disturbed)	0.05	1,877.5	1,359.6
	Roads	3.81	65.3	
	Disturbed Forest Land	2.18	376.9	
	Urban	0.19	976.6	
Low-Density Development	Forest General (Non-Disturbed)	0.05	1,693.0	1,496.3
	Roads	3.81	96.1	
	Disturbed Forest Land	2.18	376.9	
	Urban	0.19	1,130.4	
Medium-Density Development	Forest General (Non-Disturbed)	0.05	1,693.6	1,496.2
	Roads	3.81	96.1	
	Disturbed Forest Land	2.18	376.9	
	Urban	0.19	1,129.8	
Developer-Requested (High-Density) Development	Forest General (Non-Disturbed)	0.05	1,693.0	1,496.3
	Roads	3.81	96.1	
	Disturbed Forest Land	2.18	376.9	
	Urban	0.19	1,130.4	
Areal Land Use Scenario	Forest General (Non-Disturbed)	0.0545	1723.72	1,492.1
	Roads	3.8129	96.06	
	Disturbed Forest Land	2.1788	376.89	
	Urban	0.1917	1099.63	

4.3 Phosphorus Lake Model

A lake system TP loading model was developed for Washmill Lake using the method developed by Brylinsky (2004), as described in **Section 3**. A summary of results is given in **Table 4.7**.

Table 4.7: Lake System TP Model Results Summary for the Selected Development Scenarios

Parameter	Existing Condition	Low-Density	Medium-Density	Developer Requested (High-Density)	Areal Land Use
Lake Characteristics					
Lake Flushing Rate (times/year)	0.09	0.10	0.10	0.10	0.10
Lake Turnover Time (yr)	11.62	10.07	10.07	10.07	10.24
Phosphorus Budget (g/yr)					
Upstream inflow	0	0	0	0	0
Atmosphere	1,279	1,279	1,279	1,279	1,279
Land Runoff	347,452	392,213	395,311	394,997	387,495
Development	0	8,800	10,560	10,560	10,560
Sedimentation	-13,949	-20,115	-20,358	-20,342	-19,967
Total Outflow	**334,782**	**382,177**	**386,792**	**386,494**	**379,367**

Phosphorous input sources are partitioned into four categories: input from upstream waterbodies (assumed to be 0 g/yr for this exercise), atmospheric deposition, overland runoff, and development. The development parameter of the TP loading model considers the number of residences adjacent to the modelled Lake. As the exact number of residences is unknown at this stage, therefore assumptions were made that the medium-density, high-density scenarios and areal scenarios would have the same number of residences adjacent to the lake as these would be desirable lots. Reduction in land development is captured in the land run-off parameter as that calculation includes all land use within the watershed, as a result the Low-, Medium-Density, and Developer Requested Scenarios are similar and the value for the Areal Land Use Scenario is lower. Phosphorous exits the lake system through either in-lake sedimentation or lake outflow. Phosphorous, however, can become re-suspended into the water column through internal loading during periods of anoxic lake conditions.

Based on fundamental limnological principles, a lake with an exceptionally low flushing rate (on the order of a decade) has limited ability to dilute or expel incoming contaminants. While site-specific conditions (such as sediment characteristics, lake morphology, and external loading sources) would determine the precise degree of accumulation, a slow turnover time generally means that nutrients (e.g., phosphorus and nitrogen) and other contaminants (e.g., metals, bacteria, or hydrocarbons) are more likely to build up within the lake over time. Based on the model results 4% of P input remains in the lake, with 96% discharged for the existing condition, while 5% of P inputs remain in Washmill Lake for the low-, medium-, high-density and areal land-use scenarios.

Table 4.8: Model Validation of Predicted vs. Measured P Concentrations

Model Validation	P (mg/L)
Predicted P – Lake system model – Existing Condition	0.015
Measured mean P at Lake Outlet – 2023 (mg/L)	0.010
% Difference	40
Predicted P – Lake system model – Low-Density Scenario	0.019
Predicted P – Lake system model – Medium-Density Scenario	0.020
Predicted P – Lake system model – Developer Requested Scenario	0.020
Predicted P – Lake system model – Areal Land-Use Scenario	0.019

As a result of lake system nutrient loading modeling, in-lake P concentrations were predicted to have an average value of 0.015 mg/L within Washmill Lake. This represents a mesotrophic trophic status applying the CCME CWQG-FAL guidelines. When compared to measured P concentrations within Washmill Lake taken between in 2023 there is a moderate (40%) difference with the model being higher in value. Average P concentrations at the Washmill Lake outlet measured over the 2023 monitoring period did not reach the predicted value of 0.015 mg/L, as the maximum Total P concentration was found to be 0.011 mg/L.

5 Water Quality Discussion

5.1 Total Phosphorus

Area and concentration-based TP loadings within the HSA watershed are largely generated by anthropogenic sources, namely high-density residential and medium-density residential. These two land uses contributed approximately 44 to 56% of the loading to the HSA for the selected development scenarios. The existing condition annual TP loading was calculated to be 390.7 kg/year. For the four development scenarios, the low-density scenario resulted in the lowest increase in TP loading for both event-based and annual loading calculations. The reduced TP load increase for the low-density scenario is attributable to the lower high-density and medium-density residential development.

As Washmill Lake has previously identified to be of high importance to the community, as one of the lakes within the Birch Cove Wilderness Area (AECOM 2013), the implementation of mitigation measures is recommended for developments to reduce TP loads to match existing or background conditions. According to results of the lake systems P model (**Section 4.3**), Washmill Lake currently retains approximately 14 kg of P on an annual basis and is predicted to retain 20.1, 20.4, 20.3, and 20.0 kg for the low-density, medium-density, developer requested, and areal land-use scenarios, respectively (**Table 4.7**).

The predicted in-lake TP concentrations for the future development scenarios range from 0.019 mg/L to 0.020 mg/L which represent the upper end of mesotrophic trophic status range. The increase in TP within the lake predicted by the loading models pose the risk of a decline in lake water quality. The increase in nutrient concentration is directly correlated to the likelihood of harmful algal blooms. Algal blooms are associated with a number of water quality issues, e.g., cyanotoxin production, foams and scums from algae biomass that can interfere with recreational water use, or blockage of sunlight penetration within the water column that can disrupt natural biological processes within the lake.

5.2 Fecal Coliform

According to the EMC-based model results, area and concentration-based fecal coliform loadings within the HSA are largely generated by residential developments for the existing condition and development scenarios. It is noted that model parameters used for fecal coliform have a high degree of variability. Results from rainfall-event modeling in the HSA give a calculated loading of 1.28×10^{13} CFU/100 mL during the storm event. When compared to annual loading calculations within the watershed, at 7.96×10^{14} CFU/100 mL, the annual model results appear to overestimate fecal coliform loading from the watershed. The storm-based fecal coliform load modelling accounts for approximately 3% of the annual fecal coliform loading for the existing conditions scenario.

Similarly, the rainfall-event based fecal coliform loading resulted in approximately 1.5% of the annual fecal coliform loads for the four development scenarios. The increase in annual fecal coliform load from baseline conditions for each of the development scenarios was 12%, 13.1%, 13.3%, and 10% for the low-density, medium-density, developer-requested (high-density), and areal land-use scenarios, respectively.

Based on the event-based and annual fecal coliform loading model results for the development scenarios, mitigation measures will be required to reduce loads to equal existing conditions (**Section 6.2**).

5.3 Sediment

Sediment load modelling using MUSLE and RUSLEFAC calculations for the four development scenarios resulted in sediment loads of 1,492 to 1,496 tonnes/year on an annual basis and 82 to 83 tonnes per storm-event. This equates to an increase in annual sediment loading of 9.6% from existing conditions for the development scenarios. The storm event loadings represent approximately 5.4% of total annual sediment load. Baseline sediment loading was estimated to be 1,359 tonnes per year, with approximately 74 tonnes deposited during a storm event. The addition of roads, and disturbance of soils during construction of the dwellings have the potential to increase sediment loading in the watershed. Therefore, the implementation and design of mitigation measures will be required to reduce loads to equal existing conditions. These calculations were performed conservatively, without considering any erosion and sedimentation control measures. The implementation of ESC measures would reduce the transport of sediment within the watershed as these methods are highly effective (HESL 2012). Additional recommendations for sediment mitigation are presented in the following section.

6 Water Quality Conclusions and Recommendations

6.1 Phosphorous Loading Mitigation

6.1.1 LAND USE-BASED MITIGATION

Medium and High-Density residential are estimated to contribute the highest percentage of TP loading to the lake system on an annual basis for the four development scenarios. To reduce annual TP load to the watershed, the development scenarios must consider implementation of low-impact development methods to reduce loading by approximately 15% for the four land development scenarios. The following mitigation measures are designed to counter the effects of existing urban development by changing land use loading rates derived from these developments.

- The implementation of street maintenance programs to remove sediment-associated P from roadways prior to it being carried to the lake systems via stormwater runoff. Street sweeping and catch basin clean out are required routine maintenance for urban street systems to reduce sediment and total phosphorus transport to downstream receptors. Electric street sweeping and other street maintenance can be used to minimize the impact of the required maintenance operations.

- The implementation of structural Low-Impact Development (LID) measures would be expected to reduce TP loads for the development area to achieve TP loads of existing conditions. HESL (2014) provided guidelines to HRM which listed examples of LID such as:

    a. Infiltration Trenches
    b. Infiltration Basin or other surface infiltration practice
    c. Bioretention Practice
    d. Gravel wetland system
    e. Porous Pavement
    f. Wet Pond or wet detention basin
    g. Dry Pond or detention basin and
    h. Water Quality Swale
    i. Green Roofs

  It is recommended that that water management infrastructure be developed and assessed to result in no net increase in TP loads for the chosen development scenario.

- The promotion of green space creation or conservation of naturally forested areas within the new development scenarios. Native species should be used to maintain biodiversity within the watershed in the implementation of green infrastructure and naturalization projects. The loading rate for P changes substantially from low-density residential developments (0.025 gm/m^2 yr) to green space (0.015 gm/m^2 yr), indicating the promotion of green space can reduce P loadings to downstream receptors.

- Reducing the footprint of development (i.e., buildings and roads) and conserving naturally forested areas within the development scenarios. As the empirical loading rates are calculated on an areal basis (Sections 2.4 and 2.5), limiting the affected area will limit the additional load produced within the watershed.

6.1.2 ON-GOING MONITORING

On-going monitoring provides a method to measure the success of implemented mitigation measures to while keeping record of water quality within the lake system. The following monitoring activities are recommended to be conducted on an on-going basis within the lake system:

- The extension of in-lake P monitoring at deep lake locations when the lake system is completely mixed (e.g., late fall, early spring). This is recommended to capture increasing trend in lake P concentrations and associated trophic status changes caused by a release of P from vegetation and algae decay. If conducted after seasonal lake turnover, this data can also capture increase in P concentrations from the lake epilimnion.

- The continuation of profiling, surface, and lake bottom sampling at deep-water lake locations. This will allow for the monitoring of P release from benthic sediments, through the identification of anoxic zones at lake bottom, and surface and lake bottom concentration comparison.

- The continuation of flow monitoring and grab sampling at select monitoring locations to track loading reductions as a result of mitigation measures and confirm they are performing as designed. Suggested locations would be headwall locations where roadway maintenance is being implemented. An example of this monitoring would be the continuation of HRM’s LakeWatchers program in which Susies Lake (nearby) is monitored twice annually (Early May and August). Washmill Lake should be added to the LakeWatchers program as it will be situated within the proposed development area.

- During the monitoring within the HSA, an adaptive management approach should be taken to target point and nonpoint sources of P within the watershed to improve water quality. As sources of P within the watershed are identified, management measures can be applied to reduce P loading in the watershed as described above.

6.2 *E. coli* Loading Mitigation

6.2.1 INFRASTRUCTURE-BASED MITIGATION

Fecal source identification is helpful in identifying changes to infrastructure that may aid in the reduction of *E. coli* loading to recreational water bodies. *E. coli* loading can be the result of animal, human, or industrial sources entering watercourses or waterbodies. The implementation of LID technologies within the watershed, as outlined in the previous section would also aid in the removal and sedimentation of fecal coliform within the watershed.

6.2.2 PUBLIC EDUCATION

Public education efforts are expected to be most effective regarding *E. coli* loading to the lake systems as bacteria loading has a direct and potentially serious implication to human health, it affects the use of recreational water bodies, and public involvement with mitigation measures is expected to be more possible than with P loading sources. The following public education items are recommended as a result of study findings:

- Increased public education on the need to pick-up droppings from domestic animals. The surrounding Birch Cove Wilderness Area is a popular recreation area for many and signage within the area may help inform the public of risks relating to fecal coliform exceedances on human and animal health.
- Increased public education of the risk of swimming in areas where wildlife congregates. The HSA and surrounding Birch Cove Wilderness area is the habitat of many avian, and other wildlife species. Public risk awareness is needed to mitigate risk to human health from these sources.

6.2.3 ON-GOING MONITORING

To further aid in the identification of watershed land suitability in the HSA Watershed, further monitoring is recommended as follows:

- Monitoring of fecal coliform markers to better understand the sources of fecal coliform within the watershed.
- The continuation of flow monitoring and grab sampling at select monitoring locations to track loading reductions as a result of mitigation measures. An example of this monitoring would be the continuation of HRM’s LakeWatchers program in which Susies Lake is monitored twice annually (Early May and August). Washmill Lake should be added to the LakeWatchers program as it will be situated within the proposed development area.
- During monitoring within the HSA, an adaptive management approach should be taken to target point and nonpoint sources of FC and *E. coli* within the watershed to improve water quality. As sources of FC and *E. coli* within the watershed are identified, management measures can be applied to reduce FC loading in the watershed as described above.

6.3 Sediment Loading Mitigation

Baseline TSS concentrations are moderate to low within the HSA due to the limited development within the watershed but do experience increases from runoff from the adjacent quarry. If the HSA is developed following the selection of one of the proposed development scenarios, it will be important to implement erosion and sedimentation control measures to mitigate effects from development. The expected increases in sediment loading from existing conditions are estimated to be 9.6%. The implementation of construction sequencing to minimize the quantity of soil exposed at any given time is the most effective way to prevent erosion from the proposed development. **Table 6.1** presents a list of effective sediment control mitigation measures and their efficiency of removing sediment load (if properly installed) (HESL 2012). It should be noted that these ESC measures also have the capacity reduce TP and *E. coli* loads through infiltration and filtering.

Table 6.1: Event-Based Sediment Loading Results (HESL 2012)

Measure Implemented		TSS Removal Efficiency (%)
Erosion Prevention	Establishing vegetative cover	99
	Mulch, geotextile mats	90
Capture of Sediment	Dry detention ponds	10
	Wet detention ponds	63
	Vegetative filter strips	65
	Silt fencing	70
	Filter tubes or bags	45

7 Background and Design Criteria for Stormwater Management

The following summarizes the stormwater management (SWM) criteria and objectives for the HIGHWAY 102 Study Area as established in available background reports, the Halifax Regional Municipality's (HRM) Stormwater Management, and Municipal Design Guidelines and Halifax Water's (HW) Specifications for Stormwater Management.

7.1 Regulatory Considerations

7.1.1 HALIFAX WATER

HW's Stormwater Design Specifications and Supplementary Standard Specifications 2023 (DS & SSS) outline the following objectives relating to the design of new of storm drainage systems.

The storm drainage system shall:

- be designed to prevent loss of life and to protect structures and property from damage due to a major storm event;
- provide safe and convenient use of streets, lot areas and other land during and following rain and snow melt events;
- adequately convey stormwater flow from upstream sources;
- mitigate the adverse effects of stormwater flow, such as flooding and erosion, on downstream properties;
- preserve natural watercourses;
- minimize the long-term effect of development on receiving watercourses; and
- provide a safe, accessible outlet.

In order to ensure sustainable stormwater management and mitigate flooding risks, the following guidelines should be adhered to in the post-development phase:

- Post development peak flows up to the 100-year storm to be restricted to pre-development levels;
- Size culverts to convey instantaneous peak flows with a headwater depth to culvert diameter ratio of 1.0, taking into account both inlet control and outlet control. Culverts located in drainage courses or natural watercourses are to be designed to accommodate the 1:100-year return period storm, unless otherwise directed by the Engineer.
- Dry ponds are preferred over wet ponds. If wet ponds are to be privately owned and operated, they will be considered on a case-by-case basis;
- Additional pond volume allowances must include a 300mm freeboard from the 100-year water elevation; and,

- Culverts are to be sized to convey instantaneous peak flows with a headwater depth to culvert diameter ratio of 1.0 accounting for both inlet control and outlet control. Culverts located in drainage channels or natural watercourses are to be designed to accommodate the 1:100-year return period storm, unless otherwise directed by the Engineer.

7.1.1.1 Rainfall

Rainfall data will be based on the Environment and Climate Change Canada climate station Shearwater RCS (ID: 8205092). As the primary stormwater infrastructure for this site will be ultimately owned and operated by HW, the design storms provided in the DS & SSS will be used. These design storms use the Chicago Storm distribution with the following intensity/duration/frequency (IDF) parameters, with a, b, and c as the regression constants for each return period and T_d as the time of duration in hours (see **Figure 7.1**).

Storm	a	b	c
2YR	25.112	0.04959	0.578
5YR	31.196	0.03178	0.565
10YR	35.114	0.01905	0.553
25YR	40.265	0.01159	0.548
50YR	44.089	0.00874	0.544
100YR	47.924	0.00594	0.544

$$i = \frac{a}{(T_d + b)^c}$$

Figure 7.1: Halifax Water IDF Parameters, 2023

7.1.1.2 Climate Change Considerations

HW acknowledges that climate conditions are not static and with the life cycle expectation of the piped infrastructure to be 80-100 years, it is anticipated that there will be an increase in precipitation intensity due to climate change over that period. The above listed design storms from the 2023 DS & SSS include a 16% increase to the rainfall intensity based on projections for the 2080 horizon.

7.1.2 HALIFAX REGIONAL MUNICIPALITY

In the design and implementation of stormwater management systems within the Halifax Regional Municipality (HRM), adherence to the following guidelines is important for ensuring effective stormwater conveyance and environmental sustainability:

- The use of Green Infrastructure and Low Impact Development (LID) measures is preferred and encouraged.
- Aim for an average removal of 80% Total Suspended Solids (TSS) from post-development runoff on an annual loading basis.

7.1.3 NOVA SCOTIA DEPARTMENT OF ENVIRONMENT AND CLIMATE CHANGE

Nova Scotia Environment (NSE) requires that culverts be designed to have a headwater/pipe diameter ratio (H_w/D) of 1.0 for the 100-year flow return period. It should also be noted that NSE has a preference for single barrel as opposed to multiple barrel crossing structures.

Clear span opening of a watercourse crossing beneath a roadway must have a hydraulic capacity large enough to pass the 100-year peak flow with a maximum velocity of 1.8 m/s, unless otherwise approved by the Minister of Environment.

NSE also stipulates that a Watercourse Alteration Permit must be obtained for construction work within the banks of a watercourse and for work involving diversion of an existing watercourse to a new location.

A Wetland Alteration Permit would be required by NSE for work within an existing wetland area.

7.1.4 NOVA SCOTIA STATEMENT OF PROVINCIAL INTEREST REGARDING FLOOD RISK AREAS

The goal of this particular statement of provincial interest is to protect public safety and property and to reduce the requirement for flood control works and flood damage restoration in floodplains. Given that the Highway 102 Study Area is within the floodplain of a complex lake system, the provisions outlined in the statement of provincial interest regarding flood risk areas as summarized below, will be taken into account in the preparation of this report and in the recommendations provided.

1. Planning documents must identify Flood Risk Areas consistent with the Canada-Nova Scotia Flood Damage Reduction Program mapping and any locally known floodplain.
2. For Flood Risk Areas that have been mapped under the Canada-Nova Scotia Flood Damage Reduction Program, planning documents must be reasonably consistent with the following:
   (a) within the Floodway (i.e., inner portion of a flood risk area where the risk of flooding is greatest, on average once in twenty years, and where flood depths and velocities are greatest),
      (i) development must be restricted to uses such as roads, open space uses, utility and service corridors, parking lots and temporary uses, and
      (ii) the placement of off-site fill must be prohibited;
   (b) within the Floodway Fringe (i.e., outer portion of a flood risk area, between the floodway and the outer boundary of the flood risk area, where the risk of flooding is lower, on average once in one hundred years, and floodwaters are shallower and slower flowing),
      (i) development, provided it is flood proofed, may be permitted, except for

(1) residential institutions such as hospitals, senior citizen homes, homes for special care and similar facilities where flooding could pose a significant threat to the safety of residents if evacuation became necessary, and

(2) any use associated with the warehousing or the production of hazardous materials,

(ii) the placement of off-site fill must be limited to that required for flood proofing or flood risk management.

3. Expansion of existing uses must be balanced against risks to human safety, property and increased upstream and downstream flooding. Any expansion in the Floodway must not increase the area of the structure at or below the required flood proof elevation.

4. For known floodplains that have not been mapped under the Canada-Nova Scotia Flood Damage Reduction Program, planning documents should be, at a minimum, reasonably consistent with the provisions applicable to the Floodway Fringe

5. Development contrary to this statement may be permitted provided a hydrotechnical study, carried out by a qualified person, shows that the proposed development will not contribute to upstream or downstream flooding or result in a change to flood water flow patterns.

7.1.5 HALIFAX MUNICPAL PLANNING STRATEGY AND HALIFAX MAINLAND LAND USE BY-LAWS

The Halifax Municipal Planning Strategy identifies development restrictions within the Highway 102 Study Area due to environmental sensitivity and a lack of municipal services and provides specific requirements for a master stormwater management plan in support of development. In addition, the Halifax Municipal Planning Strategy provides minimum watercourse setbacks to the high-water mark or the 1 in 20-year floodplain elevation, if available.

The Land Use By-Laws for Halifax Mainland contains policies and regulations regarding watercourse setbacks and buffers, as well as development restrictions. These By-Laws are considered minimum criterial levels and additional buffer widths may be considered during later stages of the approvals process to address further protections for the ecological buffer zones.

7.2 Background Reports

The following reports have been reviewed and used in determining the SWM design criteria for the Highway 102 Corridor Development area.

- **Highway 102 Study Area Draft Report – Land Suitability Analysis, Stantec (April 2024)**: This report included both desktop and field components and included an evaluation of select biophysical characteristics (i.e., wetland habitat, watercourses, forest habitat, geology, topography, etc.), a review of contaminated sites, and a study of archaeological and cultural conditions for the study area. The objective of the land suitability analysis was to determine what portions of the study area are potentially suitable for new housing development.

- **Regional Flood Mapping Delineation Project – CBCL (on-going):** preliminary flood lines (i.e., subject to change) for the 5-year, 20-year, 100-year, and 200-year scenarios for both current climate conditions and projected climate conditions in the year 2100 were provided by HRM from the on-going Regional Flood Mapping Delineation project. These flood lines are derived from a high-level hydrologic and hydraulic analysis of flooding risks in the entire Halifax Regional Municipality and are based on a series of high-level assumptions regarding seasonal land cover, initial conditions at lakes, dam operation, coastal water elevations, rainfall distribution (Chicago distribution – 24-hour, 5 min interval), and soil conditions.
- **Park Planning and Coordination with Surrounding Land Use – Friends of Blue Mountain-Birch Cove Lakes Society (Draft, April 2023):** The report provides suggestions and recommendations regarding the initiation of park planning with surrounding land use and development decisions. The report also outlines the importance of preserving shorelines around lakes, maintaining acceptable standards of water quality and quantity into the receiving lakes, and providing adequate buffers for development.

7.3 Additional Available Data

The Nova Scotia Department of Municipal Affaires and Housing (NSDMAH) commissioned the collection of hydrologic data in the Halifax Regional Municipality (HRM) as part of the Municipal Flood Line Mapping Program (MFLMP). The scope of this project covered several distinct types of data collection for locations in HRM watersheds, including some of the remaining Future Serviced Communities identified for development by the Regional Municipal Planning Strategy (Regional Plan) and the Road to Economic, and Prosperity for African Nova Scotian Communities. Data collected included water levels, stage-discharge curves, and topographic and bathymetric surveys. This data will be of significant value in the development of detailed flood delineation in these areas.

8 Existing Conditions

8.1 Site Location

The Highway 102 Study Area is found in the southwest of HRM, south of Kearney Lake, and west of Highway 102. The proposed development area borders Susies Lake and Quarry Lake to the west and the Right-of-Way for Highway 102 to the east, totalling approximately 600 hectares of largely undeveloped land. The entire proposed development is within the Kearney Run secondary watershed. Within the study area, drainage is divided amongst Quarry Lake, Susies Lake, and Washmill Lake. **Figure 8.1** presents the Highway 102 Study Area.

8.2 Land Use

The subject site is predominantly covered with undeveloped forest over the western half, with a portion of the western edges consisting of exposed bedrock. The forest comprises a typical local assortment of various hardwood and softwood species. The eastern half of the site is predominately covered by a quarry, with the northern and southern portions consisting of undeveloped forest and wetlands.

The Washmill Lake watershed encompasses a substantial area upstream of the subject site. This area includes rural lands and a network of lakes and wetlands. This complex system within the watershed has significant implications for stormwater management and planning and is not well understood at this stage. There is currently no available flow monitoring or stage discharge curves for either Quarry Lake, Susies Lake, Charlies Lake, or Washmill Lake, and as such the hydraulic modeling completed for this study area was based on preliminary lake water levels acting as fixed boundary conditions. Flow and water level monitoring at the lakes, as well as along the watercourses that interconnect the lakes within the study area will be required to validate the stormwater model and to size proposed culvert crossings.

Study Area

Utilities

Transmission Line

Transportation

Highway

Road

Resource / Seasonal Road

Trail

Other Features

Waterway

Waterbody

Designated Wetland of Special Significance

Wetland

Wetlands (Stantec, 2023)

0 250 500 Metres

(At original document size of 8.5x11)
1:21,000

N

Notes

1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Stantec, Government of Nova Scotia, Department of Service Nova Scotia and Internal Services
3. Background: ESRI; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services

Stantec

Project Location
Halifax Regional Municipality, Nova Scotia

Prepared by AC on 2024-10-23
QR by NW on 2024-10-24

Client/Project
Halifax Regional Municipality
Future Serviced Communities Background Studies

160410459

Figure No.
8.1

Title
Highway 102 West Corridor Study Area

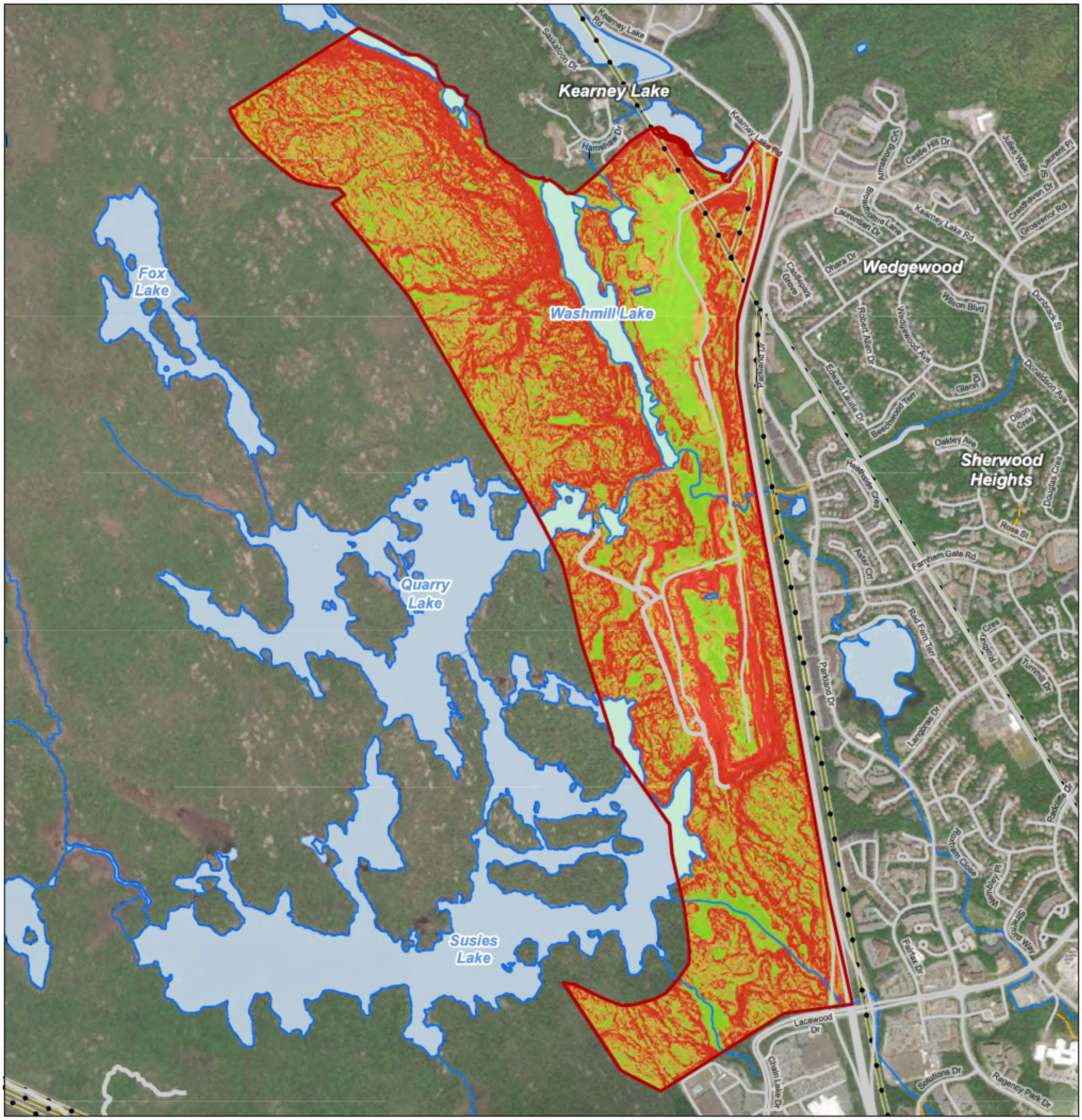
\\ca0213-ppfss01\work_group\1214\active\160410459\gis_data\mapping\ArcGIS Pro\HRM_Stormwater_Mgmt.aprx: Hwy_102_Fig3-1_Study_AreaRevised: 2024-10-24 By: acuff

8.3 Topography

The Highway 102 Study Area generally slopes in an eastward direction, primarily discharging overland into Kearney Lake, Quarry Lake, Susies Lake, and Washmill Lake. Quarry Lake and Susies Lake discharge into Washmill Lake, which ultimately discharges northward into Kearney Lake. It should be noted that Kearney Lake is outside the proposed development area.

It is understood at this time that the existing quarry pit will be allowed to fill naturally with runoff, groundwater flow and direct rainfall contribution, with the goal of the existing depression to become a proposed lake. Based on the existing topography, this lake will need to discharge to Washmill Lake as well. However, this proposed lake is conceptual in nature and its outlet to Washmill Lake has not been included in the scope of this project. Please refer to **Section 8.5.1** for further discussion on the quarry pit lake.

Stantec has analyzed LiDAR data provided by HRM to categorize steep slopes. This task was entirely performed using ESRI ArcMAP, taking into account field observations. Field teams were directed to record notable slopes near water bodies and wetlands. Steep slopes were divided into three groups based on their percentage increase: 0.0%-5.0%, 5.1% - 15.0%, and above 15%. The slope mapping is illustrated in **Figure 8.2,** while **Figure 8.3** provides existing contours.



Study Area

Slope Analysis (Percent Rise)

- 0 - 5%
- 5.01 - 15%
- >15%

Transportation

- Trail
- Highway
- Other Road

Utilities

- Transmission Line

Other Features

- Waterway
- Waterbody

0 250 500 Metres

(At original document size of 8.5x11) 1:21,000

N

Stantec

Project Location
Halifax Regional Municipality, Nova Scotia

Prepared by IP on 2023-11-09
Revised by NW on 2024-05-17
QR by SW on 2024-10-07

FIG ID: 160410459_14

Client/Project
Halifax Regional Municipality
Future Serviced Communities
Background Studies

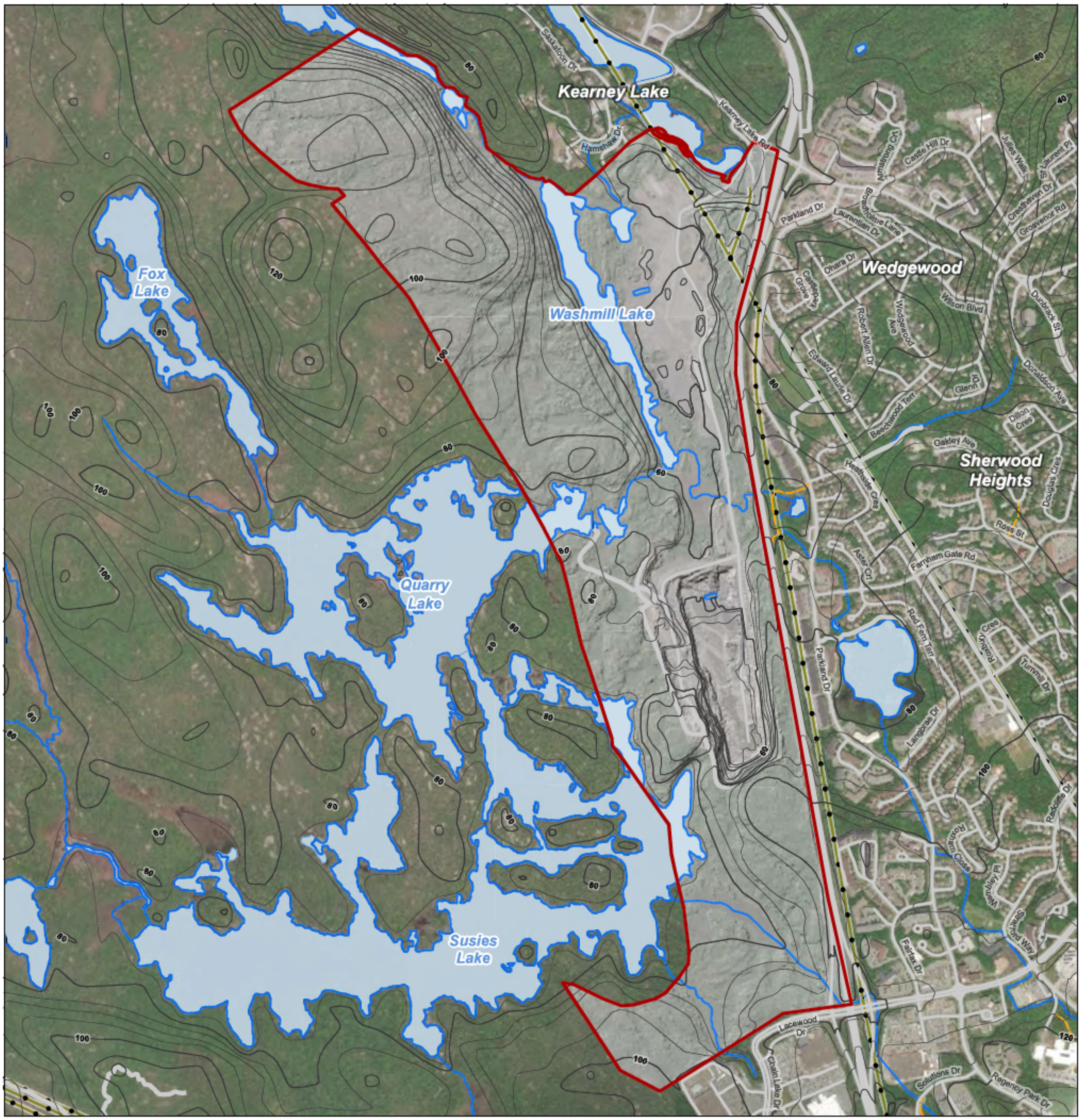
Figure No.
8.2

Title
Slope Land Suitability Analysis - Highway 102 West Corridor

Notes

1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Government of Nova Scotia, Department of Service Nova Scotia and Internal Services
3. Background: ESRI; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services

HRM FCM 2022.aprx Revised: 2024-10-29 By: acuff



Study Area

Contour (20 m)

Transportation

Trail

Highway

Other Road

Utilities

Transmission Line

Waterway

Waterbody

0 250 500 Metres

(At original document size of 8.5x11)
1:21,000

N

Stantec

Project Location
Halifax Regional Municipality, Nova Scotia

Prepared by AC on 2024-10-23
QR by NW on 2024-10-24

Client/Project
Halifax Regional Municipality
Future Serviced Communities
Background Studies

160410459

Figure No.
8.3

Title
Elevation Contours - Highway 102 West Corridor

Notes
1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Government of Nova Scotia, Department of Service Nova Scotia and Internal Services
3. Background: ESRI; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services

HRM FCM 2022.aprx Revised: 2024-10-29 By: acuff

8.4 Soil Conditions

Soil conditions for the Highway 102 Study Area were obtained from the "Nova Scotia Soil Survey Report #13 – Halifax County 1963". As depicted in **Figure 8.4**, the soil type is primarily classified as Halifax (Hx), which corresponds to a sandy loam soil with good to excessive drainage. For the northwest and southwest corners of the site the soil type is classified as Rockland (R), which corresponds to areas where at least 60% of the land is exposed bedrock. Consequently, the classification scheme has been used to categorize this as Hydrologic Soil Group C.

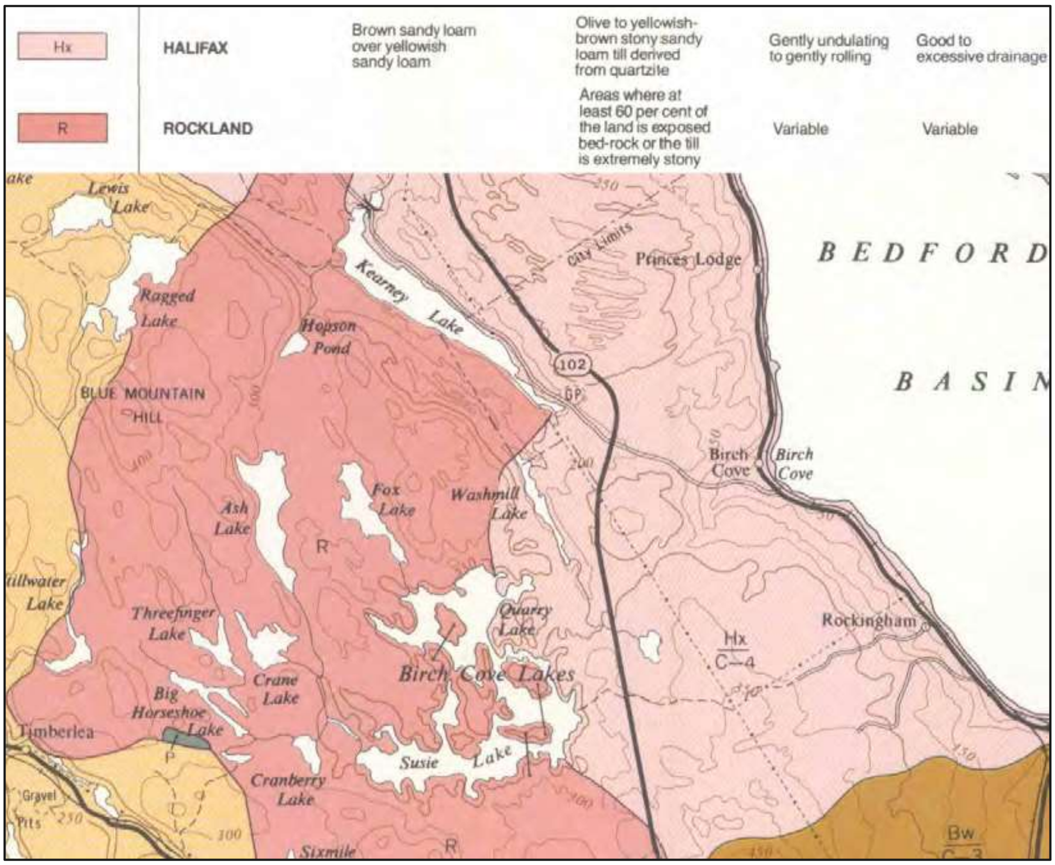


Figure 8.4: Soil Type (Nova Scotia Soil Survey Report #13 – Halifax County 1963)

8.5 Watercourses and Waterbodies

The data for wetlands and waterbodies were sourced from the Nova Scotia Open Data, complemented with the information presented in Stantec's 2024 Land Suitability Analysis for the Highway 102 Study Area.

Thirty-five (35) wetlands were identified and evaluated within the study area. While none of the evaluated wetlands were determined to be Wetlands of Special Significance (WSS), there are multiple factors that can result in a wetland being considered a WSS and further work and/or consultation with regulators may result in any of the wetlands within the HSA being considered a WSS. Stantec's Land Suitability Analysis recommended to engage with Nova Scotia Environment and Climate Change (NSECC) as early as possible to discuss potential wetland impacts (direct or indirect), the permitting process, and compensation requirements (e.g., potential opportunities for wetland restoration, enhancement, or creation).

Watercourse mapping was obtained from Stantec's Land Suitability Analysis for the Highway 102 Study Area, which identified six mapped watercourses, and four mapped waterbodies. Water quality monitoring along the watercourses was completed as part of the field study and the results were complemented with a desktop study using historical water quality reports.

As outlined in Stantec's Land Suitability Analysis, riparian zones which are areas adjacent to watercourses were considered in the analysis, in addition to the bed and banks of the watercourse. Riparian zones provide a buffer that protects the watercourse from the impacts of adjacent development and also reduce the severity of flooding on adjacent lands. This results in the creation of watercourse setbacks and buffers as established in the Draft Regional Plan or Regional Plan Review Process as the minimum criteria.

The PCSWMM software was used to create an existing drainage condition model composed of subcatchments, junctions, and conduits, which were partially parameterized based on features from the Digital Elevation Model (DEM).

The Watershed Delineation Tool (WDT) in PCSWMM was used to establish drainage patterns and channels, from which, the main channels were retained and transformed into ditches using the Transect Creator Tool. This tool utilizes the DEM to gather elevation data at each station along the transects. This comprehensive approach ensures accurate and efficient modeling of the watercourses.

The proposed site is within the Kearney Run watershed that includes Susies Lake, Quarry Lake, Washmill Lake, and Kearney Lake. Dam structures control water elevations at the outlets of Kearney Lake and Quarry Lake. The dam structure at Quarry Lake is within the proposed site development boundary and controls the flow through Bad Luck Falls, which discharge into Washmill Lake. The lakes are part of a complex drainage system and there is not sufficient data available regarding their hydrologic and hydraulic response to rainfall events, or the discharge curve(s) for the dam structures to include these in the hydrologic/hydraulic model.

8.5.1 PROPOSED QUARRY PIT LAKE

The intention of allowing the existing quarry pit to fill and become a lake, as it is currently understood, is conceptual in nature and its implications on the water quality and the hydrologic/hydraulic regime of the downstream system have not been studied. As it is further explained in the Post Development Conditions section of this report (**Section 9**), the quarry pit lake has not been included in the post development condition stormwater model for the HSA given that this artificial lake is proposed to have no hydraulic connectivity to the proposed SWM ponds and/or storm infrastructure and to provide a separate outlet to Washmill Lake.

Based on available LiDAR, the existing quarry pit is about 30 to 40 m deep and as such, it is expected that such a deep and extensive waterbody would have significant impacts on the flow regime of the existing lake network downstream.

It is therefore recommended to complete a calibrated hydrologic/hydraulic assessment of the existing lake/watercourse network within the HSA based on a flow and water level monitoring program of Susies Lake, Quarry Lake, Washmill Lake and the watercourse connecting Quarry Lake and Bad Luck Falls with Washmill Lake. The existing condition hydrologic/hydraulic analysis would be used as a base scenario to assess the impacts of the quarry pit lake on the downstream system.

8.6 Existing Drainage Areas

Existing drainage areas were delineated using LiDAR data (2019) sourced from the HRM Open Data portal, specifically the HRM 1044700063700_201901_CHM.tif file.

The Watershed Delineation Tool (WDT) was used to determine the tributary subcatchments to Quarry Lake, Susies Lake, Washmill Lake and Kearney Lake. The flow length of these subcatchments were generated from the furthest point along the boundary to the outlet, following the direction of flow.

The hydrologic parameters, which are integral to the functioning of the drainage system's subcatchments, are detailed in **Table 8.1**.

Table 8.1: Global Hydrologic Parameter for Subcatchments

Global Hydrologic Parameter	Value
Infiltration Method Subcatchments	NRCS
Conductivity (mm/hr)	0.5
Drying Time (days)	7
Curve Number for Pasture / Open Grass Area	74
Curve Number for Wetland	98
Manning's Roughness	
Impervious Surface (-)	0.013
Pervious Surface – Woodlot Area (-)	0.80
Pervious Surface – Urban Area (-)	0.25 - 0.35
Depression Storage	
Impervious Surface (mm)	1.88
Pervious Surface (mm)	3.75
Zero Imperviousness (%)	0

The USDA Natural Resources Conservation Service (NRCS) method was selected in PCSWMM to estimate infiltration. Average Curve Number (CN) values were determined based on weighted areas for each land use within the pervious portion of the subcatchment. This approach ensures that the CN values used are representative of the variation of land uses in the watershed.

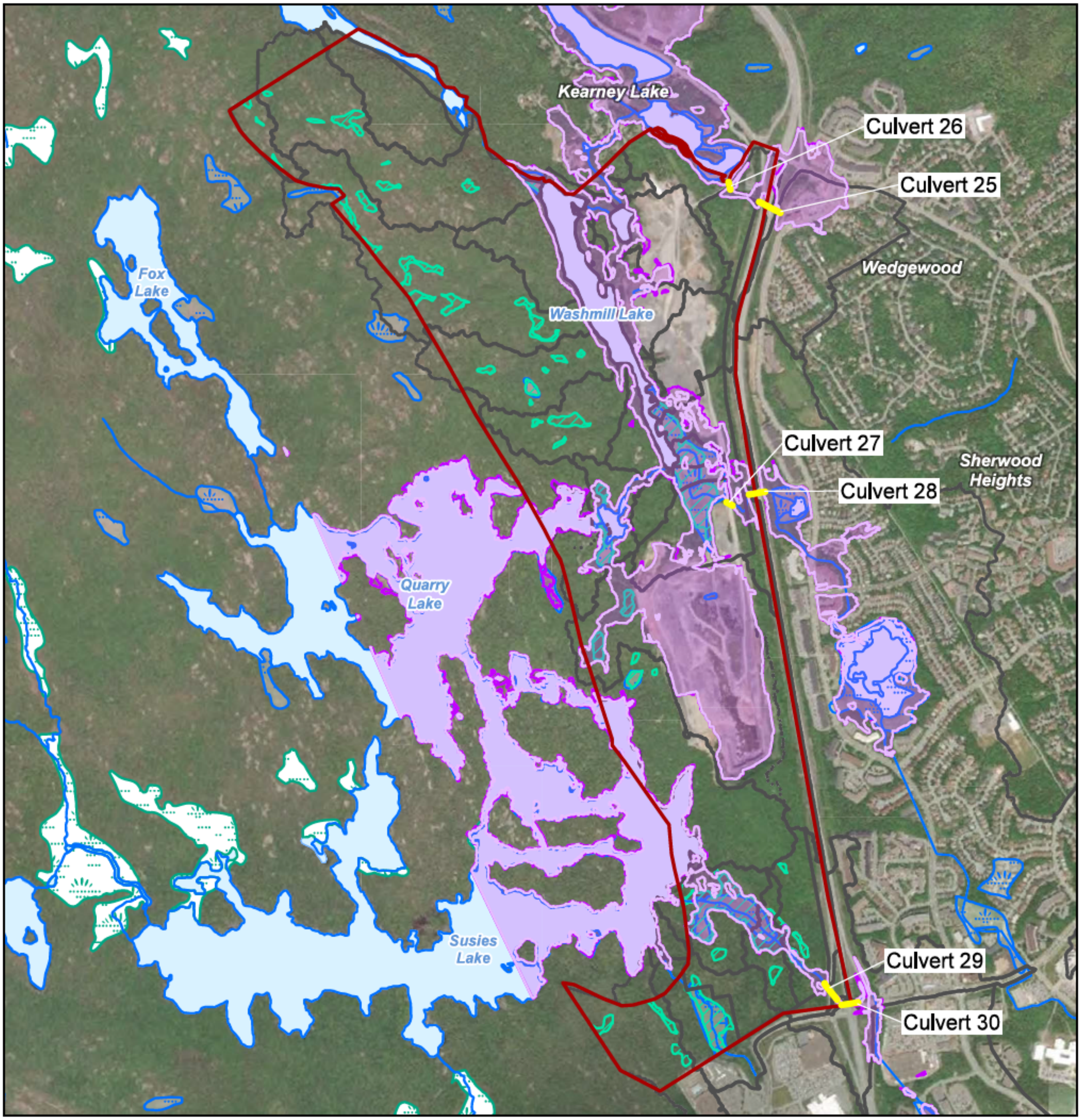
Depression storage refers to the capacity of a specific land area to retain water in its pits and depressions, thereby preventing it from flowing. The PCSWMM online help manual offers a range of values suitable for defining the depression storage for both pervious and impervious surfaces. An average value within the provided range was selected.

The existing storm drainage plan present in **Drawing EX-SD-1** in **Appendix C** illustrates the existing storm drainage plan, showcasing the watercourses and the delineated subcatchments.

8.7 Boundary Conditions

The water elevations in Quarry, Susies, and Washmill Lakes, along with their respective stage/discharge relationship at the outlet, significantly influences existing drainage conditions within the Washmill Lake watershed. Investigating the water elevation fluctuations within these lakes as a result of runoff response, and the stage/discharge relationship of the lake outlet are outside the scope of this project. However, preliminary floodlines for the 5-year, 20-year, 100-year, and 200-year scenarios for both current climate conditions and projected climate conditions in the year 2100 provided by HRM as part of the on-going Regional Flood Mapping Delineation project being completed by CBCL. These floodlines were derived from a high-level hydrologic and hydraulic analysis of flooding risks in the entire Halifax Regional Municipality and are based on a series of high-level assumptions regarding seasonal land cover, initial conditions at lakes, dam operation, coastal water elevations, rainfall distribution (Chicago distribution – 24-hour, 5-min interval), and soil conditions. **Figure 8.5** illustrates the 20-year and 100-year flood extents under the projected climate conditions in the year 2100, which were the storms used in the stormwater model.

The preliminary floodlines have been used to estimate the water elevations in Quarry, Susies, Washmill, and Kearney Lakes during various return periods. These estimated water elevations have been applied as fixed water levels, also known as boundary conditions, at the outfalls to each of these Lakes within the hydrologic/hydraulic PCSWMM model for the 100-yr storm event scenario. As illustrated in **Figure 8.5**, there are three stormwater outfalls that discharge into Washmill Lake, which ultimately flows into Kearney Lake, and one outfall that discharges into Susies Lake. In addition, there is one more outfall that discharges directly into Kearney Lake. The water elevation at each of these outfalls is determined to be 45 m, 60 m and 73m, for Kearney Lake, Washmill Lake, and Susies Lake, respectively, during a 100-year event. These are based on the topographic contours for both the current and climate change flood extent. For all other return periods, the normal flow depth within the outlet conduit or watercourse transect was used as a boundary condition at these locations. The 20-year and 100-year floodlines are also shown in **Drawing EXSD-1** in **Appendix C**.



Legend
- Study Area
- Culvert
- Existing Subcatchment
- 20yr Flood Extent (Draft, HRM 2023)
- 100yr Flood Extent (Draft, HRM 2023)

Wetlands and Waterways
- Waterway
- Waterbody
- Designated Wetland of Special Significance
- Wetland
- Wetlands (Stantec, 2023)

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Stantec

Project Location
Halifax Regional Municipality, Nova Scotia

Prepared by HB on 2024-02-13
Revised by AC on 2024-10-28

Client/Project
160410459
Halifax Regional Municipality
Future Serviced Communities
Highway 102 West Corridor Stormwater Management Plan

Figure No.
8.5

Title
Existing Conditions Preliminary Floodplain Extents

Notes
1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Stantec; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services; Government of Nova Scotia Environment and Climate Change
3. Background: ESRI; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services.

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8.8 Existing Culverts

As illustrated in the existing storm drainage plan (refer to **Appendix C**), the Study Area includes 2 existing culvert crossings (Culvert 27 and Culvert 29) and 3 culvert crossings entering the study area from external lands (Culvert 25, Culvert 28 and Culvert 30), as identified from the HRM Open data source. Each of these culverts were surveyed, and the gathered data was incorporated into the existing hydraulic model.

Upon reviewing the flood extents provided, it was observed that all existing culverts might be undersized as shown in **Table 8.2**. It is therefore recommended that these culverts be upsized to meet the NSE H/D <1 design criteria during the 100-year storm to provide adequate conveyance capacity and improve existing drainage conditions. However, as these culverts are all external to the site, these would need to be addressed by their respective owners. It is important to note that culvert upgrades would result in peak flow increases and increased flooding risks downstream and as such, it is recommended that further hydraulic analyses be completed at the detailed design stage of these culvert upgrades to assess flooding impacts downstream and locate development outside of potentially impacted areas.

Table 8.2: Existing Culverts

Culvert ID	Existing				
	Shape	Barrels	Width (m)	Height (m)	H_W/D
Culvert_25	Circular	1	0.60	0.60	4.3
Culvert_26	Circular	1	0.60	0.60	7.1
Culvert_28	Circular	1	1.5	1.5	1.8
Culvert_29	Circular	1	1.5	1.5	2.7
Culvert_30	Circular	1	1.5	1.5	2.7

9 Post Development Conditions

Stantec's planning team engaged landowners to build a development scenario for the Highway 102 Study Area and built on that scenario to provide lower and higher densities scenarios.

For the purpose of this stormwater management assessment, the high-density scenario, which results in larger impermeable surfaces, has been selected given that it is the worst-case scenario and provides a comprehensive understanding of the most conservative conditions. It should be noted that the current development plan is conceptual and subject to change based on results of further analysis and studies within the study area and to adhere to the recommendations made in Stantec's 2024 Land Suitability Analysis for the Highway 102 Study Area. Refer to **Figure 9.1** for conceptual proposed development conditions.

Moreover, it is anticipated that the stormwater management strategies for the high-density scenario will also be applicable and effective for both the low and medium density scenarios.

In the post development conditions, development is being considered in the area located immediately downstream of Culvert_28 and Culvert_29, and at the location of Culvert_27. Culvert_28, and Culvert_27 are associated with unnamed watercourse 3 and it is recommended that the proposed development plan be revisited to maintain connectivity of unnamed watercourse 3 to Washmill Lake. Culvert_29 and Culvert_30 are associated with unnamed watercourse 1 and it is recommended that the proposed development plan be revisited to maintain connectivity to Susies Lake. If the external culverts were to be upsized at some point in the future by their respective owners, it would have an impact on the peak flows reaching the proposed development area. Therefore, it is recommended that further hydraulic analyses be completed to assess flooding impacts downstream. Culvert sizing as a whole should be confirmed during later design/planning stages of this project. To reduce exposing future residents in the area to flooding risks, it is recommended to assume that culverts upstream will be upgraded and that proposed infrastructure will be located outside flood lines delineated under such scenarios.

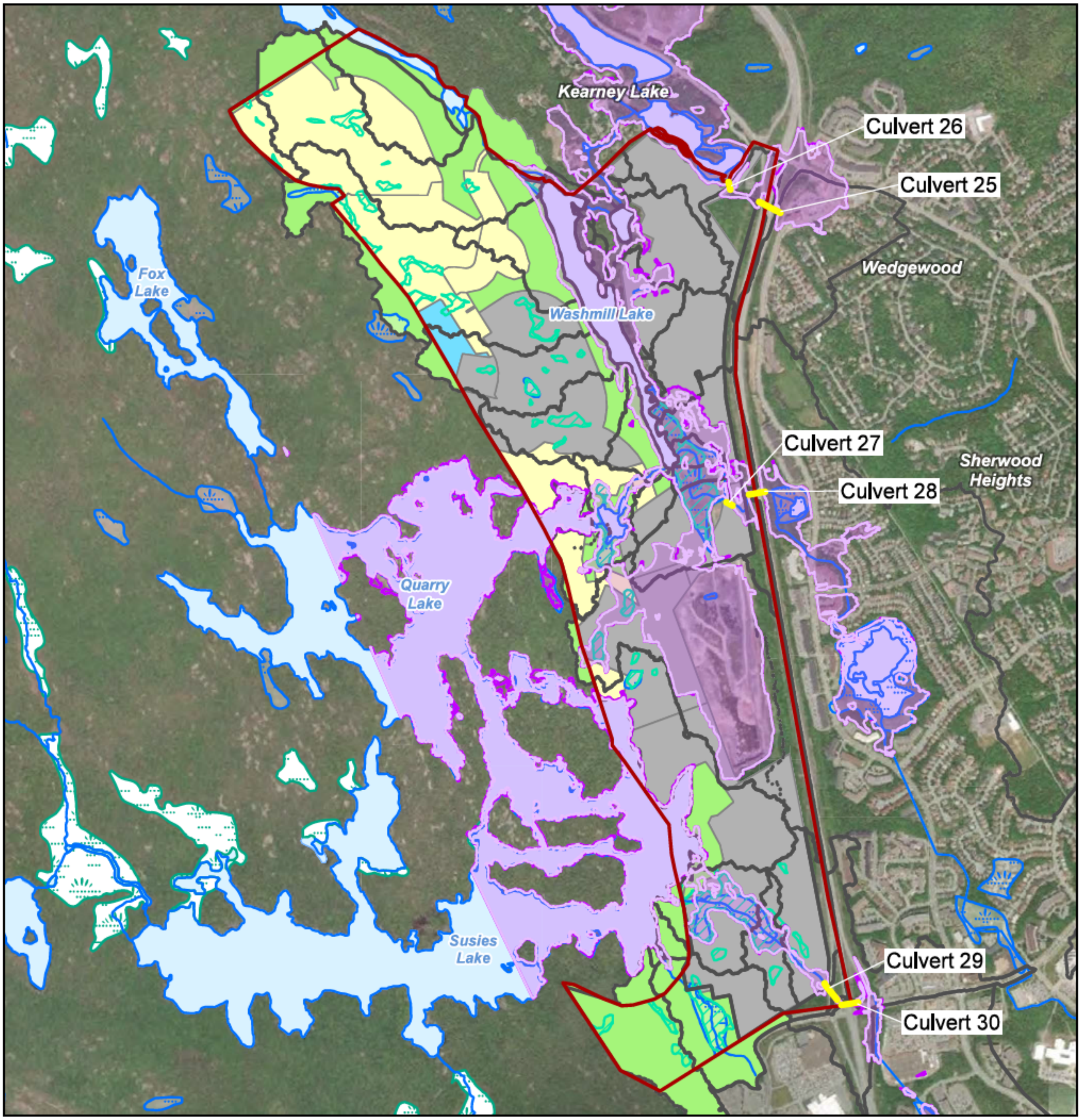
The existing quarry has been included in the current regional flood risk mapping project as a depression and it is shown to be part of Washmill Lake's floodplain in its entirety. Based on this, development should be restricted within this area as per regulatory policies. It is our understanding that the intent is to create an artificial lake in this area. However, under the conceptual proposed conditions assessed, it has been assumed that the artificial lake would not be used for stormwater management for future developments. The artificial lake has been shown to have no hydraulic connectivity to the proposed SWM ponds and/or storm infrastructure and to provide a separate outlet to Washmill Lake.

The subsequent subsections detail the various characteristics of the post-development conditions. Additionally, the post-development storm drainage plan is presented in **Drawing SD-1** in **Appendix C**.

9.1 Site Grading & Land Use

The high-density development scenario has been used to create a master grading plan designed to follow existing drainage patterns as much as possible, provide sufficient cover over trunk sewers, provide an overland flow outlet, takes into account sufficient cover over future culvert crossings and incorporates bottom and high-water elevations at end of pipe SWM facilities.

The proposed development plan consists of a diverse mix of land uses that encompasses low-density residential areas, high density multi-unit residential areas, institutional areas, mixed-use/commercial areas, as well as park and open space areas. **Figure 9.1** presents the proposed development areas.



Legend

- Study Area
- Culvert
- 20yr Flood Extent (Draft, HRM 2023)
- 100yr Flood Extent (Draft, HRM 2023)

Land Use

- Institutional
- Low Residential
- Multi Residential
- Green Space

Wetlands and Waterways

- Waterway
- Waterbody
- Designated Wetland of Special Significance
- Wetland
- Wetlands (Stantec, 2023)

0 500 1,000 Meters

(At original document size of 8.5x11)
1:21,000

N

Notes

1. Coordinate System: NAD 1983 CSRS UTM Zone 20N
2. Data Sources: Stantec; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services; Government of Nova Scotia Environment and Climate Change
3. Background: ESRI; Government of Nova Scotia, Department of Service Nova Scotia and Internal Services.

Stantec

Project Location
Halifax Regional Municipality, Nova Scotia

Prepared by HB on 2024-02-13
Revised by AC on 2024-10-28

Client/Project
160410459
Halifax Regional Municipality
Future Serviced Communities
Highway 102 West Corridor Stormwater Management Plan

Figure No.
9.1

Title
Conceptual Development and Culvert Locations

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9.2 Proposed Subcatchments

The general hydrologic parameters applied to the post-development areas are consistent with those used in the existing conditions model, as detailed in **Section 8.5.1**. The proposed subcatchments and their corresponding runoff coefficients are illustrated in **Drawing SD-1** in **Appendix C**.

Given that the concept plans are preliminary and subject to change and do not provide details on location and width of driveways and sidewalks, a representative runoff coefficient based on proposed land use was used. Average runoff coefficients based on the proposed conceptual land use were obtained from the help file for ICM SWMM, ICM InfoWorks and SWMM5 software. The average runoff coefficients (C) based on the various land uses are as follows:

- Low Density Residential: 0.65
- Multi-residential: 0.75
- Commercial: 0.85
- Institutional: 0.70
- Green Space: 0.20
- Community Park: 0.40

In the hydraulic model, the imperviousness parameters for the proposed subcatchments were obtain per the following equation, where C correspond to the runoff coefficient:

$$Percent\ Impervious = \frac{(C - 0.2)}{0.7} \times 100$$

Additionally, the flow length, which is the longest path that water is likely to take flowing over the surface, was calculated based on the area's topography and layout. The width was then computed from the total area divided by the flow length. The slope of the proposed areas is estimated to be 2% for the hydraulic assessment. Additionally, for the pervious areas within the proposed subcatchments, a CN value of 74 was used.

9.3 Boundary Conditions

For the post-development hydrologic/hydraulic PCSWMM model, the boundary conditions remain consistent with the existing conditions. Refer to **Section 8.7** for detailed information about boundary conditions.

9.4 Proposed Crossing Structures

The conceptual storm drainage plan present in **Drawing SD-1** in **Appendix C** shows the high-density development plan for the Highway 102 Study Area, which includes proposed road crossings at the existing watercourses. These crossing locations have been identified, however at this stage, there is insufficient data available to validate the watercourse peak flows and water levels associated with upstream drainage areas and the proposed development area, and therefore, only high-level conceptual sizing of these structures has been completed based on unrestricted conveyance. It is recommended that sizing of these structures be reviewed once flow monitoring and model calibration are completed for the existing watercourses.

9.5 Stormwater Management Strategy

Urbanization inevitably leads to changes in the landscape so in order to successfully implement development plans that result in balanced and environmentally sustainable development, it is key to devise an effective management strategy. This section provides a general description of stormwater management measures which, when combined, form a comprehensive approach to stormwater management in order to meet established SWM criteria and protect the surrounding natural environment.

Following discussions with HRM and HW, it was agreed that quantity control measures would be implemented to limit post-development peak flows to pre-development levels up to the 100-year storm. It is therefore recommended that quantity control measures in the form of end-of-pipe stormwater management (SWM) dry ponds be implemented at key locations within the proposed development area to mitigate post development peak flows to pre-development levels.

The current SWM pond locations are conceptual (i.e., not an approved plan) and subject to change based on results of more detailed analysis as the development plan progresses. The SWM ponds should be located outside of the floodplain based on existing topography and proposed grading to restrict post development peak flows to existing conditions levels.

An artificial lake has been shown in the location of the existing quarry, which constitutes a 40m deep depression. Under the conceptual proposed conditions assessed, the artificial lake was assumed to have no hydraulic connectivity to the proposed SWM ponds and/or storm infrastructure and to provide a separate outlet to Washmill Lake. However, the feasibility of using the existing quarry area for stormwater management purposes could be assessed during later planning/design stages, pending detailed hydraulic analysis and a cost feasibility assessment to fill part of the existing quarry.

Urbanization typically alters the water balance, leading to increased runoff and decreased infiltration, primarily due to increased impervious surfaces associated with urban development. In addition, urbanization usually results in increased sediment and phosphorus loading in receiving watercourses. Retaining native and existing ground cover should be prioritized where possible to preserve ecosystem service function, reduce volume of runoff discharged into watercourses, promote infiltration, and provide an opportunity for evapotranspiration. Where retaining native cover is not possible, it is recommended that a treatment train approach consisting of lot level best management practices (BMPs), such as directing residential roof runoff to vegetated surfaces, introducing vegetated swales, and low impact development (LID) measures such as infiltration trenches, bioswales, etc., be investigated at the detailed design stage to provide quality control of runoff prior to discharging into the receiving watercourses and to promote infiltration.

Please refer to **Section 6** for mitigation recommendations to reduce phosphorus (P) loading, *E. coli* loading, and sediment loading from the Highway 102 Study Area and achieve contaminant loads of existing conditions.

To reduce annual TP load to the watershed, future development scenarios must consider implementing a combination of measures such as a street maintenance program to remove sediment-associated P from roadways and catchbasins, along with the implementation of Low Impact Development (LID) measures to reduce loading.

The implementation of LID measures within the future developments would also aid in the removal of fecal coliform through sedimentation.

Erosion and sedimentation control measures are recommended during construction of all future developments to mitigate sediment loadings into the receiving water bodies.

Table 9.1, taken from the Credit Valley Conservation Low Impact Development Stormwater Management Planning and Design Guide (CVC, 2010, Table 3.4.1), provides a comparison of site constraints for a variety of structural LID SWM practices.

Table 9.1: Comparison of Site Constraints for a Range of Structural LID SWM Practices

LID Stormwater Management Practice	Depth to high water table or bedrock[1] (m)	Typical Ratio of Impervious Drainage Area to Treatment Facility Area	Native Soil Infiltration Rate (mm/hr)[3]	Head[4] (m)	Space[5] %	Slope[6] %	Pollution Hot Spots[7]	Set backs[8]
Rain barrel	Not applicable	[5 to 50 m^2][2]	Not applicable	1	0	NA	Yes	None
Cistern	1	[50 to 3000 m^2][2]	Not applicable	1 to 2	0 to 1	NA	Yes	U, T
Green roof	Not applicable	1:1	Not applicable	0	0	0	Yes	None
Roof downspout disconnection	Not applicable	[5 to 100 m^2][2]	Amend if < 15 mm/hr[9]	0.5	5 to 20	1 to 5	Yes	B
Soakaway, infiltration trench or chamber	1	5:1 to 20:1	Not a constraint	1 to 2	0 to 1	< 15%	No	B, U, T, W
Bioretention	1	5:1 to 15:1	Underdrain required if < 15 mm/hr	1 to 2	5 to 10	0 to 2	No	B, U, W
Biofilter (filtration only Bioretention design)	Not applicable	5:1	Not applicable	1 to 2	2 to 5	0 to 2	Yes	B, T

LID Stormwater Management Practice	Depth to high water table or bedrock[1] (m)	Typical Ratio of Impervious Drainage Area to Treatment Facility Area	Native Soil Infiltration Rate (mm/hr)[3]	Head[4] (m)	Space[5] %	Slope[6] %	Pollution Hot Spots[7]	Set backs[8]
Vegetated filter strip	1	5:1	Amend if < 15 mm/hr[9]	0 to 1	15 to 20	1 to 5	No	None
Permeable pavement	1	1:1 to 1.2:1	Underdrain required if < 15 mm/hr	0.5 to 1	0	1 to 5	No	U, W
Enhanced grass swale	1	5:1 to 10:1	Not applicable	1 to 3	5 to 15	0.5 to 6	No	B, U
Dry swale	1	5:1 to 15:1	Underdrain required if < 15 mm/hr	1 to 3	5 to 10	0.5 to 6	No	B, U, W
Perforated pipe system	1	5:1 to 10:1	Not a constraint	1 to 3	0	< 15%	No	B, U, T, W

Notes:

1. Minimum depth between the base of the facility and the elevation of the seasonally high-water table or top of bedrock.
2. Values for rain barrels, cisterns and roof downspout disconnection represent typical ranges for impervious drainage area treated.
3. Infiltration rate estimates based on measurements of hydraulic conductivity under field saturated conditions at the proposed location and depth of the practice.
4. Vertical distance between the inlet and outlet of the LID practice.
5. Percent of open pervious land on the site that is required for the LID practice.
6. Slope at the LID practice location.
7. Suitable in pollution hot spots or runoff source areas where land uses or activities have the potential to generate highly contaminated runoff (*e.g.*, vehicle fueling, servicing or demolition areas, outdoor storage or handling areas for hazardous materials and some heavy industry sites).
8. Setback codes: B = Building foundation; U = Underground utilities; T = Trees; W = drinking water wellhead protection areas.
9. Native soils should be tilled and amended with compost to improve infiltration rate, moisture retention capacity and fertility.

For the portions of the Highway 102 Study Area not underlain by exposed bedrock (i.e., the western edges of the study area), several LIDs are worth considering:

- Bioretention Cells and Rain Gardens are designed to imitate natural water cycles and are effective in removing various contaminants from runoff, while also reducing its volume and intensity;
- Permeable Pavements allow stormwater to seep through into a stone reservoir for temporary storage or infiltration;
- Vegetated Filter Strips and Swales are designed to process and reduce runoff from nearby impervious surfaces;
- Tree Plantings and Native Plantings can help absorb stormwater, decrease runoff, and enhance water quality; and,

- Rain Barrels capture and store rainwater for future use, thereby reducing stormwater runoff.

However, the specific selection, design, and positioning of these LIDs should be further investigated during the detailed design stage. The assessment should take into account factors such as the infiltration abilities of the native soils, the depth to bedrock, the groundwater table, and local regulations.

10 Hydrologic and Hydraulic Modeling

The following sections provide a comprehensive overview of the conceptual stormwater management plan for the Highway 102 Study Area developer-proposed concept plan, including outlining measures required to restrict post development peak flows to pre-development levels, identifying flood risk areas, and summarizing the limitations associated with the modeling process.

10.1 Floodplain Identification

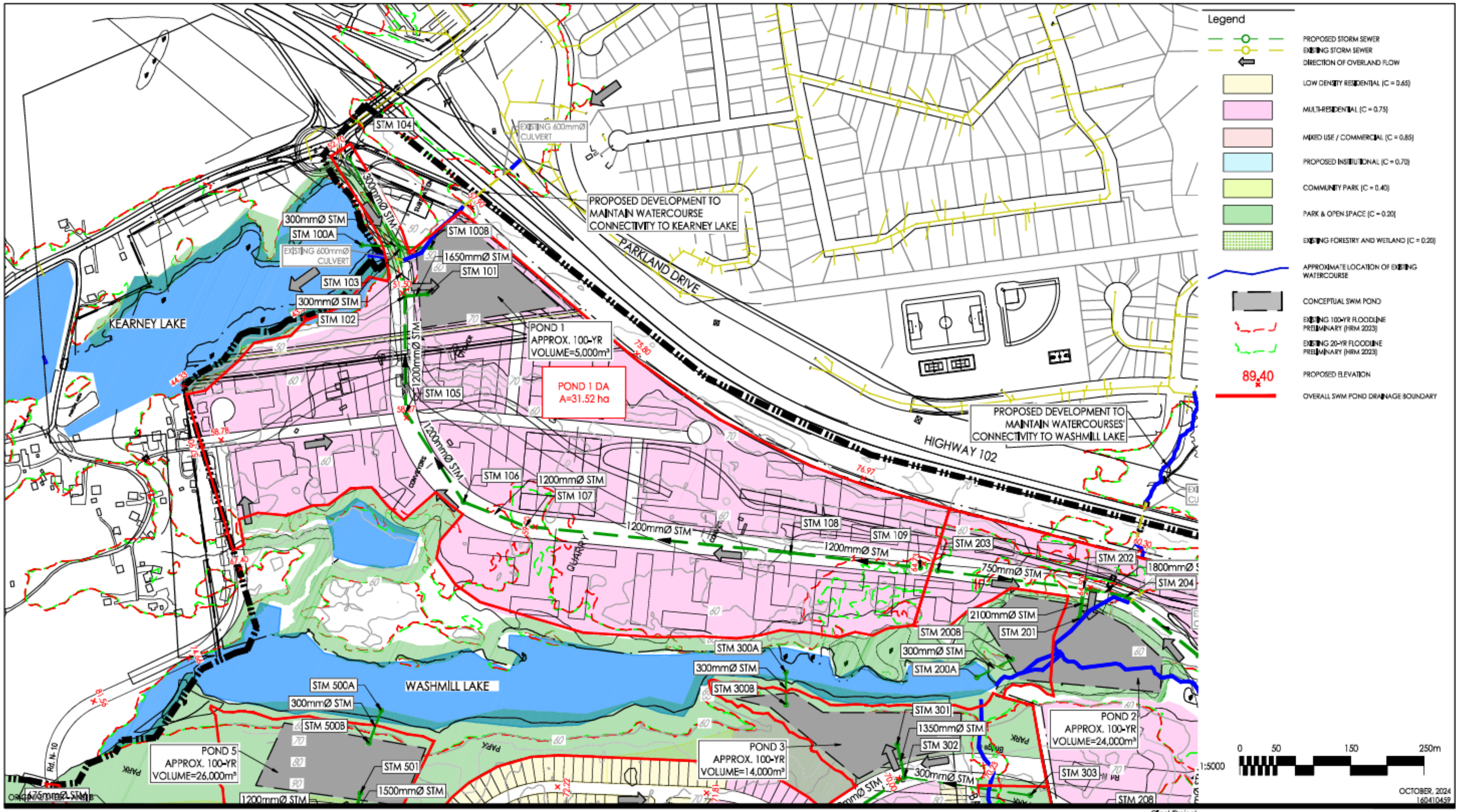
Based on the preliminary floodlines obtained from HRM, part of the proposed development lies within the floodplain. The development blocks within areas C109A, C203A, C208A, and C210A all have a portion of the development within the preliminary 100-year flood plain of Washmill Lake and the existing quarry, elevation 60.0 m. Additionally a portion of area C407A lies within the preliminary 100-year flood limit of the unnamed watercourse 1.

For the proposed development areas within the preliminary flood limits, it is recommended that the proposed roads within this area be located outside the 100-year floodline. Similarly, it is recommended that future development be restricted within the 100-year floodplain in consistency with municipal by-laws and the Nova Scotia Statement of Provincial Interest regarding flood risk areas.

10.2 Stormwater Management Dry Ponds

As presented on **Drawing SD-1** in **Appendix C**, the proposed development area would be serviced through storm sewers that would be sized to convey the 5-year runoff under free flow conditions to the proposed end of pipe SWM dry ponds for quantity control prior to discharging into the receiving watercourses. During major storm events, higher than the 5-year storm, peak overflows would be routed overland to the proposed SWM dry ponds.

A total of five SWM dry ponds have been proposed for stormwater management based on existing drainage patterns and the conceptual development plan to mitigate post development peak flows to pre-development levels for all storms from the 2-year up to the 100-year storm event. The final number, location, and size of the SWM dry ponds is to be confirmed based on best engineering principles and detailed floodplain mapping for the area, including flow monitoring and model calibration. The conceptual location and overall drainage area of the SWM ponds are shown in **Figure 10.1**, **Figure 10.2**, **Figure 10.3**, **Figure 10.4**, and **Figure 10.5**.



Notes

Client/Project
HRM
FUTURE SERVICED COMMUNITIES
STORMWATER MANAGEMENT

Figure No.
10-1

Title
OVERALL DRAINAGE AREA
TO SWM POND 1

Stantec
Stantec Consulting Ltd.
400 - 1331 Clyde Avenue
Ottawa ON
Tel. 613.722.4420
www.stantec.com

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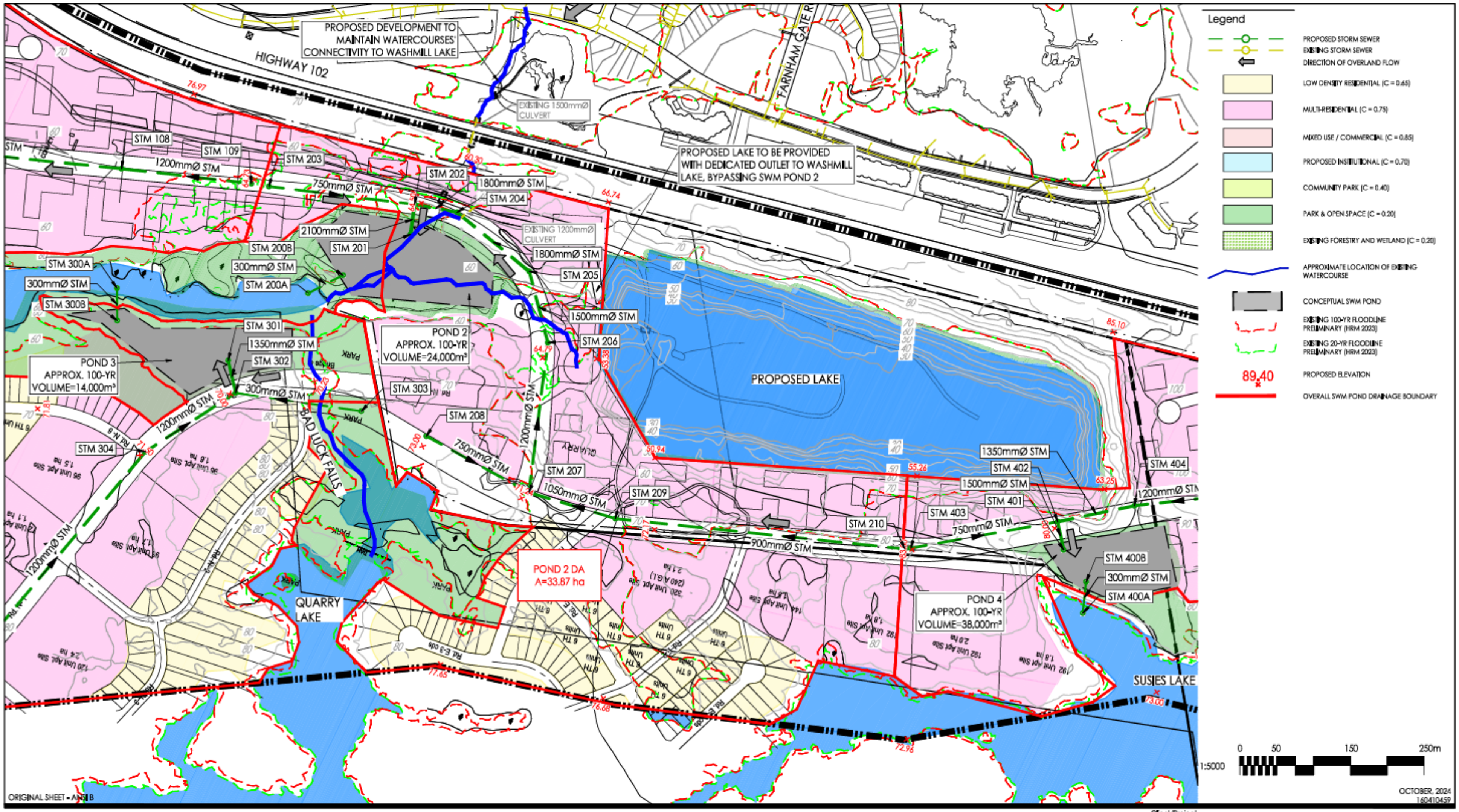

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Notes

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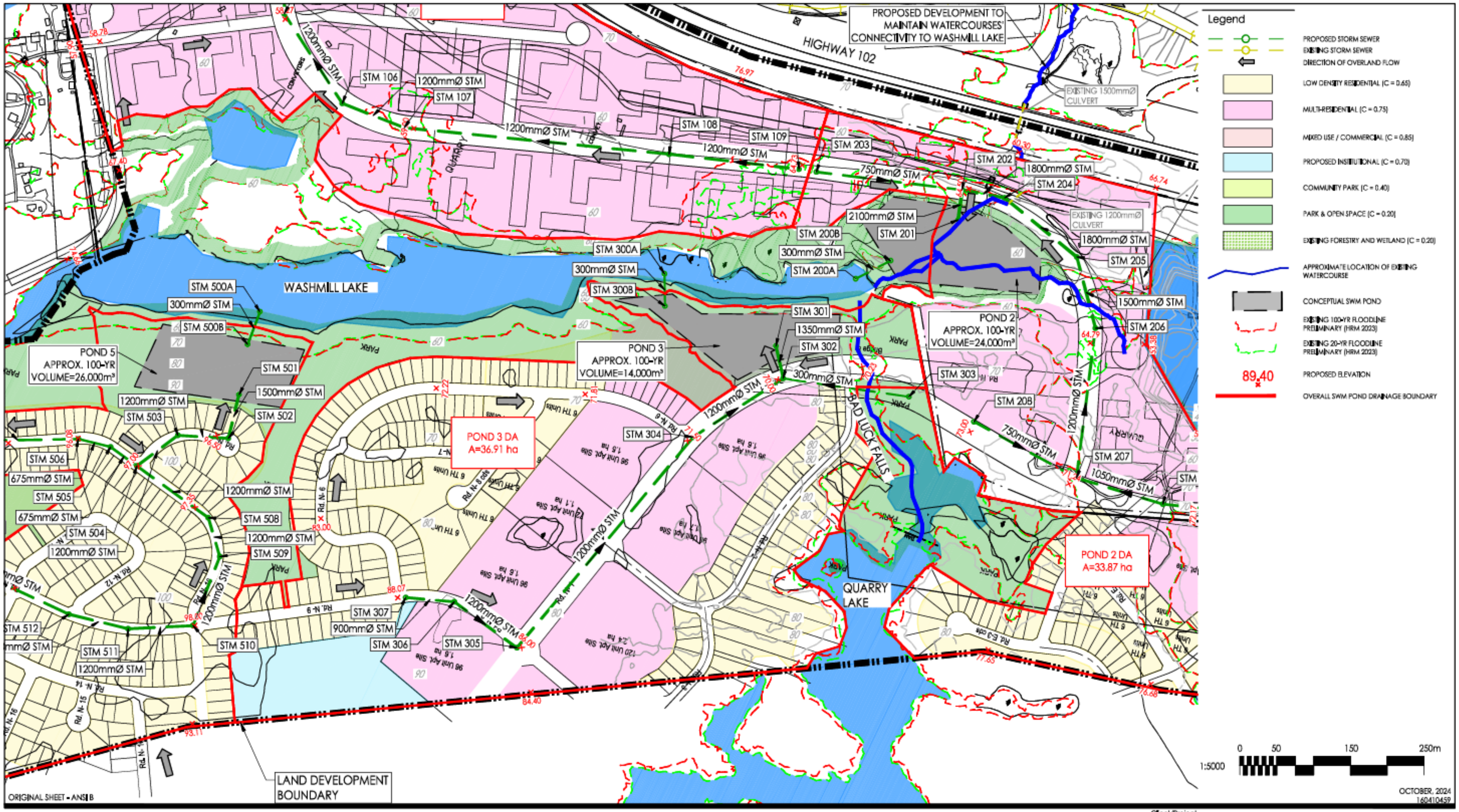
Client/Project
HRM
FUTURE SERVICED COMMUNITIES
STORMWATER MANAGEMENT

Figure No.
10-2

Title
OVERALL DRAINAGE AREA
TO SWM POND 2



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Notes

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Figure No.
10-3

Title
OVERALL DRAINAGE AREA
TO SWM POND 3

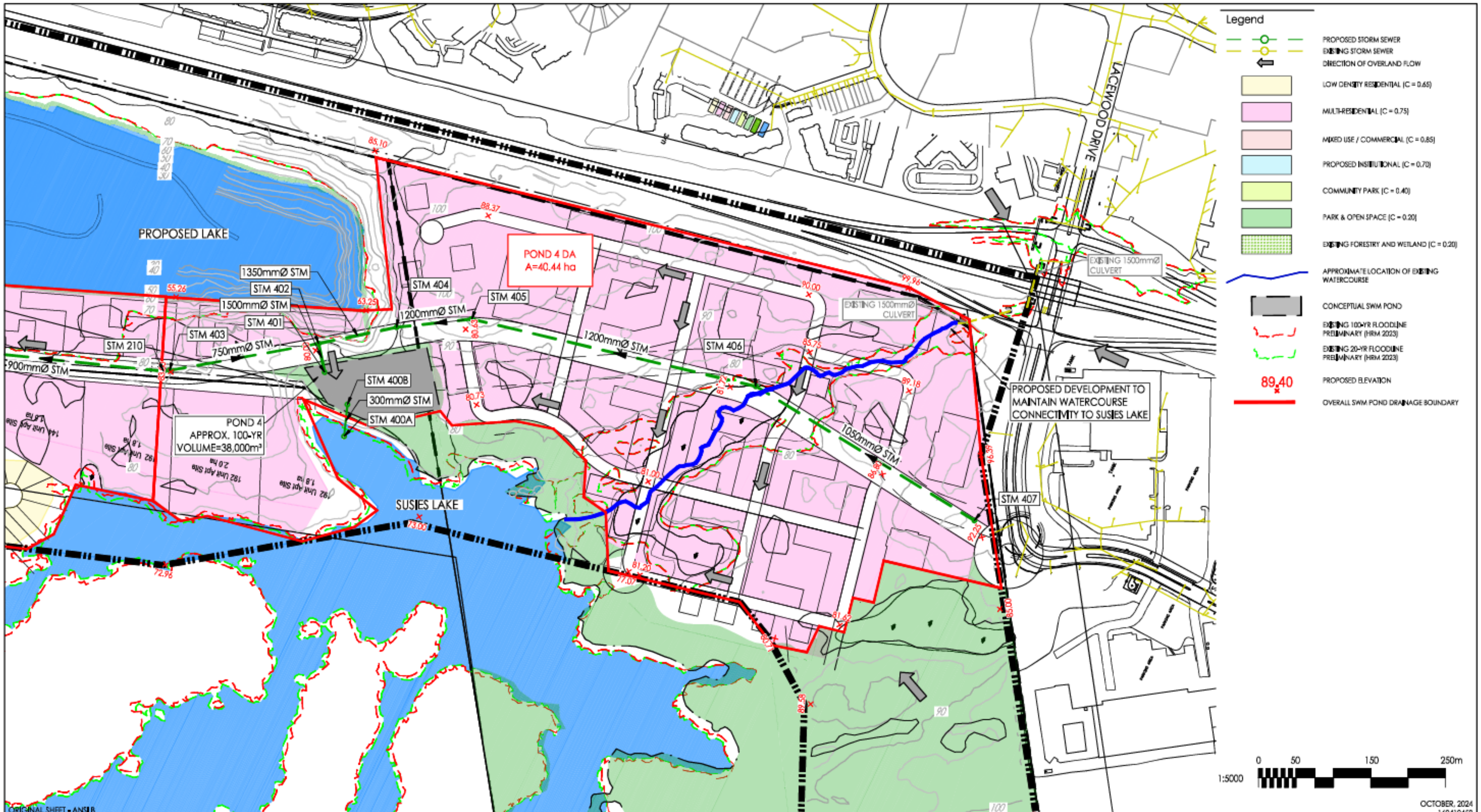

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Figure No.
10-4

Title
OVERALL DRAINAGE AREA
TO SWM POND 4

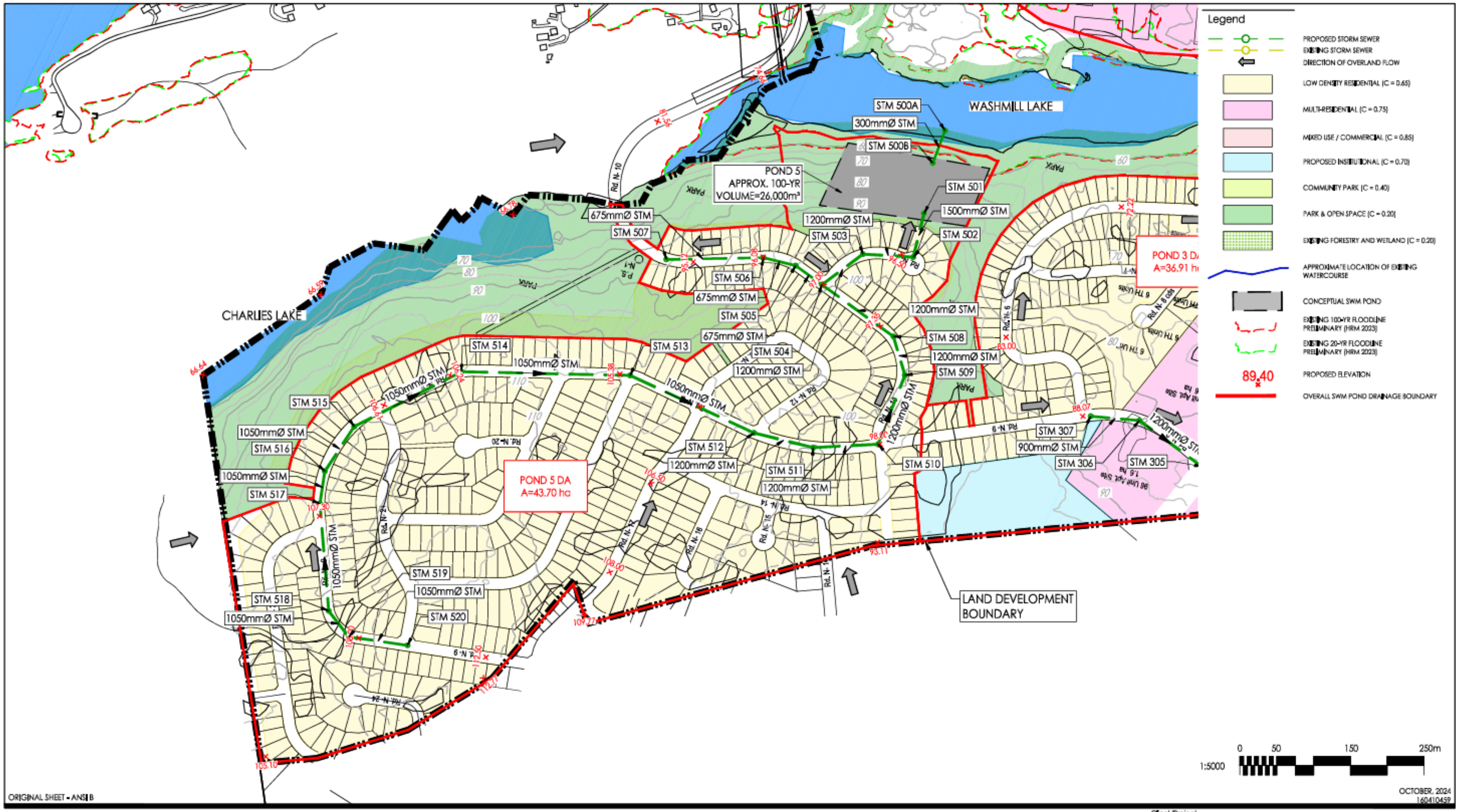

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Figure No.
10-5

Title
OVERALL DRAINAGE AREA
TO SWM POND 5

The drainage areas and approximate 100-year volume requirements for the proposed SWM dry ponds are summarized in **Table 10.1**.

Table 10.1: Proposed Pond 100-yr Volume

Pond ID	Drainage Area (ha)	100-yr Volume (m^3)
Pond 1	31.5	5,000
Pond 2	34.8	24,000
Pond 3	33.9	14,000
Pond 4	40.8	38,000
Pond 5	47.3	26,000

Although the SWM ponds are currently outside of the HRM-provided 100-year floodline, this floodline is based on a high-level model and it is subject to change based on more detailed analysis that could result in the SWM ponds being within the 100-year floodplain. In general, it is recommended that the proposed development plans for the study area be revised to avoid residential, commercial, and institutional land uses within the 100-year floodplain and to ensure that appropriately sized blocks are allocated for the SWM Ponds outside of the confirmed 100-year floodplain. In the further stages of planning and development of the site, the development plan should be revised to relocate residential development and ponds that are currently close to or within the potential flood line. By pulling back the development, and potentially adding density to the remaining, the population/development yield of the site could remain similar, and it could reduce the potential risks associated with flooding. Setback areas from watercourses and waterbodies have to be studied on a site-specific basis during subsequent area planning to determine development suitability.

The conceptual stormwater management plan shown on **Drawing SD-1** includes trunk storm sewers at key locations such as watercourse crossings and SWM pond inlets. These trunk sewers have been sized to convey the 5-year storm under free flow conditions. However, pipe sizes and SWM pond locations will be confirmed at the detailed design stage. **Table 10.2** shows preliminary trunk storm sewer characteristics.

Table 10.2: Storm Sewer Characteristics

U/S MH ID	D/S MH ID	U/S Invert Elevation (m)	D/S Invert Elevation (m)	Diameter (m)
102	POND1-S	48.149	47.995	1.80
103	102	49.757	49.499	0.30
104	103	50.352	49.787	0.30
105	102	52.238	48.299	1.20
106	105	53.571	52.268	1.20
107	106	54.415	53.601	1.20
108	107	57.694	54.442	1.20
109	108	59.316	57.721	1.20
202	POND2-S	60.340	60.300	2.10
203	202	62.093	61.694	0.75
204	202	60.462	60.404	2.10
205	204	60.619	60.492	2.10
206	205	61.200	60.649	1.50
207	206	64.48	61.499	1.20
208	207	69.065	65.098	0.75
209	207	65.859	64.633	1.20
210	209	78.012	66.159	0.90
302	POND3-S	65.400	64.950	1.50
303	302	68.520	66.800	0.30
304	302	67.940	65.750	1.50
305	304	79.970	68.040	1.20
306	305	82.140	80.030	1.20
307	306	83.490	82.170	1.05
402	POND4-S	73.690	73.495	1.50
403	402	78.943	74.890	0.75
404	402	74.460	73.840	1.50
405	404	75.314	74.610	1.50
406	405	78.220	75.335	1.20
407	406	88.655	78.368	1.05
502	POND5-S	84.080	82.000	1.50
503	502	86.470	84.140	1.50
504	503	88.860	86.500	1.50
505	504	89.820	89.690	1.05
506	505	89.980	89.850	1.05
507	506	90.390	89.990	1.05
508	504	91.910	88.920	1.50
509	508	92.600	91.940	1.50
510	509	93.640	92.630	1.50
511	510	94.550	93.670	1.50
512	511	95.410	94.580	1.50

U/S MH ID	D/S MH ID	U/S Invert Elevation (m)	D/S Invert Elevation (m)	Diameter (m)
513	512	97.209	95.440	1.50
514	513	99.730	97.440	1.20
515	514	101.390	99.760	1.20
516	515	102.150	101.420	1.20
517	516	102.630	102.180	1.20
518	517	104.120	102.660	1.20
519	518	104.590	104.150	1.20
520	519	105.430	104.620	1.20

10.3 Quantity Control Results

As shown on **Drawing SD-1**, flow points have been established at Kearney Lake and Susies Lake. Kearney Lake is used as the balance point for flows draining to both Washmill Lake and Kearney Lake as Washmill Lake outlets to Kearney Lake. The Kearney Lake balance point consists of internal uncontrolled parkland runoff as well as controlled developed land runoff from Pond 1, 2, 3 and 5. Similarly, the Susies Lake balance point consists of internal uncontrolled parkland runoff as well as controlled developed land runoff from Pond 4. It is at these two locations that the pre-development and post-development peak flows were compared. The stage-storage-discharge relationship of the proposed SWM ponds was iterated in PCSWMM in order to restrict post development peak flows close to pre-development levels for the 2, 5, 10, 25, 50, and 100-year design storms. **Table 10.3** presents the post to pre-development peak flow comparison at the different flow points along the watercourses for the 2-year, 5-year, and 100-year design storm events. Refer to **Appendix D** for a table showing peak flow results for all storm events.

Table 10.3: Post to Pre-Development Peak Flow Comparison

Flow Point ID	2-year, 24hr Chicago Peak Flow (m^3/s)		5-year, 24hr Chicago Peak Flow (m^3/s)		100-year, 24hr Chicago Peak Flow (m^3/s)	
	Existing	Proposed	Existing	Proposed	Existing	Proposed
Susies Lake	0.503	0.337	0.859	0.597	2.234	1.964
Kearney Lake	6.726	4.885	9.935	8.310	20.771	19.694

As can be seen in the above table, post development peak flows are lower than existing condition levels for all storm events, at both locations. Final sizing and location of the SWM ponds should be confirmed at the detailed design stage, pending flow monitoring, model calibration and detailed floodplain mapping for the area to ensure that post development peak flows along the watercourses are balanced within 10% (+ or -) of pre-development levels.

10.4 Modeling Limitations

The following are some of the limitations associated with the current modeling approach:

- Calibration: Flow monitoring data for the Kearney Lake watershed, which includes Washmill Lake, Susies Lake and Quarry Lake, is not available at this time and as such, the hydrologic/hydraulic PCSWMM model has not been calibrated. Hydrologic and hydraulic parameters used in this modeling exercise have been selected as discussed in this report based on available information. However, these parameters have not been calibrated to reflect the actual runoff response from the watershed, and the rain runoff response of the lakes as a result of existing dam operation at the outlet. Without calibration, the model's predictions are based solely on theoretical calculations and assumptions, which may not accurately reflect real-world conditions.
- Culvert sizing for existing watercourses and the existing Bad Luck Falls has not been completed at this time due to insufficient data available to accurately estimate existing and proposed peak flows during different return periods.

11 Floodplain & Sustainable Development

Planning and development decisions should be guided by best practices in both floodplain management and sustainable development. This process should integrate the principles of resilience to climate change and commitment to environmental conservation at each planning stage.

To guide the HRM in planning, development, and refinement of sustainable future development plans for the Highway 102 Study Area, it is recommended to develop a high-level map outlining opportunities to protect and improve the natural environment and associated limitations and constraints. It is important to note that most development constraints which include meander belt widths, existing wetlands and woodlots, and regulatory flood plains, greatly impact the environment and hence should not be altered. However other constraints such as modification to drainage may be permitted if carried out as part of an integrated planning approach such as a subwatershed study. Should there be a need to alter/affect development constraints, detailed investigation must be performed to evaluate the impact on natural features and downstream properties and infrastructure, and to establish corresponding measures to eliminate/compensate for the adverse impacts. Development constraint mapping for the study area has been provided in the Land Suitability Assessment (Stantec, 2024), as well as in this report. However, these studies do not quantify the impacts on stormwater/flooding resulting from any alterations that may be proposed as part of the development concept plans.

Additionally, it is understood at this time that the existing quarry site will be allowed to flood and become a proposed lake. As part of the on-going Regional Flood Mapping Delineation project being completed by CBCL, this location was identified as a depression and thus included in the flood lines provided by HRM. However, this proposed lake is conceptual in nature and as of the publishing of this report, no dedicated outlet design to Washmill Lake has been provided. Further studies are necessary regarding this lake's hydrological response, once an outlet is determined to control lake water levels, as well as infill costing studies, prior to finalizing any development decisions based on floodlines within its vicinity.

Wetlands effectively aid in reducing the negative impacts of frequent heavy rainfall events by collecting runoff in their naturally low-lying areas, allowing it to be slowly released into receiving watercourses, infiltrated into the soil to recharge groundwater systems, or absorbed by wetland vegetation. As a result, wetlands represent an important constraint for any development in Nova Scotia. Conservation of wetlands in the province is guided by the Nova Scotia Wetland Conservation Policy and supported by regulation under the provincial Environment Act and Activities Designation Regulations. The goals of the policy are to have no loss of Wetlands of Special Significance (WSS) and to prevent net loss in area and function for other wetlands.

As stated in the statement of provincial interest regarding flood risk areas, within the *Floodway*, development must be restricted to uses such as roads, open space uses, utility and service corridors, parking lots and temporary uses, and the placement of off-site fill must be prohibited. Within the *Floodway Fringe,* flood proofed development may be permitted except for residential institutions where flooding could pose a significant threat to the safety of residents if evacuation became necessary, and in any use associated with the warehousing or the production of hazardous materials. Additionally, the placement of off-site fill within the *Floodway Fringe* must be limited to that required for flood proofing or flood risk management.

Development contrary to the Statement of Provincial Interest regarding Flood Risk Areas may be permitted provided a hydrotechnical study, carried out by a qualified person, shows that the proposed development will not contribute to upstream or downstream flooding or result in a change to flood water flow patterns.

Based on the above, it is recommended that no active development be permitted within the limits of the 100-year regulatory floodplain. Some reduced risk uses may be considered in agreement with HRM by-laws and the Nova Scotia Statement of Provincial Interest regarding Flood Risk Areas. This is subject to design considerations that effectively mitigate and/or minimize the impact of such development on the floodplain and protect the riparian corridor functions. It is further recommended that future development phasing start in higher areas outside of the identified preliminary floodplain and that detailed floodplain mapping be completed to confirm floodplain extents and development setbacks as future developments move closer to the identified preliminary floodplain.

Moreover, any proposed development should adhere to the constraints identified in the Land Suitability Assessment constraint mapping for the Highway 102 Study Area (Stantec, 2024). This includes areas of significant wildlife habitat, wetlands, steep slopes, and other environmentally sensitive areas. In areas where development is proposed within or in proximity to the identified floodplain, suitable mitigation measures should be implemented.

In addition, the promotion of green space creation or naturally forested park areas greatly reduce volume of runoff and pollutant loading discharged into receiving watercourses and as such, it is recommended that green space be promoted within future development plans.

12 Stormwater Management Conclusions and Recommendations

The following lists the key points concluded from the stormwater analysis:

- The stormwater management plan for the Highway 102 Study Area includes storm sewers sized for the 5-year storm at 80% full flow pipe capacity, overland flow routing to end-of-pipe SWM facilities and five (5) SWM dry ponds designed to restrict post-development peak flows to existing watercourses to pre-development values for up to and including the 100-year storm. However, the analysis has identified important limitations and vulnerabilities in the layout provided by the developer. Although this layout was used to assess the feasibility of controlling post-development peak flows, it requires critical consideration of key elements. The proposed development layout and associated stormwater management requires a thorough revision based on further analysis of the land use distribution and the siting of SWM ponds, as well as detailed hydraulic modeling, to confidently mitigate risks of flooding and reduce risks of degradation to the natural assets within the study area. High density land uses can potentially reduce the footprint of development and help to maintain development and stormwater management infrastructure away from flooding risk areas.
- Quality control for the study area is to be provided through best management practices, along with the use of LID measures to provide filtration and promote infiltration within public areas. Loading reduction tracking as a result of mitigation measures can be achieved through monthly grab samples at select monitoring locations during the summer months.
- One proposed watercourse crossing has been identified, over the watercourse associated with Bad Luck Falls. However, a preliminary sizing exercise could not be completed due to limited available peak flow for the watercourse and lake response data. Additionally, the upstream dam structure on the outlet of Quarry Lake, and its response under major storms is not well understood. Future sizing should meet the $H_w/D \leq 1$ criterion for the 100-year design storm event based on a calibrated model and observed runoff response at the lakes.
- Current development plans assume an artificial lake will be provided at the site of the existing quarry depression with independent hydraulic connectivity to Washmill Lake. If the decommissioned quarry site is to become a lake, an outlet structure and channel to Washmill Lake needs to be designed and incorporated into the proposed development.
- Current development plans infringe on the preliminary 100-year floodplain extents (drainage areas C109A, C203A, C208A, C210A, and C407A).
- Two sections of the planned development area (drainage areas C208A and C407A) overlap portions of the existing watercourses. Additionally, the extents of SWM Pond 2, in its current location, may overlap portions of an existing watercourse as well.

Based on the discussion provided in this report, the following is a summary of recommendations:

- Flow monitoring in the watercourses and lakes, followed by model calibration be completed to assess existing dam operation (i.e., stage-discharge curve), determine lake water levels, confirm regulatory floodplain limits, determine culvert sizing and proposed pond sizes and locations.
- No active development be permitted within the limits of the 100-year regulatory floodplain. Some reduced risk uses may be considered in agreement with HRM by-laws and the Nova Scotia Statement of Provincial Interest regarding Flood Risk Areas. This is subject to design considerations that effectively mitigate and/or minimize the impact of such development on the floodplain and protect the riparian corridor functions. Once the above is completed it is also recommended to confirm pond sizes and locations as well as size the watercourse crossings.
- Investigation into existing dams (i.e., water control structures) at Quarry Lake, Susies Lake, and Washmill Lake to determine the rain-runoff response at the lakes is recommended to refine the boundary conditions in the model.
- An environmental impact assessment is recommended for the proposed lake at the existing quarry site to understand both the interim and final hydrologic, hydrogeologic, hydraulic and water quality implications, as well as their respective interim durations, on the overall drainage network.
- A detailed geotechnical investigation is recommended to be completed at the detailed design stage. Geotechnical recommendations should be provided for the proposed Stormwater Management (SWM) ponds, grade-raise restrictions, and the feasibility of Low Impact Developments (LIDs) in the area.
- The development concept plan be revisited to ensure SWM Ponds are located outside of the 100-year floodplain and/or delineated wetlands, to maximize the use of natural areas considering the recommendations of the Land Suitability Assessment, to consider high-density land uses that reduce sprawl to achieve this purpose, and to inform the revision of the proposed development layout and stormwater management plan to reduce risk of flooding and degradation to natural assets in the study area. The current layout includes SWM ponds located in or close to areas under risks of flooding.
- The development concept plan be revisited to incorporate options to maintain connectivity of the existing watercourses and the proposed quarry site lake to their respective downstream waterbodies, as well as grading considerations and setbacks to place development outside the preliminary flood limits.
- Future development phasing start in higher areas outside of the identified preliminary floodplain and detailed floodplain mapping be completed to confirm floodplain extents and development setbacks as future developments move closer to the identified preliminary floodplain.
- In future stages of planning and development of the site, the development plan should be revised to relocate residential development and SWM ponds that are currently close to or within the

potential floodplain. By pulling back the development, and potentially adding density to the remaining area, the population/development yield of the site could remain similar, and it could reduce the potential risks associated with flooding. The Land Suitability Report outlines that areas within 30 m of a watercourse have low suitability for development, so setback areas from watercourses and waterbodies must be studied on a site-specific basis during subsequent area planning to determine suitability.

- Retaining native and existing ground cover be prioritized where possible to preserve ecosystem service function, reduce volume of runoff discharged into watercourses/waterbodies, promote infiltration, and provide an opportunity for evapotranspiration.
- Implementing structural LID measures within public property to reduce contaminant loads for the development area to achieve contaminant loads of existing conditions.
- Implementing erosion and sedimentation control measures to mitigate effects from development during construction, as well as implementing construction sequencing to minimize the quantity of soil exposed at any given time to prevent erosion.

13 References

AECOM. 2013. Birch Cove Lakes Watershed Study – Final Report. Prepared for Halifax Regional Municipality. Project Number 60303077. August 2014.

Anderson, D. M., Glibert, P. M., & Burkholder, J. M. 2002. Harmful algal blooms and eutrophication: Nutrient sources, composition, and consequences. Estuaries, 25(4), 704–726. https://doi.org/10.1007/BF02804901

Burnhart, M., Bannerman, R., Owens, D., Hornewer, N. nd. Sources of Bacteria in Wisconsin Stormwater. Wisconsin Department of Natural Resources. Available online at: http://cws.msu.edu/documents/SourcesofBacteriainWIStormwater.pdf

Brylinsky, M. 2004. User's Manual for Prediction of Phosphorus Concentration In Nova Scotia Lakes: A Tool for Decision Making. Prepared for The Nova Scotia Water Quality Objectives and Model Development Steering Committee. Nova Scotia Department of Environment and Labour. Version 1.0. January 2004.

Canadian Council of Ministers for the Environment (CCME). 2004. Phosphorous: Canadian guidance framework for the management of freshwater systems. Environment Canada. Winnipeg, MB.

Canadian Council of Ministers for the Environment (CCME). 1999. Suspended Sediments. Water Quality Guidelines for the Protection of Aquatic Life – Freshwater. Winnipeg, MB.

CH2M HILL. 1993. Urban Stormwater Pollutant Event Mean Concentrations (EMCs) and Annual Runoff Coefficients for Calculation of Annual Pollutant Loads - Task F1 - "Pollutant Loadings", DERM Stormwater Management Master Plan, Phase I (C-9 East Basin Study). Prepared for the Metropolitan Dade County Department of Environmental Resources Management, Miami, FL.

Clement, P.M. and Gordon, D.C. 2019. Synoptic Water Quality Study of Selected Halifax-Area Lakes: 2011 Results and Comparison with Previous Surveys. Fisheries and Oceans Canada Science Branch, Maritimes Region. 2019. https://publications.gc.ca/collections/collection_2019/mpo-dfo/Fs97-4-3170-eng.pdf

Deeds, J., Amirbahman, A., Norton, S., Suitor, D., and Bacon, L. 2021. Predicting Anoxia in Low-Nutrient Temperate Lakes. Ecological Applications. April 21, 2021. https://doi.org/10.1002/eap.2361

Doucet, C. 2022. Identifying Lake Water Quality Trends and Effective Monitoring Strategies in a Rapidly Urbanizing Region. Dalhousie University, Halifax, Nova Scotia. November 2022.

Environment and Climate Change Canada (ECCC). 2024. Environment Canada Historical Climate Normals Data – Station ID 8202249. Halifax Stanfield International Airport Climate Station. Accessed March 2024.

Health Canada. 2024. Canadian Recreational Water Quality Summary Document

HESL. 2012. Phosphorus Budget Tool in Support of Sustainable Development for the Lake Simcoe Watershed. Prepared for Ontario Ministry of the Environment. March 2012.

Hutchinson Environmental Sciences Ltd. (HESL). 2014. Guidelines for No Net Increase in Phosphorus for River-lakes Secondary Planning Strategy. Prepared for the Halifax Regional Municipality. May 2014.

Lee, D.Y., Weir, S.C., Lee, H., Trevors, J.T. 2010. Quantitative identification of fecal water pollution sources by TaqMan real-time PCR assays using Bacteroidales 16s rRNA genetic markers. Applied Microbiology and Biotechnology, 88, 1373-1383.

Maine Department of Environmental Protection. 2000 (MDEP). Report No. DEPLW-112, Final Lakes TDML Report. Maine Department of Environmental Protection, Lakes Assessment Division, Augusta, Maine.

Makepeace, D., Smith, D. and Stanley, S. 1995. Urban Stormwater Quality: Summary of Contaminant Data. Critical Reviews in Environmental Science and Technology, 25(2): 93-139.

Marsalek, J. and Rochfort, Q. 2004. Urban Wet-Weather Flows: Sources of fecal contamination impacting on recreational waters and threatening drinking-water sources. Journal of Toxicology and Environmental Health, Part A: Current Issues, 67 (20-22): 1765-1777.

McCuen, R.H. 1998. Hydrologic Analysis and Design. Prentice-Hall, Inc.

McDonald, M., Truelstrip-Hansen, L., and Jamieson, R. 2016. Assessing Sources of Fecal Contamination and Pathogen Presence at Four Freshwater Beaches in the Halifax Regional Municipality. Prepared for Halifax Regional Municipality. Centre for Water Resources Studies, Dalhousie. March 2016.

Penakalapati, G., Swarthout, J., Delahoy, M.J., McAliley, L., Wodnik, B., Levy, K., and M.C. Freeman. 2017. Exposure to Animal Feces and Human Health: A Systematic Review and Proposed Research Priorities. Environmental Science & Technology. 51 (20): 11537-11552.

Pitt, R., and J. McLean. 1986. Toronto Area Watershed Management Strategy Study. Humber River Pilot Watershed Project. Ontario Ministry of the Environment. Toronto, Ontario.

Porter Dillon Limited. 1996. Birch Cove Lakes Area Environmental Study. June 1996

Prairie Climate Centre. 2019. Climate Atlas of Canada, version 2. July 10, 2019. https://climateatlas.ca

Reckhow, K.H., M.W. Beaulac and J.T. Simpson. 1980. Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients. U.S. Environmental. Protection Agency, EPA 440/5-80-011.

Strum Consulting. 2019. Water Quality Summary Susie’s Lake Watercourse Monitoring

Stantec. 2024a. Land Suitability Analysis – Highway 102 Study Area. Prepared for Halifax Regional Municipality. April 2024.

Stantec. 2024b. Halifax Regional Municipality Future Serviced Communities – Highway 102 Stormwater Management Plan. Prepared for Halifax Regional Municipality. 2024.

Stantec. 2023. Development Scenarios – Highway 102 Study Area. Prepared for Halifax Regional Municipality. December 2023.

Qiu, J., Shen, Z., Leng, G., Wei, G. 2021. Synergistic Effect of Drought and Rainfall Events on Different Patterns on Watershed Systems. Sci Rep 11, 18957 (2021). https://doi.org/10.1038/s41598-021-97574-z

Thériault and Duchesne. 2012. Quantifying the Fecal Coliform Loads in Urban Watersheds by Hydrologic/Hydraulic Modeling: Case Study of the Beauport River Watershed in Quebec. Water 2015, 7, 615-633. Available online at: https://www.researchgate.net/publication/272365254_Quantifying_the_Fecal_Coliform_Loads_in_Urban_Watersheds_by_HydrologicHydraulic_Modeling_Case_Study_of_the_Beauport_River_Watershed_in_Quebec

USDA. 1986. Urban Hydrology for Small Watersheds. Technical Release 55.

USEPA. 2001. An ArcView GIS Tool to Calculate Nonpoint Sources of Pollution in Watershed and Stormwater Projects. PLOAD V3. January 2001. Available online at http://water.epa.gov/scitech/datait/models/basins/upload/2002_05_10_BASINS_b3docs_PLOAD_v3.pdf

USEPA. 2005. Microbial Source Tracking Guidance Document. National Risk Management Research Laboratory. EPA/600/R-05/065. June 2005.

Vaccari, D.A., Strom, P.F. and Alleman, J.E. 2006. Environmental Biology for Engineers and Scientists. New Jersey: John Wiley & Sons.

Waller, D.H and W.C. Hart. 1986. Solids, nutrients and chlorides in urban runoff, p. 59-85. In, H.C. Torno, J. Marsalek and M. Desbordes [eds.], Urban runoff pollution. Springer-Verlag. Berlin.

APPENDICES

Appendix A - Water Quality Results

Organization		PorterDillon	Porter Dillon	PorterDillon	Porter Dillon	PorterDillon	PorterDillon	PorterDillon	PorterDillon	AECOM
Sampling Date		4/25/1994	4/25/1994	8/31/1994	8/31/1994	10/10/1994	10/10/1994	2/27/1995	2/27/1995	4/10/2010
COC Number		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
	UNITS	**QuarryLake1**	**QuarryLake2**	**QuarryLake1**	**QuarryLake2**	**QuarryLake1**	**QuarryLake2**	**QuarryLake1**	**QuarryLake2**	**QuarryLake**
Microbiological										
Escherichia coli	CFU/100mL									
Total Coliforms	CFU/100mL									
Inorganics										
Dissolved Chloride (Cl-)	mg/L	20.3	23.9	17.5	17.4	19.8	20.41	13.2	15.3	45.5
Colour	TCU	20	18	5	5	<3	<3	24	22	
Total Suspended Solids	mg/L									1.2
Turbidity	NTU									
Total Phosphorous	mg/L	0.0039	0.0039			0.0014	0.0017			0.007

Organization		PorterDillon	Porter Dillon	Porter Dillon	Porter Dillon	PorterDillon	PorterDillon	PorterDillon	PorterDillon	DFO	DFO	DFO
Sampling Date		4/25/1994	4/25/1994	8/31/1994	8/31/1994	10/10/1994	10/10/1994	10/10/1994	10/10/1994	4/14/1980	4/16/1991	4/16/1991
COC Number		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
	UNITS	**SusiesLake1**	**SusiesLake2**	**SusiesLake1**	**SusiesLake2**	**SusiesLake1**	**SusiesLake2**	**SusiesLake1**	**SusiesLake2**	**SusiesLake**	**SusiesLake(19)**	**SusiesLake(20)**
Microbiological												
Escherichia coli	CFU/100mL											
Total Coliforms	CFU/100mL											
Inorganics												
Dissolved Chloride (Cl-)	mg/L	28.9	37.1	16.9	17.8	19.7	20.6	16.4	25.9	7.9	9.9	11
Colour	TCU	27	22	12	11	4	3	30	29		25	30
Total Suspended Solids	mg/L											
Turbidity	NTU											
Total Phosphorous	mg/L	0.0047	0.0049			0.0025	0.0032			0.001	0.012	0.014

Organization		DFO	DFO	DFO	DFO	DFO	HRM	HRM	HRM	HRM
Sampling Date		4/29/2000	4/29/2000	4/29/2000	4/7/2011	3/31/2021	5/3/2023	8/24/2022	8/15/2023	5/5/2022
COC Number							LakeWatchers	LakeWatchers	LakeWatchers	LakeWatchers
	UNITS	**SusiesLake(19)**	**SusiesLake(19)**	**SusiesLake(20)**	**SusiesLake(19, 20)**	**SusiesLake(20)**	**SusiesLake**	**SusiesLake**	**SusiesLake**	**SusiesLake**
Microbiological										
Escherichia coli	CFU/100mL						2	ND	6	ND
Total Coliforms	CFU/100mL									
Inorganics										
Dissolved Chloride (Cl-)	mg/L	32	31.7	33.3	70	36	58	74	51	67
Colour	TCU	19	21	13	32.6	43.55				
Total Suspended Solids	mg/L									
Turbidity	NTU									
Total Phosphorous	mg/L	0.013	0.005	0.006	0.005	0.0062	0.003	0.004	0.002	0.002

Bureau Veritas ID		VPZ573	VWW739	WDQ263	WKG125	WRU174	XAT195	XKJ086	XPT452
Sampling Date		2023/04/24 12:10	2023/05/24 10:15	2023/06/20 10:25	2023/07/17 14:00	2023/08/15 12:30	2023/09/20 12:55	2023/10/26 10:10	2023/11/16 12:10
COC Number		N/A	N/A		943097-01-01	948312-01-01	954355-01-01	N/A	C#963440-01-01
	UNITS	**WASHMILL**	**WASHMILL**	**WASHMILL**	**Washmill**	**Washmill**	**Washmill**	**WASHMILL**	**WASHMILL**
Microbiological									
Escherichia coli	CFU/100mL	<10	10	60	20	<10	400	<100	<100
Total Coliforms	CFU/100mL	440	120	600	100	30	900	200	200
Inorganics									
Dissolved Chloride (Cl-)	mg/L	59	63	53	43	25	23	27	27
Colour	TCU	40	28	36	51	79	68	66	58
Total Suspended Solids	mg/L	6.6	100	1.2	23	<1.0	2.8	4	18 (1)
Turbidity	NTU	12	13	0.84	2.5	0.64	2	2.1	3.1
Total Phosphorous	mg/L	0.03	0.098	<0.004	0.019	0.004	0.006	<0.020	<0.020

Organization		Porter Dillon	PorterDillon	PorterDillon	PorterDillon	AECOM	Stantec	Stantec	Stantec	Stantec	Stantec
Sampling Date		4/25/1994	8/31/1994	10/10/1994	2/27/1995	4/10/2010	4/24/2023	5/24/2023	6/20/2023	7/17/2023	8/15/2023
COC Number							N/A	N/A		943097-01-01	948312-01-01
	UNITS	**WashmillLake**	**WashmillLake**	**WashmillLake**	**WashmillLake**	**Washmill**	**SW-19**	**SW-19**	**SW-19**	**SW-19**	**SW-19**
Microbiological											
Escherichia coli	CFU/100mL					54	<10	<10	70	40	20
Total Coliforms	CFU/100mL						270	120	620	700	170
Inorganics											
Dissolved Chloride (Cl-)	mg/L	23.5	18.8	21.7	23.7	58.4	61	64	55	47	30
Colour	TCU	19	8	4	23		37	30	35	37	74
Total Suspended Solids	mg/L					2.8	<1.0	1	1	<1.0	1
Turbidity	NTU						0.72	0.92	0.78	0.61	0.73
Total Phosphorous	mg/L	0.0049		0.0041		0.008	<0.004	<0.020	<0.004	0.01	0.004

Organization		Stantec	Stantec	Stantec
Sampling Date		9/20/2023	10/26/2023	11/16/2023
COC Number		954355-01-01	N/A	C#963440-01-01
	UNITS	**SW-19**	**SW-19(2)**	**SW-19**
Microbiological				
Escherichia coli	CFU/100mL	100	<100	<100
Total Coliforms	CFU/100mL	600	300	300
Inorganics				
Dissolved Chloride (Cl-)	mg/L	26	28	28
Colour	TCU	67	65	59
Total Suspended Solids	mg/L	1.6	<1.0	<2.9 (1)
Turbidity	NTU	1.7	1.1	1
Total Phosphorous	mg/L	0.004	<0.020	<0.020

Bureau Veritas ID		VPZ567	VWW731	WDQ260	WKG122	WRU171	XAT192	XKJ089	XPT443
Sampling Date		2023/04/24 10:50	2023/05/24 10:35	2023/06/20 10:46	2023/07/17 14:10	2023/08/15 12:45	2023/09/20 13:10	2023/10/26 10:30	2023/11/16 12:20
COC Number		N/A	N/A	N/A	943097-01-01	948312-01-01	954355-01-01	N/A	C#963440-01-01
	UNITS	**SW-17**	**SW-17**	**SW-17**	**SW-17**	**SW-17**	**SW-17**	**SW-17**	**SW-17**
Microbiological									
Escherichia coli	CFU/100mL	<10	<10	50	120	40	700	<100	<100
Total Coliforms	CFU/100mL	610	480	390	880	140	1700	<100	800
Inorganics									
Dissolved Chloride (Cl^-)	mg/L	4.3	4.4	2.7	3.4	6.8	2.3	26	4.7
Colour	TCU	22	19	44	44	79	23	60	30
Total Suspended Solids	mg/L	<1.0	19	<1.0	2.2	1.8	2.4	<2.0	2.4 (1)
Turbidity	NTU	0.31	0.42	0.35	<0.10	1.7	0.47	1.2	1.3
Total Phosphorous	mg/L	0.011	<0.020	0.005	0.01	0.007	<0.004	<0.020	<0.020

Bureau Veritas ID		VPZ568	VWW732	WDQ261	WKG123	WRU172	XAT193	XKJ088	XPT449
Sampling Date		2023/04/24 11:10	2023/05/24 10:50	2023/06/20 09:20	2023/07/17 14:20	2023/08/15 12:55	2023/09/20 13:00	2023/10/26 10:20	2023/11/16 12:30
COC Number		N/A	N/A		943097-01-01	948312-01-01	954355-01-01	N/A	C#963440-01-01
	UNITS	**SW-18**	**SW-18**	**SW-18**	**SW-18**	**SW-18**	**SW-18**	**SW-18**	**SW-18**
Microbiological									
Escherichia coli	CFU/100mL	<10	<10	40	160	80	900	<100	<100
Total Coliforms	CFU/100mL	340	90	480	280	270	1300	200	400
Inorganics									
Dissolved Chloride (Cl-)	mg/L	60	60	52	45	29	25	26	28
Colour	TCU	36	29	34	41	74	70	65	57
Total Suspended Solids	mg/L	<1.0	1.2	1	1	2.8	1.6	1.2	<2.9 (1)
Turbidity	NTU	0.72	0.45	0.94	0.71	1	1.8	1.4	0.91
Total Phosphorous	mg/L	<0.004	<0.020	<0.004	<0.004	0.004	0.005	<0.020	<0.020

Bureau Veritas ID		VPZ570	VWW734	WDQ264	WKG126	WRU175	XAT196	XKJ090	XPT453
Sampling Date		2023/04/24 09:25	2023/05/24 11:30	2023/06/20 11:36	2023/07/17 12:15	2023/08/15 13:30	2023/09/20 14:05	2023/10/26 11:25	2023/11/16 13:15
COC Number		N/A	N/A		943097-01-01	948312-01-01	954355-01-01	N/A	C#963440-01-01
	UNITS	**SW-20**	**SW-20**	**SW-20**	**SW-20**	**SW-20**	**SW-20**	**SW-20**	**SW-20**
Microbiological									
Escherichia coli	CFU/100mL	<10	<10	10	150	<10	<100	<100	<100
Total Coliforms	CFU/100mL	20	240	280	210	60	200	<100	<100
Inorganics									
Dissolved Chloride (Cl-)	mg/L	48	54	51	45	26	24	26	25
Colour	TCU	45	36	35	39	78	77	73	67
Total Suspended Solids	mg/L	<1.0	<1.0	<1.0	1.2	<1.0	2.4	<2.0	<2.6 (1)
Turbidity	NTU	0.61	0.9	0.5	0.44	0.64	2.4	0.82	0.54
Total Phosphorous	mg/L	<0.004	<0.020	<0.004	0.005	0.004	<0.004	<0.020	<0.020

Bureau Veritas ID		VPZ571	VWW735	WDQ265	WKG127	WRU176	XAT197	XKJ091	XPT455
Sampling Date		2023/04/24 12:40	2023/05/24 11:25	2023/06/20 13:30	2023/07/17 12:00	2023/08/15 13:25	2023/09/20 15:15	2023/10/26 11:15	2023/11/16 13:00
COC Number		N/A	N/A		943097-01-01	948312-01-01	954355-01-01	N/A	C#963440-01-01
	UNITS	**SW-21**	**SW-21**	**SW-21**	**SW-21**	**SW-21**	**SW-21**	**SW-21**	**SW-21**
Microbiological									
Escherichia coli	CFU/100mL	<10	20	90	70	90	300	100	<100
Total Coliforms	CFU/100mL	410	450	1300	540	310	900	1300	600
Inorganics									
Dissolved Chloride (Cl-)	mg/L	340	260	170	120	75	49	68	86
Colour	TCU	13	15	22	31	45	45	30	19
Total Suspended Solids	mg/L	<1.0	1	<1.0	1.2	1.2	1.2	1	<2.7 (1)
Turbidity	NTU	0.38	0.27	1.2	0.48	1.1	1.7	1.1	0.33
Total Phosphorous	mg/L	<0.004	<0.020	<0.004	0.013	<0.004	0.007	<0.020	<0.020

Bureau Veritas ID		VWW736	WDQ266	WKG128	WRU177	XAT198	XKJ092	XPT456
Sampling Date		2023/05/24 12:20	2023/06/20 12:30	2023/07/17 12:50	2023/08/15 14:00	2023/09/20 14:45	2023/10/26 12:30	2023/11/16 13:30
COC Number		N/A		943097-01-01	948312-01-01	954355-01-01	N/A	C#963440-01-01
	UNITS	**SW-22**	**SW-22**	**SW-22**	**SW-22**	**SW-22**	**SW-22**	**SW-22**
Microbiological								
Escherichia coli	CFU/100mL	70	140	280	10	400	<100	<100
Total Coliforms	CFU/100mL	990	1200	750	150	1200	300	500
Inorganics								
Dissolved Chloride (Cl^-)	mg/L	290	190	160	87	66	94	120
Colour	TCU	5.1	15	21	54	44	41	26
Total Suspended Solids	mg/L	<1.0	<1.0	1.4	1.4	1.8	<2.0	3
Turbidity	NTU	<0.10	0.35	0.46	0.85	1.7	2.1	1.6
Total Phosphorous	mg/L	<0.020	<0.004	0.006	0.007	0.006	<0.020	<0.020

Bureau Veritas ID		VWW737	WDQ267	WKG129	WRU178	XAT199	XKJ093	XPT457
Sampling Date		2023/05/24 12:40	2023/06/20 12:15	2023/07/17 13:00	2023/08/15 14:15	2023/09/20 15:00	2023/10/26 12:20	2023/11/16 13:40
COC Number		N/A		943097-01-01	948312-01-01	954355-01-01	N/A	C#963440-01-01
	UNITS	**SW-23**	**SW-23**	**SW-23**	**SW-23**	**SW-23**	**SW-23**	**SW-23**
Microbiological								
Escherichia coli	CFU/100mL	110	70	120	80	<100	100	<100
Total Coliforms	CFU/100mL	990	1200	880	850	2100	2000	1200
Inorganics								
Dissolved Chloride (Cl^-)	mg/L	580	500	420	260	180	260	300
Colour	TCU	9.5	17	32	57	73	34	15
Total Suspended Solids	mg/L	1.0	<1.0	9.8	<1.0	2.4	<2.0	<1.0
Turbidity	NTU	<0.10	0.71	0.36	2.7	4.1	1.9	0.45
Total Phosphorous	mg/L	<0.020	<0.004	0.01	0.007	0.011	<0.020	<0.020

Bureau Veritas ID		VPZ572	VWW738	WDQ268	WKG130	WRU179	XAT200	XII940	XPT458
Sampling Date		2023/04/24 13:10	2023/05/24 13:20	2023/06/20 12:23	2023/07/17 13:00	2023/08/15 14:45	2023/09/20 15:30	2023/10/19 11:15	2023/11/16 14:10
COC Number		N/A	N/A		943097-01-01	948312-01-01	954355-01-01	N/A	C#963440-01-01
	UNITS	**SW-25**	**SW-25**	**SW-25**	**SW-25**	**SW-25**	**SW-25**	**SW-25**	**SW-25**
Microbiological									
Escherichia coli	CFU/100mL	<1.0	<10	<10	20	40	200	<100	<100
Total Coliforms	CFU/100mL	56	280	620	590	270	1700	1300	900
Inorganics									
Dissolved Chloride (Cl-)	mg/L	380	320	290	250	130	89	150	140
Colour	TCU	<5.0	<5.0	<5.0	<5.0	38	47	12	<5.0
Total Suspended Solids	mg/L	3.8	2.8	1.6	<1.0	<1.0	1.8	<2.0	<1.0
Turbidity	NTU	1.8	1.3	0.78	4.2	3.2	4.6	2.7	1.6
Total Phosphorous	mg/L	0.16	0.17	0.065	0.082	0.034	0.023	0.073	0.13

Appendix B - Brylinsky Phosphorous Loading Model Results

Washmill Lake - Existing Conditions						
Input Parameters	**Symbol**	**Value**	**Units**	**Budgets**		
Morphology				**Hydraulic Budget (m^3)**		
Drainage Basin Area (Excl of Lake Area)	Ad	3296.3	ha			
Area Land Use Category 1- Commercial	Ad1	150.7	ha			**% Total**
Area Land Use Category 2- Forest	Ad2	1772.9	ha	Upstream Flow	0	
Area Land Use Category 3- Gravel Pit	Ad3	67.2	ha	Precipitation	105053.91	0.47
Area Land Use Category 4- Low Density Residential	Ad4	121.3	ha	Surface Runoff	22364037	99.53
Area Land Use Category 5- Medium Density Residential	Ad5	385.9	ha	Evaporation	-38793.19	0.17
Area Land Use Category 6 - High Density Residential	Ad6	251.5	ha	Total Outflow	22430298	99.83
Area Land Use Category 7- Rock/Dune/Barren	Ad7	235.6	ha	Check		100
Area Land Use Category 8- Undeveloped/Cleared	Ad8	141.3	ha	**Phosphorus Budget (gm)**		
Area Land Use Category 9- Wetlands	Ad9	104.6	ha			
Area Land Use Category 10- Roads	Ad10	65.3	ha			**% Total**
Lake Surface Area	Ao	7.525	ha	Upstream Flow	0	0
Lake Volume	V	1.93	10^6 m3	Atmospheric	1279.3098	0.37
Hydrology Inputs				Land Run off	347452	99.63
Upstream Hydraulic Inputs	Qi	0	m^3/yr	Development	0	0
Annual Unit Precipitation	Pr	1.396	m/yr	Sedimentation	-13949	4
Annual Unit Lake Evaporation	Ev	0.516	m^3/yr	Total Outflow	334782	96.000069
Point Source Hydraulic Input	Qps	0	m^3/yr	Check		100.0
Annual Unit Hydraulic Run Off - Developed	Ruv	1.15	m/yr	**Model Validation**		
Annual Unit Hydraulic Run Off - Non- Developed	Ru	1.03	m/yr			
Phosphorus Inputs				Predicted P (mg/L)	0.0149	
Upstream P input	Ju	0	gm P / yr	Measured P (mg/L)	0.01	
Annual Unit Atmospheric Phosphorus Deposition	Da	0.017	gm P / M^2 * yr	%Difference	39.357	
Land Use Category 1 P Export Coefficient	E1	0.0202	gm P / M^2 * yr			
Land Use Category 2 P Export Coefficient	E2	0.0024	gm P / M^2 * yr			
Land Use Category 3 P Export Coefficient	E3	0.015	gm P / M^2 * yr			
Land Use Catefory 4 P Export Coefficient	E4	0.025	gm P / M^2 * yr			
Land Use Category 5 P Export Coefficient	E5	0.01	gm P / M^2 * yr			
Land Use Category 6 P Export Coefficient	E6	0.03	gm P / M^2 * yr			
Land Use Category 7 P Export Coefficient	E7	0.035	gm P / M^2 * yr			
Land Use Category 8 P Export Coefficient	E8	0.0024	gm P / M^2 * yr			
Land Use Category 9 P Export Coefficient	E9	0.0108	gm P / M^2 * yr			
Land Use Category 10 P Export Coefficient	E10	0.035	gm P / M^2 * yr			
Number of Dwellings	Nd	0	#			
Average number of persons per dwelling	Nu	2.2	#			
Average fraction of Year Dwellings occupied	Npc	1	/yr			
Phosphorus load per capita per year	Si	800	gm / capita/yr			
Septic system retention coefficient	Rsp	0.5	n/a			
Point Source Input 1	PS1	0	gm/yr			
Point Source Input 2	PS2	0	gm/yr			
Point Source Input 3	PS3	0	gm/yr			
Point Source Inpit 4	PS4	0	gm/yr			
Lake Phosphorus Retention Coefficient	v	12.4	n/a			
Model Outputs						
Total Precipitation Hydraulic Input	Ppti	105053.914	m3/yr			
Total Evaporation Hydraulic Loss	Eo	38793.18958	m3/yr			
Total Hydraulic Surface Runoff	Ql	22364037.14	m3/yr			
Total Hydraulic Input	Qt	22469091	m3/yr			
Areal Hydraulic Input	qs	298.06	m3/yr			
Total Hydraulic Outflow	Qo	22430298	m3/yr			
Total Atmospheric P Input	Jd	1279.309841	gm/yr			
Total Surface Run Off P Input	Je	347452	gm/yr			
Total Development P Input	Jr	0	gm/yr			
Total P Input	Jt	348731	gm/yr			
Lake P Retention Factor	Rp	0.04	-			
Lake P Retention	Ps	13949	gm/yr			
Predicted Lake P Concentration	[P]	**0.0149**	mg/L			
Lake P Outflow	Jo	334782	gm/yr			
Lake Mean Depth	z	25.6	m			
Lake Flushing Rate	FR	0.09	times/year			
Lake Turnover Time	TT	11.62	yr			
Lake Response Time	RT(1/2)	0.06	yr			

Washmill Lake - Low Density Conditions

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (Excl of Lake Area)	Ad	3296.3	ha
Area Land Use Category 1- Commercial	Ad1	151.08	ha
Area Land Use Category 2- Forest	Ad2	1588.32	ha
Area Land Use Category 3- Gravel Pit	Ad3	67.20	ha
Area Land Use Category 4- Low Density Residential	Ad4	274.67	ha
Area Land Use Category 5- Medium Density Residential	Ad5	385.90	ha
Area Land Use Category 6 - High Density Residential	Ad6	251.54	ha
Area Land Use Category 7- Rock/Dune/Barren	Ad7	235.61	ha
Area Land Use Category 8- Undeveloped/Cleared	Ad8	141.28	ha
Area Land Use Category 9- Wetlands	Ad9	104.65	ha
Area Land Use Category 10- Roads	Ad10	96.06	ha
Lake Surface Area	Ao	7.525	ha
Lake Volume	V	1.93	10^6 m3
Hydrology Inputs			
Upstream Hydraulic Inputs	Qi	0	m^3/yr
Annual Unit Precipitation	Pr	1.396	m/yr
Annual Unit Lake Evaporation	Ev	0.511	m^3/yr
Point Source Hydraulic Input	Qps	0	m^3/yr
Annual Unit Hydraulic Run Off - Developed	Ruv	1.1	m/yr
Annual Unit Hydraulic Run Off - Non- Developed	Ru	1.02	m/yr
Phosphorus Inputs			
Upstream P input	Ju	0	gm P / yr
Annual Unit Atmospheric Phosphorus Deposition	Da	0.017	gm P / M^2 * yr
Land Use Category 1 P Export Coefficient	E1	0.0202	gm P / M^2 * yr
Land Use Category 2 P Export Coefficient	E2	0.0024	gm P / M^2 * yr
Land Use Category 3 P Export Coefficient	E3	0.015	gm P / M^2 * yr
Land Use Catefory 4 P Export Coefficient	E4	0.025	gm P / M^2 * yr
Land Use Category 5 P Export Coefficient	E5	0.01	gm P / M^2 * yr
Land Use Category 6 P Export Coefficient	E6	0.03	gm P / M^2 * yr
Land Use Category 7 P Export Coefficient	E7	0.035	gm P / M^2 * yr
Land Use Category 8 P Export Coefficient	E8	0.0024	gm P / M^2 * yr
Land Use Category 9 P Export Coefficient	E9	0.0108	gm P / M^2 * yr
Land Use Category 10 P Export Coefficient	E10	0.035	gm P / M^2 * yr
Number of Dwellings	Nd	10	#
Average number of persons per dwelling	Nu	2.2	#
Average fraction of Year Dwellings occupied	Npc	1	/yr
Phosphorus load per capita per year	Si	800	gm / capita/yr
Septic system retention coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	gm/yr
Point Source Input 2	PS2	0	gm/yr
Point Source Input 3	PS3	0	gm/yr
Point Source Inpit 4	PS4	0	gm/yr
Lake Phosphorus Retention Coefficient	v	12.4	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppti	105053.914	m3/yr
Total Evaporation Hydraulic Loss	Eo	38416.92198	m3/yr
Total Hydraulic Surface Runoff	Ql	19361776.4	m3/yr
Total Hydraulic Input	Qt	19466830	m3/yr
Areal Hydraulic Input	qs	258.17	m3/yr
Total Hydraulic Outflow	Qo	19428413	m3/yr
Total Atmospheric P Input	Jd	1279.309841	gm/yr
Total Surface Run Off P Input	Je	392213	gm/yr
Total Development P Input	Jr	8800	gm/yr
Total P Input	Jt	402292	gm/yr
Lake P Retention Factor	Rp	0.05	-
Lake P Retention	Ps	20115	gm/yr
Predicted Lake P Concentration	[P]	**0.0197**	mg/L
Lake P Outflow	Jo	382177	gm/yr
Lake Mean Depth	z	25.6	m
Lake Flushing Rate	FR	0.1	times/year
Lake Turnover Time	TT	10.07	yr
Lake Response Time	RT(1/2)	0.07	yr

Budgets		
Hydraulic Budget (m^3)		
		% Total
Upstream Flow	0	
Precipitation	105053.91	0.54
Surface Runoff	19361776	99.46
Evaporation	-38416.922	0.2
Total Outflow	19428413	99.8
Check		100
Phosphorus Budget (gm)		
		% Total
Upstream Flow	0	0
Atmospheric	1279.3098	0.32
Land Run off	392213	97.49
Development	8800	2.19
Sedimentation	-20115	5
Total Outflow	382177	95.0
Check		100
Model Validation		
Predicted P (mg/L)	0.0197	
Measured P (mg/L)	n/a	
%Difference	n/a	

Washmill Lake - Medium Density Conditions

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (Excl of Lake Area)	Ad	3296.3	ha
Area Land Use Category 1- Commercial	Ad1	152.26	ha
Area Land Use Category 2- Forest	Ad2	1588.94	ha
Area Land Use Category 3- Gravel Pit	Ad3	67.20	ha
Area Land Use Category 4- Low Density Residential	Ad4	124.14	ha
Area Land Use Category 5- Medium Density Residential	Ad5	406.60	ha
Area Land Use Category 6 - High Density Residential	Ad6	379.56	ha
Area Land Use Category 7- Rock/Dune/Barren	Ad7	235.61	ha
Area Land Use Category 8- Undeveloped/Cleared	Ad8	141.28	ha
Area Land Use Category 9- Wetlands	Ad9	104.65	ha
Area Land Use Category 10- Roads	Ad10	96.06	ha
Lake Surface Area	Ao	7.525	ha
Lake Volume	V	1.93E+00	10^6 m3
Hydrology Inputs			
Upstream Hydraulic Inputs	Qi	0	m^3/yr
Annual Unit Precipitation	Pr	1.396	m/yr
Annual Unit Lake Evaporation	Ev	0.511	m^3/yr
Point Source Hydraulic Input	Qps	0	m^3/yr
Annual Unit Hydraulic Run Off - Developed	Ruv	1.1	m/yr
Annual Unit Hydraulic Run Off - Non- Developed	Ru	1.02	m/yr
Phosphorus Inputs			
Upstream P input	Ju	0	gm P / yr
Annual Unit Atmospheric Phosphorus Deposition	Da	0.017	gm P / M^2 * yr
Land Use Category 1 P Export Coefficient	E1	0.0202	gm P / M^2 * yr
Land Use Category 2 P Export Coefficient	E2	0.0024	gm P / M^2 * yr
Land Use Category 3 P Export Coefficient	E3	0.015	gm P / M^2 * yr
Land Use Catefory 4 P Export Coefficient	E4	0.025	gm P / M^2 * yr
Land Use Category 5 P Export Coefficient	E5	0.01	
Land Use Category 6 P Export Coefficient	E6	0.03	
Land Use Category 7 P Export Coefficient	E7	0.035	
Land Use Category 8 P Export Coefficient	E8	0.0024	
Land Use Category 9 P Export Coefficient	E9	0.0108	
Land Use Category 10 P Export Coefficient	E10	0.035	
Number of Dwellings	Nd	12	#
Average number of persons per dwelling	Nu	2.2	#
Average fraction of Year Dwellings occupied	Npc	1	/yr
Phosphorus load per capita per year	Si	800	gm / capita/yr
Septic system retention coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	gm/yr
Point Source Input 2	PS2	0	gm/yr
Point Source Input 3	PS3	0	gm/yr
Point Source Inpit 4	PS4	0	gm/yr
Lake Phosphorus Retention Coefficient	v	12.4	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppti	105049	m3/yr
Total Evaporation Hydraulic Loss	Eo	38415.125	m3/yr
Total Hydraulic Surface Runoff	QI	19368626.13	m3/yr
Total Hydraulic Input	Qt	19473675	m3/yr
Areal Hydraulic Input	qs	258.28	m3/yr
Total Hydraulic Outflow	Qo	19435260	m3/yr
Total Atmospheric P Input	Jd	1279.25	gm/yr
Total Surface Run Off P Input	Je	395311	gm/yr
Total Development P Input	Jr	10560	gm/yr
Total P Input	Jt	407150	gm/yr
Lake P Retention Factor	Rp	0.05	-
Lake P Retention	Ps	20358	gm/yr
Predicted Lake P Concentration	[P]	**0.0199**	mg/L
Lake P Outflow	Jo	386792	gm/yr
Lake Mean Depth	z	25.6	m
Lake Flushing Rate	FR	0.1	times/year
Lake Turnover Time	TT	10.07	yr
Lake Response Time	RT(1/2)	0.07	yr

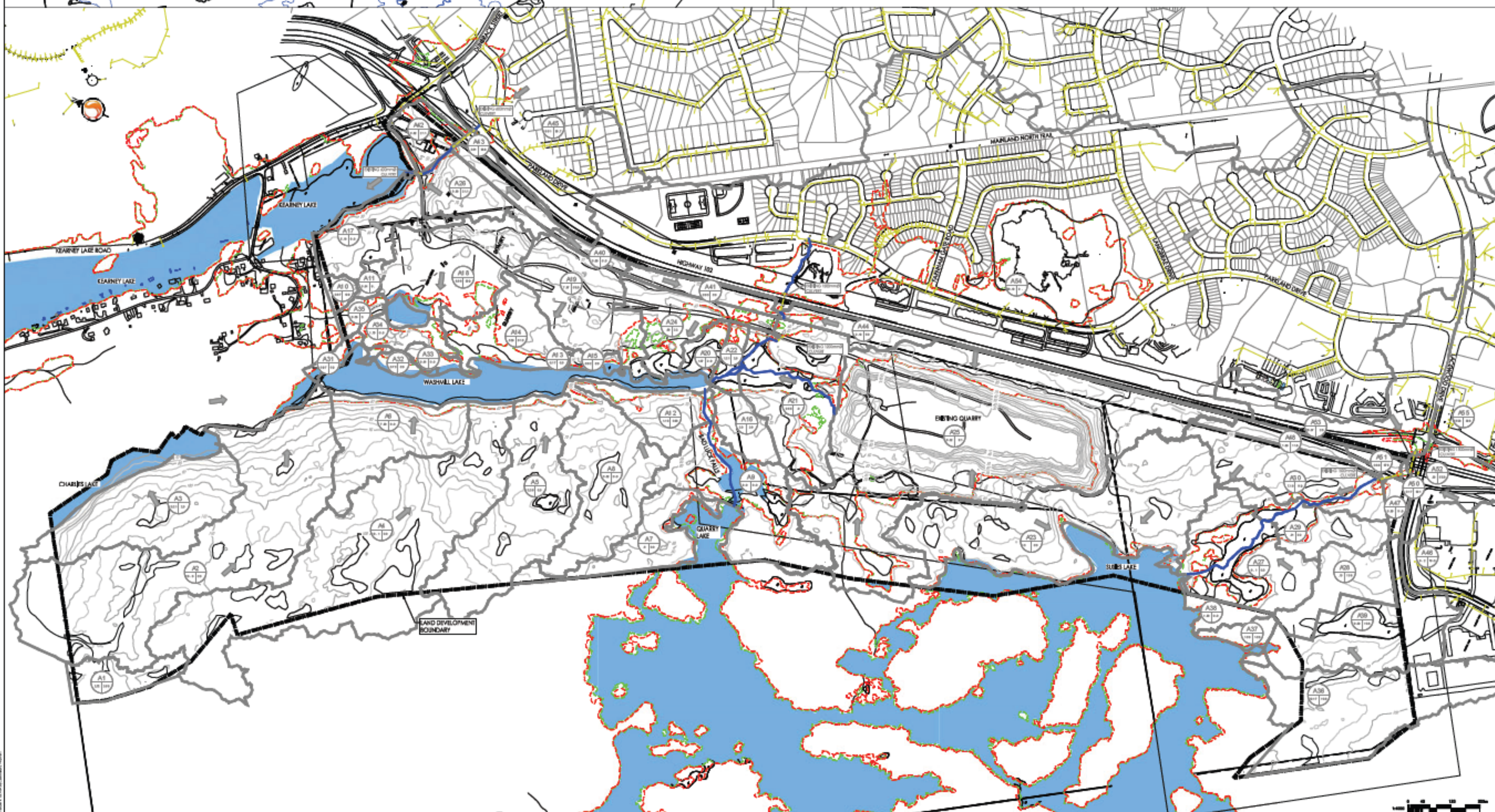
Budgets		
Hydraulic Budget (m^3)		
		% Total
Upstream Flow	0	
Precipitation	105049	0.54
Surface Runoff	19368626	99.46
Evaporation	-38415.125	0.2
Total Outflow	19435260	99.8
Check		100
Phosphorus Budget (gm)		
		% Total
Upstream Flow	0	0
Atmospheric	1279.25	0.31
Land Run off	395311	97.09
Development	10560	2.59
Sedimentation	-20358	5
Total Outflow	386792	94.999877
Check		99.99
Model Validation		
Predicted P (mg/L)	0.0199	
Measured P (mg/L)	n/a	
%Difference		

Washmill Lake - Developer / High Density Conditions			
Input Parameters	**Symbol**	**Value**	**Units**
Morphology			
Drainage Basin Area (Excl of Lake Area)	Ad	3296.3	ha
Area Land Use Category 1- Commercial	Ad1	152.89	ha
Area Land Use Category 2- Forest	Ad2	1588.32	ha
Area Land Use Category 3- Gravel Pit	Ad3	67.20	ha
Area Land Use Category 4- Low Density Residential	Ad4	121.31	ha
Area Land Use Category 5- Medium Density Residential	Ad5	409.43	ha
Area Land Use Category 6 - High Density Residential	Ad6	379.56	ha
Area Land Use Category 7- Rock/Dune/Barren	Ad7	235.61	ha
Area Land Use Category 8- Undeveloped/Cleared	Ad8	141.28	ha
Area Land Use Category 9- Wetlands	Ad9	104.65	ha
Area Land Use Category 10- Roads	Ad10	96.06	ha
Lake Surface Area	Ao	7.525	ha
Lake Volume	V	1.93	10^6 m3
Hydrology Inputs			
Upstream Hydraulic Inputs	Qi	0	m^3/yr
Annual Unit Precipitation	Pr	1.396	m/yr
Annual Unit Lake Evaporation	Ev	0.511	m^3/yr
Point Source Hydraulic Input	Qps	0	m^3/yr
Annual Unit Hydraulic Run Off - Developed	Ruv	1.1	m/yr
Annual Unit Hydraulic Run Off - Non- Developed	Ru	1.02	m/yr
Phosphorus Inputs			
Upstream P input	Ju	0	gm P / yr
Annual Unit Atmospheric Phosphorus Deposition	Da	0.017	gm P / M^2 * yr
Land Use Category 1 P Export Coefficient	E1	0.0202	gm P / M^2 * yr
Land Use Category 2 P Export Coefficient	E2	0.0024	gm P / M^2 * yr
Land Use Category 3 P Export Coefficient	E3	0.015	gm P / M^2 * yr
Land Use Catefory 4 P Export Coefficient	E4	0.025	gm P / M^2 * yr
Land Use Category 5 P Export Coefficient	E5	0.01	
Land Use Category 6 P Export Coefficient	E6	0.03	
Land Use Category 7 P Export Coefficient	E7	0.035	
Land Use Category 8 P Export Coefficient	E8	0.0024	
Land Use Category 9 P Export Coefficient	E9	0.0108	
Land Use Category 10 P Export Coefficient	E10	0.035	
Number of Dwellings	Nd	12	#
Average number of persons per dwelling	Nu	2.2	#
Average fraction of Year Dwellings occupied	Npc	1	/yr
Phosphorus load per capita per year	Si	800	gm / capita/yr
Septic system retention coefficient	Rsp	0.5	n/a
Point Source Input 1	PS1	0	gm/yr
Point Source Input 2	PS2	0	gm/yr
Point Source Input 3	PS3	0	gm/yr
Point Source Inpit 4	PS4	0	gm/yr
Lake Phosphorus Retention Coefficient	v	12.4	n/a
Model Outputs			
Total Precipitation Hydraulic Input	Ppti	105049	m3/yr
Total Evaporation Hydraulic Loss	Eo	38415.125	m3/yr
Total Hydraulic Surface Runoff	Ql	19361776.4	m3/yr
Total Hydraulic Input	Qt	19466825	m3/yr
Areal Hydraulic Input	qs	258.18	m3/yr
Total Hydraulic Outflow	Qo	19428410	m3/yr
Total Atmospheric P Input	Jd	1279.25	gm/yr
Total Surface Run Off P Input	Je	394997	gm/yr
Total Development P Input	Jr	10560	gm/yr
Total P Input	Jt	406836	gm/yr
Lake P Retention Factor	Rp	0.05	-
Lake P Retention	Ps	20342	gm/yr
Predicted Lake P Concentration	[P]	**0.0199**	mg/L
Lake P Outflow	Jo	386494	gm/yr
Lake Mean Depth	z	25.6	m
Lake Flushing Rate	FR	0.1	times/year
Lake Turnover Time	TT	10.07	yr
Lake Response Time	RT(1/2)	0.07	yr

Budgets		
Hydraulic Budget (m^3)		
		% Total
Upstream Flow	0	
Precipitation	105049	0.54
Surface Runoff	19361776	99.46
Evaporation	-38415.125	0.2
Total Outflow	19428410	99.8
Check		100
Phosphorus Budget (gm)		
		% Total
Upstream Flow	0	0
Atmospheric	1279.25	0.31
Land Run off	394997	97.09
Development	10560	2.6
Sedimentation	-20342	5
Total Outflow	386494	94.9999508
Check		100
Model Validation		
Predicted P (mg/L)	0.0199	
Measured P (mg/L)	n/a	
%Difference		

Appendix C - Storm Drainage Plans

Subcatchment Name	Area(ha)	Imperv. (%)
A1	2.2	25.0
A10	0.7	13.9
A11	0.1	9.4
A12	3.3	0.0
A13	0.7	0.0
A14	5.9	51.3
A15	0.2	0.0
A16	2.4	2.9
A17	5.8	6.6
A18	8.8	56.0
A19	7.4	58.9
A2	2846	0.0
A20	1.7	2.9
A21	9.5	4.9
A22	1.1	2.9
A23	1914	0.0
A24	4.9	22.4
A25	4042	48.1
A26	3.9	21.1
A27	8.1	0.0
A28	4.3	10.6
A29	4.1	0.2
A3	1071	2.0
A30	7.6	11.6
A31	0.7	0.0
A32	0.3	0.0
A33	0.1	0.0
A34	1.3	0.0
A35	0.6	9.4
A36	1317	10.6
A37	1.0	10.6
A38	1.6	0.0
A39	9.2	10.6
A4	3811	0.0
A40	0.9	5.0
A41	2.0	5.0
A42	3.2	21.1
A43	0.1	96.8
A44	2.6	5.0
A45	1911	38.7
A46	4017	70.9
A47	0.3	11.6
A48	1.9	11.6
A49	0.0	11.6
A5	1279	0.0
A50	0.7	52.1
A51	0.8	57.5
A52	4.3	55.9
A53	1017	42.5
A54	18C12	34.4
A55	5516	32.6
A6	7.0	0.0
A7	4.4	0.0
A8	9.2	0.0
A9	8.4	0.0



Stantec

Stantec Consulting Ltd.
400–1331 Clyde Avenue
Ottawa ON
Tel. 613.722.4420
www.stantec.com

Legend

- APPROXIMATE LOCATION OF EXISTING WATERCOURSES
- WATERCOURSE FLOW POINT, REFER TO REPORT FOR DETAILS
- EXISTING DRAINAGE AREA ID
- EXISTING DRAINAGE AREA ha
- EXISTING DRAINAGE BOUNDARY
- EXISTING [illegible] FLOODLINE PRELIMINARY (HRM, 2020)
- EXISTING [illegible] FLOODLINE PRELIMINARY (HRM 2020)

Notes

1. CONTOUR INTERVAL IS 5.0m.

KEY PLAN

Revision
By Appd. YY.MM.DD
Dwn. Chkd. Dsgn. YY.MM.DD
Permit-Seal

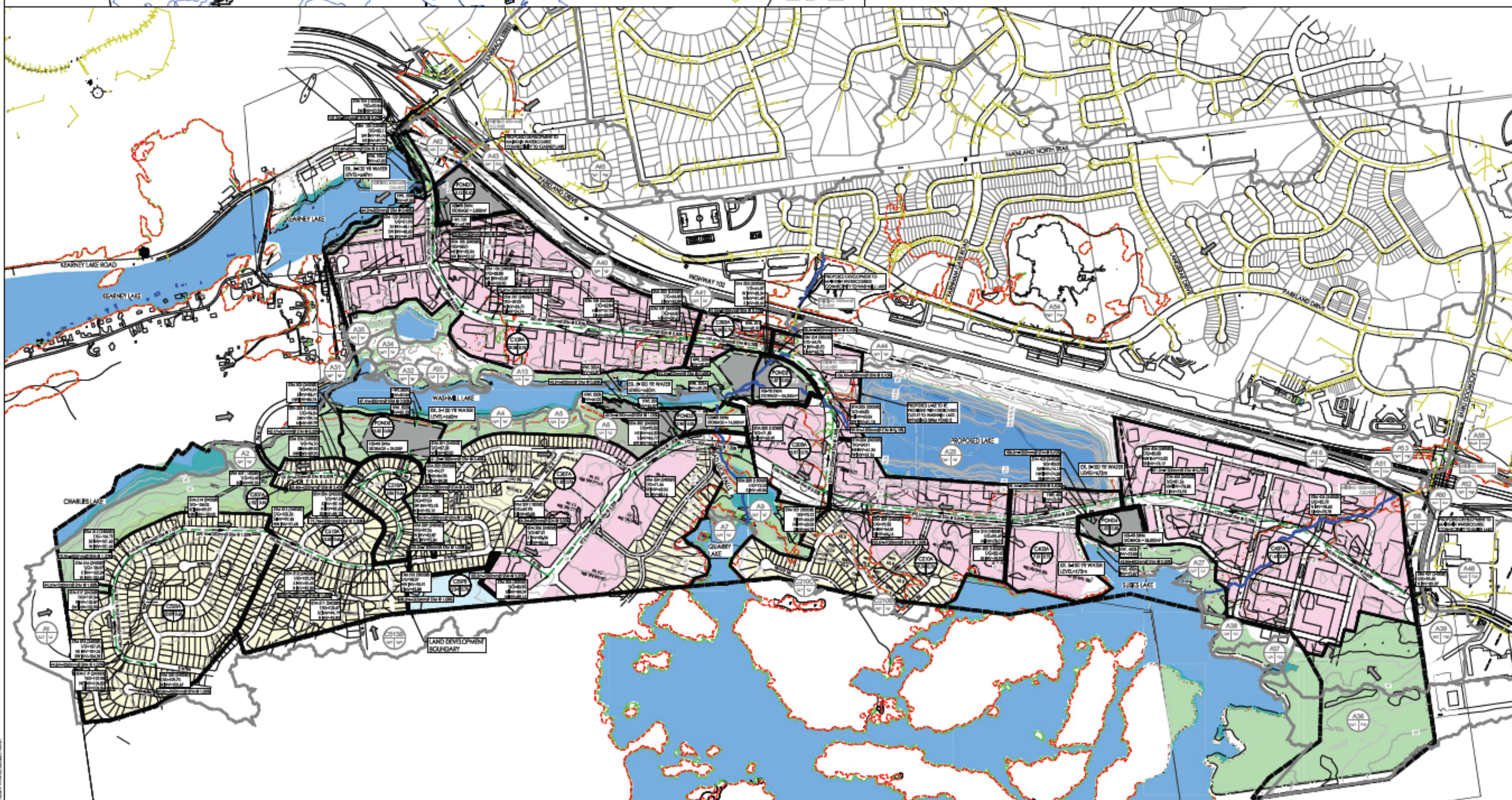
Client/Project
HALIFAX REGIONAL MUNICIPALITY

Future Serviced Communities
Highway 102
Halifax, Nova Scotia

Title
HIGHWAY 102
EXISTING STORM DRAINAGE PLAN

Project No.	Scale	
160410459	AS NOTED	
Drawing No.	Sheet	Revision
EXSD-1	4 of 5	2

Flow Point ID	2-year, 24hr Chicago Peak Flow (m^3/s)			5-year, 24hr Chicago Peak Flow (m^3/s)			10-year, 24hr Chicago Peak Flow (m^3/s)			25-year, 24hr Chicago Peak Flow (m^3/s)			50-year, 24hr Chicago Peak Flow (m^3/s)			100-year, 24hr Chicago Peak Flow (m^3/s)		
	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference
Susies Lake	0.503	0.337	-0.166	0.859	0.597	-0.261	1.169	0.878	-0.291	1.576	1.279	-0.297	1.902	1.613	-0.289	2.234	1.964	-0.270
Washmill Lake	6.726	4.885	-1.841	9.935	8.310	-1.625	12.450	10.948	-1.502	15.722	14.300	-1.421	18.165	16.989	-1.175	20.771	19.694	-1.077



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Legend

Notes

1. CONTOUR INTERVAL IS 5.0m.
2. SIZE AND LOCATION OF PROPOSED SWM PONDS TO BE CONFIRMED BASED ON FLOODPLAIN MAPPING FOR THE EXISTING WATERCOURSES.
3. NO ACTIVE DEVELOPMENT MAY BE PERMITTED WITHIN THE LIMITS OF THE 100-YEAR REGULATORY FLOODPLAIN. SOME REDUCED-RISK USES, SUCH AS RECREATIONAL SPORTS FIELDS AND TRAILS, MAY BE CONSIDERED. THIS IS SUBJECT TO DESIGN CONSIDERATIONS THAT EFFECTIVELY MITIGATE AND/OR MINIMIZE THE IMPACT OF SUCH DEVELOPMENT ON THE FLOODPLAIN AND PROTECT THE RIPARIAN CORRIDOR FUNCTIONS.
4. THE DEVELOPMENT CONCEPT PLAN HAS NOT BEEN APPROVED AND IS SUBJECT TO CHANGE.
5. THE SWM POND LOCATION SHOWN IS CONCEPTUAL AND SUBJECT TO CHANGE BASED ON RECOMMENDATIONS FROM FURTHER STUDIES. ALL SWM PONDS ARE TO BE LOCATED OUTSIDE OF THE REGULATORY FLOODPLAIN.

KEY PLAN

Revision

Permit-Seal

Client/Project
HALIFAX REGIONAL MUNICIPALITY

Future Serviced Communities
Highway 102
Halifax, Nova Scotia

Title
HIGHWAY 102
CONCEPTUAL STORM DRAINAGE PLAN

Project No. 160410459
Drawing No. SD-1
Sheet 3 of 5
Revision 2

Appendix D - Post to Pre-Development Peak Flow Results

8	1	2	3	4	5	6	7	8	9	10	11	12	13
Count	Flow Point ID	2-year, 24hr Chicago Peak Flow (m^3/s)			5-year, 24hr Chicago Peak Flow (m^3/s)			10-year, 24hr Chicago Peak Flow (m^3/s)			25-year, 24hr Chicago Peak Flow (m^3/s)		
		Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference
3	Susies-Lake	0.503	0.337	-0.166	0.859	0.597	-0.261	1.169	0.878	-0.291	1.576	1.279	-0.297
5	Washmill-Lake	6.726	4.885	-1.841	9.935	8.310	-1.625	12.450	10.948	-1.502	15.722	14.300	-1.421

8	1	14	15	16	17	18	19	20	21	22	23	24	25
Count	Flow Point ID	50-year, 24hr Chicago Peak Flow (m^3/s)			100-year, 24hr Chicago Peak Flow (m^3/s)			Peak Flow Percent Increase					
		Existing	Proposed	Difference	Existing	Proposed	Difference	2yr	5yr	10yr	25yr	50yr	100yr
3	Susies-Lake	1.902	1.613	-0.289	2.234	1.964	-0.270	-33.0%	-30.4%	-24.9%	-18.8%	-15.2%	-12.1%
5	Washmill-Lake	18.165	16.989	-1.175	20.771	19.694	-1.077	-27.4%	-16.4%	-12.1%	-9.0%	-6.5%	-5.2%