Halifax Regional Municipality

Shubenacadie Lakes Subwatershed Study – Preliminary Report

draft for discussion

Prepared by:

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Project Number:

60221657

Date:

June, 2012

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June 28, 2012

Mr. Paul Morgan
Community Planning
HRM Steering Committee
P.O. Box 1749
Halifax, NS B3J 3A5

Dear Mr. Morgan:

Project No: **60221657**

Regarding: **Shubenacadie Lakes Subwatershed Study – Preliminary Report**

AECOM is pleased to submit the attached draft Preliminary Report for the Shubenacadie Lakes Subwatershed Study. As required by HRM's Terms of Reference, the report recommends preliminary water quality objectives for key lakes in the watershed, and was the subject of a public presentation on June 13th, 2012.

Please do not hesitate to telephone the undersigned should you have any questions or require additional details.

Sincerely,
AECOM Canada Ltd.

(unsigned draft)

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RD:mm
Encl.

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Executive Summary

The 2006 Halifax Regional Municipal Planning Strategy requires that watershed studies are undertaken before a Community Vision exercise and in advance of community design work undertaken through the secondary planning process. In response to requests by property owners of the "Port Wallis Lands" to begin planning for new serviced communities, Regional Council has directed that a watershed study be completed for the Shubenacadie Lakes subwatershed.

AECOM was contracted by HRM in August 2011 to complete the Shubenacadie Subwatershed Study in two phases:

1. present a series of recommended water quality objectives for key receiving water bodies within the watershed in a Preliminary Report; and,
2. address the remaining objectives of Regional Plan Policy E-17 in a Final Report.

This preliminary report presents the water quality objectives for comment by the public and HRM so that questions and clarifications can be addressed in the final report. The final report will identify areas that are suitable and not suitable for development, determine the amount of development that can be accommodated while maintaining water quality objectives, recommend measures to protect and manage quantity and quality of surface and groundwater and recommend regulatory controls and management strategies to achieve the desired water quality objectives.

The following tasks were completed to arrive at the water quality objectives presented below:

- Existing water quality data were reviewed and a supplementary sampling program was undertaken to establish a baseline of the water quality in key water courses;
- Other jurisdictional approaches to setting water quality objectives for lakes were reviewed and an approach was developed to recommend water quality objectives for the Shubenacadie Lakes subwatershed.
- Water quality objectives were set for each lake for total phosphorus and for the watershed as a whole for nitrate, un-ionized ammonia, total suspended solids, chloride and the bacteria *Escherichia coli*, commonly called *E. coli*;
- A limited flow monitoring program was initiated to help calibrate the nutrient and stormwater loading models used to evaluate water quality objectives; and
- Using HRM's LiDAR data, spatial modelling was completed to delineate watershed and sub-watershed boundaries and to identify vernal ponds, wetlands and intermittent streams.

The Shubenacadie Lakes subwatershed is situated on the southern edge of the Nova Scotia Southern Upland physiographic region and has a surface area of approximately 388 km^2. Surface water flow within the watershed is generally south to north in the larger lakes, although the smaller lakes in the upper watershed actually flow to the southeast. Existing water level control structure dams are located along the historic Shubenacadie Canal.

Lakes are central ecological and hydrological components of most watersheds. Lake chemistry is a function of the inflow of surface waters (and hence upstream activities), groundwater discharge to the lake, deposition to the lake surface from the atmosphere, and re-suspension of lake bottom sediments. The term "trophic status" is used to describe biological productivity within a lake. Trophic status depends on the amount of nutrients available to enhance plant growth and is a critical measure of lake water quality. The trophic status can be determined by measuring nutrient concentrations (phosphorus and nitrogen), algal density and, in some lakes, water clarity.

Lakes with few nutrients and low biological productivity are referred to as "oligotrophic". Lakes with higher nutrient concentrations and high productivity are referred to as "eutrophic". Eutrophic lakes are characterised by abundant plant life, including algae, and consequent low water clarity. Lakes with an intermediate productivity are called "mesotrophic" and generally combine the qualities of oligotrophic and eutrophic lakes. Classification of lake trophic status into oligotrophic, mesotrophic or eutrophic provides a simplified framework for lake management and a point of reference for lake managers. There are many means of classifying lake trophic status but all are based on measurements of trophic status indicators such as phosphorus concentration, algal concentration or water clarity and assigning lakes to a category based on the values measured.

Existing Water Quality

In order to establish water quality objectives and prevent any further deterioration in water quality, water quality data collected in the past six years were used to assess current conditions, prior to any further development in the watershed. Historical data was used for comparison purposes, when appropriate. The year 2006 was selected as starting year since this is the first year of the ongoing, comprehensive data set collected by or on behalf of HRM. In addition, AECOM is undertaking additional limited water quality sampling at four locations on a quarterly basis over the course of this project.

Overall, the current water quality of the lakes in the Shubenacadie watershed is good. For the most part, the lakes are mesotrophic systems, characterized by relatively low concentrations of nutrients and chlorophyll α. Most of the lakes in the watershed also have low concentrations of total suspended solids (TSS), nitrate, chloride, and *E. coli*.

However, several of the lakes are meso-eutrophic to eutrophic systems, which can likely be attributed to their small size, proximity to highly developed areas, and nutrient inputs from both non-point and point sources. Point source inputs are primarily private and public waste water treatment plant discharges, sanitary sewer overflows and waste water treatment plant by-passes. Non-point sources of total phosphorus in urban areas include failing septic systems, yard and golf course fertilizers, agricultural activities such as riding stables, and pet and waterfowl droppings. Chloride concentrations are above the Canadian Water Quality Guidelines in a three lakes (First, Banook and Micmac) and this is likely due to street and parking lot runoff containing dissolved winter road salt. Impervious surfaces, such as paved streets, parking lots and sidewalks tend to increase road runoff, which in turn increases chloride concentrations in nearby waterbodies relative to undeveloped areas. These results suggest that water quality has already been degraded in some of the smaller lakes that are in close proximity to highly developed areas (e.g., Lisle Lake, Duck Lake and Beaver Pond). Future development must be planned in recognition that urbanization may have a significant impact on the water quality of downstream waterbodies.

Water Quality Objectives

The water quality objectives are based upon a scientific understanding of the Shubenacadie Lakes subwatershed and widely accepted standards of water quality. These recommended water quality objectives will be used by HRM to establish the acceptable standards that HRM and the public agree will achieve the long term management goals for the Shubenacadie Lakes subwatershed.

The parameters most likely to be negatively influenced as a result of land use changes are: total phosphorus, nitrate, ammonia, total suspended solids, chloride and *E. coli*. Given their sensitivity to development, these parameters were selected as "indicators" upon which to base water quality objectives.

All indicator parameters, with the exception of total phosphorus, have definitive Canadian Water Quality Guideline (CWQG) limits. Because the CWQGs are set to protect the most sensitive species, and because water quality in the Shubenacadie lakes is currently better than these objectives, AECOM recommends that the CWQGs for nitrate, un-ionized ammonia, total suspended solids, and chloride be adopted for the Shubenacadie Lakes subwatershed. HRM currently uses the guideline of 200 CFU/100 mL for *E. coli* for body contact recreation, which is the same as the Health Canada value of 2000 *E. coli*/L. AECOM suggests this value is appropriate for the *E. coli* parameter.

With respect to phosphorus, Environment Canada (CCME 2004) provides a classification of trophic status for lakes and rivers. For the Shubenacadie Lakes subwatershed AECOM recommends building on this classification with each water body categorized into one trophic status based on existing conditions either measured or predicted based on model results. As a result, the management objective would be to meet or maintain the trophic status of a water body so the water quality objective for total phosphorus becomes the upper limit of the total phosphorus (TP) range indicated in the table below for each trophic state. This approach is consistent with the objectives of the 2006 Halifax Regional Municipal Planning Strategy, which seeks "to maintain the existing trophic status of our lakes and waterways to the extent possible."

Water Quality Objectives, Early Warning Alert Value and Proposed Evaluation Methodology for Alert Values for Total Phosphorus (µg/L) in Shubenacadie Lakes subwatershed

Lake	Trophic State Objective	Numerical Objective	Early Warning	Evaluation
Grand, Lewis	Oligotrophic	< 10 µg/L	9 µg/L	Based on 3 year running average
Charles, Micmac, Banook, First, Second, Third, Thomas, Fletcher, Tucker, Kinsac, Barrett, and Powder Mill	Mesotrophic	< 20 µg/L	15 µg/L	
Loon, William, Rocky, Springfield	Mesotrophic	< 20 µg/L	18 µg/L	
Cranberry	Mesotrophic	< 20 µg/L	20 µg/L	
Fenerty	Meso-Eutrophic	22 µg/L	22 µg/L	Fenerty should be maintained at its current average phosphorus concentration of 22 µg/L.
Duck and Lisle	Both Duck (43 µg/L) and Lisle (50 µg/L) are eutrophic lakes. Water quality should not be allowed to deteriorate further and should be improved where feasible.			
Miller, Beaverbank, Fish and Beaver Pond	Insufficient data exist. More sampling is required to set WQO for these lakes.			

Additional work will be completed to meet the remaining objectives of Regional Plan Policy E-17 for presentation in the final report. The potential effects of future land use changes on the trophic state and phosphorus concentrations in the primary lakes will be assessed using a Lake Capacity Model (LCM) that has been employed previously in the Halifax region. While the LCM addresses nutrient loading in a steady state manner by accounting for changes in land use, it does not address the dynamic nature of pollutant delivery nor the benefits of stormwater management best practices in an adequate and time dependent manner. Consequently, AECOM will also adapt the U.S. Environmental Protection Agency's StormWater Management Model management model to predict phosphorus loads within the Shubenacadie Lakes subwatershed. These models will also be used to assess the benefits that could be achieved from mitigation measures to reduce the impacts of development, reduce or maintain phosphorus loadings and maintain or improve lake trophic state. The final report will also recommend a cost effective water quality monitoring program in the light of existing data and water bodies that need to be assessed as a result of planned development.

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1. Introduction

Halifax Regional Municipality (HRM) in 2002 adopted the HRM Water Resources Management Study (Dillon Consulting Ltd. 2002) as a basis for developing watershed planning policies. Following from this study, HRM uses the watershed as the basic unit of land use planning, since the critical environmental functions and features within a watershed are linked together, and all may be affected by land use decisions within the watershed. This approach is consistent with the provincial Water Resources Management Study, which adopts a watershed-based Integrated Water Management approach to water protection and conservation (NSE 2010).

The 2006 Halifax Regional Municipal Planning Strategy (also called the Regional Plan) requires that watershed studies are undertaken before a Community Vision exercise and in advance of community design work undertaken through the secondary planning process. In response to requests by property owners of the “Port Wallis Lands” to begin planning for new serviced communities through HRM’s secondary planning process, Regional Council has directed that a watershed study be completed for the Shubenacadie Lakes subwatershed.

AECOM was contracted by HRM in August 2011 to complete the Shubenacadie Lakes subwatershed Study in two phases:

1. present a series of recommended water quality objectives for key receiving water bodies within the watershed in a Preliminary Report; and,
2. address the remaining objectives of Regional Plan Policy E-17 in a final report.

The water quality objectives contained in the Preliminary Report will be presented to the public and to Regional Council for comment so that questions and clarifications can be addressed in the final report.

1.1 Watershed Study Planning Context

As noted, the Regional Plan requires that watershed studies are undertaken in advance of community design work undertaken through the secondary planning process. In response to requests by developers of the “Port Wallis Lands” to begin the secondary planning processes, Regional Council has directed that a watershed study be completed for the Shubenacadie Lakes subwatershed.

Section 2.3 of the Regional Plan states:

> *“Although it is not the intention of this Plan to achieve pristine conditions for every watershed, there is a desire to achieve public health standards for body contact recreation and to maintain the existing trophic status of our lakes and waterways to the extent possible. Our lakes, waterways and coastal waters should not be further degraded.”*

The final report of the watershed study will identify areas that are suitable and not suitable for development within the watershed, determine the amount of development that can be accommodated while maintaining water quality objectives in the receiving watercourses, recommend measures to protect and manage quantity and quality of surface and groundwater and recommend regulatory controls and management strategies to achieve the desired water quality objectives.

This watershed study complements the Halifax Regional Wastewater Management Functional Plan, currently underway, which will provide Halifax Water with a management plan for the existing wastewater system and identify upgrades required to comply with new performance guidelines adopted by the Canadian Council of Ministers of the

Environment (CCME 2009). Based on these guidelines, the Federal Government has published draft Wastewater System Effluent Regulations, which are expected to be finalized in 2012. The watershed study also incorporates and builds upon information presented in the Water Quality Monitoring Functional Plan, mandated by the Regional Plan's Policy E-18 and completed in 2009 (Stantec 2009, updated 2010).

1.2 Study Objectives

The primary objective of the Shubenacadie Lakes Subwatershed Study, as expressed in Regional Plan Policy E-17, is to "determine the carrying capacity of the watersheds to meet the water quality objectives which shall be adopted following the completion of the studies." Carrying capacity is a measure of the watershed's ability to accommodate inputs from both man-made and naturally occurring pollutant sources without experiencing a significant decline in water quality and ecological function.

The ultimate objective of the study is to provide a number of guidelines and recommendations for the planning, design and implementation of new developments that will protect the water quality from further degradation. More specifically, the objectives of watershed study are listed in Policy E-17 of the Regional Plan:

1. Recommend measures to protect and manage quantity and quality of groundwater resources;
2. Recommend water quality objectives for key receiving watercourses in the watershed;
3. Determine the amount of development and maximum inputs that receiving lakes and rivers can assimilate without exceeding the water quality objectives recommended for the lakes and rivers within the watershed;
4. Determine the parameters to be attained or retained to achieve marine water quality objectives;
5. Identify sources of contamination within the watershed;
6. Identify remedial measures to improve fresh and marine water quality;
7. Recommend strategies to adapt HRM's stormwater management guidelines to achieve the water quality objectives set out under the watershed study;
8. Recommend methods to reduce and mitigate loss of permeable surfaces, native plants and native soils, groundwater recharge areas, and other important environmental functions within the watershed and create methods to reduce cut and fill and overall grading of development sites;
9. Identify and recommend measures to protect and manage natural corridors and critical habitats for terrestrial and aquatic species, including species at risk;
10. Identify appropriate riparian buffers for the watershed;
11. Identify areas that are suitable and not suitable for development within the watershed;
12. Recommend potential regulatory controls and management strategies to achieve the desired objectives; and
13. Recommend a monitoring plan to assess if the specific water quality objectives for the watershed are being met.

1.3 Scope of the Preliminary Report

In order to achieve the Preliminary Report objectives, the following tasks were completed:

- The study scope was presented to the Dartmouth Lakes Advisory Board, the Shubenacadie Canal Commission and the Shubenacadie Watershed Environmental Protection Society in November 2011 to explain the work to be undertaken and to hear any concerns or issues;

- Existing water quality data were reviewed and a supplementary sampling program was undertaken to establish a baseline of the water quality in key water courses;
- A review of other jurisdictional approaches to setting water quality objectives for lakes was undertaken. Based on this information, an approach was developed for recommending water quality objectives for the Shubenacadie Lakes subwatershed. Water quality objectives were set for each lake for total phosphorus and for the watershed as a whole for nitrate, un-ionized ammonia, total suspended solids, chloride and the bacteria *Escherichia coli*, commonly called *E. coli*;
- In order to address an information gap of past monitoring within the Shubenacadie Lakes subwatershed, a limited flow monitoring program was initiated to help calibrate the nutrient and stormwater loading models used to evaluate water quality objectives; and
- Using HRM's LiDAR data, spatial modelling was completed for the watershed. The LiDAR data were used to delineate watershed and sub-watershed boundaries and to identify vernal ponds, wetlands and intermittent streams. The LiDAR data were also critical to the pre- and post-development analysis of land uses and impervious surfaces for use in the nutrient modelling.

1.4 Scope of the Watershed Study (Final Report)

Upon completion of the Preliminary Report, additional work will be undertaken to meet the remaining objectives of Policy E-17 for presentation in the final report, including:

- Previous steady state nutrient loading models used within the watershed will be reviewed in order to identify any required changes to the assumptions and model variables on which the models were based in order to re-run these models;
- A steady state nutrient loading model (Lake Capacity Model [LCM]) will be used to determine predicted in-lake phosphorus concentrations and thus predicted lake trophic state. These models will be calibrated against current measured total phosphorus (TP) in-lake concentrations;
- A standard dynamic 1-dimensional flow model (Stormwater Management Model [SWMM]) will be developed for the watershed and calibrated to the current measured TP in-lake concentrations;
- Land use within the watershed will be spatially modelled to provide details on current land use within each sub-watershed and to project land use forward for three scenarios: "existing conditions, "HRM authorized developments" for areas where development agreements have been approved or are in the process of being approved, and "Proposed Development" encompassing the Port Wallis Lands, which are designated by the Regional Plan for potential future development;
- The steady state and dynamic models will be used to evaluate total phosphorus loadings to the lakes within the watersheds under the current and longer term development scenarios in order to predict the impacts on the lakes when compared to the recommended water quality objectives. This step will include assessing the opportunities for remedial actions to protect or recover lake water quality such that water quality objectives are met;
- The opportunities for land exchanges and alternative development scenarios will be assessed to better protect the water resources;
- The opportunities for the application of stormwater management tools to reduce loadings of sediment and phosphorus to the water bodies both within new developments and as options for retrofitting built areas will be evaluated;

- A cost effective and environmentally sound water quality monitoring program for the watershed in the light of existing data and water bodies that need to be assessed as a result of planned development will be recommended;
- A water quantity monitoring program to better calibrate the stormwater model and to confirm the predicted impacts of development on flow and pollutant loading will be recommended; and,
- The potential for existing control structures to affect water quantity and quality in downstream watercourses will be evaluated. The evaluation will provide a quantitative assessment of the impact on water quality measures and a qualitative assessment of the sophistication of management needed to be effective.

The draft final report and the final report will also incorporate the changes to the preliminary report based on discussions with the Dartmouth Lakes Advisory Board, the project Steering Committee and responses from public reviews.

1.5 General Description of the Shubenacadie Lakes Subwatershed

The Shubenacadie Lakes subwatershed is largely located within HRM, stretching north from Cranberry Lake in the former City of Dartmouth along the historic Shubenacadie Canal system through Fall River and Wellington to the outlet of Grand Lake. The watershed also extends northwest through Waverly, Windsor Junction and Beaverbank to Springfield Lake. Covering approximately 388 km^2, the Shubenacadie Lakes Watershed Area is an ecologically diverse area of forests, freshwater lakes, streams and wetlands (Figure 1).

In general, surface water flow through the watershed is from the south to north. Lake Charles is the headwater lake of the Shubenacadie Lakes watershed but discharges both north and south due to the presence of the Shubenacadie Canal control structures at its north and south ends. Historical reports suggest that approximately 60% of its discharge flows north to William and on to Lakes Thomas, Fletcher and Grand (pers. comm. B. Hart SCC). The remaining 40% of the discharge from Lake Charles flows south to Lakes Micmac and Banook, and ultimately to Dartmouth Cove in Halifax Harbour[1]. Grand Lake is also fed by Second, Third and Beaverbank Lakes via Kinsac Lake, while Lake William receives discharge from First Lake, Rocky Lake and Powder Mill Lake.

Within the watershed, water level control structures associated with the historic Shubenacadie Canal are found at the south end of Lake Charles (Locks 2 and 3 in Shubie Park, Dartmouth), at the north end of Lake Charles (the Portobello Inclined Plane), between Lake Thomas and Fletchers Lake (Lock 4, partially collapsed) and connecting Fletchers Lake to Grand Lake (Lock 5, restored). Lock 1 is located at the outflow of Lake Banook, upstream of Sullivan's Pond. A gate in Lock 1 is used by Halifax Water to manage and maintain water levels in Lake Banook. At the other end of the watershed, Lock 6 is located in the Shubenacadie River approximately 2 km downstream from Grand Lake.

The watershed hosts a range of land uses from urban and commercial developments in the south to more rural settlements and open space / natural environments further north (Figure 2). Historical residential development in much of the watershed is associated with the numerous lakes which characterise this area. Villages within the watershed include Waverly, Beaverbank, Windsor Junction, Fall River and Wellington. To a certain extent, these villages have blended together as development has in-filed forested areas between them, but much of the central and northern portions of the watershed retain a rural character. Fall River is designed by HRM as a Rural Commuter Centre, with the goal of focusing low and medium-density development around a hub along Highway 102 that is within easy commuting distance of downtown Halifax and Dartmouth. This area will have a blend of commercial, institutional and recreational uses and HRM encourages open space design subdivisions. Residences range from older homes and cottages to modern suburban homes and low rise apartment buildings.

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[1] *Survey and flow data collected for this study suggest a large proportion of the water flows south, rather than north.*

Figure 1. Shubenacadie Lakes Subwatershed

Figure 2. Land Zoning

Commercial activity includes light manufacturing, small businesses, mini-strip malls, grocery and convenience stores, restaurants, and medical and dental facilities. Schools, community and recreation centres and places of worship are also present in the developed areas.

The watershed also hosts the Rocky Lake Quarry southwest of Lake William and the Conrad Brothers Quarry east of Lake Charles. More recently, an application was made to develop new aggregate quarries off Perrin Drive in Fall River and off the Old Guysborough Road near the Stanfield International Airport. The watershed has also experienced gold mining in the past (the Waverley and Montague Mines), although no mines are currently active within the watershed. Finally, two golf courses are located within the watershed: New Ashburn Golf Club on the shores of Kinsac Lake and Oakfield Golf and Country Club, which borders Fish Lake and Grand Lake.

Over the past few decades, the watershed has experienced significant development pressure, mainly in the form of residential subdivisions, and continued growth unconnected to municipal water and sewer services is expected. Surface water quality in the area is vulnerable to the effects of development and declines in water quality have been documented over the past 30 years (Vaughan Engineering 1993; Scott *et al.* 1991). Key issues related to water quality in include poorly maintained and malfunctioning residential septic systems, depletion of groundwater resources and the impacts of stormwater runoff from suburban development.

1.6 Structure of the Preliminary Report

This watershed study report is organized into the following principal sections:

Section 1: ....Introduction. This section of the report introduces the study and provides the overall context, scope and approach to the work.

Section 2: ....Existing Environmental Conditions. This section describes climate, geology, groundwater, terrestrial and aquatic ecological resources and surface water resources and includes a brief discussion of the water quality data available for the analysis of these resources.

Section 3: ....Spatial Data Processing. Section 3.0 describes spatial data acquisition and processing (GIS and mapping) that form the foundation for the analysis of future development on the natural water resources of the watershed. Included here are discussions of the existing land use and an overview of the development scenarios used in the modelling of future impacts. This section also includes a discussion of the physical and biophysical constraints associated with development in the subwatershed.

Section 4: ....Receiving Water Quality Objectives. This section reviews various jurisdictional approaches and their water quality objectives. Key parameters are selected for analysis and objective setting based on the fact that they are known to be strongly influenced by urbanization. The recommended water quality objectives are set based on the recent water quality data from the watershed in conjunction with guidance from these sources of information.

2. Existing Environmental Conditions

2.1 Climate

The Shubenacadie Lakes subwatershed is slightly inland from the immediate climatic influence of the Atlantic Ocean (NSDNR 2003). Located largely within the Eastern Ecoregion, which stretches from Bedford Basin to Guysborough, the Shubenacadie Lakes subwatershed is characterized by warmer summers and cooler winters than those of the Atlantic Coastal Ecoregion. The mean winter temperature is colder (-5.0 C) than the Western Ecoregion where the mean winter temperature is -3.5°C (Webb and Marshall 1999). Within the Shubenacadie Lakes subwatershed, the mean annual temperature is approximately 6.3°C, while the mean summer temperature is 16°C and the mean winter temperature is -4°C. The total annual average precipitation is 1,452.2 mm.

As inputs to the numerical models, climate and precipitation normals between 1971 and 2000 were obtained from Environment Canada's Stanfield International Airport meteorological station. These data are presented in Table 1.

Table 1. Temperature and Precipitation Climate Normals

Air Temperature Climate Normals (1971-2000)			
Month	**Daily Maximum (°C)**	**Daily Minimum (°C)**	**Daily Average (°C)**
January	-1.2	-10.7	-6.0
February	-1.1	-10.2	-5.6
March	3.0	-5.8	-1.4
April	8.4	-0.5	4.0
May	15.0	4.5	9.8
June	20.3	9.6	15.0
July	23.6	13.5	18.6
August	23.3	13.5	18.4
September	18.8	9.3	14.1
October	12.7	3.8	8.3
November	639	-0.7	3.1
December	1.4	-7.1	-2.8
Year	**11.0**	**1.6**	**6.3**

Precipitation Climate Normals (1971-2000)			
Month	**Rainfall (mm)**	**Snowfall (mm)**	**Precipitation (mm)**
January	100.6	54.6	149.2
February	69.0	50.1	114.4
March	96.4	41.1	134.5
April	96.1	20.9	118.3
May	106.2	3.3	109.7
June	98.3	0.0	98.3
July	102.2	0.0	102.2
August	92.7	0.0	92.7
September	103.6	0.0	103.6
October	126.4	2.3	128.7
November	133.0	14.4	146.0
December	114.5	43.9	154.8
Year	**1238.9**	**230.5**	**1452.2**

Wind normals over the same period were obtained from Environment Canada's Shearwater Airport meteorological station (Table 2).

Table 2. Wind Speed and Direction Normals

Wind Climate Normals (1971-2000)			
Month	**Speed (km/h)**	**Most Frequent Direction**	**Maximum Hourly Speed (km/h)**
January	18.1	W	83.0
February	17.7	NW	97.0
March	17.8	NW	78.0
April	16.9	N	85.0
May	14.0	S	72.0
June	12.8	S	77.0
July	11.3	S	87.0
August	11.1	SW	60.0
September	12.8	SW	97.0
October	14.8	W	80.0
November	16.5	NW	89.0
December	17.7	W	89.0
Year	**15.1**	**W**	

Lake evaporation normals were obtained from Environment Canada’s Truro Climate station (Table 3). Truro hosts the closest Environment Canada monitoring station with long-term evaporation data.

Table 3. Evaporation Normals

Month	Lake Evaporation (mm)
January	0
February	0
March	0
April	0
May	2.9
June	3.4
July	3.6
August	3.2
September	2.3
October	1.3
November	0
December	0
Year	0
Total	**16.70**

2.1.1 Climate Change

The emission of atmospheric greenhouse gases (GHG) is inducing a series of climatic changes, most notably an increase in global mean temperatures and an intensification of the global hydrological cycle (Meehl 2007). To assess the magnitude of these changes and understand their impact on climate, modelling teams around the world have created numerical models that couple atmospheric circulation, the ocean and surface climatological processes. Given an initial climatic state and the evolution of GHG concentrations, these Global Climate Models (GCM) simulate the Earth’s climate over hundreds, if not thousands of years.

Typically, models contributing to the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report have a horizontal resolution of about 250 km, meaning that changes to local weather patterns cannot be adequately described by GCMs. Rather, GCMs strive to accurately reproduce climate statistics, the large scale mean state and seasonal cycle of climatic variables, rather than local weather conditions (Randall 2007).

The consequences of temperature change on river runoff patterns and quantities are not yet clearly determined. Rainfall and evaporation patterns (spatial and temporal) will be modified and it is expected that the variability of extreme events (floods and droughts) will increase, but it is not possible to quantify this change (Pancura and Lines 2005). Analysis of the effect of climate change on hydrologic and water quality in temperate urban streams is further complicated by the usually much stronger signal resulting from direct human activities such as land clearing and urbanization.

Although HRM is taking a risk management approach to managing the effects of climate change anticipated within the municipality over the next 100 years (HRM 2007), any measurement of a hydrologic response of the Shubenacadie Lakes watershed is not possible due to the absence of historical flow measurements within the watercourses. Given this, impacts from climate change are assumed to be masked by anthropogenic changes for the 20 year time horizon of this project and so the effects of climate change were not analyzed in this study.

2.2 Geology and Hydrogeology

Groundwater resources were recently assessed and described in great detail in the Fall River – Shubenacadie Lakes Watershed Study, completed in July 2009. The work was undertaken on behalf of HRM by Jacques Whitford (now Stantec) in collaboration with ABL Environmental Consultants Ltd. and the Centre for Water Resources Studies at Dalhousie University. A critical component of their report was the Groundwater Resources Study, which described the physical hydrological setting, groundwater quality, aquifer characteristics and potable groundwater supplies within the Shubenacadie Lakes watershed. In the geology and groundwater descriptions below, AECOM has relied extensively on Jacques Whitford's' comprehensive report since the basic geology and groundwater resources have not changed since their 2009 report was completed. The reader is referred to Jacques Whitford's excellent summary tables of groundwater pumping data, water well construction characteristics and local aquifer properties.

2.2.1 Topography and Drainage

Figure 3 illustrates the surficial geology of the Shubenacadie Lakes subwatershed. The term surficial geology refers to the loose deposits of soil, sand, gravel and other material deposited on top of the bedrock. These materials generally consist of glacial till (a mix of clay, sand, gravel and boulders) combined with alluvial deposits (left by moving water) and lacustrine deposits (deposited as lake sediments) (Utting 2011).

The most recent glaciation ended approximately 12,500 year ago when the glaciers that had covered Nova Scotia and scoured the soil and bedrock of the countryside receded to the north (Goodwin 2004). The surficial materials left by glaciers are deposited on much older, durable bedrock which has been folded and fractured since it was originally deposited. The structural features of the bedrock, combined with the overlaying glacial deposits, control the surface water flow patterns and direction within the watershed.

Drainage follows the northeast-southwest bedrock trend of the folded metamorphosed sedimentary rocks that underlay much of the watershed. A series of northwest trending fault lines is superimposed on this trend, which may be responsible for the orientation of certain lakes and streams (Jacques Whitford 2009). At the northern extremity of the watershed, the area northeast of Grand Lake is underlain by much younger, softer sediments and the drainage patterns are less distinct.

2.2.2 Surficial Geology

Glacial Till

Much of the watershed is underlain by flat to undulating glacial till, although a series of the drumlin hills are present in the area stretching from Beaverbrook thorough Fenerty Lake to Springfield Lake. Drumlins are low, smoothly rounded, elongate oval mounds of glacial till. The thickness of the glacial till typically averages a few metres, but may exceed 20 m where drumlin hills are present (Jacques Whitford 2009).

The Lawrencetown Till covers much of the northern portion of the watershed, and is derived from sedimentary rocks of the Windsor lowlands further north. The reddish-brown Lawrencetown Till typically has low hydraulic conductivity (it does not easily transmit groundwater) and is easily eroded by surface water runoff.

The till cover on the remainder of the watershed is of two types: a light brown slate till and a light blueish grey quartzite till (Stea and Fowler 1980). The slate and quartzite tills are typically thin, loosely compacted and contain angular cobbles of the parent bedrock. The slate till is not common but can be found near Waverly between Lake Thomas and Rocky Lakes, south of Springfield Lake and southwest of the Stanfield International Airport. The quartzite till is found west of Grand Lake and underlies most of the southeast portion of the watershed from Lake Thomas to Lake Charles.

Figure 3. Surficial Geology

Jacques Whitford (2009) noted that the till aquifer in Halifax Country exhibits slightly higher yield potential than wells drilled in till in other parts of the province. This information is based on only five wells tested on McNabbs Island and at Upper Lawrenecetown and so may not be representative of glacial tills within the watershed.

Stratified Sand and Gravel Deposits

Although no stratified sand and gravel are mapped at surface, groundwater well records suggest that these deposits may underlay glacial till deposits at the bedrock contact. These units may have a moderate to high hydraulic conductivity by are generally suitable only for individual residential requirements and modest housing densities (Jacques Whitford 2009).

Alluvial Deposits

Water-lain or alluvial deposits are present along the floodplains of major watercourses and their tributaries within the watershed. These materials were deposited during flood cycles when past flow rates were much higher due to glacial meltwater. In some areas, these flood deposits continue to be deposited in modern times. Alluvial deposits consist of fine to medium grained sands with or without finer materials. When present, the finer materials indicate more quiet-water depositional environments. These deposits typically have moderate hydraulic conductivity and are generally not very thick. Alluvial deposits are found west of Kinsac Lake and along the Shubenacadie River near the outlet of Grand Lake.

Weathered Bedrock

Area of shallow surficial cover with outcrops of exposed bedrock are present between Fletcher and Kinsac Lakes south of Wellington (granite bedrock), west of Grand Lake (quartzite bedrock), east of Fall River (granite bedrock), east of Wellington (slate bedrock), and southeast of Lake William (quartzite bedrock). This fractured bedrock can be highly permeable, allowing direct and rapid transport of surface water (including contaminants) to the bedrock aquifer.

2.2.3 Bedrock Geology

Figure 4 illustrates the bedrock geology underlying the Shubenacadie Lakes watershed.

Most of the watershed is underlain by northeast-trending fractured and metamorphosed slate and quartzite of the Meguma Group of rocks. These rock units were later intruded by younger Devonian-age granite which further metamorphosed the Meguma Group rocks. As noted above, even younger sedimentary rocks consisting largely of shale, sandstone gypsum and limestone of the Windsor Group occur in the extreme north of the watershed, northwest of Grand Lake (Keppie 2000)/

In this area, the Meguma Group is composed of the Halifax Formation (generally slate) and the Goldenville Formation (generally quartzite) (Keppie 2000). The Halifax Formation slate is among the youngest of the Meguma Group rocks, and was the last to be deposited directly on top of the older Goldenville Formation quartzite. The slate underlies approximately 45% of the watershed. This metamorphosed sedimentary rock was originally a fine grained shale (a sedimentary rock composed of clay and silt) but has been transformed through heat and pressure into a dense compact fractured slate. Three layers of slate cross the watershed in northwest – southeast trending bands (Figure 4). The underlying Goldenville quartzite is present beneath approximately 45-50% of the watershed and occupies much of space between the bands of Halifax slate. The quartzite, a metamorphic rock, was originally composed of sandstone and silty sandstone before undergoing metamorphism and transformation into the durable quartzite. The repeated metamorphic events are responsible for the historic gold mineralization in the Waverly area. The gold is mineralogically associated with arsenic sulphide (arsenopyrite), which results in elevated arsenic concentrations in groundwater (Grantham 1976; Bottomly 1984).

Figure 4. Bedrock Geology

The slates of the Halifax Formation host sulphide minerals in the form of pyrite and pyrrhotite (Fox *et al.* 1997). Excavation of these sulphide-bearing rocks can result in acid rock drainage (ARD) which occurs when sulphide minerals exposed to the air oxidize to produce sulphuric acid. ARD can cause serious direct ecological impacts to aquatic habitats and may enter the groundwater flow region, eventually contaminating wells (HRM 2011). While newly exposed slates will oxidize rapidly, acid generation decreases as the iron sulphide minerals are transformed to iron oxide (Fox *et al.* 1997). Within the Shubenacadie Lakes watershed, excavation of ARD-generating rock remains a serious potential problem for surface and groundwater quality in the central and an northern areas: North Beaverbank, Beaverbank, Wellington Station, Fletchers Lake and the airport.

Granite is the least common bedrock type, occupying approximately 5% of the watershed. This intrusive rock was forced into the Meguma Group sedimentary rocks causing fracturing along the contact. Jacques Whitford (2009) reports that this fracturing may enhance well yields along the contact (Porter 1982) and may also result in increased mineralization within the groundwater. Granite can be seen in the Fall River area between Fletcher and Kinsac Lakes and is also found in at the extreme eastern side of the watershed, east of Soldier Lake.

The Windsor Group of rocks is present at the northern extremity of the watershed north and west of Grand Lake and occupy approximately 3% of the watershed. These younger sedimentary rocks are considerably different from the older more durable metamorphosed Meguma Group units. The earliest of these marine sedimentary rocks consist of anhydrite, salt, marine dolostone and limestone. Later deposits consist of gypsum, siltstone, marine limestone and dolostone.

2.2.3.1 Groundwater Recharge

Groundwater recharge is the process by which surface water falling as precipitation within a watershed infiltrates through the soil to reach and “recharge” the groundwater aquifer. The permeability or the ability of soils to convey groundwater flow is the most important factor influencing groundwater recharge rates across the watershed. Although groundwater recharge will occur everywhere within a watershed, from a practical point of view, only thick, higher permeability soils can transmit enough recharge to support a groundwater resource. Once infiltrating surface water reaches the water table it moves horizontally (and can move vertically) from areas of high elevation to areas of low elevation – typically from the high-elevation watershed divide towards the various lakes and streams situated at the lowest topographic elevation. On a local scale, groundwater within surficial deposits flows laterally to the nearest spring, lake, stream or wetland.

Groundwater is a critical natural resource since it eventually seeps into lakes, streams and wetlands where cold, clean groundwater is a key factor in maintaining the ecological health of these systems. In addition, groundwater is used as a potable water source by many residents within HRM, who depend on its reliability and high quality.

In assessing changes to water quality within a watershed, recharge to groundwater is an important consideration since high density residential and commercial development tends to reduce the recharge to groundwater through the construction of impermeable buildings and pavement. This may restrict the groundwater supply to wetlands and streams, causing ecological and water quality changes to important habitats. At the same time, reduction in recharge may result in less availability for residential users, or changes in water quality due to blasting, excavation and dewatering activities.

Groundwater recharge varies seasonally, with the highest rates occurring in the spring during snow melt and spring rainfall events and the lowest rates occurring in the winter months when most precipitation falls as snow. In Nova Scotia, the climate is moderate in the winter months and precipitation falls as both rain and snow. Under these conditions, the seasonal variation in recharge rates is less pronounced than in areas where winter precipitation accumulates as snow and melts over a short period in the springtime.

As noted in Jacques Whitford (2009), groundwater flow in Nova Scotia occurs on the intermediate and locate scale, with typical distances between points of recharge (where the bedrock aquifer is receiving water) and points of discharge (where the aquifer releases water to lakes, streams and springs) is less than a few kilometres (Lin 1975). They go on to suggest that the maximum distance between recharge and discharge within the watershed is in the range of 3 to 5 km. At a more regional scale, recharge to deep bedrock aquifers within the Shubenacadie watershed may originate in the Mount Uniacke area, outside of the watershed boundary.

Deep groundwater recharge is restricted by the low permeability of the bedrock. Thick sequences of glacial materials that can host extensive and productive aquifers are generally not present in the Shubenacadie watershed. Given that these thick deposits often contribute infiltration to deeper bedrock aquifers, it is expected that the percentage of groundwater recharge that reaches deep geological units is very low.

In general, glacial tills are considered aquitards, which inhibit significant infiltration to deeper soil or rock aquifers below the till cover. As aquitards, most of soils developed on glacial tills within the Shubenacadie Lakes watershed show infiltration rates of 250 mm or less, with the main component of groundwater movement occurring as shallow lateral flow toward streams and lakes. In areas with very thin overburden, recharge is controlled by the underlying very low permeability bedrock geology. The main function of the surficial till units will be to hold precipitation near surface long enough to prevent rapid runoff.

Areas with soil cover consisting of alluvial and lacustrine sediments cover an estimated 5% of the watershed, and have the highest potential groundwater recharge, exceeding 350 mm/year. Recharge through glaciofluvial outwash and hummocky till representing 4% coverage in the watershed represents the next highest potential groundwater recharge rates of 250 to 350 mm/year. Areas where coverage consists of drumlin deposits represents the highest coverage relative coverage within the watershed at 41% of coverage having potential groundwater recharge rates of 140 – 250 mm/year. Areas dominated by till deposits consisting of till blanket or veneer (24% coverage) and areas where bedrock is exposed or covered by thin soils (12% coverage) have potential groundwater recharge rates in the order of 70 to 140 mm/year. Urbanized areas exhibit the lowest potential recharge rates, typically less than 70 mm/yr, due to the impermeable surfaces resulting from pavement and buildings.

A water budget model was developed for the Shubenacadie Lakes watershed to determine the relative proportion of water that infiltrates as recharge to groundwater aquifers compared to the remaining water available for surface runoff to streams, lakes and wetlands. Based on the water budget modelling presented in the final report, groundwater recharge represents a relatively small proportion of the total water budget for the watershed. Approximately 33,855,823 m^3/yr (10%) will infiltrate the ground as recharge and the remaining 318,144,673 m^3/yr (90%) will become surface runoff. The surficial till units and drumlin deposits are not thick enough to hold capture precipitation and rather they function to hold precipitation near surface long enough to prevent rapid runoff. When rainfall or snow melt encounters the bedrock, most of the precipitation will runoff via overland flow into the surface watercourses, rather than infiltrate into the ground.

2.2.3.2 Groundwater Well Characteristics

The ability of a rock formation to yield water depends on the inter-connectedness of the pores spaces and fractures within the aquifer. How quickly the water flows is partly dependent on how big the pores are, how interconnected the pores or fractures are, and how much energy (head or water pressure) is available to move the water through the aquifer. Primary porosity refers to the porosity associated with water-filled pore spaces between the individual grains, while secondary porosity in bedrock is formed as a result of secondary fractures, joints, bedding planes and faults. Massive crystalline rocks such as granite generally have very little, if any, primary porosity and water typically moves along fractures. In granite, groundwater flow to wells relies on openings developed in the bedrock aquifer through fracturing, faulting and weathering.

Municipal water supply services do not extend across the Shubenacadie Lakes subwatershed and so many residents rely on groundwater wells to meet their potable water needs. In general, municipal water services have been extended to certain areas near Lake Charles, Rocky Lake, First Lake, Second Lake and Third Lake, as well as in the Waverly/Lake Thomas area. Water service has also been provide along Beaverbank Road from Middle Sackville.

An excellent summary of groundwater quantity and existing groundwater supplies is presented in Jacques Whitford (2009). Using the Nova Scotia Water Well Records database, the authors identified more than 3,000 wells in or near the Shubenacadie Lakes watershed and presented the well statistics in 13 communities within the watershed. This information is summarized below and will be presented in more detail in the final report.

Well depths range from less than 50 ft. deep (23/2789 wells) to more than 600 ft deep (3/2789 wells) but most wells are 101 to 250 ft deep (1584/2789 wells). Typical well yields are low, ranging from 0.1 to 5 imperial gallons per minute (ipgm) but at least 14 wells produced more than 50 ipgm. Approximately 60% of the wells are installed in the Halifax Formation slate aquifer, 21% in the Goldenville Formation quartzite, 7% in granite and the remaining 3% in sand and gravel or gypsum aquifers. In the Fall River area, the mean well depth is 62.5 m and the mean well yield is 2 igpm. When the wells from all communities are compared, it appears that higher mean well yields (>3 igpm) are available to the north at Horne Settlement, Oakfield, and Frenchman's Road and at Middle Beaverbank/Kinsac, while lower mean yields (<2 igpm) are found at Lewis Lake, Fall River and Fletchers Lake.

2.2.3.3 Groundwater Quality

Using historical and recent water quality data from pumping tests, NSE case investigations, and private information from past projects in the watershed, Jacques Whitford (2009) was able to compile general water quality characteristics of each of the aquifers exploited by residential wells in the watershed. These characteristics are summarized in Table 4. Jacques Whitford (2009) was also able to summarize the properties of each of these aquifers by reviewing 28 pumping tests from the NSE Pumping Test Inventory and combining the information with "a detailed statistical analysis of 410 pumping tests for the six identified aquifers" The pumping test database (Halifax County) includes: 34 drilled wells in Halifax Formation slate, 45 drilled wells in Goldenville Formation quartzite, 47 drilled wells in granite, 3 wells in the Windsor Group rocks, 5 dug wells in glacial till and 11 dug or screened wells in sand and gravel.

Table 4. Summary of Groundwater Quality, Shubencacadie Lakes Subwatershed Aquifers

Aquifer Type	Description	Water Quality	Reported Quality Issues
Glacial Till	• Silty to sandy till	• Hard when associated with Windsor Group rocks; can be corrosive	• Elevated iron, manganese, color, taste, turbidity
Sand and Gravel	• Stratified sand and gravel	• Soft, possibly corrosive, excellent quality	• May corrode plumbing, may exhibit elevated iron and manganese
Halifax Formation Slate	• Fractured metamorphic bedrock	• Moderately hard and alkaline, slightly corrosive, moderate TDS, calcium bicarbonate groundwater of moderate to good chemical quality	• Elevated iron, manganese and hardness
Goldenville Formation Quartzite	• Fractured metamorphic bedrock	• Moderately hard and alkaline, neutral, moderate TDS, calcium bicarbonate groundwater of good chemical quality	Elevated iron, manganese, arsenic and hardness. Arsenic is typically elevated above the 10 μg/L drinking water guideline
Granite	• Igneous bedrock	• Moderately hard, neutral, calcium-bicarbonate groundwater of good to excellent chemical quality	• Concentrations of arsenic, uranium, fluoride, iron, manganese can locally exceed drinking water guidelines. Radionuclides radon-222 and lead-210 have also been reported. Elevated iron and manganese and other metals may be found in wells drilled along the contact with Meguma Group rocks.

Aquifer Type	Description	Water Quality	Reported Quality Issues
Windsor Group Shale/Sandstone	• Sedimentary bedrock	• Hard to very hard, calcium bicarbonate groundwater of moderate to high TDS.	• Elevated strontium and sulphate may occurs in gypsum-hosted wells.
Gypsum	• Massive evaporate deposit	• Very hard, calcium sulphate groundwater with high TDS	• Typically non-potable

Note: TDS= total dissolved solids; μg/L = micrograms per litre
Source: Compiled from information presented in Jacques Whitford 2009

2.3 Ecological Resources

2.3.1 Resource Description

2.3.1.1 Ecological Land Classification

The Shubenacadie Lakes watershed is located largely within the Eastern Ecoregion, with a small portion of the watershed (northeast of Grand Lake) located in the Valley and Central Lowlands Ecoregion (NSDNR 2003). An ecoregion is an area that shares climate and certain physical features such as elevation, topography, bedrock type and vegetation. Ecoregions are further subdivided into ecodistricts, which are major landform types with geology and soils distinct from adjacent ecodistricts NSDNR 2003). The central portion of the Shubenacadie Lakes watershed falls within the Eastern Interior Ecodistrict, and is characterised by linear bedrock ridges with visible bedrock in areas where the glacial till is thin. Where the till is thicker, the ridged topography is less apparent and thick softwood forests occur. The ecodistrict is underlain by resistant Meguma Group quartzite and slate. The thickness of the till is variable across the ecodistrict, ranging from 1 - 10 m but averaging less than 3 m. The composition of the forests in this ecodistrict strongly reflects the depth of the soil profile (NSDNR 2003).

Western and northwestern portions of the watershed (Beaverbank and north toward Mount Uniake) are located within Eastern Drumlin Ecodistrict. Here, the well-drained drumlins and hummocks support pure stands of tolerant hardwoods, such as yellow birch, sugar maple and beech, which thrive on the crests and upper slopes. On the lower slopes, pure stands of red spruce are found around the drumlins. Between drumlins black spruce occupy the wetter, imperfectly drained soils. Formed by glacial ice movement the drumlins in this ecodistrict are orientated north-south indicating the route of the glaciers toward the Atlantic Ocean. The eastern drumlin fields are underlain by Meguma Group greywacke and slate, blanketed by fine-textured tills derived from these underlying and adjacent rocks. The drumlins are derived from carboniferous rocks from the north as well as material from the Cobequid Hills and Pictou-Antigonish Highlands. The soils are predominantly fine textured loams over sandy clay loams (NSDNR 2003).

Areas to the north near Grand Lake are located in the Central Lowland Ecodistrict. Much of the ecodistrict is fairly level with hummocky to undulating topography, with elevations seldom exceeding 90 m above sea level. This ecodistrict is underlain by shale, limestone, sandstone and gypsum. Most of the ecodistrict has fine textured soils comprised of loams, silts and clays. These deep, reddish-brown soils are characteristic of the ecodistrict and have been derived from the underlying sedimentary rock. Forests of the Central Lowlands Ecodistrict are predominantly softwood. Only on a few well-drained hills will pure stands of tolerant upland hardwood be found (NSDNR 2003).

Residential and commercial development is found in the central-west portions of the watershed. In the recent past, development tended to be clustered in villages and along the waterfronts of lakes, but residential development has now extended away from the lakeshores in many areas. The most highly developed lakes include Lewis and Springfield in the northwest, Tucker, First, Third, Kinsac, Thomas and Fletchers in the central part of the watershed, Rocky, William and Charles to the south, and (to a lesser extent) Grand in the northeast (Jacques Whitford 2009).

2.3.1.2 Wetlands and Upland Vegetation

<u>*Wetlands*</u>

Wetlands perform a variety of ecological functions. They provide important habitat for flora and fauna, provide natural corridors for the movement of wildlife, improve water quality, mitigate flooding and are valued for educational and aesthetic purposes by the public. In Nova Scotia, a wetland is defined as

> *"an area commonly referred to as marsh, swamp, fen or bog that either periodically or permanently has a water table at, near or above the land's surface or that is saturated with water. Such an area sustains aquatic processes as indicated by the presence of poorly drained soils, hydrophytic vegetation and biological activities adapted to wet conditions" (Government of Nova Scotia 2011).*

There are a number of wetlands within the Shubenacadie Lakes subwatershed, covering an area of approximately 186 km^2 (Figure 5). Wetland in the Shubenacadie Lakes subwatershed include swamp and marshland along the corridor between Grand and Kinsac Lakes, diverse wetland types around Beaver Bank Lake and north of Grand Lake, bog and fen wetlands in the northwest corner of the watershed, swamp and marshland areas east of Soldier Lake, and marsh and fen wetlands near Fall River (Jacques Whitford 2009).

Swamps are wetlands dominated by trees and shrubs. They are common along the drier portions of floodplains and riparian areas of rivers and streams. In shrub swamps, shrubs occupy more than half of the habitat with sedges as the typical ground cover. Grasses, sedges or rushes commonly occupy open areas. In wooded swamps, trees dominate, but there are usually several other levels of vegetation, including shrubs, ferns and a variety of herbaceous plants (Government of Nova Scotia 2011).

A marsh is a shallow-water wetland with water levels that fluctuate daily, seasonally or annually. Water may occasionally disappear completely, exposing sediments. High nutrient levels in these ecosystems lead to high plant productivity and rapid decomposition rates at the end of the growing season. Marshes that are seasonally dry usually accumulate very little organic matter, while more stable and permanently saturated marshes, can accumulate organic material to significant depths. Emergent aquatic plants such as rushes, reeds, grasses and sedges, as well as floating and submerged aquatic plants such as brown mosses, liverworts, and macroscopic algae are typical species found in marshes.

A bog is a wetland characterized by the accumulation of *Sphagnum* moss in the form of peat. The water table is generally at or just below the surface of the bog, and they can either be treed or treeless. The bog surface, which is raised or level with the surrounding terrain, is virtually unaffected by surface runoff or groundwater from the surrounding terrain. A fen is a ground or surface water-fed peatland saturated with water and typically dominated by sedges and brown mosses. Groundwater and surface water movement is a common characteristic that distinguishes fens from bogs. The vegetation in fens is more diverse than in bogs and is related to the depth of the water table and water chemistry. In general, sedges and mosses dominate wetter fens where the water table is above the surface. Shrubby trees such as tamarack, birch and willow are prominent in drier fens. Black spruce are common on the driest fen sites where moss hummocks provide microhabitats above the water table.

Upland Vegetation

Much of the Shubenacadie Lakes subatershed is undeveloped, with second growth natural forest cover found throughout the area (Figure 5). The general forest classification for the area is the Halifax Red Spruce-Hemlock-Pine Zone, underlain by granitic bedrock (Loucks 1968). Nearly half of forested areas are softwood dominated, closely followed by mixed wood areas, with hardwood-dominated forest covering the smallest portion of the watershed. Newer growth dominates the area east of Highway 102, while the remainder of the watershed hosts a full range of age classes (Jacques Whitford 2009).

Rare and Endangered Species

In Nova Scotia, plants and animals of conservation concern may be found:

1. Listed under the Federal *Species at Risk Act* (SARA)
2. Listed under the Nova Scotia *Endangered Species Act* (NSESA)
3. Listed as Vulnerable (Yellow) or Threatened (Red) by the Nova Scotia Department of Natural Resources (NSDNR)
4. Listed as rare (S1-S2) by the Atlantic Canada Conservation Data Centre (ACCDC)

Sixteen federally or provincially listed plant and fungi species are potentially present within the Shubenacadie Lakes subwatershed, while three of these species (the Black Ash, Capitate Spikerush, and Grass-leaved Goldenrod) have been documented within the watershed (Jacques Whitford 2009).

These three species are listed as yellow (sensitive to human activities or natural events) by NSNDR. Both Black Ash and Grass-leaved Goldenrod are listed nationally as S3 (uncommon), while Capitate Spikerush is listed nationally as S2 (rare) by ACCDC. All three species prefer similar habitats: the Black Ash prefers riparian areas, swamps, and other wet sites; Capitate Spikerush thrives in rich wetlands and riparian areas associated with slow moving water, while the Grass-leaved Goldenrod prefers open wetlands, wet meadows, and sandy lakeshores. Given these habitat preferences, development is unlikely to directly impact these species, since their habitats would typically be protected thought riparian buffers and a general prohibition of development within wetlands.

Two federally-listed and one provincially-listed fish species are known from the Shubenacadie River. These species are Atlantic salmon (federally Endangered Bay of Fundy Population), Striped Bass (federally Threatened Bay of Fundy Population) and Atlantic sturgeon (provincially Red-listed: known or thought to be at risk). Two freshwater mussel species reported from the Stewiacke River and thought possible in the Shubenacadie River are the provincially yellow-listed Swollen Wedge Mussel and the Triangle Floater Mussel.

The Mainland Moose, a provincially-listed Endangered species since 2003 is also reported as possible throughout the watershed (Jacques Whitford 2009). There are only approximately 1000 mainland moose in the province. The Chebucto Group of moose, which occupy areas within HRM, consists of an exceptionally small group of about 30 animals. NSDNR has noted that no moose have been reported north of Highway 103 for the last number of years, such that they are unlikely to be present within the watershed boundaries (Snaith 2001; Tony Nette – 2009 NSDNR pers. comm. in Dillon Consulting 2009).

The common loon is listed as yellow (sensitive to human activities or natural events) by NSDNR and is typically found nesting on islands or similar protected areas, and may also be found around lakes in the watershed area. Loons have been heard in Second Lake area as recently as 2011 and in Third Lake in 2012 (pers.comm. R. Dmytriw, AECOM 2012).

Figure 5. Wetlands and Significant Vegetation

Two other listed species, the Little Brown Bat (yellow listed by NSDNR) and the Wood Turtle (federally listed as Threatened) may be present within the watershed but have not been positively identified (Jacques Whitford 2009).

2.3.1.3 Other Land Use Types

For land use planning purposes, additional restricted-development land types are located within the watershed (Figure 5). A large block of undeveloped Aboriginal-owned land is located on the west side of Grand Lake. Laurie and Oakfield Provincial Parks are located on the east side of Grand Lake, while the Waverly Game Sanctuary occupies a large area east of Miller and Soldier Lakes. Crown lands that nearly surround Second Lake have been set aside as a future municipal park, while a C2 crown block of forest parkland with hiking trails is located on the west side of Lake Thomas. Finally, a designated provincially-managed old forest area is located at the northern tip of Kinsac Lake.

2.4 Surface Water Resources

2.4.1 Lake Chemistry

Lakes are central ecological and hydrological components of most watersheds. Lake chemistry is a function of the inflow of surface waters (and hence upstream activities), groundwater discharge to the lake, deposition to the lake surface from the atmosphere, and re-suspension of lake bottom sediments. All these processes are modified by the interaction of biological, physical, and chemical activities or processes within the lake. The processes and functions that are important to understanding lake chemistry are illustrated in Figure 6.

Large lakes may have complex water quality patterns due to diverse and chemically distinct inflows from creeks and rivers combined with complex basin shapes. Water circulation within and through the lake is a core physical process that controls lake water quality. Lake water circulation results from currents generated from inflows, wind, and currents that result when water masses within the lake have different densities. Density currents most commonly occur in response to water masses of different temperatures within a lake.

Deeper lakes in temperate climates undergo a seasonal cycle of thermal stratification, which creates gradients of temperature and dissolved oxygen within the lake. When a lake is of uniform temperature, water is easily circulated throughout its entire depth (water column) by wind-driven mixing. This is referred to as “lake overturn” and occurs in the spring and the autumn when lakes warm or cool to approximately 4°C, the temperature at which water is most dense. At this temperature, surface waters sink to the bottom and wind action promotes mixing of the entire water column, exposing the waters to the atmosphere and re-oxygenating the lake. As the lake warms in the summer (or cools in the winter) a density gradient is re-established, with less dense waters at the surface. Throughout much of the year, a deep lake is thermally stratified due to either heating or cooling at the surface. The boundary between warm and cold waters in a lake is called the “thermocline”, and is governed by the water clarity (depth of solar penetration) and the depth to which waters are mixed by the wind. The thermocline isolates water below from the water above such that no further mixing or turnover occurs after stratification. As a result, oxygen concentrations can be depleted, becoming anoxic (< 0.5 mg/L dissolved oxygen) in the deep waters of lakes (hypolimnion) during the summer and winter as decomposition of organic matter consumes the oxygen in the water. This has implications for aquatic life that require oxygen to live, and may also result in the production of toxic compounds, and the release of phosphorus from the sediments to the water overlying the sediments. The reduced oxygen concentrations persist in the hypolimnion until the next period of lake overturn, at which time the entire water column is again mixed. At this time, phosphorus accumulated in the hypolimnion is mixed with the surface waters of the lake.

Figure 6: Lake Processes

Lake ice cover is another important physical process. On larger lakes, ice generally forms later than in small lakes due to the greater heat storage of larger water bodies, but will remain in place until spring. Once ice is formed, the lake water is isolated from oxygen exchange with the atmosphere and from mixing by the wind. As a result, no oxygen replenishment occurs and the lake may become anoxic under ice cover. The length of ice cover can significantly influence the water quality of the lake. Within the Shubenacadie Lakes subwatershed, ice cover on lakes is typically of short duration and so winter oxygen depletion is less common than in more continental climates.

2.4.2 Water Quality

There is no single or simple measure of water quality. Surface waters naturally contain a wide variety of dissolved and suspended substances, and human activities inevitably add to this mixture. As a result, researchers have developed various approaches to measuring water quality. A single water sample may be tested for a few substances, or for a few hundred, depending on the objectives or concerns at the time of the study. Scientists may also study aquatic organisms and the bottom sediments of lakes and rivers to help assess the overall quality of freshwater systems.

Among the many substances found in water, specific indicators of water quality include:

a) ***Physical Characteristics*** such as temperature, dissolved oxygen, colour, Dissolved Organic Carbon (DOC), Total Suspended Solids (TSS) and turbidity. Temperature and dissolved oxygen are largely driven by lake morphometry (shape and structure of the lake basin) and climate but dissolved oxygen can be altered by excessive nutrient load and the introduction of oxygen demanding substances to a lake. Colour and DOC are governed by the organic content of water and result from the decomposition of vegetation in a lake and its watershed. Lakes with a large amount of wetland in their watershed will have high levels of colour and DOC while lakes that are groundwater dominated will have lower concentrations. TSS and turbidity are added by particles of soil or algal cells in the water column that reduce water clarity. They are indicators of urban runoff, algal growth and, indirectly, light transmission through the water column since light stimulates algae populations.

b) ***Chemical Characteristics****:*

1. ***General Water Chemistry:***
   Alkalinity, pH, total hardness, conductivity, anions (chlorides, sulphide, and iron), and cations (calcium, magnesium, and sodium) help to characterize and differentiate each lake. They generally reflect the characteristics of geology and soils in the watershed of a lake, and the relative importance of groundwater (which is more highly mineralized) and surface water (which is less mineralized). The pH is a measure of the acidity or alkalinity of a water body. Lower alkalinity waters (pH<7) typifies the Shubenacadie Lakes subwatershed lakes. The higher levels of alkalinity "buffer" or protect a water body against changes in pH from the addition of acidic or basic substances such as sulphate from acid rain or alkaline minerals in glacial deposits. Hardness and conductivity measure the concentration of dissolved minerals while anions and cations indicate the specific ions making up the mineral content. Concentrations of these parameters are generally stable in surface water, and need not be sampled frequently in order to characterize a lake.

2. ***Trace Metals****:*
   Metals including lead (Pb), cadmium (Cd), iron (Fe), copper (Cu), and zinc (Zn) reflect the natural geology of a watershed but, at high concentrations can impair aquatic life and therefore may be considered pollutants. They can also be added to lakes by industrial processes, urban runoff and land use practices such as landfilling. Concentrations of these parameters in surface water are typically stable over the short to medium term, and need not be sampled frequently. In the urban environment, many trace metals are found to be associated with

particulate materials, such as soil and grit particles. As such, they can be partially managed by stormwater management practices that also remove solids. Measurements of TSS therefore help to interpret metals levels.

3. ***Nutrients**:*
   Total phosphorus (TP), total kjeldahl nitrogen (TKN), ammonia (NH_3), nitrate (NO_3), and dissolved organic carbon (DOC) describe the nutrient characteristics of a lake. Nutrients (phosphorus and nitrogen forms) are critical water quality indicators, given the significance of nutrient enrichment in urban lakes and their role in stimulating changes in water clarity and nuisance algae growth, which may include toxic cyanobacteria. Nutrient sources of importance to urban lakes include urban runoff that contains organic matter, dog and bird feces, and fertilizer residues. Phosphorus can also be released from the sediments of a lake if the sediments lack oxygen. Although chlorophyll, the photosynthetic pigment in algae, is not, strictly speaking, a nutrient it is used as an indicator of algal response to lake nutrients.

4. ***Bacteria**:*
   Although only Grand and Fletcher Lakes in the Shubenacadie Lakes watershed are sources of public potable water, any of the lakes may be used for private supplies to lakeside residences. Most if not all lakes within the subwatershed are used for recreational activities such as swimming, canoeing and other water sports. Bacterial counts are good indicators of problems related to urban runoff such as discharges from storm sewers, overflows or by-passes from sanitary sewers and sewage treatment facilities, as well as cross-connections between sanitary and storm sewers and inputs from wildlife and domestic animals. Bacterial counts may increase as a result of urbanization and development and thus they are important indicators of general lake system health.

2.4.3 Trophic Status and Nutrients

The term “trophic status” is used to describe biological productivity within a lake. Trophic status depends on the amount of nutrients available to enhance plant growth, including floating algae called phytoplankton. Algae are important to the overall ecology of the lake because they are the base of the food chain, providing food for zooplankton (microscopic invertebrate animals, which are, in turn, food for other organisms, including fish. Excessive productivity or plant growth is visible as degraded water clarity, algae and weed accumulation on shore and decreased oxygen concentrations in the water column.

In most lakes, phosphorus is the nutrient in shortest supply and its absence acts to limit the production of aquatic life. When present in excess, phosphorus stimulates nuisance algal blooms and can result in reduced water clarity and reduced oxygen concentrations in deep lake waters.

Lakes become naturally enriched in nutrients over long periods of time in a process known as eutrophication. Where the amount of phosphorus in a lake is enriched by human activity this process is accelerated and is termed cultural enrichment or cultural eutrophication. Nutrients can come from many sources, such as fertilizers applied to suburban lawns, golf courses, and agricultural fields, deposition from the atmosphere, erosion of soil containing nutrients, urban runoff and sewage treatment plant discharges.

The trophic status of a lake can be determined by measuring nutrient concentrations (phosphorus and nitrogen), algal density (either directly as algal biomass or indirectly as chlorophyll *α* and, in some lakes, water clarity. Although water clarity is influenced by soil particles, colour, and dissolved organic carbon, it is also an indication of biological productivity. The more productive a lake is the greater the algal growth and therefore the less clear the water becomes.

One way to measure water clarity is using a Secchi disc. The disc is lowered into the lake until the observer loses sight of it. The depth of the water where the disk vanishes and reappears is the Secchi depth. Shallower Secchi depths indicate water that has lower clarity (is more turbid) and high Secchi depths indicate clearer water. This method is used primarily for its simplicity and low cost. When used to compare between similar lakes or to assess changes over time, is a good index of lake productivity.

Lakes with few nutrients and low productivity are referred to as “oligotrophic”. They are typically clear water lakes with sparse plant life, high oxygen levels in deep waters and low fish production. In contrast, lakes with higher nutrient concentrations and high productivity are referred to as “eutrophic”. They have abundant plant life, including algae. Lakes with an intermediate productivity are called “mesotrophic” and generally combine the qualities of oligotrophic and eutrophic lakes. Additionally, many lakes in Nova Scotia are “dystrophic”. These brownish or yellowish colored lakes are commonly characterized by a lack of nutrients, a low pH (acidic) and high humus content. Plant and animal life are typically sparse, and the water has a high oxygen demand. Algal abundance in dystrophic lakes is limited by light penetration rather than phosphorus concentrations which can confound the trophic state classification.

Classification of lake trophic status into oligotrophic, mesotrophic or eutrophic, although somewhat subjective, provides a simplified framework for lake management and a point of reference for lake managers. There are many means of classifying lake trophic status but all are based on measurements of trophic status indicators such as phosphorus concentration, algal concentration or water clarity and assigning lakes to a category based on the values measured. Environment Canada (CCME 2004) provided the following classification (Table 5) of trophic status for lakes and rivers, as taken from Vollenweider and Kerekes (1982) and Dodds *et al.* (1998).

Table 5. Trophic Status Based Trigger Ranges for Canadian Waters (CCME, 2004)

Trophic Status	Trigger Ranges for Total Phosphorus (µg/L)	
	Lakes	Rivers and Streams
Ultra-oligotrophic	<4	-
Oligotrophic	4-10	<25
Mesotrophic	10-20	25-75
Meso-eutrophic	20-35	-
Eutrophic	35-100	>75
Hypereutrophic	>100	-

2.4.4 Urbanizing Lakes

Halifax is a unique metropolitan centre by virtue of the large number of lakes within its urban boundaries. The location of the lakes makes them particularly valuable assets to the urban population. This section of the report discusses the characteristics, features and values of urban lakes, what they are, and how they differ from other lakes.

Some of the characteristics that define urban lakes include (Schueler and Simpson 2001):

1. They have a watershed to drainage area ratio of at least 10:1, meaning that their watersheds exert a strong influence on water quality within the lake;
2. Their watersheds contain at least 5% impervious cover as an index of urban development. This promotes stormwater runoff and increases the likelihood of contaminant introduction to the lakes; and
3. They are generally managed for recreation, flood control, water supply or some other direct human use.

Urban lakes face different problems than those in rural areas. Residential and commercial development with its increasing areas of concrete, asphalt and buildings leaves more of the urban environment impermeable to rainwater and snowmelt. Urbanization also alters the state of natural vegetation, destroying or thinning existing vegetation or changing vegetation types. Urbanization leads to an increasing volume of runoff water, faster runoff from the watershed to the lake, decreased ability for water to naturally infiltrate into the soil and introduction of pollutants to the lake.

This “non-point” source of pollution poses the most serious threat to the water quality of urban lakes. During rainstorms, urban non-point sources of pollution contribute sediments, oil, anti-freeze, road salt, pesticides, nutrients and pet and waterfowl droppings. These are carried into surface waterways by overland runoff and storm sewer systems. This urban runoff generally accelerates the eutrophication or natural aging process of urban lakes by adding sediment and nutrients. These added nutrients can result in algal blooms, decreased water clarity, and an increase in the amount of rooted aquatic plants growing in the shallow near-shore waters of a lake. All of these can reduce the recreational value of a lake by hindering swimming, boating, fishing and reducing its overall aesthetics. Moreover, large algae populations can cause odour problems and can lead to the depletion of a lake’s oxygen supply and possibly fish kills. Additionally, the increase in impervious surfaces and heat retention of these surfaces can result in the increased speed and volume of runoff in urban areas and during the summer may increases water temperature, which can also adversely affect the lake’s aquatic health.

“Point source” pollutant inputs to lakes, normally considered to be outfalls from waste water treatment plants, may also degrade the quality of lake waters depending on the extent of wastewater treatment prior to discharge. Sewage treatment facility overflows and bypasses during storms or malfunction can also occur. High nutrient loads, especially phosphorus from wastewater treatment facilities, can significantly add to the natural and non-point loading of phosphorus to lakes resulting in their rapid eutrophication.

Urban lakes are invaluable to urban environments. Yet, due to the very fact that they are located within urban watersheds, these lakes are adversely affected by stormwater runoff and heavy recreational use that results from the easy access of urban lakes to the public. A comprehensive management approach that includes techniques both in-lake and within the lake’s watershed, must be used to protect urban lakes from pollution sources. It is more cost-effective to manage urban development within the watershed in order to maintain established water quality objectives than to try to retrofit the watershed after the lake has degraded to an unacceptable condition.

2.4.5 Lake Description

2.4.5.1 Morphometry and Characteristics of the Lakes

The lakes in the Shubenacadie Lakes subwatershed range in size from approximately 5 ha (Lisle Lake) to 1,877 ha (Grand Lake). Of the lakes in which depth information is available (Table 6), Grand Lake is the deepest, with an average depth of 18.4 m, and Lake Thomas and Fletchers Lake are the shallowest with average depths of 3.6 and 3.7 m, respectively.

Table 6. Morphometry of Lakes in Shubenacadie

Lake	Surface Area (ha)	Maximum Depth (m)	Average Depth (m)	Volume (m^3)[1]
Barrett Lake	9.0			
Beaver Pond	15.0			
Beaverbank Lake	68.7			
Loon Lake	76.6			
Cranberry Lake South	11.2			
Lake Charles	141.4	27[b]	7.9[a]	1117 x 10^6
Duck Lake	9.5			
Fenerty Lake	64.7			
First Lake	82.7			
Fish Lake	51.0			
Kinsac Lake	168.1			
Lake William	301.8	27[b]	11.4[a]	4367 x 10^6
Lisle Lake	5.4			
Miller Lake	125.8			
Powder Mill Lake	43.1			
Rocky Lake	147.5			
Second Lake	112.7			
Springfield Lake	81.3			
Third Lake	84.7			
Tucker Lake	32.6			
Fletchers Lake	100.7	9[b]	3.7[a]	373 x 10^6
Grand Lake	1877		18.4[a]	34713 x 10^6
Lake Thomas	112.9	12[b]	3.6[a]	406 x 10^6
Lake Banook	41.5			
Lake Micmac	104.2			
Lewis Lake	76.5			

Notes: a) from Jacques Whitford 2009: [b]from Scott et al. 1991
1. Based on surface area and mean depth.

2.4.5.2 Data Sources

One of the key objectives of the Shubenacadie Lakes subwatershed study is to establish water quality objectives to prevent any further deterioration in water quality.

Historical water quality data provides a good benchmark for understanding how conditions change over time. The purpose of this study is to establish water quality objectives upon which to prevent any further deterioration in water quality. Water quality data collected during the past 10 years was used to assess current conditions in the Shubenacadie watershed, prior to any further development. Although historical data was available, the last ten years of data was selected for inclusion in the data analysis portion of the report, as this represented current conditions in the watershed.

Water quality data for the Shubenacadie lakes and tributaries were obtained from the various programs of Halifax Regional Municipality (HRM), Jacques Whitford (now part of Stantec), Nova Scotia Lake Inventory, Municipality of East Hants (MEH), and AECOM. Water quality data collected prior to 2002 were available from Scott *et al.* (1991) and the Shubenacadie Watershed Environmental Protection Society (SWEPS), but as described above, were not used in the data analysis. Four additional sampling locations in the watershed were added by AECOM to supplement the spatial coverage of water quality data. Table 7 presents the data sources used for this report. All sampling locations are on Figure 7.

Table 7. Data Used to Establish Current Water Quality in Shubenacadie

Sampled by	Sampling Location	Sampling Period	Parameters
HRM	Barrett Lake, Beaver Pond, Lake Charles, Cranberry Lake, Duck Lake, Fenerty Lake, First Lake, Fletcher's Lake, Grand Lake, Kinsac Lake, Lake Banook, Lake Micmac, Lisle Lake, Loon Lake, Miller Lake, Powder Mill Lake, Red Bridge Pond, Rocky Lake, Second Lake, Springfield Lake, Third Lake, Lake Thomas, Tucker Lake, and Lake William	2006-2011	Nutrients, General Chemistry, Bacteria, Ammonia, Metals
Jacques Whitford	Beaverbank Lake, Lake Charles, Fish Lake, Fletcher's Lake, Grand Lake, Lake Thomas, and Lake William	2007	Nutrients, General Chemistry, Bacteria
Nova Scotia Lakes Inventory	Cranberry Lake, Fletchers Lake, Grand Lake, Kinsac Lake, Powder Mill Lake, and Lake William	2002-2007	Nutrients, General Chemistry, Ammonia, Metals
Municipality of East Hants	Grand Lake, Fletchers Lake Outlet, Kinsac Lake Outlet, Lake Thomas Outlet	2009-2011	Total Phosphorus, Total Suspended Solids, Ammonia, Metals
AECOM	Lake Charles, Fletchers Lake Outlet, Grand Lake Outlet, and Kinsac Lake Outlet	2011-2012	Nutrients, General Chemistry, Bacteria

Figure 7: Water Quality Sampling Stations

The HRM lakes water quality data were provided to AECOM by HRM in Excel spreadsheets. AECOM also downloaded files from the HRM website at http://www.halifax.ca/environment/lakesandrivers.html. Nova Scotia Lakes Inventory Program data were obtained electronically from http://www.gov.ns.ca/nse/surface.water/lakesurveyprogram.asp. Data for water quality samples collected within the Shubenacadie Lakes subwatershed were extracted from the data provided from the website. It should be noted that the Nova Scotia Lakes Inventory data did not include a reference map so confirmation of the latitude and longitude co-ordinates was not possible.

Easting and Northing co-ordinates were provided for most sampling locations for HRM based on sample co-ordinates included with the HRM 2006 sampling results. Where co-ordinates were not provided for the HRM lake station datasets, HRM provided co-ordinates electronically by email or manually marked maps showing the locations which were then mapped for the database. Latitude and Longitude co-ordinates were provided with the Nova Scotia Lakes Inventory Data. These data were converted to Easting and Northing co-ordinates using GIS.

Original reports were reviewed for the reported laboratory detection limits (when available) and data points that were below these detection limits were indicated by the “<“ sign and the detection limit. For detection limits that were not provided, AECOM contacted HRM for clarification. For parameters further used in AECOM’s calculations, an additional column was inserted into the database with the detection limit without the “<“ sign so that the value could be used in subsequent reporting.

2.4.5.3 Water Quality Data Analysis

As described more fully in section 4.2, data analysis focussed on a few key “indicator parameters” that are sensitive to changes in land use within a watershed. These parameters included: total phosphorus (TP), total kjeldahl nitrogen (TKN), and chlorophyll α as indicators of nutrient enrichment and trophic status; total suspended solids (TSS), colour and Secchi depth as indicators of water clarity; and nitrate, ammonia, *E. coli*, and dissolved chloride as indicators of anthropogenic or “human” influences. The minimum, maximum, median, average, and standard deviation were calculated for the key parameters of interest where there was sufficient number of data points in the Shubenacadie Lakes.

When analyzing laboratory results for most parameters, data points that were less than the detection limit were taken at the detection limit concentration. For example, for TSS with a detection limit of 1 mg/L; reported values of <1 mg/L were processed as 1 mg/L. If however, variable detection limits indicated that some detections limits were well above the background water quality based on the results from samples with lower detection limits, then these high detection limit data were discarded. This was especially the case for total phosphorus where the use of high detection limit data could significantly affect the setting of water quality objectives.

Total phosphorus (TP) has different detection limits depending on the technique used to analyze the samples. For example, a metal scan which included TP has a detection limit of 20 µg/L (0.02 mg/L) and the colourimetric technique has a detection limit ranging from 2 to 5 µg/L (0.002 to 0.005 mg/L). The threshold for moving from the mesotrophic to eutrophic trophic status is 20 µg/L (0.020 mg/L) – the high detection limit. Any data point equal to or less than the detection limit of 20 µg/L (0.020 mg/L) was removed from analysis, as the actual phosphorus concentration could be an order of magnitude less than the detection limit, and the lake predicted in a higher trophic state if these high detection limits were used. If a data point was above the detection limit of 20 µg/L (0.020 mg/L) the value was retained for data analysis, and was considered representative of an actual phosphorus concentration. Data points with values less than the lower detection limits of total phosphorus were considered equal to the detection limit, as this was considered a conservative measure, and it did not interfere with the interpretation of the trophic status.

All replicate samples were used in the analysis as another value for the same sampling date.

Given the number of phosphorus data points available for the larger Shubenacadie lakes (resulting from samples being collected from various locations and depths), the data were condensed to increase sample size and to facilitate data interpretation. This was completed by pooling total phosphorus analytical results for multiple sampling locations within the same lake if no significant differences in analytical results between the locations were observed. SigmaPlot (version 11.0) was used to generate box and whisker plots and to draw statistical conclusions. The p-value of 0.05 was used for all statistical tests. The Shapiro-Wilk test was applied to see if the data sets followed a normal distribution. Based on the results of the Shapiro-Wilk test, an analysis of variance (ANOVA) test was run. If all of the data was normally distributed, a one-way ANOVA was run (test based on the mean). If any of the data sets were not normally distributed, the Kruskal-Wallis one-way ANOVA on ranks was conducted (test based on the median). If a significant difference was detected between the mean/median between groups a post-hoc test was conducted. Either the Tukey Test (used with the one-way ANOVA), or the Dunn's test (used with the Kruskal-Wallis one-way ANOVA) was selected as the appropriate post-hoc test. The post-hoc test compares all possible pairwise datasets and isolates which specific dataset differs from another. However, significant differences between the median values for sampling locations within the same lake were not detected, so this step was not completed.

The results of the data pooling exercise indicate that the total phosphorus results for individual sampling locations within Lakes Charles, Fletchers, Grand, Kinsac and Thomas Lakes are not statistically different. Given this, these results can be considered representative of the lakes as a whole for the purpose of developing water quality objectives. A summary of the statistical tests and graphs completed as part of the pooling exercise will be presented in final report.

TSS, ammonia, nitrate, chloride and *E. coli* data were also pooled for Lake Charles, Fletchers, Grand, Kinsac and Thomas Lakes, since the statistical analysis indicated TP results for individual sampling locations within these lakes were not significantly different. Considering this, it is appropriate to handle all data from a given lake in a uniform manner based on the most important parameter – total phosphorus.

2.4.5.4 General Water Quality

Table 8 presents a summary of the water quality data for key receiving lakes in the watershed. The sections that follow describe and compare the water quality results for parameters for parameters susceptible to change due to urban development within the watershed.

Table 8 Summary of Shubenacadie Lakes Water Quality Data

		Total Phosphorus (mg/L)	Dissolved Chloride (mg/L)	TSS (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	ChlA (acid) (ug/L)	Secchi depth (m)	Colour (TCU)	E.Coli (cfu or mpn/100 mL)
Barrett Lake	**n**	17	16	17	12	14	17	15	16	8
	min	0.002	28	1.0	0.05	0.050	0.6	2.1	10.0	1
	max	0.025	68	14.0	0.12	0.090	8.3	4.7	38.0	82
	mean	0.011	49	4.1	0.07	0.055	2.7	3.3	20.3	7
	median	0.011	50	5.0	0.06	0.050	1.9	3.5	19.5	5
	25%	0.008	40	2.0	0.05	0.050	1.4	2.6	14.0	3
	75%	0.015	56	5.0	0.08	0.050	2.8	3.9	25.8	23
	standard deviation	0.006	12	3.1	0.03	0.013	2.2	0.9	8.3	28
Beaver Pond	**n**	1	1	1	NA	NA	1	1	NA	NA
	min	0.023	34	4.0	NA	NA	24.5	1.2	NA	NA
	max	0.023	34	4.0	NA	NA	24.5	1.2	NA	NA
	mean	0.023	34	4.0	NA	NA	24.5	1.2	NA	NA
	median	0.023	34	4.0	NA	NA	24.5	1.2	NA	NA
	25%	0.023	34	4.0	NA	NA	24.5	1.2	NA	NA
	75%	0.023	34	4.0	NA	NA	24.5	1.2	NA	NA
	standard deviation	NA	NA	NA	NA	NA	NA	NA	NA	NA
Beaverbank Lake	**n**	2	4	4	4	NA	4	2	NA	NA
	min	0.010	8	2.0	0.05	NA	0.2	2.0	NA	NA
	max	0.012	27	7.0	0.05	NA	6.0	2.5	NA	NA
	mean	0.011	14	3.3	0.05	NA	3.0	2.3	NA	NA
	median	0.011	11	2.0	0.05	NA	2.9	2.3	NA	NA
	25%	0.011	10	2.0	0.05	NA	1.2	2.1	NA	NA
	75%	0.012	15	3.3	0.05	NA	4.8	2.4	NA	NA
	standard deviation	0.001	9	2.5	NA	NA	2.7	0.4	NA	NA

		Total Phosphorus (mg/L)	Dissolved Chloride (mg/L)	TSS (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	ChlA (acid) (ug/L)	Secchi depth (m)	Colour (TCU)	E.Coli (cfu or mpn/100 mL)
Loon Lake	**n**	15	14	14	12	14	15	14	15	6
	min	0.004	46	1.0	0.05	0.011	0.1	1.8	5.0	1
	max	0.043	102	5.0	0.20	0.200	6.3	5.6	30.0	17
	mean	0.015	78	3.5	0.07	0.063	2.6	4.1	9.8	2
	median	0.011	79	5.0	0.05	0.050	2.4	4.0	7.0	1
	25%	0.006	71	1.3	0.05	0.050	1.2	3.7	5.0	1
	75%	0.016	90	5.0	0.07	0.058	3.8	5.2	11.7	10
	standard deviation	0.012	17	1.9	0.04	0.043	1.8	1.2	7.0	7
Cranberry Lake South	**n**	17	16	16	12	14	17	9	16	7
	min	0.003	43	1.0	0.05	0.014	0.2	1.2	7.0	1
	max	0.050	200	5.0	0.50	0.120	28.2	3.6	16.9	649
	mean	0.020	102	3.3	0.14	0.056	5.0	2.4	31.0	10
	median	0.020	92	4.0	0.08	0.050	2.9	2.5	14.0	4
	25%	0.009	72	1.0	0.05	0.050	1.5	2.2	11.0	3
	75%	0.025	125	5.0	0.18	0.060	4.6	2.5	20.3	34
	standard deviation	0.013	46	1.9	0.14	0.022	6.9	0.6	8.1	241
Lake Charles	**n**	21	18	20	14	14	20	17	17	13
	min	0.002	39	1.0	0.16	0.006	0.8	2.5	0.1	1
	max	0.039	67	5.0	0.44	0.170	6.7	7.0	1.0	93
	mean	0.010	54	2.7	0.31	0.059	2.9	4.0	0.5	7
	median	0.008	56	1.0	0.32	0.050	2.5	3.8	0.4	11
	25%	0.005	46	1.0	0.25	0.050	1.7	3.0	0.3	2
	75%	0.010	59	5.0	0.40	0.050	4.0	4.4	0.5	15
	standard deviation	0.008	8	2.0	0.09	0.036	1.6	1.2	0.3	24
Duck Lake	**n**	16	16	16	12	14	16	14	15	8
	min	0.019	18	4.0	0.05	0.050	9.3	0.6	8.0	1
	max	0.180	198	12.0	0.06	0.130	52.7	1.6	64.0	409

		Total Phosphorus (mg/L)	Dissolved Chloride (mg/L)	TSS (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	ChlA (acid) (ug/L)	Secchi depth (m)	Colour (TCU)	E.Coli (cfu or mpn/100 mL)
Duck Lake	**mean**	0.043	80	7.0	0.05	0.060	25.0	1.1	21.2	6
	median	0.030	70	6.0	0.05	0.050	23.1	1.1	19.0	4
	25%	0.024	41	5.0	0.05	0.050	16.4	0.9	13.0	1
	75%	0.042	111	8.5	0.05	0.050	33.5	1.2	24.0	23
	standard deviation	0.039	48	2.7	0.003	0.024	11.7	0.3	13.6	142
Fenerty Lake	**n**	16	16	16	12	14	15	16	15	7
	min	0.005	9	1.0	0.05	0.050	1.9	1.0	16.0	1
	max	0.036	17	5.0	0.19	0.170	28.2	2.5	76.0	2
	mean	0.022	14	4.0	0.07	0.069	10.0	1.7	37.0	1
	median	0.021	15	5.0	0.05	0.050	8.0	1.6	31.0	1
	25%	0.015	13	3.0	0.05	0.050	4.1	1.5	22.0	1
	75%	0.029	15	5.0	0.07	0.070	13.8	1.9	51.0	2
	standard deviation	0.009	2	1.3	0.04	0.036	7.8	0.4	18.7	0.5
First Lake	**n**	17	16	16	12	14	17	16	16	7
	min	0.002	89	1.0	0.05	0.012	0.7	1.5	5.0	1
	max	0.046	150	5.0	0.23	0.210	19.8	8.1	28.0	37
	mean	0.011	120	3.3	0.10	0.063	4.7	4.1	9.3	3
	median	0.008	126	3.5	0.06	0.050	3.7	3.8	6.5	2
	25%	0.006	107	1.8	0.05	0.050	1.9	2.8	5.0	1
	75%	0.011	136	5.0	0.14	0.058	5.1	5.0	10.6	8
	standard deviation	0.010	20	1.8	0.06	0.045	4.4	1.7	6.4	13
Fish Lake	**n**	2	2	2	2	NA	2	2	NA	NA
	min	0.017	17	1.0	0.05	NA	2.5	2.7	NA	NA
	max	0.019	19	1.0	0.05	NA	5.0	3.0	NA	NA
	mean	0.018	18	1.0	0.05	NA	3.8	2.9	NA	NA
	median	0.018	18	1.0	0.05	NA	3.8	2.9	NA	NA
	25%	0.018	18	1.0	0.05	NA	3.2	2.8	NA	NA

		Total Phosphorus (mg/L)	Dissolved Chloride (mg/L)	TSS (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	ChlA (acid) (ug/L)	Secchi depth (m)	Colour (TCU)	E.Coli (cfu or mpn/100 mL)
	75%	0.019	19	1.0	0.05	NA	4.4	2.9	NA	NA
	standard deviation	0.001	1	NA	NA	NA	1.8	0.2	NA	NA
Kinsac Lake	**n**	17	16	16	12	14	17	16	16	7
	min	0.003	12	1.0	0.05	0.009	0.8	1.8	15.0	1
	max	0.040	22	5.0	0.14	0.080	6.9	3.8	66.0	14
	mean	0.012	18	3.1	0.07	0.051	3.5	2.7	37.0	3
	median	0.011	18	3.5	0.06	0.050	3.4	2.8	37.0	4
	25%	0.008	17	1.0	0.05	0.050	2.1	2.3	24.5	1
	75%	0.013	20	5.0	0.10	0.050	5.0	3.0	49.0	4
	standard deviation	0.008	3	2.0	0.03	0.015	1.9	0.6	14.9	5
Lake William	**n**	20	19	17	12	17	18	18	19	7
	min	0.002	31	1.0	0.05	0.006	1.0	2.5	10.0	1
	max	0.032	46	5.0	0.26	0.340	5.8	4.5	34.0	6
	mean	0.009	38	3.1	0.14	0.064	2.6	3.5	18.4	2
	median	0.007	39	3.0	0.12	0.050	2.6	3.5	17.0	1
	25%	0.005	33	1.0	0.08	0.050	1.7	3.1	11.5	1
	75%	0.011	43	5.0	0.20	0.050	3.1	3.9	20.5	4
	standard deviation	0.007	5	2.0	0.07	0.076	1.2	0.6	8.0	2
Lisle Lake	**n**	8	8	8	4	6	7	5	7	3
	min	0.022	18	2.0	0.05	0.050	0.9	1.0	12.0	1
	max	0.092	36	16	0.15	0.170	82.9	2.3	44.0	84
	mean	0.050	26	6.6	0.08	0.070	23.2	1.6	25.6	10
	median	0.042	25	5.0	0.05	0.050	8.4	1.6	21.0	12
	25%	0.031	21	2.8	0.05	0.050	2.1	1.2	13.0	7
	75%	0.070	32	8.5	0.08	0.050	33.1	2.0	38.0	48
	standard deviation	0.026	7	5.2	0.05	0.049	32.8	0.5	14.4	45

		Total Phosphorus (mg/L)	Dissolved Chloride (mg/L)	TSS (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	ChlA (acid) (ug/L)	Secchi depth (m)	Colour (TCU)	E.Coli (cfu or mpn/100 mL)
Miller Lake	**n**	3	3	2	3	3	3	2	3	2
	min	0.007	14	5.0	0.18	0.050	1.1	1.8	38.5	1
	max	0.013	26	5.0	0.28	0.140	3.0	3.2	83.0	5
	mean	0.011	19	5.0	0.23	0.101	2.3	2.5	57.5	2
	median	0.012	18	5.0	0.23	0.112	2.7	2.5	51.0	3
	25%	0.009	16	5.0	0.21	0.081	1.9	2.2	44.8	2
	75%	0.013	22	5.0	0.25	0.126	2.9	2.9	67.0	4
	standard deviation	0.004	6	NA	0.05	0.046	1.0	1.0	23.0	3
Powder Mill Lake	**n**	18	17	17	12	15	17	15	17	7
	min	0.002	35	1.0	0.05	0.006	1.3	2.0	5.0	1
	max	0.050	58	27	0.21	0.070	9.6	5.4	29.0	26
	mean	0.010	47	4.4	0.08	0.050	3.5	3.8	13.6	3
	median	0.009	50	2.0	0.05	0.050	2.7	3.6	12.0	2
	25%	0.006	41	1.0	0.05	0.050	2.0	3.2	8.0	2
	75%	0.011	51	5.0	0.06	0.050	4.5	4.4	14.4	5
	standard deviation	0.011	7	6.1	0.06	0.014	2.3	1.0	7.6	9
Rocky Lake	**n**	17	16	16	12	14	17	13	16	7
	min	0.002	38	1.0	0.05	0.005	1.7	1.5	5.0	1
	max	0.050	92	136	0.54	0.090	31.7	5.5	29.0	26
	mean	0.016	70	11	0.22	0.060	8.4	2.9	16.0	2
	median	0.015	73	3.5	0.23	0.055	8.5	2.5	15.6	1
	25%	0.008	60	1.8	0.10	0.050	4.8	2.0	8.0	1
	75%	0.018	81	5.0	0.26	0.078	10.8	3.0	21.3	2
	standard deviation	0.012	16	33	0.15	0.022	7.1	1.3	8.5	9
Second Lake	**n**	16	16	14	12	13	16	12	15	7
	min	0.002	23	1.0	0.05	0.005	0.7	2.2	5.0	1
	max	0.060	42	43	0.20	0.290	7.4	7.2	34.0	40

		Total Phosphorus (mg/L)	Dissolved Chloride (mg/L)	TSS (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	ChlA (acid) (ug/L)	Secchi depth (m)	Colour (TCU)	E.Coli (cfu or mpn/100 mL)
Second Lake	**mean**	0.012	34	6.1	0.07	0.072	2.0	4.1	16.1	3
	median	0.008	36	5.0	0.05	0.050	1.5	3.9	16.0	2
	25%	0.006	29	1.3	0.05	0.050	1.4	3.5	11.0	1
	75%	0.013	37	5.0	0.05	0.070	2.1	4.6	19.5	8
	standard deviation	0.014	6	11	0.06	0.068	1.5	1.3	7.5	14
Springfield Lake	**n**	16	16	16	12	14	15	15	15	8
	min	0.004	15	1.0	0.05	0.050	0.9	1.8	5.0	1
	max	0.041	26	33	0.34	0.080	4.8	4.8	42.0	5
	mean	0.014	20	5.2	0.09	0.054	2.5	2.9	15.1	2
	median	0.010	20	5.0	0.05	0.050	2.1	2.9	12.0	1
	25%	0.009	20	1.8	0.05	0.050	1.9	2.5	9.0	1
	75%	0.018	22	5.0	0.11	0.050	3.1	3.1	17.0	2
	standard deviation	0.010	3	7.6	0.09	0.009	1.1	0.8	10.5	1
Third Lake	**n**	17	16	16	12	14	17	14	16	7
	min	0.002	24	1.0	0.05	0.005	1.2	2.1	5.0	1
	max	0.050	32	5.0	0.48	0.100	23.2	5.7	38.0	9
	mean	0.010	28	3.1	0.11	0.052	4.7	3.8	15.8	2
	median	0.008	29	3.5	0.06	0.050	2.9	3.7	13.0	1
	25%	0.004	26	1.0	0.05	0.050	2.5	3.4	9.0	1
	75%	0.009	31	5.0	0.10	0.050	4.0	4.3	18.8	4
	standard deviation	0.011	3	2.0	0.12	0.020	5.2	1.0	9.1	3
Tucker Lake	**n**	17	16	17	12	14	17	17	16	8
	min	0.002	34	1.0	0.05	0.050	1.4	1.0	5.0	1
	max	0.032	51	5.0	0.09	0.060	15.9	4.7	41.0	26
	mean	0.010	44	3.4	0.06	0.051	4.1	3.1	17.4	6
	median	0.009	44	5.0	0.05	0.050	3.0	3.2	15.0	6
	25%	0.007	40	1.0	0.05	0.050	2.1	2.4	12.3	4

		Total Phosphorus (mg/L)	Dissolved Chloride (mg/L)	TSS (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	ChlA (acid) (ug/L)	Secchi depth (m)	Colour (TCU)	E.Coli (cfu or mpn/100 mL)
	75%	0.012	48	5.0	0.05	0.050	4.2	3.9	19.5	12
	standard deviation	0.007	5	1.9	0.01	0.004	3.6	1.0	9.4	9
Fletcher's Lake	**n**	20	19	19	13	15	21	17	17	7
	min	0.002	27	1.0	0.05	0.038	0.9	1.7	11.0	1
	max	0.036	40	5.0	0.26	0.100	4.8	4.1	47.0	30
	mean	0.010	34	2.9	0.13	0.059	2.8	2.9	21.3	4
	median	0.009	34	2.0	0.15	0.050	2.7	2.9	20.0	2
	25%	0.005	31	1.0	0.07	0.050	1.8	2.5	13.0	2
	75%	0.011	39	5.0	0.17	0.060	4.0	3.2	27.0	12
	standard deviation	0.009	4	1.9	0.07	0.018	1.3	0.6	9.9	11
Grand Lake	**n**	19	22	22	18	14	24	16	16	7
	min	0.002	15	1.0	0.05	0.010	0.5	2.9	11.0	1
	max	0.060	21	5.0	0.31	0.080	4.1	6.3	32.0	4
	mean	0.008	19	2.8	0.11	0.050	2.0	4.3	19.0	1
	median	0.005	19	2.0	0.11	0.050	1.7	4.1	18.5	1
	25%	0.003	17	1.0	0.09	0.050	1.1	3.7	14.0	1
	75%	0.007	21	5.0	0.12	0.050	2.8	4.4	24.0	1
	standard deviation	0.013	2	1.8	0.05	0.019	1.1	1.0	5.8	1
Lake Thomas	**n**	32	28	29	21	26	31	29	29	13
	min	0.002	27	1.0	0.05	0.023	1.1	2.2	8.0	1
	max	0.082	45	9.0	0.30	0.110	4.0	5.9	61.0	14
	mean	0.011	38	3.4	0.16	0.054	2.3	3.5	20.6	3
	median	0.008	39	5.0	0.17	0.050	2.0	3.2	17.0	2
	25%	0.007	34	1.0	0.10	0.050	1.5	2.9	12.0	2
	75%	0.012	42	5.0	0.21	0.050	2.9	4.0	27.0	7
	standard deviation	0.014	5	2.2	0.07	0.015	0.9	0.9	11.5	4

		Total Phosphorus (mg/L)	Dissolved Chloride (mg/L)	TSS (mg/L)	Nitrate (mg/L)	Ammonia (mg/L)	ChlA (acid) (ug/L)	Secchi depth (m)	Colour (TCU)	E.Coli (cfu or mpn/100 mL)
Lake Banook	**n**	17	16	16	11	14	17	16	16	7
	min	0.002	65	1.0	0.05	0.006	0.5	2.0	5.0	1
	max	0.044	210	5.0	0.29	0.260	5.9	7.4	32.1	11
	mean	0.010	151	3.4	0.11	0.068	2.0	4.4	7.6	4
	median	0.008	169	4.5	0.07	0.050	1.4	4.0	5.0	6
	25%	0.003	115	1.0	0.05	0.050	1.1	3.0	5.0	2
	75%	0.012	183	5.0	0.15	0.058	2.2	5.6	6.3	9
	standard deviation	0.011	46	1.8	0.08	0.058	1.5	1.6	6.9	4
Lake Micmac	**n**	17	16	16	12	14	17	15	16	7
	min	0.002	59	1.0	0.05	0.005	0.5	2.2	5.0	1
	max	0.052	236	5.0	0.30	0.180	4.4	5.8	23.0	27
	mean	0.010	145	3.2	0.14	0.061	1.6	4.3	8.5	4
	median	0.008	150	3.5	0.11	0.050	1.2	4.5	6.0	2
	25%	0.002	99	1.0	0.06	0.050	0.9	3.8	5.0	1
	75%	0.012	182	5.0	0.20	0.050	2.0	4.8	9.8	19
	standard deviation	0.012	53	1.9	0.09	0.039	1.2	1.1	5.3	11
Lewis Lake	**n**	3	3	3	3	NA	3	2	NA	NA
	min	0.007	12	1.0	0.05	NA	1.7	2.8	NA	NA
	max	0.010	13	1.0	0.05	NA	3.6	3.5	NA	NA
	mean	0.008	12	1.0	0.05	NA	2.4	3.1	NA	NA
	median	0.007	12	1.0	0.05	NA	2.0	3.1	NA	NA
	25%	0.007	12	1.0	0.05	NA	1.9	2.9	NA	NA
	75%	0.009	13	1.0	0.05	NA	2.8	3.3	NA	NA
	standard deviation	0.002	1	NA	NA	NA	1.0	0.5	NA	NA

NA - not available. No data.

Total Suspended Solids

Total suspended solids (TSS) consist of silt, clay, fine particles of organic and inorganic matter, plankton and other microscopic organisms. Increased TSS reduces water clarity and is an indicator of urban runoff, algal growth and light transmission. The median TSS concentration within the individual Shubenacadie lakes was low, ranging from <1 to 6 mg/L (Figure 8). The concentration of TSS measured in Duck Lake, which had the highest median concentration (6 mg/L), ranged from 4 to 12 mg/L. Higher TSS concentrations are possibly a result of high chlorophyll *α* concentrations, which had an average concentration of 25 µg/L.

Several of the remaining lakes had median TSS concentrations that were equal to the detection limit. Based on existing water quality, TSS is a not currently water quality concern within the Shubenacadie lakes. Water quality objectives will be set for this parameter since TSS may increase as a result of urbanization within the watershed.

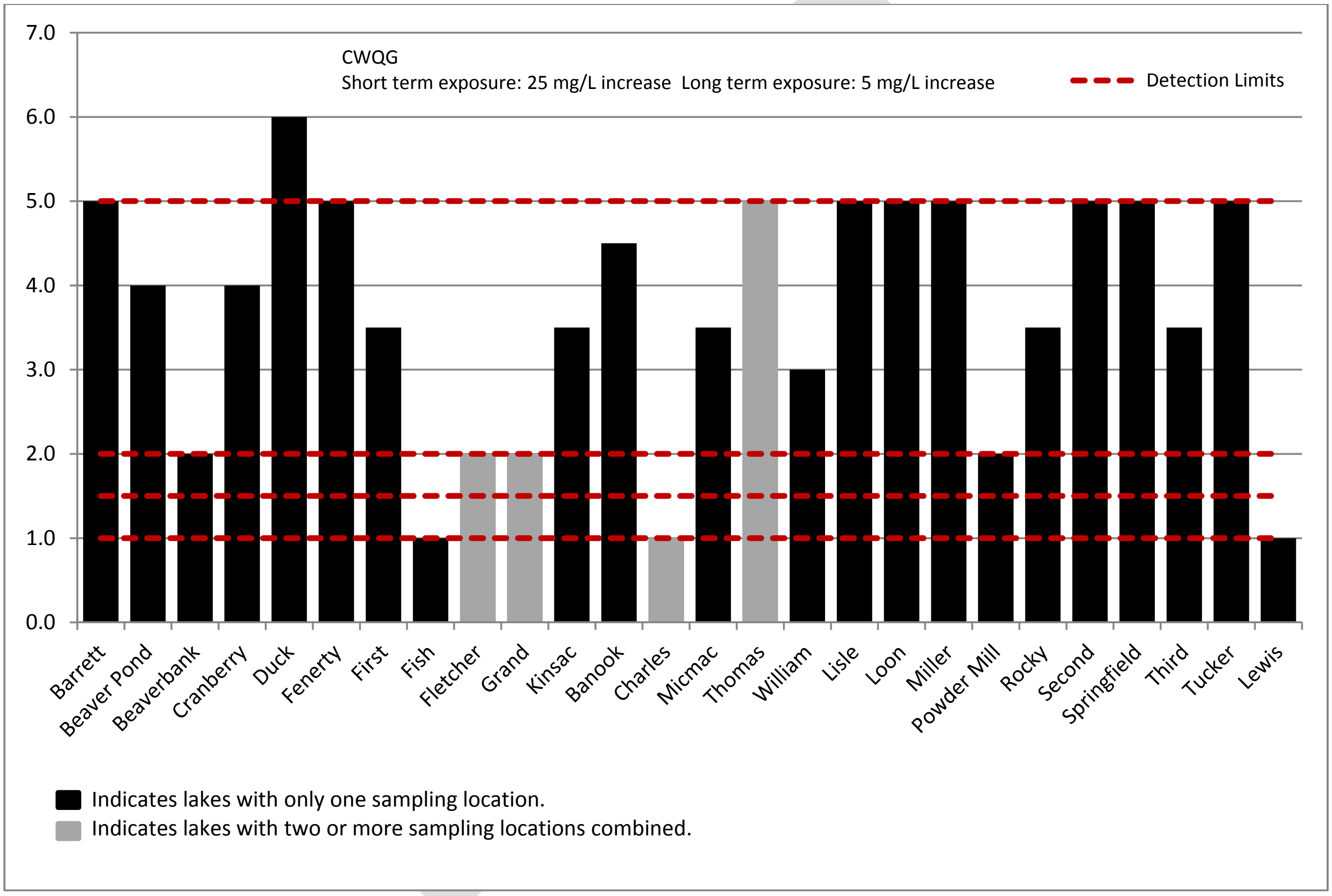

Figure 8: Median TSS Concentrations (mg/L) in Shubenacadie Lakes (2002-2011)

Ammonia

Elevated levels of ammonia in a lake would be indicative of an man-made input from failing septic systems, sewer overflows or cross connections between sanitary sewers and storm sewers. For many of the Shubenacadie lakes the median ammonia concentration was equal to the detection limit (Figure 9). Exceptions to these low concentrations were noted in Miller Lake and Rocky Lake with median concentrations of 0.11 mg/L and 0.05 mg/L, respectively. The ammonia concentration ranged from <0.05 to 0.14 mg/L at Miller Lake, and <0.01 to 0.09 mg/L at Rocky Lake. The higher ammonia concentration at Miller Lake may be a result of septic effluent entering the lake. The situation at Rocky Lake is less obvious however both lakes would require a detailed investigation to identify the source of ammonia loadings from septic systems.

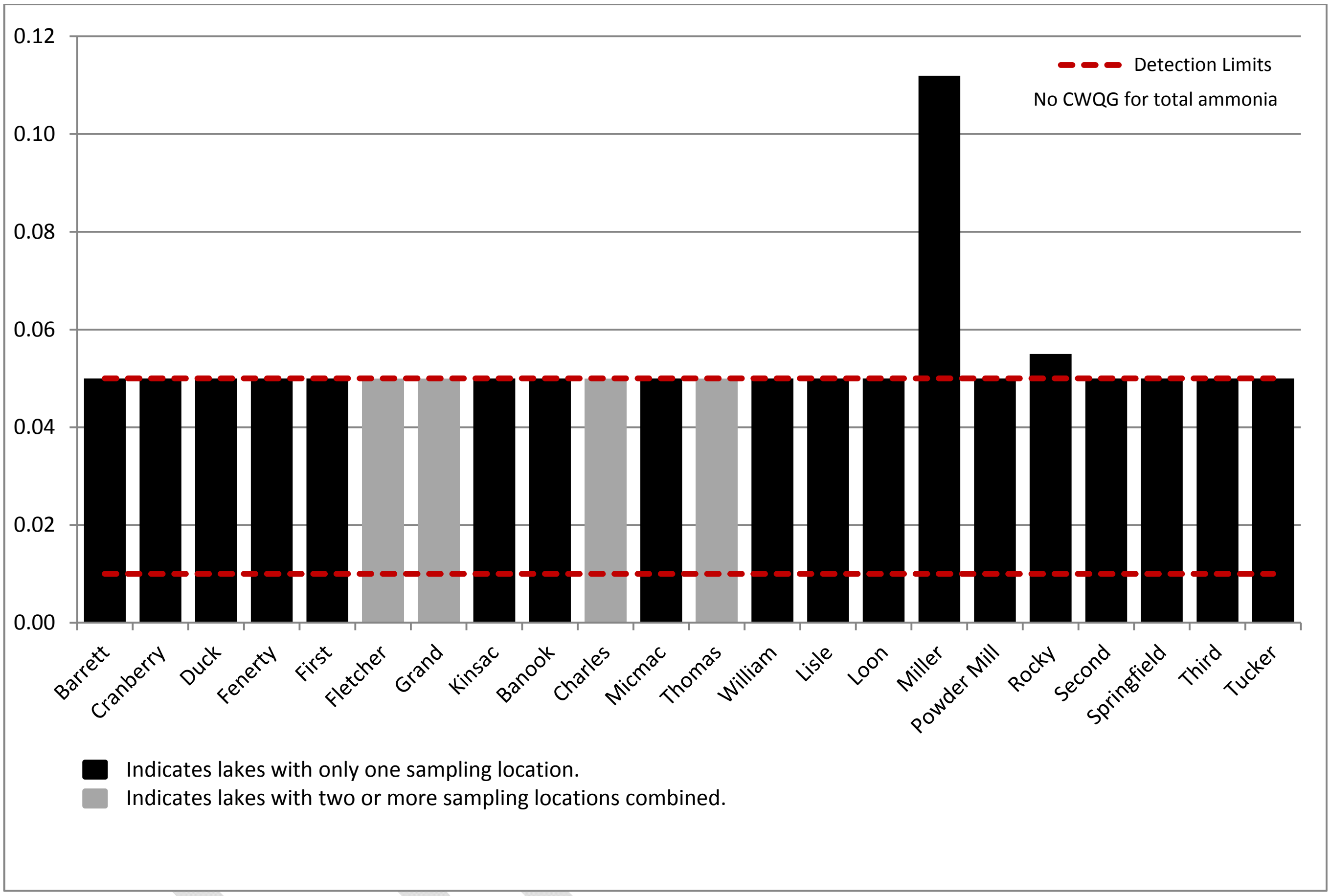

Figure 9: Ammonia Concentrations (mg/L) in Shubenacadie Lakes (2002-2011)

Nitrate

Excessive levels of nitrate in a lake is also indicative of an anthropogenic inputs such as failing septic systems, sanitary sewer overflows and cross connections between sanitary and storm sewers. Many of the lakes in Shubenacadie subwatershed exhibit nitrate concentrations equal to the detection limit; median nitrate concentrations ranged from <0.05 to 0.34 mg/L (Figure 10). The highest nitrate concentrations were observed at Lake Charles, followed by Miller Lake and Rocky Lake. Lake Charles may be affected by leaking sanitary sewers or over flows during high flow events. Miller and Rocky Lakes appear to be affected by failing septic systems as noted above. Nevertheless, all lakes were well below the Canadian Water Quality Guideline (CWQG) for nitrate (13 mg/L).

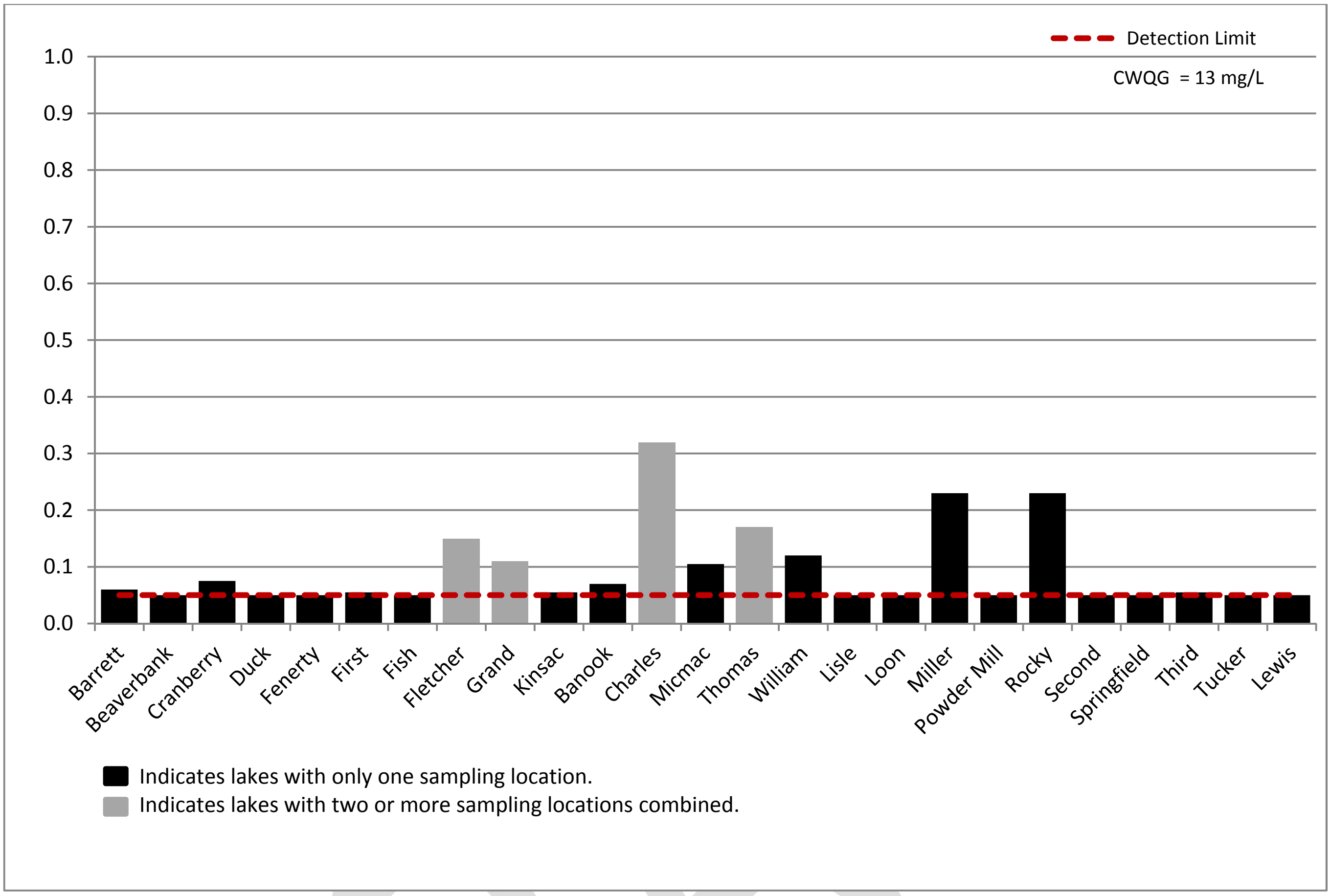

Figure 10. Median Nitrate Concentrations (mg/L) in Shubenacadie Lakes (2002-2011)

Chloride

High concentrations of chloride are indicative of anthropogenic input from road salting practices or effluent from waste water treatment plants and septic systems. Median chloride concentrations at three sampling locations exceeded the CWQG for chloride (i.e., >120 mg/L, long-term exposure; Figure 11). These lakes, First Lake (89 to 150 mg/L), Lake Banook (65 to 210 mg/L) and Lake Micmac (59 to 236 mg/L) are located adjacent to high density residential and commercial areas, which have a higher degree of impervious surfaces such as roads and parking lots that require winter salt applications. During a rain event or during snow melt following a snow accumulation period, these impervious surfaces can increase overland flow to stormwater ditches and pipes, which in turn can increase chloride concentrations in nearby waterbodies. The median concentration of chloride in the other lakes was below the CWQG and generally below 90 mg/L.

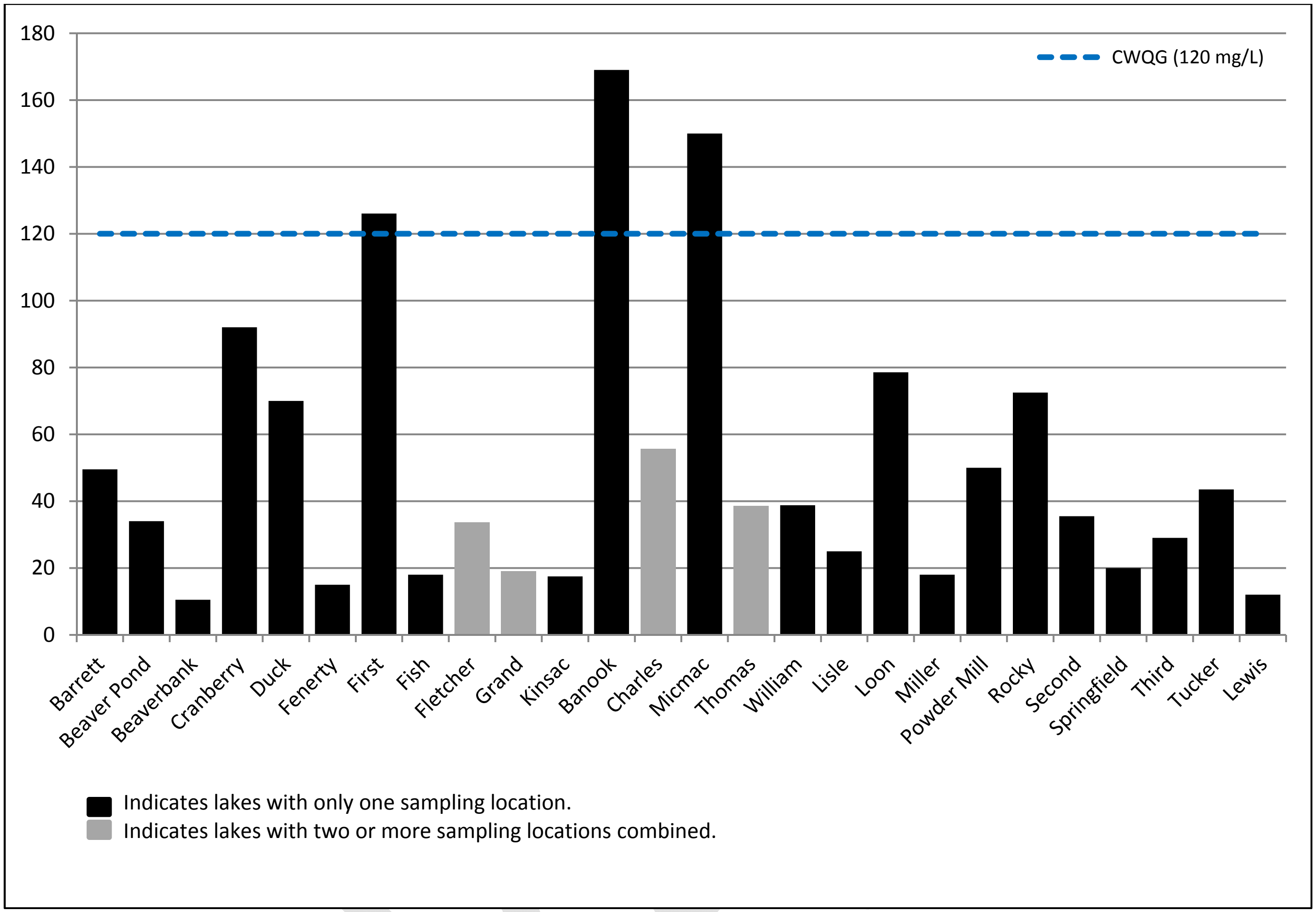

Figure 11. Median Chloride (mg/L) Concentrations in Shubenacadie Lakes (2002-2011)

E. coli

E. coli bacteria are also suggestive of anthropogenic or man-made inputs, again due to failing septic systems, overflows from sanitary sewers and cross connections between sanitary and storm sewers. *E. coli* bacteria may also originate from waterfowl and other wildlife. Excessive bacteria can negatively affect human health and can compromise recreational use of lakes in the summer months. Two common measurements of bacteria in aquatic environments are most probable number (MPN) and colony-forming units (CFU), both which are typically reported in a water volume of 100 mL. *E. coli* concentrations reported in both units were deemed essentially equivalent and combined for the purpose of data analysis. The geometric mean[2] *E. coli* measurements from the individual Shubenacadie lakes were low, ranging from 1 to 12 cfu or mpn/100 mL (Figure 12), and well below CDWQ limits.

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[2] *Many wastewater dischargers, as well as regulators who monitor swimming beaches and shellfish harvest areas, must test for and report fecal coliform bacteria concentrations. Often, the data must be summarized as a "geometric mean" (a type of average) of all the test results obtained during a reporting period. Typically, public health regulations identify a precise geometric mean concentration at which shellfish beds or swimming beaches must be closed.*

A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the calculation if a straight average (arithmetic mean) were used. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000 fold over a given period. Geometric mean is really a log-transformation of data to enable meaningful statistical evaluations.

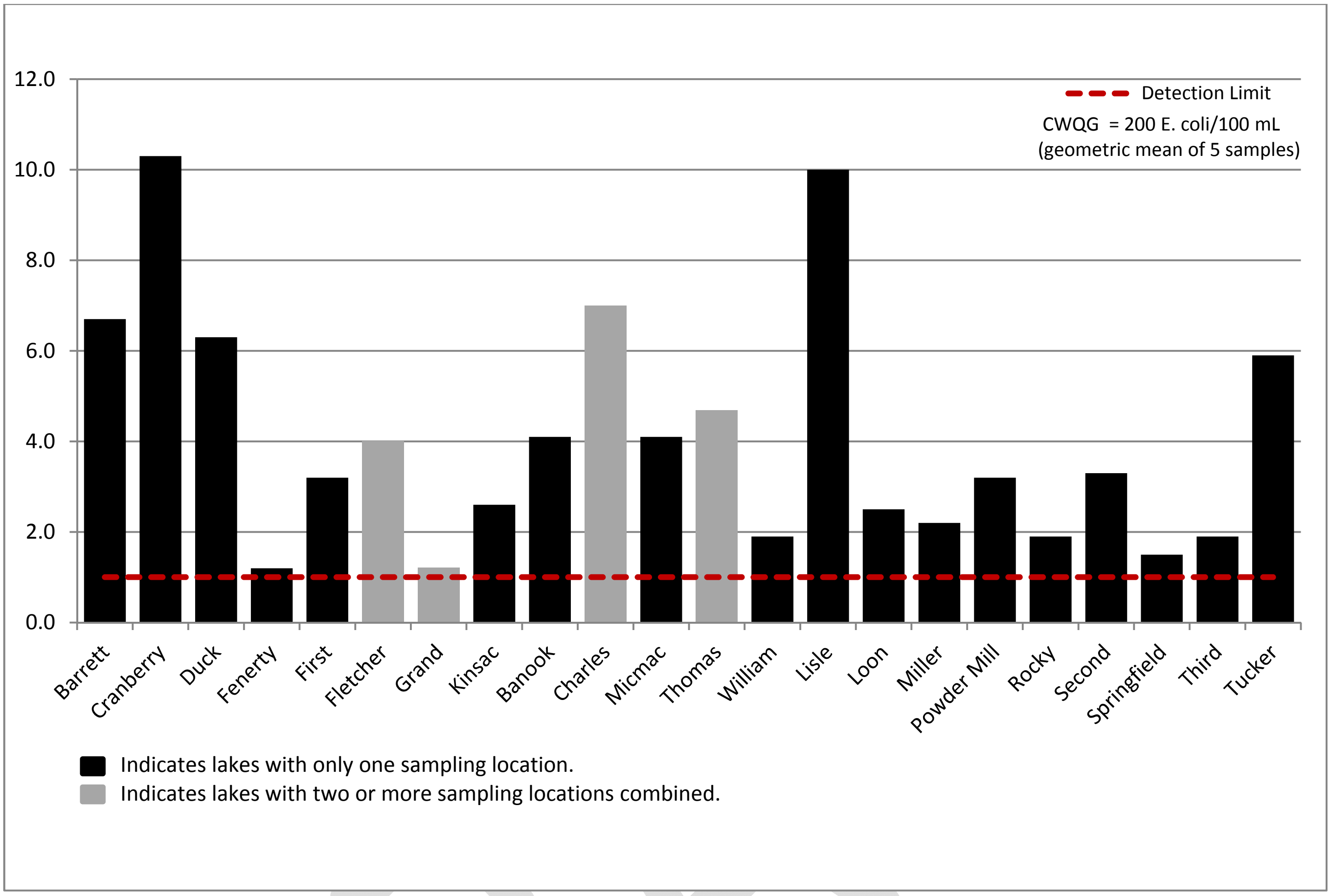


Figure 12.Geometric Mean of available *E. coli* Measurements (CFU or MPN per 100 mL) in Shubenacadie Lakes (2002-2011)

Total Phosphorus

The trophic states of lakes in the Shubenacadie system were classified based on the mean total phosphorus concentration, as defined by Environment Canada (CCME 2004). Most of the lakes are mesotrophic (i.e., 10 to 20 µg/L), with 19 of 26 lakes in this range. Grand and Lewis Lakes are the only two lakes that have mean total phosphorus concentrations in the oligotrophic range (i.e., 4 to 10 µg/L), indicating high water quality. Beaver Pond, Cranberry Lake, and Fenerty Lake were classified as meso-eutrophic (i.e., >20 to 35 µg/L), and Duck and Lisle Lakes was classified as eutrophic (i.e., >35 µg/L; Table 8, Figure 13).

Lisle Lake was classified as eutrophic since total phosphorus concentrations ranged from 22 to 92 µg/L, with a median concentration of 42 µg/L. Lisle Lake is small (5.3 ha) and is in close proximity to a medium density residential area. It is downstream of a watercourse that receives Springfield Lake waste water treatment plant effluent. Lisle Lake flows into Fenerty Lake, which is been classified as mFig 13 Teso-eutrophic: total phosphorus concentrations ranged from 5 to 36 µg/L, with a median concentration of 20 µg/L. Given that Fenerty Lake has little development in its subwatershed, it appears that upstream phosphorus inputs from Lisle Lake may be impacting its water quality.

Figure 13. Total Phosphorus Concentrations (µg/L) in Shubenacadie Lakes (2002-2011)

Duck Lake was also classified as eutrophic. The mean total phosphorus concentration in this lake was high at 43 µg/L. The Woodbine Trailer Park off of Beaver Bank Road is located near Duck Lake and there may an influence from the waste treatment facility of this trailer park on the lake. There are anecdotal reports that Duck Lake received untreated sewage in the past and there may be a historical accumulation of phosphorus in the sediments that is contributing TP to the water column. This lake would have to be investigated further to understand the source of such high TP concentrations.

Chlorophyll α

All plants, algae, and cyanobacteria that photosynthesize contain chlorophyll *α*. Although chlorophyll *α* is not a nutrient, it can be used as an indicator of algal response (reproduction and growth) to lake nutrients. Beaver Pond and Duck Lake have the highest chlorophyll *α* concentrations (median values of 24.5 and 23.12 µg/L, respectively), indicating high algal abundance and reflecting the high phosphorus concentrations measured in these lakes (Figure 14). Other lakes with elevated chlorophyll *α* concentrations were Fenerty, Lisle and Rocky Lakes. Fenerty and Lisle lakes have phosphorus concentrations in the meso-eutrophic to eutrophic range, and Rocky Lake has phosphorus concentrations in the mesotrophic range. The chlorophyll *α* concentrations in all other lakes was low and below 5 µg/L.

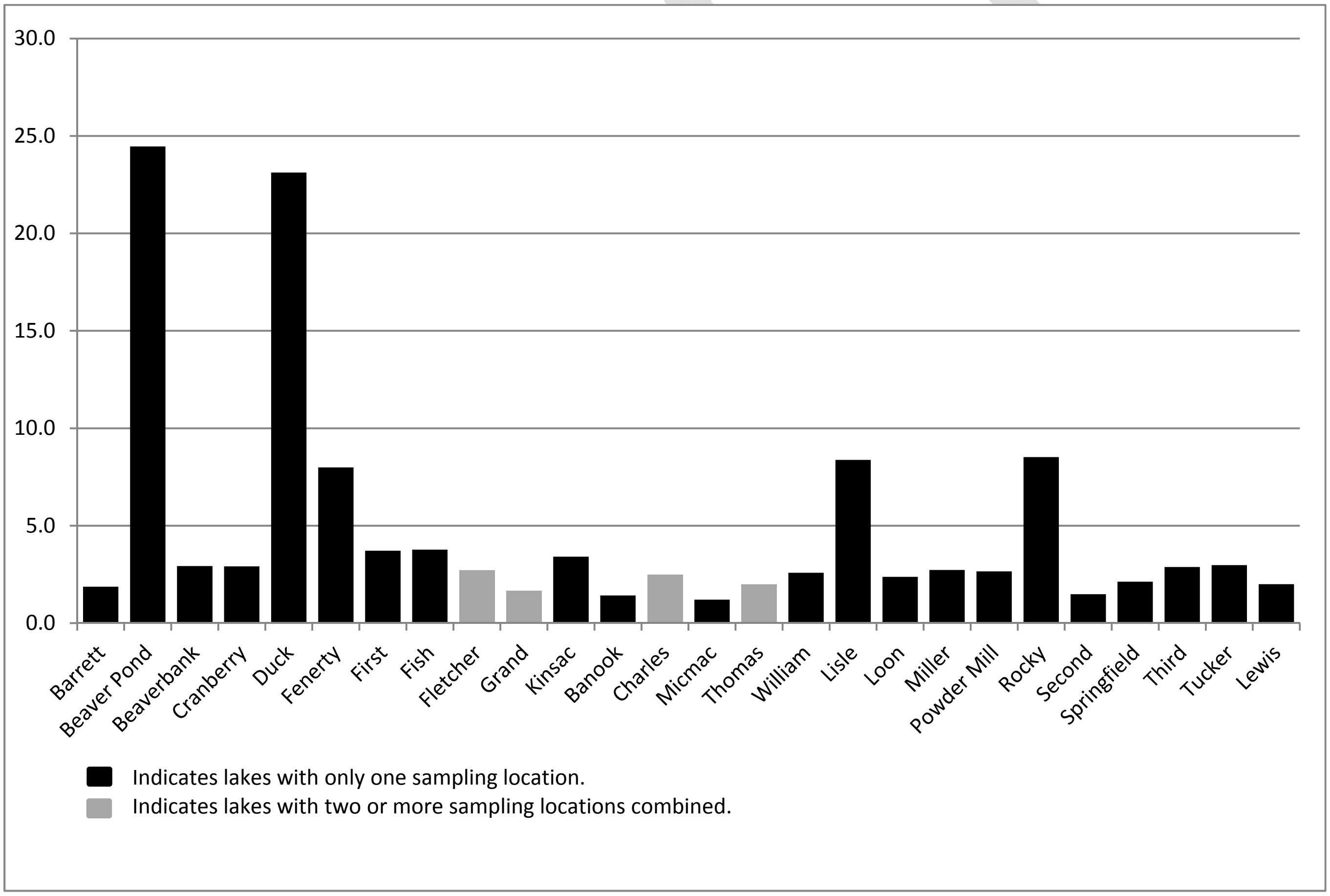


Figure 14. Median Chlorophyll *α* concentrations (µg/L) in Shubenacadie Lakes

2.4.5.5 *Nitrogen to Phosphorus Ratios*

In order to manage lake eutrophication, the accepted approach is to control the nutrient that is feeding plant growth within the lake. There are three primary nutrients required for plant growth – phosphorus, nitrogen and carbon – and for most water bodies, phosphorus is the limiting nutrient. That is, phosphorus becomes depleted and stops plant or algal growth before either nitrogen or carbon becomes depleted. Phosphorus is most commonly derived from anthropogenic activities in the watershed and thus phosphorus inputs can be controlled through reduction of non-point sources (fertilizer applications, changes to land use, malfunctioning septic systems) or point sources such as overflows and discharges from sewage treatment plants.

One method of determining if phosphorus is the limiting nutrient is to calculate the total nitrogen (TN) to total phosphorus (TP) ratio in a lake. Ratios of TN:TP ≤14 are limited in nitrogen, while lakes with ratios of TN:TP >15 are limited in phosphorus and the TN:TP ratio generally decreases with increased TP (Downing and McCauley 1992).

To determine if phosphorus is the limiting nutrient with respect to plant and algal growth in the Shubenacadie lakes watershed, the TN:TP ratio was calculated for each lake (Table 9). The TN:TP ratio for all lakes was >15, indicating that they are phosphorus limited. Miller Lake had the highest ratio (138), likely due to the high concentration of nitrogen compounds in this lake. Beaver Pond and Lisle Lakes had the lowest ratios (17 and 18, respectively), indicating that they are potentially moving towards a nitrogen limiting system, due to the high concentrations of phosphorus in these lakes.

Table 9. Nitrogen to Phosphorus Ratio for Lakes in the Shubenacadie Watershed

Lake	N:P Ratio	Lake	N:P Ratio
Beaver Pond	17	**Cranberry South**	49
Lisle	18	**Micmac**	50
Duck	23	**Rocky**	50
Fish	25	**Second**	51
Loon	37	**Tucker**	55
Beaverbank	39	**First**	57
Fenerty	41	**Fletcher**	57
Springfield	41	**Grand**	60
Barrett	43	**Third**	65
Charles	43	**Powder Mill**	77
William	43	**Thomas**	79
Kinsac	46	**Miller**	138
Banook	48		

2.4.5.6 *Relationships between Trophic Status Indicators*

Although there are a variety of phosphorus inputs to urban lakes, natural sources are generally associated with suspended solids (TSS, particulate matter from soil particles and urban runoff) or with dissolved organic carbon (DOC; from organic matter in wetlands and vegetation in the watershed). Analysis of the relationships among these three trophic status indicators can help to assess the various sources of phosphorus between lakes. Figures 15 to 18 show the relationships for all measurements of these trophic status indicators.

Due to the low concentrations of TSS (most sample results are at the detection limit for this parameter), no meaningful relationship was observed between TSS and phosphorus in the lakes (Figure 15). In lakes with high phosphorus concentrations (meso-eutrophic to eutrophic lakes) there is evidence that increased TSS concentrations may correspond to increased phosphorus concentrations, however the relationship is not statistically significant (Figure 16).

In the absence of DOC data, colour data were used as an indication of phosphorus origin. Like DOC, colour is governed by the organic content of water and generally reflects the product of decomposition of vegetation in a lake and its watershed. High color values result from the decomposition of vegetation, which gives the water a brown, tea-like colour. Figure 17 shows that there is no significant relationship between colour and total phosphorus in the Shubenacadie lakes. These results indicate that factors other than DOC influence phosphorus measurements.

Phosphorus was found to be the limiting nutrient to plant and algal growth in the Shubenacadie lakes. This means that additional phosphorus loads to the lakes can result in increased plant and algal growth and a deterioration in water quality. Figure 18 presents the relationship between total phosphorus and chlorophyll *α* on a log-log scale. While a statistically significant relationship between these two parameters cannot be observed based on current data, it should be noted that the chlorophyll *α* concentrations in the high-phosphorus meso-eutrophic and eutrophic lakes (Beaver Pond, Fenerty Lake, Duck Lake, and Lisle Lake) were among the highest chlorophyll *α* concentrations reported.

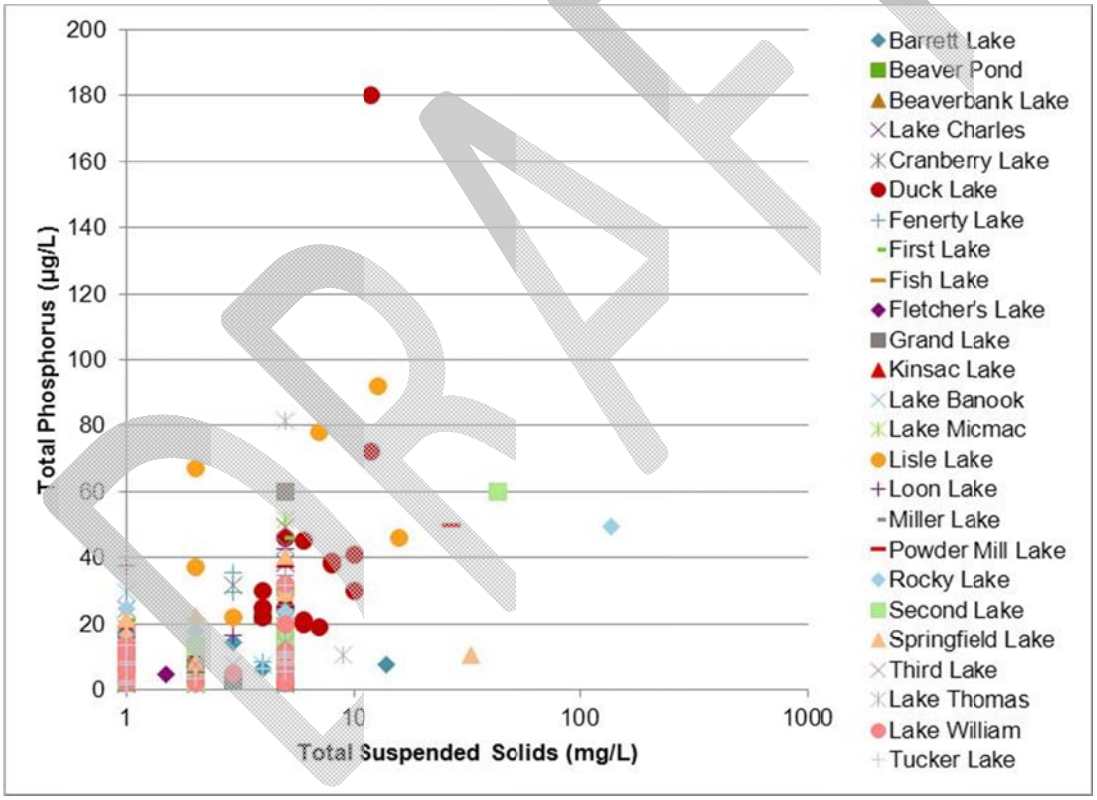


Figure 15 Relationship between Total Suspended Solids and Total Phosphorus in all Shubenacadie Lakes

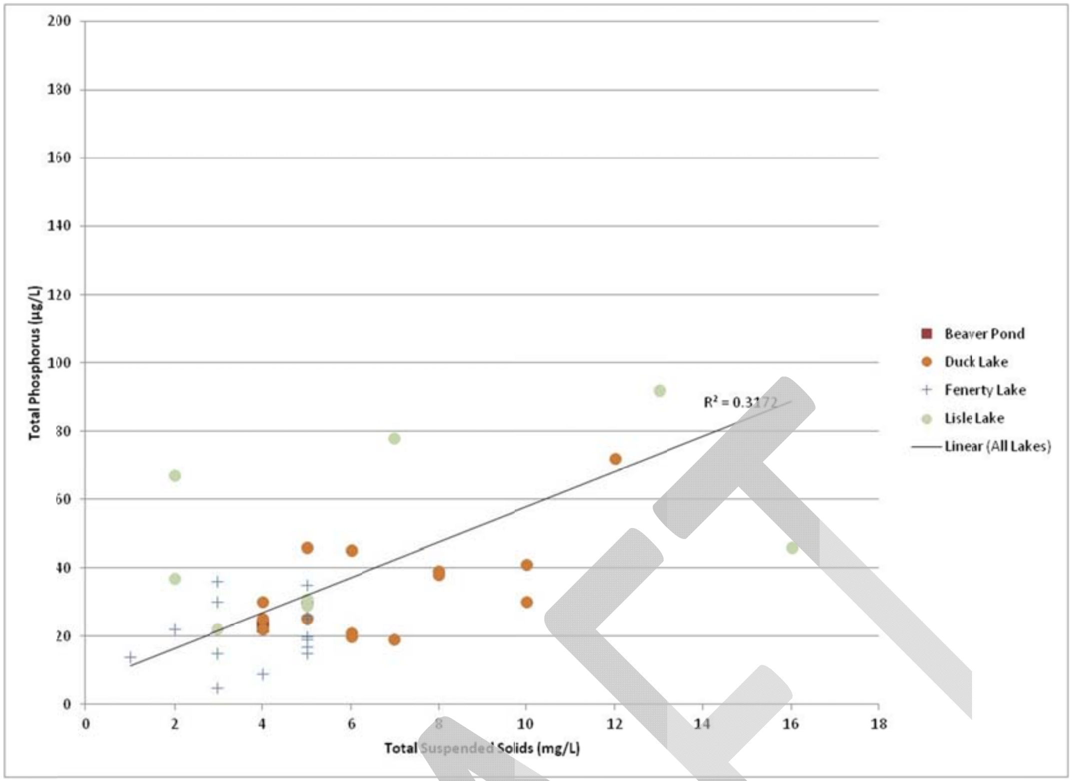


Figure 16. Relationship between Total Suspended Solids and Total Phosphorus in Shubenacadie Lakes (meso-eutrophic-eutrophic lakes only)

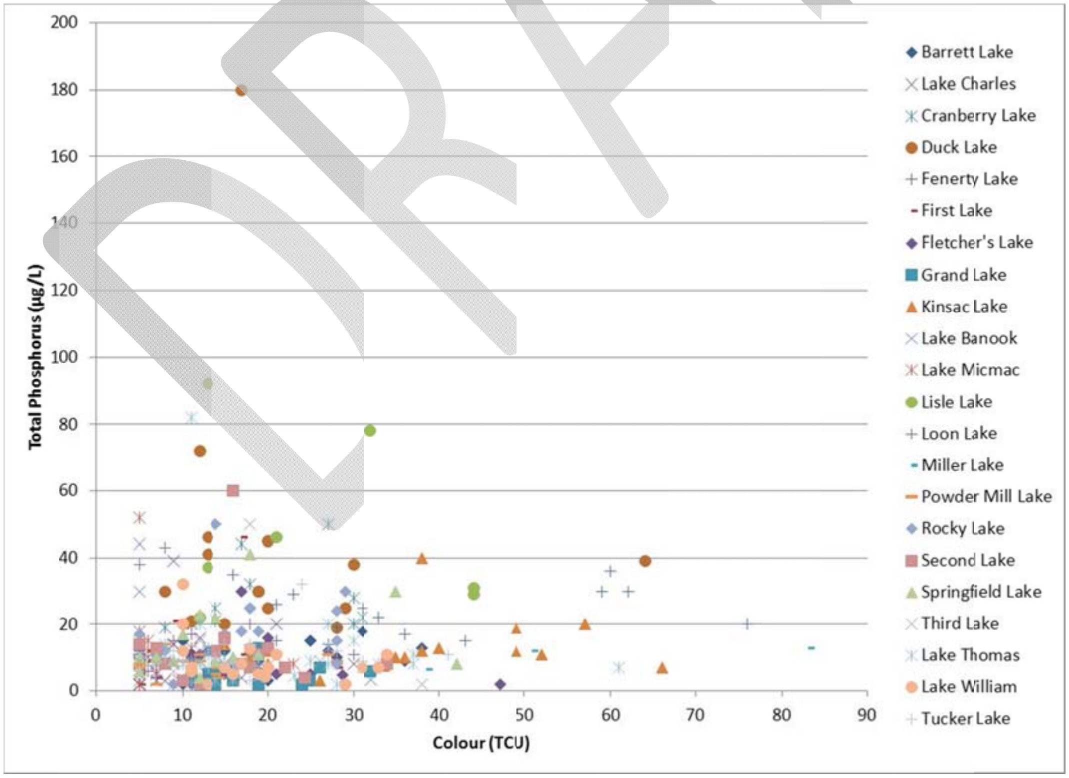


Figure 17. Relationship between Colour and Total Phosphorus in Shubenacadie Lakes

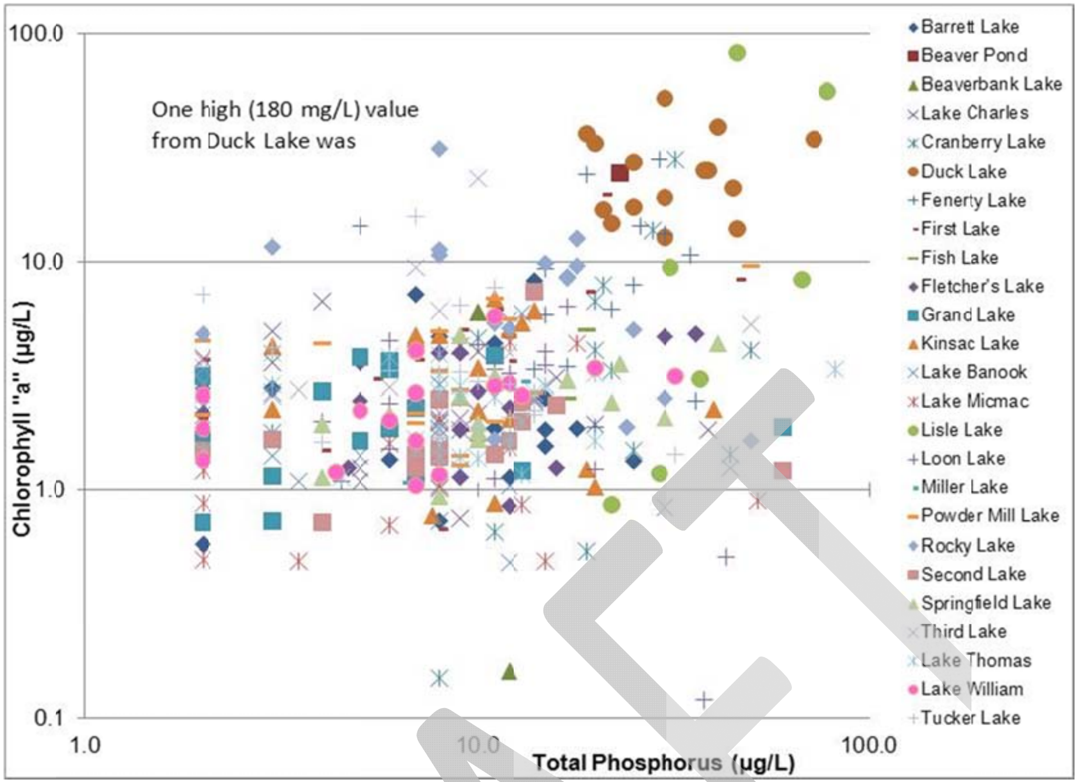


Figure 18. Relationship between Total Phosphorus and Chlorophyll α in Shubenacadie Lakes

2.4.6 Water Clarity Relationships

In natural waters, colour is due mainly to the presence of dissolved organic matter from soil and decaying vegetation. Recreational lake users most often perceive water quality as a function of water clarity; clear waters are considered clean. Both colour and Secchi depth provide an indication of water clarity. Shallower Secchi depths indicate water has lower clarity, while high Secchi depths indicate clear waters. No clear relationship is apparent between TSS and Secchi depth based on current data (Figure 19). This may be due to the high frequency of TSS samples at the detection limit. Given the relatively low TSS concentrations in most lakes, TSS does not appear to be the main factor in water clarity in the Shubenacadie lakes.

The relationship between colour and water clarity is much stronger: Secchi depth decreases with increasing colour (Figure 20). Fenerty and Kinsac lakes had higher colour values than the other lakes.

High concentrations of chlorophyll *α* can sometimes result in reduced water clarity. Figure 21 presents the relationship between Secchi depth and chlorophyll *α*. Overall, water clarity decreases rapidly as chlorophyll α concentrations increase. As indicated in this figure, this relationship provides a good fit for the equation provided.

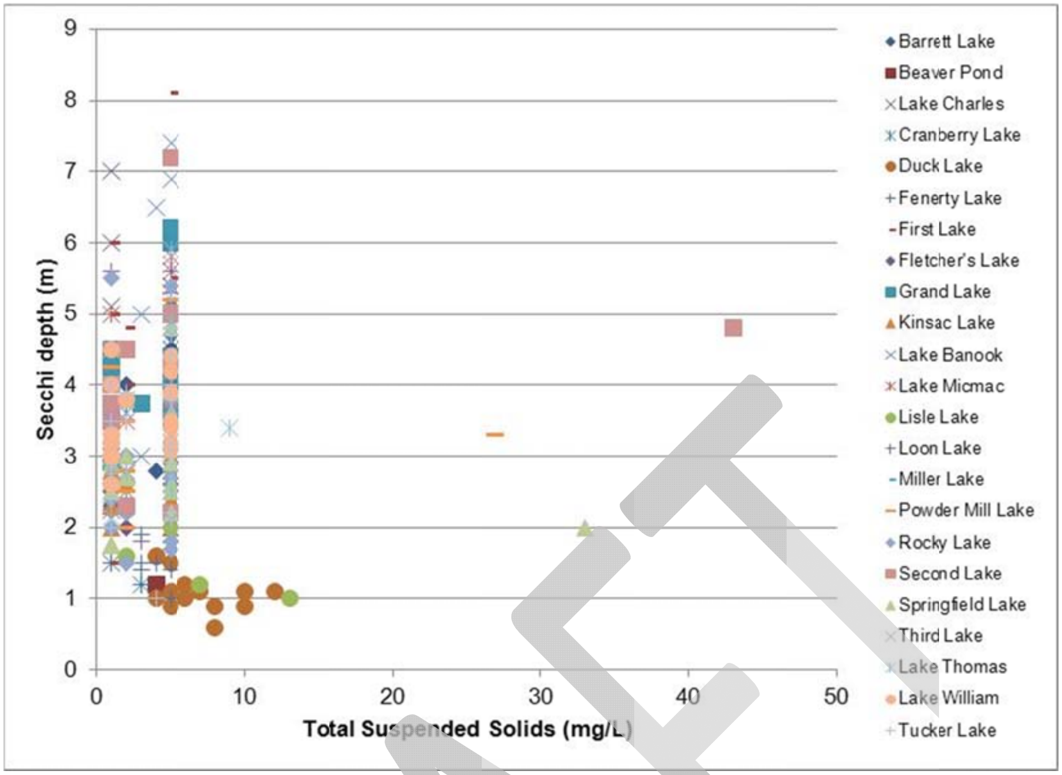


Figure 19. Relationship between Secchi Depth and TSS in Shubencadie Lakes

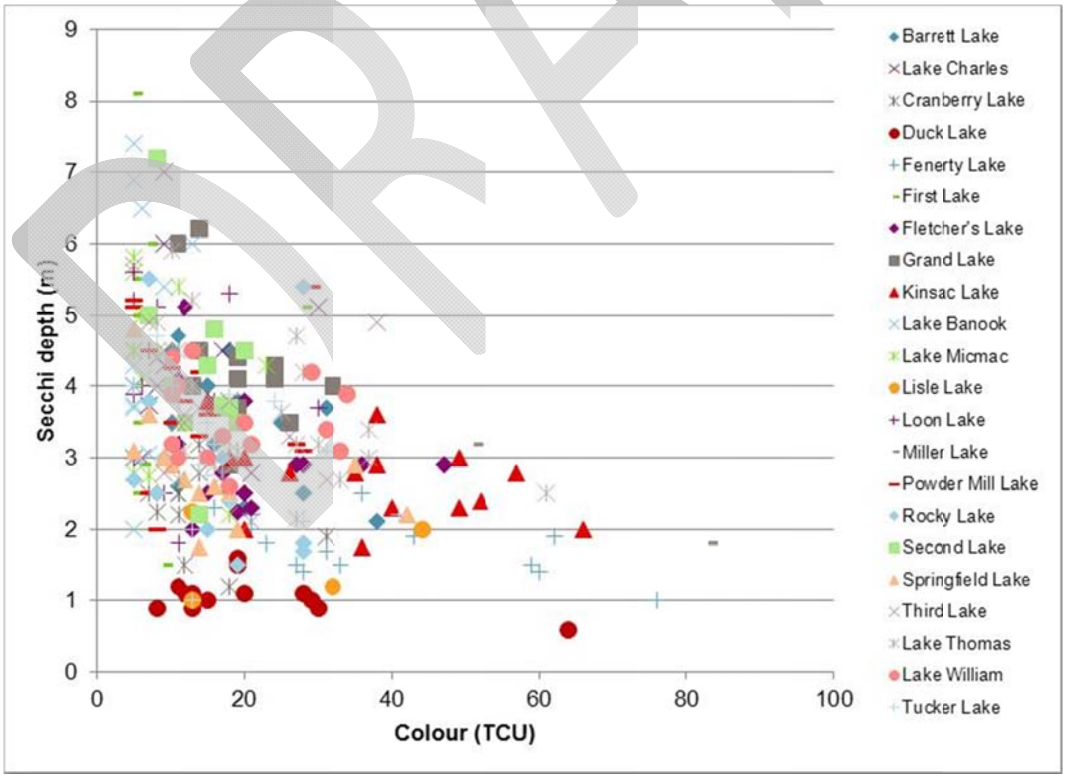


Figure 20. Relationship between Colour and Secchi Depth in Shubencadie Lakes

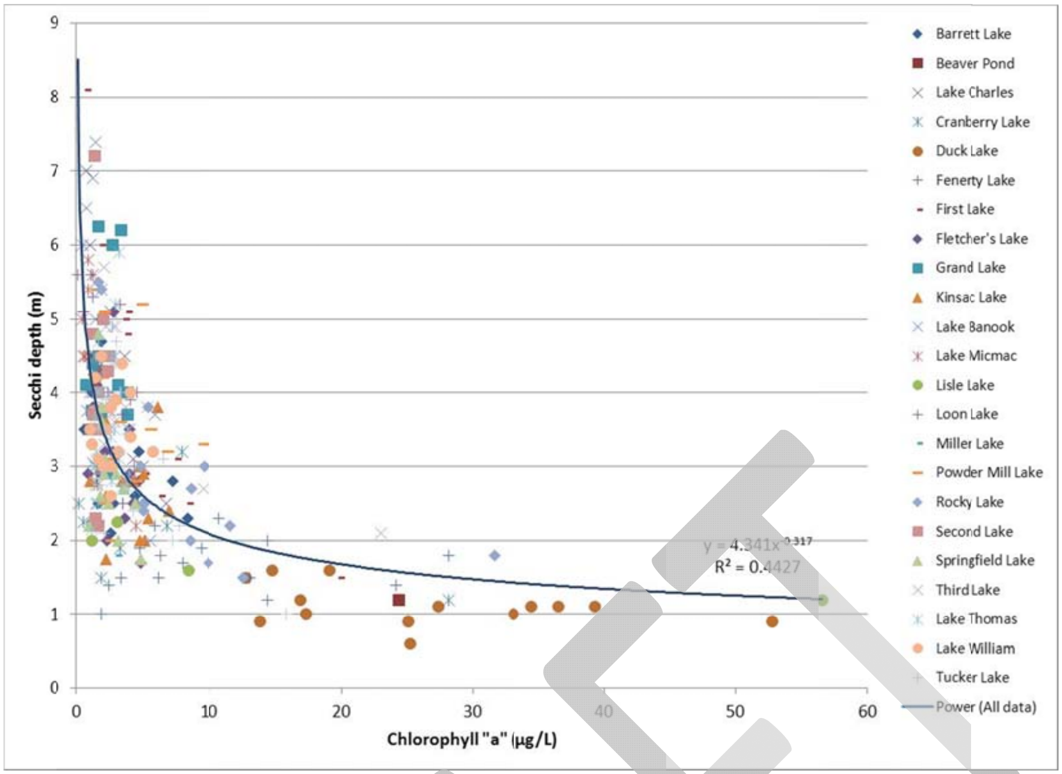


Figure 21: Relationship between Secchi Depth and Chlorophyll α in Shubenacadie Lakes

2.4.6.1 Summary

Overall, the current water quality of the lakes in the Shubenacadie subwatershed is good. For the most part, the lakes are mesotrophic systems, characterized by relatively low concentrations of nutrients and chlorophyll α. Most of the lakes in the subwatershed also have low concentrations of TSS, nitrate, chloride, and *E. coli*.

However, a few of the lakes are meso-eutrophic to eutrophic systems, which can likely be attributed to their small size, proximity to highly developed areas, and non-point and point source nutrient inputs. Point source inputs are primarily private and public waste water treatment plant discharges, sanitary sewer overflows and waste water treatment plant by-passes. Non-point sources of total phosphorus in urban areas include failing septic systems, yard and golf course fertilizers, agricultural activities such as riding stables, and pet and waterfowl droppings. Chloride concentrations are above the CWQG in a three lakes (First, Banook and MicMac) and this is likely due to street and parking lot runoff containing dissolved winter road salt. Impervious surfaces, such as paved streets, parking lots and sidewalks tend to increase road runoff, which in turn increases chloride concentrations in nearby waterbodies relative to undeveloped areas. These results suggest that water quality has already been reduced in some of the smaller lakes that are in close proximity to highly developed areas (i.e., Lisle Lake, Duck Lake and Beaver Pond). Future development must be planned in recognition that urbanization may have a significant impact on the water quality of downstream waterbodies.

2.4.7 Water Quantity

Water quantity within a watershed is a function of the watershed hydrology and hydraulics. Hydrology is defined as the movement of water while hydraulics refers to the properties that aid or impede water movement. A number of factors affect the hydrology of a watershed such as the land use, local topography, soil types, groundwater inputs or baseflow and precipitation received in the watershed. Once the water has made its way to the nearby streams or lakes, the various hydraulic processes carry the water though the system. Factors that impact watershed hydraulics include: channel roughness, channel geometry, storage areas such as lakes and wetlands, channel slope and structures that limit channel flow (such as dams or road crossings).

Urbanization in a watershed has a significant impact on both the watershed hydrology and hydraulics. Urbanization typically increases the impervious surface areas within the watershed. This results in stormwater that would have infiltrated into the soil discharging directly into the lakes and streams. This creates a greater peak or maximum flow in the watershed after a rainfall event as opposed to the more gradual, lower peak flow of a natural watershed. These higher peak flows can lead to increased flooding and erosion within the watershed. The lakes within the watershed are able to provide significant amounts of storage to buffer the effects of these flow increases, however constrictions in the rivers (such as road crossing or other structures) may cause flood impacts in the areas downstream of the development if the increased flows that result from development are not controlled. High flows resulting from urbanization also typically produce greater loadings of suspended solids and nutrients to the water courses. The addition of nutrients can result in decreased water quality and increased trophic state, which is usually inconsistent with the public desire to maintain high water quality for aesthetic value and recreational activities.

To better understand the implications of land use in the Shubenacadie Lakes subwatershed, hydrologic/hydraulic models were created to assess the effects of land uses changes over time in the watershed. Details of these models will be presented in the final report.

The Shubenacadie Canal system consists of a series of lock structures that were initially opened for operation in 1856 and ceased commercial use in 1870. The construction Shubenacadie Canal system permanently changed the hydraulics of the Shubenacadie waterways, and even though the canal structure are not in use today, the grade changes and deep cuts that were required to create the canal still influence the hydraulics of the watershed.

2.4.7.1 AECOM Supplementary Water Quantity Data

In order to address the absence of concurrent flow measurements within the Shubenacadie watershed, AECOM is undertaking monthly flow measurements at four locations to evaluate the hydrology and hydraulics within the subwatershed. Flow is estimated using a water level logger installed within the stream. As depth is only one component of the equation, a rating curve is developed to correlate flow to changes in water depth. To do so, a number of velocity measurements are collected across the stream channel using a current velocity meter to measure actual flow within the water course. Specific measurements of flow are correlated to the level logger depth at the point in time when the flow measurements were taken. Flow was monitored at four locations:

- Charles Lake outlet;
- Kinsac Lake outlet; and
- Fletchers Lake outlet; and
- Grand Lake outlet.

Flow measurements were collected on a monthly basis from November 2011 to May 2012 for a total of 7 flow measurements to date. This time period provides a diverse range of flows, from high flows observed in the fall and winter months to low flows recorded during the spring. The range of flows and the time period over which they were collected will provide a reliable rating curve that can be applied to estimate continuous flow, based on water levels recorded by the water level logger.

This hydrometric data was applied to the subwatershed study for two applications:

- Estimating the amount of baseflow that can be expected in the watershed for an average year; and
- Validating the model to ensure it is not under or over estimating the flows in the watershed.

Details of the model will be presented in the final report including the results of the hydrometric monitoring program, the rating curves developed for each site and the hydrographs for the monitoring period.

3. Data Processing (GIS) for Land use and Watershed Mapping

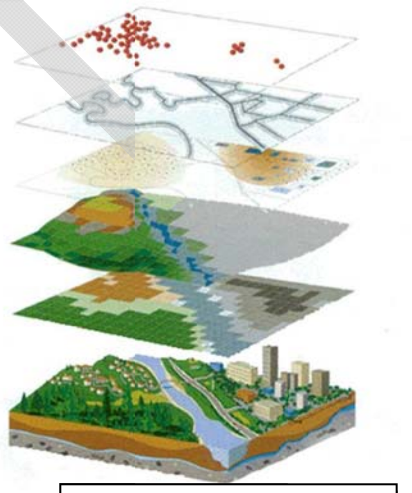
3.1 Application of GIS for Data Processing

A Geographical Information Systems (GIS) is a system of computer hardware and software used for managing and manipulating spatial geographic data. GIS was a key tool in the preparation and manipulation of data for this project. A discussion of the details regarding the GIS data will be provided in the final report. The GIS-based work for this project included:

1. Data input from maps, aerial photos, satellites, surveys, and other sources
2. Data storage, retrieval, and query
3. Data transformation, analysis, and modelling, including spatial statistics
4. Data reporting, such as maps, reports, and plans

Spatial features are stored in a co-ordinate system (latitude/longitude, state plane, UTM, etc.) which references a particular place on the earth. Descriptive attribute information, in tabular form, is associated with a point, line or polygon feature. Spatial data and associated attributes in the same co-ordinate system can then be layered together, as shown in Figure 14, for mapping and analysis.

A detailed background review of the GIS files available at the Halifax Regional Municipality (HRM), of GIS information used in previous reports, and sources freely available on the Internet, was conducted. Table 10 identifies all those files that were received directly from HRM or downloaded from the Internet. Details on additional sources of GIS information will be provided in the final report. Files were acquired, organized and saved in a GIS file geo-database for multiple uses within the project.



Spatial GIS

Table 10. GIS Files Received and Downloaded

Data Name	Source	Status	Notes	Project Use
Base Data	HRM	Received from HRM		
Parcels	HRM	Received from HRM		Land use classifications
Zoning	HRM	Received from HRM		Land use classifications
Building Polygons	HRM	Received from HRM	Detailed account of Building footprints	Land use classifications
Contours 1 m	HRM	Received from HRM	In the form of DEM/DSM	Land use classifications
Watersheds	HRM	AECOM to Create	In the form of DEM/DSM (Derived by AECOM)	Hydraulic modelling
Lakes	HRM	Received from HRM		Land use classifications
Streams	HRM	Received from HRM		Watershed Delineation / Constraint Mapping
DEM_2m	HRM	Received from HRM	Derived from LiDAR by Monette and Hopkinson of AGRG	Watershed Delineation / Constraint Mapping

Data Name	Source	Status	Notes	Project Use
Slope Grid	HRM	Received from HRM	In the form of DEM/DSM (Derived by AECOM)	Hydraulic modelling / Constraint Mapping
Fall River Subdivisions 2007	HRM	Received from HRM		Land use classifications
Port Wallis Lands	HRM	Received from HRM		Land use classifications
First Nations Reserves	HRM	Received from HRM	Indian and Northern Affairs Canada	Land use classifications
Sewage Treatment Plants	HRM	Received from HRM		
Soils	HRM	Received from HRM		Water Budget Analysis
GLFUM Reg Plan	HRM	Received from HRM	General Land use planning description	Land use classifications
Proposed HWY 113 Alignment	NSTPW	Received from HRM		Land use classifications
Forest Inventory	NSDNR			Land use classifications
IRM Data	NSDNR			
Flow Accumulation	NSDNR	Downloaded from Website	Used to compare to LiDAR GIS results	Watershed Delineation
Wetlands	NSDNR	Downloaded from Website / Received from HRM		Land use classifications / Constraint Mapping
Significant Habitat	NSDNR	Downloaded from Website / Received from HRM		Land use classifications / Constraint Mapping
Old unique forests	NSDEL (Dept. of Envt & Labour)	Received from HRM		Land use classifications / Constraint Mapping
Ecosites	NSDEL (Dept. of Envt & Labour)			
Highly scientific natural areas	NSDEL (Dept. of Envt & Labour)			
Lakes & costal	NSDEL (Dept. of Envt & Labour)			
Sites of Ecological Significance	NSDEL (Dept. of Envt & Labour)			
Ortho	NSDNR	Not Used		
Ortho	BING Imagery	Used via Arc GIS		
Crown Land	NSDNR	Received from HRM		To create Land use classifications
Trails	HRM			
Rare flora	Atlantic Canada Conservation Data Centre			
Special Areas	Atlantic Canada Conservation Data Centre			
ELC (Eco Districts - high level)	Mineral Resource Branch	Downloaded from Website		
Surficial Geology		Downloaded from Website		
Deer Wintering Areas	NSDNR			
Wet Areas	NSDNR	Downloaded from Website		
Restricted & Limited Use	NSDNR	Downloaded from Website	all files	
Transportation & Utility Features	NSDNR	Downloaded from Website		
Mineral Resource Land use		Downloaded from Website		

3.2 LiDAR

Light Detection And Ranging, or LiDAR, is a system for measuring ground surface elevation from an airplane. LiDAR combines global positioning satellite (GPS), precision aircraft guidance, laser range finding, and high speed computer processing to collect ground elevation data. Mounted on an aircraft, a high-accuracy scanner sweeps the laser pulses across the flight path and collects information by bouncing laser beams off the ground and measuring its return time to the aircraft. Depending on the laser pulses time of return, the resulting information will capture the ground or bedrock (referred to as a digital elevation model, or DEM) or the tops of trees / houses (referred to as a digital surface mode, or DSM) (Figure 22).

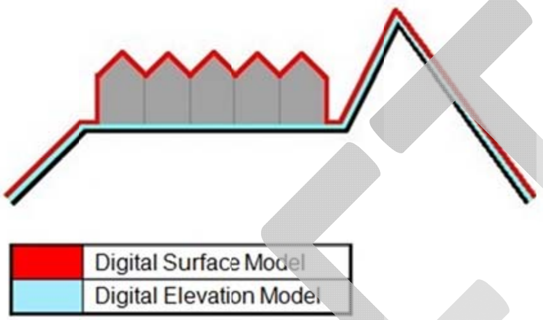


Figure 22. Illustration of Digital Surface Model (DSM) and Digital Elevation Model (DEM)

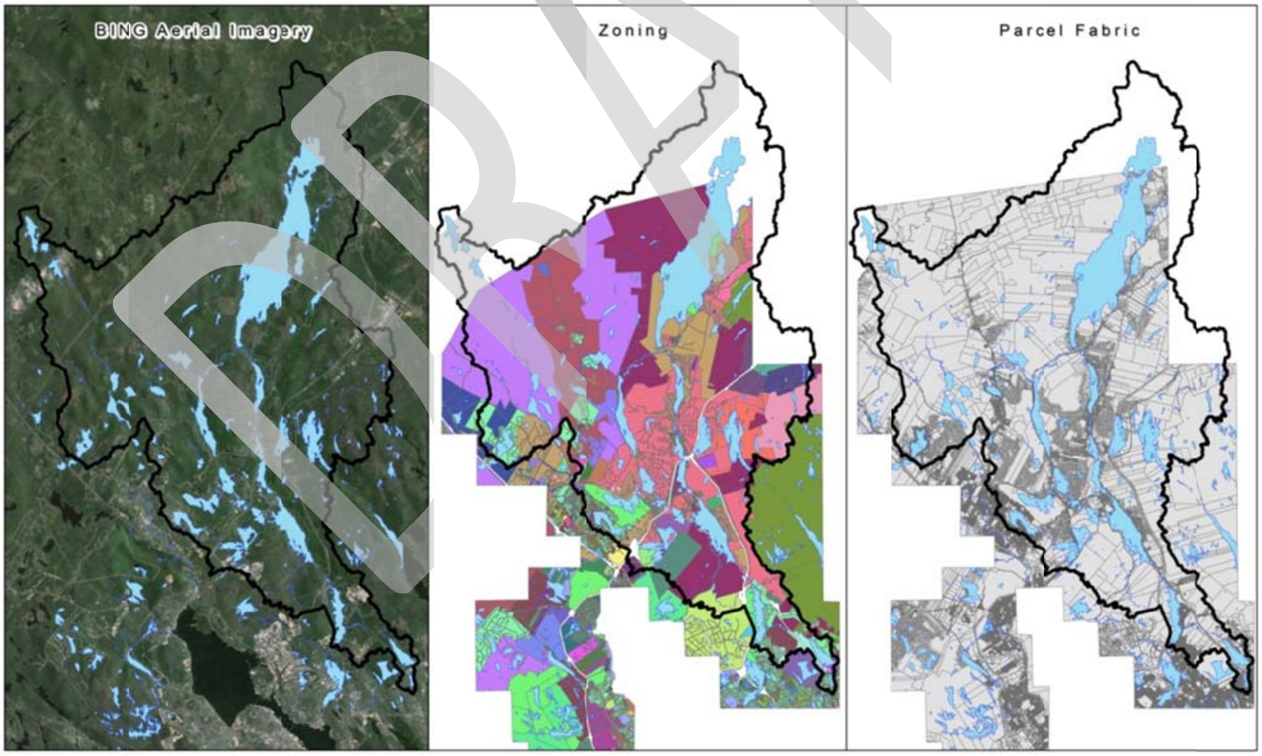


Figure 23. Illustration of Data Layers Use to Develop Land Use in Shubenacadie Lakes Subwatershed

A DEM and DSM are numerical representations of terrain elevation. They store terrain data in a grid format of co-ordinates and corresponding elevation values. The grid size is a compromise between the required accuracy, available information and computation time. The smaller the grid size, the more accurate the results from the DEM/DSM will be. HRM contracted Monette and Hopkinson of Applied Geomatics Research Group (AGRG), supervised by Dr. Tim Webster, to convert LiDAR points flown in 2007, to gridded surface (Webster, 2010). The purpose was to create a DEM from the LiDAR ground points for most of the HRM. Detailed documentation on this process will be provided in the final report. The resulting DEM grid has 2 m grid resolution which is highly accurate and useful for the mapping undertaken in this study.

3.3 Watershed Delineation

A key use of a DEM is the ease with which it can extract topographic information of hydraulic interest. Techniques are available for extracting slope properties, catchments areas, drainage divides, and channel networks. These techniques are faster and provide more precise and reproducible measurements than traditional manual techniques applied to topographic maps (Trible 1991). As such, they have the potential to greatly assist in the parameterization of hydraulic surface runoff models, especially for large watersheds (i.e., >10 km^2) where manual determination of drainage networks and subwatershed properties are tedious, time consuming, error-prone, and often highly subjective processes. The automatic techniques also have the advantage of generating digital data that can be readily imported and analyzed through GIS.

Using the LiDAR derived 2 m DEM, the Shubenacadie Lakes subwatershed was delineated. A brief description and function of the steps required to create a watershed boundary in GIS can be seen in Table 11. A more in-depth and detailed account of the watershed model will be presented in the final report.

Table 11. Overview of Watershed Modelling

Options	Functions
Hydrological Modelling	Creates watersheds and calculates their attributes
Flow Direction	Computes the direction of flow for each cell in a DEM
Identify Sinks	Creates a grid showing the location of sinks or areas of internal drainage in a DEM
Fill Sinks	Fills in the sinks in a DEM, creating a new DEM
Flow Accumulation	Calculates the accumulated flow or number of up-slope cells, based on a flow direction grid
Stream Networks	Isolating out areas of concentrated flow
Stream Order	Method of classifying streams based upon their number of tributaries
Pour Point Placement	Everything upstream of a pour point will define a single watershed
Watershed	Creates a watershed based upon a user-specified flow accumulation threshold

The subwatershed model uses the DEM to identify low points in the surface and assumes they are flow paths or watercourses. In order to ensure the flow of water in the model represented actual watershed flow conditions, a quality assurance / quality control (QA/QC) step was undertaken. This step involved verification of the watercourses used in the model through a detailed analysis of air photos and local knowledge of the landscape. During this process, those watercourses that did not meet the QA/QC review were deleted from the model or identified as intermittent or ephemeral watercourses.

3.4 Existing Development

An integral part of the hydraulic modelling was the development of a detailed land use layer. HRM does not keep a detailed account of its land use classifications in their GIS repertoire, thus a combination of aerial photo interpretation; HRM by-law zoning regulations and parcel fabric were combined to create a comprehensive existing land use layer (Figure 24).

Figure 24. Existing Land Use

Since the Shubenacadie Lakes subwatershed is largely undeveloped, the existing land use file was merged with environmental GIS data such as wetlands, significant wildlife habitat and old growth forest. For a more in-depth analysis of the ground cover, forest classification was broken down further by percent tree cover. Those tree stands averaging less than 60% tree cover were classified as Forest – Meadow while all others remained Forest. Using air photo interpretation, exposed bedrock was manually added into the land use layer. These environmental classifications are an important part of the land use model because the different land uses, whether natural or man-made, imply different surface water runoff rates based mainly on the extent of evaluation of impervious areas. Table 12 details the existing land use classifications.

Table 12. Existing Land Use Classifications

Land Use	Description	General Classification
Bedrock	Rock visible from air photo	Bedrock
Commercial	Shops / malls / box stores	Commercial
Crown Land	Provincial land	Forest
Forest	Significant tree cover	Forest
Forest - Meadow	Open grass lands / minimal tree cover	Forest - Meadow
Forest - Old Growth	Designated old growth by NSDNR	Forest
Forest - Sensitive Habitat	Designated sensitive by NSDNR	Forest
High Density Residential	Parcel < 0.5 ha	Residential
Medium Density Residential	Parcel > 0.5 ha <1.5 ha	Residential
Low Density Residential	Parcel >1.5 ha	Residential
Industrial	Industrial	Industrial
Institutional	Schools / library	Institutional
Open Space	Park or inner city open area	Forest - Meadow
Path	Concrete path too small for car	Roadway
Power Lines	Designated by Zoning	Forest - Meadow
Quarry	Open Pit	Quarry
Roadway	All major / minor road	Roadway
Water	Lakes / Rivers	Water
Wetland	designated wetland by NSDNR	Wetland

3.5 Development in the Shubenacadie Lakes Subwatershed

The objective of the modelling work undertaken in this study is to understand how development will affect the water quality within the lakes and rivers of the Shubenacadie Lakes subwatershed. The general factors that have been incorporated into the modelling for development in the watershed are considered below. The models are designed to provide an evaluation of the benefits of mitigation measures on managing the water quality within the watershed. Thus, starting from existing conditions, the models will consider three development scenarios, namely "existing conditions", "HRM authorized subdivision agreements" for areas where development agreements have been approved or are in the process of being approved; and "Proposed Development" encompassing the Port Wallis Lands which are designated by the Regional Plan for potential future development.

3.5.1 Authorized Development Agreements

In order to understand potential changes to water quality from development within the watershed, three development scenarios will be modelled. In the first case, the current state of development or "existing conditions" will be modelled. Based on information provided by HRM, existing land use conditions are shown on Figure 24. In the second case, the study will add all authorized developments within the watershed (Figure 25). Finally, the additional impacts of both the authorized and the proposed development commitments – the Port Wallis Lands – will be assessed (also shown on Figure 25).

Figure 25. HRM Authorized Subdivision Agreements and Port Wallis Lands

Short to medium term development will occur in the central portion of the watershed. In total, approximately 20 developments have been authorized by HRM, and many are currently under construction (Table 13). Since it is not possible to predict when each of these subdivisions will be completed, the effects from these developments are grouped together as future inputs to the waterbodies in the Shubenacadie subwatershed. Generally speaking, the subdivisions are low density residential developments without municipal sewer or water services. These developments are required to have provincially approved on-site or communal septic treatment systems. In contrast, the Port Wallis Lands consist of a mix of low, medium and high density development and will be fully serviced by municipal water and wastewater infrastructure.

Table 13. HRM Authorized Subdivision Agreements (2012)

		# Lots Proposed	# Lots Approved (May 2012)	Total Lots
1	Fog Hill Estates	38	10	48
2	Oakfield Woods	78	10	88
3	Oakfield Estates	50	0	50
4	Cindy Drive Extension	0	8	8
5	Brookhill Estates	25	0	25
6	Oaken Hills	80	50	130
7	Cameron Lands	20	0	20
8	Schwartzwald	36	75	111
9a	Lake Fletcher Estates	629	171	800
9b	St Andrew’s Village West	128	50	178
9c	St Andrew’s Village	18	47	65
10a	Lost Creek	110	108	218
10b	Carriagewood Estates	32	0	32
11	Guptil Place	0	19	19
12	Monarch	18	48	66
13	Sidhu Investments	21	0	21
14	Charleswood Open Sp	100	0	100
15	Hudson	0	9	9
16	Sackville Acres	90	0	90
17	Lively Hills	117	0	117
18	Lakeleaf Acres	70	47	117
19	Lakecrest Acres	170	101	271
20	Newridge	28	28	56
	TOTAL	**1858**		

Source: HRM

The extent of current sanitary sewer coverage is illustrated in Figure 26. One of the most significant impacts on lake water quality is the proximity of private septic systems owned by those people and businesses who do not have access to municipal services. This is especially a concern in areas where the land is only slightly above the surface water level and the septic systems may not function very well due to high water tables. Further, maintenance of septic systems is often minimal until a serious problem occurs. As a result, many older septic systems are virtually non-functioning. We expect this to be the case in many of the long-established properties adjacent to the lakes of Shubenacadie Lakes subwatershed. Consequently in lake modelling for TP, the ability of a septic system to keep phosphorus from reaching a water body (i.e., the retention) may range from 100% for a new system with a large buffer between the system and the shoreline to virtually 0% for an old, poorly maintained system close to the shore and with a high water table.

Figure 26. Sewer Coverage

3.5.2 Development Constraints

Critical to the modelling is the concept of development constraints that restrict development in sensitive areas or areas that may result in disproportionately high impacts on the lake water quality. A constraints map (Figure 27) has been developed for use in the water quality/quantity models. The elements of the constraints map include proximity to watercourses, protection of wetlands, slope, significant woodlots, protected habitat or locations of rare and endangered species and the presence of acid generating rock close to the surface.

As illustrated in Figure 27 we have assumed that there will be an automatic 20 m setback for all development along watercourses, contiguous wetlands and lakes. This buffer should ideally be retained in a natural vegetation state to eliminate overland flow during storm events and to provide a buffer zone for nutrients, pesticides and other pollutants from developed areas both during and following construction. Wetlands provide important aquatic habitat and potentially retain nutrients and other pollutants rather than allowing them to reach water courses. We have assumed that this buffer will also protect wetlands that are connected with watercourses. Further, we have applied the 20 m buffer to significant wildlife habitat areas and old growth forests as mapped by NSDNR.

The Halifax Mainland Land Use By-Law regarding the “slope constraint to development” {14QA(1)} states that:

> *“No development permit shall be issued for any development within 20 m of the ordinary high water mark of any watercourse. Where the average positive slopes within the 20 m buffer are greater than 20%, the buffer shall be increased by 1 m for each additional 2% of the slope, to a maximum of 60 m.”*

The draft River Lakes Environmental Protection Policy offers what we believe is a more rigorous and more readily enforceable constraint to development on land with a slope >20%. Specifically it states that there will be a “Prohibition of the removal of vegetation on all areas with slopes of 20% or more …” Evidently this is intended to apply to all areas; however, for the modelling it has been assumed that this constraint only applies within the 20 m buffer along water courses, lakes and wetlands and thus it applies regardless of slope.

Many water bodies in the HRM area are sensitive to acidification. The slates of the Halifax Formation are especially prone to producing acid drainage when exposed to the air. We note that there are existing regulations on development on these slates and consequently have not considered them as a development constraint for our purposes.

Figure 27. Constraints

4. Receiving Water Quality Objectives

4.1 Introduction

One of the principal objectives of the watershed study is to evaluate existing water quality conditions and recommend water quality objectives for the main lakes within the watershed. The water quality objectives are based upon a scientific understanding of the Shubenacadie Lakes subwatershed and widely accepted standards of water quality. These objectives will protect and maintain the high quality of the water within the watershed in light of the HRM development plans. These recommended water quality objectives will be used by HRM to establish the acceptable standards that HRM and the public agree will achieve the long term management goals for the Shubenacadie Lakes subwatershed.

4.2 Water Quality Indicators

Suburban development within the Shubenacadie Lakes subwatershed will require removal and transformation of forested and natural areas for residential and commercial communities. Given this, a short list of critical parameters or water quality indicators used to establish water quality objectives was derived based on those parameters most likely to be negatively affected by development within the watershed. Deterioration of these parameters will negatively affect recreational use, aquatic life and passive enjoyment or aesthetics of these lakes.

The parameters most likely to be negatively influenced as a result of these land use changes are: **total phosphorus, nitrate, ammonia, total suspended solids, chloride and *E. coli*.** Given their sensitivity to development, these parameters were selected as “indicators” upon which to base water quality objectives (**Error! Reference source not found.**). Other parameters such as metals, oil and grease, chlorophyll *α*, and nitrogen, may also increase due to development in the watershed; however, watershed management and implementation of mitigation measures to reduce development impacts to the “indicator parameters” will also limit the changes to all of these parameters. For example, metals concentrations may increase in the watershed but it is likely that the metals will be associated with the transport of suspended solids to the lake as a result of clearing and construction activities in the watershed and increased runoff as a result in increased surface hardening. Consequently, management of suspended sediment within the lake will not only help reduce phosphorus concentrations but also metals. Nevertheless, to avoid a large number of water quality objectives that need to be monitored through expensive water quality monitoring programs, we have restricted setting water quality objectives to the few variables that we think will provide protection of the watershed while focusing the monitoring efforts. There may be, at some time in the future, a need to undertake more specialized monitoring programs and to set specific water quality objectives to individual lakes or even parts of lakes. An example of this might be in relation to impacts from specific developments or land use changes that may warrant targeted investigation such as a new quarry development or a large new “big box” shopping facility. However, at the present time it is essential to implement a focussed and effective water quality management program based on these selected water quality indicators and their associated objectives and early warning values.

Table 14. Changes to Water Quality Parameters from Watershed Development

Water Quality Parameter	Effect of Development	Rationale for inclusion as Indicator Parameter
TP	Increase from fertilizer runoff, stormwater runoff, waste water treatment plant (WWTP) by-passes and overflows, septic systems	Increases in phosphorus can increase growth of algae and aquatic plants which can in turn reduce water clarity and dissolved oxygen
NO3	Increase from fertilizer runoff, WWTP by-	Increases in nitrate can increase growth of

Water Quality Parameter	Effect of Development	Rationale for inclusion as Indicator Parameter
	passes and overflows, septic systems, urban runoff, stormwater discharge.	algae and aquatic plants which can in turn reduce water clarity and dissolved oxygen
Ammonia	Increase from fertilizer runoff, WWTP by-passes and overflows, urban runoff, effluents from some industrial and commercial activities	Un-ionized ammonia is a portion of ammonia that can be toxic to aquatic life at elevated concentrations
TSS	Increase from deforestation, construction activities, gravel operations, WWTP bypasses and overflows, and stormwater runoff from urban areas/hard surfaces	Increases in suspended solids can reduce water clarity, alter habitat, and interfere with feeding, physiological and behavioural in fish and affect benthic production and periphyton communities.
Chloride	Increase due to spray from road salting practices, stormwater runoff, WWTP bypass overflows, and long-range transport	Increases chloride results in increased salinity, thereby affecting the ability of some organisms to osmoregulate (affecting endocrine balance, oxygen consumption, and physiological processes (Holland et al., 2010)).
E. coli	Increase due to septic systems, WWTP bypass overflows, and stormwater runoff	An indicator of fecal contamination in recreational water

4.3 Review of Water Quality Guidelines and Objectives from Other Jurisdictions

The province of Nova Scotia has not yet developed comprehensive water quality objectives (WQOs) for the lakes and rivers in the province although WQOs have been recommended for specific lakes. When developing water quality objectives for Shubenacadie, the guidelines and objectives from other jurisdictions were consulted for direction. The Canadian Water Quality Guidelines (CWQG) provides a benchmark for a consistent level of protection across Canada. The CWQG are derived according to a nationally endorsed scientific protocol, in which all components of the aquatic ecosystem are considered using the available scientific data in association with reviews and guidelines developed in other jurisdictions (e.g., United States Environmental Protection Agency (USEPA), Netherlands, and European Union). The CWQG "are set at such values to as to protect all forms of aquatic life and all aspects of the aquatic life cycles". They are conservative values, set at levels to protect the most sensitive forms of aquatic life.

National standards for parameters in surface waters in the USA have been developed by the USEPA. The USEPA standards are widely used benchmarks based on leading edge scientific research. The USEPA has developed a strategy to address nutrient enrichment of waterbodies that includes the use of regional and waterbody– type approach to set nutrient criteria. The state of Vermont, which has developed comprehensive water quality objectives in association with USEPA guidelines, was selected for comparison as it has similarities with Nova Scotia with respect to latitude, climate and geology. **Error! Reference source not found.** summarizes the CWQG, USEPA, and Vermont water quality guidelines and standards for the key indicator parameters identified for the Shubenacadie Lakes subwatershed.

Table 15. Water Quality Guidelines and Standards from Canada, USEPA and Vermont

Parameter	CWQG	USEPA	Vermont
TP	Trophic Status Approach	• Ecoregion Based Approach	• Lake specific – maximum increase of 1 mg/L
NO_3	• 13 mg NO_3/L	• n/a	• 5.0 mg/L as NO_3-N
Un-ionized Ammonia	• 0.019 mg/L	• Temperature/pH dependent	• EPA values
TSS	• Short term exposure: 25 mg/L increase • Long term exposure: 5 mg/L increase	• <10 % of the seasonal value	• Water Class dependent
Chloride	• 120 mg/L (chronic toxicity guideline) • 640 mg/L (acute toxicity guideline)	• 230 mg/L chronic concentration (CC) • 860 mg/L maximum concentration (MC)	• n/a
E. coli	• 2000 *E. coli*/L[1] (geometric mean of 5 samples)	• 126 *E. coli*/100 mL (geometric mean of 5 samples)	• Water Class dependent

Note: 1. Health Canada Guidelines for Recreational Water Quality

All indicator parameters, with the exception of total phosphorus, have definitive CWQG limits. The concentrations of these parameters are unlikely to be affected by local geology, but are responsive to land use within the watershed.

4.4 Recommended Water Quality Objectives for Shubenacadie Lakes Subwatershed

Recommended WQOs for the Shubenacadie Lakes subwatershed have been derived for the indicator parameters most sensitive to changes in land use within the watershed. The WQOs and early warning alert values for these indicators can be used in association with the monitoring data to indicate a reduction in water quality in the lakes and prompt management action or mitigation. Early warning alert values are provided with the WQOs on the basis that it is desirable to have a warning that an objective is being approached. This permits a response and implementation time for mitigation measures. Objectives and alerts should not be based on single data points as there is considerable natural variability in water quality within a watershed. In light of this natural variation, a water quality evaluation methodology is proposed.

Water quality in the Shubenacadie Lakes subwatershed is good, and concentrations of most indicator parameters presently below CWQG (Table 8). **Because the CWQGs are set to protect the most sensitive species, and because water quality in the Shubenacadie Lakes is currently better than these objectives (for most lakes), we recommend that the CWQGs for nitrate, un-ionized ammonia, total suspended solids, and chloride be adopted for the Shubenacadie Lakes watershed.** HRM currently uses the guideline of 200 CFU/100 mL for *E. coli* for body contact recreation, which is the same as the Health Canada value of 2000 *E. coli*/L[3]. We suggest this value is appropriate for the *E. coli* parameter. These values are illustrated in Table 16.

Table 16. Recommended Water Quality Objectives for Shubenacadie Lakes subwatershed Excluding TP

Parameter	Derivation of Objective	Shubenacadie Lakes Watershed Water Quality Objective	Early Warning Alert Value	Evaluation Method for Objective/Alert Value
NO_3 – Nitrate	CCME	• 13 mg NO_3/L	• ≤10 mg/L	• 75th percentile of 3 year historical data
Un-ionized Ammonia	CCME	• 0.019 mg/L	• ≤0.014 mg/L	• 75th percentile of 3 year historical data
Total Suspended Solids (TSS)	CCME	• Short term: 25 mg/L increase • Long term: 5 mg/L increase	• Lake dependent	• 75th percentile of 3 year historical data not to exceed base line by more than 5 mg/L
Chloride	CCME	• 120 mg/L	≤90 mg/L	• 75th percentile of 3 year historical data
E. coli	Nova Scotia	• 200 *E. coli*/100 mL	• 200 *E. coli*/100 mL	• Geometric mean of 5 samples

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[3] *Note these are the same measurements but expressed for a different volume (mL versus L) and consequently the number of allowable counts changes in accordance with the volume of the sample.*

Parameter	Derivation of Objective	Shubenacadie Lakes Watershed Water Quality Objective	Early Warning Alert Value	Evaluation Method for Objective/Alert Value
	and Health Canada	• (geometric mean of 5 samples)		

4.5 A Review of Water Quality Guidelines and Objectives for Total Phosphorus

Currently there are no national guidelines for phosphorus, although several provinces have developed their own guidelines or objectives. The development of national guidelines has been hindered by the need to consider the following factors that affect the nature of phosphorus as a pollutant:

a) It is non-toxic and is a required and limiting nutrient in fresh water, such that small increases stimulate aquatic productivity;

b) The natural or baseline water quality and trophic status for lakes varies extensively across Canada;

c) The detrimental effects of phosphorus are indirect, resulting from algal growth and oxygen depletion, and so there is a lot of variation in phosphorus concentrations associated with observed effects;

d) The effects of phosphorus on primary biological production are modified by natural factors that attenuate light (i.e., Dissolved Organic Carbon or turbidity). These factors can mask the effects of increased phosphorus by reducing the biological response normally associated with elevated phosphorus concentrations;

e) The effects of phosphorus on surface water are partially aesthetic (i.e., decreased water clarity), and so determination of thresholds of effect is somewhat subjective; and

f) Phosphorus concentrations can vary substantially in surface water, as a result of season, differences between river and lake systems and as a result of natural factors in the landscape such as geology, soils and wetlands.

These factors have been accommodated in the guidelines developed by several provinces. Provincial total phosphorus water quality guidelines vary from 5-15 µg/L in British Columbia to 50 µg/L in Alberta (Table 17) and reflect, in part, the differences in natural water quality across Canada.

Table 17. Provincial Water Quality Objectives for Total Phosphorus (µg/L)

	Lakes	Rivers
British Columbia	5-15	
Alberta	50	
Manitoba	25	50
Ontario	10, 20	30
Quebec	Background + 50% increase (upper limits of 10 and 20 µg/L)	

4.5.1 Canadian Guidance Framework for Phosphorus

Environment Canada (CCME 2004) developed a framework for the management of phosphorus. The framework offers a tiered approach where phosphorus concentrations should i) not exceed predefined "trigger ranges"; and ii) not increase more than 50% from the baseline or reference condition. The trigger ranges are based on the range of phosphorus concentrations in water that define the reference trophic status for a site. If the defined range is met or exceeded then management action is "triggered", to assess the problem, determine its causes and implement solutions. For lakes and rivers, trophic status classifications have been developed as ranges of phosphorus concentrations which reflect the fact that not all lakes respond in a clear and precise manner. Environment Canada (CCME 2004) provided a classification of trophic status for lakes and rivers (see Table 5) as adapted from Vollenweider and Kerekes (1982) and Dodds *et al.* (1998).

4.6 Development of Total Phosphorus Water Quality Objectives

For the Shubenacadie lakes we recommend building on this classification with each water body categorized into one trophic status based on existing conditions either measured or predicted based on model results. **As a result, the management objective would be to meet or maintain the trophic status of a water body so the water quality objective for TP becomes the upper limit of the TP range indicated in Table 18 for each trophic state**. If a monitoring program showed that the trophic status of the water body was changing to the next higher trophic state (i.e., the water quality objective was being exceeded) then management action would be warranted to protect the lake and in this case the water quality objective becomes a "trigger value" for action. This approach is consistent with the objectives of the Regional Plan, which seeks "to maintain the existing trophic status of our lakes and waterways to the extent possible."

In Section 2.4, the water quality data from the Shubenacadie Lakes subwatershed was reviewed. Most of the lakes were classified as mesotrophic; characterized by low to moderate (10 to 20 μg/L) concentrations of phosphorus and chlorophyll *α*. Grand Lake and Lewis Lake were oligotrophic, with low concentrations (<10 μg/L) of total phosphorus. Fenerty lake was classified as meso-eutrophic, with an average phosphorus concentration of 22 μg/L. Both Duck and Lisle Lakes were eutrophic, with average phosphorus concentrations of 43 and 50 μg/L respectively

Unfortunately, mitigation measures to reduce TP concentrations are seldom instantaneous or completely effective, so water quality objectives combined with early warning values are often used to evaluate lake quality rather than waiting for the specific TP water quality objective to be met or exceeded. Early warning indicators such as trends in phosphorus concentrations or trigger concentrations just below the objective value are highly appropriate management tools for water bodies. There are a variety of ways to determine whether or not water quality objectives or early warning indicators are being met or exceeded. The selection of the best early warning system depends on a number of things including the size and hydraulic turnover rate of the lake, ongoing land use changes within the watershed, natural water quality variability, the extent of baseline data, the design of the monitoring program and the importance placed on the protection of the lake by regulators and residents. As can be seen from the water quality summary of the Shubenacadie Lakes above, there is considerable variability in TP measurements and single values (low or high) are not an appropriate basis for management decisions. Thus, the approach to setting phosphorus water quality objectives needs to be accompanied by a scientific rationale for testing whether or not the water quality is changing. The proposed approach for each lake is presented in Table 18.

Lake-specific TP objectives and early warning values have been developed based on existing data. Table 18 provides a summary of the TP water quality objectives and early warning values and a method to evaluate whether or not the objective or alert value is being approached for each lake. Insufficient data exist to establish phosphorus objectives for Miller Lake, Beaverbank, Fish Lake and Beaver Pond. Additional monitoring must be conducted, so that water quality objectives and alert values can be developed for these lakes.

Table 18. Water Quality Objectives, Early Warning Values and Proposed Evaluation Methodology for Alert Values for Total Phosphorus (µg/L) in the Shubenacadie Lakes subwatershed

Lake	Trophic State Objective	Numerical Objective	Early Warning	Evaluation
Grand, Lewis	Oligotrophic	< 10 µg/L	9 µg/L	Based on 3 year running average
Charles, Micmac, Banook, First, Second, Third, Thomas, Fletcher, Tucker, Kinsac, Barrett and Powder Mill	Mesotrophic	< 20 µg/L	15 µg/L	
Loon, William, Rocky, Springfield	Mesotrophic	< 20 µg/L	18 µg/L	
Cranberry	Mesotrophic	< 20 µg/L	20 µg/L	
Fenerty	Meso-Eutrophic	22 µg/L	22 µg/L	Fenerty should be maintained at its current average phosphorus concentration of 22 µg/L.
Duck and Lisle	Both Duck (43 µg/L) and Lisle (50 µg/L) are eutrophic lakes. Water quality should not be allowed to deteriorate further and improved where feasible.			
Miller, Beaverbank, Fish, and Beaver Pond	Insufficient data exist. More sampling is required to set WQOs for these lakes.			

5. Next Steps

Additional work will be completed as part of this project to meet the remaining objectives of Policy E-17 for presentation in the final report. In particular, an extensive modelling effort will be undertaken to define existing water quality conditions and evaluate the impacts of current conditions on receiving water quality with respect to discharge and water quality. In particular, we will be assessing the effect of future land use changes on the trophic state and phosphorus concentrations in the primary lakes using a Lake Capacity Model (LCM) that has been employed previously in the Halifax region. The LCM model is a steady state empirically derived model that predicts the trophic state of a receiving water body. The trophic state indicates the response of the lake to phosphorus loadings.

However, urbanization usually results in extensive changes to the hydrology of a watershed and as noted elsewhere in this report, the peak flows tend to increase due to a faster and higher rate of runoff and reduced infiltration. The higher peak flow results in greater erosion. These changes result from the reduction of pervious surfaces due to the increase in roof area, parking lots, roads etc. and more direct delivery of pollutants including phosphorus to the watercourses. The management of stormwater in urban areas through the use of various techniques is critical to maintaining water quality in urbanizing watersheds. While the LCM deals with this in a steady state manner by accounting for changes in land use, it does not address the dynamic nature of pollutant delivery nor the benefits of stormwater management best practices in an adequate and time dependent manner. Consequently, we will also adapt a stormwater management model to predicting phosphorus loads within the Shubenacadie Lakes subwatershed. The strength of this model is that it considers the hydrology of the watercourse and how this will be impacted by development and predicts not only changes in flow but also changes in sediment and phosphorus loading. The model adopted here is the U.S. Environmental Protection Agency's StormWater Management Model (SWMM).

These two models will be compared based on the fact that the LCM has historically been applied in the region (Scott and Hart 2004; Porter Dillon Limited 1996) and the fact that the SWMM model is more appropriate and accurate for managing urbanizing lakes with a strong influence from stormwater. Both models will employ the three land use scenarios outlined above to generate loadings for the watershed and evaluating the predicted impacts of land use changes. They will also be used to evaluate the lake water quality objectives presented in this preliminary report and to assess the benefits that could be achieved from mitigation measures to reduce the impacts of development, reduce or maintain phosphorus loadings and maintain or improve lake trophic state. The mitigation measures that will be considered using one or both models may include alternatives to individual septic systems, stormwater quantity and quality management for new developments and for existing urbanized areas, alternative land use patterns (e.g., sensitive land areas protected from development through land exchanges or alternative development scenarios) and various size buffer strips.

Also as part of the final report AECOM will recommend a cost effective and environmentally sound water quality monitoring program for the watershed in the light of existing data and water bodies that need to be assessed as a result of planned development. Considerations will also have to be given to developing a water quantity monitoring program for the watershed to better calibrate the stormwater model and to confirm the predicted impacts of development on flow and pollutant loading and the benefits of the mitigation options.

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7. Glossary

Acidification	Raising the acidity (lowering the pH) of a water body by adding an acid.
Alluvial	Soil or earth material which has been deposited by running water, as in a riverbed, floodplain, or delta.
Anoxic	(1) Denotes the absence of oxygen, as in a body of water. (2) Of, relating to, or affected with anoxia; greatly deficient in oxygen; oxygenless as with water.
Anthropogenic	Referring to changes or activities that are man-made, rather than those resulting from natural processes.
Aquifer	A geologic formation, a group of formations, or a part of a formation that is water bearing. A geological formation or structure that stores or transmits water, or both, such as to wells and springs. Use of the term is usually restricted to those water-bearing structures capable of yielding water in sufficient quantity to constitute a usable supply.
Aquitard	A saturated, but poorly permeable bed that impedes groundwater movement and does not yield water freely to wells, but which may transmit appreciable water to or from adjacent aquifers and, where sufficiently thick, may constitute an important groundwater storage unit. Aquitards are characterized by values of leakance that may range from relatively low to relatively high. Aerial extensive aquitards of relatively low leakance may function regionally as boundaries of aquifer flow systems.
Baseflow	Runoff that has passed into the ground, has become groundwater, and has been discharged into a stream channel as spring or seepage water.
Batholith	A mass of igneous rock that forms intrusively and can rise to the surface.
Bathymetry	(1) The measurement of the depth of large bodies of water (oceans, seas, ponds and lakes). (2) The measurement of water depth at various places in a body of water. Also the information derived from such measurements.
Bedrock	Solid rock that lies beneath soil, loose sediments, or other unconsolidated material.
Bog	A wet, overwhelmingly vegetative substratum which lacks drainage and where humic and other acids give rise to modifications of plant structure and function.
Catchment Area (syn. watershed or subwatershed)	All lands enclosed by a continuous hydrologic drainage divide and lying upslope from a specified point on a stream.
Chloride	Negative chlorine ions, Cl-, found naturally in some surface waters and groundwaters and in high concentrations in seawater. Higher-than-normal chloride concentrations in fresh water, due to sodium chloride (table salt) that is used on foods and present in body wastes, can indicate sewage pollution. The use of highway de-icing salts can also introduce chlorides to surface water or groundwater. Elevated groundwater chlorides in drinking water wells near coastlines may indicate saltwater intrusion.

Chlorophyll	(1) The green pigments of plants. There are seven known types of chlorophyll, *Chlorophyll α* and *Chlorophyll b* are the two most common forms. A green photosynthetic coloring matter of plants found in chloroplasts and made up chiefly of a blue-black ester. (2) Major light gathering pigment of all photosynthetic organisms and is essential for the process of photosynthesis. The amount present in lake water depends on the amount of algae and is therefore used as an common indicator of water quality.
Dissolved Organic Carbon	A measure of the organic compounds that are dissolved in water. In the analytical test for DOC, a water sample is first filtered to remove particulate material, and the organic compounds that pass through the filter are chemically converted to carbon dioxide, which is then measured to compute the amount of organic material dissolved in the water.
Dissolved Oxygen	The amount of free (not chemically combined) oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per litre, parts per million, or percent of saturation. Adequate concentrations of dissolved oxygen are necessary for the life of fish and other aquatic organisms and the prevention of offensive odours. Dissolved oxygen levels are considered the most important and commonly employed measurement of water quality and indicator of a water body's ability to support desirable aquatic life. The ideal dissolved oxygen level for fish is between 7 and 9 milligrams per litre (mg/L); most fish cannot survive at levels below 3 mg/L of dissolved oxygen. Secondary and advanced wastewater treatment techniques are generally designed to ensure adequate dissolved oxygen in waste-receiving waters.
Drift	To be carried along by current of air or water. Bogs depend primarily on precipitation for their water source, and are usually acidic and rich in plant residue with a conspicuous mat of living green moss. Only a restricted group of plants, mostly *mycorrhizal* (fungi, heaths, orchids, and saprophytes), can tolerate bog conditions.
Drumlin	An elongated hill or ridge of glacial drift.
Dystrophic	Characterized by having brownish acidic waters, a high concentration of humic matter, and a small plant population.
Ecoregion	A recurring pattern of ecosystems associated with characteristic combinations of soil and landform that characterize that region.
Epilimnetic	Relation to an eplimnion. An eplimnion is the warm upper layer of a body of water with thermal stratification, which extends down from the surface to the thermocline, which forms the boundary between the warmer upper layers of the epilimnion and the colder waters of the lower depths, or hypolimnion. The epilimnion is less dense than the lower waters and is wind-circulated and essentially homothermous.
Eutrophication	Pertaining to a lake or other body of water characterized by large nutrient concentrations such as nitrogen and phosphorus and resulting high productivity. Such waters are often shallow, with algal blooms and periods of oxygen deficiency. Slightly or moderately eutrophic water can be healthful and support a complex web of plant and animal life. However, such waters are generally undesirable for drinking water and other needs.
Fen	Low land covered wholly or partly with water. A type of wetland that accumulates peat deposits. Fens are less acidic than bogs, deriving most of their water from groundwater rich in calcium and magnesium.

Fluvial	Of or pertaining to rivers and streams; growing or living in streams ponds; produced the action of a river or stream.
Glaciation	Alteration of the earth's solid surface through erosion and deposition by glacier ice.
Hydraulics	(1) The study of liquids, particularly water, under all conditions of rest and motion. (2) The branch of physics having to do with the mechanical properties of water and other liquids in motion and with the application of these properties in engineering.
Hydrology	The science of waters of the earth, their occurrence, distribution, and circulation; their physical and chemical properties; and their reaction with the environment, including living beings.
Hypolimnion	The lowermost, non-circulating layer of cold water in a thermally stratified lake or reservoir that lies below the thermocline, remains perpetually cold and is usually deficient of oxygen. Also see Thermal Stratification.
Impervious Surface	a surface that prevents or severely limits the infiltration of surface precipitation from rainwater and snowmelt to the soil below. Typical impervious surfaces include roads, driveways, sidewalks, buildings, and certain types of non-fractured bedrock.
Lacustrine	Pertaining to, produced by, or inhabiting a lake.
LiDAR	An acronym for Light Detection And Ranging. A system for measuring ground surface elevation from an airplane.
Marsh	An area of soft, wet, low-lying land, characterized by grassy vegetation that does not accumulate appreciable peat deposits and often forming a transition zone between water and land. A tract of wet or periodically inundated treeless land, usually characterized by grasses, cattails, or other monocotyledons (sedges, lilies, irises, orchids, palms, etc.). Marshes may be either fresh or saltwater, tidal or non-tidal.
Mesotrophic	A lake or other body of water characterized by moderate nutrient concentrations such as nitrogen and phosphorus and resulting significant productivity. Such waters are often shallow, with algal blooms and periods of oxygen deficiency. Slightly or moderately eutrophic water can be healthful and support a complex web of plant and animal life. However, such waters are generally undesirable for drinking water and other needs.
Morphometry	The shape and structure of the lake basin
Non-Point Source of Pollution	Pollution discharged over a wide land area, not from one specific location. These are forms of diffuse pollution caused by sediment, nutrients, organic and toxic substances originating from land use activities, which are carried to lakes and streams by surface runoff. Non-point source pollution, by contrast, is contamination that occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land surface, it picks up soil particles and pollutants such as nutrients and pesticides. Some of the polluted runoff infiltrates into the soil to contaminate (and recharge) the groundwater below. The rest of the runoff deposits the soil and pollutants in rivers, lakes, wetlands, and coastal waters. Originating from numerous small sources, non-point source pollution is widespread, dispersed, and hard to pinpoint.

Oligotrophic	Pertaining to a lake or other body of water characterized by extremely low nutrient concentrations such as nitrogen and phosphorus and resulting very moderate productivity. Oligotrophic lakes are those low in nutrient materials and consequently poor areas for the development of extensive aquatic floras and faunas. Such lakes are often deep, with sandy bottoms and very limited plant growth, but with high dissolved-oxygen levels. This represents the early stages in the life cycle of a lake.
Overburden	The earth, rock, and other materials that lie above a desired ore or mineral deposit.
Pelagic	Referring to the open sea or open part of a large lake at depth.
Phosphorus	An element that is essential to plant life but contributes to an increased trophic level (eutrophication) of water bodies.
Point Source Pollution	Pollutants discharged from any identifiable point, including pipes, ditches, channels, sewers, tunnels, and containers of various types.
Quartzites	A hard metamorphic rock made up of interlocking quartz grains that have been cemented by silica.
Sediment	Fragmental or clastic mineral particles derived from soil, alluvial, and rock materials by processes of erosion, and transported by water, wind, ice, and gravity.
Surficial Geology	the loose deposits of soil, sand, gravel and other material deposited on top of the bedrock
Recharge	Introduction of surface or groundwater to groundwater storage such as an aquifer.
Riparian	Pertaining to the banks of a river, stream, waterway, or other, typically, flowing body of water as well as to plant and animal communities along such bodies of water.
Runoff	(1)That part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. It is the same as streamflow unaffected by artificial diversions, imports, storage, or other works of humans in or on the stream channels. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or groundwater runoff. (2) The total discharge described in (1), above, during a specified period of time. (3) Also defined as the depth to which a drainage area would be covered if all of the runoff for a given period of time were uniformly distributed over it.
Stormwater Runoff	The water and associated material draining into streams, lakes, or sewers as the result of a storm.
Swamp	Wet, spongy land; low saturated ground, and ground that is covered intermittently with standing water, sometimes inundated and characteristically dominated by trees or shrubs, but without appreciable peat deposits. Swamps may be fresh or salt water and tidal or non-tidal.
Temperature	The degree of hotness or coldness. A measure of the average energy of the molecular motion in a body or substance at a certain point.
Till	The mixture of rocks, boulders, and soil picked up by a moving glacier and carried along the path of the ice advance. The glacier deposits this till along its pathon the sides of the ice sheet, at the toe of the glacier when it recedes, and across valley floors when the ice sheet melts. These till deposits are akin to the footprint of a glacier and are used to track the movement of glaciers. These till deposits can be good sources of groundwater, if they do not contain significant amounts of impermeable clays.

Thermal Stratification	The vertical temperature stratification of a lake or reservoir which consists of: (a) the upper layer, or epilimnion, in which the water temperature is virtually uniform; b) the middle layer, or thermocline, in which there is a marked drop in temperature per unit of depth; and (c) the lowest stratum, or hypolimnion, in which the temperature is again nearly uniform.
Thermocline	(1) The region in a thermally stratified body of water which separates warmer oxygen-rich surface water from cold oxygen-poor deep water and in which temperature decreases rapidly with depth. (2) A layer in a large body of water, such as a lake, that sharply separates regions differing in temperature, so that the temperature gradient across the layer is abrupt. (3) The intermediate summer or transition zone in lakes between the overlying epilimnion and the underlying hypolimnion, defined as that middle region of a thermally stratified lake or reservoir in which there is a rapid decrease in temperature with water depth. Typically, the temperature decrease reaches 1°C or more for each metre of descent.
Total Kjeldahl Nitrogen	Total concentration of nitrogen in a sample present as ammonia or bound in organic compounds.
Total Phosphorus	The sum of reactive, condensed and organic phosphorus.
Total Suspended Solids	Solids, found in waste water or in a stream, which can be removed by filtration. The origin of suspended matter may be man-made wastes or natural sources such as silt.
Trophic State	A measurement of the biological productivity of a water feature.
Turbidity	Water containing suspended matter that interferes with the passage of light through the water or in which visual depth is restricted. The turbidity may be caused by a wide variety of suspended materials, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and other microscopic organisms and similar substances.
Uplands	(1) The ground above a floodplain; that zone sufficiently above and/or away from transported waters as to be dependent upon local precipitation for its water supplies. (2) Land which is neither a wetland nor covered with water.
Vernal Pond	(1) Wetlands that occur in shallow basins that are generally underlain by an impervious subsoil layer (e.g., a clay pan or hard pan) or bedrock outcrop, which produces a seasonally perched water table. (2) A type of Wetland in which water is present for only part of the year, usually during the wet or rainy seasons (e.g., spring).
Water Budget	A method for measuring the amount of water entering, being stored and leaving a watershed.
Water Quality	A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Watershed	(1) All lands enclosed by a continuous hydrologic drainage divide and lying upslope from a specified point on a stream. Also called a catchment area. (2) A ridge of relatively high land dividing two areas that are drained by different river systems.
Wetland	Areas where water saturation is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the surrounding environment. The single feature that all wetlands have in common is a soil or substrate that is saturated with water during at least a part of the growing season. These saturated conditions control the types of plants and animals that live in these areas. Other common names for wetlands are Swamp, Fen, Bog, and Marsh.

8. Acronyms

ACCDC	Atlantic Canada Conservation Data Centre
ARD	Acid Rock Drainage
CCME	Canadian Council of Ministers of the Environment
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DEM	Digital Elevation Model
DOC	Dissolved Organic Carbon
DSM	Digital Surface Model
GCDWQ	Guidelines for Canadian Drinking Water Quality
GCM	Global Climate Model
GHG	Greenhouse Gas
GIS	Geographical Information System
GPS	Global Positioning System
HNWTA	Halifax Northwest Trails Association
HRM	Halifax Regional Municipality
IPCC	Intergovernmental Panel on Climate Change
LCM	Lakeshore Capacity Model
LiDAR	Light Detection and Ranging
NH_3	Ammonia
NO_3	Nitrate
NSDFA	Nova Scotia Department of Fisheries and Aquaculture
NSE	Nova Scotia Environment
NSDNR	Nova Scotia Department of Natural Resources
NSEA	Nova Scotia Endangered Species Act
SARA	Species at Risk Act
SWMM	Stormwater Management Model
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
WWTP	Waste Water Treatment Plant