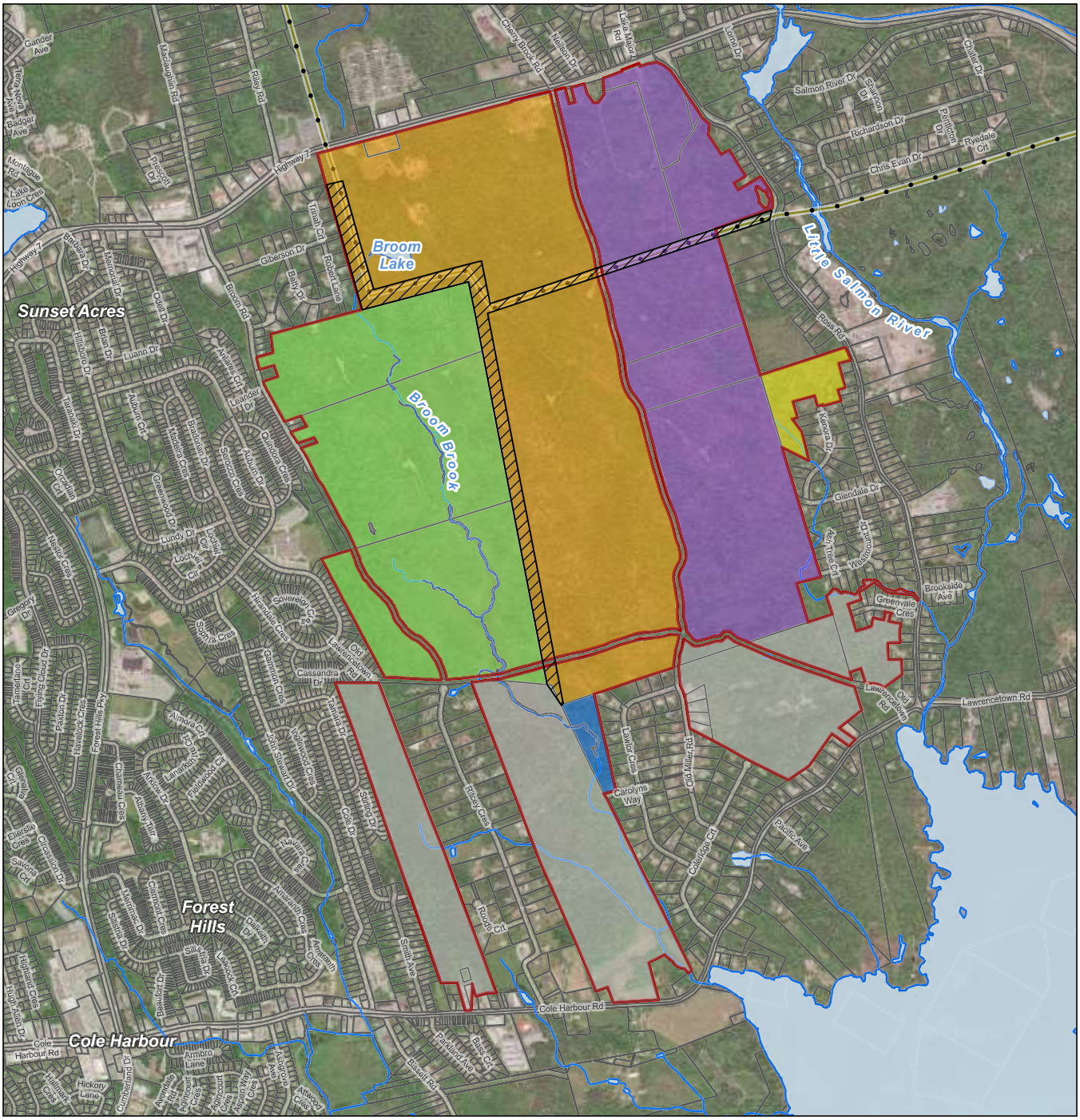
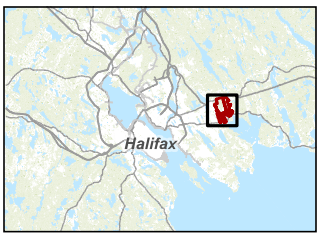




Legend

- Study Area
- Akoma Holdings Incorporated
- Annada Properties Limited
- Kiel Developments Limited
- Halifax Regional Municipality
- Private Land Owner
- Jim Morash Construction Limited
- Nova Scotia Power Easement (Approximate)
- Transmission Line
- Waterway
- Waterbody
- Properties

0 250 500 Metres

(At original document size of 8.5x11)
1:22,000

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Stantec

Project Location
Halifax Regional Municipality,
Nova Scotia

Prepared by JSa on 2023-04-06
TR by JAtkins on 2023-04-06
QR by NW on 2024-11-28

Client/Project
Halifax Regional Municipality
Future Serviced Communities
Background Studies

Fig ID: 160410459_041

Figure No.
3-3

Title
Westphal Land Ownership

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

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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 Westphal Stormwater Management Plan (Stantec 2024b) using PCSWMM (Computational Hydraulics Inc. of Guelph, Ontario, CA) to firstly estimate the runoff from the WSA watershed. The 2-yr 24-hr Chicago design storm was used as it is one of the design storms used for the Westphal Stormwater Management Plan (Stantec 2024b). Land use-based curve numbers (CN) were selected for use with the SCS method of rainfall runoff estimation (**Table 3.5**) (Stantec 2024b). Initial abstraction of 1.88 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 3.5**. The hydrologic model results were then used to validate the runoff volumes from the rain-event based model.

Table 3.5 Land Use Runoff Parameters

Land Use	Curve Number[1]	Runoff Coefficient[1]
Commercial Development	92	0.85
Institutional	89	0.70
Forest	65	0.14
Parks/Undeveloped/Grassed	61	0.20
High-Density Residential	85	0.75
Medium-Density Residential	85	0.75
Low-Density Residential	72	0.65
Rock/Dune/Barren	83	0.18
Road	98	0.90
Water	99	0.99
Wetland	99	0.99
[1] McCuen 1998		

3.4.1 PARAMETER SELECTION FOR PRECIPITATION EVENT BASED PHOSPHORUS MODEL

EMC Total P 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 3.6** below. The on-site wastewater systems for the low-density scenario were assumed to not contribute a measurable P load during storm events and predominantly contribute to annual loads during baseflow/low flow conditions.

Table 3.6 Event Mean Total Phosphorous Concentrations for Select Land Uses

Land Use	Total Phosphorous Event Mean Concentration (mg/L)
Commercial Development / Institutional	0.30[A]
Forest	0.15[B]
Park/Undeveloped/Grassed	0.56[B]
High-Density Residential	0.22[B]
Medium-Density Residential	0.45[B]
Low-Density Residential	0.36[B]
Rock/Dune/Barren	0.12[C]
Road	0.62[B]
Wetland	0.10[A]
[A] CH2M HILL 1993; [B] Pitt and MacLean 1986; [C] USEPA 2001	

3.4.2 PARAMETER SELECTION FOR PRECIPITATION EVENT BASED FECAL COLIFORM LOADING MODEL

EMC FC data were sourced for the land use distribution found within the studied watersheds, as presented in **Table 3.7**. 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. FC 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 completed by Theriault and Duchesne (2012) on FC loading in urban watersheds in Quebec. Commonly referenced literature sources were used for the remaining EMC values. Barnhart et al. (n.d.) found higher bacteria counts in runoff from residential areas and attributed loadings to wildlife rather than domestic animals. Variation in bacterial loadings from specific land uses was 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 significant wildlife use but minimal runoff volume comparison with a grassed site. As noted in the United States Environmental Protection Agency (USEPA) Preliminary Data Summary of Urban Stormwater Best Management Practices (1999), literature values for land use-based FC EMCs vary greatly between studies and show a strong trend of seasonal fluctuation. On-site wastewater systems for the low-density scenario are assumed to not discharge measurable loads of fecal coliform in the watershed as typically systems in NS provide significant removal (Jamieson 2014).

Table 3.7 Event Mean Fecal Coliform Concentrations for Select Land Uses

Land Use	Fecal Coliform Event Mean Concentration (CFU/100 mL)
Commercial Development / Institutional	4,500[A]
Agriculture Field within Low-Density Residential	3,100[A]
Forest	500[B]
Park/Undeveloped/Grassed	10,365[C]
High-Density Residential	7,750[A]
Medium-Density Residential	7,750[A]
Low-Density Residential	7,750[A]
Road	1,400[B]
Wetland / Water	n/a
[A] Theriault and Duchesne 2012; [B] CH2M HILL1993; [C] 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 3.8 provides the input parameters used to calculate the MUSLE precipitation event sediment load for total watershed area that includes the WSA.

Table 3.8 MUSLE Input Parameters

Input	Value	Assumptions	MUSLE Source
Rainfall Factor (Rw)	560.24	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	0.78	General Forest cover is average slope across the watershed and average flow length (4% slope, 250 m length)	Wall et al. 2002 Table LS-1
Roads (Paved and Gravel)	0.60	Roads and Transmission lines use the maximum slope and flow length in watershed, (3% 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

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 (*). The on-site wastewater system loading rate applies to on-site wastewater systems within 300 m of watercourses/waterbodies. It is assumed for this study that the residential development lots will be conservatively less than 300 m from watercourses/waterbodies. Selected parameters are presented in **Table 3.9**.

Table 3.9 Area-based Phosphorous Loading Rates for Select Land Uses

Land Use	Phosphorous Loading Rate ($g/m^2 \cdot yr$)
Commercial Development*	0.0202[A]
Forest*	0.0024[B]
Park/Undeveloped/Grassed*	0.015[B]
High-Density Residential*	0.035[A]
Medium-Density Residential*	0.030[A]
Low-Density Residential*	0.025[A]
Institutional*	0.042[B]
Road	0.35[C]
Agriculture	0.0108[C]
Wetland*	0.0024[B]
Barren	0.0166[B]
On-site Wastewater Systems	160[D]

[A] Waller and Hart 1986; [B] Reckhow *et al.* 1980; [C] MDEP 2000; [D] P production of 800 g/capita/year (Dillon et al. 1986) with a soil retention coefficient of 0.8 (Sinclair et al. 2014) to calculate a rate of 160 g/capita/year (Poltarowicz 2017); * - indicates loading rate from Brylinsky (2004)

3.5.2 PARAMETER SELECTION FOR ANNUAL FECAL COLIFORM LOADING MODEL

As there is limited areal-loading data available for land use associated FC loading, EMC values were used to determine the annual loading of FC from the studied watershed. Using the climate normal average annual precipitation value of 1,414.2 mm (**Section 2**), the event-based loading method was used to calculate the FC loading associated with the annual depth of rainfall. Input parameters are presented in

Table 3.10 below. Due to limited available data, FC loading from wetlands and Rock/Dune/Barren land uses were assumed to be similar to forest/park land use. Similarly, FC loading from institutional land use was assumed to be similar to commercial development land use. On-site wastewater systems for the low-density scenario are assumed to not discharge measurable loads of fecal coliform in the watershed as typically systems in NS provide significant removal (Jamieson 2014).

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

Land Use	Fecal Coliform Loading Rate (CFU/ha·yr)
Commercial Development/Institutional	4.99×10^5
Forest/Park	6.94×10^3
Agriculture	1.38×10^6
High-Density Residential	3.62×10^5
Medium-Density Residential	1.46×10^7
Low-Density Residential	2.83×10^5
Road	1.10×10^6

3.5.3 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.

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-3	Wall et al. 2002, p56
Slope length and Steepness Factor (LS)			
General Forest Cover	0.35	General Forest cover is average slope across the watershed and average flow length (2% slope, 250 m length)	Wall et al. 2002 Table LS-1
Roads (Paved and Gravel)	0.60	Roads and Transmission lines use the maximum slope and flow length in watershed, (4% 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 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

The WSA is located within two watersheds – Cow Bay River and Little Salmon River Watersheds. The pollutant loads are estimated for the existing condition, low-density, medium-density, developer requested and areal land use scenarios for the combined two watershed areas that comprise the WSA and eventually discharge to Cole Harbour.

4.1 Storm-Event Model

4.1.1 PHOSPHOROUS

Precipitation event-based Total P loading was completed for a design storm event with a 2-year 24hr precipitation occurring over the studied watershed. Resultant Total P loading for the existing conditions, low-density, medium-density, developer requested, and areal land-use scenarios are predicted with results given in **Table 4.1**. When compared to the annual phosphorous load, the event-based Total P loading is approximately 8% of the annual load for each scenario, including existing condition (see **Section 4.2.1** for annual load results). Compared to the existing conditions Total P loading, the development scenarios result in an increase of Total P loading of 6.7%, 5.1%, 4.7% and 3.8% for the low-density, medium-density, developer requested, and areal land-use scenarios, respectively.

Assuming the same area and rainfall amount across all land uses, Total P loading is highest from roadways, followed by low-density residential, medium-density residential then high-density residential. As a result, as the land use shifts from low-density residential to high-density residential storm-event based Total P loading decreases.

Table 4.1 Predicted Storm Event P Loading for Existing Condition and Development Scenarios

Development Scenario	Land Use	Area (ha)	P Loading (kg)	Land Use Percentage	P Load Percentage
Existing Conditions	Commercial + Institutional	481.0	28.1	6.9%	10.8%
	Forest	2,532.9	7.6	36.3%	2.9%
	Undeveloped/Grass/Park	331.6	8.4	4.8%	3.2%
	High-Density Residential	21.1	0.8	0.3%	0.3%
	Medium-Density Residential	66.6	4.1	1.0%	1.6%
	Low-Density Residential	2,515.3	166.9	36.1%	64.0%
	Rock/Dune/Barren	171.3	0.6	2.5%	0.2%
	Road	324.4	41.2	4.7%	15.8%
	Water	403.4	-	5.8%	-
	Wetland	123.6	3.1	1.8%	1.2%
	Total	**6971.2**	**260.8**	**100.0%**	**100.0%**
Low-Density Scenario	Commercial + Institutional	481.1	28.1	6.9%	10.1%
	Forest	2,271.9	6.8	32.6%	2.4%
	Undeveloped/Grass	331.6	8.4	4.8%	3.0%
	High-Density Residential	21.1	0.8	0.3%	0.3%
	Medium-Density Residential	66.6	4.1	1.0%	1.5%
	Low-Density Residential	2,760.1	183.2	39.6%	65.8%
	Rock/Dune/Barren	171.3	0.6	2.5%	0.2%
	Road	340.4	43.3	4.9%	15.5%
	Water	403.4	-	5.8%	
	Wetland	123.6	3.1	1.8%	1.1%
	Total	**6971.2**	**278.3**	**100.0%**	**100.0%**
Medium-Density Scenario	Commercial + Institutional	482.2	28.1	6.9%	10.3%
	Forest	2,270.9	6.8	32.6%	2.5%
	Undeveloped/Grass	331.6	8.4	4.8%	3.0%
	High-Density Residential	167.7	6.4	2.4%	2.3%
	Medium-Density Residential	104.4	6.5	1.5%	2.4%
	Low-Density Residential	2,575.6	171.0	36.9%	62.4%
	Rock/Dune/Barren	171.3	0.6	2.5%	0.2%
	Road	340.4	43.3	4.9%	15.8%
	Water	403.4	-	5.8%	
	Wetland	123.6	3.1	1.8%	1.1%
	Total	**6971.2**	**274.0**	**100.0%**	**100.0%**

Development Scenario	Land Use	Area (ha)	P Loading (kg)	Land Use Percentage	P Load Percentage
Developer Requested Scenario	Commercial + Institutional	483.9	28.2	6.9%	10.3%
	Forest	2,269.2	6.8	32.6%	2.5%
	Undeveloped/Grass	331.6	8.4	4.8%	3.1%
	High-Density Residential	207.24	7.9	3.0%	2.9%
	Medium-Density Residential	114.9	7.1	1.6%	2.6%
	Low-Density Residential	2,525.7	167.6	36.2%	61.4%
	Rock/Dune/Barren	171.3	0.6	2.5%	0.2%
	Road	340.4	43.3	4.9%	15.9%
	Water	403.4	-	5.8%	
	Wetland	123.6	3.1	1.8%	1.1%
	Total	**6971.2**	**273.0**	**100.0%**	**100.0%**
Areal Land Use Scenario	Commercial + Institutional	483.3	27.9	6.9%	10.3%
	Forest	2,318.73	7.0	33.3%	2.6%
	Undeveloped/Grass	331.6	8.4	4.8%	3.1%
	High-Density Residential	170.0	6.5	2.4%	2.4%
	Medium-Density Residential	105.2	6.5	1.5%	2.4%
	Low-Density Residential	2,523.6	167.5	36.2%	61.9%
	Rock/Dune/Barren	171.3	0.6	2.5%	0.2%
	Road	340.4	43.3	4.9%	16.0%
	Water	403.4	-	5.8%	-
	Wetland	123.6	3.1	1.8%	1.1%
	Total	**6971.2**	**270.7**	**100.0%**	**100.0%**

4.1.2 FECAL COLIFORM

Precipitation event-based FC loading was completed for a design storm event with a 2-year 24-hr duration precipitation depth occurring over the studied watershed, with results given in **Table 4.2**. Resultant FC loading for the four scenarios is shown in **Table 4.2**. From existing conditions, this represents an increase in FC load of 7.6%, 8.6%, 8.9% and 7.2% for the low-density, medium-density, developer requested and areal land use scenarios, respectively.

Table 4.2 Predicted FC Loading during Storm Event for Existing Condition and Development Scenarios

Development Scenario	Existing Condition Land Use	Area (ha)	FC Loading (CFU)	Land Use Percentage	FC Load Percentage
Existing Conditions	Commercial + Institutional	481.0	4.27E+12	6.9%	11.6%
	Forest + Wetland	2,656.5	2.66E+11	38.1%	0.7%
	Undeveloped/Grassed	331.6	1.55E+12	4.8%	4.2%
	Low-Density Residential	2,515.3	2.88E+13	36.1%	77.8%
	Medium-Density Residential	66.6	8.91E+11	1.0%	2.4%
	High-Density Residential	21.1	2.82E+11	0.3%	0.8%
	Rock/Dune/Barren	171.3	2.57E+10	2.5%	0.1%
	Road	324.4	9.31E+11	4.7%	2.5%
	Water	403.4	-	5.8%	
	Total	**6,971.2**	**3.70E+13**	**100.00%**	**100.00%**
Low-Density Scenario	Commercial + Institutional	481.1	4.28E+12	6.9%	10.7%
	Forest + Wetland	2,395.5	2.40E+11	34.4%	0.6%
	Undeveloped/Grassed	331.6	1.55E+12	4.8%	3.9%
	Low-Density Residential	2,760.1	3.16E+13	39.6%	79.3%
	Medium-Density Residential	66.6	8.91E+11	1.0%	2.2%
	High-Density Residential	21.1	2.82E+11	0.3%	0.7%
	Rock/Dune/Barren	171.3	2.57E+10	2.5%	0.1%
	Road	340.4	9.77E+11	4.9%	2.5%
	Water	403.4	-	5.8%	-
	Total	**6,971.2**	**3.98E+13**	**100.00%**	**100.00%**
Medium Density Scenario	Commercial + Institutional	482.2	4.29E+12	6.9%	10.7%
	Forest + Wetland	2,394.5	2.39E+11	34.3%	0.6%
	Undeveloped/Grassed	331.6	1.55E+12	4.8%	3.9%
	Low-Density Residential	2,575.6	2.94E+13	36.9%	73.3%
	Medium-Density Residential	104.4	1.40E+12	1.5%	3.5%
	High-Density Residential	167.7	2.24E+12	2.4%	5.6%
	Rock/Dune/Barren	171.3	2.57E+10	2.5%	0.1%
	Road	340.4	9.77E+11	4.9%	2.4%
	Water	403.4	-	5.8%	
	Total	**6,971.2**	**4.02E+13**	**100.00%**	**100.00%**
Developer Requested Scenario	Commercial + Institutional	483.9	4.30E+12	6.9%	10.7%
	Forest + Wetland	2,392.8	2.39E+11	34.3%	0.6%
	Undeveloped/Grassed	331.6	1.55E+12	4.8%	3.8%
	Low-Density Residential	2,525.7	2.89E+13	36.2%	71.7%
	Medium-Density Residential	114.9	1.54E+12	1.6%	3.8%
	High-Density Residential	207.2	2.77E+12	3.0%	6.9%

Development Scenario	Existing Condition Land Use	Area (ha)	FC Loading (CFU)	Land Use Percentage	FC Load Percentage
	Rock/Dune/Barren	171.3	2.57E+10	2.5%	0.1%
	Road	340.4	9.77E+11	4.9%	2.4%
	Water	403.4	-	5.8%	
	Total	**6,971.2**	**4.03E+13**	**100.00%**	**100.00%**
Areal Land Use Scenario	Commercial + Institutional	483.3	4.30E+12	6.9%	10.8%
	Forest + Wetland	2,442.3	2.44E+11	35.0%	0.6%
	Undeveloped/Grassed	331.6	1.55E+12	4.8%	3.9%
	Low-Density Residential	2,523.6	2.88E+13	36.2%	72.8%
	Medium-Density Residential	105.2	1.41E+12	1.5%	3.6%
	High-Density Residential	170.0	2.27E+12	2.4%	5.7%
	Rock/Dune/Barren	171.3	2.57E+10	2.5%	0.1%
	Road	340.4	9.77E+11	4.9%	2.5%
	Water	403.4	-	5.8%	
	Total	**6,971.2**	**3.96E+13**	**100.00%**	**100.00%**

4.1.3 SEDIMENT

The total event-based soil loss load (tonnes) for each development scenario is presented in **Table 4.3**. 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-density, developer requested, and medium-density scenarios represent a sediment load increase of 5.7% to 5.8% when compared to the existing condition, as low, medium, and high-density areas are assumed to have similar sediment loading rates for the WSA, based on breakdown of land use areas and loading rates. Further, the areal land use scenario represents a sediment load increase of 4.8% when compared to the existing condition.

Table 4.3 Event-Based Sediment Loading Results for Existing Condition and Development Scenarios

Development Condition	Land Use	A (tonnes/ha)	Area (ha)	Total Storm Event Load (tonnes)
Existing Condition	Forest General (Non-Disturbed)	0.0089	2,827.8	841
	Roads	0.4815	324.4	
	Disturbed Forest Land	0.3577	331.6	
	Urban	0.1754	3,084.0	
Low-Density Development	Forest General (Non-Disturbed)	0.0089	2,566.8	889
	Roads	0.4815	340.4	
	Disturbed Forest Land	0.3577	331.6	
	Urban	0.1754	3,328.9	
Medium Density Scenario	Forest General (Non-Disturbed)	0.0089	2,565.8	889
	Roads	0.4815	340.4	
	Disturbed Forest Land	0.3577	331.6	
	Urban	0.1754	3,329.9	
Developer Requested Scenario	Forest General (Non-Disturbed)	0.0089	,2564.1	890
	Roads	0.4815	340.4	
	Disturbed Forest Land	0.3577	331.6	
	Urban	0.1754	3,331.7	
Areal Land-Use Scenario	Forest General (Non-Disturbed)	0.0089	2,613.6	882
	Roads	0.4815	340.4	
	Disturbed Forest Land	0.3577	331.6	
	Urban	0.1754	3,282.1	

Forest General is the sum of Forested, Wetland and Rock/Dune/Barren Land Use Types
Disturbed Forest Land is the Undeveloped + Grassed + Park Land Use Type
Urban is the sum of the Commercial, Institutional, Low-Density, Medium-Density and Developer Requested Scenarios

4.2 Annual Watershed Loading Model

Modelling was completed to predict changes in land use associated contaminant loadings for four proposed development scenarios – low-density, medium-density, developer-requested, and areal land-use scenarios. Models were completed for TP, FC, and sediment using methods described in **Section 3**.

4.2.1 PHOSPHORUS

The annual Total P loading from the WSA watershed for all scenarios is shown in **Table 4.4**. The modelled annual Total P load for the existing condition scenario corresponds to an annual loading rate of 0.02924 g P/m^2·yr. This loading rate is a slightly higher than the P export loading rates measured by Scott et. al. (2000) for watersheds in the Halifax area as presented in Brylinsky (2004).

Table 4.4 Predicted Annual P Loads for Existing Condition and Development Scenarios

Development Scenario	Land Use	Area (ha)	Annual P Loading (kg/year)	Land Use Percentage	P Load Percentage
Existing Condition	Commercial	441.3	89.1	6.3%	4.4%
	Forest	2,532.9	60.8	36.3%	3.0%
	Undeveloped/Grassed	331.6	49.7	4.8%	2.4%
	Low-Density Residential	2,515.2	628.8	36.1%	30.8%
	Medium-Density Residential	66.6	20.0	1.0%	1.0%
	High-Density Residential	21.1	7.4	0.3%	0.4%
	Institutional	39.6	16.7	0.6%	0.8%
	Wetland	123.6	3.0	1.8%	0.1%
	Rock/Dune/Barren	171.3	28.4	2.5%	1.4%
	Road	324.4	1135.4	4.7%	55.7%
	Water	403.4	0.0	5.8%	0.0%
	Total	**6,971.2**	**2,039.3**	**100.0%**	**100.0%**
Low-Density Condition	Commercial	441.5	89.2	6.3%	3.8%
	Forest	2,271.9	54.9	32.6%	2.3%
	Undeveloped/Grassed	331.6	49.7	4.8%	2.1%
	Low-Density Residential	2,760.1	690.0	39.6%	29.4%
	Medium-Density Residential	66.6	20.0	1.0%	0.9%
	High-Density Residential	21.1	7.4	0.3%	0.3%
	Institutional	39.7	16.7	0.6%	0.7%
	Wetland	123.6	3.0	1.8%	0.1%
	Rock/Dune/Barren	171.3	28.4	2.5%	1.2%
	Road	324.4	1135.4	4.9%	48.4%
	Water	403.4	0.0	5.8%	0.0%
	On-site Wastewater Systems	1,583 [A]	253.3	-	10.8%
	Total	**6,971.2**	**2,348.0**	**100.0%**	**100.0%**
Medium-Density Scenario	Commercial	442.5	89.4	6.3%	4.1%
	Forest	2,270.9	54.5	32.6%	2.5%
	Undeveloped/Grassed	331.6	49.7	4.8%	2.3%
	Low-Density Residential	2,575.6	643.9	36.9%	29.7%
	Medium-Density Residential	104.4	31.3	1.5%	1.4%
	High-Density Residential	167.7	58.7	2.4%	2.7%
	Institutional	39.6	16.7	0.6%	0.8%
	Wetland	123.6	3.0	1.8%	0.1%
	Rock/Dune/Barren	171.3	28.4	2.5%	1.3%

Development Scenario	Land Use	Area (ha)	Annual P Loading (kg/year)	Land Use Percentage	P Load Percentage
	Road	340.4	1191.5	4.9%	55.0%
	Water	403.4	0.0	5.8%	0.0%
	Total	**6,971.2**	**2,167.1**	**100.0%**	**100.0%**
Developer Requested Condition	Commercial	444.2	89.7	6.4%	4.1%
	Forest	2,269.2	54.5	32.6%	2.5%
	Undeveloped/Grassed	331.6	49.7	4.8%	2.3%
	Low-Density Residential	2,525.7	631.4	36.2%	29.1%
	Medium-Density Residential	114.9	34.5	1.6%	1.6%
	High-Density Residential	207.2	72.5	3.0%	3.3%
	Institutional	39.6	16.7	0.6%	0.8%
	Wetland	123.6	3.0	1.8%	0.1%
	Rock/Dune/Barren	171.3	28.4	2.5%	1.3%
	Road	340.4	1191.5	4.9%	54.9%
	Water	403.4	0.0	5.8%	0.0%
	Total	**6971.2**	**2,171.9**	**100.0%**	**100.0%**
Areal Land Use Condition	Commercial	443.6	89.6	6.4%	4.2%
	Forest	2,318.7	55.6	33.3%	2.6%
	Undeveloped/ Grassed	331.6	49.7	4.8%	2.3%
	Low-Density Residential	2,523.6	630.9	36.2%	29.3%
	Medium-Density Residential	105.2	31.6	1.5%	1.5%
	High-Density Residential	170.0	59.5	2.4%	2.8%
	Institutional	39.6	16.7	0.6%	0.8%
	Wetland	123.6	3.0	1.8%	0.1%
	Rock/Dune/Barren	171.3	28.4	2.5%	1.3%
	Road	340.4	1191.5	4.9%	55.3%
	Water	403.4	0.0	5.8%	0.0%
	Grand Total	**6,971.2**	**2,156.5**	**100.0%**	**100.0%**
Notes: [A] Estimated population on residential on-site wastewater systems					

Of the proposed development scenarios, the areal land use condition scenario has the lowest annual Total P load (2,156 kg P/yr); this may be attributed to the reduced disturbed area compared to the medium-density and developer requested scenarios. The low-density scenario has the highest annual load due to the additional Total P load from the on-site wastewater systems. In existing condition, medium-density, high-density and areal land use scenarios, roads, and low-density residential areas account for 84 to 88% of annual loading within the watershed with other sources proportionally illustrated in **Figure 4.1**. The low-density scenario has 78% of the annual Total P load from roads and low-density residential with 10% of the annual load from the onsite wastewater systems.



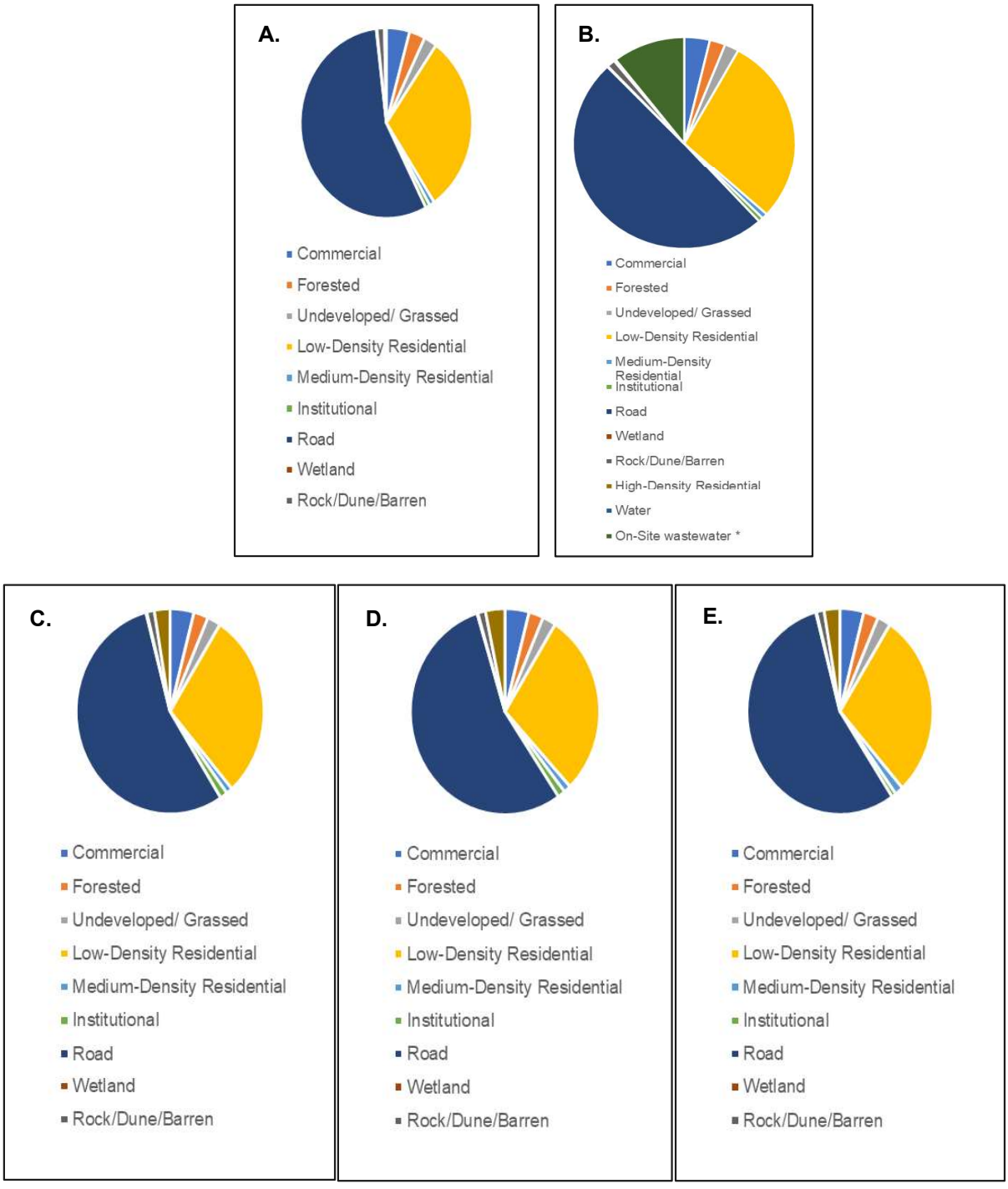


Figure 4.1 TP Loading - Existing Conditions (A), Low-Density (B), Medium-Density (C), High-Density (D), Areal Land Use (E)

4.2.2 FECAL COLIFORM

The annual FC loading from Westphal watersheds for the existing conditions, low-density, medium-density, developer requested and areal land-use scenarios, respectively are shown in **Table 4.5**. For the WSA commercial and institutional land use areas account for approximately 7% of the land use within the watershed and contribute to approximately 20-21% of the annual FC loading, exhibiting the highest influence per ha on FC rates. The second highest land use is Low-Density Residential which occupies 36.1 to 36.9% of the WSA and contributes 59.1 to 65.6% of the annual FC loading. Together these two land uses make up 79.1 to 85.7% of the annual FC loading.

Table 4.5 Predicted Annual FC Loads for Existing Condition and Development Scenarios

Development Scenario	Land Use	Area (ha)	Annual FC Loading (CFU/year)	Land Use Percentage	FC Load Percentage
Existing Condition	Commercial + Institutional	481.0	2.60E+14	6.9%	20.7%
	Forest + Wetlands	2,656.5	2.07E+13	38.1%	1.6%
	Undeveloped/ Grassed	331.6	1.26E+14	4.8%	10.1%
	Low-Density Residential	2515.3	5.52E+11	0.3%	0.0%
	Medium-Density Residential	66.6	2.34E+13	1.0%	1.9%
	High-Density Residential	21.1	1.16E+13	4.7%	0.9%
	Rock/Dune/Barren	171.3	1.35E+13	2.5%	1.1%
	Road	324.4	7.99E+14	36.1%	63.7%
	Water	403.4		5.8%	0.0%
	Total	**6971.2**	**1.26E+15**	**100.00%**	**100.00%**
Low-Density Condition	Commercial + Institutional	481.1	2.69E+14	6.9%	20.1%
	Forest + Wetlands	2,395.5	1.86E+13	34.4%	1.4%
	Undeveloped/ Grassed	331.6	1.26E+14	4.8%	9.4%
	Low-Density Residential	2,760.1	8.56E+12	0.3%	0.6%
	Medium-Density Residential	66.6	2.34E+13	1.0%	1.7%
	High-Density Residential	21.1	1.21E+13	4.9%	0.9%
	Rock/Dune/Barren	171.3	2.18E+12	2.5%	0.2%
	Road	340.4	8.77E+14	39.6%	65.6%
	Water	403.4		5.8%	0.0%
	Total	**6,971.2**	**1.34E+15**	**100.00%**	**100.00%**
Medium Density Condition	Commercial + Institutional	482.2	2.70E+14	6.9%	20.0%
	Forest + Wetlands	2394.5	1.86E+13	34.3%	1.4%
	Undeveloped/ Grassed	331.6	1.26E+14	4.8%	9.3%
	Low-Density Residential	2575.6	6.80E+13	2.4%	5.0%
	Medium-Density Residential	104.4	3.66E+13	1.5%	2.7%
	High-Density Residential	167.7	1.21E+13	4.9%	0.9%
	Rock/Dune/Barren	171.3	2.18E+12	2.5%	0.2%

Development Scenario	Land Use	Area (ha)	Annual FC Loading (CFU/year)	Land Use Percentage	FC Load Percentage
	Road	340.4	8.19E+14	36.9%	60.5%
	Water	403.4		5.8%	0.0%
	Total	**6971.2**	**1.35E+15**	**100.00%**	**100.00%**
Developer Requested Condition	Commercial + Institutional	483.9	2.71E+14	6.9%	20.0%
	Forest + Wetlands	2392.8	1.86E+13	34.3%	1.4%
	Undeveloped/ Grassed	331.6	1.26E+14	4.8%	9.3%
	Low-Density Residential	2525.7	8.40E+13	3.0%	6.2%
	Medium-Density Residential	114.9	4.03E+13	1.6%	3.0%
	High-Density Residential	207.2	1.21E+13	4.9%	0.9%
	Rock/Dune/Barren	171.3	2.18E+12	2.5%	0.2%
	Road	340.4	8.03E+14	36.2%	59.1%
	Water	403.40		5.8%	0.0%
	Total	**6971.2**	**1.36E+15**	**100.00%**	**100.00%**
Areal Land Use Scenario	Commercial + Institutional	483.3	2.71E+14	6.9%	20.2%
	Forest + Wetlands	2442.3	1.90E+13	35.0%	1.4%
	Undeveloped/ Grassed	331.6	1.26E+14	4.8%	9.4%
	Low-Density Residential	2523.6	6.89E+13	2.4%	5.2%
	Medium-Density Residential	105.2	3.69E+13	1.5%	2.8%
	High-Density Residential	170.0	1.21E+13	4.9%	0.9%
	Rock/Dune/Barren	171.3	2.18E+12	2.5%	0.2%
	Road	340.4	8.02E+14	36.2%	59.9%
	Water	403.4		5.8%	0.0%
	Total	**6971.2**	**1.34E+15**	**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 2,056 tonnes/year leaving the watershed, with no mitigation measures in place. The low-density and medium-density scenarios, has a total annual sediment loading rate of 2,190 tonnes/year while the developer requested scenarios has total annual sediment loading rate of 2,191 tonnes/year. The areal land use scenario has an annual sediment load of 2,170 tonnes/year. The development scenarios have similar annual loads due to having similar total developed areas with the same sediment loading rates applied to the different densities (low, medium, and high). The areal land use scenario has the lowest sediment loading rates as the higher percentage of undisturbed forest land results in less disturbed sediment entering the watershed. The low-density, medium-density, developer requested, and areal land-use scenarios represent a sediment load increase of 6.5%, 6.5%, 6.6%, and 5.5% respectively, when compared to the existing condition.

Table 4.6 Predicted Annual Sediment Loads for Existing Condition and Development Scenarios

Development Condition	Land Use	A (tonnes/ha/yr)	Area (ha)	Total Annual Load (tonnes/yr)
Existing Condition	Forest General (Non-Disturbed)	0.011	2,827.8	2,056
	Roads	1.385	324.4	
	Disturbed Forest Land	0.426	331.6	
	Urban	0.466	3,084.0	
Low-Density Development	Forest General (Non-Disturbed)	0.011	2,566.8	2,190
	Roads	1.385	340.4	
	Disturbed Forest Land	0.426	331.6	
	Urban	0.466	3,328.9	
Medium Density Scenario	Forest General (Non-Disturbed)	0.011	2,565.8	2,190
	Roads	1.385	340.4	
	Disturbed Forest Land	0.426	331.6	
	Urban	0.466	3,329.9	
Developer Requested Scenario	Forest General (Non-Disturbed)	0.011	2,564.1	2,191
	Roads	1.385	340.4	
	Disturbed Forest Land	0.426	331.6	
	Urban	0.466	3,331.7	
Areal Land Use Scenario	Forest General (Non-Disturbed)	0.011	2,613.6	2,170
	Roads	1.385	340.4	
	Disturbed Forest Land	0.426	331.6	
	Urban	0.192	3,282.1	

Forest General is the sum of Forested, Wetland and Rock/Dune/Barren Land Use Types
Disturbed Forest Land is the Undeveloped + Grassed + Park Land Use Type
Urban is the sum of the Commercial, Institutional, Low-Density, Medium-Density and Developer Requested Scenarios



5 Water Quality Discussion

5.1 Total Phosphorus

Area and concentration-based Total P loadings associated with land uses within the watersheds that include the WSA are largely generated by anthropogenic sources, namely low-density residential and roads. These two land uses contributed approximately 85% of the loading for the existing condition and development scenarios, except for the annual Total P load in the low-density scenario which includes P loading from on-site wastewater systems. Total P loads from residential land use are mitigated in the existing condition and medium density, development scenarios by municipal wastewater services and centralized wastewater treatment, which remove these additional loads from the watershed. The existing condition annual Total P loading was calculated to be 2,039 kg/year and the storm event existing Total P load was estimated to be 12.8% of the annual Total P loading at 261 kg per storm event.

For the proposed development scenarios, the areal land use scenario resulted in the lowest increase in Total P loading for the annual loading and storm-event loading calculations with an increase in load of 5.7% and 3.8%, respectively. This is compared to annual loading and storm-event loading increases of 15.1% and 16.7% for the low-density scenario; 6.1% and 5.1% for the medium-density scenario and 6.5% and 4.7% for the high-density scenario.

The reduced Total P load for the areal land use scenario is attributable to the intensity of development within the watershed and no on-site wastewater systems. From a watershed management perspective, annual Total P loading is easier to assess with respect to changes in loads and concentrations due to a development with periodic monitoring in surface water receivers throughout the year. Storm event sampling requires a more intensive program to assess changes in loads and receiver's concentrations during the relatively short durations of the precipitation events (e.g., less than one day) and potentially does not capture other sources (e.g., on-site wastewater systems).

The low-density scenario annual P loading includes on-site wastewater systems, which with the other land use Total P loads represents a 18% increase from the existing condition. This is due to the increased development footprint in comparison to the areal land use scenario and the additional 250 kg annual load from the on-site wastewater systems. For this scenario consideration of centralized wastewater treatment to remove the wastewater Total P load from the watershed should be considered or P treatment technologies within the on-site wastewater treatment systems.

Future development for the WSA should consider the conservation of natural forested area, rather than the expansion of development within the watershed. As shown by the areal land use scenario, a mix of higher density, smaller footprint housing may mitigate the loss of forested area within the watershed and reduce the Total P load. The implementation of mitigation measures such as Low Impact Development (LID) technologies will be required for developments to reduce Total P loads to match existing or background conditions. It is estimated that Total P reduction of approximately 6% is needed to achieve a no net increase of Total P to the watershed for loads associated with land uses and not on-site wastewater system contributions, phosphorous loading mitigation measures are discussed in **Section 6.1**.

5.2 Fecal Coliform

According to the EMC-based model results, area, and concentration-based FC loadings within the WSA are largely generated by residential developments, commercial developments, and undeveloped/grassed areas for the existing conditions and development scenarios. It is noted, however, that model parameters used for FC have a high degree of variability. Results from rainfall-event modeling in the WSA give a calculated baseline load of 3.70×10^{13} CFU/100 mL during a 2yr-24hr Chicago design storm event. When compared to annual loading calculations within the watershed, at 1.26×10^{15} CFU/100 mL, the annual model results appear to overestimate FC loading from the watershed. The storm event FC load modelling accounts for approximately 2.9% of the annual FC loading for the existing conditions scenario. Similarly, the rainfall-event based FC loading resulted in approximately 3.0 % of the annual FC loads for the four development scenarios.

The increase in annual FC load from baseline conditions for each of the development scenarios was 6.6%, 7.7% and 8.1% for the low-density, medium-density, and developer requested scenarios, respectively, whereas the areal land use scenario was similar to the low-density scenario at 6.6%.

Based on the event-based and annual FC loading model results for the development scenarios, mitigation measures will be required to reduce loads to equal existing conditions, these are discussed in **Section 6**.

5.3 Sediment

Sediment load modelling using MUSLE and RUSLEFAC calculations for the development scenarios resulted in sediments loads of 2,170 to 2,190 tonnes/year on an annual basis and 882 to 890 tonnes per storm-event. Baseline sediment loading was estimated to be 2,056 tonnes per year, with approximately 841 tonnes deposited during a storm event.

For the proposed development scenarios, the areal land use scenario resulted in the lowest sediment load for the annual loading and storm-event loading calculations with an increase in load of 5.5% and 4.8%, respectively. This is compared to annual loading and storm-event loading increases of 6.5% and 5.7% for the low-density scenario; 6.5% and 5.7% for the medium-density scenario and 6.6% and 5.8% for the high-density scenario.

The addition of roads, and disturbance of soils during construction of the development scenarios 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, considering no erosion and sedimentation control measures were applied. The implementation of ESC measures would greatly reduce the transport of sediment within the watershed as these methods are highly effective (HESL 2012). Additional recommendations for sediment mitigation are presented in **Section 6.3**.

6 Water Quality Conclusions

The proposed development scenarios for the WSA within the two existing watersheds (Cow Bay River and Little Salmon River), which discharge to Cole Harbour present challenges to local water quality as land use change can impact the lake and watershed systems. Existing Total P concentrations in the WSA watercourses are within the meso-eutrophic range.

The four development scenarios evaluated in this study resulted in increased loading of TP, FC, and sediment within the watersheds in the WSA. Of the development scenarios evaluated, the low-density and areal land-use scenarios resulted in the lowest increase in loading for FC and sediment parameters, and storm-based Total P loads. The annual Total P load for the low-density scenario was highest due to contributions from on-site wastewater systems. These results demonstrate that the factors which have the greatest impact on contaminant loading are developed area and total population. The implementation of structural LID measures would be expected to reduce contaminant loads for the development area to achieve contaminant loads of existing conditions. For the low-density residential development scenario, centralized wastewater treatment should be considered to reduced loads or P treatment technologies in the on-site wastewater systems. The recommendation is to limit the increase in contaminant loading from existing conditions with development in the WSA. The no-net increase of loading approach as developed by HESL (2014) should be considered for any development scenario within the WSA

6.1 Phosphorous Loading Mitigation

6.1.1 LAND USE-BASED MITIGATION

Low-density residential and road land uses are estimated to contribute the highest percentage of Total P loading on an annual basis for the four development scenarios. In the low-density scenario on-site wastewater systems is third with respect to their contribution to the annual Total P load. To reduce the annual Total P load to the watershed, the development scenarios must consider implementation of LID methods to reduce loading by approximately 6% for medium, developer requested and areal land use land development scenarios. For the low-density scenario an 18% decrease in Total P loading is required to manage Total P loads to the watershed. In addition to implementing LID methods, centralized wastewater treatment should be considered to remove the household wastewater Total P load from the watershed or consider phosphorus treatment technologies in the on-site wastewater systems.

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 Roads 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 LID measures would be expected to reduce Total P loads for the development area to achieve Total P 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 Total P loads for the chosen development scenario.

- The promotion of green space creation or naturally forested park 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. As shown through this study, the reduction of development area (areal land-use scenario) was able to reduce Total P load to the surrounding watershed. The prioritization of green space over developed land has been shown to reduce contaminant loading to the watershed.

- 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.

- Minimizing sprawl in urbanization patterns and building up rather than out will result in more sustainable urban development.

- For the low-density residential development scenario centralized wastewater treatment should be considered to reduce Total P watershed loads. If centralized wastewater treatment is not an option, on-site wastewater systems should include P reducing technologies in the septic tank or prior to the disposal field to reduce watershed Total P loads.

6.1.2 ON-GOING MONITORING

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

- The extension of in-lake P monitoring at Broom Lake when the lake system is completely mixed (e.g., late fall, early spring). To determine internal loading capacities of Broom Lake, additional Bathymetry surveys of the lake should be completed prior to monitoring. Following this, the recommended monitoring would be adding this site to the list of HRM's LakeWatchers program (2023), which monitors lake twice annually – in May and August. This is recommended to capture any increasing trend in lake P concentrations and associated trophic status changes caused by a release of P from vegetation and algae decay. If carried out after seasonal lake turnover, this data can also capture any increase in P concentrations from the lake epilimnion.
- Depth profiling and surface and lake bottom sampling at deep-water lake locations in Broom Lake should be conducted. 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 implementation 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 Road maintenance is being implemented.
- As part of monitoring within the WSA, an adaptive management approach should be applied to target point and nonpoint sources of P within the WSA to improve water quality. As sources of P within the watersheds are identified, management measures can be applied to reduce P loading in the watersheds containing the WSA 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 FC 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 dogs. The trails located within the Little Salmon River watershed are a popular recreation area for many, especially ATV users, and signage within the park may help inform the public of risks relating to FC exceedances on human and animal health.
- Increased public education of the risk of swimming in areas where wildlife congregates. The WSA is the habitat of many avian, and other wildlife species. Public risk awareness is needed to mitigate risk to human health from these sources, particularly within Broom Lake as it is relatively a small water body (0.56 ha).
- Continuation of public education with respect to public beach closures. Regardless of the source of bacteria loadings, high bacteria events represent a risk to public health when they occur in areas used for recreational purposes.

6.2.3 ON-GOING MONITORING

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

- Monitoring of fecal coliform markers to better understand the sources of FC within the watershed.
- The implementation 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 adding Broom Lake to the list of HRM's LakeWatchers program lakes are monitored twice annually (early May and August).
- During the monitoring within the WSA, 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 relatively low in watercourses within the WSA, including Broom Brook. The unnamed brook had higher TSS concentration (average 35.6 mg/L) at SW-27 for baseline conditions. If the WSA is developed following the selection of one of the proposed development scenarios, it will be important to implement ESC Measures to mitigate any effects from development. The expected increases in sediment loading from existing conditions are up to 5%. 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 Total P and *E. coli* loads through infiltration and filtering.

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

Measure Implemented		Percent Efficiency of TSS Removal
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 Westphal Development 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 are to be restricted to pre-development levels;
- Size culverts to convey instantaneous peak flows with a headwater depth to culvert diameter ratio (Hw/D) 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;
- For ponds to be taken over by Halifax Water, the preference is for dry ponds. If wet ponds are to be privately owned and operated, they will be considered on a case-by-case basis; and,
- Additional pond volume allowances must include a 300mm freeboard from the 100-year water level.

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, **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

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 storm IDF parameters 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 as per Administrative Order Number 2020-010-OP is important for ensuring effective stormwater conveyance and environmental sustainability:

- Multi-unit, commercial and industrial sites are required to demonstrate that the stormwater system is designed to provide an average annual removal of 80% Total Suspended Solids (TSS) from post-development runoff; and,
- The use of Green Infrastructure and Low Impact Development (LID) measures is preferred and encouraged.

7.1.3 NOVA SCOTIA DEPARTMENT OF ENVIRONMENT AND CLIMATE CHANGE

Nova Scotia Environment (NSE) requires that culverts are designed to have a headwater/pipe diameter ratio (Hw/D) of less than or equal to 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 Westphal Study Area is within the floodplain of two watercourses, 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 COLE HARBOUR/WESTPHAL MUNICIPAL PLANNING STRATEGY LAND USE BY-LAWS

The Municipal Planning Strategy for Cole Harbour/Westphal contains recommendations to develop floodplain mapping for the Little Salmon, Bissett and Smelt Brook River systems in order to establish policies and regulations to restrict development within the floodplains.

Similarly, the Land Use By-law for Cole Harbour/Westphal contains policies and regulations regarding watercourse and coastal area setbacks and buffers, as well as development restrictions. While this project does not include floodplain mapping for the Little Salmon River or the Broom Brook, the policies and regulations included in the municipal standards should be considered for the Westphal Study Area through future planning reviews.

7.2 Background Reports

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

- **AKOMA - Main Street, Dartmouth Transportation Impact Study, Fathom Studio (2021):** This report presents a study of the impacts of a proposed 400-unit residential development on the AKOMA Family Center site. It discusses the development's compatibility with existing infrastructure, its accessibility by transit and active transportation networks, and the need for sound access management principles for future development initiatives along the Main Street Corridor.

- **Site Analysis of the Akoma Property, John Zuck and Associates (2021):** This report, prepared for Akoma Holdings Incorporated, aims to guide development planning for the Akoma lands in Westphal, Nova Scotia by identifying physical opportunities and constraints for development. The study area comprises two properties, PID 40150567 and PID 41391764, fronting on Highway 7 and Old Miller Road, and Old Lawrencetown Road and Old Miller Road, respectively. The existing development includes the Old Home Site and some minor features, while the rest of the site remains largely undeveloped. The report emphasizes the importance of studying environmental conditions and processes to identify development opportunities and limitations, with a focus on leveraging green infrastructure to reduce costs and enhance development quality.

- **Westphal Study Area Draft Report – Land Suitability Analysis, Stantec (March 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 assumptions regarding seasonal land cover, initial conditions at lakes, dam operation, coastal water levels, rainfall distribution (Chicago distribution – 24-hour, 5 min interval), and soil conditions.

8 Existing Conditions

8.1 Site Location

The Westphal study area is located to the east of Dartmouth, and is bounded by Highway 107 to the north, Robert Lane and Broom Road to the west, Ross Road to the east, and Cole Harbour Rd to the south. The Westphal Study Area is within the Shore Direct and Little Salmon River watersheds. **Figure** 8.1 presents the Westphal Study Area.

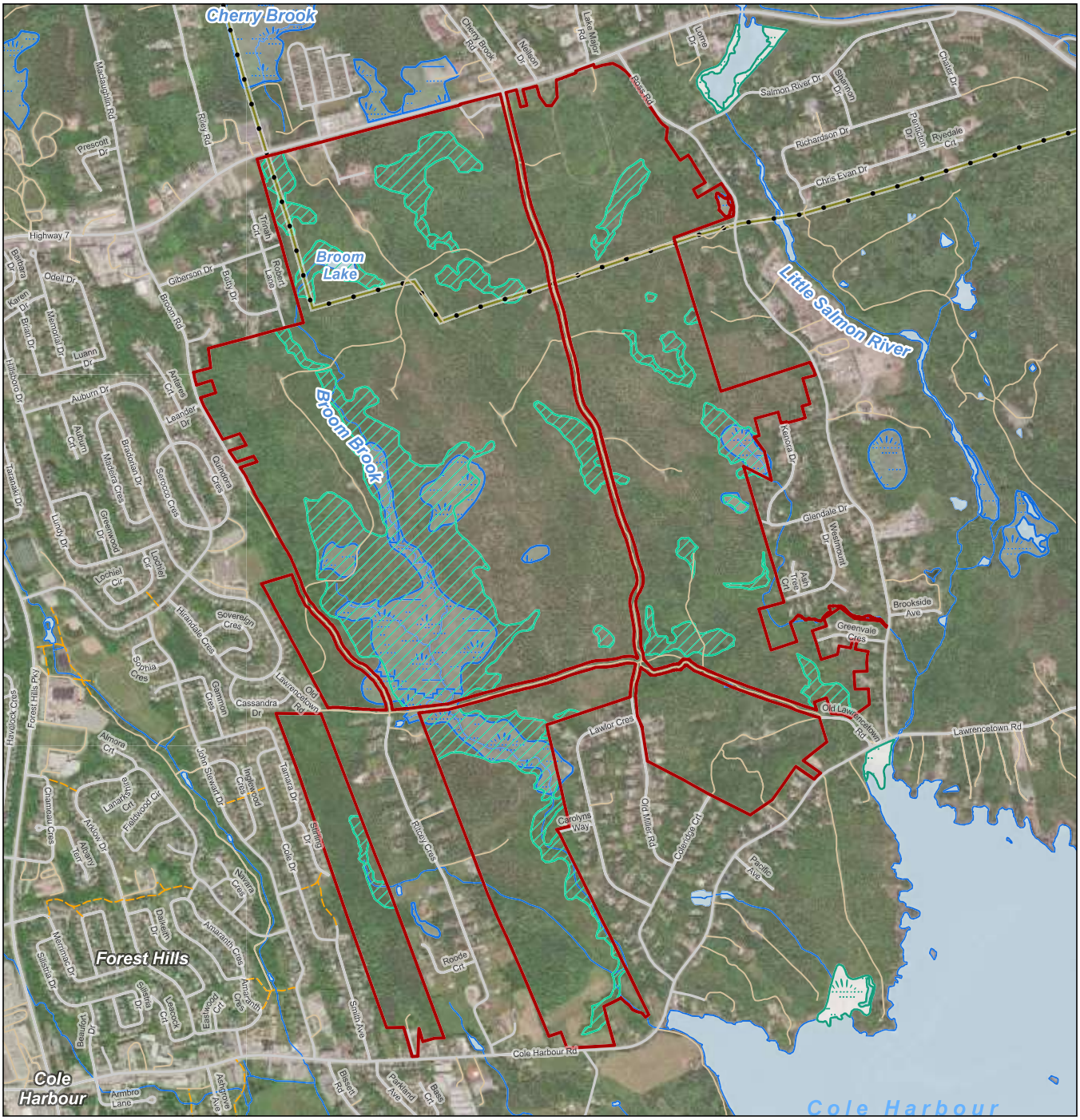
8.2 Topography

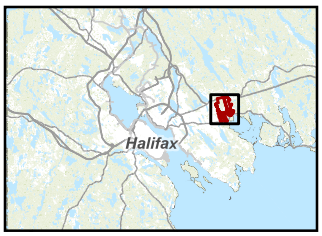
The Westphal study area generally slopes south towards Cole Harbour in the Atlantic Ocean.

Stantec has analyzed LiDAR data provided by HRM (2019) 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 shows existing contours.

8.3 Land Use

The Westphal Study Area, covering an area of approximately 417 hectares, largely remains in its natural state. The site is intersected by an easement belonging to Nova Scotia Power, looping around Broom Lake. Dense forest cover characterizes the majority of the study area.





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 2024-10-22
QR by NW on 2024-10-23

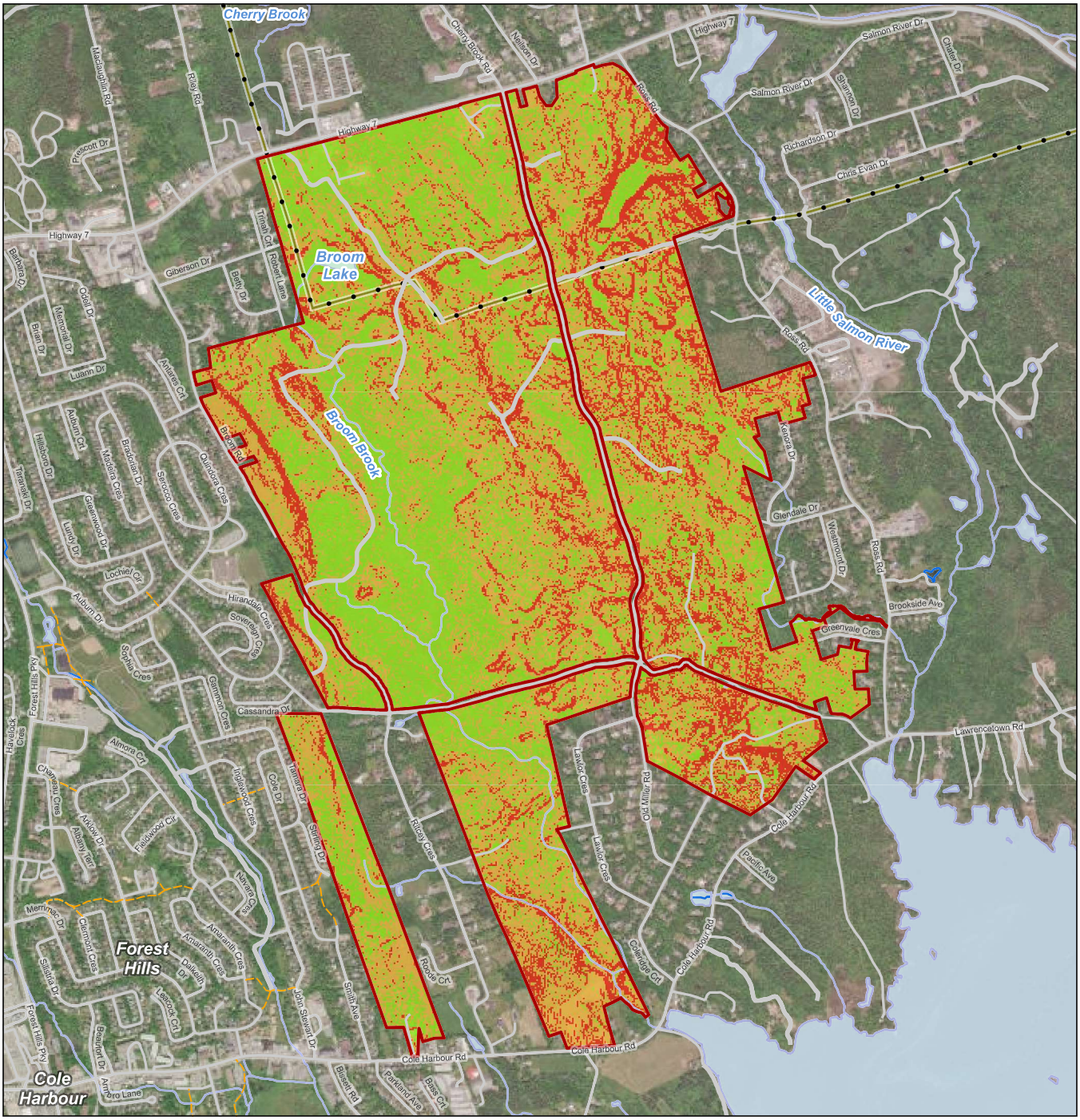
Client/Project
160410459
Halifax Regional Municipality
Future Serviced Communities
Background Studies

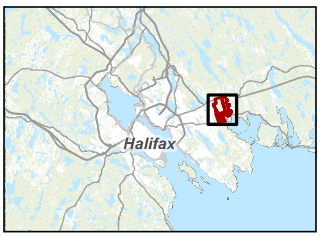
Figure No.
8.1

Title
Westphal Study Area

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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

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

Client/Project
Halifax Regional Municipality
Future Serviced Communities
Background Studies

Fig ID: 160410459_014

Figure No.
8.2

Title
Slope Land Suitability Analysis - Westphal

HRM FCM 2022.aprx Revised: 2024-12-06 By: niwhite

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