Environment AECOM

Halifax Regional Municipality

Shubenacadie Lakes Subwatershed Study – Final Report

Prepared by:

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Project Number:

60221657

Date:

April, 2013

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April 16, 2013

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

Dear Mr. Morgan:

Project No: 60221657

Regarding: Shubenacadie Lake Subwatershed Study – Final Report

AECOM is pleased to submit the attached Final Report for the Shubenacadie Lakes Subwatershed Study. The report includes the water quality objectives established in the Preliminary Report and addresses the remaining requirements of HRM Regional Plan Policy E-17 with respect to future development within the Shubenacadie Lakes Subwatershed.

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

Sincerely,
AECOM Canada Ltd.

[redacted]

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RD:mm

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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 Wallace Lands" to begin planning for a new serviced community, Regional Council has requested the completion of a watershed study 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 recommended water quality objectives for key receiving water bodies within the subwatershed in a Preliminary Report; and,
2. address the remaining objectives of Regional Plan Policy E-17 in a Final Report.

This Final Report identifies areas that are suitable and not suitable for development, determines the amount of development that can be accommodated while maintaining the recommended water quality objectives, recommends measures to protect and manage quantity and quality of surface and groundwater and suggests regulatory options and management strategies to achieve the desired water quality objectives.

The Shubenacadie Lakes subwatershed is located largely within the Eastern Ecoregion, with a small portion of the subwatershed (northeast of Grand Lake) located in the Valley and Central Lowlands Ecoregion. The subwatershed has a surface area of approximately 388 km^2. In general, surface water flows through the subwatershed from south to north. Lake Charles is the headwater lake of the Shubenacadie Lakes subwatershed but discharges both north and south due to the presence of the Shubenacadie Canal control structures at its north and south ends.

The subwatershed 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. Historical residential development in much of the subwatershed is associated with the numerous lakes which characterise this area. Fall River is designed under HRM planning documents as a Rural Commuter Centre, with the goal of focusing low and medium-density development around a hub along Highway 102. Residences range from older homes and cottages to modern suburban homes and low rise apartment buildings.

<u>Existing Water Quality</u>

In order to establish water quality objectives and prevent 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 subwatershed. Pre-2006 historical data were 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 completed limited additional 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 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 total suspended solids (TSS), nitrate, chloride and *E. coli*.

However, several of the lakes are meso-eutrophic to eutrophic systems. This is likely due 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 for the protection of aquatic life in 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 indicate 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 the water quality objectives were based.

All indicator parameters, with the exception of total phosphorus, have definitive Canadian Water Quality Guideline (CWQG) protection of aquatic life (PAL) limits. Because the CWQGs for the protection of aquatic life are set to protect the most sensitive species, and because water quality in the Shubenacadie Lakes subwatershed is currently better than these objectives, this report recommends that the CWQGs PAL for nitrate, un-ionized ammonia, total suspended solids (TSS), 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 value recommended by Health Canada. AECOM suggests this value is appropriate for the *E. coli* parameter.

With respect to phosphorus, Environment Canada 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 state based on existing conditions either measured or predicted by 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.” Phosphorus water quality objectives by lake are summarized in the table below.

Water Quality Objectives, Early Warning Alert Values 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.			

<u>Development Scenarios</u>

The potential effects of future land use changes on the trophic state and phosphorus concentrations in the lakes are assessed using a Lake Capacity Model (LCM) that has been employed previously in the Halifax region. The LCM estimates phosphorus loading to each lake and predicts lake response (i.e., changes in the trophic state) from these phosphorus loadings. This study also uses a stormwater management model (SWMM) to assess changes to hydrology and sediment loading from development and predict the resulting phosphorus loading in each subwatershed. In order to compare the SWMM and LCM results, the SWMM base development case assumes no stormwater management facilities will be used in future developments.

In reality, all future development within the watershed should be required to implement stormwater management facilities to control runoff water quantity and maintain its quality. In this study, future stormwater management facility designs were not available. Consequently, a simplified approach was taken to estimate the improvements to water quality based on the use of advanced stormwater management within all new developments. Removal rates of 80% or higher for TSS and 50% for TP were used as a standard applied to stormwater discharges in each subwatershed. These removal rates are used as an indication of what might be expected through the rigorous application of stormwater management measures.

For both models, the results are presented for three modeling scenarios:

1. Modeling Scenario 1: Existing Conditions;
2. Modeling Scenario 2: HRM Authorized Subdivision Agreements; and,
3. Modeling Scenario 3: Scenario 2 plus fully developed and serviced Port Wallace Lands.

Because the models operate from totally different principals, agreement between them is a good indication of the reliability of the results. These models together not only predict the likely future responses of the lakes to development pressures but can also be used to evaluate the benefit from development-specific mitigation measures that would permit the lakes to meet the proposed water quality objectives following development.

Modeling Results

Change between current conditions and the three development scenarios are illustrated in the table below for the two models (LCM = Lake Capacity Model; SWMM = Stormwater Management Model). The agreement between the predicted results from the two models is very good and the differences can generally be explained in the way in which the models respond to different land use characteristics or the impact of changing land uses.

Measured and Modeled Ice-Free Lake Phosphorus Concentrations

Lake	Measured µg/L Average concentration ± standard deviation (number of samples)	Scenario 1: Existing Conditions (LCM/SWMM) µg/L	Scenario 2: HRM Authorised Subdivisions (LCM/SWMM) µg/L	Scenario 3: Scenario 2 + Fully Developed Port Wallace (LCM/SWMM) µg/L
Cranberry	20±13(17)	17/24	17/24	17/24
Loon	15±12(15)	14/15	14/15	1415
Charles	10±8(21)	10/15	**11/11**	**14/13**
Micmac	10±12(17)	10/NM	10/NM	**11/**NM
Banook	10±11(17)	10/NM	10/NM	**11/**NM
First	11±10(17)	12/10	**12/11**	**12/11**
Rocky	16±12(17)	16/24	**18/26**	**18/26**
Second	12±14(16)	13/12	**16/15**	**16/15**
Third	10±11(17)	11/11	**14/14**	**14/14**
Powder Mill	10±11(17)	11/18	**12/20**	**12/20**
William	9±7(20)	9/12	**12/13**	**12/14**
Soldier	n/a(0)	11/5	11/5	11/5
Miller	11±4(3)	12/10	**13/11**	**13/11**
Thomas	11±14(32)	13/11	**15/12**	**15/12**
Fletcher	10±9(20)	10/10	**11/**10	**11/**10
Grand	8±13(19)	9/7	**11/8**	**11/8**
Fish	18±1(2)	14/17	**15/18**	**15/18**
Springfield	14±10(16)	14/14	**17/17**	**17/17**
Lisle	50±26(8)	51/44	**54/45**	**54/45**
Fenerty	22±9(16)	18/7	**21/9**	**21/9**
Lewis	8±2(3)	9/7	**12/10**	**12/10**
Hamilton	n/a(0)	12/3	**13/**3	**13/**3
Tucker	10±7(17)	10/12	**15/17**	**15/17**
Beaverbank	11±1(2)	11/5	**12/**5	**12/**5
Barrett	11±6(17)	11/10	**16/15**	**16/15**
Duck	43±39(16)	44/42	**62/60**	**62/60**
Beaver Pond	23(1)	29/11	**34/13**	**34/13**
Kinsac	12±8(17)	14/6	**16/8**	**16/8**

Note: NM = not modeled.

Note: Bold values indicate changes; that is, modeled values differing for Scenario 2 from Scenario 1 or for Scenario 3 from either Scenario 1 or 2. To the extent possible, the lakes are listed from south to north and from upstream to downstream.

Under development Scenario 2, predicted phosphorus concentrations and thus trophic state in Cranberry, Loon, Micmac, Banook, First, Powder Mill and Soldier lakes are expected to remain unchanged. This is because there is little development planned in the catchments of these lakes.

Predicted phosphorus concentrations in all other lakes will increase under this modeling scenario. For the most part, concentrations are expected to increase by 1 to 4 μg/L, with an average increase of 2 μg/L across the entire subwatershed. This modeled increase was found with both the LCM and the SWMM.

Phosphorus concentrations in Duck, Tucker and Barrett lakes are predicted to increase the most: by 19, 5 and 5 μg/L, respectively for both the LCM and 17, 7 and 4 μg/L, respectively for the SWMM under Scenario 2. The relatively low increase in phosphorus concentrations in most other lakes is due to the small scale of development in the subwatershed compared to the size of the subwatershed. Although many lakes are expected to show increases in phosphorus concentrations under Scenario 2, the magnitude is low (within confidence limits of measured concentrations); nevertheless, trophic state changes will occur due to slight increases in phosphorus concentrations for Lake William (predicted only by the LCM as the SWMM already indicated a mesotrophic state for existing conditions) and for Lewis and Grand lakes based only on the prediction of the LCM. These lakes may therefore exceed the proposed water quality objective of “no change to the trophic state” as a result of the development already authorized by HRM. The small magnitude of the phosphorus concentration increase, the natural variability of phosphorus concentrations in these lakes and the general proximity of the modeled concentrations to the trophic state boundary demonstrate the need for continued monitoring and the implementation of available measures to reduce loadings through mitigation.

The low density residential development modeled with Scenario 2 does not result in a significant increase on the mean TSS concentration as given by Table 5-5 of the Halifax Regional Municipality Stormwater Management Guidelines (Dillon 2006). The mean TSS concentration is expected to increase from 19.0 mg/L for a forest or wetland area to 22.1 mg/L for a low density residential area. Scenario 3 however; is expected to have a more significant impact on the water quality of Lake Charles because development would result in mean TSS concentrations increasing from 19.0 mg/L for forested to 47.7 mg/L for high density residential.

The most significant impact to TSS concentrations is expected to occur in Lake Charles as a result of the Scenario 3 development. Note that the model has considered the base case situation for the Port Wallace lands without stormwater management as well as with advanced stormwater management for the reduction of TSS and associated TP loadings (80% or higher removal of TSS and 50% for TP). A minor increase in TSS may also be observed in Grand Lake as a result of the cumulative impacts of the subwatershed development.

With regard to cumulative annual loadings, the impacts of development would have the most significant impact on Grand Lake, as it is located the furthest downstream in the subwatershed. Scenario 2 would see an increase predominately in Grand Lake, with the total mass of TSS increasing by 24%. However, this absolute increase is still relatively small due to the very low average TSS concentration in Grand Lake (3 ± 2 mg TSS/litre based on 22 samples). Scenario 3 results in an increased TSS load of 40% for Lake Charles. With the use of SWM techniques within the Port Wallace Lands, the increase of TSS may be reduced by 80% depending on the facility performance for an absolute load of approximately 197,072 Kg/year compared to the existing estimated load of 182,474 Kg/yr.

Summary

For each model type and model scenario, the predicted ice-free total phosphorus concentration for each lake is summarized as a trophic state below. In general, trophic state is only predicted to increase in either of the models as a result of the scenarios for Cranberry, Rocky, Grand and Lewis Lakes.

Predicted Trophic States using Modified LCM and SWMM

Lake	Measured	Scenario 1: Existing Conditions		Scenario 2: HRM Authorised Subdivisions		Scenario 3: Scenario 2 + Fully Developed Port Wallace	
		LCM	SWMM	LCM	SWMM	LCM	SWMM
Cranberry	mesotrophic	mesotrophic	meso-eutrophic	mesotrophic	meso-eutrophic	mesotrophic	meso-eutrophic
Loon, Charles, First, Second, Third, Miller, Thomas, Fletcher, Fish, Springfield, Tucker, Barrett, Powder Mill	mesotrophic	mesotrophic		mesotrophic		mesotrophic	
William	oligotrophic	oligotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic
Micmac, Banook	mesotrophic	mesotrophic	n/a	mesotrophic	n/a	mesotrophic	n/a
Rocky	mesotrophic	mesotrophic	meso-eutrophic	mesotrophic	meso-eutrophic	mesotrophic	meso-eutrophic
Soldier	n/a	mesotrophic	oligotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic
Grand	oligotrophic	oligotrophic	oligotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic
Lisle, Duck	eutrophic	eutrophic	eutrophic	eutrophic	eutrophic	eutrophic	eutrophic
Fenerty	meso-eutrophic	meso-eutrophic	oligotrophic	meso-eutrophic	oligotrophic	meso-eutrophic	oligotrophic
Lewis	oligotrophic	oligotrophic	oligotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic
Hamilton	n/a	mesotrophic	oligotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic
Beaverbank	mesotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic
Beaver Pond	meso-eutrophic	meso-eutrophic	mesotrophic	meso-eutrophic	mesotrophic	meso-eutrophic	mesotrophic
Kinsac	mesotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic

Many different stormwater management techniques can be applied to meet water quality objectives. Stormwater management at the individual development level should be designed to achieve “no net increase” in sediment and phosphorus load and peak flows. If this cannot be achieved, then the impact on water quality has to be factored into the development plan and water quality protection plan for the entire watershed.

Development-specific stormwater management proposals should be assessed relative to their ability to achieve the no net increase target. If a specific development cannot demonstrate that it will have no net increase, then HRM can consider alternatives to the development as proposed or reassessment of other mitigation measures within the subwatershed. New development applications in the watershed may incorporate the measures detailed within HRM’s Stormwater Management Guidelines to reduce or eliminate the impacts to water quality and quantity from development through the application of a subwatershed-specific or development-specific SWMM. The benefit of these measures can be evaluated by using the SWMM on a development scale and integrating it into the watershed scale SWMM developed here so that existing conditions and post-development conditions can be assessed relative to the water quality management objectives for the watershed.

Water Quality and Quantity Monitoring

A simplified water quality monitoring program is presented that addresses the fundamentals of watershed management. This approach includes the essential elements of monitoring and represents the minimum sampling effort required for water quality and quantity assessment and management. The program is summarized in the table below.

Minimum Water Sampling Program Recommended for Birch Cove Lakes Subwatershed

Lake	General Location	Access	Sample Timing	Other
Highest Priority				
"A" Lake (Fall River)	Outflow from lake	shore	Spring, summer, fall	No water quality data currently, shoreline developed with more development planned for subwatershed
Beaver Pond	Outflow from lake	shore	Spring, summer, fall	Only one water quality sample to date showing lake is eutrophic with further development planned in subwatershed
Rocky Lake	Outflow from lake	shore	Spring, summer, fall	Existing conditions indicate mesotrophic with some effect from development
Second Lake	Outflow from lake	shore	Spring, summer, fall	Existing conditions indicate mesotrophic with some effect from development, local industry may also be a concern
Fenerty Lake	Outflow from lake	shore	Spring, summer, fall	Existing conditions indicate mesotrophic with some effect from development
Grand Lake	Outflow from lake	shore	Spring, summer, fall	Routine monitoring, co-locate quality and quantity stations with level and temperature loggers, lake is too large to allow deterioration so early warning is essential
Second Priority				
Charles, Kinsac, Fletchers Lakes	Outflow from lake	shore	summer	Future pressure due to ongoing development, co-locate quality and quantity stations with level and temperature loggers
Third Priority				
Barrett, Beaverbank, Loon, Cranberry, First, Fish, William, Powder Mill, Springfield, Third, Tucker, Thomas, Lewis Lakes	Outflow from lake	shore	summer	Routine monitoring to evaluate lake trophic state and other water quality objectives

Lake	General Location	Access	Sample Timing	Other
Banook, Micmac Lakes	Mid-lake sampling	boat	summer	Routine monitoring to evaluate lake trophic state and other water quality objectives
Miller Lake	Outflow from lake	shore	summer	Routine monitoring with a special investigation of high ammonia concentrations to identify sources

At each station, water samples should be collected and analysed at a minimum for: total phosphorus (low level), total suspended solids (low level), chloride and chlorophyll α. In field measurements of pH, conductivity, temperature, dissolved oxygen, and air temperature should also be collected.

For establishing baseline conditions and evaluating the effects of specific developments on lake water quality, additional monitoring is required. However, this is not the purpose of the monitoring program outlined here; development-specific monitoring should be considered complimentary to this program.

Further refinement of the calibration curves for measuring flow and predicting development effects on these flows is integral to the water quality program and modeling. We strongly recommend the maintenance of the four flow monitoring sites within the subwatershed throughout the duration of the development as this information will be essential to verifying the model and adapting it to actual measurements which will be necessary to protect the lakes through adaptive environmental management practices including confirming the need for additional mitigation.

Distribution of Lake Charles Flow

Lake Charles is the headwater lake of the Shubenacadie Lakes subwatershed 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. The remaining 40% of the discharge from Lake Charles flows south to Lakes Micmac and Banook and ultimately to Dartmouth Cove in Halifax Harbour. As part of this project, the lock structures downstream and their elevations were surveyed and these were used in the model along with other surveyed points. Based on this, the SWMM model indicates that during storm events the outlet to Micmac and Banook lakes conveys approximately 90% of the flow while the outlet to Lake William conveys the remaining 10% of the flow. Due to safety considerations, no flow measurements could be made in the field to verify this apparent result. These results should be confirmed though a field assessment.

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1 Introduction

Halifax Regional Municipality (HRM) in 2002 adopted the HRM Water Resources Management Study (Dillon Consulting Ltd. 2003) as a basis for developing subwatershed planning policies. Following from this study, HRM uses the watershed or subwatershed 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 Strategy, 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 Wallace Lands” to begin planning for a new serviced community 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 subwatershed 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 were presented to the public in late 2012 so that questions and clarifications can be addressed in the Final Report. The table below summarizes the comments received and shows where there are addressed in the report.

Table of Concordance Listing Reviewer Comments

Item	Reviewer Comment	Source	Addressed
1	Biological indicators (fish/plants species) can be useful as early warning indicators for pollution problems.	Halifax Watershed Advisory Board – HWAB (30 July 2012)	Agreed – but this study uses chemical rather than biological indicators to set water quality objectives.
2	Metals should be included in parameters and reviewed. The report does note that metals are usually associated with the transport of suspended solids so the management of suspended sediment will also help reduce metals. However, dissolved metals, as a result of increased traffic and blasting (particularly pyritic slates), would not be indicated by increased suspended solids.	HWAB (30 July 2012)	Metals and pH have been measured in over 20 lakes within the subwatershed. These data were compiled as part of this study and forwarded to B. McDonald on July 26, 2012. Dissolved metal concentrations may temporarily increase due to localized construction but this does not represent a chronic risk to water quality.
3	The Tables show “early warning levels”. Before these levels are reached, trends should be noted and monitored.	HWAB (30 July 2012)	Agreed – please see section 6 Recommendations for Water Quality and Quantity Monitoring.

Item	Reviewer Comment	Source	Addressed
4	Remediation measures should be suggested.	HWAB (30 July 2012)	Measures to improve water quality are presented throughout the report and in Section 7(e) and (f).
5	Acid rain should be considered.	HWAB (30 July 2012)	There is little that lake managers can do to counter the effects of acid rain. The effects of acid rain are not within the scope of this work.
6	Setting water quality objectives is necessarily subjective because of the diversity between watersheds -phosphorus is widely considered as a significant parameter.	HWAB (30 July 2012)	Agreed.
7	In order to include the entire watershed, Hants county should be involved in this study.	HWAB (30 July 2012)	Water quality data obtained from the Municipality of East Hants were used in this study.
8	Millar Lake should be included in Table 9, Ammonia concentrations. Ammonia levels in this lake, possibly associated with the airport via Soldier Lake, are alarming. The source of the ammonia should be found.	HWAB (30 July 2012)	Miller Lake is included in Table 9. Elevated nitrogen values may be associated with airport inputs via Soldier Lake, the Miller Lake Scout Camp and/or the Miller Lake wastewater treatment plant. Additional sampling to identify the ammonia source is recommended at Miller Lake (see Table 28).
9	Wilson Lake is part of the system and should be included	HWAB (30 July 2012)	Wilson Lake is included in the study.
10	The Lake Charles River flows into Sawmill River. Could this be diverted? Water control structures should be examined.	HWAB (30 July 2012)	Comment addressed to HRM.
11	The Sawmill River Watershed should be included.	HWAB (30 July 2012)	The Sawmill River, currently piped from the outlet of Sullivan's Pond, receives discharge from Lakes Banook and Micmac. Water quality in these lakes is addressed in section 5.2.1 (Scenario 3) but study of the entire Sawmill River Watershed is outside of the scope of this report.
12	The HRM Lakes Water Quality Sampling Program should be reinstated. This program provided much of the background data for this study and is needed for water quality monitoring in the future.	HWAB (30 July 2012)	Comment addressed to HRM. Water sampling program is recommended in section 7.
13	If there is no public sampling system, monitoring should be paid for by developers (tested by HRM personnel, results to local Watershed Advisory Boards)	HWAB (30 July 2012)	Comment addressed to HRM.

Item	Reviewer Comment	Source	Addressed
14	Is monitoring for each development being considered?	HWAB (30 July 2012)	Comment addressed to HRM.
15	A permanent water quality monitoring system could be installed for $50,000	HWAB (30 July 2012)	Comment addressed to HRM.
16	A future step could be to undertake receiving water studies, including total receivable inputs	HWAB (30 July 2012)	Comment addressed to HRM.
17	Flows should be monitored	HWAB (30 July 2012)	Agreed. Addressed in section 6 Recommendations for Water Quality and Quantity Monitoring.
18	The volume of water needs to be measured. Flushing could cause pollutants to accumulate or dilute them.	HWAB (30 July 2012)	Agreed. Addressed in section 6 Recommendations for Water Quality and Quantity Monitoring.
19	Permanent stream gauging devices are needed to monitor flows	HWAB (30 July 2012)	Permanent stations would be useful and perhaps less expensive over the long term but flows can also be measured periodically as suggested in section 6 Recommendations for Water Quality and Quantity Monitoring.
20	Flow data is needed for modelling purposes.	HWAB (30 July 2012)	Agreed. Flow data was collected as part of this study and is recommended in section 6.
21	The inflow to lakes downstream of development should be monitored.	HWAB (30 July 2012)	Comment addressed to HRM.
22	By not undertaking flood plain mapping, an opportunity has been missed.	HWAB (30 July 2012)	Comment addressed to HRM; flood plain mapping is not within this scope of work.
23	Storm water runoff must be controlled. Engineering limits (White Book) must be made more stringent.	HWAB (30 July 2012)	Comment addressed to HRM; Stormwater management recommendations are presented in Section 7(g).
24	Storm water should be treated to maintain quality.	HWAB (30 July 2012)	Comment addressed to HRM; Stormwater management recommendations are presented in Section 7(g).
25	Specific measures to help achieve 100% on-site storm water retention should be suggested.	HWAB (30 July 2012)	Stormwater management recommendations are presented in Section 7(g).
26	Multiple jurisdictions involved in storm water management is recognized as a problem.	HWAB (30 July 2012)	Comment addressed to HRM.
27	In open space developments, road-building is not controlled which could lead to erosion, sedimentation, etc.	HWAB (30 July 2012)	Stormwater management recommendations are presented in Section 7(g).
28	HRM should require regular pumping of septic tanks. In clustered	HWAB	Comment addressed to HRM;

Item	Reviewer Comment	Source	Addressed
	systems, water use would have to be monitored for each household – to decide when pumping necessary and who is putting how much water into the system.	(30 July 2012)	This issue is discussed in section 7(c).
29	The establishment of Wastewater Management Districts should be promoted. Within the districts, residents could club together to pay for pumping the tanks of those who cannot afford it.	HWAB (30 July 2012)	Comment addressed to HRM.
30	Wastewater cluster systems with STPs should be encouraged in place of individual septic systems. In time, HRM should take these over and run them.	HWAB (30 July 2012)	Comment addressed to HRM.
31	Blasting (and the associated dust) could represent a problem as there are slates in this area.	HWAB (30 July 2012)	Agreed. Construction on slate is regulated through provincial legislation.
32	Blasting of pyritic slates releases dissolved metals to ground water and surface water. This significantly lowers pH, elevates ammonia (which converts to nitrates) and depletes oxygen.	HWAB (30 July 2012)	Agreed. Construction on slate is regulated through provincial legislation.
33	Slate disposal should be monitored.	HWAB (30 July 2012)	Slate disposal is regulated through provincial legislation.

1.1 Subwatershed Study Planning Context

As noted, the Regional Plan requires that subwatershed studies are completed in advance of community design work undertaken through the secondary planning process. In response to requests by developers of the “Port Wallace Lands” to begin the secondary planning processes, Regional Council has directed that a subwatershed 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 subwatershed, 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 subwatershed study identifies areas that are suitable and not suitable for development within the subwatershed, determines the amount of development that can be accommodated while maintaining water quality objectives in the receiving watercourses, recommends measures to protect and manage quantity and quality of surface and groundwater and suggests regulatory controls and management strategies to achieve the desired water quality objectives.

This subwatershed study complements the Halifax Regional Wastewater Management Functional Plan (CBCL and AECOM 2012), which provides 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 published the Wastewater Systems Effluent Regulations under the Fisheries Act in late 2012.

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 subwatershed 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 subwatershed;
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 subwatershed;
4. Determine the parameters to be attained or retained to achieve marine water quality objectives;
5. Identify sources of contamination within the subwatershed;
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 subwatershed 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 subwatershed 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 subwatershed;
11. Identify areas that are suitable and not suitable for development within the subwatershed;
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 subwatershed are being met.

1.3 Scope of the Subwatershed 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 watercourses;
- 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 subwatershed 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 majority of the subwatershed. The LiDAR data were used to delineate subwatershed and sub-subwatershed 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. LiDAR data were not available for the extreme northern end of Grand Lake; for this area 5 metre contour intervals were used and merged with contours taken from the LiDAR data.

The Preliminary Report was posted on the HRM website and presented to the Dartmouth Lakes Advisory Board, the Shubenacadie Canal Commission and the Shubenacadie Watershed Environmental Protection Society on June 13, 2012. Upon completion of the Preliminary Report, additional work was undertaken to meet the remaining objectives of Policy E-17 for inclusion in the Final Report, including:

- Previous steady state nutrient loading models used within the subwatershed were reviewed in order to identify any 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]) was used to determine predicted in-lake phosphorus concentrations and thus predict lake trophic state. This model was calibrated against current measured total phosphorus (TP) lake concentrations;
- A standard dynamic 1-dimensional flow model (Stormwater Management Model [SWMM]) was developed for the subwatershed and calibrated to the current measured lake TP concentrations;
- Land use within the subwatershed was spatially modelled to provide details on current land use within each sub-subwatershed and to project land use forward for three scenarios: "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 Wallace Lands;
- The steady state and dynamic models were used to evaluate total phosphorus loadings to the lakes 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 included assessing the

opportunities for remedial actions to protect or recover lake water quality such that water quality objectives are met;

- Opportunities to use stormwater management to reduce loadings of sediment and phosphorus to the water bodies both within new developments were evaluated; and,
- A water quality monitoring program for the subwatershed is recommended in the light of existing data and water bodies that need to be assessed as a result of planned development. The water quantity monitoring program is also intended to better calibrate the stormwater model and to confirm the predicted impacts of development on flow and pollutant loading.

1.4 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 (Figure 1). The subwatershed also extends northwest through Waverley, Windsor Junction and Beaverbank to Springfield Lake. Covering approximately 388 km^2, the Shubenacadie Lakes subwatershed is an ecologically diverse area of forests, freshwater lakes, streams and wetlands.

In general, surface water flow through the subwatershed is from the south to north. Lake Charles is the headwater lake of the Shubenacadie Lakes subwatershed 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 subwatershed, water level control structures of 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 subwatershed, Lock 6 is located in the Shubenacadie River approximately 2 km downstream from Grand Lake.

The subwatershed 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 subwatershed is associated with the numerous lakes which characterise this area. Villages within the subwatershed include Waverley, 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 subwatershed retain a rural character. Fall River is designated 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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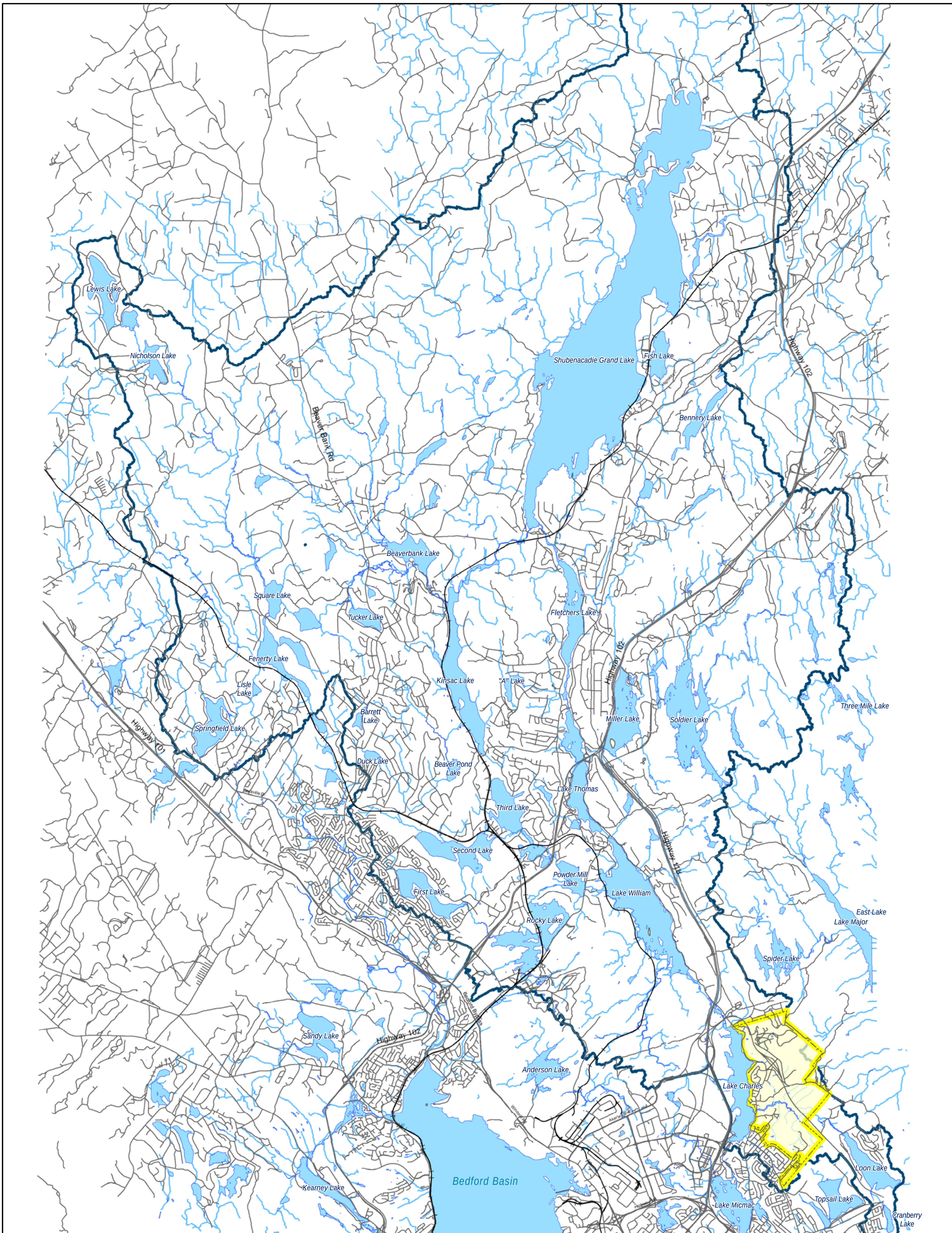
[1] *Survey and flow data collected for this study and model results suggest a large proportion of the water flows south, rather than north. This is discussed further in Section 5.3.1.*

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.

1.4.1 Potential Sources of Pollution Within the Subwatershed

The subwatershed 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 subwatershed has also experienced gold mining in the past (the Waverley and Montague Mines), although no mines are currently active within the subwatershed. Finally, two golf courses are located within the subwatershed: 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 subwatershed 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.



Roads

Watercourse

Shubenacadie Lakes Watershed

Port Wallace Lands

Water

Halifax Regional Municipality
Shubenacadie Lakes Subwatershed Study

Shubenacadie Lakes Watershed

March 2013	1:100,000	Datum: NAD83 Zone 17 Source: HRM
P#: 60221657	V#: 002	Figure 1

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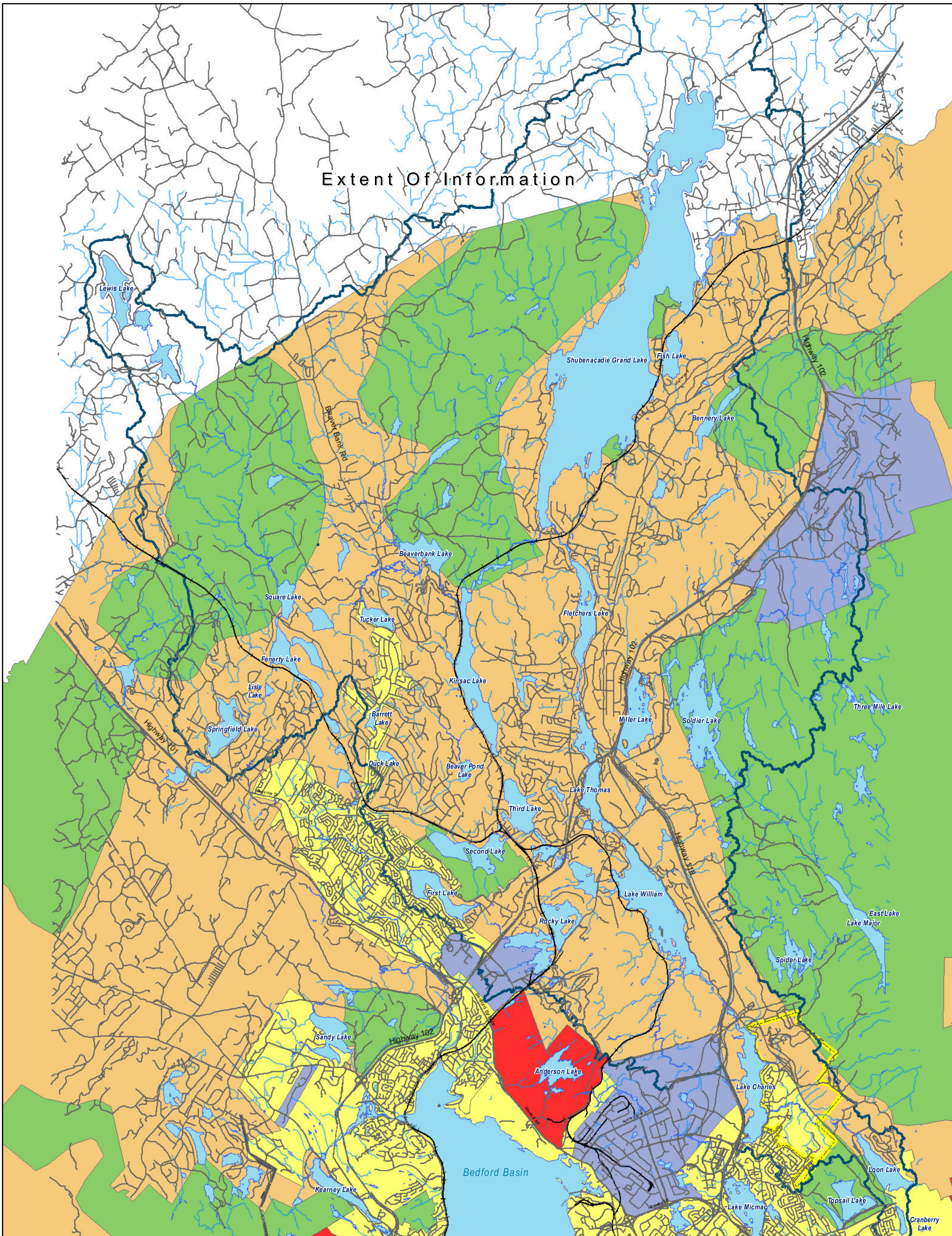
Kilometers



Roads
Watercourse
Water
Shubenacadie Lakes Watershed
Port Wallace Lands

Business and Industrial Parks
Open Space and Natural Resource
Rural Commuter
Urban Reserve
Urban Settlement

Halifax Regional Municipality
Shubenacadie Lakes Subwatershed Study

Zoning and Land Ownership

March 2013	1:100,000	Datum: NAD83 Zone 20 Source: HRM
P#: 60221657	V#: 002	Figure 2

AECOM

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Kilometers

1.5 Structure of the Report

This subwatershed 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 subwatershed. Included here are discussions of the existing land use and an overview of the development scenarios used in the modelling of future impacts.

Section 4: .... Receiving Water Quality Objectives. This section reviews various jurisdictional approaches and their water quality objectives. The recommended water quality objectives are based on the recent water quality data from the subwatershed in conjunction with guidance from these sources of information.

Section 5: .... Water Quality and Quantity Models. This section presents the steady state nutrient loading model (Lake Capacity Model [LCM]) that was used to predict in-lake phosphorus concentrations and thus future lake trophic state. It also presents a dynamic 1-dimensional flow model (Stormwater Management Model [SWMM]) which was developed to predict the impacts on the lakes when compared to the recommended water quality objectives.

Section 6: .... Water Quality and Quantity Monitoring Program: This section describes a proposed water quality and quantity monitoring program for the subwatershed.

Section 7: .... Summary of Policy E-17 Objectives.

Section 8: .... Summary and Conclusions.

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

Since the planning horizon for this study extends over 20 years it is appropriate to consider the potential impacts of climate change on water quality and water quantity within the subwatershed. Although this time frame may be too short to expect significant changes to the water budget of the area, it is worth considering climate change trends and probable future effects to precipitation patterns in this analysis.

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 et al. 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 years.

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

In general, a gradual increase in the temperature of the planet has been observed over the past century, and is expected to continue into the future, at least for some decades. The direct effects of temperature change, however, are far from clear. While the extremes seem to be most apparent in the northern polar regions, it is more difficult to understand the changes in temperate regions where hydrologic and water quality records usually extend only a few decades. 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 subwatershed is essentially impossible due to the absence of historical flow measurements within the watercourses. Consequently, for the 20 year time horizon of this project, impacts from climate change are assumed to be masked by anthropogenic changes directly within the subwatershed.

In Nova Scotia, climate projections suggest that climate will become increasingly variable with more frequent and more extreme storm events. Increased evaporation is expected due to increased atmospheric and ocean temperatures, along with reduced precipitation in summer and increased precipitation in winter. Generally speaking, there will be changes to the amount, timing and nature of precipitation. The rising ocean temperature may promote cyclonic activity further north than is currently the case, placing Atlantic Canada along the trajectory for more numerous, stronger hurricanes and tropical storms.

In forested subwatersheds, reports indicate that water quality and quantity are likely to be affected by climate change resulting in reduced snowpack, earlier peak snowmelts, warmer summer temperatures, and flooding (Hodgkins *et al.* 2003). With respect to changes to vegetation cover, both positive and negative outcomes are predicted. On one hand, transitional forest types as found in the Acadian Forest Region are forecasted to support additional stands of temperate broadleaved species with climate change. These species are associated with high water quality. On the other hand, climate change effects such as increased frequency and severity of insect/disease outbreak, windthrow, and forest fires have negative implications for water quality (Jones *et al.* 2009), as does increased erosion and flooding.

In summary, climate change is expected to result in dryer summers, wetter winters and more extreme precipitation events that can lead to flooding. Extreme storm events can flush nutrients from forested and urban areas into the watercourses resulting in rapid but temporary deterioration in water quality as the nutrients are flushed through subwatershed. These events may also re-suspend and remove phosphorus-laden sediments from ponds, rivers and lakes. Dryer summers suggest forest and aquatic ecosystems will be stressed and vulnerable to unusual weather events, while low stream flow reduces the potential that natural and man-made nutrient inputs can be adequately diluted, leading to an overall lowering of water quality. Finally, flooding liberates nutrients from dry forest soils and in-ground septic systems leading to water quality impacts.

2.2 Geology and Hydrogeology

Groundwater resources were recently assessed and described in great detail in the Fall River – Shubenacadie Lakes Subwatershed 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 subwatershed. 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 summary tables of groundwater pumping data, water well construction characteristics, and local aquifer properties. For convenience, certain tables from this report are reproduced in Appendix A.

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 subwatershed.

Drainage follows the northeast-southwest bedrock trend of the folded metamorphosed sedimentary rocks that underlay much of the subwatershed. 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 subwatershed, 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

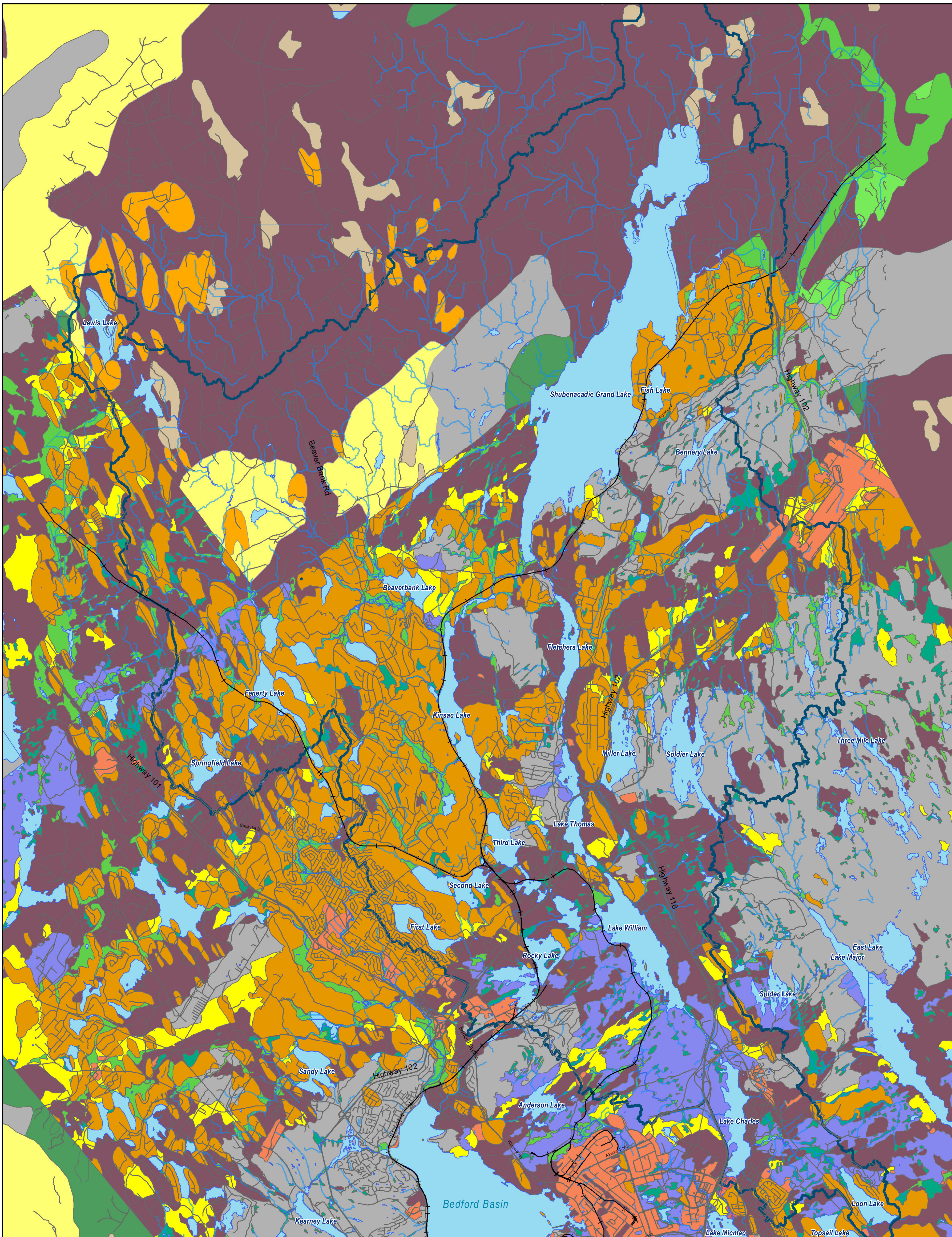
Glacial Till

Much of the subwatershed 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 subwatershed, 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 subwatershed 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 Waverley 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 subwatershed from Lake Thomas to Lake Charles.

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 McNabs Island and at Upper Lawrencetown and so may not be representative of glacial tills within the subwatershed.



Roads
Watercourse
Water
Shubenacadie Lakes Watershed

Surficial Geology

- Alluvial
- Anthropogenic
- Bedrock
- Drumlins
- Hummocky till
- Lacustrine
- Till blanket
- Till veneer
- Organic Deposits

Halifax Regional Municipality
Shubenacadie Lakes Watershed Study

Surficial Geology

October 2012	1:100,000	Datum: NAD83 Zone 17 Source: HRM
P#: 60221657	V#: 002	
AECOM		Figure 3

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Kilometers

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 alluvial deposits are present along the floodplains of major watercourses and their tributaries within the subwatershed. 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

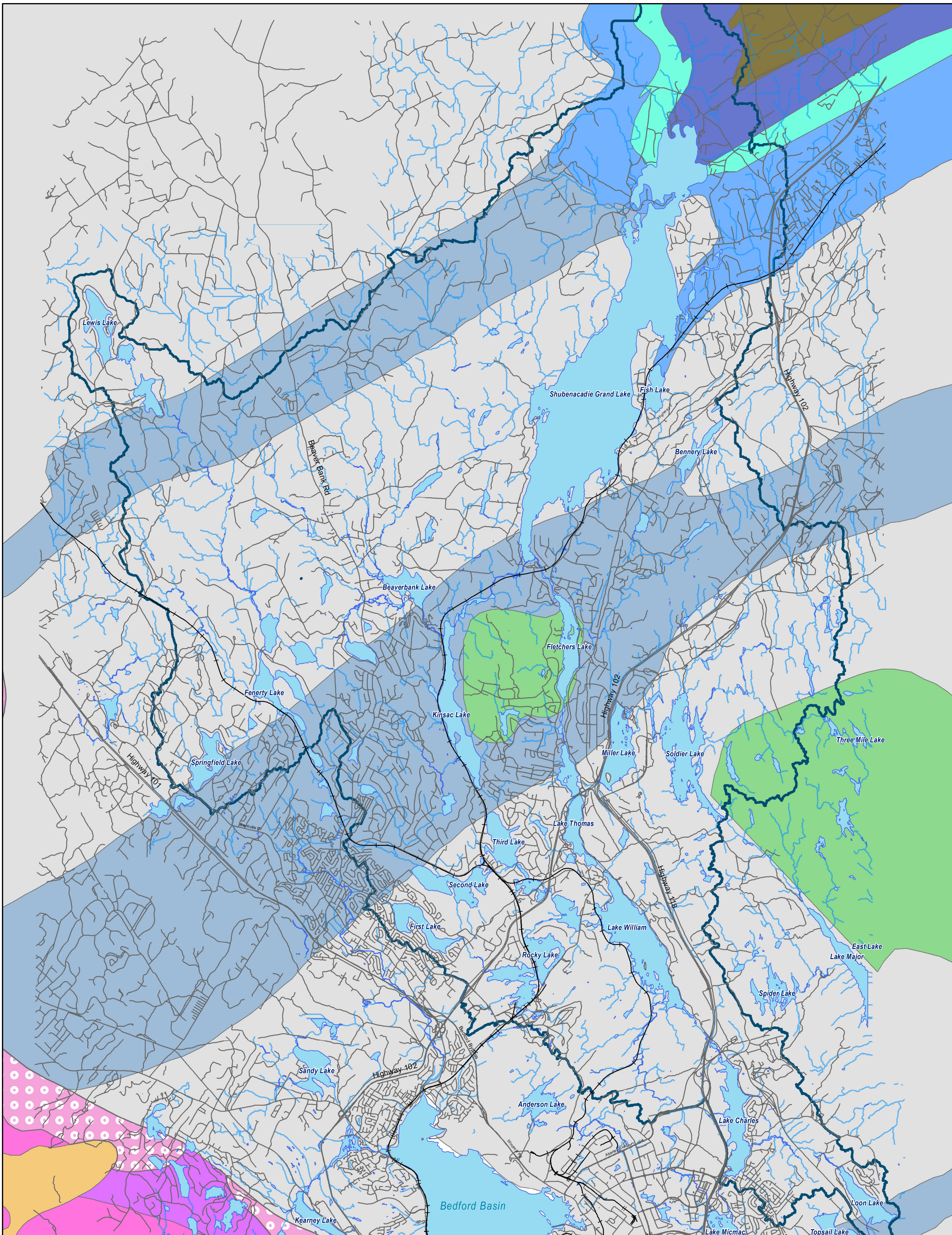
Area of shallow surficial cover with outcrops of exposed bedrock are present between Fletcher and Kinsac Lakes south of Wellington (granite bedrock), west of Grand Lake (quartzite bedrock), east of Fall River (granite bedrock), east of Wellington (slate bedrock), and southeast of Lake William (quartzite 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 subwatershed.

Most of the subwatershed 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 subwatershed, northwest of Grand Lake (Keppie 2000).

The Meguma Group in this area 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 subwatershed. 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 subwatershed in northwest – southeast trending bands (Figure 4). The underlying Goldenville quartzite is present beneath approximately 45-50% of the subwatershed 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 Waverley area. The gold is associated with arsenic sulphide (arsenopyrite), which results in elevated arsenic concentrations in groundwater (Grantham 1976; Bottomly 1984).



- Watercourses
- Roads
- Water
- Shubenacadie Lakes Watershed

Meguma Group
- Goldenville Formation
- Halifax Formation

Devonian Granite
- Tantallon Leucomonzogranite
- Halifax Peninsula Leucomonzogranite
- Sandy Lake Monzogranite
- Granodiorite
- Muscovite Biotite Monzogranite

Windsor Group
- White Quarry, Stewiackes and Grays River Formations
- Wentworth Station and Elderbank Formations
- Murphy Road, Pesaquid and Green Oaks Formation

Geology Ref: MacDonald and Horne (1987)

Halifax Regional Municipality
Shubenacadie Lakes Subwatershed Study

Bedrock Geology

October 2012	1:100,000	Datum: NAD83 Zone 17 Source: HRM
P#: 60221657	V#: 002	Figure 4

AECOM

0 1.5 3 6
Kilometers

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 subwatershed, excavation of ARD-generating rock remains a serious potential problem for surface and groundwater quality in the central and northern areas: North Beaverbank, Beaverbank, Wellington Station, Fletchers Lake and the airport.

Granite is the least common bedrock type, occupying approximately 5% of the subwatershed. 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 subwatershed, east of Soldier Lake.

The Windsor Group of rocks is present at the northern extremity of the subwatershed north and west of Grand Lake and occupies approximately 3% of the subwatershed. 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.

Groundwater Recharge

Groundwater recharge is the process by which surface water falling as precipitation within a subwatershed 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 subwatershed. Although groundwater recharge will occur everywhere within a subwatershed, 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 subwatershed 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 subwatershed who depend on its reliability and high quality.

In assessing changes to water quality within a subwatershed, 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. Changes to water quality and quantity may also occur from 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 local 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 this subwatershed is in the range of 3 to 5 km. At a more regional scale, recharge to deep bedrock aquifers within the Shubenacadie Lakes subwatershed may originate in the Mount Uniacke area, outside of the subwatershed 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 subwatershed. 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 subwatershed show infiltration rates of 250 mm or less, with groundwater movement occurring mainly 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 subwatershed, and have the highest potential groundwater recharge, exceeding 350 mm/year. Recharge through glaciofluvial outwash and hummocky till representing 4% coverage in the subwatershed represents the next highest potential groundwater recharge rates of 250 to 350 mm/year. Areas covered by drumlin deposits (41% of the subwatershed) have moderate potential groundwater recharge rates at 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 subwatershed 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 presented in Appendix A, groundwater recharge represents a relatively small proportion of the total water budget for the subwatershed. Approximately 34,000,000 m^3/yr (10%) will infiltrate the ground as recharge and the remaining 318,000,000 m^3/yr (90%) will become surface runoff. The surficial till units and drumlin deposits are not thick enough to store precipitation, 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.

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 may be, 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 piped water 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 Waverley/Lake Thomas area. Water service has also been provided 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 subwatershed and presented the well statistics in 13 communities within the subwatershed. This information is summarized below.

Well depths range from less than 15 m deep (23/2789 wells) to more than 183 m deep (3/2789 wells) but most wells are 31 to 76 m 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.

Groundwater Quality

Using historical and recent water quality data from pumping tests, NSE case investigations, and private information from past projects in the subwatershed, Jacques Whitford (2009) was able to compile general water quality characteristics for each aquifer exploited by residential wells in the subwatershed. 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.
Windsor Group Shale/Sandstone	Sedimentary bedrock	Hard to very hard, calcium bicarbonate groundwater of moderate to high TDS.	Elevated strontium and sulphate may occur 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

Ecological Land Classification

The Shubenacadie Lakes subwatershed is located largely within the Eastern Ecoregion, with a small portion of the subwatershed (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, major landform types with geology and soils distinct from adjacent ecodistricts NSDNR 2003). The central portion of the Shubenacadie Lakes subwatershed 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 till thickness 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 subwatershed (Beaverbank and north toward Mount Uniacke) 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 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 younger rocks to 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 and elevations seldom exceed 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 located in the central-west portions of the subwatershed. 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 subwatershed, Rocky, William and Charles to the south, and (to a lesser extent) Grand in the northeast (Jacques Whitford 2009).

Wetlands and Upland Vegetation

Wetlands

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 wetland types within the Shubenacadie Lakes subwatershed; together they cover a surface area of approximately 186 km^2 (Figure 5). Wetlands 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 subwatershed, 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 is common on the driest fen sites where moss hummocks provide microhabitats above the water table.

Upland Vegetation

Much of the Shubenacadie Lakes subwatershed 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 subwatershed. Newer growth dominates the area east of Highway 102, while the remainder of the subwatershed 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); and,
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 subwatershed (Jacques Whitford 2009).

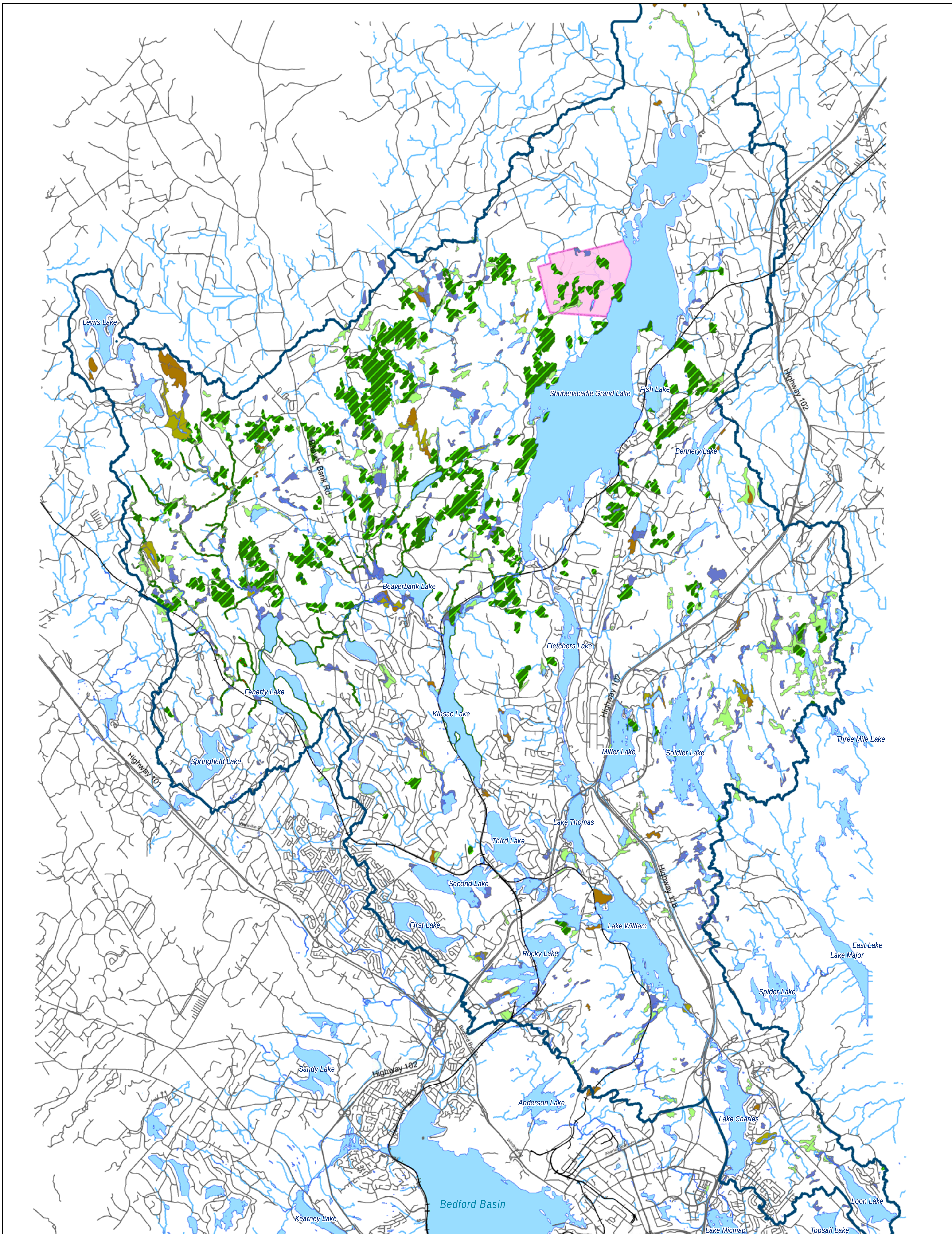
These three species are listed as yellow (sensitive to human activities or natural events) by NSNDR. Both Black Ash and Grass-leaved Goldenrod are listed nationally as S3 (uncommon), while Capitate Spikerush is listed nationally as S2 (rare) by ACCDC. All three species prefer similar habitats: the Black 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 subwatershed (Jacques Whitford 2009). There are only approximately 1,000 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 subwatershed 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 subwatershed area. Loons have been heard in Second Lake area in 2011 and in Third Lake in 2012 (pers.comm. R. Dmytriw, AECOM 2012).



Roads
Watercourse
Water
Shubenacadie Lakes Watershed
First Nations Land
Forest - Old Growth
Forest Significant Wildlife Habitat

Wetland Classification

Bog or Fen
Fen
Marsh
Swamp
Water

Halifax Regional Municipality
Shubenacadie Lakes Subwatershed Study

Wetlands and Significant Vegetation

October 2012	1:100,000	Datum: NAD83 Zone 17 Source: HRM
P#: 60221657	V#: 002	

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Figure 5

0 1.5 3 6
Kilometers

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 subwatershed but have not been positively identified (Jacques Whitford 2009).

The Grand Lake natural corridor describes an expanse of mostly privately-held land along the Shubenacadie Canal system extending from Halifax Harbour along the canal through Grand Lake. Natural heritage values include wildlife movement (waterfowl, shorebird and sparrow migration), riparian habitat, and cultural-historic significance and recreational use.

Other Land Use Types

For land use planning purposes, additional restricted-development land types are located within the subwatershed (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 Waverley 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 provincial 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.

Port Wallace Lands

The Port Wallace land is approximately 667 ha of mixed forest, wetland and existing residential development on the eastern side of Lake Charles. These lands also include the Conrad Brothers quarry and limited commercial development at the Montague Road / Highway 107 overpass (Figure 5a).

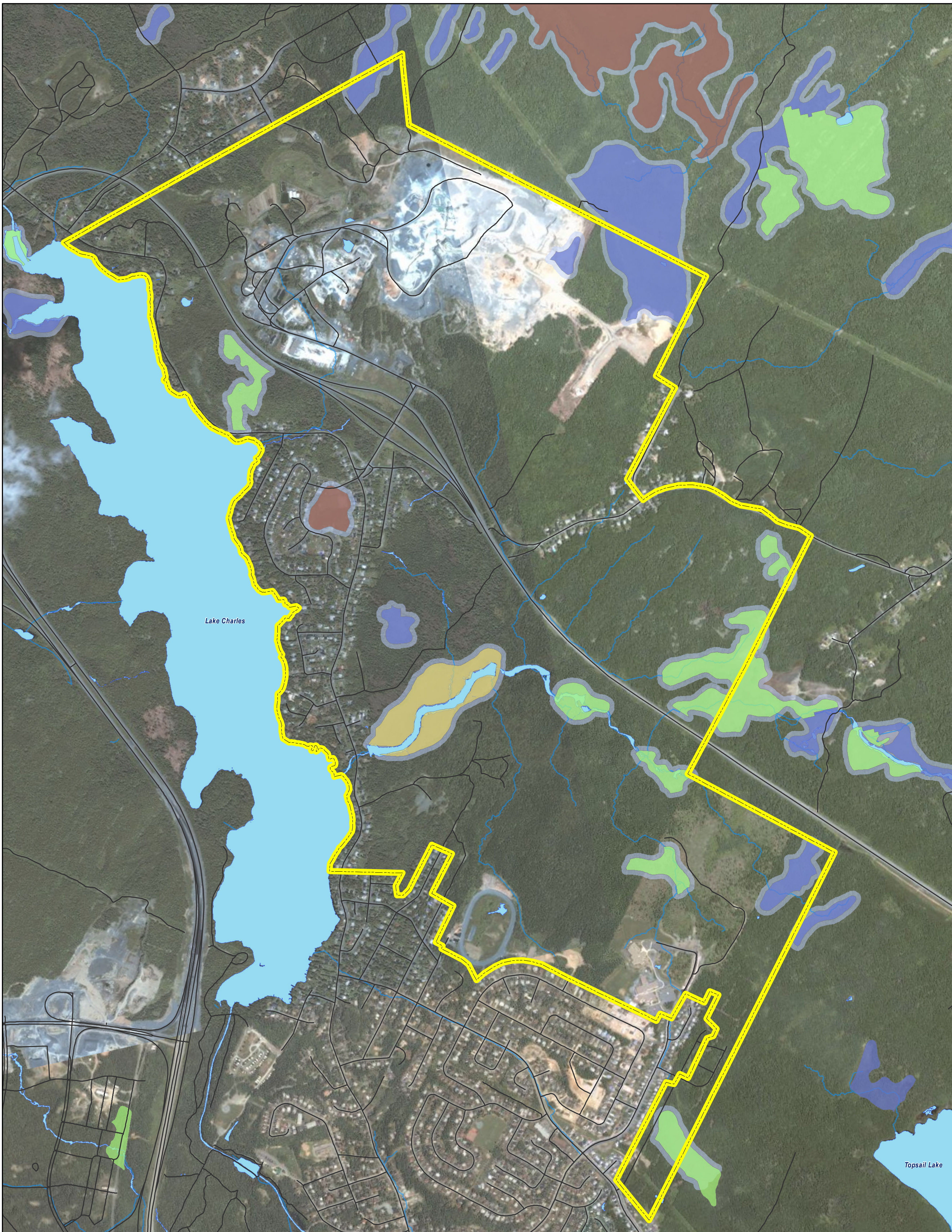
The southern portion of the property is traversed by a significant watercourse, which receives discharge from series of creeks or small streams, including the outlet from Loon Lake upstream of the Port Wallace land. This central watercourse and its tributaries contribute flow to a large fen wetland that drains southwest, beneath Waverly Road and into Lake Charles. In addition to the fen wetland, there are several other wetland types on the property, including several marshes and swamps as well as a bog, partially infilled by a sports field, located between Waverly Road and Craigburn Drive.

Wetlands are highly productive ecosystems valued for their species richness and diversity. Wetlands may suffer damage from poorly planned or regulated development within their watersheds. Changes to wetland hydraulics and water quality may occur though increases in stormwater runoff (both in terms of quantity and velocity) and degradation of water quality from increased total suspended solids, nutrients and warmer water temperatures. As described in Section 7.0(g), opportunities are available during the secondary planning process to assess and protect wetland ecosystems and to manage the changes to stormwater runoff that result from residential and commercial development.

2.4 Surface Water Resources

2.4.1 Lake Chemistry

Lakes are central ecological and hydrological components of most subwatersheds. 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 important to understanding lake chemistry are illustrated in Figure 6.



Roads
Watercourse
Shubenacadie Lakes Watershed
Port Wallace Lands
Water
Wetland Constraint (20m)

Wetland Types

Bog or Fen
Fen
Marsh
Swamp
Water

Halifax Regional Municipality
Shubenacadie Lakes Subwatershed Study

Port Wallace Lands

April 2013	1:15,000	Datum: NAD83 Zone 17 Source: HRM
P#: 60221657	V#: 002	**Figure 5a**

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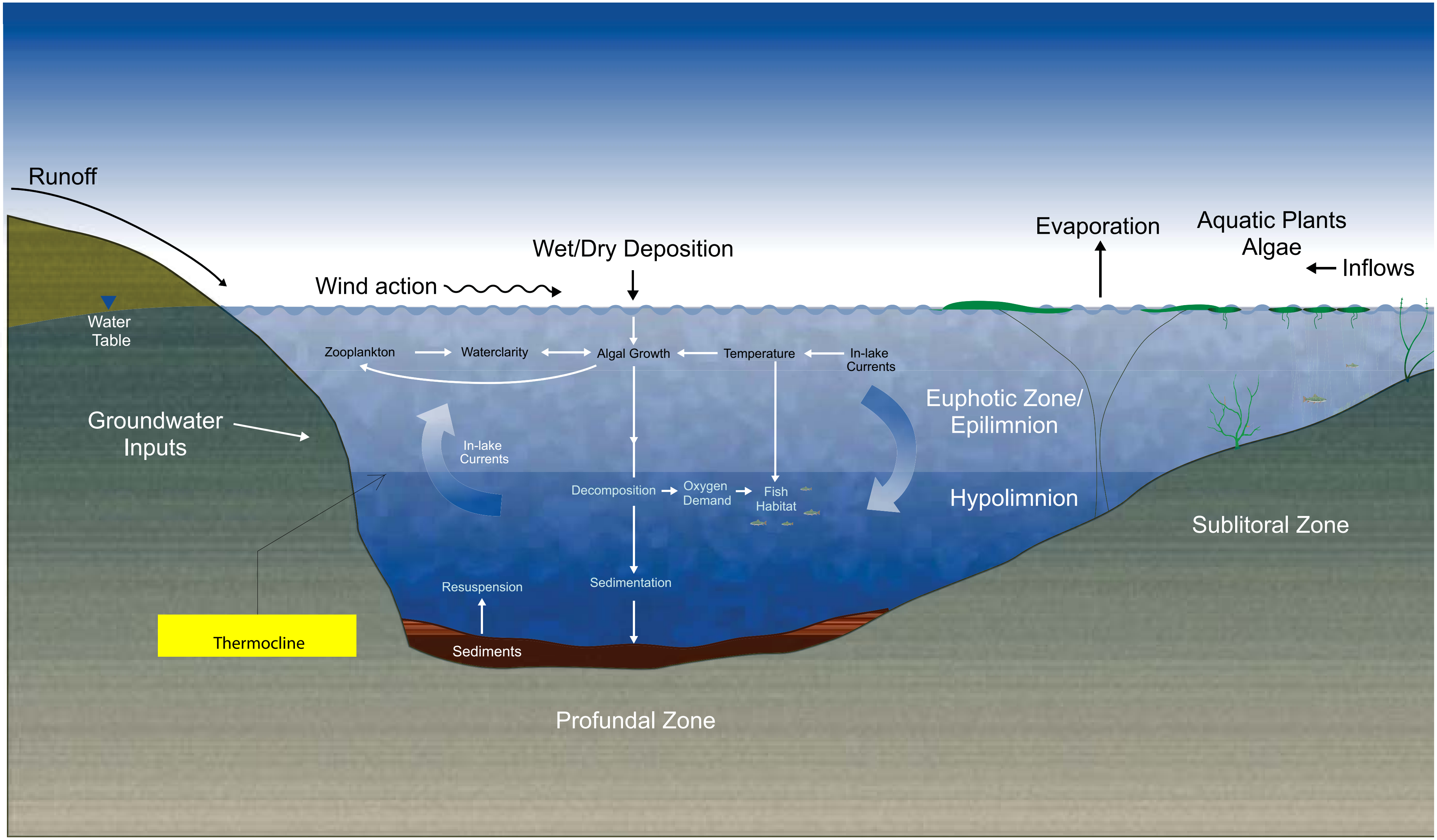
Kilometers

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 by wind-driven mixing. This is referred to as “lake overturn” and occurs in the spring and autumn when lakes warm or cool to approximately 4°C, the temperature at which water is most dense. At this temperature, surface waters sink and wind 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 warmer, less dense waters 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 light 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 in the deep waters of lakes (hypolimnion) during the summer and winter as decomposition of organic matter consumes the oxygen in the water. This may harm aquatic life that require oxygen to live, and may also result 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.



LEGEND

Designed By:	DLS	Drawn By:	SBB
Checked By:	DLS	Approved By:	DLS
Date Issued:	May 2012	Project No.:	?????

Schematic Diagram of Lake Processes that Influence Water Quality

Schematic Cross-Section

AECOM

FIGURE 6

N:\Projects\2004\41255\2005\Final\Images\Fig3.2

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 subwatershed. Lakes with a large amount of wetland in their subwatershed 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 subwatershed 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 subwatershed 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 subwatershed are registered water supplies, 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 biological productivity and 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 subwatershed to drainage area ratio of at least 10:1, meaning that their subwatersheds exert a strong influence on water quality within the lake;

2. Their subwatersheds 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 subwatershed 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 subwatersheds, 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 subwatershed, must be used to protect urban lakes from pollution sources. It is more cost-effective to manage urban development within the subwatershed in order to maintain established water quality objectives than to try to retrofit the subwatershed after the lake has degraded to an unacceptable condition.

2.4.5 Lake Description

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 for which depth information is available (Table 6), Lakes Charles and Lake William are the deepest, with maximum depths of 27 m although Grand Lake has the maximum average depth. Many of the lakes in the subwatershed are very shallow at less than 3 m deep.

Table 6. Morphometry of Lakes in Shubenacadie Subwatershed

Lake	Surface Area (ha)	Maximum Depth (m)	Average Depth (m)	Volume (m^3)[d]
Barrett Lake	9.0	6[a]		
Beaver Pond	15.0			
Beaverbank Lake	68.7	2[a]		
Loon Lake	76.6	6[a]		
Cranberry Lake	11.2	3[a]		
Lake Charles	141.4	27[b]	7.9[c]	1117×10^6
Duck Lake	9.5	3[a]		
Fenerty Lake	64.7	2[a]		
First Lake	82.7	23[a]		
Fish Lake	51.0	1[a]		
Kinsac Lake	168.1	5[a]		
Lake William	301.8	27[b]	11.4[c]	4367×10^6
Lisle Lake	5.4			
Miller Lake	125.8	4[a]		
Powder Mill Lake	43.1			
Rocky Lake	147.5	3[a]		
Second Lake	112.7	12[a]		
Springfield Lake	81.3	1[a]		
Third Lake	84.7	24[a]		
Tucker Lake	32.6	6[a]		
Fletchers Lake	100.7	9[b]	3.7[c]	373×10^6
Grand Lake	1877	7[a]	18.4[c]	34713×10^6
Lake Thomas	112.9	12[b]	3.6[c]	406×10^6
Lake Banook	41.5	12[a]		
Lake Micmac	104.2	6[a]		
Lewis Lake	76.5	2[a]		

Notes: a) estimated from available bathymetric maps; b) from Jacques Whitford 2009:c) from Scott et al. 1991
d) Based on surface area and mean depth.

Data Sources

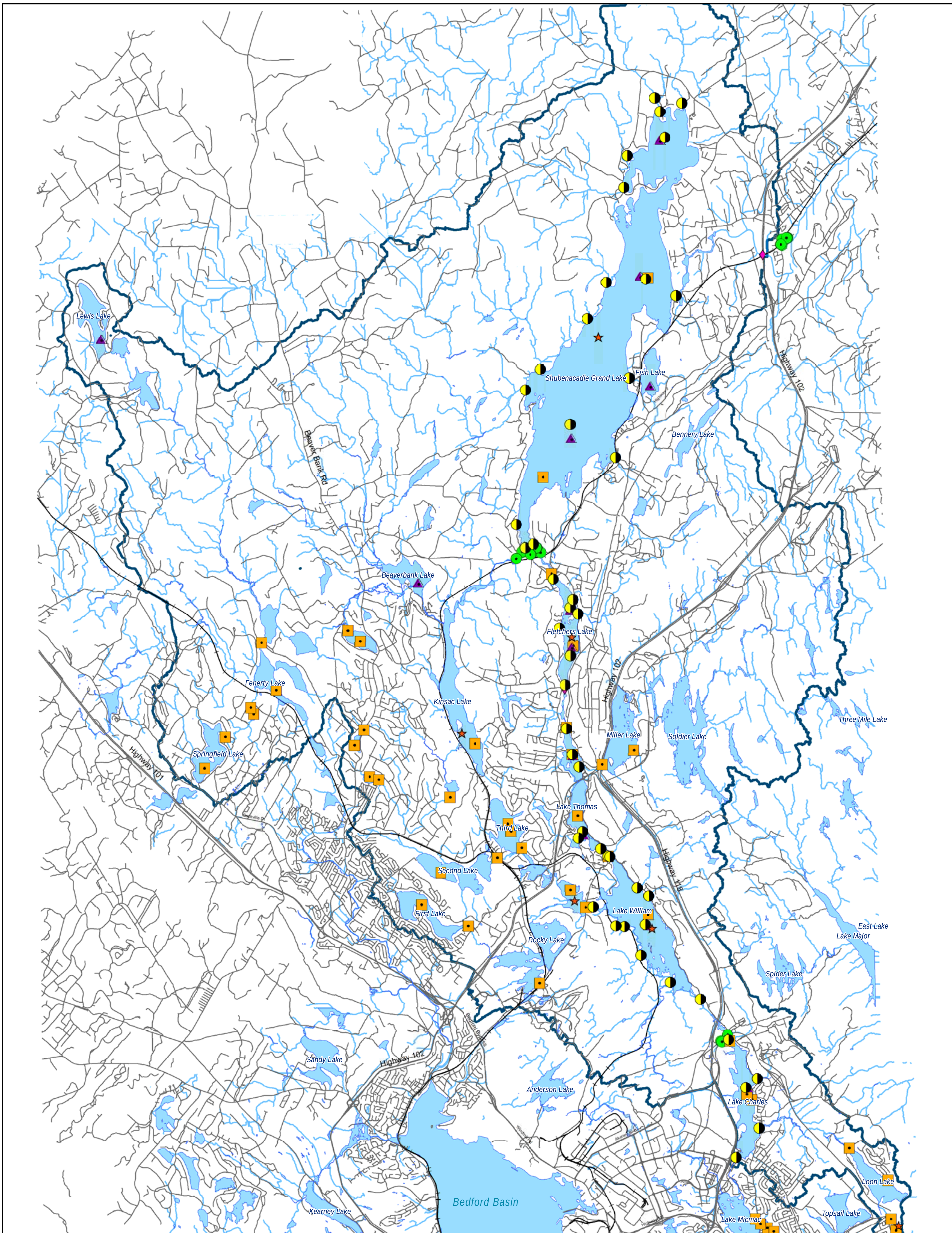
One of the key objectives of the Shubenacadie Lakes subwatershed study is to establish water quality objectives to prevent any further deterioration in water quality.

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 subwatershed, 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 subwatershed.

Water quality data for the Shubenacadie lakes and tributaries were obtained from the various programs of Halifax Regional Municipality (HRM), Jacques Whitford (now 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 subwatershed 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 shown on Figure 7.

Table 7. Water Quality Data in the Shubenacadie Subwatershed

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 Fisheries and Aquaculture	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



- AECOM
- Halifax Regional Municipality
- Jaques Whitford
- MEH
- Nova Scotia Lake Inventory
- SNC Lavalin
- Scott et al.

- Roads
- Watercourse
- Water
- Shubenacadie Lakes Watershed

Halifax Regional Municipality
Shubenacadie Lakes Watershed Study

Current Surface Water Quality Monitoring Stations

October 2012	1:100,000	Datum: NAD83 Zone 20 Source: HRM
P#: 60221657	V#: 002	
AECOM		**Figure 7**

0 1.5 3 6
Kilometers

* Scott et al. (1991) is: R.S. Scott, W.C. Hart, and D.H. Waller. April 1991. "Water Quality in the Headwaters of the Shubenacadie River System"

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.

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 subwatershed. 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.

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.

General Water Quality

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

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
	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

		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	**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	**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
	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

		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%	0.042	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
	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

		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)
	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
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

		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%	0.013	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
	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

		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)
	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
	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

		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%	0.011	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
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

		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)
	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 not currently a 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 subwatershed.

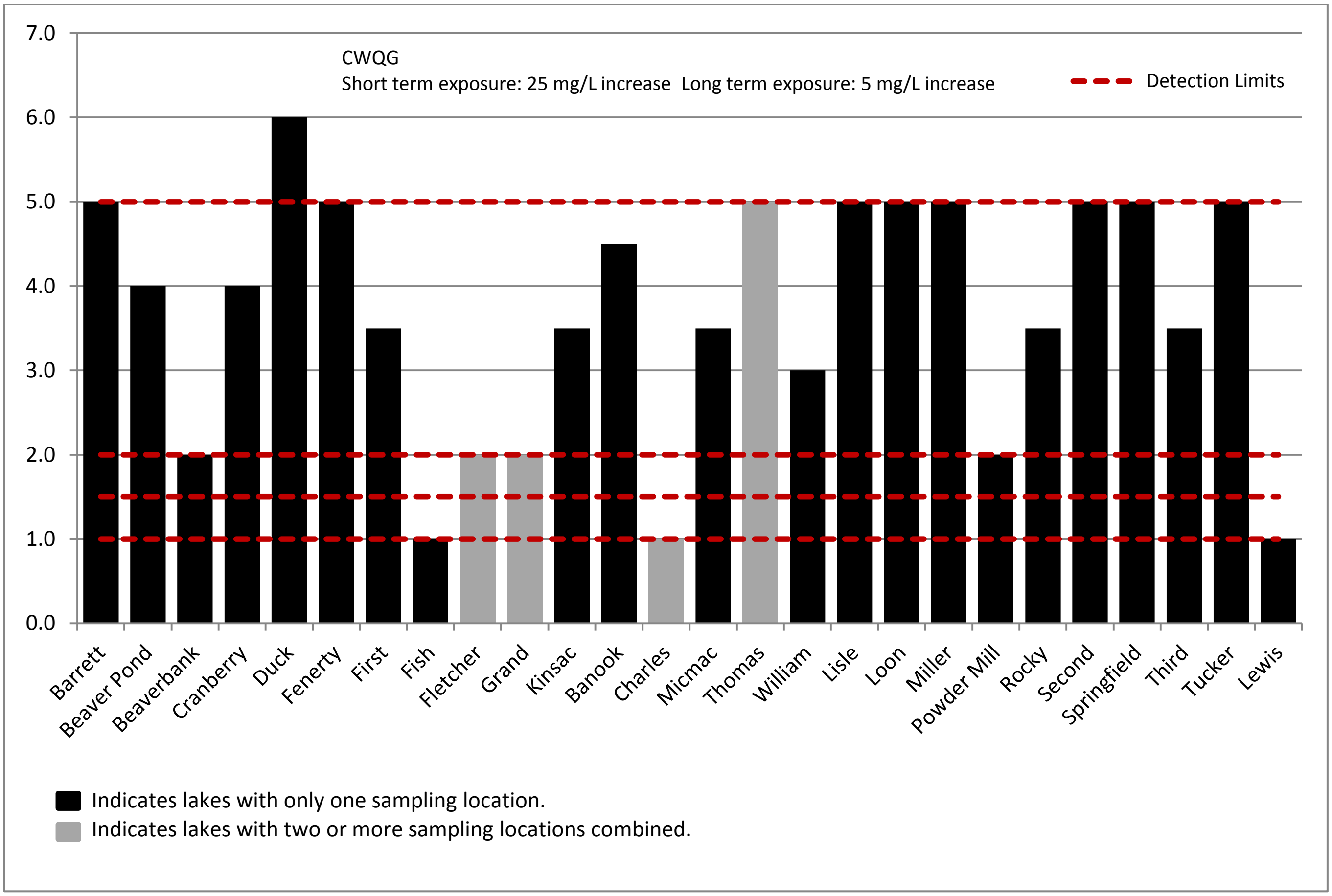


Figure 8. Median TSS Concentrations (mg/L) in Shubenacadie Lakes (2002-2011)

Ammonia

Elevated levels of ammonia in a lake would be indicative of a 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, possibly from the Aerotech or Miller Lake sewage treatment plants and/or the Scouts Canada camp. 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.

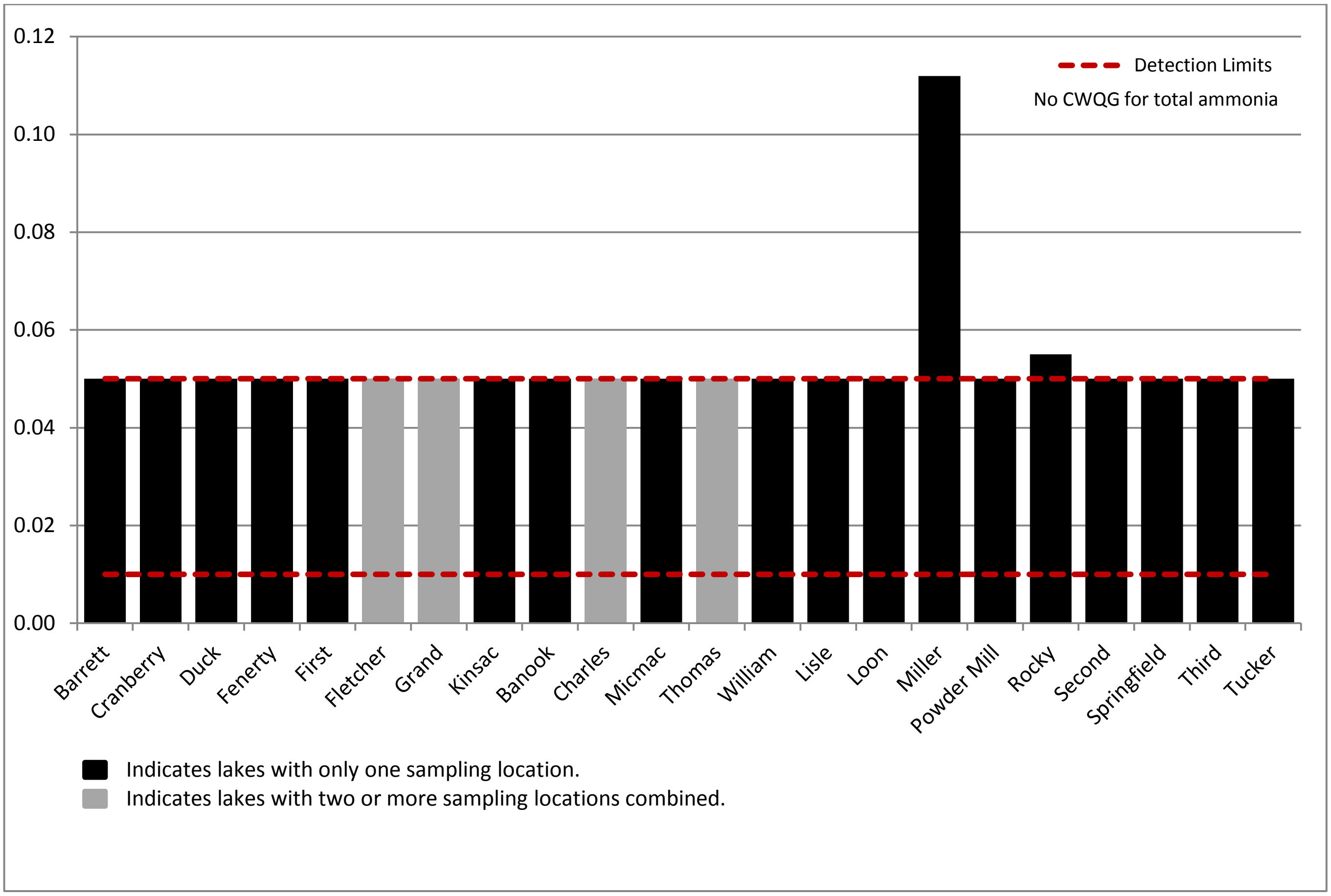


Figure 9. Ammonia Concentrations (mg/L) in Shubenacadie Lakes (2002-2011)

Nitrate

Excessive levels of nitrate in a lake is also indicative of man-made 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 for the protection of aquatic life (CWQG PAL) for nitrate (13 mg/L).

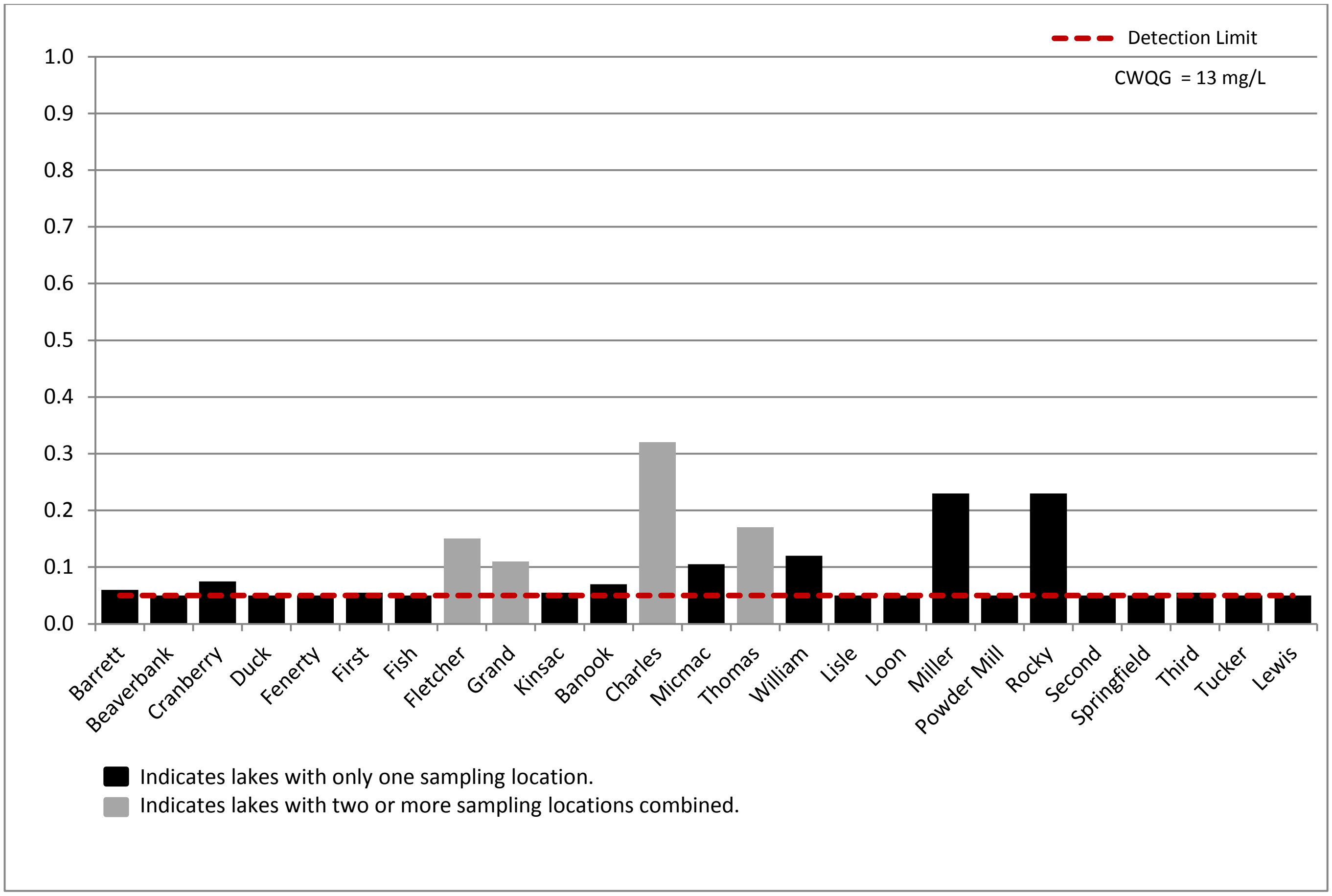


Figure 10. Median Nitrate Concentrations (mg/L) in Shubenacadie Lakes (2002-2011)

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 PAL 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 PAL and generally below 90 mg/L.

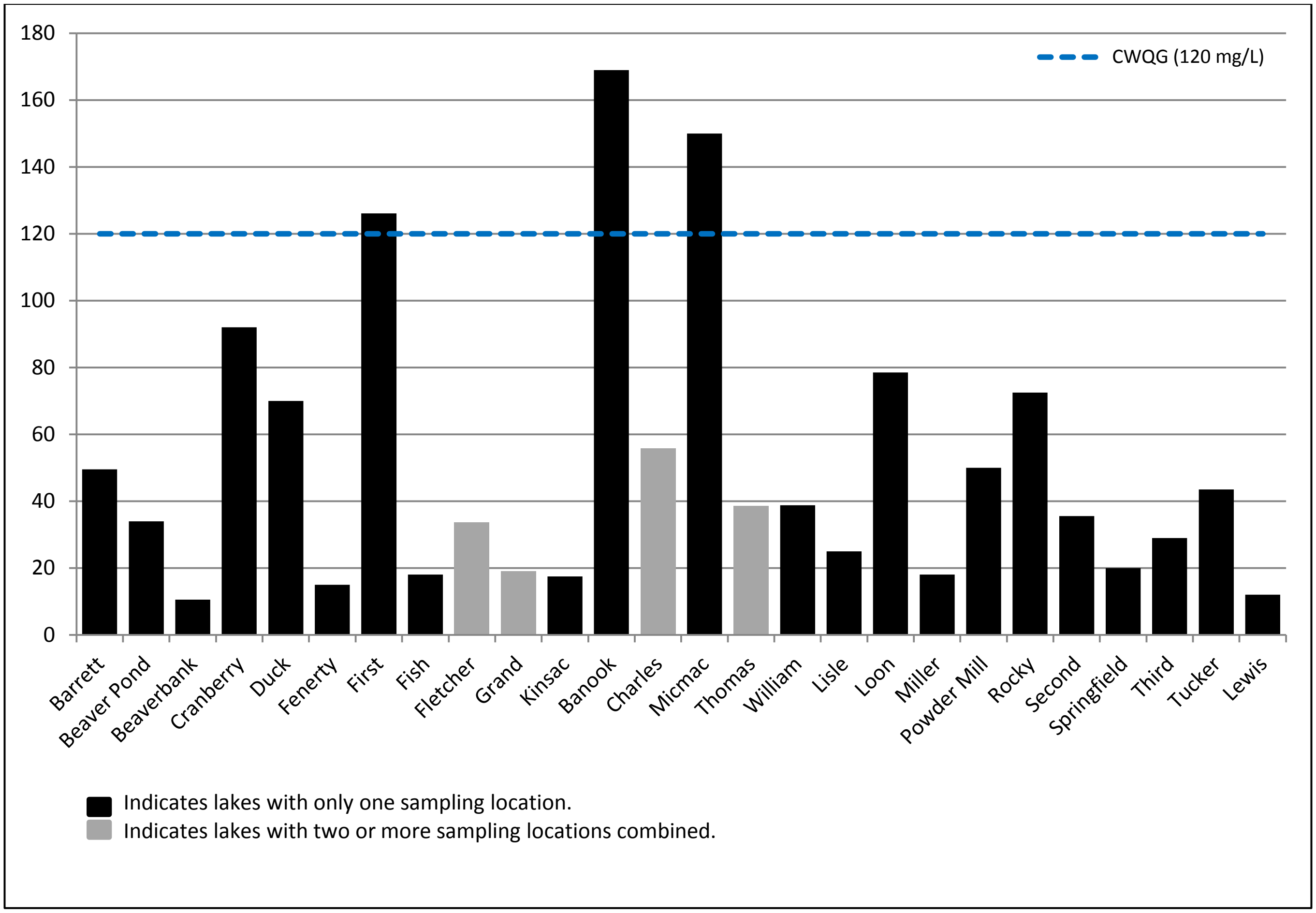


Figure 11. Median Chloride (mg/L) Concentrations in Shubenacadie Lakes (2002-2011)

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.

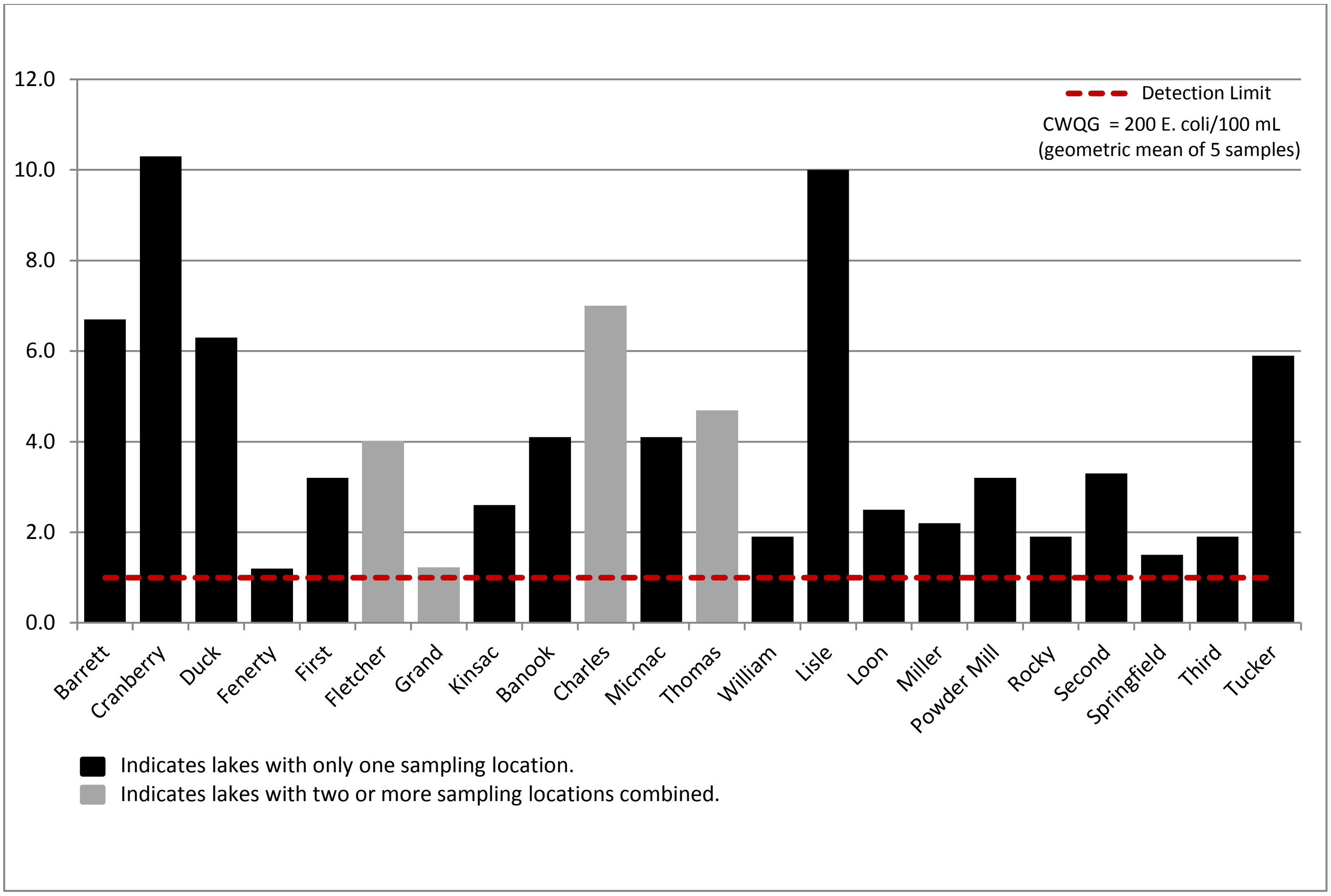


Figure 12. Geometric Mean of *E. coli* Measurements (CFU or MPN per 100 mL) (2002-2011)

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 meso-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.

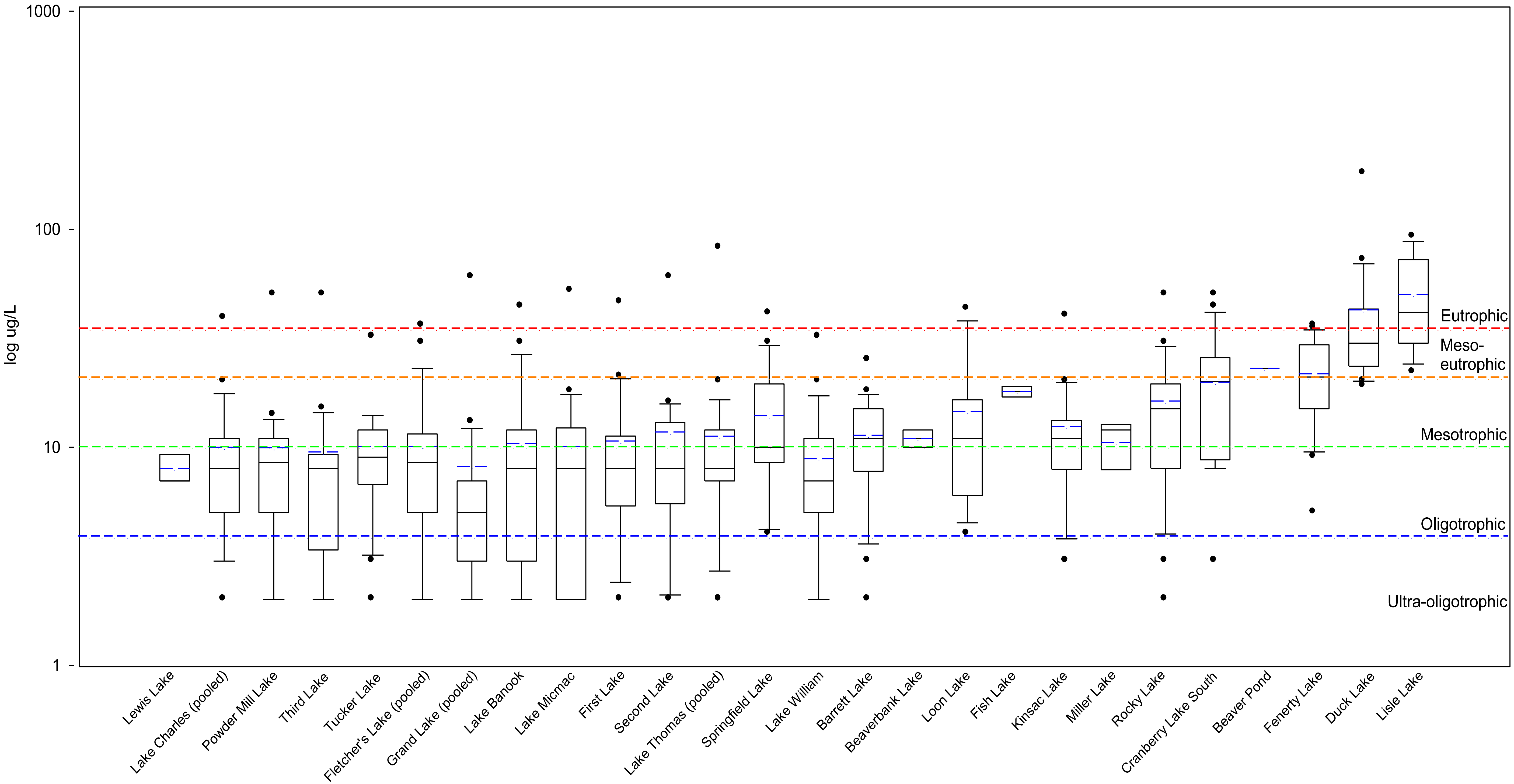


Figure 13. Total Phosphorus Concentrations (µg/L) in Shubenacadie Lakes (2002-2011)

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.

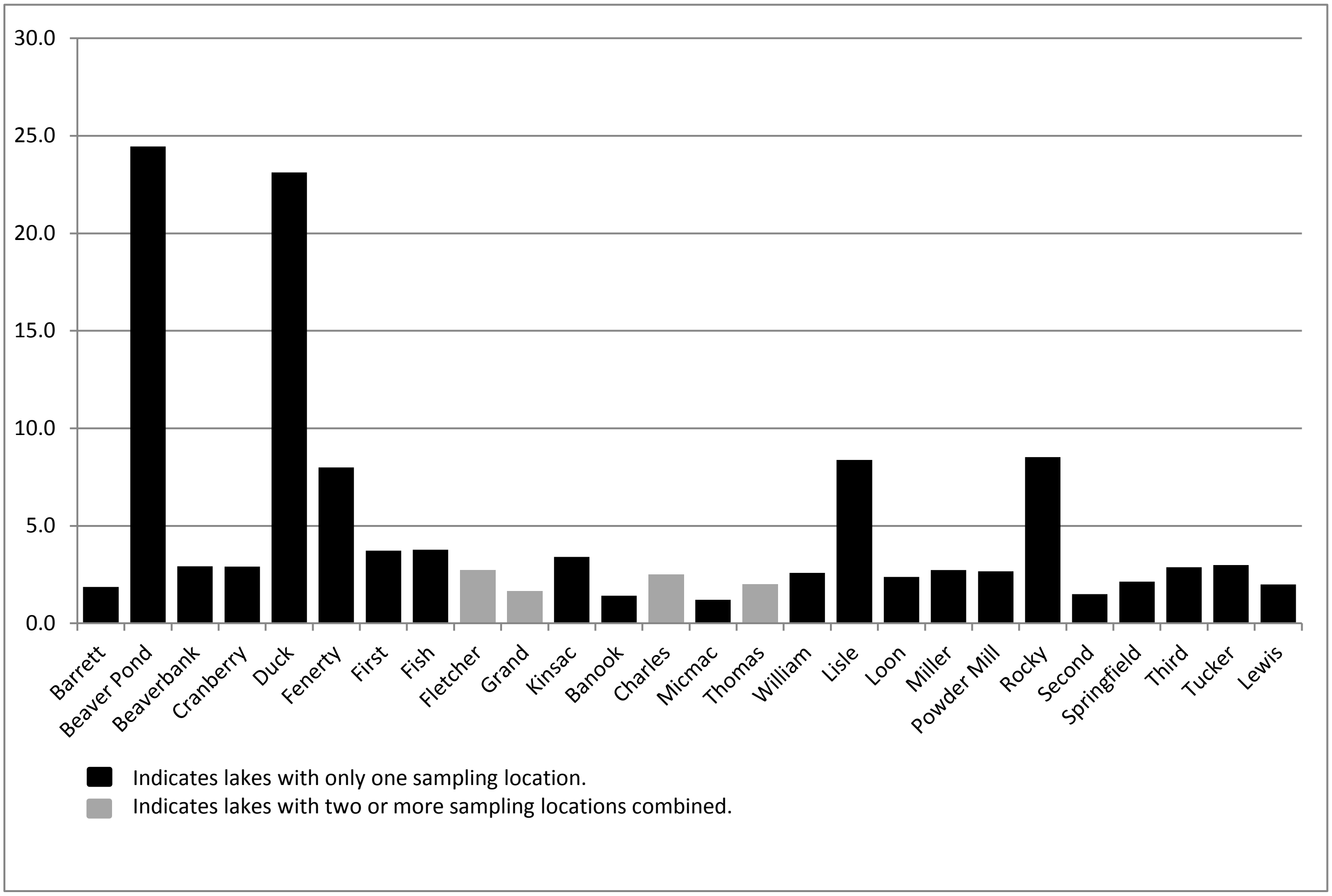


Figure 14. Median Chlorophyll *α* concentrations (μg/L) in Shubenacadie Lakes

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 human activities in the subwatershed 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 subwatershed, 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 Subwatershed

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			

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 subwatershed). 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 subwatershed. 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.

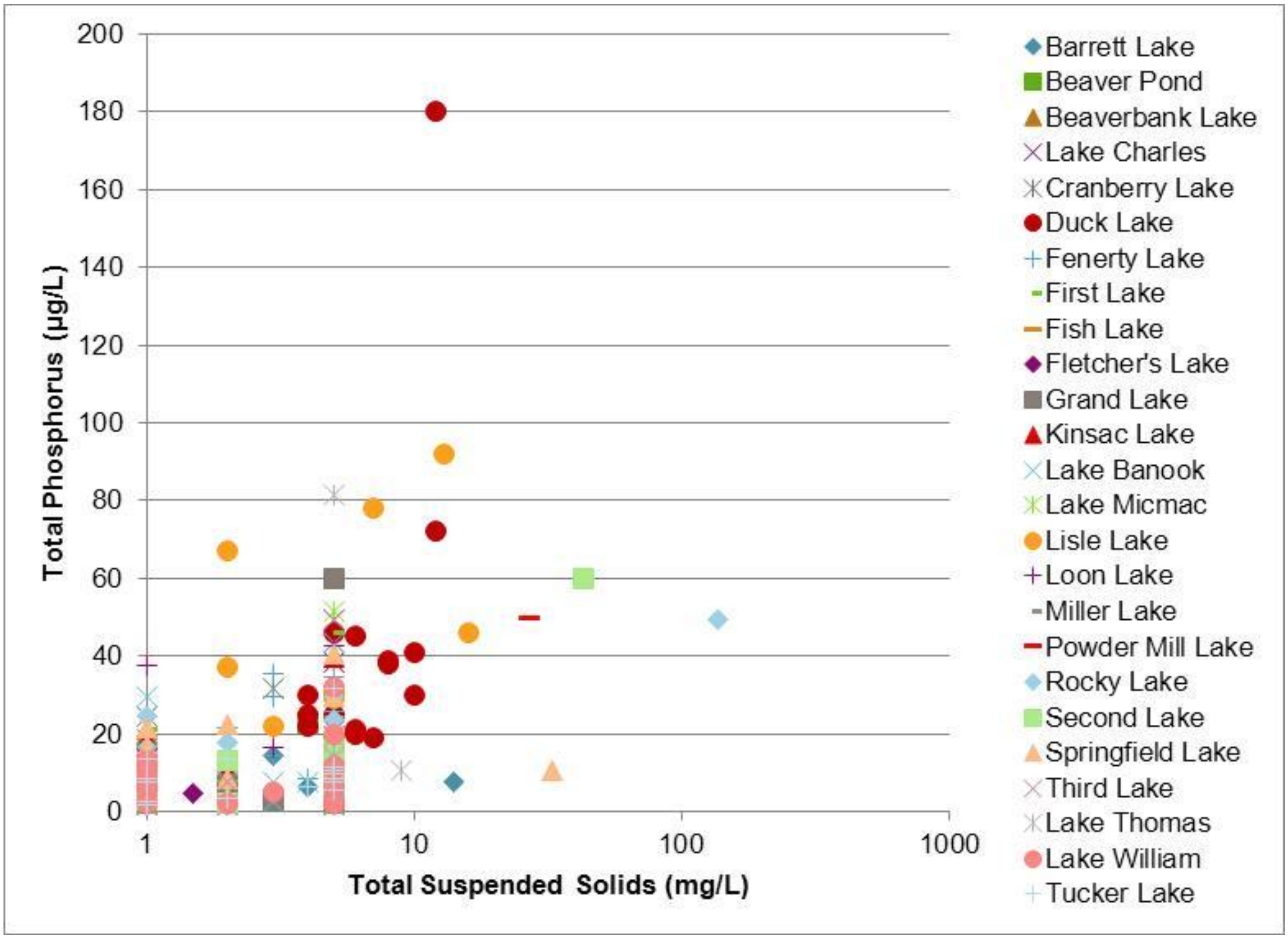


Figure 15. Relationship between Total Suspended Solids and Total Phosphorus in all Shubenacadie Lakes

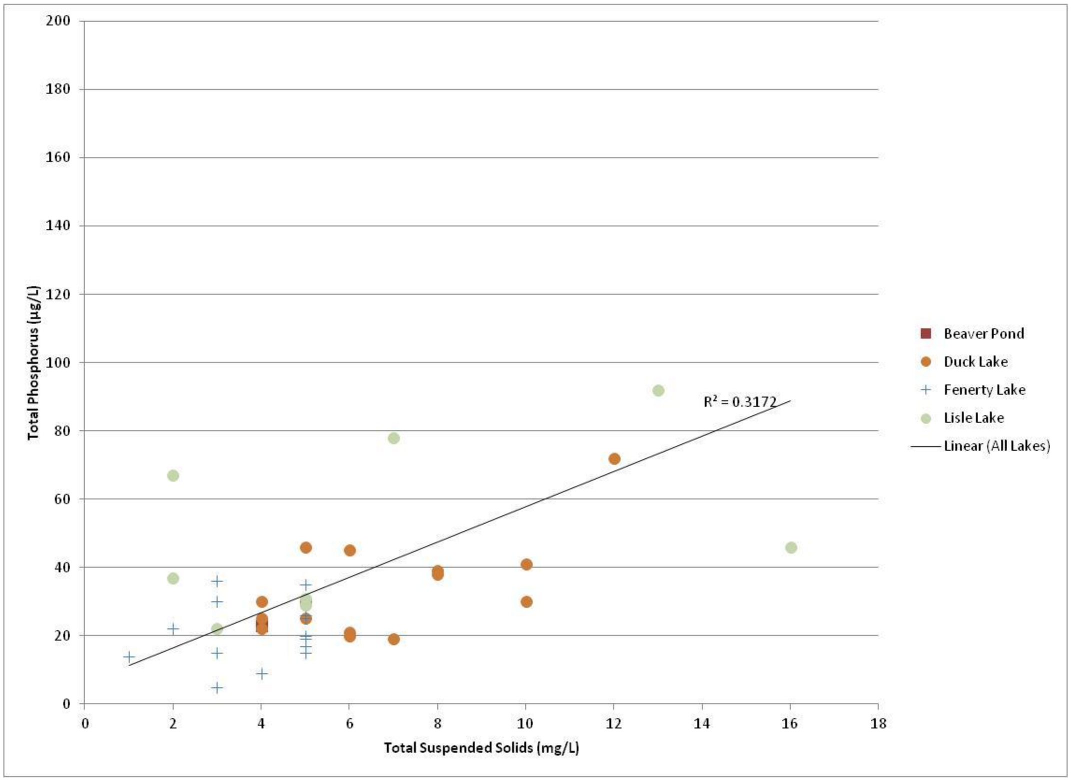


Figure 16. Relationship between Total Suspended Solids and Total Phosphorus in Shubenacadie Lakes (meso-eutrophic-eutrophic lakes only)

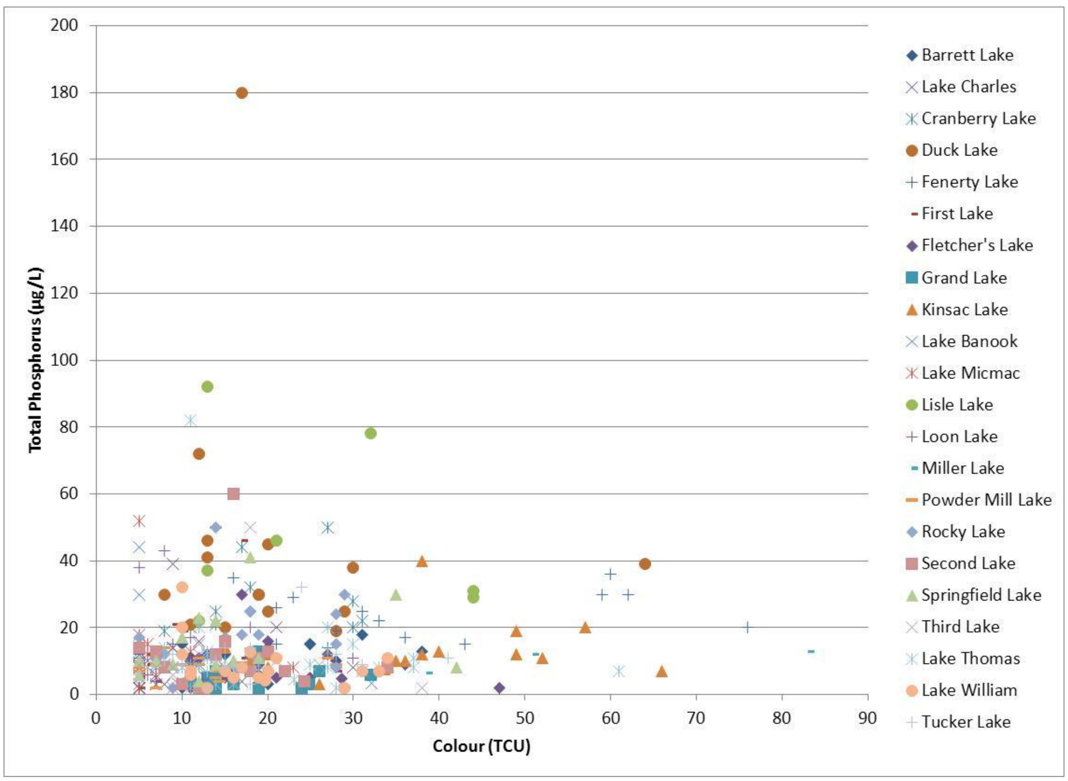


Figure 17. Relationship between Colour and Total Phosphorus in Shubenacadie Lakes

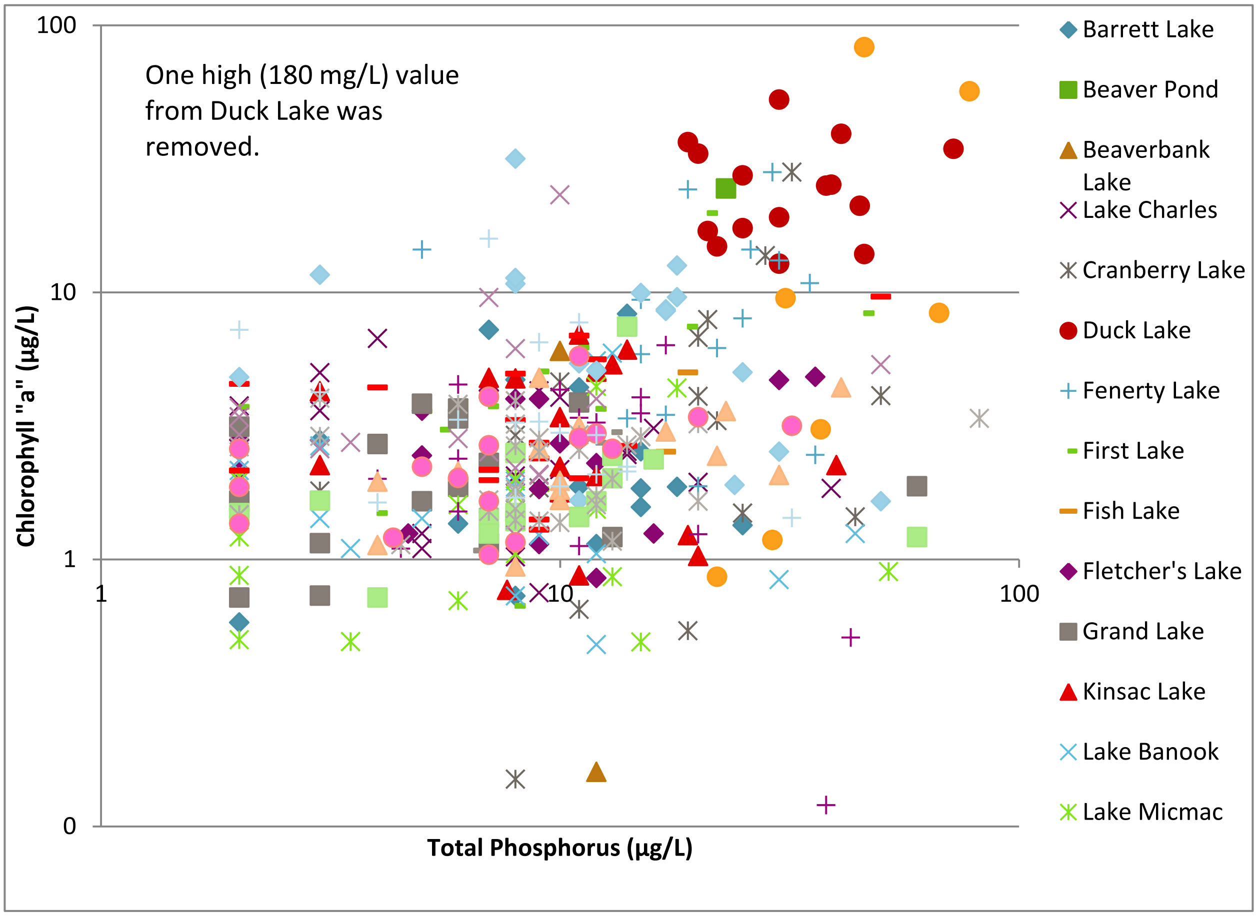


Figure 18. Relationship between Total Phosphorus and Chlorophyll α in Shubenacadie Lakes

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.

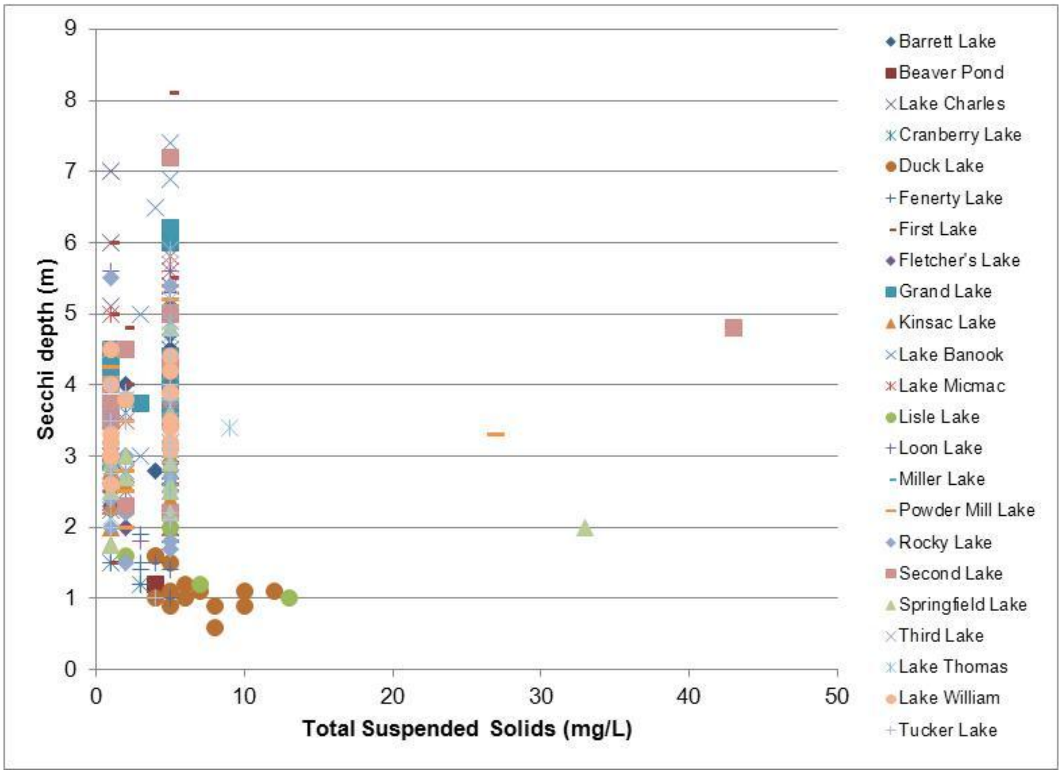


Figure 19. Relationship between Secchi Depth and TSS in Shubenacadie Lakes

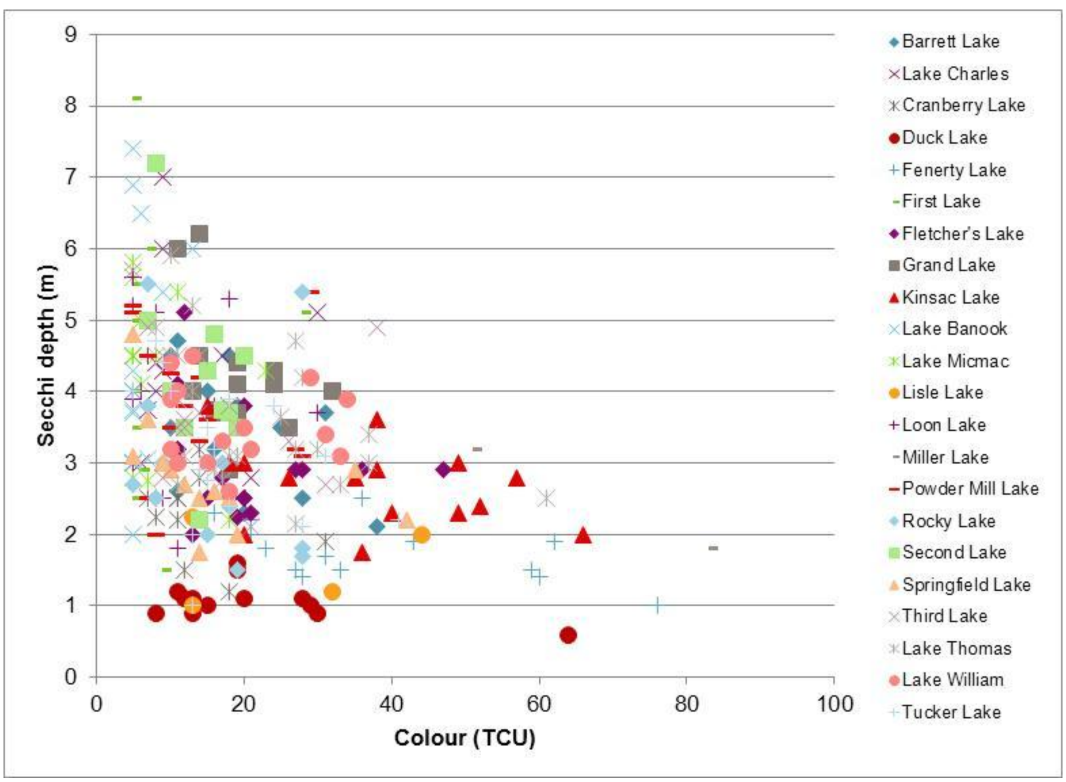


Figure 20. Relationship between Colour and Secchi Depth in Shubenacadie Lakes

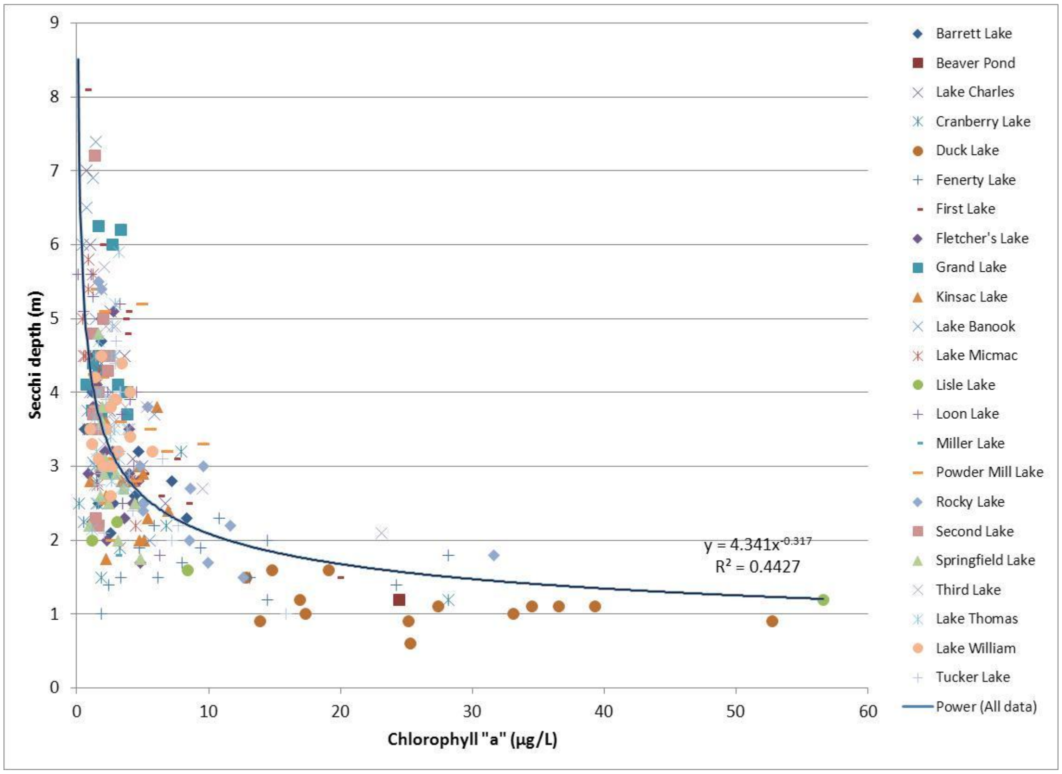


Figure 21. Relationship between Secchi Depth and Chlorophyll α in Shubenacadie Lakes

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 PAL 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 subwatershed is a function of the subwatershed 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 subwatershed such as the land use, local topography, soil types, groundwater inputs or baseflow and precipitation received in the subwatershed. 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 subwatershed 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 subwatershed has a significant impact on both the subwatershed hydrology and hydraulics. Urbanization typically increases the impervious surface areas within the subwatershed. 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 subwatershed after a rainfall event as opposed to the more gradual, lower peak flow of a natural subwatershed. These higher peak flows can lead to increased flooding and erosion within the subwatershed. The lakes within the subwatershed 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.

The Shubenacadie Lakes subwatershed has been hydraulically altered by the creation of the Shubenacadie Canal system consists which consists of a series of lock structures. The construction of the Shubenacadie Canal system permanently changed the hydraulics of the Shubenacadie waterways, and even though the canal structures are not in use today, the grade changes and deep cuts that were required to create the canal still influence the hydraulics of the subwatershed.

AECOM Supplementary Water Quantity Data

In order to address the absence of concurrent flow measurements within the Shubenacadie subwatershed, AECOM undertook monthly flow measurements at three 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 three locations:

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

A fourth location, Grand Lake outlet, was also measured but sampling conditions were difficult due to the extreme flows and data proved too variable to be useful.

Flow measurements were collected on a monthly basis from November 2011 to May 2012 although not all stations were captured each month (Appendix B). 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 provide reliable rating curves 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 subwatershed for an average year; and,
- Validating the model to ensure it is not under or over estimating the flows in the subwatershed.

Details of the model, the rating curves developed for each site and the hydrographs for the monitoring period are presented in Appendix C.

3 Data Processing (GIS) for Land use and Subwatershed 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. GIS source files are listed in Appendix D while a discussion of the details regarding the GIS data is presented in Appendices E and F. 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 on the figure to the right, 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 are given in Appendix D. Files were acquired, organized and saved in a GIS file geo-database for multiple uses within the project.

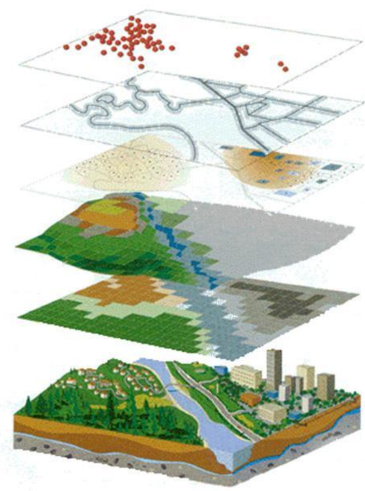


Illustration of Spatial Data Layering in GIS

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
Subwatersheds	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		Subwatershed Delineation / Constraint Mapping
DEM_2m	HRM	Received from HRM	Derived from LiDAR by Monette and Hopkinson of AGRG	Subwatershed Delineation / Constraint Mapping
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 Wallace 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	Subwatershed 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	NSE	Received from HRM		Land use classifications / Constraint Mapping
Ecosites	NSE			Land use classifications / Constraint Mapping
Highly scientific natural areas	NSE			Not used
Lakes & costal	NSE			All mapping
Sites of Ecological Significance	NSE			Land use classifications / Constraint Mapping
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			Land use classifications / Constraint Mapping

Data Name	Source	Status	Notes	Project Use
	Centre			
Special Areas	Atlantic Canada Conservation Data Centre			Land use classifications / Constraint Mapping
ELC (Eco Districts - high level)	NSDNR, Mineral Resource Branch	Downloaded from Website	Not used	
Surficial Geology		Downloaded from Website		Geology Mapping
Deer Wintering Areas	NSDNR			Land use classifications / Constraint Mapping
Wet Areas	NSDNR	Downloaded from Website		Land use classifications / Constraint Mapping
Restricted & Limited Use	NSDNR	Downloaded from Website	all files	Land use classifications / Constraint Mapping
Transportation & Utility Features	NSDNR	Downloaded from Website		All maps
Mineral Resource Land use	NSDNR	Downloaded from Website		Geology Mapping

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).

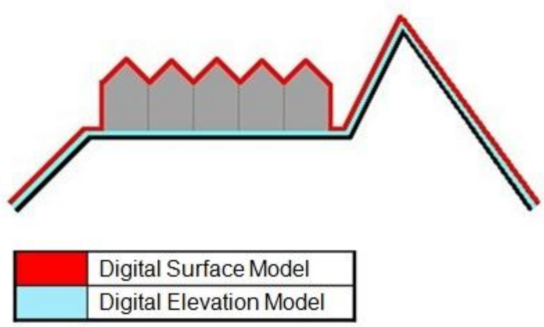


Figure 22. Illustration of Digital Surface Model (DSM) and Digital Elevation Model (DEM)

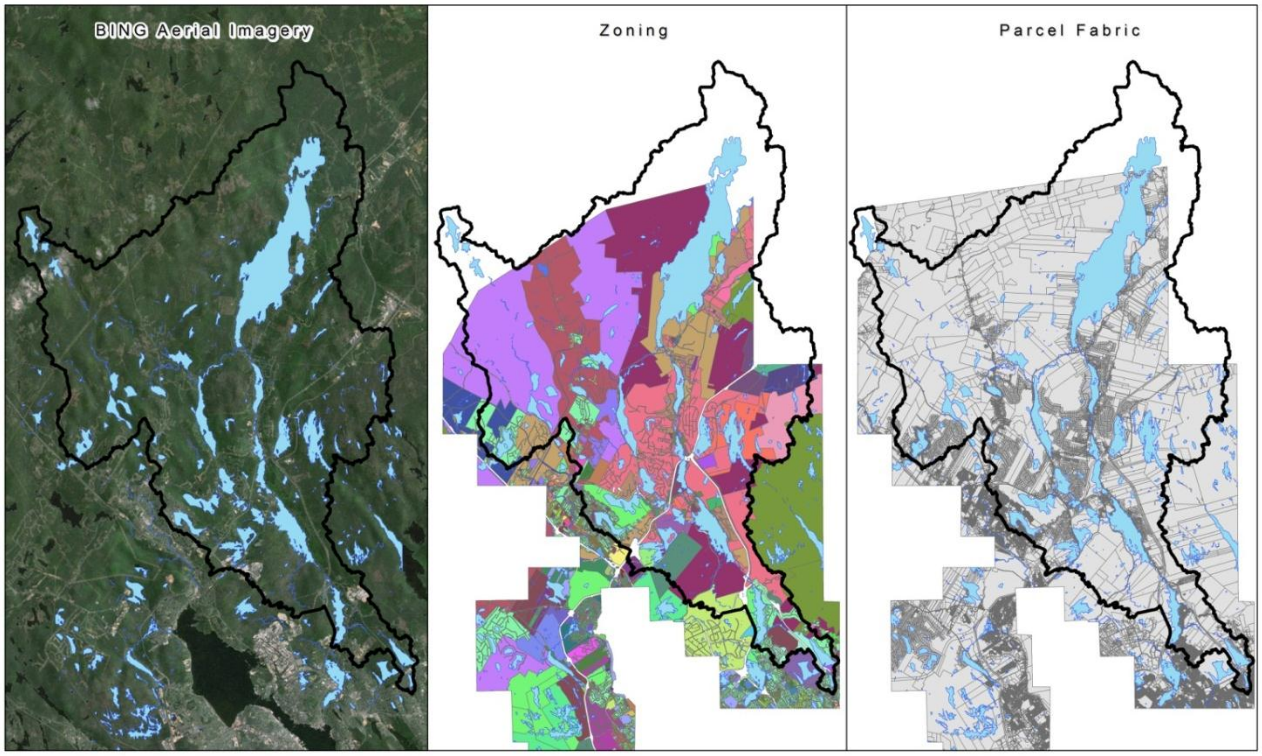


Figure 23. Illustration of Data Layers Use to Develop Land Use in Shubenacadie Lakes Subwatershed

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 and Ngo, 2010). The purpose was to create a DEM from the LiDAR ground points for most of the HRM. Detailed documentation on this process is given in Appendix F. The resulting DEM grid has 2 m grid resolution which is highly accurate and useful for the mapping undertaken in this study.

3.3 Subwatershed 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 (Tribe 1991). As such, they have the potential to greatly assist in the parameterization of hydraulic surface runoff models, especially for large subwatersheds (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 subwatershed boundary in GIS can be seen in Table 11.

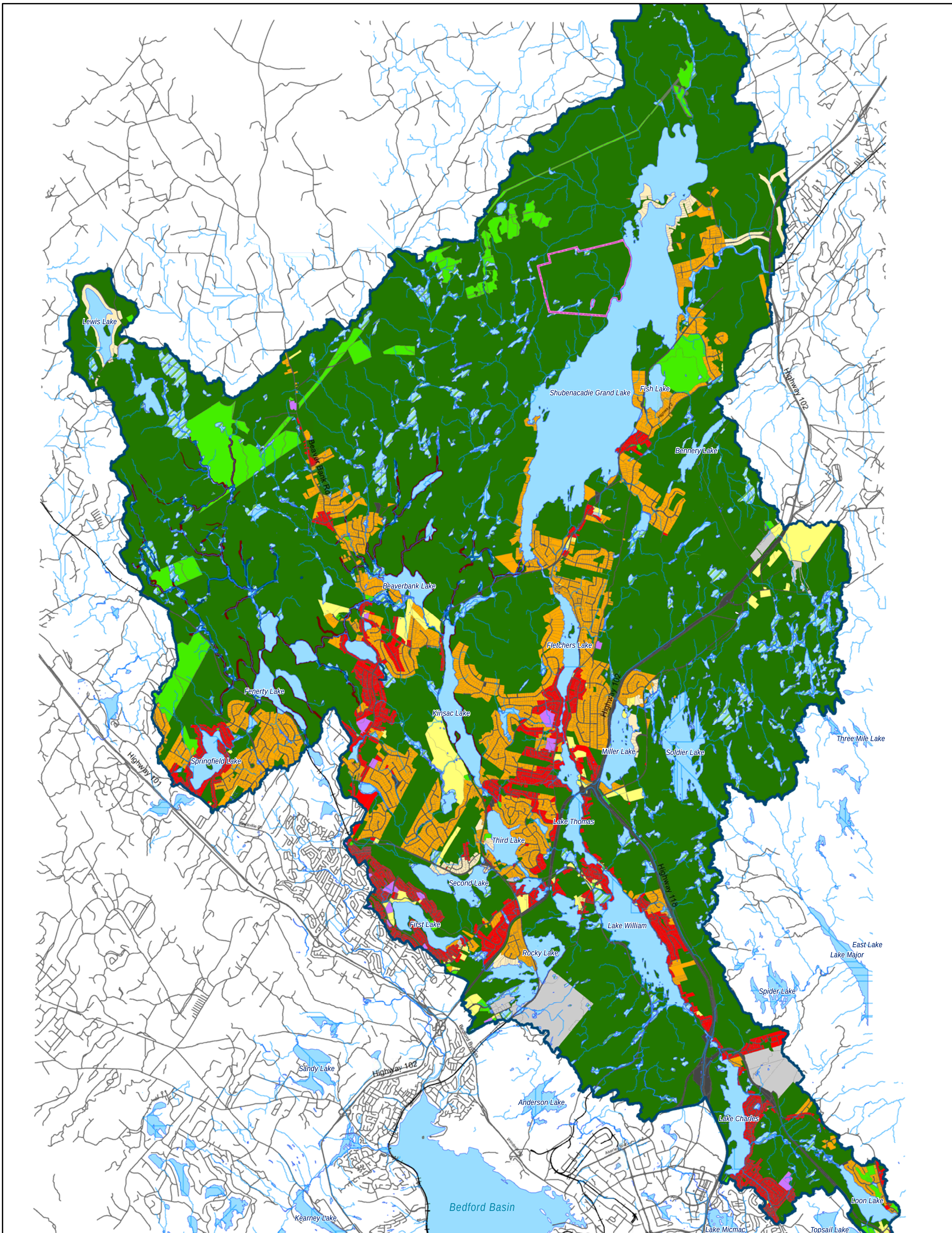
Table 11. Overview of Subwatershed Modelling

Options	Functions
Hydrological Modelling	Creates subwatersheds 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 subwatershed
Subwatershed	Creates a subwatershed 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 subwatershed 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).



Existing Land Use

- Roads
- Railroads
- Watercourse
- Lakes
- Shubenacadie Lakes Watershed
- First Nations Land
- Forest
- Forest - Meadow
- Forest - Sensitive Habitat
- Wetland
- Wetland - Sensitive Habitat
- Commercial
- High Density Residential
- Industrial
- Institutional
- Low Density Residential
- Open Space
- Medium Density Residential
- Power Lines
- Roadway

Halifax Regional Municipality
Shubenacadie Lakes Subwatershed Study

Existing Land Use

October 2012	1:100,000	Datum: NAD83 Zone 17 Source: HRM
P#: 60221657	V#: 002	

Figure 24

AECOM

0 1.5 3 6
Kilometers

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

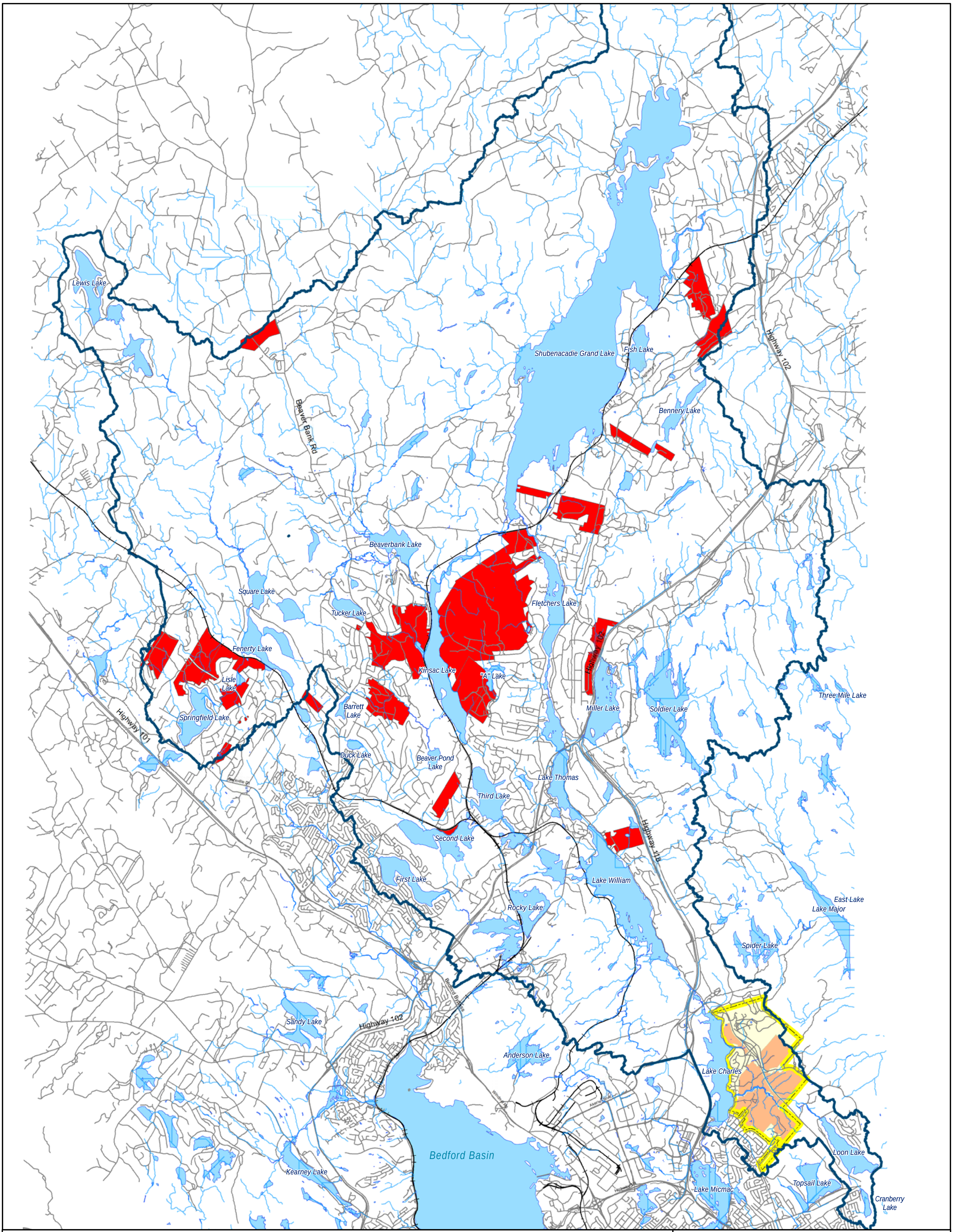
Land Use	Description	General Classification
Bedrock	Rock visible from air photo	Bedrock
Commercial	Shops / malls / box stores	Commercial
Crown Land	Provincial land	Forest
Forest	Significant tree cover	Forest
Forest – Meadow	Open grass lands / minimal tree cover	Forest - Meadow
Forest - Old Growth	Designated 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 models are designed to provide an evaluation of the benefits of mitigation measures on managing the water quality within the subwatershed. The models consider three development scenarios: “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 Wallace Lands, which are designated by the Regional Plan for potential future development.

3.5.1 HRM Authorized Subdivision Agreements

As noted, three development scenarios were modelled. In the first case, the current state of development or "existing conditions" was modelled. Based on information provided by HRM, existing land use conditions are shown on Figure 24. In the second case, the study added all authorized subdivision agreements within the subwatershed (Figure 25). Finally, the additional impacts of both the authorized and the proposed development commitments – the Port Wallace Lands – were assessed (also shown on Figure 25).



Roads
Watercourse
Authorized Subdivision To Be Built
Port Wallace Lands
Shubenacadie Lakes Watershed
Water

Halifax Regional Municipality
Shubenacadie Lakes Subwatershed Study

HRM Authorized Subdivision Agreements

March 2013	1:100,000	Datum: NAD83 Zone 17 Source: HRM
P#: 60221657	V#: 002	Figure 25

AECOM

0 1.5 3 6
Kilometers

Short to medium term development will occur in the central portion of the subwatershed. In total, approximately 20 subdivisions 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 Wallace Lands consist of a mix of low, medium and high density development and will be fully serviced by municipal water and wastewater infrastructure.

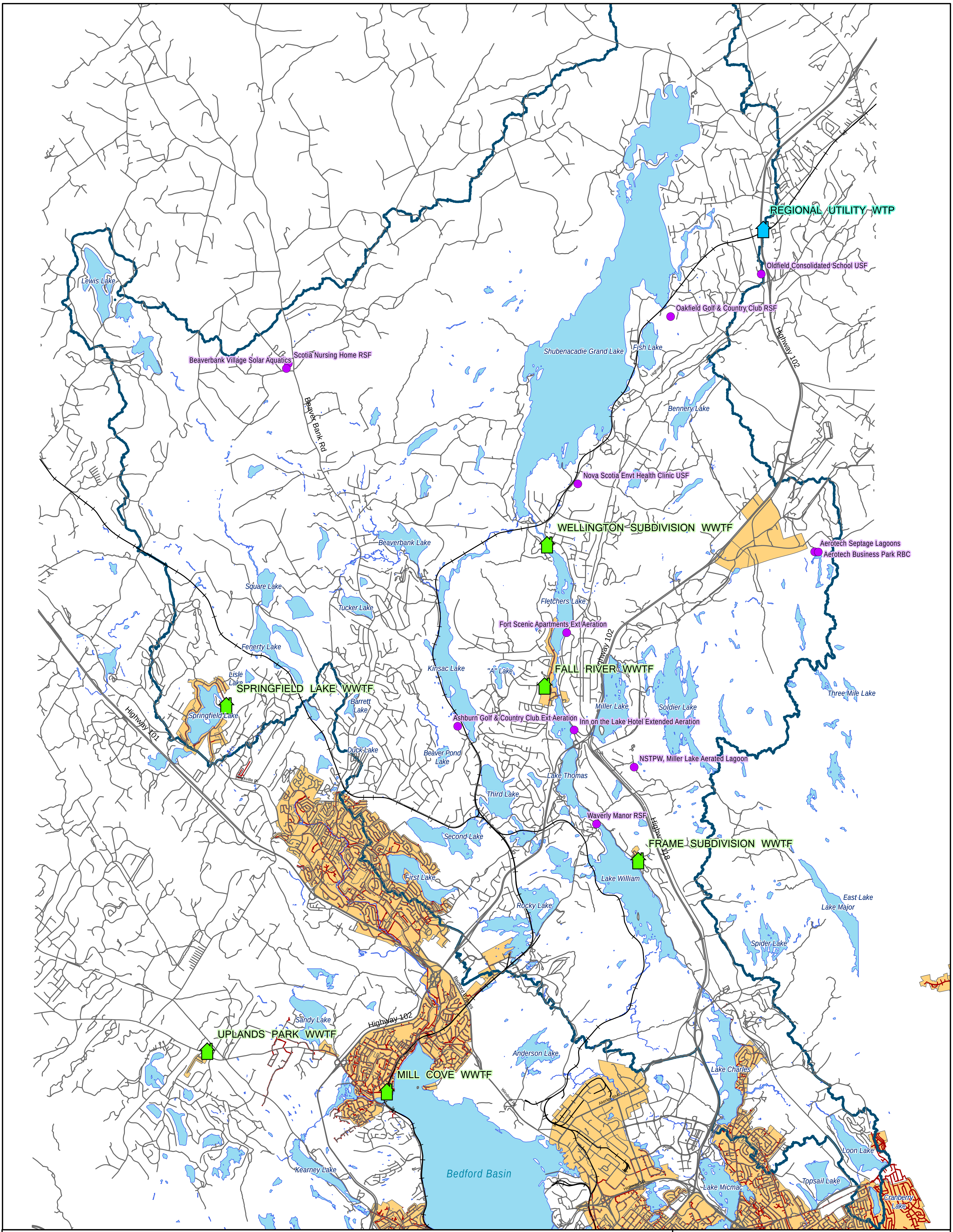
Table 13. HRM Authorized Subdivision Agreements (2012)

		# 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.



- Wastewater Treatment Facility
- Water Treatment Facility
- Private Septic Systems
- Roads
- Watercourse
- Sewer Pipes
- Sewershed
- Water
- Shubenacadie Lakes Watershed

Halifax Regional Municipality
Shubenacadie Lakes Subwatershed Study

Existing Serviced Lands

March 2013	1:100,000	Datum: NAD83 Zone 17 Source: HRM
P#: 60221657	V#: 002	

AECOM

Figure 26

0 1.5 3 6
Kilometers

3.5.2 Development Constraints

Critical to the modelling is the concept of development constraints that restrict or prohibit 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, locations of rare and endangered species and the presence of acid generating rock close to the surface.

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

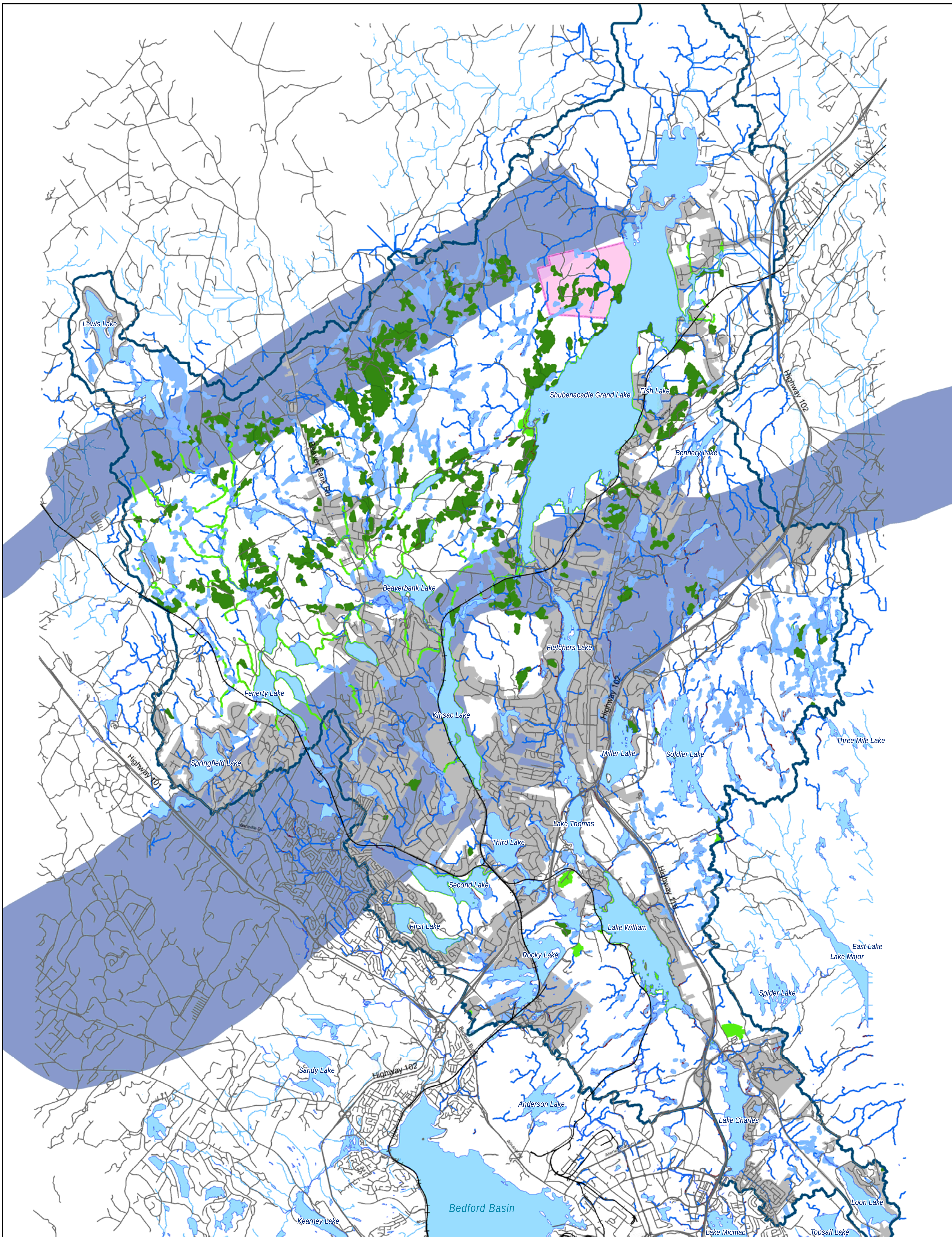
A review and analysis of setbacks and vegetated buffers in Nova Scotia was undertaken by Hydrologic Systems Research Group (2012). The effectiveness of buffer widths varies depending on the pollutant of interest. For sediment and phosphorus, a 5 m buffer will remove an estimated 50% of these pollutants. The 20 m buffer along all water courses used in the constraint analysis is reported to eliminate more than 70% of suspended sediment and more than 60% of phosphorus (Hydrologic Systems Research Group 2012).

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."*

While this policy is applied by HRM during the development agreement process, it cannot be easily integrated into the constraints applied to the modeling for this study. This is because it is difficult to identify these steep areas at the scale of an entire subwatershed, and because there is not enough of them to significantly affect the results of the model, compared to other factors such as development type, private septic systems, etc. 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.



Roads
Watercourses
Water
Isolated Wetlands
Shubenacadie Lakes Watershed
First Nations Land

Constraints

Water & Contiguous Wetland Buffer 20m
Acid Generating Slate (Halifax Formation)
Significant Wildlife Habitat Buffer 20m
Old Growth Forests Buffer 20m
Riparian Buffer 20m
Slope Greater than 20%
Existing Development

Halifax Regional Municipality
Shubenacadie Lakes Subwatershed Study

Constraints

October 2012	1:100,000	Datum: NAD83 Zone 17 Source: HRM
P#: 60221657	V#: 002	**Figure 27**

AECOM

0 1.5 3 6
Kilometers

4 Receiving Water Quality Objectives

4.1 Introduction

One of the principal objectives of the subwatershed study is to evaluate existing water quality conditions and recommend water quality objectives for the main lakes within the subwatershed. 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 subwatershed 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 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. 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 (Table 14). Other parameters such as metals, oil and grease, chlorophyll *α*, and nitrogen, may also increase due to development in the subwatershed; however, subwatershed management and implementation of mitigation measures to reduce development impacts to the “indicator parameters” will also limit the changes to these other parameters.

Table 14. Changes to Water Quality Parameters from Subwatershed 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-passes and overflows, septic systems, urban runoff, stormwater discharge.	Increases in nitrate can increase growth of 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 from application of road salt, 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

Water Quality Parameter	Effect of Development	Rationale for inclusion as Indicator Parameter
		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[3]. Given this, when developing water quality objectives for Shubenacadie, the guidelines and objectives from other jurisdictions were consulted for direction. The Canadian Water Quality Guidelines for the protection of aquatic life (CWQG PAL) 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 PAL "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 that includes the use of regional and waterbody - type approaches 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. Table 15 summarizes the CWQG, USEPA, and Vermont water quality guidelines and standards for the key indicator parameters identified for the Shubenacadie Lakes subwatershed.

[3] In order to maintain their current trophic state, HRM (through the former Harbour East Community Council) adopted a total phosphorus concentration of 15 μg/L for Morris and Russell Lakes in Dartmouth.

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

Parameter	CWQG PAL	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, 2012

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

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 subwatershed. 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 subwatershed. 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 PAL (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 PAL 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[4]. We suggest this value is appropriate for the *E. coli* parameter. These values are illustrated in Table 16.

4. 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.

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

Parameter	Derivation of Objective	Shubenacadie Lakes Subwatershed 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 the most recent 3 year historical data
Un-ionized Ammonia	CCME	• 0.019 mg/L	• ≤0.014 mg/L	• 75th percentile of the most recent 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 the most recent 3 year historical data not to exceed baseline by more than 5 mg/L
Chloride	CCME	• 120 mg/L	≤90 mg/L	• 75th percentile of the most recent 3 year historical data
E. coli	Nova Scotia and Health Canada	• 200 *E. coli*/100 mL • (geometric mean of 5 samples)	• 200 *E. coli*/100 mL	• 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 <u>the upper limit of the TP range</u> 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 subwatershed, 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[5].

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. Cranberry Lake is unique in this situation as its average TP concentration is already at 20 µg/L, the boundary from mesotrophic to meso-eutrophic. Ideally TP should not increase in Cranberry Lake and efforts to decrease TP should be initiated. Consequently, the early warning value has been set above the current average concentration to alert that further deterioration of trophic conditions may be occurring supporting the need to implement remedial options. Insufficient data exist to establish phosphorus objectives for Miller Lake, Beaverbank, Fish Lake and Beaver Pond. Additional monitoring is required before 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] *This assumes that a water quality monitoring program is maintained to characterize changes to the lake relative to the existing or baseline conditions.*

5 Water Quality and Quantity Modeling

5.1 Introduction

Historically a version of the Ontario Lakeshore Capacity Model (LCM) has been used to estimate the phosphorus loading from the subwatershed to the lakes in Halifax (Scott and Hart 2004; Soliman 2008). This model depends on phosphorus loading coefficients applied for different land uses. The phosphorus loading coefficients were developed initially from soil erosion coefficients based on the Universal Soil Loss Equation (USLE) beginning in the 1930s (Wischmeier and Smith 1960; Wischmeier and Smith 1978) and later the Revised Universal Soil Loss Equation (RUSLE).

The RUSLE predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. This erosion model was created for use in farming systems, but is also applicable to non-agricultural conditions such as construction sites and has been refined for urban and urbanizing areas. Linking soil loss to phosphorus concentrations ultimately provides a prediction of the total phosphorus delivered to water courses from runoff. Because the model assumes that everything is in steady state, it predicts an average annual TP loading from a specific land use for the year. Summing the land uses for the sub-subwatershed provides an average load of TP for the subwatershed under the given land uses.

Linked to 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. This model has been developed over a forty year period based on data for lakes and reservoirs from around the world. The historical basis for this relationship is derived from the work of Vollenweider (1968, 1975) and Vollenweider and Kerekes (1982) who recognized similarities among lakes with respect to trophic response to nutrient input and defined nutrient loading criteria for lakes as a function of selected hydrologic and geomorphologic characteristics (e.g. mean depth, hydraulic residence time or areal water loading). This work was pursued and modified by others including Dillon and Rigler (1975), Larsen and Mercier (1976), Chapra (1977), Walker (1977) and Reckhow (1979). The resultant lake response relationships are generally widely accepted and are used here to predict lake trophic state in response to modeled nutrient loadings.

Urbanization usually results in extensive changes to the hydrology of a subwatershed and as noted the peak flows tend to increase due to a faster and higher rate of runoff and reduced infiltration. The higher peak flows result in greater erosion, which delivers more suspended solids (with their adsorbed phosphorus load) to nearby watercourses. These changes are due to the reduction of pervious surfaces due to the increase in roof area, parking lots, roads etc. and result in the more direct delivery of pollutants to watercourses. The management of stormwater in urban areas through the use of various stormwater management techniques[6] is critical to maintaining water quality in urbanizing subwatersheds. While the RUSLE 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, this study also adopts a stormwater management model (SWMM) to predict phosphorus loads within the Shubenacadie 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 loading and thus phosphorus concentrations. The SWMM model adopted here is the U.S. Environmental Protection Agency's StormWater Management Model.

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[6] see for example HRM's *Stormwater Management Guidelines (*Dillon Consulting Ltd. 2006*), Stormwater Best Management Practice Design Guide (USEPA, 2004)* and *Stormwater Pollution Prevention Handbook* (TRCA, 2001).

These two models have been used in this subwatershed and the results compared because there are strengths and weaknesses of both models in this application. The LCM has been used first because it has historically been applied in the region. The LCM is designed to consider directly the potential impact from septic systems and other point sources of phosphorus to lakes systems (e.g. sewage treatment plant discharges).

The SWM model is designed to assess the effect of urbanization on stormwater runoff to watercourses and urban lakes with respect to, specifically, flow and total suspended sediments, which are strongly influenced by urbanization. On the other hand, the SWM model does not directly consider the potential impact from septic systems and other point sources of phosphorus to lakes systems. It is also evident that the SWMM has difficulty in approximating the lake retention factors, likely because of the lake sizes which are generally much larger than most urban lakes. At the same time, stormwater management may be less of an issue in this subwatershed because of the generally low density of the proposed development. In order to accommodate the large number of septic systems within the Shubenacadie subwatershed in the SWMM, we have used the estimated loadings from septic systems generated from the LCM model. The LCM uses a phosphorus retention coefficient applied to septic systems to estimate septic system loadings within the SWMM. Unfortunately, the SWMM is not able at this time to transfer the septic system loading downstream (i.e. from the lake which is surrounded by residences on septic systems to the next downstream lake). Thus, at the present time there is a downstream transfer of phosphorus from septic systems that is not built into the SWM model and consequently some under-estimating of downstream transfers occurs. Nevertheless, despite the limitations both models will be considered below to predict loadings for the subwatershed and evaluate the impact of land use changes.

5.2 Lake Capacity Nutrient Loading Model – Steady State

A refined version of Ontario's LCM was used to assess potential changes in water quality from proposed development within the Shubenacadie subwatershed. The model, developed by Dillon and Rigler (1975) was calibrated on Canadian Shield lakes in Ontario (Dillon *et al.* 1986, Hutchinson *et al.* 1991) and has since been applied to lakes in Nova Scotia (e.g. Scott and Hart 2004; Soliman 2008). As noted above, this is a mass-balance, steady state model that quantifies linkages between natural sources of phosphorus (e.g. atmospheric deposition, in-lake cycling), human inputs from shoreline development (land use), water balance, lake morphometry, and the ice-free TP concentration of a lake (Paterson *et al.*, 2006). A mass-balance model calculates a budget of the phosphorus inputs to a lake minus losses to the sediments and the outflow of the lake. The model assumes that the resulting concentration of phosphorus in the lake is equal to that of the outflow, and seasonal fluctuations in hydraulic and phosphorus loadings can be neglected.

For each lake the specific inputs to the model include:

- Areas for each land use (e.g. forest, meadow, residential, etc.);
- Phosphorus export coefficient for each land use;
- Hydraulic inputs and hydrology; and
- Point sources (septic systems, waste water treatment plant discharge and sanitary sewer overflows)

Using this information the model calculates:

- Hydraulic budget;
- Phosphorus loads from all land uses, point sources and septic systems; and
- Predicted lake total phosphorus concentration (ice-free).

The model version used for the Shubenacadie subwatershed was based on that developed by Brylinsky (2004) for Nova Scotia lakes. Model input parameters (e.g. export coefficients) and calibrations are detailed in Appendix H. Areas for each land use within a subwatershed were calculated using GIS, as described in Sections 3.3 and 3.4. The model calculates a TP loading from the various land uses, upstream catchments, atmospheric inputs, and septic systems, as well as the areal water loading for the subwatershed to determine the amount of TP retained within the lake. Calculation of in-lake TP retention is critical to larger lakes as otherwise the transport of TP to downstream lakes would be excessive thus over-predicting TP downstream (see Appendix I). Results are presented for three modeling scenarios:

4. Modeling Scenario 1: Existing Conditions
5. Modeling Scenario 2: HRM Authorized Subdivision Agreements
6. Modeling Scenario 3: Scenario 2 plus fully developed Port Wallace Lands

5.2.1 Results

Model results are presented below. Model output files are provided in Appendix I.

Modeling Scenario 1: Existing Conditions

The surface area of the different land uses within each sub-subwatershed is presented in Appendix H. The modeled TP concentrations for each lake under the existing conditions and following future development are presented in Table 19. In general, there is good agreement between measured and predicted lake phosphorus concentrations. Modeled phosphorus concentrations for Fish and Beaver Pond, although outside of their measured concentrations by 20%, were considered reasonable estimates of phosphorus concentrations for these lakes due to the small sample sizes (two and one samples respectively). All other lakes were within 20% of their field measurements (a general guideline of model validity).

Table 19. Measured versus Modeled Total Phosphorus Concentrations (μg/L)

Lake	Measured[1]	Scenario 1: Existing Conditions	Difference[2]
Cranberry	20±13(17)	17	-15%
Loon	15±12(15)	14	-14%
Charles	10±8(21)	10	0%
Micmac	10±12(17)	10	0%
Banook	10±11(17)	10	0%
First	11±10(17)	12	-5%
Rocky	16±12(17)	16	-6%
Second	12±14(16)	13	0%
Third	10±11(17)	11	0%
Powder Mill	10±11(17)	11	0%
William	9±7(20)	9	0%
Soldier	n/a(0)	11	n/a
Miller	11±4(3)	12	8%

Lake	Measured[1]	Scenario 1: Existing Conditions	Difference[2]
Thomas	11±14(32)	13	13%
Fletcher	10±9(20)	10	0%
Grand	8±13(19)	9	12.5%
Fish	18±1(2)	14	**-22%**
Springfield	14±10(16)	14	0%
Lisle	50±26(8)	51	2%
Fenerty	22±9(16)	18	-18%
Lewis	8±2(3)	9	12.5%
Hamilton	n/a(0)	12	n/a
Tucker	10±7(17)	10	-5%
Beaverbank	11±1(2)	11	0%
Barrett	11±6(17)	11	0%
Duck	43±39(16)	44	2.3%
Beaver Pond	23(1)	29	**26%**
Kinsac	12±8(17)	14	16%

Notes:
1. Average concentration ± standard deviation (number of samples)
2. %Difference = [(Scenario 1 – Measured) / Scenario 1] x 100
Bolded values indicate modeled values differing greater than 20% from average value.
To the extent possible, the lakes on this table are ordered from upstream to downstream and from south to north.

Figure 28 shows the relative distribution of the TP inputs within each sub-subwatershed. The relative importance of loadings from the land use, development[7] and upstream lakes is evident. Phosphorus loading to Cranberry (south), Loon, Fish, Springfield, First, Beaver Pond, Charles and Soldier is dominated by surface runoff, indicating that these lakes that occur in the upstream portions of the subwatersheds are most affected by land use changes in their subwatersheds. Phosphorus loads in Kinsac, Thomas, Fletcher, Grand, Banook, Fenerty, Miller and Hamilton lakes are controlled by inputs from upstream lakes. Changes in upstream catchments (either by land use changes or "development") will have the most effect on phosphorus concentrations of these lakes. Tucker, Barrett, Duck, Lewis, Third and Lisle are dominated by "development" phosphorus loadings. Development represents loadings of phosphorus from septic systems and point sources. For the Shubenacadie Lakes subwatershed, all point sources loadings are from waste water treatment plant (WWTP) effluent discharges. Loading to Micmac is shared evenly between upstream lakes and surface runoff. Loading to Second Lake is divided equally between surface runoff and input from septic systems.

[7] *Development refers to septic system and point source inputs (e.g. wastewater treatment plant effluent)*

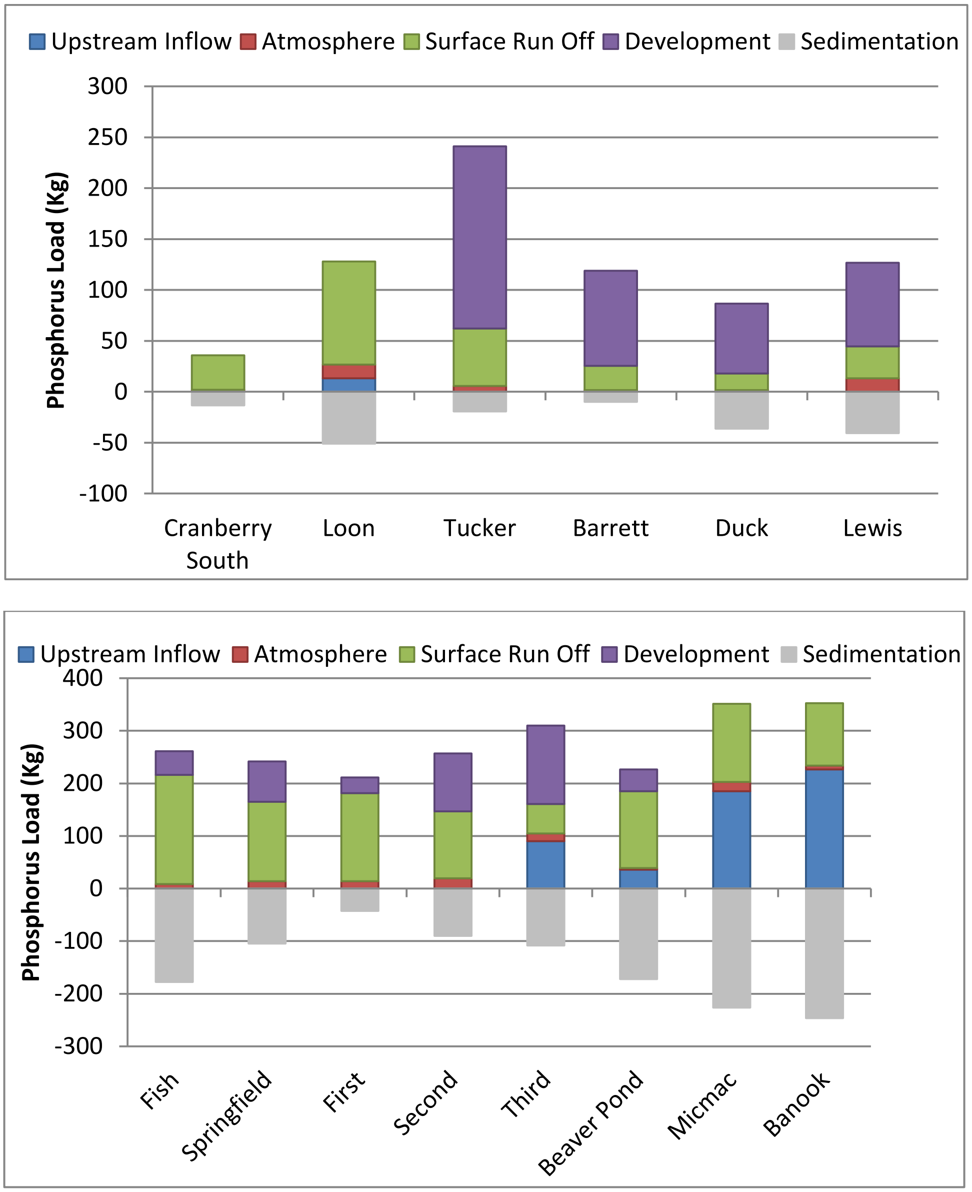
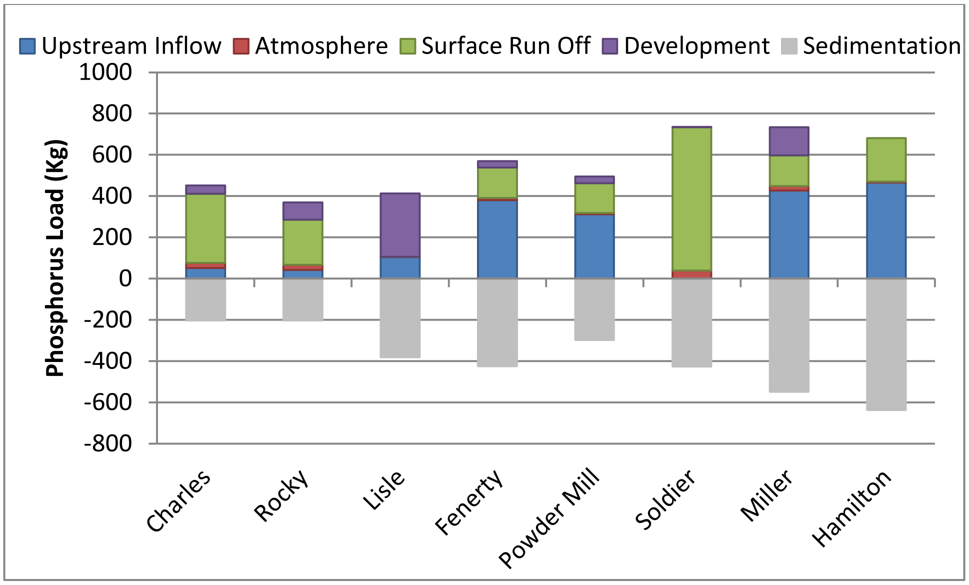
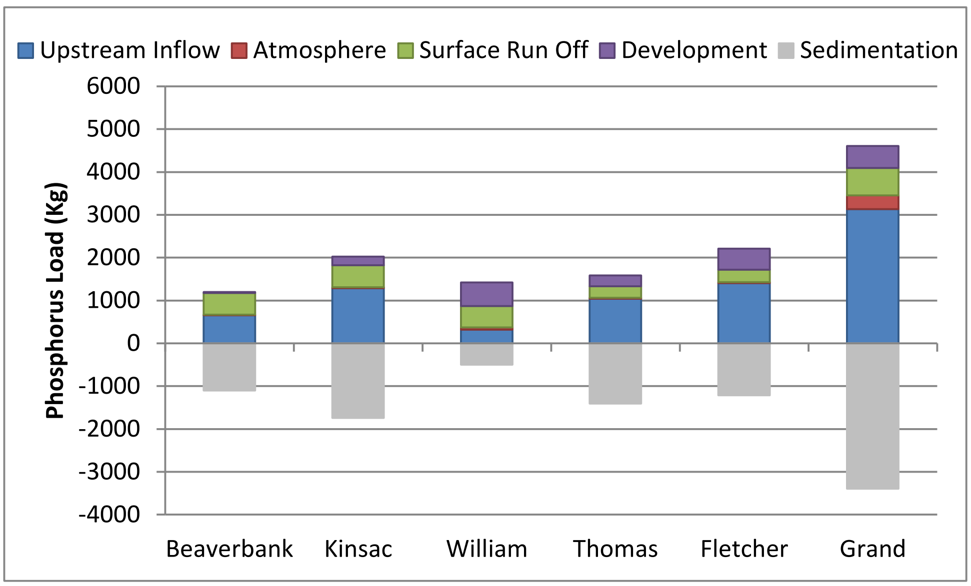


Figure 28. Phosphorus Inputs and Loadings (Kg) to Lakes in the Shubenacadie Subwatershed under Modeling Scenario 1: Existing Conditions





Note: "Development" inputs refers to septic systems and point source loadings

Figure 29. Phosphorus Inputs and Loadings (Kg) to Lakes in the Shubenacadie Subwatershed under Modeling Scenario 1: Existing Conditions

Modeling Scenario 2: HRM Authorized Subdivision Agreements

This modeling scenario represents the build out of all current HRM authorized subdivision agreements in the Shubenacadie subwatershed. Model results following development are shown in Table 20, while a summary of the percent land use changes for each sub-subwatershed is presented in Table 21.

In this scenario the catchments of Barrett, Beaverbank, Beaver Pond, Duck, Fenerty, Fish, Fletchers, Shubenacadie Grand, Kinsac, Miller, Second, Springfield, Third, Tucker, and William lakes experience development (Table 21 Figure 25). In addition the land uses in A, Bennery, Cranberry (north), and Soldier subwatersheds also undergo changes. Most of the development occurs in and around the subwatersheds of Kinsac and Fletcher's Lakes, changing from forested areas to low residential development (Table 21). Catchments of Cranberry, Loon, Charles, Micmac, Banook, First, Rocky, Thomas, Lewis and Hamilton do not undergo changes in this scenario.

Table 20. Measured and Modeled Ice-Free Lake Total Phosphorus Concentrations (LCM)

Lake	Measured µg/L Average concentration ± standard deviation (number of samples)	Scenario 1: Existing Conditions µg/L	Scenario 2: HRM Authorised Subdivisions µg/L	Scenario 3: Scenario 2 + Fully Developed Port Wallace µg/L
Cranberry	20±13(17)	17	17	17
Loon	15±12(15)	14	14	14
Charles	10±8(21)	10	**11**	**14**
Micmac	10±12(17)	10	10	**11**
Banook	10±11(17)	10	10	**11**
First	11±10(17)	12	**12**	**12**
Rocky	16±12(17)	16	**18**	**18**
Second	12±14(16)	13	**16**	**16**
Third	10±11(17)	11	**14**	**14**
Powder Mill	10±11(17)	11	**12**	**12**
William	9±7(20)	9	**12**	**12**
Soldier	n/a(0)	11	11	11
Miller	11±4(3)	12	**13**	**13**
Thomas	11±14(32)	13	**15**	**15**
Fletcher	10±9(20)	10	**11**	**11**
Grand	8±13(19)	9	**11**	**11**
Fish	18±1(2)	14	**15**	**15**
Springfield	14±10(16)	14	**17**	**17**
Lisle	50±26(8)	51	**54**	**54**
Fenerty	22±9(16)	18	**21**	**21**
Lewis	8±2(3)	9	**12**	**12**
Hamilton	n/a(0)	12	**13**	**13**
Tucker	10±7(17)	10	**15**	**15**
Beaverbank	11±1(2)	11	**12**	**12**

Lake	Measured µg/L Average concentration ± standard deviation (number of samples)	Scenario 1: Existing Conditions µg/L	Scenario 2: HRM Authorised Subdivisions µg/L	Scenario 3: Scenario 2 + Fully Developed Port Wallace µg/L
Barrett	11±6(17)	11	**16**	**16**
Duck	43±39(16)	44	**62**	**62**
Beaver Pond	23(1)	29	**34**	**34**
Kinsac	12±8(17)	14	**16**	**16**

Note: Bolded values indicate modeled values differing for Scenario 2 from Scenario 1 or for Scenario 3 from either Scenario 1 or 2. To the extent possible, the lakes on this table are ordered from upstream to downstream and from south to north.

Under development Scenario 2, predicted phosphorus concentrations and thus trophic state in Cranberry, Loon, Micmac, Banook, First, Powder Mill and Soldier lakes are expected to remain unchanged. This is because there is little development planned in the catchments of these lakes (Table 21).

Predicted phosphorus concentrations in all other lakes will increase under this modeling scenario. For the most part, concentrations are expected to increase by 1 to 4 µg/L, with an average increase of 2 µg/L across the entire subwatershed. This modeled increase was found with both the LCM and the SWMM.

Phosphorus concentrations in Duck, Tucker and Barrett lakes are predicted to increase the most: by 19, 5 and 5 µg/L, respectively for both the LCM and 17, 7 and 4 µg/L, respectively for the SWMM under Scenario 2. The relatively low increase in phosphorus concentrations in most other lakes is due to the small scale of development in the subwatershed compared to the size of the subwatershed. Although many lakes are expected to show increases in phosphorus concentrations under Scenario 2, the magnitude is low (within confidence limits of measured concentrations); nevertheless, trophic state changes will occur due to slight increases in phosphorus concentrations for Lake William (predicted only by the LCM as the SWMM already indicated a mesotrophic state for existing conditions) and for Lewis and Grand lakes based only on the prediction of the LCM. These lakes may therefore exceed the proposed water quality objective of "no change to the trophic state" as a result of the development already authorized by HRM. The small magnitude of the phosphorus concentration increase, the natural variability of phosphorus concentrations in these lakes and the general proximity of the modeled concentrations to the trophic state boundary demonstrate the need for continued monitoring and the implementation of available measures to reduce loadings through mitigation.

With the development of the Port Wallace Lands (Scenario 3), predicted phosphorus concentrations in Charles, Micmac, and Banook lakes are modeled to increase. The increase in phosphorus concentrations in Charles (from 11 to 14 µg/L for the LCM and 11 to 13 µg/L for the SWMM) is due to the change in Port Wallace land use, while the increased concentrations in Micmac (from 10 to 12 µg/L) and Banook (from 10 to 11 µg/L) are from increased upstream loadings from Lake Charles. Phosphorus concentrations in Lake William may also increase slight (from 13 to 14 µg/L for the SWMM; no change predicted in the LCM). Although phosphorus concentrations in these lakes are expected to increase, the magnitude is very low, within the range of measured concentrations, and there is no associated change in trophic state.

Table 21. Percent (%) of Drainage Basin Area for Each Land Uses under Different Modeling Scenarios

Land Use	Commercial		Forest		Meadow		High Density Residential		Industrial		Institutional		Low Density Residential		Medium Density Residential		Open Space		Roadway		Water		Wetland		Quarry	
Subwatershed	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Charles1			58	39			14	32			1	1			2	2			12	12			4	4	10	10
Powder Mill	4	4	52	52			14	14							10	10			10	10	7	7	3	3		
William			78	76			6	6	1	1			0	2	3	3			5	5	1	1	6	6		
Second	2	2	63	59			8	8					6	10	9	9			8	8			3	3		
Third	1	1	29	21	1	0	5	5					6	14	45	45		1	11	11	1	1				
Soldier	4	4	80	79					1	1				1	1	1			3	3	2	2	9	9		
Miller	6	6	46	44			1	1					5	7	24	24			13	13	1	1	3	3		
Fletcher			45	30			8	8			2	2		15	35	35			6	6	1	1	2	2		
Grand			87	86	3	3							1	1	4	4			1	1	1	1	3	3		
Fish			65	64			2	2						1	12	12	8	0	3	3	5	5	3	3		
Fenerty			68	62	9	9								6	10	10			3	3	3	3	7	6		
Springfield			28	17	10	2	17	17						18	33	33	2	2	8	8			2	2		
Tucker			17	7			45	45						10	17	17			11	11			10	10		
Beaverbank	2	2	74	73	5	5	2	2						1	8	8			2	2	2	2	6	6		
Kinsac	6	6	64	40			5	5						24	16	16			3	3	1	1	4	4		
Lisle			29	6										23	64	64			2	2			5	5		
Barrett			43	43			26	26			4	4			15	15			11	11						
Duck			43	43			22	22							23	23			6	6			6	6		
Beaver Pond	6	6	33	33			4	4			1	1			46	46			8	8			1	1		

[1]For Charles Lake only, the land use changes are for Scenario 3 rather than Scenario 2. All other land use changes are Scenario 2 as noted.
Notes: Lakes not listed in table will have no proposed land use changes over the study period, 1. Land use for Charles represents the fully developed Port Wallace Lands: Modeling Scenario 3, denotes combined subwatersheds, see Table 1Appendix H for details, no value indicates land use not present, NA – represents instances in which the previous area was 0.*

Modeling Scenario 3: Scenario 2 plus fully developed Port Wallace Lands

This modeling scenario represents the development of Port Wallace. Model results are shown in Table 20. The percent land use change is presented in Table 21.

In this modeling scenario the catchment of Charles Lake is the only Shubenacadie subwatershed that experiences change in its land use (Table 21). In this development just under 300 ha of forest will be converted into high density residential development. The Charles subwatershed is presently serviced by sanitary sewers as well, and under the future development scenario the high residential development is assumed to be serviced.

With the development of the Port Wallace Lands, predicted phosphorus concentrations in Charles, Micmac, and Banook lakes are modeled to increase. The increase in phosphorus concentrations in Charles (from 11 to 14 µg/L for the LCM and 11 to 13 µg/L for the SWMM) is due to the change in Port Wallace land use, while the increased concentrations in Micmac (from 10 to 12 µg/L) and Banook (from 10 to 11 µg/L) are from increased upstream loadings from Lake Charles. Phosphorus concentrations in Lake William may also increase slight (from 13 to 14 µg/L for the SWMM; no change predicted in the LCM). Although phosphorus concentrations in these lakes are expected to increase, the magnitude is very low, within the range of measured concentrations, and there is no associated change in trophic state.

5.3 Stormwater Management Model (SWMM) – 1-Dimensional Dynamic

The hydrologic and hydraulic subwatershed models were developed using the USEPA's StormWater Management Model (SWMM). The SWMM is capable of modeling open channel watercourses, piped collection systems, surface storage, overland flow routes, and pond control structures, water quality pollutant loading and particulate settling. In this study, the latest version (SWMM5, Build 5.0.022, released April 2011) was used to simulate the stormwater runoff response under existing and proposed land use conditions and to analyze the changes that the subwatershed will realize with development.

The *hydrologic* module of SWMM5 is used to simulate the surface runoff and other water loss characteristics of land surfaces (i.e., evapotranspiration, infiltration, and surface storage) in response to precipitation, evaporation, and temperature. The hydrology module requires input data that describes the characteristics of local rainfall, overland flow, slope, land use, and soil properties.

The *hydraulic* module is used to simulate the conveyance, attenuation, and routing of stormwater through the natural and built environment. As noted, it is capable of representing the complex hydraulics of open channel watercourses, piped collection systems, ponds/lakes, and control structures such as pumps, orifices, and weirs.

The *water quality* module was used to simulate the generation of total suspended solids (TSS) loadings and total phosphorous (TP) from each sub-subwatershed. This processes included pollutant buildup during dry weather periods and washoff during rainfall events. The TSS and TP concentrations were subsequently routed through the rivers and the deposition of particulate solids in the lakes was simulated.

The base development case for this model was assumed to have no stormwater management facilities to control water quantity and quality because this is a necessary starting point to evaluate the potential impacts of development. Since the Lake Capacity Model also does not consider stormwater management to reduce nutrient inputs, this base case is necessary for comparison of results between the two models. Once the base case response is understood, subsequent model results can incorporate varying stormwater management efficiencies to assess different mitigation measures and lake sensitivities. In this report, Scenario 3 stormwater management model results (described below) show water quality impacts from developments that have used advanced stormwater management methods to reduce phosphorus and suspended solids concentrations entering natural watercourses.

Similarly to the LCM, the results are presented for four modeling scenarios:

1. Modeling Scenario 1: Existing Conditions;
2. Modeling Scenario 2: HRM Authorized Subdivision Agreements; and,
3. Modeling Scenario 3: Scenario 2 plus fully developed Port Wallace Lands.

Given that the HRM authorized subdivision agreements involve low density residential developments, stormwater management (SWM) was not incorporated into Modeling Scenario 2. Modeling Scenario 3 however consists of higher density development that would warrant the use of stormwater management to control runoff.
In this study, a spreadsheet-based model was used to estimate the treatment performance of typical “advanced” SWM facilities in order to assess the effect that these facilities would have on water quality at the sub-subwatershed scale. The long-term treatment performance and pollutant removal rates of SWM facilities have been extensively studied and documented by Winer (2000). The HRM Stormwater Management Guidelines (Dillon Consulting Limited 2006) give the removal rates for a wet pond of 80% or higher for TSS and 50% TP. These removal rates were applied to the modeled data to quantify the potential treatment efficiency of the SWM facilities with respect to TSS and TP. These removal rates are optimal and have been used here as an indication of what may be achieved through the rigorous application of stormwater management measures.

Details of model development and input parameters are included in Appendix J.

New development applications in the subwatershed should incorporate the measures detailed within HRM’s Stormwater Management Guidelines to reduce or eliminate the impacts to water quality and quantity that may occur as a result of development. The benefit of these measures can be evaluated by using the SWMM to compare existing conditions to post-development conditions on a development-specific basis. Such an evaluation will allow greater precision than the analysis conducted at the subwatershed level for this report.

5.3.1 Flow from Lake Charles

As noted above, Lake Charles is the headwater lake of the Shubenacadie Lakes subwatershed 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, Shubenacadie Canal Commission). The remaining 40% of the discharge from Lake Charles flows south to Lakes Micmac and Banook and ultimately to Dartmouth Cove in Halifax Harbour.

The SWMM permitted an assessment of this reported distribution of flow. AECOM was unable to survey the cross sections and their respective elevations due to the depth of the water; however, the lock structures downstream and their elevations were surveyed and these were used in the model along with other surveyed points. Both outlets have been assumed to have been created with similar outlet configurations. Based on this, the SWMM model assessed total cumulative flows from each outlet during storm events. The modeling showed that the outlet to Micmac and Banook lakes conveyed approximately 90% of the flow while the outlet to Lake William conveyed the remaining 10% of the flow. Due to safety considerations field measurements could not be taken to verify the model results. From a hydraulic perspective, the modeling results are reasonable, given the water levels and elevations of the lakes downstream in the Shubenacadie system, whereas the flows to the Bedford basin would reach sea level over a much shorter distance with the same vertical drop. These results should be confirmed though field assessment.

5.3.2 Development Effects on Water Quality – SWMM Model Results

The modeling predicts total suspended sediment (TSS) concentrations which are directly related to the TP concentrations and loadings of TP to each lake in the subwatershed. SWMM is able to generate continuous time series of water quality results as opposed to examining the overall loading on an annual basis (steady state). Determination of sediment loadings generation is based on land use. The amount of sediment that enters the watercourses is a factor of both the landuse and the hydrology for each subcatchment. The changes in landuse due to development are presented in Table 22.

The water quality modeling assessment was used (based on time series for an “average” year of precipitation, 1452.2 mm, Canadian Climate Normals presented in Table 1) to determine average annual pollutant concentrations in the lakes. Removal of sediment and nutrients from river systems is assumed to be negligible in comparison to the removal through sedimentation in lakes. The modeled time series of TP and TSS concentrations for the “average” year was then used to calculate the average annual concentrations.

Many lakes in the Shubenacadie subwatershed are also impacted by inputs of phosphorus from septic systems and waste water treatment plant discharges. In some lakes, the TP inputs from septic systems will account for a significant portion of the TP load. Numerical TP results from the “Development” load were extrapolated from the LCM model and incorporated into the SWMM results. This method assumes that septic inputs are not routed to downstream lakes, and consequently, the TP load to downstream lakes is likely under-estimated where a significant septic input is present in the upstream lakes. The details regarding the TSS and TP concentration calculations are presented in Appendices H and I.

The SWMM model was also not used to model lakes Micmac and Banook. These lakes are fully developed and so no additional land use changes are expected in their subwatersheds. The Port Wallace Lands development will however impact on Charles Lake and this will have an indirect future impact on Micmac and Banook Lakes. Based on this, it was determined that the LCM model would be appropriate to assess the water quality impacts of the upstream development on these lakes with the recommendation that, should stormwater management within the lake subwatersheds be considered at some time in the future, the benefit of storm water management mitigation could be specifically assessed for these two important recreational lakes using the SWM model at a lake subwatershed scale as opposed to this regional scale model.

Table 22. Percent Changes in Land Use for Subwatersheds

	Forest	Grass	Meadow	Bare	Bedrock	Regular Roof	Impermeable Pavement	Gravel	Wetland	Water
	A: Change in Land use from Scenario 1 to Scenario 2									
Barrett, Charles, Cranberry, Duck, First, Lewis, Loon, Powder Mill, Rocky and Thomas Lakes	No change									
Beaverbank Lake	-0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Beaver Pond	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fenerty Lake	-1.5%	1.2%	-0.3%	0.0%	0.0%	0.3%	0.3%	0.0%	0.0%	0.0%
Fish Lake	-0.1%	-0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fletcher Lake	-4.3%	2.8%	0.0%	0.0%	0.0%	0.6%	0.6%	0.0%	0.3%	0.0%
Grand Lake	-0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Kinsac Lake	-6.6%	4.3%	0.1%	0.0%	0.0%	1.1%	1.1%	0.0%	0.0%	0.0%
Lake William	-0.4%	0.3%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%
Lisle Lake	-4.5%	3.0%	0.0%	0.0%	0.0%	0.7%	0.7%	0.0%	0.1%	0.0%
Miller Lake	-0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Second Lake	-1.0%	0.6%	0.1%	0.0%	0.0%	0.2%	0.2%	0.0%	0.0%	0.0%
Springfield Lake	-0.7%	1.4%	-2.3%	0.0%	0.0%	0.8%	0.7%	0.0%	0.0%	0.0%
Third Lake	-1.4%	0.4%	0.5%	0.0%	0.0%	0.3%	0.2%	0.0%	0.0%	0.0%
Tucker Lake	-2.4%	1.7%	0.0%	0.0%	0.0%	0.4%	0.4%	0.0%	0.0%	0.0%
	B: Change in Land use from Scenario 2 to Scenario 3 (Only Charles Lake is affected by the change in Scenario 3)									
Charles Lake	-17.5%	6.8%	0.0%	0.0%	0.0%	6.8%	3.9%	0.0%	0.0%	0.0%

Total Phosphorus – SWMM Results

The TP concentrations following a typical storm event over a 10 day period are presented in Figure 29. This figure illustrates the effect of a storm event on TP concentrations as the water and associated sediment load move through the subwatershed. The analysis focused on lakes that were expected to experience changes as a result of development in their catchment or upstream of their catchment. Due to the lagged response time for Grand Lake, a period of 29 days is presented to capture the flow of TP though the system for a larger storm event. Also shown on these figures is the anticipated time series change in water level depth as a result of the typically storm. Figure 29 shows short term increases of TP in Charles Lake under the Scenario 3 development, compared to Scenario 1 and 2. Lakes William and Thomas are not expected to be significantly impacted. Fletchers and Kinsac lakes generally have increases in peak loadings, under Scenario 2 compared to existing. Grand Lake shows sustained high TP concentrations under Scenarios 2 and 3. The high residence time of TP in Grand Lake may have a greater impact on trophic state of this lake than the short term peak expected in most other lakes and thus Grand Lake monitoring should watch this carefully.

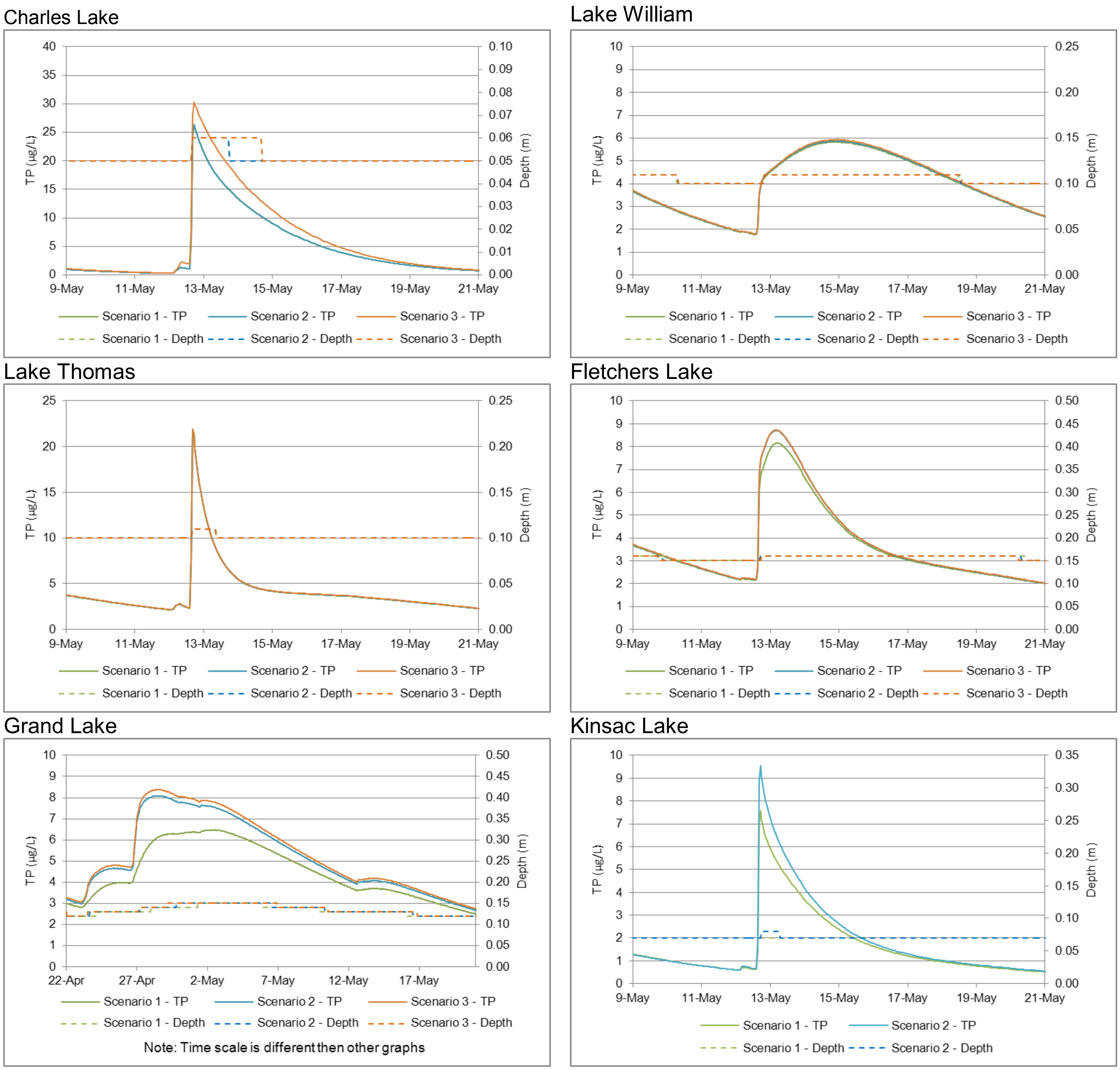


Figure 30. TP Concentration and Water Depth Plots Under All Development Scenarios at Charles, William, Thomas, Fletchers, Grand and Kinsac Lakes for a Typical Storm Event

Total Phosphorus – Modeling Scenario 1: Existing Conditions

The modeled TP concentrations for each lake under the existing conditions (Scenario 1) are presented in Table 23. In general, there is good agreement between measured and predicted lake phosphorus concentrations. The majority of the lakes were within 20% of the field measurements. Modeled phosphorus concentrations for Beaverbank and Beaver Pond, although outside of their measured concentrations by 20%, were considered reasonable estimates of phosphorus concentrations for these lakes due to the low sample sizes (two and one samples respectively). Fenerty and Kinsac are both underestimated, likely due to the fact that the modeling didn't account for septic inputs from the upstream lakes. Tucker, Rocky, Powder Mill and William lakes are all overestimated by the SWMM model, compared to measured concentrations. The land uses within the Rocky Lake subwatershed include quarry as well as commercial and industrial development and the modeling did not account for any stormwater management that may have been present. Powder Mill Lake may also have stormwater management facilities that have not been factored in to this calculation. This may result in the model overestimating the TP. On the other hand, all four of these lakes have a large number of septic systems which were not factored in here (Rocky = 147, Powder Mill = 58, William = 882 and Tucker = 316). Thus the cause of these over-estimates is not clear at this time. The overestimate in Rocky Lake may also contribute to the higher concentration in Lake William. All other lakes were within 20% of their field measurements (a general guideline of model validity).

Table 23. Measured versus Modeled Total Phosphorus Concentrations (µg/L)

Lake	**Measured** Average concentration ± standard deviation (number of samples)	**Scenario 1: Existing Conditions**	**Difference**
Cranberry	20±13(17)	24	19%
Loon	15±12(15)	15	-3%
Charles	10±8(21)	10	3%
First	11±10(17)	10	-9%
Rocky	16±12(17)	**24**	**53%**
Second	12±14(16)	12	-2%
Third	10±11(17)	11	12%
Powder Mill	10±11(17)	**18**	**80%**
William	9±7(20)	**12**	**32%**
Soldier	n/a	5	
Miller	11±4(3)	10	-7%
Thomas	11±14(32)	11	-2%
Fletcher	10±9(20)	10	-4%
Grand	8±13(19)	7	-18%
Fish	18±1(2)	17	-7%
Springfield	14±10(16)	14	1%
Lisle	50±26(8)	44	-12%
Fenerty	22±9(16)	**7**	**-68%**
Lewis	8±2(3)	7	-14%
Hamilton	n/a	3	

Lake	**Measured** Average concentration ± standard deviation (number of samples)	Scenario 1: Existing Conditions	Difference
Tucker	10±7(17)	**12**	**24%**
Beaverbank	11±1(2)	**5**	**-58%**
Barrett	11±6(17)	10	-6%
Duck	43±39(16)	42	-1%
Beaver Pond	23(1)	**11**	**-54%**
Kinsac	12±8(17)	**6**	**-47%**

Note: Bolded values indicate modeled values differing greater than 20% from measured values

Modeling Scenario 2: HRM Authorized Subdivision Agreements

This modeling scenario represents the build out of all HRM authorized subdivision agreements in the Shubenacadie subwatershed. Model results following development are shown in Table 24, while a summary of the percent land use changes for each sub-subwatershed is presented in Table 22.

In this scenario the catchments of Barrett, Beaverbank, Beaver Pond, Duck, Fenerty, Fish, Fletchers, Grand, Kinsac, Miller, Second, Springfield, Third, Tucker, and William lakes experience development (Table 22, Figure 25). In addition, changes in land uses occur between Scenario 1 and Scenario 2 for Bennery, Cranberry (north), and Soldier subwatersheds but most of the development occurs in and around the subwatersheds of Kinsac and Fletchers Lakes, changing from forested areas to low residential development (Table 24). Catchments of Cranberry (south), Loon, Charles, First, Rocky, Thomas, Lewis and Hamilton do not undergo changes in this scenario.

Table 24. Measured and Modeled Ice Free Mean Lake TP Concentrations (SWMM)

Lake	Measured µg/L Average concentration ± standard deviation (number of samples)	Scenario 1: Existing Conditions µg/L	Scenario 2: HRM Authorized Subdivisions µg/L	Scenario 3: Scenario 2 + Fully Developed Port Wallace µg/L
Cranberry (south)	20±13(17)	24	24	24
Loon	15±12(15)	15	15	15
Charles	10±8(21)	10	**11**	**13**
First	11±10(10)	10	**11**	**11**
Rocky	16±12(17)	24	**26**	**26**
Second	12±14(16)	12	**15**	**15**
Third	10±11(17)	11	**14**	**14**
Powder Mill	10±11(17)	18	**20**	**20**
William	9±7(20)	12	**13**	**14**
Soldier	n/a	5	5	5
Miller	11±4(3)	10	**11**	**11**
Thomas	11±14(32)	11	**12**	**12**
Fletcher	10±9(20)	10	10	10

Lake	Measured µg/L Average concentration ± standard deviation (number of samples)	Scenario 1: Existing Conditions µg/L	Scenario 2: HRM Authorized Subdivisions µg/L	Scenario 3: Scenario 2 + Fully Developed Port Wallace µg/L
Grand	8±13(19)	7	**8**	**8**
Fish	18±1(2)	17	**18**	**18**
Springfield	14±10(16)	14	**17**	**17**
Lisle	50±26(8)	44	**45**	**45**
Fenerty	22±9(16)	7	**9**	**9**
Lewis	8±2(3)	7	**10**	**10**
Hamilton	n/a	3	3	3
Tucker	10±7(17)	12	**17**	**17**
Beaverbank	11±1(2)	5	5	5
Barrett	11±6(17)	10	**15**	**15**
Duck	43±39(16)	42	**60**	**60**
Beaver Pond	23(1)	11	**13**	**13**
Kinsac	12±8(17)	6	**8**	**8**

Note: Bolded values indicate modeled values differing for Scenario 2 from Scenario 1 or for Scenario 3 from either Scenario 1 or 2

Predicted phosphorus concentrations in Cranberry (south), Loon, Soldier, Fletcher, Hamilton and Beaverbank are expected to remain unchanged from Scenario 1 to Scenario 2. This is because there is no or limited development in or upstream of their respective catchment areas.

Increases of TP are observed in most of the lakes. The increase is typically a result from the reduction in septic system retention from 67% to 50% to account for the aging of the current septic systems (see Appendix I). Similarly to the LCM, the predicted total phosphorus concentrations in the lakes are expected to increase by 1 to 3 µg/L. Total phosphorus concentrations in Duck, Tucker and Barrett lakes are predicted to increase the most by 18, 5 and 5 µg/L respectively, due to the increased inputs from both aging septic systems and new septic systems within the subwatershed.

The increase in TP concentration as a result of changes in land use (i.e. not including the effect of septic systems) are predicted to be equal to or less than 1 µg/L with the greatest impacts as a result of land use to be experienced in Grand Lake. The lakes that experience less than 1 µg/L include Beaverbank, Beaver Pond, Fenerty, Fletcher, Hamilton, Kinsac, Lisle, Second, Springfield, Third, Tucker and William.

Although many lakes are expected to increases in phosphorus concentrations, the magnitude is low (within confidence limits of measured concentrations) and all lakes are predicted to stay within their current trophic state.

Modeling Scenario 3: Scenario 2 plus fully developed Port Wallace Lands

This modeling scenario represents the development of Port Wallace. Model results are presented in Table 24. The percent land use change is presented in Table 22.

In this modeling scenario the catchment of Charles Lake is the only Shubenacadie subwatershed that experiences change in its land use. In this development, just under 300 ha will be converted from forest into high density residential housing. The Charles Lake subwatershed is presently serviced by sanitary sewers as well, and under the future development scenario the high residential development is assumed to be fully serviced.

Predicted phosphorus concentrations in Charles and William lakes are modeled to increase by up to 2 μg/L from the Scenario 2. Although the phosphorus concentration in these lakes is expected to increase, the magnitude is low (within confidence limits of measured concentrations) and all lakes are predicted to stay within their current trophic state. As noted in the LCM model, this development will also have some impact on Lakes Micmac and Banook but these have not been modeled using the SWM model here.

Total Suspended Solids

The average annual TSS concentrations are presented in Table 25 and annual TSS mass is presented in Table 26. Where data were available, predicted concentrations for Scenario 1 were compared to the measured average TSS concentrations. There is good agreement between modeled and measured values for Second, Third, Springfield, Lisle, Lewis, Tucker, Beaverbank, Barrett, Duck, Beaver Pond and Kinsac. For the other lakes, the estimated TSS is generally higher than the measured data. This difference may be reflection of the timing of collection of water quality samples. Samples are typically collected during dry weather events or following storm events as illustrated by the low standard deviations associated with the TSS measurements. Monitoring programs do not generally capture the “first flush” or high discharge periods associated with storm events when TSS concentrations are highest.

The nature of the development modeled with Scenario 2, is low density residential throughout the subwatershed. This type of development does not significantly increase on the mean pollutant concentrations as given by Table 5-5 of the Halifax Regional Municipality Stormwater Management Guidelines (Dillon 2006). The mean TSS concentration is expected to increase from 19.0 mg/L for a forest or wetland area to 22.1 mg/L for a low density residential area. Scenario 3 however; is expected to have a more significant impact on the water quality of Lake Charles because development would result in mean TSS concentrations increasing from 19.0 mg/L for forested to 47.7 mg/L for high density residential.

The most significant impact to TSS concentrations is expected therefore to occur in Lake Charles as a result of the Scenario 3 development. Note that the model has considered the base case situation for the Port Wallace lands without stormwater management as well as with advanced stormwater management for the reduction of TSS and associated TP loadings. A minor increase in TSS may also be observed in Grand Lake as a result of the cumulative impacts of the subwatershed development.

Table 25. Modeled Ice Free and Measured Lake TSS Concentrations - SWMM (mg/L)

Lake	Measured Average TSS Concentration ± standard deviation (number of samples	Scenario 1: Existing Conditions	Scenario 2: HRM Authorized Subdivisions	Scenario 3: Scenario 2 + Fully Developed Port Wallace	Scenario 3: Scenario 2 + Fully Developed Port Wallace with SWM[1]
Cranberry	3 ± 2(16)	22	22	22	
Loon	4 ± 2(14)	14	14	14	
Charles	3 ± 2(20)	9	9	**11**	10
First	3 ± 2(16)	9	9	9	
Rocky	11 ± 33(16)	21	21	21	
Second	6 ± 11(14)	7	7	7	

Lake	Measured Average TSS Concentration ± standard deviation (number of samples	Scenario 1: Existing Conditions	Scenario 2: HRM Authorized Subdivisions	Scenario 3: Scenario 2 + Fully Developed Port Wallace	Scenario 3: Scenario 2 + Fully Developed Port Wallace with SWM[1]
Third	3 ± 2(16)	6	6	6	
Powder Mill	4 ± 6(17)	13	13	13	
William	3 ± 2(17)	8	8	8	
Soldier	n/a	5	5	5	
Miller	5(3)	8	8	8	
Thomas	3 ± 2(29)	8	8	8	
Fletcher	3 ± 2(19)	7	7	7	
Grand	3 ± 2(22)	5	**6**	6	
Fish	1(2)	14	14	14	
Springfield	5 ± 8(16)	10	10	10	
Lisle	7 ± 5(8)	8	8	8	
Fenerty	4 ± 1(16)	6	6	6	
Lewis	1(3)	1	1	1	
Hamilton	n/a	3	3	3	
Tucker	3 ± 2(17)	5	5	5	
Beaverbank	3 ± 3(4)	4	4	4	
Barrett	4 ± 3(17)	2	2	2	
Duck	7 ± 3(16)	8	8	8	
Beaver Pond	4(1)	5	5	5	
Kinsac	3 ± 2(16)	5	5	5	

[1]SWM removal rates assume an 80% reduction in TSS which has only been applied here to the Port Wallace lands development

With regard to cumulative annual loadings, the impacts of development would have the most significant impact on Grand Lake, as it is located the furthest downstream in the subwatershed. Scenario 2 would see an increase predominately in Grand Lake, with the total mass of TSS increasing by 24%. However, this absolute increase is still relatively small due to the very low average TSS concentration in Grand Lake (3 ± 2 mg TSS/L based on 22 samples). Scenario 3 results in an increased TSS load of 40% for Lake Charles. With the use of SWM techniques within the Port Wallace lands the increase of TSS may be reduced by 80% depending on the facility performance for an absolute load of approximately 197,072 Kg/year compared to the existing estimated load of 182,474 Kg/yr.

Table 26. Modeled TSS Mass - SWMM (Kg/yr)

Lake	Scenario 1: Existing Conditions	Scenario 2: HRM Authorized Subdivisions (% increase over Existing Conditions)		Scenario 3: Scenario 2 + Fully Developed Port Wallace (% increase over Scenario 2) (without SWM)	
	Kg/Year	Kg/Year	%	Kg/Year	%
Cranberry (south)	32317	32317	0%	32,317	0%
Loon	64643	64643	0%	64,643	0%
Charles	182474	182474	0%	255,205	**40%**
First	178627	178627	0%	178,627	0%
Rocky	285634	285657	0%	285,657	0%
Second	70848	72705	**3%**	72,705	0%
Third	75511	78221	**4%**	78,221	0%
Powder Mill	310282	312402	**1%**	312,402	**0%**
William	313440	316476	**1%**	319,808	**1%**
Soldier	36719	36784	0%	36,784	0%
Miller	65551	66114	**1%**	66,114	0%
Thomas	373267	375576	**1%**	377,826	**1%**
Fletcher	384945	402275	**5%**	404,258	0%
Grand	575029	712445	**24%**	736,887	**3%**
Fish	53837	53927	0%	53,927	0%
Springfield	79202	85073	**7%**	85,073	0%
Lisle	109099	117681	**8%**	117,681	0%
Fenerty	68724	74232	**8%**	74,232	0%
Lewis	3609	3609	0%	3,609	0%
Hamilton	37941	40383	**6%**	40,383	0%
Tucker	55925	57516	**3%**	57,516	0%
Beaverbank	108100	111178	**3%**	111,482	0%
Barrett	18621	18619	0%	18,619	0%
Duck	10152	10151	0%	10,151	0%
Beaver Pond	41867	42607	**2%**	42,607	0%
Kinsac	240687	272771	**13%**	272,771	0%

5.4 Summary of Development Impacts on Predicted Lake Trophic State

The potential effect of subwatershed development on the trophic state of lakes within the Shubenacadie subwatershed was determined using the in-lake concentrations predicted by both the modified LCM and the SWMM for each of the three development scenarios. For each model and model scenario, the predicted ice-free total phosphorus concentration for each lake is summarized as a trophic state (Table 27) based on the TP concentrations in Table 17. The change between current conditions and three future development scenarios is illustrated for the two nutrient input models. Only the cases where the models disagree have been differentiated. These differences can be explained by the way in which the models respond to different land characteristics and/or the impact of changing land uses and the associated effect of septic systems on lake trophic state. In general, trophic state is only predicted to increase in either of the models as a result of the scenarios for Cranberry, Rocky, Grand and Lewis Lakes.

Table 27. Predicted Trophic States using Modified LCM and SWMM

Lake	Measured	Scenario 1: Existing Conditions		Scenario 2: HRM Authorised Subdivisions		Scenario 3: Scenario 2 + Fully Developed Port Wallace	
		LCM	SWMM	LCM	SWMM	LCM	SWMM
Cranberry	mesotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic
Loon, Charles, First, Second, Third, Miller, Thomas, Fletcher, Fish, Springfield, Tucker, Barrett, Powder Mill	mesotrophic	mesotrophic		mesotrophic		mesotrophic	
William	oligotrophic	oligotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic
Micmac, Banook	mesotrophic	mesotrophic	n/a	mesotrophic	n/a	mesotrophic	n/a
Rocky	mesotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic
Soldier	n/a	mesotrophic	oligotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic
Grand	oligotrophic	oligotrophic	oligotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic
Lisle, Duck	eutrophic	eutrophic	eutrophic	eutrophic	eutrophic	eutrophic	eutrophic
Fenerty	mesotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic
Lewis	oligotrophic	oligotrophic	oligotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic
Hamilton	n/a	mesotrophic	oligotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic
Beaverbank	mesotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic
Beaver Pond	mesotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic	mesotrophic
Kinsac	mesotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic	mesotrophic	oligotrophic

Note: To the extent possible the lakes in this table are generally ordered from south to north and upstream to downstream.

6 Recommendations for Water Quality and Quantity Monitoring

The recent report prepared for HRM titled “Water Quality Monitoring Functional Plan” (Stantec 2009) considers at some length where monitoring has come from within the Halifax Region and provides extensive discussion on this current situation, undertakes a review of best practices and provides a rationale for a water quality monitoring program development including program costs and funding sources, data management and community engagement and education. This report provides an excellent context for recommending a water quality and quantity monitoring plan for the Shubenacadie Lake subwatershed.

The Water Quality Monitoring Functional Plan identifies Tier I waterbodies as “High Vulnerability” while Tier II signifies “Moderate Vulnerability”. A risk characterization process was designed to assign vulnerability rankings to subwatersheds as a function of landscape and hydrologic parameters that could be readily generated from existing databases. For the Shubenacadie subwatershed, the Stantec (2009) report recommended that Loon, Charles, Banook, Micmac and Fletcher Lakes be sampled as Tier I high priority lakes. Other lakes also recommended as Tier 1 lakes included Cranberry, First, Thomas, Miller, Powder Mill, Rocky, Second and Third. All other lakes in the subwatershed (Barrett, Beaver Pond, Beaverbank, Fenerty, Kinsac, Lisle, Springfield, Tucker and Grand) were considered Tier 2 lakes. Further, Tier I sampling locations were to have in-lake sampling programs consisting of monthly collections during the ice free season (April – December) and at least one sample during the winter season. Tier II sampling locations are to be sampled quarterly following the seasonal thermal regime of temperate lakes (spring turnover, peak summer stratification, fall turnover and peak winter stratification. Various groups of parameters were proposed for various sampling times with Group 1 analysis[8] being undertaken at each sampling event. The report also indicated that a sampling station is to be established at the deepest part of the lake basin.

No “Flowing Water Systems” sample sites were recommended for monitoring within the Shubenacadie subwatershed in Stantec (2009).

6.1 Summary of Lake Data Used in this Assessment

AECOM did not analyse all available water quality data for the Shubenacadie subwatershed, rather, the focus was on existing conditions and consequently only water quality data from 2006 to 2011 were considered. 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 subwatershed. 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.

[8] *Group 1 analysis included: pH, conductivity, temperature profile, dissolved oxygen profile, Secchi depth, air temp., cloud cover, ice depth, time, total phosphorus (low detection limit), Chlorophyll α, E. coli.* Turbidity, colour.

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 aggregated to increase sample size and to facilitate data interpretation. This was achieved by pooling total phosphorus analytical results for multiple sampling locations within the same lake if differences in analytical results between the locations were not statistically significant. 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 the data were 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 indicated that the total phosphorus results for individual sampling locations within Lakes Charles, Fletchers, Grand, Kinsac and Thomas Lakes are not statistically different. This analysis was only applied to the TP data, however it is assume to also be applicable to the other water quality parameters used for setting water quality objectives in order to have a common statistical approach for TSS, ammonia, nitrate, chloride and *E. coli* data. While this analysis was undertaken for setting water quality objectives, it is also instructive for the development of the recommended sampling program, specifically that multiple sites within lakes are not necessarily required to describe lake water quality.

In order to address the absence of concurrent flow measurements within the Shubenacadie subwatershed, AECOM undertook monthly flow measurements at four locations to evaluate the hydrology and hydraulics within the subwatershed. Flow was monitored at three locations:

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

Attempts were made to measure flow at the outlet of Grand Lake on four occasions but high current conditions prevented the collection of accurate data.

6.2 Recommended Sampling Program for Shubenacadie Subwatershed

6.2.1 Water Quality and Quantity

Based on our analysis we recommend an expanded but simplified water quality monitoring program for HRM's consideration. We believe this program addresses the fundamentals of subwatershed management while providing a cost-effective alternative to the sampling proposed for this study area under the Water Quality Monitoring Functional Plan (Stantec, 2009). This approach is based on some simple but essential elements of monitoring that will provide, in time, an effective assessment tool for the basic management of the water quality of the subwatershed. These elements include but may not be limited to:

- Complete standardization of sampling and analysis with respect to:
    - Single agency responsible for collection of all samples – actual sampling may be contracted under the direct control of the single agency;
    - Location of sample collection – a single sample site per lake preferably at the outlet and in association with flow measurements (significantly reduces costs);
    - Frequency – minimum of 3 samples per year – spring, summer and fall (winter samples are nice but ice and flow conditions often make these difficult and unsafe to obtain);
    - Timing – minimum of 72 hours after significant rainfall event (e.g. 10 mm in 24 hours) – this should help avoid some of the high concentrations observed that can be attributed to rainfall events;
    - Field Techniques – location, field parameters and methods should all be standardized;
    - Analytical techniques –consistent with respect to parameters requested, methods used for analysis and analytical detection limits (e.g. low detection limit methods for TP). This is achievable only though a single source management of sampling, analysis and data storage;
- Storage of data in a secure searchable database;
- Consistent and routine data verification and validation;
- Verification and validation of all historical data as feasible;
- Inclusion of detection limits along with actual data; and,
- Integration of data results periodically by updating of water quality models.

The sampling program outlined below will not provide the scientific information necessary to fully understand lake processes and lakes ecosystems but is the "bare bones" requirement for water quality assessment and management. The Water Quality Monitoring Functional Plan (Stantec, 2009) was intended to develop a water quality monitoring program that considered the background context and known pressures on water quality in HRM (e.g., development, acid rock, land use, combined stormwater and sewer systems). This Plan was used to develop a long-term water quality monitoring program at a regional scale, in addition to development-specific monitoring requirements. The more focused program proposed here is not as robust as that presented in Stantec 2009 but is less expensive and meets, in our opinion, the minimum program necessary to manage and protect these lakes. This basic program is outlined in Table 23. We present these in three priorities.

In addition to the proposed monitoring program, we recommend further investigation of two lakes in the subwatershed, specifically Duck and Lisle. These lakes currently have high TP concentrations (Duck Lake = 43 µg TP/L and Lisle Lake = 50 µg TP/L). Duck Lake is expected to exhibit increased TP concentrations in the future due to planned development around the lake. Duck Lake is reported to have received sewage in the past from the Woodbine Trailer Park. Although we believe that this is no longer occurring, the accumulated TP in the sediments of this small (surface area of 9 ha) and shallow (maximum depth of 3 m) lake may be contributing to prolonging the eutrophic conditions in the lake.

Lisle is a small lake (5 ha surface area) that receives the effluent from a waste water treatment plant which loads almost 300 Kg TP per year. This loading is likely responsible for highly eutrophic state of Lisle Lake. Lisle Lake simply lacks the assimilative capacity to handle these loadings and ideally the effluent discharge should be re-located. Even after the phosphorus load is reduced, it is possible that Lisle Lake will not recover without further mitigation due to accumulation of phosphorus in the sediments which may continue to re-circulate for many years. Additional investigation will help identify mitigation requirements over and above removal of the waste water treatment plant discharge.

Table 28. Minimum Water Sampling Program Recommended for Birch Cove Lakes Subwatershed

Lake	General Location	Access	Sample Timing	Other
Highest Priority				
A Lake (Fall River)	Outflow from lake	shore	Spring, summer, fall	No water quality data currently, shoreline developed with more development planned for subwatershed
Beaver Pond	Outflow from lake	shore	Spring, summer, fall	Only one water quality sample to date showing lake is eutrophic with further development planned in subwatershed
Rocky Lake	Outflow from lake	shore	Spring, summer, fall	Existing conditions indicate mesotrophic with some effect from development
Second Lake	Outflow from lake	shore	Spring, summer, fall	Existing conditions indicate mesotrophic with some effect from development, local industry may also be a concern
Fenerty Lake	Outflow from lake	shore	Spring, summer, fall	Existing conditions indicate mesotrophic with some effect from development
Grand Lake	Outflow from lake	shore	Spring, summer, fall	Routine monitoring, co-locate quality and quantity stations with level and temperature loggers, lake is too large to allow deterioration so early warning is essential
Second Priority				
Charles, Kinsac, Fletchers Lakes	Outflow from lake	shore	summer	Future pressure due to ongoing development, co-locate quality and quantity stations with level and temperature loggers
Third Priority				
Barret, Beaverbank, Loon, Cranberry South, First, Fish, William, Powder Mill, Springfield, Third, Tucker, Thomas, Lewis Lakes	Outflow from lake	shore	summer	Routine monitoring to evaluate lake trophic state and other water quality objectives
Banook, Micmac Lakes	Mid-lake sampling	boat	summer	Routine monitoring to evaluate lake trophic state and other water quality objectives
Miller Lake	Outflow from lake	shore	summer	Routine monitoring with a special investigation of high ammonia concentrations to identify sources

At each station, water samples should be collected and analysed at a minimum for: total phosphorus (low level), total suspended solids (low level), chloride and chlorophyll α. In field measurements of pH, conductivity, temperature, dissolved oxygen, and air temperature should also be collected.

For establishing baseline conditions and evaluating the effects of specific developments on lake water quality, additional monitoring is required. However, that is not the purpose of this monitoring program, and should be considered complimentary to the program outlined here.

Integral to the water quality program and the modeling is the inclusion of further development of the calibration curves for measuring flow and predicting the effect of development on these flows. We strongly recommend the maintenance of the five flow monitoring sites within the subwatershed throughout the duration of the development as this information will be essential to verifying the model and adapting it to actual measurements which will be necessary to protect the lakes through adaptive environmental management practices including confirming the need for additional mitigation.

7 Summary of Policy E-17 Objectives

A complementary objective of the study is to provide a number of guidelines and recommendations for the planning, design and implementation of new developments that will help mitigate the water quality impacts from further development. More specifically, the objectives of subwatershed study are listed in Policy E-17 of the Regional Plan. Each sub-heading of Policy E-17 listed below with a reference to where the item is addressed within the report, or if the sub-heading is not addressed directly in the report, it is addressed below.

a) Recommend measures to protect and manage quantity and quality of groundwater resources.

Please see section 2.2 Geology and Hydrogeology and Appendix A Water Budget.

Based on the results of the water budget modelling for the existing conditions scenario, and consideration of future potential development areas in the subwatershed, changes in land uses in the Shubenacadie Lakes subwatershed are not expected to significantly affect the groundwater flow regime within the subwatershed. This is because most of the subwatershed is underlain by low permeability bedrock, which does not permit significant infiltration or "recharge" of the regional groundwater table. Groundwater recharge represents a relatively small proportion of the total water budget for the subwatershed. Of the surplus water calculated for the subwatershed, approximately 10% of total precipitation will infiltrate into the ground as recharge while the remaining 90% will become runoff. Future development will be supplied with municipal potable water rather than using groundwater supplies.

b) Recommend water quality objectives for key receiving watercourses in the subwatershed.

Water quality objectives are established in section 4.4 Recommended Water Quality Objectives for Shubenacadie Lakes Subwatershed for nitrate, un-ionized ammonia, total suspended solids, chloride and *E. coli.* These were selected as key water quality indicators that will be impacted by urbanization. Early warning alert values and the method by which the objective or the alert were to be calculated were also determined. Section 4.6 Development of Total Phosphorus Water Quality Objectives for Shubenacadie Lakes Subwatershed developed TP objectives for each lake based on maintaining the current lake trophic state as measured by TP concentrations. The objective, an early warning alert value and the method of determining each was provided.

c) 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 subwatershed.

It is very difficult to provide a single expression of the amount of development or nutrient inputs that a lake can assimilate before the water quality objectives are exceeded. This is because of the inter-connectedness of the subwatershed and because the range of nutrient delivery that is derived from different development types (that is, different land uses). With respect to the inter-connectedness, using the available capacity on an upstream lake will also use some portion of capacity on all downstream lakes. Alternatively, using available capacity on a downstream lake could easily eliminate or preclude the capacity on an upstream lake. With respect to the effect of different types of development, for example, the phosphorus export coefficient used in the LCM in this study ranges from 130 g/ha/yr to 2020 g/ha/yr for low density residential and commercial or industrial land uses, respectively. Thus the type of development must also be known. In addition, municipal policy requires that stormwater management plans, designed to manage both runoff water quality and quantity are submitted in support of applications for development agreement. These stormwater management plans use various combinations of best management practices and engineered facilities to manage runoff and each of these practices and installations have different efficiencies and effects on water quality.

With this variability in mind, the effects of the different development scenarios modeled for this study are described in section 5.4 Summary of Development Impacts on Predicted Trophic State. The results of Scenario 2 (HRM Authorized Developments) indicate that water quality objectives will be exceeded (defined as a transition to a more nutrient rich trophic status) in Cranberry South, Rocky and Grand Lakes. When development within the Port Wallace Lands are added (Scenario 3) there is an increase in TP loadings to some of the affected lakes but no predicted change in trophic state for any of the lakes. The implementation of advanced storm water management in the Port Wallace lands should reduce the impact of this development significantly.

One of the most significant impacts on lake water quality is the presence of septic systems. Clearly, it is not practical or cost effective to replace all exisiting septic systems with municipal services. At the same time, existing systems are not contravening existing municipal or provincial regulation. However, the relative cost and practicality of providing alternatives for septic systems, such as advanced communal treatment systems or partial sanitary sewer connections, should be considered as part of an overall effort to protect water quality in these lakes. Other options such as regularly mandated system pumpings and inspectons have been used in other jurisdictions[9] and may be considered by HRM.

d) Determine the parameters to be attained or retained to achieve marine water quality objectives

The Shubenacadie Lakes subwatershed does not have a marine component, as do other subwatersheds that include a marine estuary. Due to the very good quality of Grand Lake and the stringent water quality objectives set for this lake, existing and future inputs from the Shubenacadie Lakes subwatershed to the Minas Basin and Dartmouth Cove will not have a measureable effect on marine water quality.

e) Identify sources of contamination within the subwatershed

Sources of pollution within the Shubenacadie Lakes subwatershed are described in Vaughan (1993) and Jacques Whitford (2009) and are presented briefly in section 1.4.1. These sources include:

Roads and highways. Snow removed during winter plowing contains contaminants (particulate matter, oil and grease, metals) that are released to surface ditches and watercourses during spring thaw. Road salt used for de-icing is highly soluble and can also negatively affect water quality.

Halifax Formation pyritic slates. Development that exposes or excavates pyrite-bearing Halifax Formation rock may generate low pH runoff that can have serious negative effects on aquatic life. Acidification can also increase the solubility of metals from lake sediments.

Mine Wastes. The historic Waverley mining area is associated with piles of mine waste which contain arsenic and mercury. These heavy metals may be transported to surface water when disturbed. Mine waste may also be present as lake sediments in Lakes Charles, William, Thomas and Fletcher (Mudroch and Clair 1985).

Industrial activity. Runoff and discharges associated with development in the AeroTech business park, quarries southwest of Lake William and east of Lake Charles, and possibly at other businesses (such as golf courses) can negatively affect surface water quality.

As described throughout the report, the primary human activity impacting water quality is changes to land use resulting from development. Development typically results in increased stormwater surface runoff and may include

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[9] See the Municipality of Chelsea, QC: By-law 460-96 “By-law Concerning the emptying of septic tanks of single-family dwellings on the Municipality of Chelsea’s territory” and By-law 680-06 “By-law establishing rates and environmental monitoring as applicable to septic systems with tertiary treatment including discharge to the environment”.

the installation of residential septic systems, both of which result in increased nutrient loading. With over 4,855 septic systems currently within 300 m of a watercourse within the Shubenacadie Lakes subwatershed, the effect of these on existing water quality could be significant in some lakes and this will be exacerbated with further development in un-serviced areas.

Development may also be associated with overflows from municipal waste water collection systems. The impact of the wastewater overflows is difficult to quantify for several reasons:

1. Overflows typically occur during extreme weather events. The timing, frequency and severity of these events are not possible to predict and so the water quality impacts from overflows cannot be quantified or modeled.

2. Halifax Water monitors the volumes and locations of overflows but does not measure the concentration of effluent released to the environment during an overflow event. Given this, it is not possible to gauge the nutrient loading that may occur during these events.

As a result, these overflows cannot be addressed within the models used for the subwatershed. We assume that reduction and ideally elimination of these overflows will be a priority within the plans for expansion of the waste water collection and treatment system within the subwatershed.

f) Identify remedial measures to improve fresh and marine water quality

Many of the upstream, non-developed portions of the subwatershed are pristine and so would not benefit from water quality improvement efforts. The clear exceptions to this are Lisle and Duck Lakes which have been affected by residential development and the nutrient loading from a sewage treatment plant and discharges from a trailer park, respectively. Alternatives to the discharge location of the sewage treatment system at Lisle Lake should be considered as this small lake lacks the capacity to handle the phosphorus loadings from this plant. Evidently, a sewage treatment plant now services the Woodbine trailer park at Duck Lake and the discharge is now downstream of the lake; however, this lake warrants further investigation to assess mitigation options to improve water quality.

The proposed developments are not predicted to further increase the trophic state of the other lakes in the subwatershed; however, phosphorus concentrations are expected to rise somewhat due largely to existing septic systems (over 4,855 septic systems are within 300 m of watercourses) and to new septic systems installed close to the lakes. Maintenance of existing septic systems and alternatives to septic systems, including shared advanced waste water treatment systems should be considered.

Specific actions could include:

1. Undertake a survey of septic systems to better characterize their age, maintenance and functionality. Older systems (more than 15 years) should be subjected to a dye test to verify they continue to function as designed. Replace degraded septic systems or require alternatives (aerobic systems, holding tanks etc.) if the site is not capable of accommodating a conventional septic system under current design specifications. Encourage residents to have systems inspected and pumped on a regular basis.

2. Retrofit or improve existing stormwater management systems through the introduction of sediment/water control basins, constructed wetlands, vegetated swales, flow-through filter strips, stormwater infiltration systems and disconnection of all roof drains from stormwater systems.

3. Ban phosphorus containing fertilizers and encourage proper and minimal use of other fertilizers and herbicides.

4. Encourage homeowners to plant naturalized riparian buffers or increase the width and density of existing buffers.

5. Educate residents to prevent grass clippings and fallen leaves from entering the stormwater collection system

6. Encourage homeowners to pick up after pets.

7. Educate residents to use non phosphate soaps when washing vehicles or use a car wash.

8. Educate residents to not drain oil or antifreeze or other potentially harmful wastes into municipal drains and provide collection centers for these liquid wastes for safe disposal.

9. Require sediment management on construction projects including silt fencing to control runoff and washing of vehicles prior to departing the site to avoid mud and dirt being deposited on roadways for eventual runoff into storm sewers.

10. Report illegal dumping or unusual conditions in lakes and streams (high suspended sediments, oil sheens, algae blooms).

11. Strive to eliminate sewage system overflows through expansion of the system and upgrades as appropriate.

12. Maintain the water quality and water quantity monitoring program at a base level such as recommended here to ensure compliance with water quality objectives and expand the database for future modeling enhancements.

13. Apply a no net change to flow, suspended sediment and phosphorus loads from new developments by requiring site specific evaluations and implementation and maintenance of storm water mitigation measures.

As noted above, marine water quality was not considered during this study since the subwatershed does not include a marine estuary component.

g) Recommend strategies to adapt HRM’s stormwater management guidelines to achieve the water quality objectives set out under the subwatershed study

HRM’s Stormwater Management Guidelines (Dillon 2006) describes a set of criteria for the design of stormwater management best management practices (BMPs) to minimize the negative water quality effects of stormwater runoff from urban development. In this report, the term “best management practice” applies to both in-ground infrastructure (pipes, retention basins, etc.) as wells as activities, such as street cleaning and land use restrictions, that may impact water quality. As the report notes:

> There is no single BMP that suits every development, and a single BMP cannot satisfy all stormwater control objectives. Therefore, cost-effective combinations of BMPs may be required that will achieve the objectives.

At this time, stormwater control infrastructure requires provincial approval from Nova Scotia Environment under the Environment Act and in accordance with the Storm Drainage Works Approval Policy. HRM’s authority with respect to stormwater management comes from the HRM Charter Act, which allows HRM to make and enforce municipal by-laws related to land use. Existing municipal planning strategies already include certain land use restrictions that have beneficial effects on water quality. These restrictions include, for example, prohibiting or limiting construction within flood plains, wetlands and steep slopes. In addition, municipal planning strategies also include stormwater management provisions, such as the requirement to obtain municipal approval of stormwater management plans, water quality monitoring plans and erosion control plans prior to development approval.

HRM by-laws and policies that address stormwater include the Halifax Water Regulations and Guidelines for Stormwater Management, which describe the design requirements for stormwater infrastructure, the Halifax Water Rules and Regulations, and Design and Construction Guidelines that regulate the quality of discharges into HRM sewers. However, these mechanisms are limited in the extent to which they can protect water quality (Dillon Consulting Ltd. 2006). The Rules and Regulations specify single point source water quality limits, but there is no direction for how to achieve the limits. The most effective way of adapting HRM's Stormwater Management Guidelines to achieve the water quality objectives outlined in the current report is to implement a stormwater and erosion control by-law. Such a by-law would have statutory authority under the Environment Act and would permit direct enforcement of its provisions by municipal regulators. An example by-law is present in Dillon Consulting Ltd (2006).

Other strategies that may be useful in adapting HRM's stormwater management guidelines to achieve the water quality objectives include:

- Implementation of financial resources or financial mechanisms (including cost sharing) such as a storm sewer use charge for large commercial, industrial and institutional customers to fund infrastructure (including retrofitting), testing, operation and maintenance;

- Exploration of new stormwater management and treatment technologies;

- Educational programs to encourage homeowners to reduce sediment and other pollutant discharge (fertilizers, grass cuttings) to storm sewers; and,

- Apply a no net change to flow, suspended sediment and phosphorus loads from new developments by requiring site specific evaluations and implementation and maintenance of storm water mitigation measures.

With specific reference to the future development of the Port Wallace Lands, it is worth underlining the importance of maintaining pre-development stormwater flow and quality characteristics following development. This is because Lake Charles, the immediate recipient of these flows, is both a headwater lake (so any water quality effects will cascade downstream in a cumulative manner), and a lake that flows in two directions (so effects will be distributed to a number lakes already experiencing the effects of urbanization). As a first step, the wetlands and watercourses should be carefully mapped by biologists trained in wetland delineation to ensure no net loss in area and function, as outlined in the Nova Scotia Wetland Conservation Policy (NSE 2011). Second, all wetlands (not only those that are contiguous with open watercourses) should be protected by a minimum 20 wide buffer zone to help filter surface runoff from developed areas. Third, as recommended in the Proposed River-lakes Secondary Planning Strategy (drafted for the Fall River-Wellington-Windsor Junction areas), before a development agreement is finalized, the proponent should demonstrate the development will result in "no net export of phosphorus" following development. The Proposed River-lakes Secondary Planning Strategy can be viewed at http://www.halifax.ca/visionhrm/FallRiver/. These practices will help minimize predicted changes to water quality including total phosphorus in Lake Charles and in downstream lakes both north and south of Lake Charles.

h) 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 subwatershed and create methods to reduce cut and fill and overall grading of development sites

The replacement of permeable soils by roads, sidewalks and roofs can be reduced during the design and approval process. A common method is to cluster buildings and infrastructure in defined, less permeable or otherwise less sensitive areas in order to maximize permeable vegetated open space. Stormwater management best management practices and design standards aimed at promoting infiltration rather than runoff can be required during the site plan approval process. These measures are described in detail in HRM's Stormwater Management Guidelines and would include, for example, discharge of roof drainage to infiltration trenches or ponds, the use of vegetated swales and perforated conveyance pipes, and the installation of wet ponds and artificial wetlands.

With respect to reducing the loss of native plants and soils, a "constraints to development" map was developed as part of this project and these lands were assumed to be protected from future development within the models. Areas of particular ecological significance include wetlands and watercourses (and their associated riparian buffers). Every effort should be directed at protecting and maintaining these sensitive areas from disturbance.

Development may inadvertently disturb or destroy vegetation communities such as wetlands, riparian buffers and vegetation found in indistinct flow conveyance channels that play a significant role in maintaining water quality. Developers should be requested to provide detailed "wet areas mapping" of properties proposed for development so these vegetation communities can be accurately delineated and their hydrological functions maintained.

i) Identify and recommend measures to protect and manage natural corridors and critical habitats for terrestrial and aquatic species, including species at risk

As noted in section 2.3 Ecological Resources, sixteen federally or provincially listed plant and fungi species are potentially present, while three of these species (the Black Ash, Capitate Spikerush, and Grass-leaved Goldenrod) have been documented within the subwatershed. All three species prefer similar habitats: riparian areas, swamps, and other wet sites. These habitats would typically be protected thought riparian buffers and a general prohibition of development within wetlands.

Jacques Whitford (2009) suggested that HRM consider a 200 m wide "restricted use and development buffer" along the Grand Lake natural corridor. The intention of the buffer is to restrict high impact uses on privately owned land and protect the corridor due to its natural heritage values as a wildlife corridor, recreational area, canoe route and historically significant cultural area.

j) Identify appropriate riparian buffers for the subwatershed

Under Watercourse Setbacks and Buffers The Halifax Mainland Land Use By-Law" [14QA(1)] states:

> "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."

As noted in section 3.5.2 Development Constraints, the 20 m buffer along all water courses is reported to eliminate more than 70% of suspended sediment and more than 60% of phosphorus (Hydrologic Systems Research Group 2012). The maintenance of a minimum 20 m wide riparian buffer is appropriate for all watercourses within the subwatershed.

k) Identify areas that are suitable and not suitable for development within the subwatershed

Please see section 3.5.5 Development Constraints and Figure 27, which identifies areas suitable and not suitable for development. Unsuitable areas include:

- Watercourses;
- Wetlands;
- Watercourse riparian buffers;
- All areas with slopes of 20% or more; and,
- Designated habitats and old growth forests.

If land is not constrained, then the land is suitable for development except that the total area of development and the nature of the development need to be planned so as to meet the adopted water quality objectives. For example, development on acid producing Halifax Formation slate and existing mine waste piles must be carefully planned to prevent water quality impacts when these materials are disturbed.

l) Recommend potential regulatory controls and management strategies to achieve the desired objectives

Regulatory controls and programs already in place that contribute to the maintenance of water quality include:

- Halifax Water Regulations and Guidelines for Stormwater Management;
- Halifax Water Rules and Regulations;
- Design and Construction Specifications (Municipal Water & Wastewater Systems, 2012);
- HRM Municipal Design Guidelines 2013;
- 2009 Stormwater Inflow Reduction program;
- Source Control / P2 (Pollution Prevention Division); and,

- **Other programs (Wastewater/Stormwater Collection Division)**
  - Cleaning, inspection, repair and maintenance of sewers and pumping stations;
  - Asset Management Assessment;
  - Regional Wastewater Functional Plan; and,
  - Integrated Resource Plans.

As noted earlier in this section, a stormwater management by-law would be helpful to manage and enforce stormwater related nutrient and sediment inputs to watercourses. In addition to such a by-law, the following additional controls and strategies are recommended for consideration:

1. Adopt the proposed water quality objectives for the waterbodies.

2. Preserve natural storage, infiltration and filtration functions; develop SWM systems that reproduce or mimic natural functions.

3. Revisit land use planning restrictions that provide for stormwater management (such as restricting development in flood zones, in sensitive areas, on slopes, in wetlands, etc.) and compare them with similar policies in other jurisdictions to determine if these policies should be updated or upgraded to improve their effectiveness.

4. Require developers to demonstrate no net increase of sediment and TP loadings to adjacent water features.

5. Require developers to financially support a water quality monitoring program to assess compliance with the water quality objectives.

6. Enforcement of stormwater management for quality and quantity as per the HRM Stormwater Management Guidelines.

7. Elimination of sanitary sewer overflows within the subwatershed.

8. Elimination of Waste Water Treatment Plant by-passes within the subwatershed.

9. Inspection and testing of septic systems in the subwatershed; phased replacement if they are not functioning due to high water table, poor design, inadequate maintenance or too close to surface water. Consideration of alternative treatment systems to replace existing septic systems.

m) Recommend a monitoring plan to assess if the specific water quality objectives for the subwatershed are being met

The monitoring plan is described in Section 6: Recommendation for Water Quality and Quantity Monitoring. The continuation of a monitoring plan is critical to evaluation of early warning values and objectives that have been set.

8 Summary and Conclusions

The primary objective of the Shubenacadie Subwatershed Study, as expressed in Regional Plan Policy E-17, is to "determine the carrying capacity of the subwatersheds to meet the water quality objectives which shall be adopted following the completion of the studies." Water quality objectives based on existing water quality were established in sections 4.4 and 4.6 and were based on the recommendation that the lakes not experience a significant increase in trophic state. Carrying capacity, or the effects of the different development scenarios on water quality, is described in section 5.4.

With respect to carrying capacity, this study used a refined version of the Ontario Lakeshore Capacity Model (LCM) similar to that used in past studies in the subwatershed. The LCM modeled existing phosphorus loading to each lake and predicted lake response (i.e., trophic state) from these loadings. The LCM accounts for changes in land use and assumes that the lakes are in equilibrium with their subwatershed (i.e. steady state conditions). The LCM specifically considers land use and the impact of septic systems and waste water treatment plant discharges to the lakes but it does not address the dynamic nature of flow and pollutant delivery in subwatershed runoff and transfers between lakes within the subwatershed. Neither is it capable of assessing the benefits resulting from the implementation of stormwater management best practices in urbanizing subwatersheds. Consequently, this study used the stormwater management model (SWMM) in parallel with the LCM. The SWMM assesses changes to hydrology in each subwatershed and calculates pollutant loading from development (sediment and total phosphorus) then predicts the resulting phosphorus loading/concentration in each lake. In order to compare the SWMM and LCM results, the SWMM existing conditions and any development scenarios must initially assume no stormwater management facilities will be used in future developments.

As described throughout the report, the primary human activity impacting water quality is changes to land use resulting from development within the subwatershed. The low density nature of most of this development means that the major impacts on lake water quality appear to have resulted from the conversion of forested land to residential property and the installation of septic tanks to serve these residences. Both result in increased nutrient loading as quantified by the LCM. With over 4,855 septic systems currently within 300 m of a watercourse within the Shubenacadie Lakes subwatershed, the effect of these on existing water quality could be significant in some lakes and this will be exacerbated with further development in un-serviced areas.

Development impacts are also associated with overflows and by-passes from municipal waste water collection systems. The impact of the wastewater overflows and by-passes is difficult to quantify as they are not typically documented except for the volume and location of WWTP by-passes. Unfortunately TP concentrations of these are not measured and thus the total loading of TP released to the environment during an overflow event cannot be quantified. We assume that reduction and ideally elimination of these overflows will be a priority within the plans for expansion of the waste water collection and treatment system within the subwatershed.

The proposed developments are not predicted to further increase the trophic state of the other lakes in the subwatershed; however, phosphorus concentrations are expected to rise somewhat due largely to existing and new septic systems close to the lakes. Maintenance of existing septic systems and alternatives to septic systems, including shared advanced waste water treatment systems should be considered.

Future high density development within the subwatershed will be required to implement stormwater management facilities to control runoff water quantity and maintain its quality. A detailed knowledge of the type and size of each stormwater management facility was not available for all future developments within the subwatershed. Consequently, a simplified approach was taken for the Port Wallace land to estimate the improvements to flow, total suspended solids (TSS) and total phosphorus (TP) loadings based on the implementation of advanced stormwater management within all new developments. In this case, removal rates of 80% or higher for TSS and 50% for TP were used as a standard applied to stormwater discharges in each sub-subwatershed. These removal rates are optimal and have been used here as an indication of what might reasonably be expected through the rigorous application of advanced stormwater management practices.

The benefits from storm water management for future development within the Shubenacadie Lakes subwatershed for Scenario 2 will not be great. Scenario 2 would see an increase predominately in Grand Lake, with the total mass of TSS increasing by 24%. The percentage increase is misleading; however, due to the very low average existing TSS concentration in Grand Lake (3 ± 2 mg TSS/L based on 22 samples). Scenario 3 results in an increased TSS load of 40% for Lake Charles. With the use of SWM techniques within the Port Wallace lands the increase of TSS may be reduced by 80% depending on the facility performance for an absolute load of approximately 197,072 Kg/year compared to the existing estimated load of 182,474 Kg/yr. These predictions should be confirmed or validated through:

- the collection of supplementary water quality monitoring data for these lakes in the context of early warning values and quality objectives;
- continued tracking of land use changes that affect the model;
- re-runs of subwatershed or lake-specific models with the above noted updates as appropriate to confirm predictions; and,
- further analysis including modeling of proposed SWM facilities for future developments to verify there is no net increase in peak flow, sediment and phosphorus loads from the proposed developments.

Stormwater management at the individual development level should be designed to adhere to the “no net increase” target in full recognition that if this cannot be achieved, then the impact on water quality has to be factored into the development plan and water quality protection plan for the entire subwatershed.

Development-specific stormwater management proposals should be assessed relative to their ability to achieve the no net increase target. If a specific development cannot demonstrate that it will have no net increase, then HRM can consider alternatives to the development as proposed (e.g. reduced development area either for the development under consideration or elsewhere; reduced intensity of development here or elsewhere) or reassessment of other mitigation measures (such as retrofitting or requiring more stringent treatment in future developments) within the Shubenacadie Lakes subwatershed. To achieve this, new development applications in the subwatershed should incorporate the measures detailed within HRM’s Stormwater Management Guidelines to reduce or eliminate the impacts to water quality and quantity through the application of a subwatershed-specific or development-specific SWMM. The benefit of these measures can be evaluated by using the SWMM on a development scale and integrating these site specific results into the subwatershed scale SWMM developed here so that existing conditions and post-development conditions can be assessed relative to the water quality management objectives for the subwatershed.

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11 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. subwatershed 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 subwatershed.
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.
Subwatershed	(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.

13 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

Appendix A

Water Budget

Table of Contents

List of Tables and Figures

1. Water Budget

A *water budget* is used to describe the movement of water in and through a basin. In this report, the Shubenacadie Lakes subwatershed boundary is the limit of the basin for which the water budget is developed. The *total precipitation* (P) is the water that falls both as rainfall and as snow and constitutes the total amount of water available for hydrological processes such as stream flow and groundwater recharge. A water budget also considers the amount of water that is returned back to the atmosphere by both *evaporation* and plant *transpiration* in the combined process called *evapotranspiration* (ET).

The water budget equation is not complicated. For a given time period (often one year), the water budget balances the gains and losses of water within the watershed with the quantities of water stored in the watershed. The water budget equation is expressed as follows:

$$P = RO + R + ET + \Delta S_s + \Delta G_s$$

Where:

P = Precipitation (mm/yr);
RO = Runoff (mm/yr);
R = Groundwater Recharge (mm/yr);
ET = Evapotranspiration (mm/yr);
ΔS_s = Change in soil moisture storage (mm/yr); and,
ΔG_s = Change in groundwater storage (mm/yr).

In a large watershed where the groundwater system boundaries coincide with surface water divides, the change in groundwater storage can be assumed to equal zero ($\Delta G_s = 0$). For precipitation, long term meteorological data averaged over the 30 year period of 1971 – 2000 were obtained from Environment Canada for the Halifax Stanfield International Airport climate station (Station ID 8202250). Evapotranspiration can be defined as either potential evapotranspiration or actual evapotranspiration. Potential evapotranspiration is estimated using temperature data and incoming solar radiation (often referred to as the daylight correction factors) from data measured within the watershed. The daylight correction factors are dependent upon the latitude of the watershed or meteorological station, with the understanding that areas closest to the equator will have the most daily sunlight and therefore the highest potential evapotranspiration rates. Actual evapotranspiration expands upon potential evapotranspiration to include changes in soil moisture and monthly precipitation rates. Actual evapotranspiration rates are used in this analysis for the Shubenacadie Lakes subwatershed.

Average soil moisture storage was estimated at 200 mm. This low value reflects the extensive areas of shallow or exposed bedrock, sandy till deposits and a lack of lacustrine or glaciolacustrine clay soils which tend to hold water.

2. Shubenacadie Lakes Subwatershed Water Surplus

Assuming that changes in soil moisture storage (ΔS_s) are negligible and that there is no change in groundwater storage (ΔG_s) in the watershed, the total *water surplus* available for *surface runoff* to the surface water system and *infiltration* as groundwater recharge can be determined. Using the same formula terms described above, the water surplus (mm/yr) is expressed as:

$$Surplus = P - ET$$

The proportion of the water surplus that infiltrates into the soil and ultimately into the underlying bedrock aquifer or runs off as overland surface sheet flow to streams and lakes depends primarily upon the characteristics of the soils, the topography, the land use and the vegetative cover. This concept is based upon the fact that water will infiltrate more easily through flat lying, high permeability soils than through steep slopes or low permeability soils. Water that infiltrates to the ground "recharges" the shallow water table and flows laterally towards streams and lakes. In areas with thick soil cover, this recharge may migrate first into deeper groundwater aquifer systems before eventually discharging into surface water systems.

Surface runoff or sheet flow, on the other hand, generally coincides with rainfall events. As the surficial soil become saturated by rainfall, water may runoff overland to low lying areas. This process is especially pronounced during the spring snow melt where the melting snowpack is forced to runoff because the upper soil layers are still frozen and do not allow infiltration. In Nova Scotia where the temperature can fluctuate above and below the freezing point, the melting of the snowpack is not usually a major runoff event compared to colder regions where the accumulated snow melts over a short time period in the spring.

The actual evapotranspiration for the Shubenacadie Lakes subwatershed was calculated using the method described in Thornthwaite and Mather (1957), using a monthly time step and assuming soil moisture of 200 mm. A daylight correction factor for 44 degrees latitude was applied. The overall water surplus determined for the Halifax Stanfield International Airport meteorological station represents the difference between the mean annual precipitation (P) and the actual evapotranspiration (ET). The water surplus is presented in Table 2-1.

Table 2-1– Birch Cove Lakes Watershed Water Surplus

Meteorological Station	Total Annual Precipitation (mm)	Actual Annual Evapotranspiration (mm)	Annual Water Surplus (mm)
Halifax Stanfield International Airport	**1,452**	**545**	**908**

Notes: 1. Data obtained from the 1971 – 2000 average at Halifax Stanfield International Airport (Environment Canada) weather station.
2. Actual Evapotranspiration calculated using the Thornthwaite and Mather (1957) method.

The annual water budget and water surplus calculations for the Shubenacadie Lakes subwatershed require a number of assumptions, including:

- Temperature and precipitation data measured at the Halifax Stanfield International Airport weather station from 1971-2000 are representative of the climate conditions in the Shubenacadie Lakes sub watershed.
- Data analysis based on the Halifax Stanfield International Airport station applies to the entire watershed area.
- Soil moisture storage remains relatively constant at 200 mm annually and is representative of conditions throughout the watershed.

3. Groundwater Recharge Modelling

Based on the calculated annual water surplus, groundwater recharge and surface water runoff rates were calculated for the Shubenacadie Lakes sub watershed using a Geographic Information System (GIS) based analytical model. This model assumes that volumes of domestic and municipal groundwater taking are negligible compared to flow through the system, and that groundwater and/ or surface water inflow from outside the watershed is also negligible. The model integrates slope, land use (vegetative cover), and geology over a 1000 x 1000 m grid to estimate potential groundwater recharge rates and runoff volumes for the watershed.

The first step in this GIS model was to calculate the volume of surplus water available for infiltration and runoff, which is the difference between precipitation and evapotranspiration. This step is described above.

The second step was to partition the surplus water into runoff and infiltration. A variety of infiltration coefficients was determined for each of the different geologic, vegetative and topographic units within the watershed. The land use mapping and digital elevation model were used to assign values for slope and vegetative cover. Once coefficients were applied to each unit, they were combined within the GIS model to create a layer of infiltration distribution over the entire watershed.

The infiltration distribution, in combination with the distribution of water surpluses, produced a model of the spatial variability of groundwater recharge across the Shubenacadie Lakes subwatershed, from which the estimated recharge distribution mapping was produced (Figure 1 below).

3.1.1 Calibration

One of the data gaps identified by AECOM upon project initiation was the lack of stream flow information within the Shubenacadie Lakes subwatershed. To address this data gap, AECOM conducted stream flow measurements in several watercourses within the watershed over a 10 month period. This data was used to create flow rating curves and determine “baseflow” Baseflow is the portion of stream flow that comes from groundwater seepage into the stream. During most of the year, stream flow is composed of both groundwater seepage (baseflow) and surface runoff. When groundwater provides the entire flow of a stream, baseflow conditions are said to exist. Stream flow measurements during low-flow conditions, such as during extensive periods without rain, are conducted to assess a stream’s baseflow conditions, which is the groundwater contribution to stream flow.

In assessing the water budget, AECOM assigned infiltration factors to surficial geology units based on our professional judgement and experience. To assess whether these infiltration factors are accurate, a calibration exercise was conducted using data from the closest Water Survey of Canada hydrometric monitoring station. Station 01J001 is located on the Sackville River at Bedford. The purpose of the calibration exercise was two-fold: 1) to obtain an estimate the mean annual baseflow conditions for the area by using data for the Sackville River watershed; and 2) to assess whether the assumed soil infiltration values applied for another comparable watershed were reasonable and appropriate by comparing the baseflow value estimated by the water budget model with the baseflow estimate obtained from analysis of the Sackville River hydrograph. The calibration exercise was also performed on data from the nearby Birch Cove Lakes watershed as part of a study undertaken at the same time as the Shubenacadie Lakes study.

The hydrometric station for the Sackville River at Bedford is appropriate for estimating baseflow because it represents an unregulated watershed system and because of its close proximity to the Shubenacadie Lakes subwatershed. Baseflow separation analysis of the Sackville River hydrograph indicated an estimated mean annual baseflow of 400 to 600 $m^{3/}$yr for the Sackville River watershed. The calibration exercise involved applying the assumed soil infiltration factors to the Sackville River watershed and assessing the effects to baseflow conditions in that watershed. Using the baseflow estimate from the Sackville River, AECOM adjusted the soil infiltration factors applied to the surficial geology units within the Sackville watershed until there was a better match between the water budget model and baseflow estimates. Following this step, the revised soil infiltration factors from the Sackville watershed were then applied to soils in the Shubenacadie Lakes subwatershed.

4. Existing Conditions

4.1.1 Results of the Water Budget Calculations and Modelling

The results of the water budget calculations and modelling are presented on Figure 1, which shows the potential estimated groundwater recharge for the Shubenacadie Lakes sub watershed. The purpose of this map is to highlight areas where there is a greater estimated potential for groundwater recharge, which should correspond to more productive hydrostratigraphic units as well as stream and river systems with a higher relative proportion of baseflow. The opposite is true for surface runoff: areas where there is a greater potential for surface runoff should correspond to poorly developed groundwater resource areas and higher peak flows in streams. While surface runoff is evaluated as a part of the water budget exercise, it is not presented as part of water budget discussion since it is addressed in the stormwater management modelling section of the main report.

The total estimated potential annual groundwater recharge and surface runoff for the Shubenacadie Lakes sub watershed is 34,000,000 m^3/yr and 318,000,000 m^3/yr, respectively. This means that on average, groundwater recharge accounts for approximately 10% of the total water balance in the watershed, while surface runoff accounts for the remaining 90%. These divisions between recharge and runoff seem reasonable given the distribution of exposed bedrock and thin soil cover. As previously described, much of the groundwater recharge would involve shallow infiltration into surface soils followed by lateral migration into stream and lake systems.

4.1.2 Groundwater Recharge – Shubenacadie Lakes Sub Watershed

The permeability of surficial soils (i.e., 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 basin, from a practical point of view, only higher permeability soils can transmit enough recharge to support a groundwater resource.

Groundwater recharge varies seasonally with the highest rates occurring in the spring (May to early July) during snow melt and spring rainfall events and the lowest rates occurring in the dry period of late summer (August) and winter months (November to April) when most precipitation falls as snow.

Areas with soil cover consisting of alluvial (moving water) and lacustrine (lake sediment) deposits cover an estimated 5% of the sub watershed, and have the highest potential groundwater recharge, exceeding 350 mm/year. Recharge through glaciofluvial outwash and hummocky till representing 4% coverage in the sub watershed represents the next highest potential groundwater recharge rates of 250 to 350 mm/year. Areas where coverage consists of drumlin deposits (low, smoothly rounded, elongate oval mounds of glacial till) represents the highest relative coverage within the sub 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 (25% coverage) have potential groundwater recharge rates in the order of 70 to 140 mm/year. Areas where bedrock is exposed (11% coverage) or covered by thin soils (1% coverage) and urbanized areas (1% coverage) exhibit the lowest potential recharge rates, typically less than 70 mm/yr. Groundwater recharge is limited in urbanized areas or areas with anthropogenic cover due to the impermeable surfaces resulting from pavement and buildings. Surface water features, mainly lakes, cover the remaining 11% of the land cover within the Shubenacadie Lakes subwatershed.

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 subwatershed 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. Thick sequences of glacial materials that can host extensive and productive unconfined aquifers are generally not present in the Shubenacadie Lakes subwatershed. Given that these 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.

4.1.3 Groundwater Recharge – Port Wallis Lands

The Port Wallis lands contain a significant proportion of land coverage exhibiting high groundwater recharge potential (>350 mm/yr – the darkest grey color on Figure 1 below). High recharge surface deposits consist of alluvial and lacustrine deposits. These areas also correspond with marsh, swamp and bog or fen features. Areas covered by hummocky till have the next highest groundwater recharge potential, ranging from 250 to 350 mm/year. Groundwater recharge in areas within the Port Wallis lands covered by thin till veneer deposits is low; these deposits have groundwater recharge rates of less than 70 mm/year.

5. Impact of Development

The results of the water budget analysis suggest that given the soils, topography and existing land use conditions (vegetative cover) in the Shubenacadie Lakes subwatershed, most precipitation runs off, rather than recharges groundwater. Based on the results of the water budget modelling under existing conditions and also in consideration of future development planned for the watershed (HRM authorized subdivision agreements), changes in land uses in the Shubenacadie Lakes subwatershed are not expected to significantly affect the groundwater flow regime within the watershed.

Efforts should be made to maintain and reduce the loss of groundwater recharge areas of future development lands (including Port Wallis lands) by limiting activities that impede groundwater recharge such as land cover with impermeable surfaces. Site grading and storm water management should be applied in these areas to direct precipitation and surface water runoff to areas of high groundwater recharge potential. Areas of high groundwater recharge potential may also be sensitive to activities and land uses that may pose a risk to groundwater contamination. Examples include petroleum storage tanks, microbiological contamination from malfunctioning septic systems, industrial activities, sanitary sewer overflow areas, application of road salt and fertilizers. Efforts should be made to limit these activities and land uses within areas of high groundwater recharge potential.

With respect to development of the Port Wallis lands on the shore of Lake Charles, future residences will be serviced by municipal water and sewer infrastructure. Given this, there is little risk of microbiological contamination of nearby potable water wells from Port Wallis development. Nonetheless, efforts should be made to protect the groundwater recharges areas with recharge potential > 140 mm/ year since this infiltrated water quickly discharges to Lake Charles. This includes reducing impermeable surfaces and using site grading and storm water management to focus run-off towards high recharge areas. The areas within the Port Wallis lands identified as having moderate to high (> 140 mm/year) groundwater recharge potential (Figure 1) correspond to areas with sensitive habits (i.e. marsh, swamp, bog, fen) and their 20 m buffers.

The water budget analysis and groundwater recharge potential mapping conducted as a part of this study should not be interpreted as an evaluation of groundwater resource potential. Future development in other areas of the subwatershed where potable water supply will be sourced by groundwater wells will require further evaluation. Jacques Whitford (2009) indicated that the bedrock aquifer in highly developed areas around Fall River centre may be over-exploited. Further investigation of this condition was recommended to better assess groundwater resource availability for further development. This recommendation is carried forward for evaluation of other areas of the Shubenacadie Lakes subwatershed where future development is to be serviced by groundwater supply wells.

6. Summary

In summary, groundwater recharge represents a relatively small proportion of the total water budget for the Shubenacadie Lakes sub watershed. Of the surplus water calculated for the watershed, approximately 34,000,000 m^3/yr or 10% of total precipitation will infiltrate into the ground as recharge while the remaining 318,000,000 m^3/yr (90%) will become runoff. While there is some degree of soil cover across a majority of the sub watershed area (e.g. exposed bedrock coverage is 11%), the surficial deposits, namely surficial till units and drumlin deposits are not thick enough to capture and hold precipitation over the long term. Instead, they function to retain precipitation 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.

Areas within the Shubenacadie Lakes subwatershed with soil cover consisting of alluvial and lacustrine deposits (5% coverage) have the highest potential groundwater recharge rates, exceeding 350 mm/year. Recharge through glacial outwash and hummocky till deposits representing 4% coverage and the next highest potential groundwater recharge rates of 250 – 350 mm/year. Areas where coverage consists of drumlin deposits represents the highest relative coverage within the sub watershed at 41% of coverage having potential groundwater recharge rates of 140 – 250 mm/year. Areas consisting of till blanket or till veneer, representing 6% of the land cover in the watershed, have the next highest potential groundwater recharge rates, ranging from 70 to 140 mm year. Areas where bedrock is exposed or covered by thin soils (12% total coverage) and urbanized areas (1% coverage) exhibit the lowest potential recharge rates, typically less than 70 mm/yr. Surface water features, mainly lakes, cover the remaining 11% of the land cover.

Efforts should be made to maintain and reduce the loss of groundwater recharges areas of future development lands by limiting activities that impede groundwater recharge such as land cover with impermeable surfaces. Site grading and stormwater management should be applied in these areas to direct precipitation and surface water runoff to areas of high groundwater recharge potential. These areas may also be sensitive to activities and land uses that may pose a risk to groundwater contamination such as petroleum storage tanks, microbiological contamination from malfunctioning septic systems, industrial activities, sanitary sewer overflow areas, application of road salt and fertilizers.

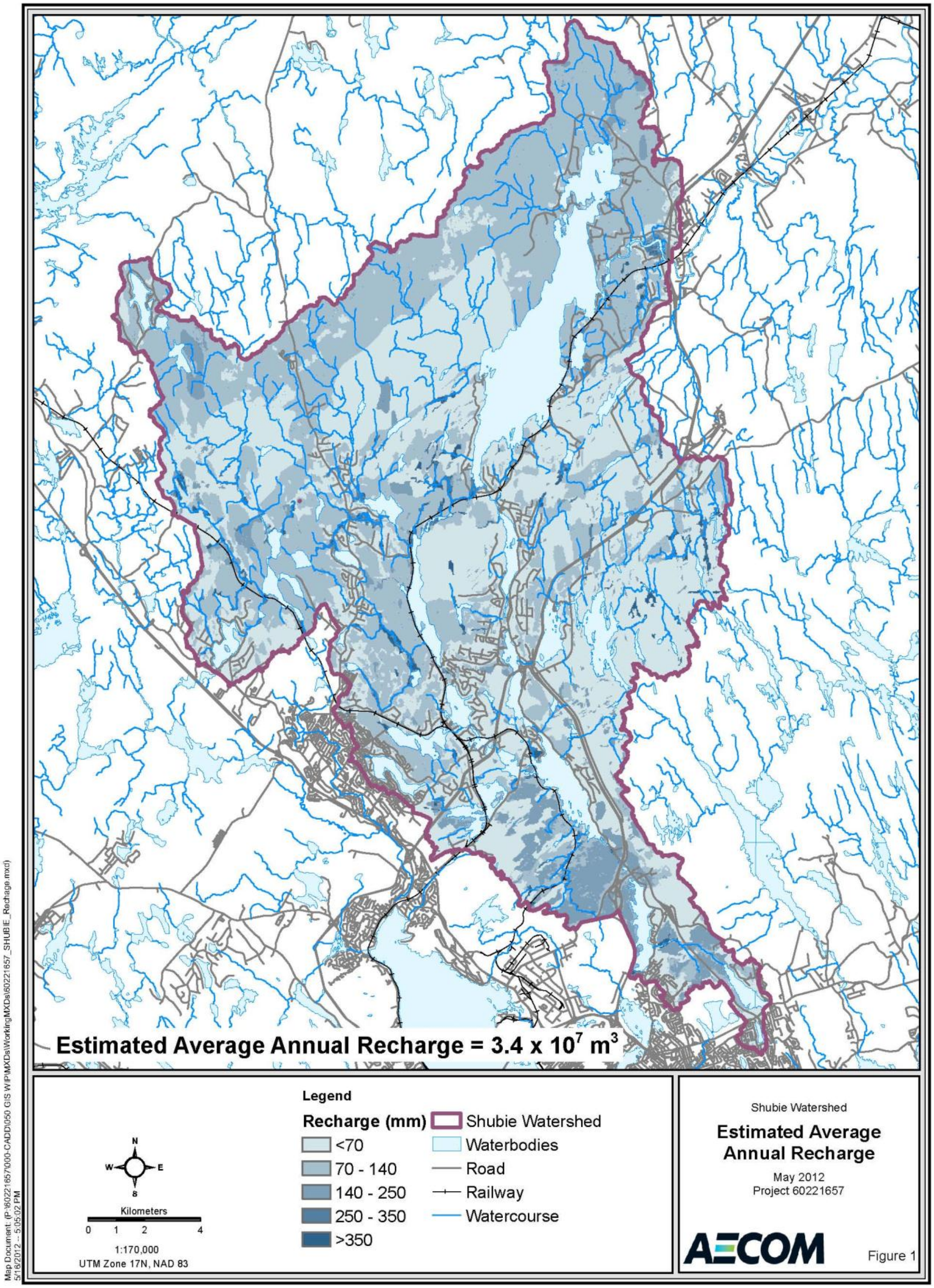

Figure 1 - Estimated Average Annual Recharge

Jacques Whitford Report

Groundwater Resource Study
Fall River – Shubenacadie Lakes Watershed Study

For Halifax Regional Municipality

June 2008 – Project #1025549

Tables

TABLE 2-1 **Summary of Hydraulic Testing Data - Halifax County, NS.**

AQUIFER		Well Details				Pumping Well					Aquifer	
		Well Depth (m)	Casing Dia. (mm)	Casing Length (m)	Duration (hr)	Static Water (m)	Hydraulic Properties T (m2/d)	Q/s (m3/d/m)	Q20 (igpm)	K (cm/s)	T (m2/d)	S (units)
Halifax Fm Slate	Minimum	32.6	100	3.4	4	0.3	0.03	0.21	0.2	3.1E-06	0.9	3.0E-06
	Maximum	166.7	203	63.1	72	34.4	61.6	54.8	110.0	2.8E-04	57.6	2.8E-03
	Mean	83.7	184	18.2	66	9.6	3.7	4.9	10.6	5.9E-05	21.0	1.0E-03
	Geomean	78.0	182	12.7	62	5.8	0.9	1.8	4.3	2.6E-05	6.2	1.4E-04
	median	83.8	203	12.2	72	6.1	0.9	1.3	4.7	3.3E-05	4.5	3.0E-04
	STD	30.6	27	18.6	15	7.9	10.6	10.3	19.9	7.4E-05	31.8	1.5E-03
	N	34	32	21	34	33	34	32	34	21	3	3
Goldenville Fm Greywacke	Minimum	15.2	152	2.7	1	0.1	0.02	0.01	0.2	3.8E-07	6.5	8.5E-05
	Maximum	137.2	203	63.1	73	20.5	32.0	30.0	80.0	2.5E-01	6.5	8.5E-05
	Mean	72.0	186	18.9	56	6.8	2.7	4.0	8.1	1.1E-02	6.5	8.5E-05
	Geomean	63.8	185	13.0	41	4.3	0.7	1.2	2.6	3.5E-05	6.5	8.5E-05
	median	64.6	203	12.8	72	5.5	0.7	1.3	2.5	1.8E-05	6.5	8.5E-05
	STD	33.4	23	17.9	27	5.4	5.5	6.1	15.8	5.2E-02	-	-
	N	45	41	25	44	43	43	39	43	23	1	1
Granite	Minimum	15.8	127	3.1	1	0.5	0.06	0.17	0.2	2.2E-06	1.0	5.0E-05
	Maximum	131.1	203	67.7	74	37.3	24.1	57.6	148.0	4.0E-04	1.0	5.0E-05
	Mean	69.4	184	12.4	62	7.5	2.3	4.9	9.5	6.3E-05	1.0	5.0E-05
	Geomean	63.5	183	9.4	50	4.9	1.1	2.0	4.2	2.7E-05	1.0	5.0E-05
	median	73.1	203	7.0	72	5.5	1.1	1.6	4.4	2.9E-05	1.0	5.0E-05
	STD	27.1	25	12.4	23	7.8	4.0	9.5	21.7	1.0E-04	-	-
	N	47	43	32	47	47	42	42	47	29	1	1
Windsor Group Limestone/Shale	Minimum	33.5	155	-	72	1.5	1.5	1.9	2.8	-	-	-
	Maximum	47.5	155	-	72	12.1	17.0	7.5	37.1	-	-	-
	Mean	40.5	155	-	72	6.8	9.3	4.7	20.0	-	-	-
	Geomean	39.9	155	-	72	4.3	5.1	3.8	10.2	-	-	-
	median	40.5	155	-	72	6.8	9.3	4.7	20.0	-	-	-
	STD	9.9	0	-	0	7.5	11.0	4.0	24.3	-	-	-
	N	2	2	3	2	2	2	2	2	0	0	0
Sand & Gravel	Minimum	3.4	100	5.5	5	1.3	0.91	3.65	0.4	3.6E-03	2238.0	7.2E-02
	Maximum	30.2	3048	26.5	72	12.1	197	505	682	8.3E-02	2238.0	7.2E-02
	Mean	10.6	956	15.5	53	3.1	44.9	99.7	84.4	4.3E-02	2238.0	7.2E-02
	Geomean	8.2	493	12	39	2	14.6	34.9	8.1	1.7E-02	2238.0	7.2E-02
	median	7.0	914	15.1	72	2.0	14.3	38.0	6.3	4.3E-02	2238.0	7.2E-02
	STD	9.0	1095	11.5	28	3.1	65.0	158.1	211.6	5.6E-02	-	-
	N	11	11	4	11	11	9	10	10	2	1	1

TABLE 2-1 Summary of Hydraulic Testing Data - Halifax County, NS.

AQUIFER		Well Details				Pumping Well					Aquifer	
		Well Depth (m)	Casing Dia. (mm)	Casing Length (m)	Duration (hr)	Static Water (m)	Hydraulic Properties T (m2/d)	Q/s (m3/d/m)	Q20 (igpm)	K (cm/s)	T (m2/d)	S (units)
Glacial Till	Minimum	4.3	914	-	72	0.3	9.1	13.5	2.8	-	-	-
	Maximum	5.5	3048	-	72	2.8	34.0	127.6	8.4	-	-	-
	Mean	4.9	2428	-	72	1.3	16.3	43.2	4.3	-	-	-
	Geomean	4.8	2228	-	72	1.0	14.4	30.0	3.9	-	-	-
	median	4.9	2895	-	72	1.1	14.3	26.8	3.5	-	-	-
	STD	0.6	911	-	0	0.9	10.2	47.7	2.3	-	-	-
	N	5	5	5	5	5	5	5	5	0	0	0

TABLE 2-2 Summary of Hydraulic Properties - Provincial Range and Mean

Bedrock		Well Details					Pumping Well				Aquifer	
		Well Depth (m)	Casing Dia. (mm)	Casing Length (m)	Duration (hr)	Static Water (m)	Hydraulic Properties T (m2/d)	Q/s (m3/d/m)	Q20 (igpm)	K (cm/s)	T (m2/d)	S (units)
Halifax Fm Slate	Minimum	29.0	100	3.0	2	flowing	0.01	0.01	0.1	3.1E-06	0.91	3.0E-06
	Maximum	191.7	203	67.7	74	52.1	170.0	124.3	166.0	7.1E-03	95.8	2.8E-03
	Mean	77.9	168	20.7	64	8.3	6.1	7.5	12.9	3.2E-04	32.7	6.3E-04
	Geomean	72.4	155	14.3	59	4.5	1.3	2.3	5.2	3.6E-05	3.5	3.2E-05
	median	76.8	155	13.4	72	5.0	1.3	1.9	4.9	3.8E-05	10.4	4.0E-05
	STD	29.5	23	19.1	17	9.4	19.3	16.7	23.2	1.3E-03	34.1	9.7E-04
	N	92	87	33	92	91	89	86	91	30	8	9
Goldenville Fm Greywacke	Minimum	13.7	152	2.7	1	flowing	0.00	0.01	0.1	1.4E-07	5.12	1.3E-05
	Maximum	184.7	203	63.1	90	35.1	68.2	87.4	156.0	2.5E-01	6.5	8.5E-05
	Mean	74.8	178	17.7	61	6.0	5.0	8.9	12.9	8.3E-03	5.8	4.8E-05
	Geomean	65.6	155	12.0	72	3.1	1.1	2.0	4.1	2.5E-05	5.8	3.3E-05
	median	67.8	155	12.3	72	3.2	1.1	1.9	3.7	2.6E-05	5.8	4.5E-05
	STD	36.5	24	17.4	23	6.8	11.1	17.5	23.9	4.3E-02	0.7	2.9E-05
	N	98	87	29	97	98	98	90	98	3.2E+01	3	3.0E+00
Granite	Minimum	22.3	127	3.1	2	flowing	0.06	0.17	0.2	1.0E-06	1.00	5.0E-05
	Maximum	131.1	203	67.7	74	37.3	48.9	164.1	222.0	2.2E-03	250.0	5.0E-04
	Mean	67.3	174	13.3	64	6.3	3.9	9.3	16.9	1.4E-04	65.3	2.8E-04
	Geomean	62.4	155	10.3	55	3.7	1.5	3.0	5.7	3.2E-05	15.8	1.6E-04
	median	61.3	155	7.6	72	3.4	1.3	2.5	5.2	2.9E-05	5.1	2.9E-04
	STD	25.3	24	11.9	21	7.0	7.2	21.3	36.9	3.8E-04	106.7	1.8E-04
	N	84	77	37	84	84	80	79	84	3.2E+01	5	5.0E+00

TABLE 2-2 Summary of Hydraulic Properties - Provincial Range and Mean

Bedrock		Well Details					Pumping Well Hydraulic Properties				Aquifer	
		Well Depth (m)	Casing Dia. (mm)	Casing Length (m)	Duration (hr)	Static Water (m)	T (m2/d)	Q/s (m3/d/m)	Q20 (igpm)	K (cm/s)	T (m2/d)	S (units)
Sand & Gravel	Minimum	1.8	72	1.6	3	0.4	0.91	3.65	0.4	1.7E-03	50.00	1.5E-04
	Maximum	67.1	3048	43.3	666	27.0	3333	4564	2200	2.1E-01	5967	3.0E-01
	Mean	19.9	312	15.4	66	4.8	362.5	310.8	257.3	7.9E-02	1069.2	5.6E-02
	Geomean	15.1	212	11	50	3	108.6	116.8	66.1	3.5E-02	629.2	1.0E-02
	median	15.3	155	11.2	72	3.1	118.2	120.8	75.2	9.4E-02	596.7	3.1E-02
	STD	14.5	477	11.8	69	4.7	616.6	588.4	422.2	6.9E-02	1285.2	7.7E-02
	N	99	88	22	98	93	85	92	91	11	25	24
Glacial Till	Minimum	2.7	914	2.74	1	0.3	3.9	13.5	0.5	-	-	-
	Maximum	5.5	3048	5.49	72	2.8	96.3	236.3	8.4	-	-	-
	Mean	4.2	1686	4.21	37	1.6	20.7	62.3	2.8	-	-	-
	Geomean	4.1	1449	4.10	10	1.4	12.6	39.9	2.0	-	-	-
	median	4.3	991	4.27	37	1.3	11.1	28.8	2.8	-	-	-
	STD	0.9	940	0.93	35	0.8	26.5	67.4	2.2	-	-	-
	N	10	10	10	10	10	10	10	10.0	0.0E+00	0	0.0E+00
Windsor Group Limestone/Shale	Minimum	18.3	100	6.1	16	flowing	0.3	0.2	1.1	2.0E-03	7.5	1.3E-04
	Maximum	123.4	203	49.0	73	26.5	64.0	98.6	231.0	2.0E-03	37.3	2.2E-02
	Mean	54.1	162	28.3	63	8.0	13.2	21.1	33.3	2.0E-03	26.4	7.3E-03
	Geomean	48.5	155	20.9	59	5.1	6.3	10.5	14.9	-	21.2	9.6E-04
	median	47.5	155	27.4	72	5.9	6.7	12.5	15.8	2.0E-03	34.5	3.2E-04
	STD	26.2	23	18.4	18	7.6	16.9	24.9	46.8	0.0E+00	13.4	1.0E-02
	N	27	25	5	27	27	27	24	27.0	2	3	3

TABLE 5-1 Well Statistics for Communities in Fall River Shubenacadie Lakes Watershed Study Area

Community	Statistic	Well Depth	Casing Length	Well Diameter	Well Yield	Static Water Level	Till Thickness
BEAVERBANK	Minimum	25	8	5	0	1	0
	maximum	645	275	7	100	190	260
	Average	234	97	6	5	55	86
	Median	220	88	6	2	49	76
	STD	98	63	0	9	39	63
	N	460	430	288	428	184	437
FALL RIVER	Minimum	33	6	1	0	0	0
	maximum	610	232	7	55	300	230
	Average	200	48	6	3	31	37
	Median	184	30	6	2	20	18
	STD	98	38	0	5	33	39
	N	872	774	525	818	307	750

TABLE 5-1 Well Statistics for Communities in Fall River Shubenacadie Lakes Watershed Study Area

Community	Statistic	Well Depth	Casing Length	Well Diameter	Well Yield	Static Water Level	Till Thickness
FENERTYS	Minimum	26	15	2	1	1	2
	maximum	400	214	7	90	140	206
	Average	161	47	6	7	26	35
	Median	142	34	6	4	20	25
	STD	76	37	0	11	28	39
	N	112	105	105	108	57	106
FLETCHER LAKE	Minimum	27	11	6	0	0	0
	maximum	490	150	7	80	290	220
	Average	241	52	6	3	40	44
	Median	240	40	6	1	25	30
	STD	92	36	0	6	44	42
	N	281	242	174	269	112	245
FRENCHMANS ROAD	Minimum	100	20	6	0	9	3
	maximum	360	144	6	60	120	130
	Average	196	81	6	7	39	71
	Median	185	85	6	3	28	77
	STD	64	33	0	13	31	34
	N	34	32	34	34	14	32
GRAND LAKE	Minimum	60	20	6	0	0	2
	maximum	360	92	6	15	70	183
	Average	182	32	6	4	19	31
	Median	160	20	6	3	11	15
	STD	79	19	0	5	25	43
	N	25	23	25	24	12	21
GRAND LAKE Station	Minimum	45	6	6	0	0	1
	maximum	320	71	6	125	30	70
	Average	157	29	6	5	17	14
	Median	140	22	6	2	17	7
	STD	78	14	0	14	9	14
	N	80	76	80	78	26	67
HORNE SETTLEMENT	Minimum	60	20	6	0	2	4
	maximum	410	137	6	100	65	135
	Average	177	63	6	16	32	50
	Median	143	60	6	6	30	46
	STD	89	37	0	22	19	36
	N	39	37	39	38	15	37

TABLE 5-1 Well Statistics for Communities in Fall River Shubenacadie Lakes Watershed Study Area

Community	Statistic	Well Depth	Casing Length	Well Diameter	Well Yield	Static Water Level	Till Thickness
KINSAC	Minimum	45	19	6	0	8	2
	maximum	485	290	7	50	200	285
	Average	218	100	6	5	51	85
	Median	205	89	6	2	40	78
	STD	92	60	0	7	44	57
	N	190	177	124	185	75	177
LAKEVIEW	Minimum	65	21	6	1	10	6
	maximum	375	112	6	7	49	105
	Average	212	51	6	3	24	34
	Median	203	36	6	2	18	19
	STD	102	43	0	3	16	38
	N	6	4	6	6	5	6
LEWIS MILLS/Lake	Minimum	60	14	6	0	0	0
	maximum	385	104	7	17	100	100
	Average	190	37	6	3	22	29
	Median	200	25	6	2	20	21
	STD	77	24	0	3	22	26
	N	51	48	51	50	19	48
MIDDLE BEAVERBANK	Minimum	39	18	6	0	0	2
	maximum	415	263	7	30	140	250
	Average	199	72	6	6	32	55
	Median	190	38	6	3	26	26
	STD	73	66	0	6	27	62
	N	126	120	104	126	62	116
NORTH BEAVERBANK	Minimum	65	11	6	0	3	0
	maximum	405	144	7	30	40	138
	Average	206	28	6	5	16	18
	Median	200	20	6	2	15	8
	STD	81	20	0	7	9	25
	N	49	48	41	48	21	44
OAKFIELD	Minimum	50	12	6	1	8	1
	maximum	343	147	6	30	80	122
	Average	162	54	6	6	31	46
	Median	167	37	6	3	25	31
	STD	78	40	0	6	23	39
	N	55	53	55	53	25	44

TABLE 5-1 Well Statistics for Communities in Fall River Shubenacadie Lakes Watershed Study Area

Community	Statistic	Well Depth	Casing Length	Well Diameter	Well Yield	Static Water Level	Till Thickness
SPRINGFIELD LAKE	Minimum	50	12	6	1	3	1
	maximum	360	90	6	20	100	60
	Average	149	30	6	5	21	19
	Median	134	20	6	3	12	10
	STD	73	17	0	5	24	19
	N	40	39	37	40	23	39
WELLINGTON	Minimum	100	20	6	0	8	2
	maximum	306	65	6	20	40	200
	Average	174	33	6	5	26	35
	Median	162	22	6	2	30	14
	STD	50	17	0	7	16	49
	N	16	15	15	15	3	16
WELLINGTON STATION	Minimum	43	7	6	0	0	1
	maximum	405	225	6	76	140	225
	Average	185	41	6	4	27	33
	Median	172	23	6	2	20	12
	STD	90	32	0	7	28	42
	N	256	237	216	249	100	223
WINDSOR JUNCTION	Minimum	40	3	6	0	12	0
	maximum	750	365	8	30	201	235
	Average	220	77	6	4	45	65
	Median	200	44	6	3	28	39
	STD	118	71	0	6	46	59
	N	94	89	62	78	29	84

AECOM

Appendix B

Water Sampling Methodology

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List of Tables and Figures

1. Introduction

This Appendix describes the field methodology employed by AECOM to collect water samples and stream velocity measurements at selected sites within the Shubenacadie Lakes subwatershed.

2. Methodology

2.1 Water Quality Field Measurements

Water quality grab samples and field data were collected by AECOM staff on a quarterly basis for the duration of the sampling program (Table 2-1). The water quality sampling location was identified in the field by AECOM personnel for each of the following sampling stations. AECOM sampling stations in the Shubenacadie Lakes subwatershed are shown in green on Figure 7 in the main report.

Table 2-1 Water Quality Grab Samples – All Parameters

Station Name	Grand Lake Outlet	Fletchers Lake Outlet	Kinsac Lake Outlet	Lake Charles Outlet
Water Quality Grab Sample ID	HRM-SL-GL	HRM-SL-FL	HRM-SL-KL	HRM-SL-CL
Sample Coordinates	0457852, 4975516	0450796, 4967974	0450396, 4967853	0455905, 4954163
Sample Dates	2011/08/25	2011/08/25	2011/08/25	2011/08/25
	2011/11/03	2011/11/03	2011/11/02	2011/11/02
	2012/05/23	2012/05/23	2012/05/23	2012/05/23
	2012/08/08	2012/08/08	2012/08/08	2012/08/08

Note: NS = not sampled

Water quality grab samples were collected in laboratory-supplied bottles. Bottles that did not contain preservative were triple rinsed with flowing stream water and held at approximately 0.15 m below the surface water level to fill the bottle. Samples were immediately placed in a cooler with loose ice. Visual and olfactory observations of the water sample (odour, colour/clarity and/or suspended solids) were also documented by the AECOM field representative. The time the sample was collected was also recorded. One blank sample and one replicate sample were taken for each sample event. The water samples were transported to Maxxam Laboratories of Bedford, NS by AECOM and were submitted for laboratory analysis of:

1. Chloride
2. Chlorophyll α
3. fecal coliform by membrane filtration (most probable number, MPN/100 mL)
4. Nitrogen – nitrate (as N)
5. Nitrogen – nitrite
6. Nitrogen TKN – water (as N)
7. Total organic carbon – total (TOC),
8. Pheophytin A
9. Phosphorus – orthophosphate
10. Total suspended solids (TSS)
11. Turbidity,
12. Total phosphorus (TP) – low level detection limit

13. Dissolved phosphorus – low level detection limit

Additionally, water quality field data and grab samples for laboratory analysis of total suspended solids (TSS) were collected by AECOM personnel, generally on a monthly basis for the duration of the sampling program (Table 2-2).

Table 2-2 Water Quality Grab Samples – TSS

Station Name	Grand Lake Outlet	Fletchers Lake Outlet	Kinsac Lake Outlet	Lake Charles Outlet
Water Quality Grab Sample ID	HRM-SL-GL	HRM-SL-FL	HRM-SL-KL	HRM-SL-CL
Sample Coordinates	0457840, 4976524	0450787, 4967962	0457839, 4976355	0455900, 4954157
TSS Sample Dates	2011/08/25	2011/08/25	2011/08/25	2011/08/25
	2011/11/03	2011/11/03	2011/11/02	2011/11/02
	2012/01/18	2012/01/18	2012/01/18	2012/01/18
	2012/02/15	2012/02/15	2012/02/15	2012/02/15
	2012/03/20	2012/03/20	2012/03/20	2012/03/20
	2012/04/04	2012/04/04	2012/04/04	2012/04/04
	2012/05/23	2012/05/23	2012/05/23	2012/05/23
	2012/08/08	2012/08/08	2012/08/08	2012/08/08

Note: NS = not sampled

The water data and grab samples were collected by AECOM staff in accordance with industry technical standards. In-situ field water quality data was obtained using an AquaRead AquaMeter, calibrated within 12 hours prior to the beginning of each sampling event. The probe of the AquaMeter was placed in an area of the stream with unobstructed flow, free from thick vegetation, and with sufficient depth. Time was allowed for the measurements to reach equilibrium (generally 30-60 seconds) and the following data were recorded: temperature (^{O}C), oxygen reduction potential (ORP), pH, dissolved oxygen (DO), electrical conductivity (EC), total dissolved solids (TDS), salinity, and turbidity.

2.2 Stream Velocity Measurements

Stream velocity measurements were collected by AECOM personnel on a monthly basis (where possible) for the duration of the sampling program (Table 2-3). A suitable stream flow measurement location was identified in the field by AECOM staff at each station and prepared for future sampling by staking a stream cross-section.

Table 2-3 Stream Flow Measurements

Station Name and Coordinates	Stream Velocity Measurement Location	Stream Velocity Measurement Dates
Fletchers Lake Outlet (0450805, 4967906)	Approximately 50 m upstream of logger install (across from the pathway leading from the neighbour's yard)	• 2011/11/30 • 2012/01/18 • 2012/02/15 • 2012/03/20 • 2012/04/04 • 2012/05/23 • 2012/08/08
Kinsac Lake Outlet (0457839, 4976360)	Approximately 0.5 m upstream of logger install (upstream of bridge)	• 2012/01/18 • 2012/02/15 • 2012/04/04 • 2012/05/23 • 2012/08/08
Lake Charles Outlet (0455908, 4954160)	Base of bridge (upstream side)	• 2011/11/03 • 2011/12/01 • 2012/01/18 • 2012/02/15 • 2012/03/20 • 2012/04/04 • 2012/05/23 • 2012/08/08
Grand Lake Outlet (0445797, 4948422)	Approximately 0.5 m upstream of upstream side of bridge on Old Enfield Road	• 2012/04/04 • 2012/05/23*

Note: *water level artificially high at logger location due to extension of fishing wharf

Stream velocity measurements were collected by AECOM personnel in accordance with the Gartner Lee Limited Standard Operating Procedure *Stream Gauging Protocols and Methodology,* with the following modification: all flow measurements were taken at 60% of the total water depth in order to standardize the procedure at all water crossings.

Velocity measurements were always taken at the same location in order to develop a representative rating curve. The stream bottom and banks were stable and major rocks and boulders were be re-located if possible to minimize any backwater effects. The stream flow measurement transect was marked with survey stakes on the left and right bank or two points were marked for the crossing (e.g. flagging tape tied to trees). These markers were left in place so the future flow measurements could be made at the same location. At each stream flow measurement location, a cross section sketch and location sketch was prepared and the location was photographed. The number of vertical readings in the velocity measurement cross section was determined based on the stream width, generally using 10-15 evenly spaced verticals measurements were made per stream.

Stream velocity measurements were collected using a Flo-Mate Model 2000 unit. One person took stream flow measurements, across the channel always standing on the downstream side with the rod and meter upstream, while the other person recorded the reading. The velocity was recorded in the middle of the vertical, as shown in Figure 2-1, taking an average or stabilized flow rate over a 45 second period at 60% of the total depth. After the meter was positioned it was allowed to sit for approximately 10 seconds before turning it on so that any turbulence created by the operator was dissipated.

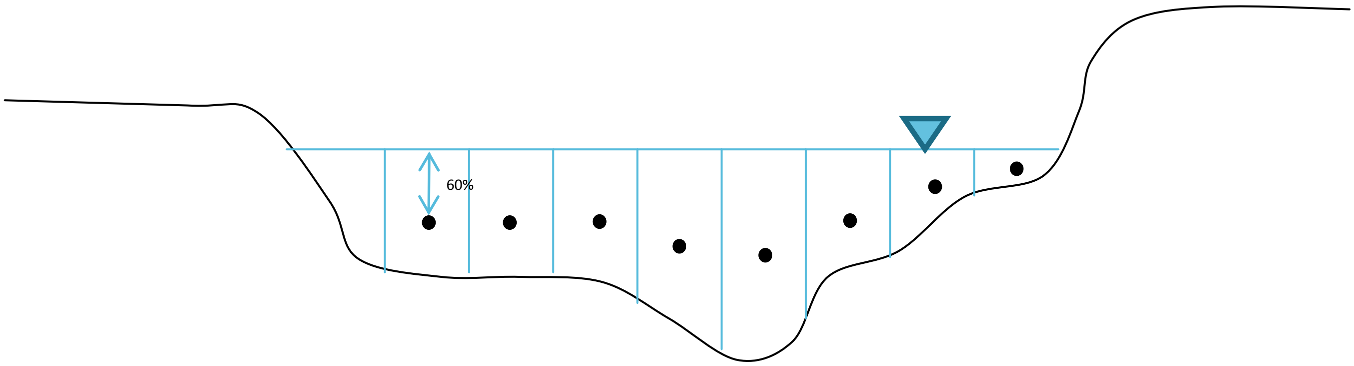


Figure 2-1 Flow Measurement Locations

The following information regarding stream flow measurements was recorded: adjacent land use, aquatic vegetation, substrates, flow (fast, moderate, slow, very slow, none), width of stream, vertical/tape distance, total depth, depth of meter, time and velocity.

2.3 Installation of Depth and Temperature Loggers

The logger installation methods varied according to the sampling station

Grand Lake Outlet: The temperature logger was originally installed upstream of the bridge on Old Enfield Road about 2 m from bank, but was moved to its permanent location on November 4, 2011. Both the depth and temperature loggers were installed on the base of a wharf extending approximately 2 m out into the stream and out into the main channel of the stream (just under the bridge). A long piece of angle iron was connected to two large circular bolts with plastic zip-ties, one at each end. The angle iron unit was then submerged under water and fastened to the leg of the wharf with zip-ties, creating a protective sleeve for the loggers. The loggers were then fastened to the wharf and to the angle iron using zip-ties and aircraft cable, then dropped down through the angle iron unit until the loggers were just touching the stream floor and protected from any potential damage from debris. During the August 8, 2012 sampling event, the sampling team discovered that most of the extended fishing wharf and the temperature and depth loggers had been removed.

Fletchers Lake Outlet: The temperature logger was installed approximately 3-4 m from the stream bank across the stream from the pathway leading from the neighbour's yard, under 3 rocks in a row. The temperature logger could not be relocated. The depth logger was installed using a cinderblock weighted unit placed on the stream bed in the main channel of the stream, approximately 50 m upstream of logger install. A long piece of angle iron was fastened to a cinderblock using concrete screws and plastic zip-ties. A long piece of plastic PVC pipe was then fastened to the angle iron using a metal pipe clamp, creating a protective sleeve for the logger. The logger was then fastened to the angle iron and the PVC using zip-ties and aircraft cable, then dropped down through the PVC until the logger was on the stream bed and protected from any potential damage from debris. The cinderblock was carefully positioned in the stream such that the cinder would not obstruct flow reaching the logger and secured in place using native rocks located onsite. The primary logger was replaced with a new depth logger following approximately a month of data collection, as there was some question regarding its functionality.

Kinsac Lake Outlet: Both the depth and temperature loggers were installed using a cinderblock weighted unit placed on the stream bed in the main channel of the stream, approximately 5 m upstream of the bridge. The construction method described above (Fletchers Lake Outlet) was used.

Lake Charles Outlet: Both the depth and temperature loggers were installed using a cinderblock weighted unit placed on the stream bed in the main channel of the stream, approximately 10 m upstream of the bridge. The construction method described above (Fletchers Lake Outlet) was used. A second depth logger was added to the primary logger following approximately two months of data collection in order to QA/QC the data being collected, as there was some question regarding its functionality. During the August 8, 2012 sampling event, the sampling team discovered that the primary depth logger (#45329) had been removed.

2.4 Retrieval of Data from Automated Sampling Installations

Temperature and depth loggers were installed at the following locations by AECOM staff and downloaded on a monthly basis (where possible) for the duration of the sampling program (Tables 2-4 and 2-5):

Table 2-4 Temperature Loggers

Station Name and Coordinates	Logger Name	Temperature Logger Serial Number	Temperature Logger Installation Date	Temperature Logger Download Dates
Grand Lake Outlet (0457840, 4976524)	HRM-SL-Grand_Outlet	10000015	2011/10/02	• 2011/10/31 • 2011/11/30 • 2012/01/18 • 2012/02/15 • 2012/03/20 • 2012/04/04 • 2012/05/23
Fletchers Lake Outlet (0450786, 4967963)	HRM-SL-Fletchers_Outlet	10000017	2011/10/02	• 2012/05/23 • 2012/08/08
Kinsac Lake Outlet (0457839, 4976355)	HRM-SL-Kinsac	10000016	2011/10/02	• 2011/10/31 • 2011/11/30 • 2012/01/18 • 2012/02/15 • 2012/03/20 • 2012/04/04 • 2012/05/23 • 2012/08/08
Lake Charles Outlet (0455900, 4954157)	HRM-SL-Charles_Outlet	10000130	2011/10/12	• 2011/11/02 • 2011/12/01 • 2012/01/19 • 2012/02/15 • 2012/03/20 • 2012/04/04 • 2012/05/23 • 2012/08/08

Table 2-5 Depth Loggers

Station Name and Coordinates	Logger Name	Depth Logger Serial Number	Depth Logger Installation Date	Depth Logger Download Dates
Grand Lake Outlet (0457840, 4976524)	HRM-SL-Grand_Outlet	0051032510	2011/11/04	• 2011/11/30 • 2012/01/18 • 2012/02/15 • 2012/03/20 • 2012/04/04 • 2012/05/23
Fletchers Lake Outlet (0450787, 4967962)	HRM-SL-Fletchers_Outlet HRM-SL-Fletchers_Outlet_Rep	1021159 K6294	2011/11/30 2012/01/18	• 2012/01/18 • 2012/02/15 • 2012/03/20 • 2012/04/04 • 2012/05/23 • 2012/08/08
Kinsac Lake Outlet (0457839, 4976355)	HRM-SL-Kinsac	0015021159	2011/11/04	• 2011/11/30 • 2012/01/18 • 2012/02/15 • 2012/03/20 • 2012/04/04 • 2012/05/23 • 2012/08/08
Lake Charles Outlet (0455900, 4954157)	HRM-SL-Charles_Outlet HRM-SL-Charles_Outlet_QAQC	45329 K5998	2011/11/03 2012/01/18	• 2011/12/02 • 2012/01/18 • 2012/02/15 • 2012/03/20 • 2012/04/04 • 2012/05/23 • 2012/08/08*

Appendix C

Hydrometrics

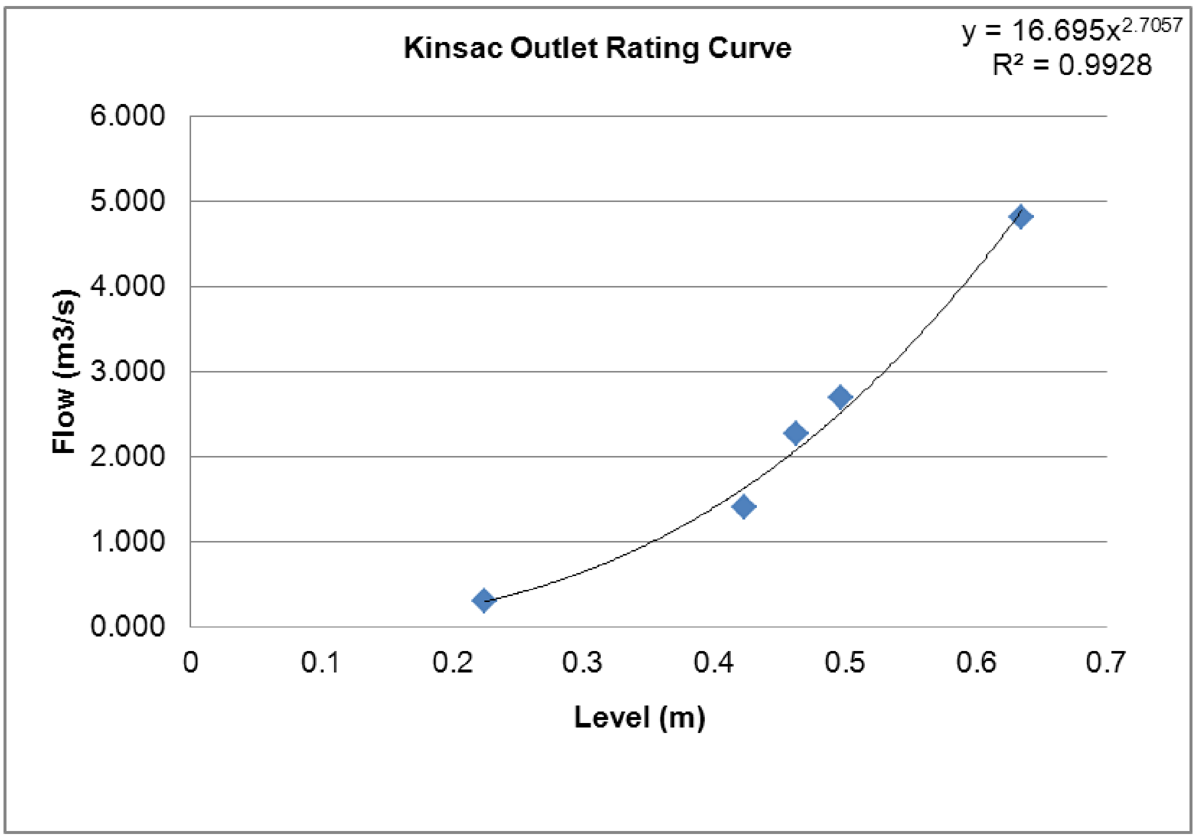
Hydrometric Monitoring Data

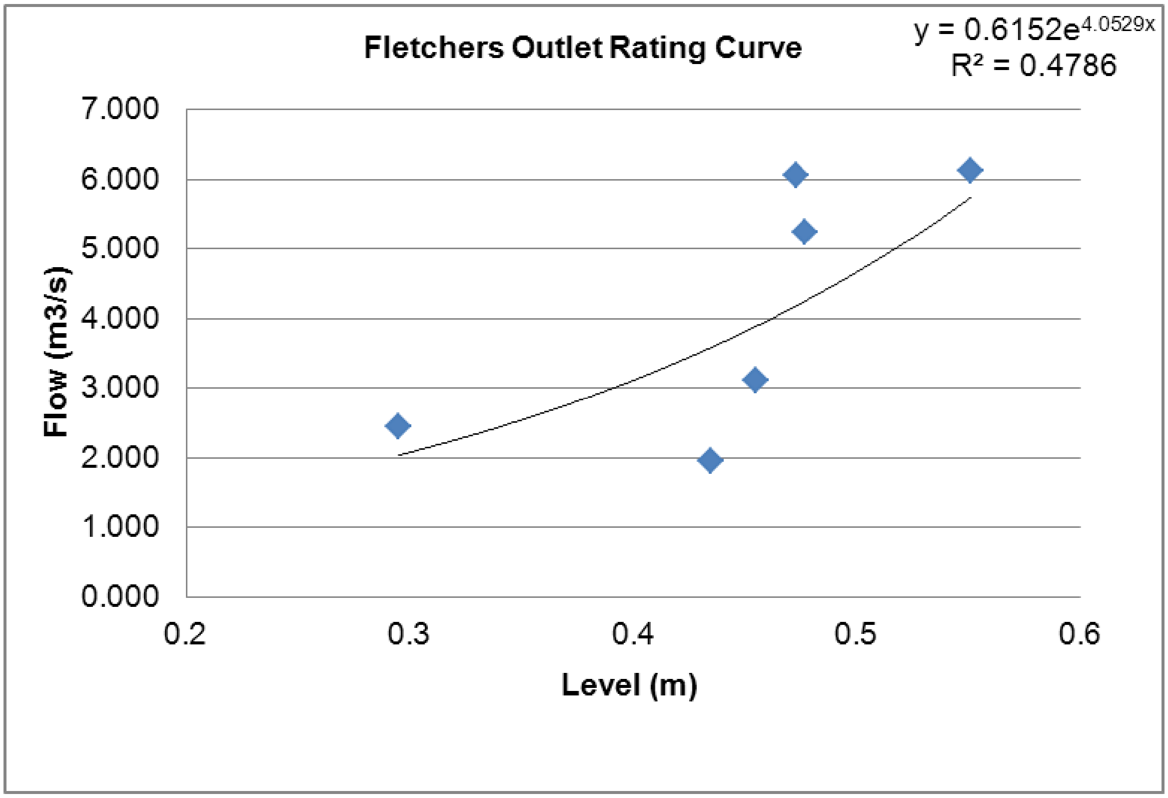
Four flow monitoring stations were established in the Shubenacadie Watershed. A map of station locations has been included in Figure 7 of the main body of the report. At each monitoring location, a depth logger was installed and flow measurements were collected monthly to develop a stage discharge relationship or a rating curve. The stage discharge relationship was uses to estimate a continuous flow record for the period of monitoring.

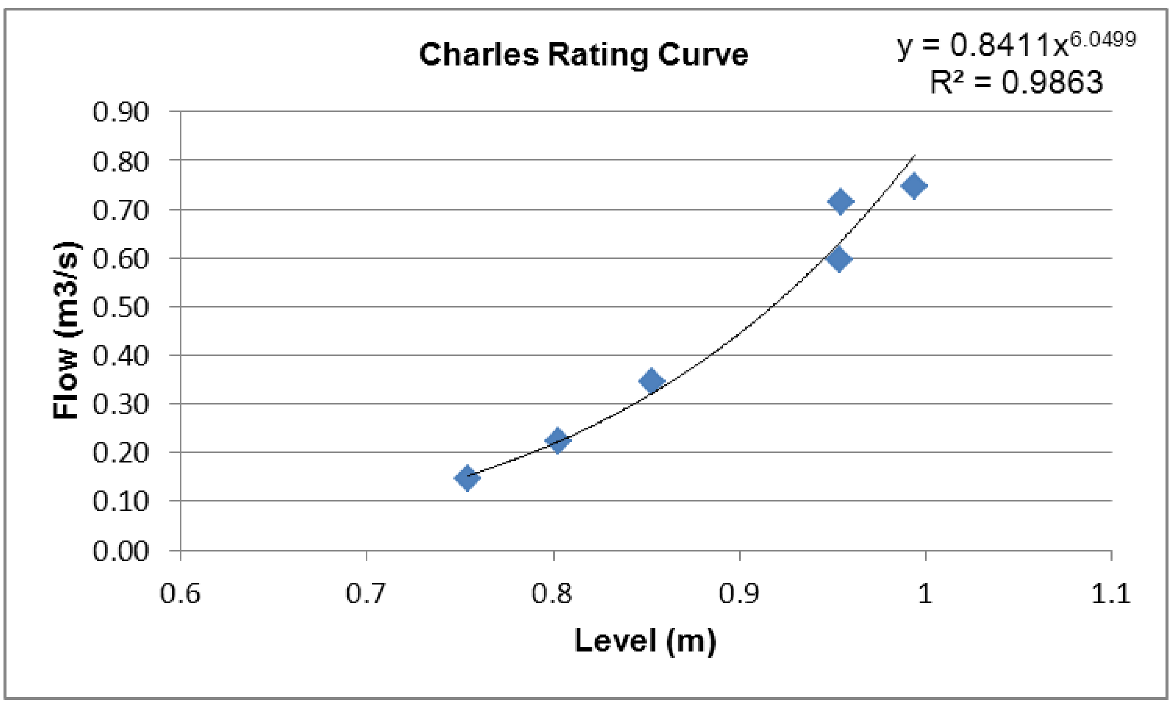
Stage discharge relationships were developed for three locations: Charles Lake, Fletchers Lake and Kinsac Lake. A level logger was also installed at the outlet of Grand Lake; however flow conditions (such as high velocity) often prohibited stream flow measurements from being collect. This resulted in insufficient data to develop a rating curve for Grand Lake.

Some of the larger storm events captured over the course of the monitoring period exceeded the capacity of the rating curve. As such the flows for the larger storm events are estimated values.

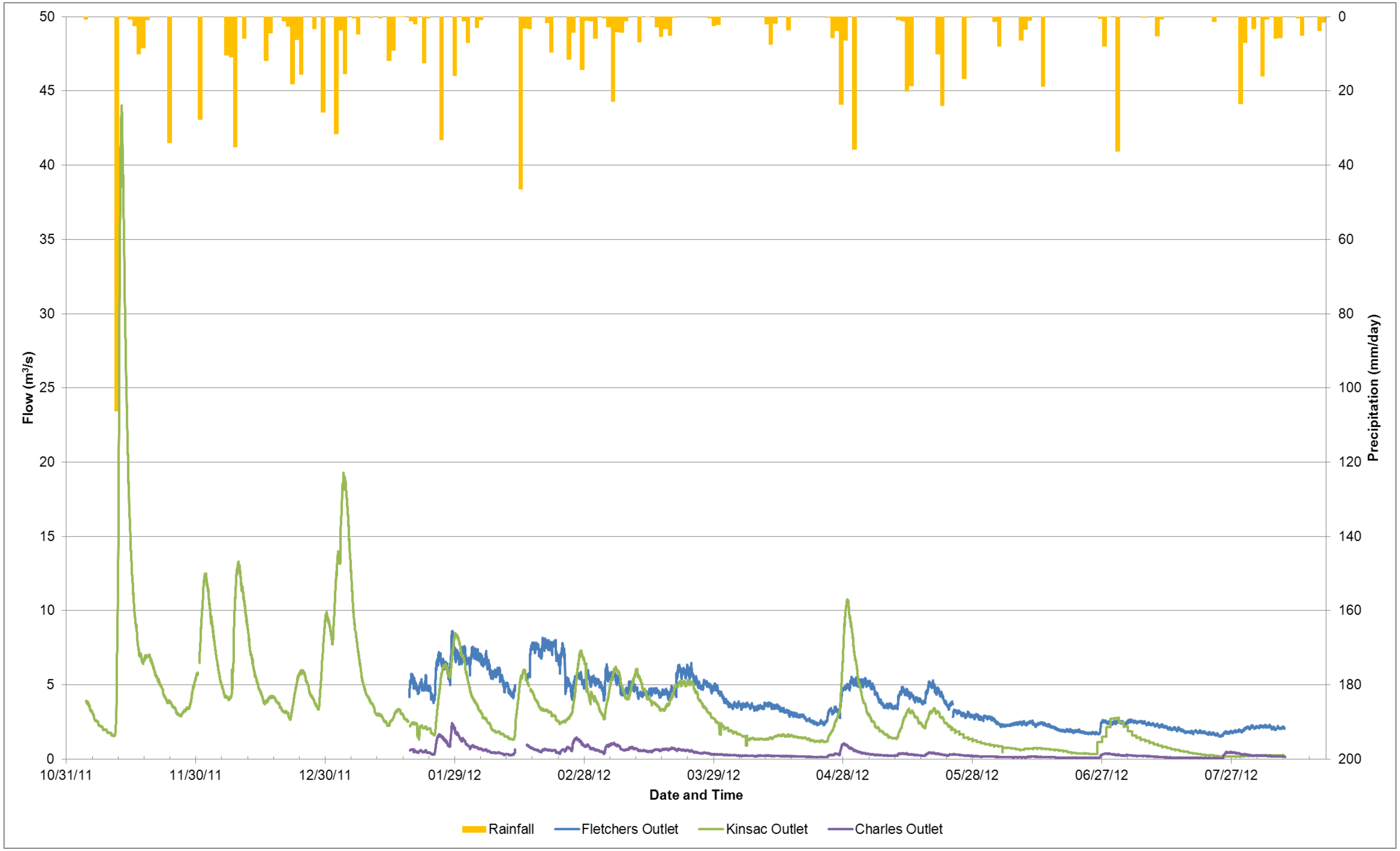
Rating Curves

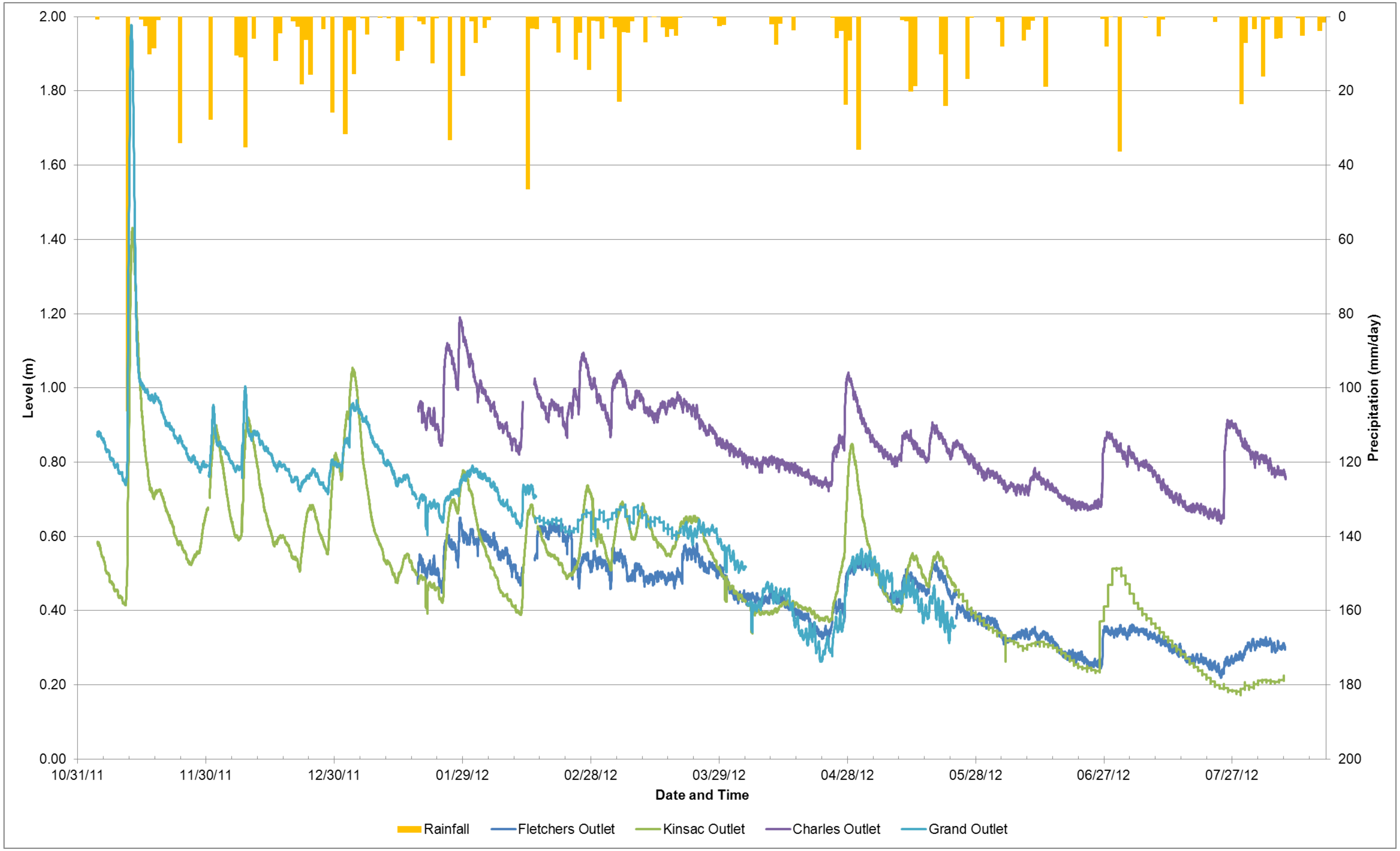



Fletchers Outlet Rating Curve
y = 0.6152e^4.0529x
R² = 0.4786
Flow (m3/s)
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
0.2
0.3
0.4
0.5
0.6
Level (m)


Charles Rating Curve
y = 0.8411x^6.0499
R² = 0.9863
Flow (m3/s)
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.6
0.7
0.8
0.9
1
1.1
Level (m)

Hydrograph and Water Level Plots




2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Level (m)
0
20
40
60
80
100
120
140
160
180
200
Precipitation (mm/day)
10/31/11
11/30/11
12/30/11
01/29/12
02/28/12
03/29/12
04/28/12
05/28/12
06/27/12
07/27/12
Date and Time
Rainfall
Fletchers Outlet
Kinsac Outlet
Charles Outlet
Grand Outlet

Appendix D

Background Report Analysis of GIS Files and Sources

Background Report Analysis of GIS Files and Sources

Source	Map Name	Map Details	Report Name	Location	Status	Notes
County of Halifax	Location Map, Districts 14 & 17, Ex.3-2		Shubenacadie Lakes Planning/Pollution Control Study	Project file background report. Received from HRM		Vaughan Eng., 1993
	Slate, Mining Contaminants & wateshed Contratints, Ex. 8-1a					
	Slate, Mining Contaminants & wateshed Contratints, Ex. 8-1b					
	Poor Soil Constraints, Ex. 8-2a					
	Poor Soil Constraints, Ex. 8-2b					
	Slope Constraints, Ex. 8-3a					
	Slope Constraints, Ex. 8-3b					
	Watercourse Constraints, Ex. 8-4a					
	Watercourse Constraints, Ex. 8-4b					
	Remoteness Constraints, Ex. 8-5a					
	Remoteness Constraints, Ex. 8-5b					
	Zones of Development Senisitivity, Ex. 8-6a	Colour coded for suitable development: moderate, low, very low, soil condition, slope				
	Zones of Development Senisitivity, Ex. 8-6b	Colour coded for suitable development: moderate, low, very low, soil condition, slope				
	Servicing Strategy, Ex. 11-1	4 categories: on lot/on site, managed on sie, shared/collective, proposed road				
HRM	Land Use & Transportaiton Plan, Port Wallis, 1A	study boundry, pot. Boundry,water lines,sewerlines,prop. Rte, inland water rte,coastal water rte,transit rte,future transit rte,trails,future transit hub,prp residential,prp comm.,lakes, wetland area&buffer, wetland watercourse&buffer	Cost of Servicing Plan, Regional Planning Greenfield Sites	Project file background report. Received from HRM		CBCL Limited, Report No. 07165, 2009
	Servicing, Port Wallis, 1B	study area,prp gravity san.sewer,exist gravity sewer, prp forcemain, prp san pump stn., exist san pump stn, prp san MH, exist san MH, prp watermain, exist watermain, prp reservoir, exist resevoir, prp press reducing valve chamber, exist press reducing valve chamber				
	Land Use & Transportaiton Plan, Sandy Lake, 2A	study boundry, phase boundry, waterlines, sewerlines, prp trans rte, inland water rte, coastal water rte, transit rte, future transit rte, future transit hub, prp residential, prp comm, prp indust, HRM lands, exist dev, lakes, wetland areas & buffers, wetland/watercourse buffer				
	Servicing, Sany Lake, 2B	study area,prp gravity san.sewer,exist gravity sewer, prp forcemain, prp san pump stn., exist san pump stn, prp san MH, exist san MH, prp watermain, exist watermain, prp reservoir, exist resevoir, prp press reducing valve chamber, exist press reducing valve chamber				

Background Report Analysis of GIS Files and Sources

Source	Map Name	Map Details	Report Name	Location	Status	Notes
HRM, con't	Land use and Transportation Plan, Hwy 102 W Corridor, 3A	study area,prp gravity san.sewer,exist gravity sewer, prp forcemain, prp san pump stn., exist san pump stn, prp san MH, exist san MH, prp watermain, exist watermain, prp reservoir, exist resevoir, prp press reducing valve chamber, exist press reducing valve chamber	Cost of Servicing Plan, Regional Planning Greenfield Sites	Project file background report. Received from HRM		
	Servicing Hwy 102 W Corridor, 3B	study area,prp gravity san.sewer,exist gravity sewer, prp forcemain, prp san pump stn., exist san pump stn, prp san MH, exist san MH, prp watermain, exist watermain, prp reservoir, exist resevoir, prp press reducing valve chamber, exist press reducing valve chamber				
HRM	Figure 6-1	Areas where sewer services have been or may be extended, water service districts, watersheds	HRM Water Resource Management Study	project file background report		Dec. 2002
HRM	page 29	Shows 46 Watershed divides of Nova Scotia	Water for Life: Nova Scotia's water resource management strategy	project file background report		
HRM, updated by Annapolis Group Inc.	Figure 1.1, Bedford West Planning Area		Bedford West Planning Area, Subwatershed Management Plan	project file background report		Jacques Whitford, May 2004
	Figure 3.1, watersheds in the Bedord West Planning Area	Areas 1, 2A, 2B, 3, 4A, 4B, 5A, 5B				
	Figure 4.1, Land Use Existing Development	Crown lands, rural resid., urban resid., indust., comm., hwy 102 & 113, institutional, park				
	Figure 5.1, Wetlands	planning areas, roads, watercourse, contour, waterbody, land, wetlands				
	Figure 5.2, Services in & Around Bedford West Study Area	Bedford West study area, rural central water & onsiet sewage, rural onsite services, urban central water & sanitary				
	Figure 5.3, Slopes in the Bedford West Planning Area	red = grade between 15%&20%, green = grade greater then 20%				
	Figure 5.4, Soils Map	colour coded for: aspotogan, bridgewater, castley, gibraltar, halifax, rockland, water, wolfville, roads, watercourse, waterbody				
City of Halifax	1.1	Study Area	Birch Cove Lakes Area Environmental Study, Task 2 Report	Project file background report. Received from HRM		Porter Dillon, Prj # 94-1872-04-01, 1996
	Map 2.1 - Scale 1:25000	Topographic Base Map				
	Map 2.2 - Scale 1:25000	Slopes				
	Map 2.3 - Scale 1:25000	Physiography				
	Map 3.1 - Scale 1:25000	Drainage Divides and Bathymetry				
	Figure 3.2	Water Quality Sample Sites Outside Primary Study Area				
	Map 4.1 - Scale 1:25000	Significant Tree Stands				
	Map 4.2 - Scale 1:25000	Rare Species				
	Map 4.3 - Scale 1:25000	Significant Wetlands				
	Map 5.1 - Scale 1:25000	Bedrock Geology				
	Map 5.2 - Scale 1:25000	Soils				
	Figure 6	Water Quality Sample Sites Outside Primary Study Area				

Background Report Analysis of GIS Files and Sources

Source	Map Name	Map Details	Report Name	Location	Status	Notes
City of Halifax, con't	Map 6.1 - Scale 1:25000	Shoreline Classification	Birch Cove Lakes Area Environmental Study, Task 2 Report	Project file background report. Received from HRM		
	Map 7.1 - Scale 1:25000	Viewshed 1				
	Map 7.2 - Scale 1:25000	Viewshed 2				
	Map 7.3 - Scale 1:25000	Viewshed 3				
	Map 7.4 - Scale 1:25000	Viewshed 4				
	Map 7.5 - Scale 1:25000	Viewshed 5				
	Map 7.6 - Scale 1:25000	Viewshed 6				
	Map 7.7 - Scale 1:25000	Approximate Waterbody Viewshed				
	Map 7.8 - Scale 1:25000	Special Places				
	Map 8.1 - Scale 1:25000	Land & Resource Use				
	Map 9.1- Scale 1:25000	Heritage Resources				
	Map 11.1 - Scale 1:25000	Suitability for Low and Medium Density Residential Dev.				
	Map 11.2 - Scale 1:25000	Assets for Low ansd Medium Density Residential				
	Map 11.3- Scale 1:25000	Suitability for High Density Residential				
	Map 11.4 - Scale 1:25000	Assets for High Density Residential & Large Scale Commercial & Indust. Dev.				
	Map 11.5 - Scale 1:25000	Suitability for Large Scale Commercial and Developed Recreational Facilities				
	Map 11.6 - Scale 1:25000	Assets for Developed Recreation Facilities				
	Map 11.7 - Scale 1:25000	Suitability for Passive Recreation				
	Map 11.8 - Scale 1:25000	Assets for Passive Recreation				
NS Dept. of Trans.	Figure 9-5.1	GPS Collar Data of Six Different Moose, Jan 04-Mar 06	Nova Scotia Dept. of Transportation & Infrastructure Renewal, Highway 113, EA	Project file background report. Received from HRM		Dillon, Prj. # 08-9611-1000, Nov. 2009
	Figure 9-5.2	Results of Winter Survey, Jan 03 Where a Min. of 25 Moose at 12 locations				
	Figure 9-5.3	Results of Winter Survey, Jan 09 Where a min. of 28 Moose at 13 locations				
Annapolis Group Inc.	Figure 1, Scale 1:5000	Papermill Lake Bathymetric Map	Water Quality Impact Assessment of Water Bodies Contained in the Bedford West Planning area using a Phosphorus Loading Model Approach	Project file background report. Received from HRM		Rep # 04-02: RS Scott & WC Hart, Centre for Water Resources Studies Dalhousei University, April 2004
	Figure 2, Scale 1:5000	Kearney Lake Bathymetric Map				
	Figure 3, Scale 1:5000	Washmill Lake Bathymetric Map				
	Figure 4, Scale 1:5000	Quarry Lake Batheymentric Map				
	Figure 5, Scale 1:5000	Susies Lake Bathymetric Map				
	Figure 6 - Existing & Future Land Use Distribution	Crown lands, rural resid., urban resid., indust., comm., hwy 102 & 113, institutional, park				
	Figure 1 - Bedford West Study Area, Watershed Delineation	Floe direction, steam, street, storm sewer, contour-25m intervals, contour-5m intervals, watershed boundary, sub-watershed boundary, lake, crownland	Appendix A - Bedford Watershed Area			CBCL - Jan. 2004
	Land Use Distribution Existing, Bedford West, Bedford South & Papermill Lake	Crown lands, rural resid., urban resid., indust., comm., hwy 102 & 113, institutional, park	Appendix A - Bedford Watershed Area			Feb. 2004
	Bedford Dams	Existing Development Model Schematic	Appedix B - Bedford Model Schematic			SGE Acres - Bedford Dams Stomwater Management Study

Background Report Analysis of GIS Files and Sources

Source	Map Name	Map Details	Report Name	Location	Status	Notes
HRM	Figure 5.1, Property Ownership	Annapolis Basin, Sisters of Charity, Crown, City of Halifax Park, Other	Birch Cove Lakes Environmental Study	Project filing background report. Revieved from HRM		Porter Dillon, Prj.#94-1872-04, Jan. 1996
	Figure 6.1 - Scale 1:25000	Conceptual Collector Road Network and Study Area Access Points				

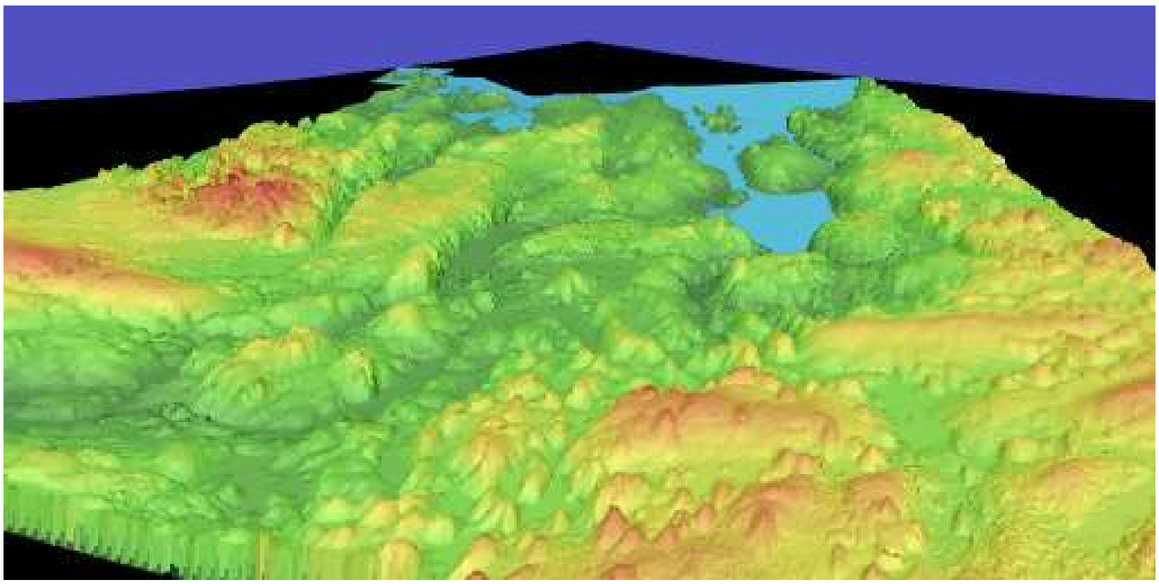
AECOM

Appendix E

Lidar Surface Modeling

Lidar surface Modeling for the

Halifax Regional Municipality



By

Dr. Tim Webster and Lyly Ngo

Applied Geomatics Research Group

NSCC Middleton

For

John Charles and Roger Wells

Halifax Regional Municipality

Contents

List of Figures

Introduction

The Halifax Regional Municipality had BHP acquire airborne lidar for two large sections of the municipality in 2007, the surrounding area of Halifax harbor consisting of 1170 km^2 and another area along the coast to the west (Fig. 1). The data were acquired using an Optech ALTM 2050 operating with a laser pulse repetition frequency of 50 kHz and recorded the first and last laser returns. The scan angle was 20 degrees either side of nadir with an average flying height of 1200 m above the ground. The survey was conducted between May 12th and 15th, 2007 and consisted of 6 flights. These lidar point data were classified by the data provider into “ground” (.GRD) and delivered as ASCII files, as well as a set of points representing first returns (.FST) and another representing the last returns (.LST). The ASCII files were delivered in 1 km tiles that did not have any overlap between them. As a result, when the lidar points were used to construct a gridded surface, in the case of ground points the production of a DEM, seams existed between the grids. This is a result of edge artifacts introduced by the gridding process, regardless of which method is used, at the edge of the tiles. The Geological Survey of Canada constructed a preliminary DEM where all of the smaller DEM tiles were used to build a large mosaic. However, as mentioned, the mosaic contained the seams between the tiles. Monette and Hopkinson of AGRG processed the ASCII ground points into a DEM for the tiles surround the harbor only. While doing that project they established a TerraScan™ project that had overlapping blocks for the entire study area, although only the tiles or blocks adjacent the harbor were processed to build a seamless DEM. The DEM was constructed using the Inverse Distance Weighting (IDW) method in Surfer™. The resultant surface was then used and the waterfront was “cleaned” to remove objects in the water such as floating docks, ships, etc. and ensure the wharves and jetty edges of the model were sharp. This was a manual and time consuming process conducted by Monette and Hopkinson. An additional contract to Monette and Hopkinson of AGRG was given to examine the coastal area of Cole Harbor for coastal flooding and the condition of the lidar. It was during this exercise that possible discrepancies with the constraint of lidar acquisition during low tide may not have been strictly adhered to by BHP as the elevation of the lidar flight lines over water was variable.

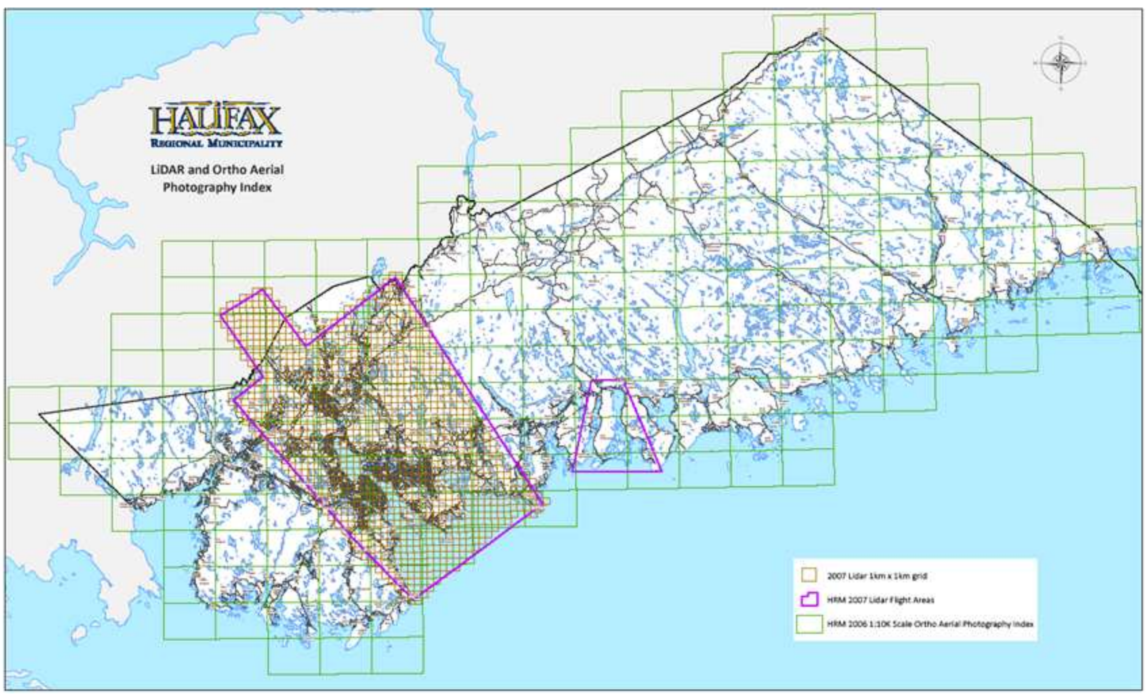


Figure 1 Extent of the lidar survey area conducted May, 2007. The purple outline around Halifax Harbor with the 1 km grid (brown) was the focus of this project.

The purpose of this research contract was to re-build the DEM from the lidar ground points for the entire study area, ensuring it was a seamless product and to incorporate the cleaned harbor DEM that was previously constructed. In addition to this, we were to further investigate and document the state of the tide during the lidar acquisition in the Cole Harbor area. After discussions with staff at HRM, it was decided to also build two other surface models from the lidar data; a Digital Surface Model (DSM) which represents all of the valid lidar returns, “ground points” and “non-ground points” which could include buildings and trees, as well as a Normalized Height Model (NHM) which is constructed by subtracting the DEM from the DSM which effectively represents the height of the objects above the ground, ie. Tree or building heights. The surface models were to be at variable resolutions including grid cells of 1 m, 2 m, and 5 m. In addition to producing the surface models, which can be used for analysis but are cumbersome for direct visualization and interpreting the terrain or height of objects, Colour Shaded Relief (CSR) image maps were also produced in JPEG2000 format. This format allows for large datasets to be managed easier and can be used directly in GIS of a backdrop to visualize and interpret the terrain. The lidar data and other surface models (ie. The harbor DEM) were delivered to HRM in a UTM Zone 20 NAD83 map projection with elevations relative to CGVD28 based on the HT2 geoid-ellipsoid undulation model supplied by NRCan. The DEM, DSM, and NHM Arc grid models at the resolutions and the CSR maps were constructed in a UTM projection. The ArcGIS™ grids of the multiple surface models at the variable resolutions were also projected into the Modified Transverse Mercator projection for zone 5 based on the ATS777 datum (MTM zone 5 ATS77).

Methods

Recall that the original data were delivered in tiles without overlap (Fig. 2). This current project took advantage of a Terrascan™ project that had previously been established where each tile or block had a 40 m overlap (Fig. 3). The ASCII files

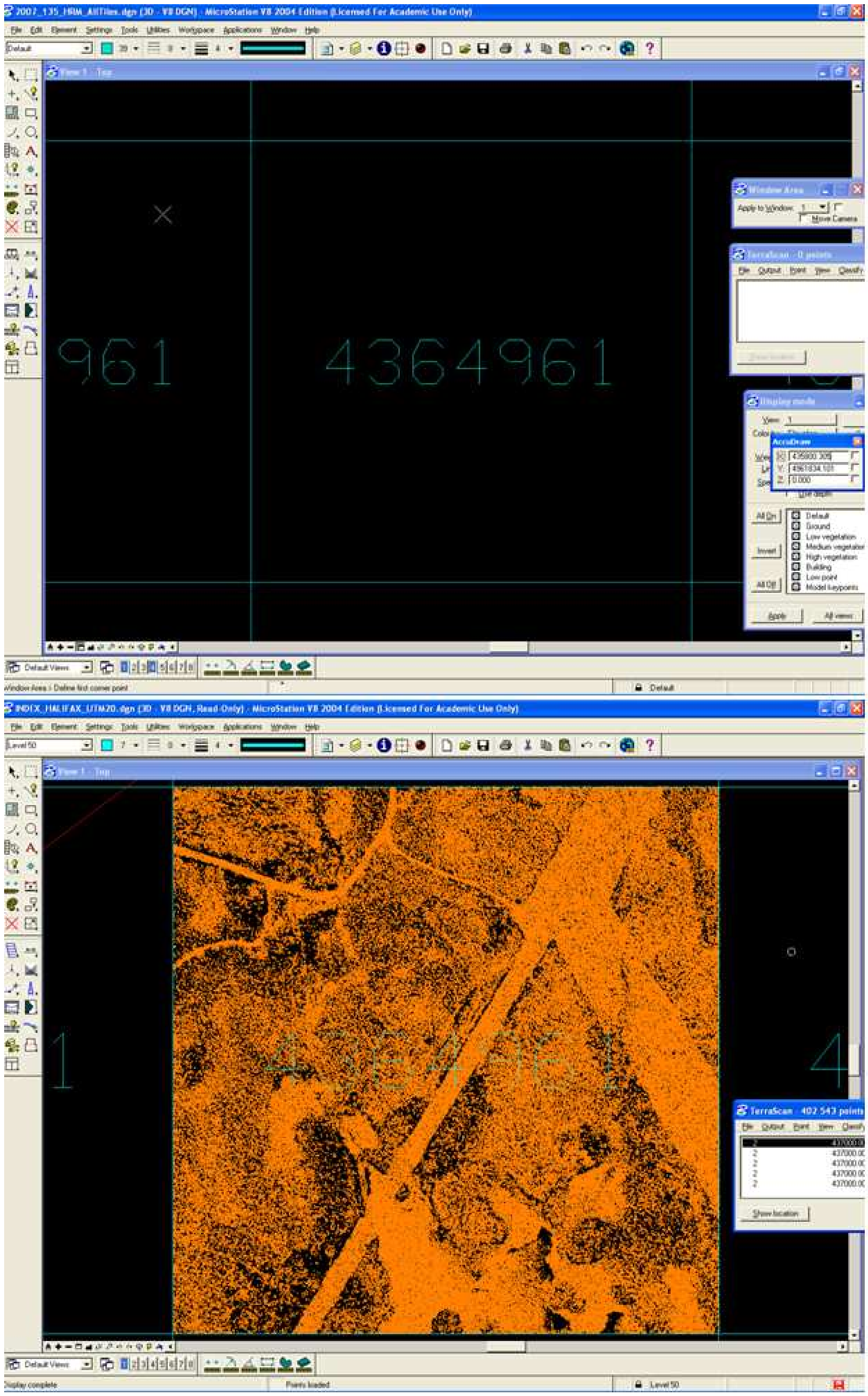


Figure 2 original tile boundary (top) and with the ground points (bottom) coloured orange. Note there is no overlap between tiles.

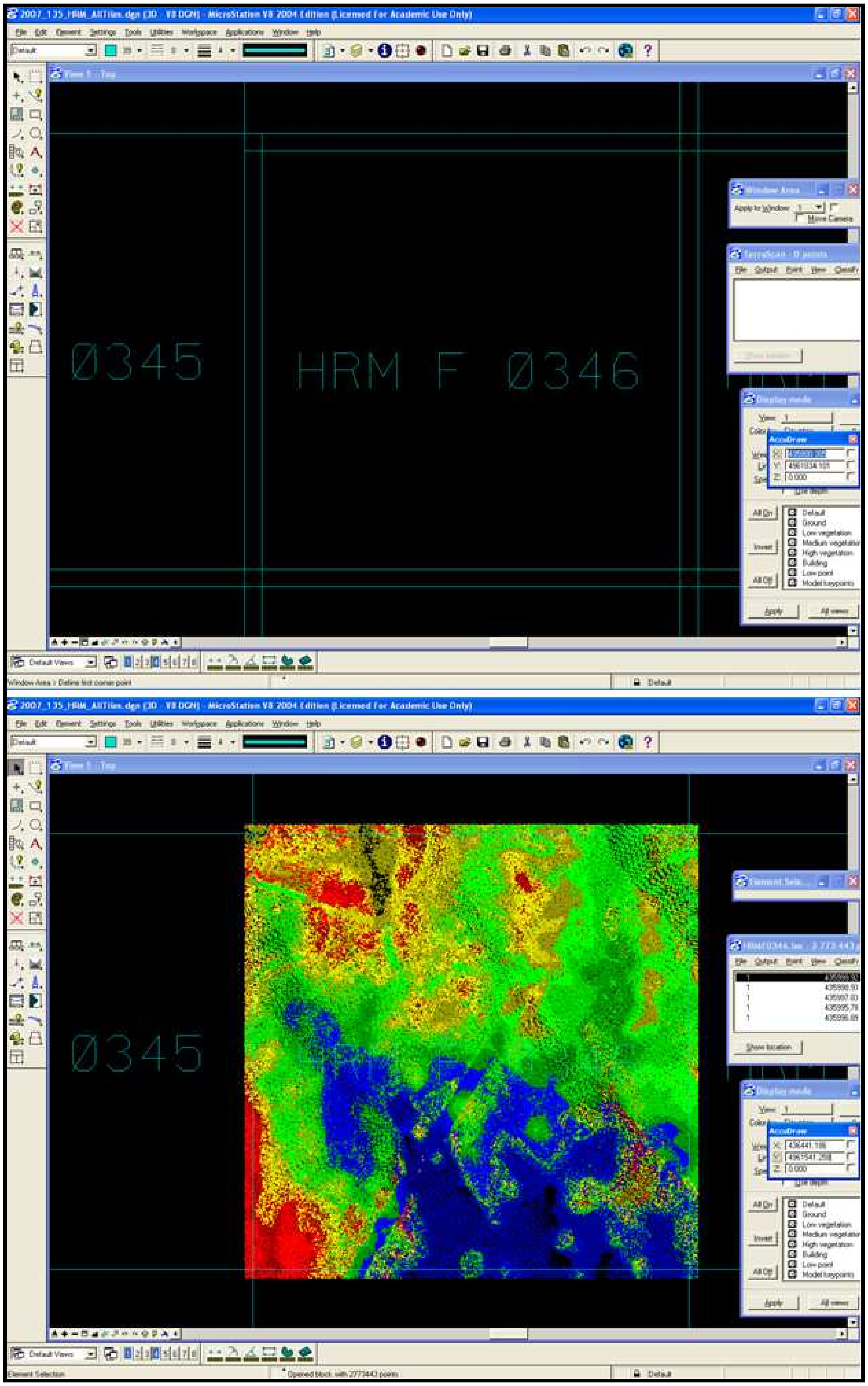


Figure 3 New tiles with 40 m overlap (top). The ASCII points were read into this new project and blocked with 40 m overlap. The points are colour coded by elevation with the original boundary (bottom).

representing the ground were then read into this project and new binary LAS files generated. In addition to this Terrascan™ project, another project was established to read the ASCII first and last points, which effectively represents all of the lidar returns, into Terrascan and blocked with the overlap and new LAS files produced. The ground LAS files were then interpolated into a series of DEM tiles using the Lidar Toolkit produced by Giamatics where the edges were trimmed by 10 m, thus removing erroneous values inherent in the interpolation process. The interpolation method used was IDW, since the new DEM had to be consistent with the harbor DEM which was constructed using the IDW method. In the case of the harbor DEM, Surfer™ was used to interpolate the surface. The Lidar toolkit parameters are not identical to those in Surfer™ , thus some experimentation was conducted to ensure that the DEM surface outside of the harbor DEM was very similar and could easily be blended to form a continuous model. The individual 1 m DEM tiles were then used to construct a large mosaic of the study area. This proved to be very challenging because of the file size and number of blocks. This could only be achieved by constructing smaller mosaics representing 3-4 rows of blocked DEMs, then mosaicking these subsections together. The resultant 1m DEM mosaic was then imported into PCI Geomatica™ along with the harbor DEM and a model was written to merge the harbor DEM with the large mosaic. This resulted in a DEM for the entire area that had clean sharp edges along the harbor. This mosaic was then shaded and inspected for other possible issues. Since the IDW method was used to interpolate the surface and it uses a search radius in which points are given a higher weighting the closer you are to them and the Z value decays to nothing as one moves farther away from them (inverse distance weighting), areas of sparse points are represented as “no data” in the resultant DEM surface. This would occur in areas of no “ground points” such as building locations or in the case of lakes or smooth water where no lidar returns were recovered. Since part of our objective was to build a continuous model for the DEM and use this in combination with the DSM, which would not have holes in the surface for the buildings for example, to construct a normalized height model (DSM-DEM), we proceeded to fill the holes in the DEM. In the case of holes generated as a result of a building location, the holes were replaced based on the surrounding elevation values. In the case of the lakes where some lidar returns were recorded but not for the entire lake, we used the mean elevation of the lake based on the lidar surfaces and the 1:10,000 NSTDB GIS layer to fill the holes and replace the lake surfaces. This proved satisfactory for most of the lakes, however it did cause some issues as a result of the vintage of the lake layer being older than the lidar and changes that had occurred on the landscape. This is addressed later in the report.

Another TerraScan™ project was established that utilized the same set of 1040 m overlapping tiles and the first (.FST) and last (.LST) ASCII lidar points were imported. The resultant blocked LAS files were then used to construct a new lidar surface which is termed the Digital Surface Model (DSM) which utilized all of the points (ground points were classified by BHP from the first and last returns). Since we wanted to represent buildings and other features that had sharp elevation discontinuities as accurately as possible in the raster model, a Triangular Irregular Network (TIN) was constructed and a linear interpolation to a 1 m grid cell was applied. The IDW method has a tendency to smooth sharp edges and blur such features as a result of its weighted averaging and distance decay characteristics. The DSM is an important surface to construct and is done routinely in Webster's group at AGRG. The reason it is important is the fact it uses all of the valid lidar returns and facilitates the identification of possible "ground" classification errors. Once the DSM & DEM were constructed they were colourized and merged with the shaded relief (hill shade from the northwest 315 degrees at an angle of 45 degrees to the horizon and a 5 times vertical exaggeration applied) to form colour shaded relief maps (CSR). These maps were used to facilitate a visual assessment of the data. After close inspection of the entire dataset it was observed that there were holes in the DEM at locations that were not expected, ie. Not buildings or lakes. By comparing if the holes existed in both the DEM and DSM, then one could surmise that no lidar points were recorded, as often happens over specular surfaces such as smooth water. However, if the holes existsed in the DEM, but not in the DSM, then this implies that the "ground" classification was in error (Fig. 4).

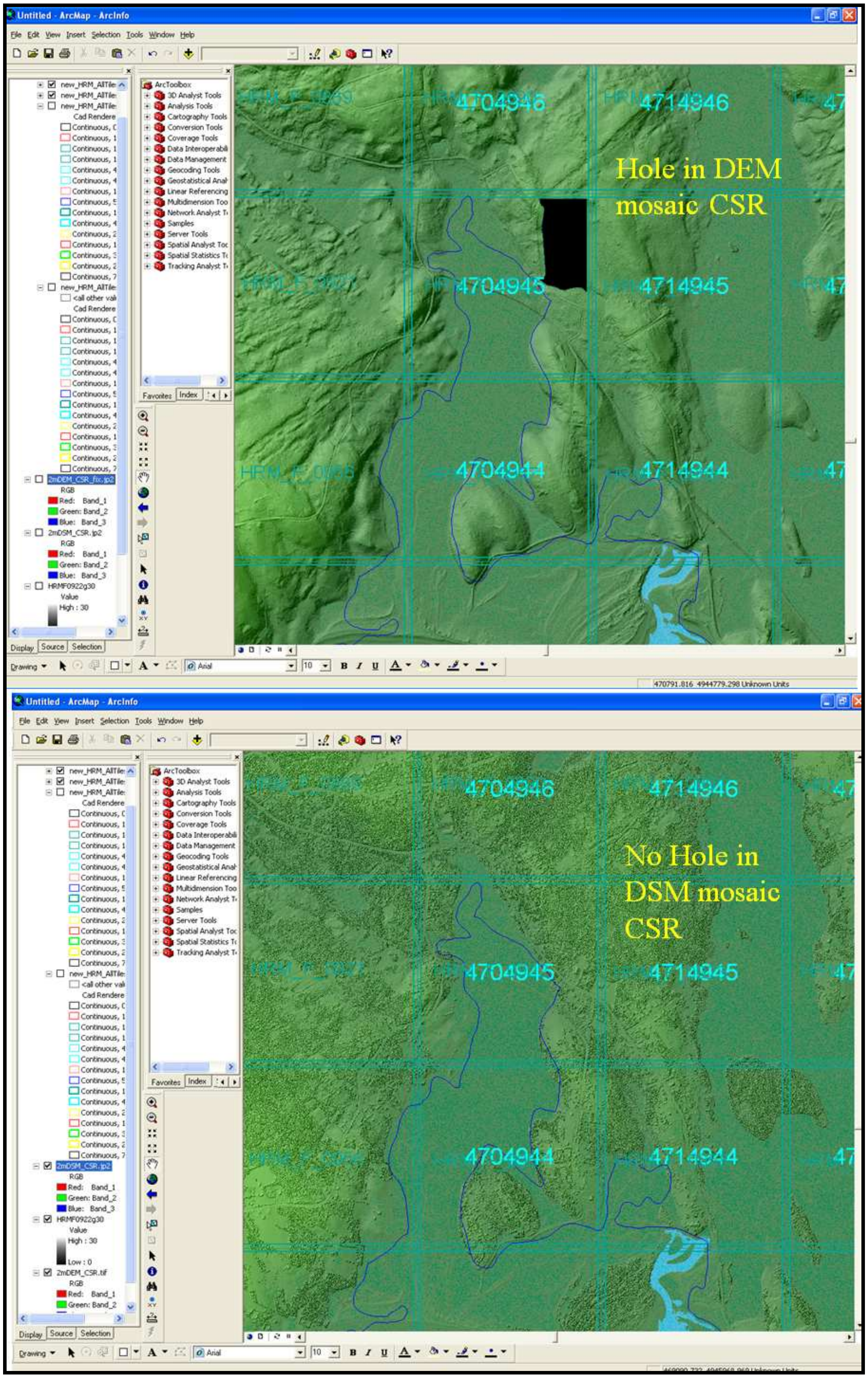


Figure 4 Example of probable ground classification error. This results in a hole in the DEM (top) that is not present in the DSM (bottom).

We observed a few cases where the lidar points were not correctly classified as ground. Since we had a project that contained the vendor supplied classified "ground" points and another project that contained all of the lidar points, we were able to determine that it was a classification error. We then classified ground from all of the lidar points and re-gridded the DEMs for those blocks where errors were observed (Fig. 5).

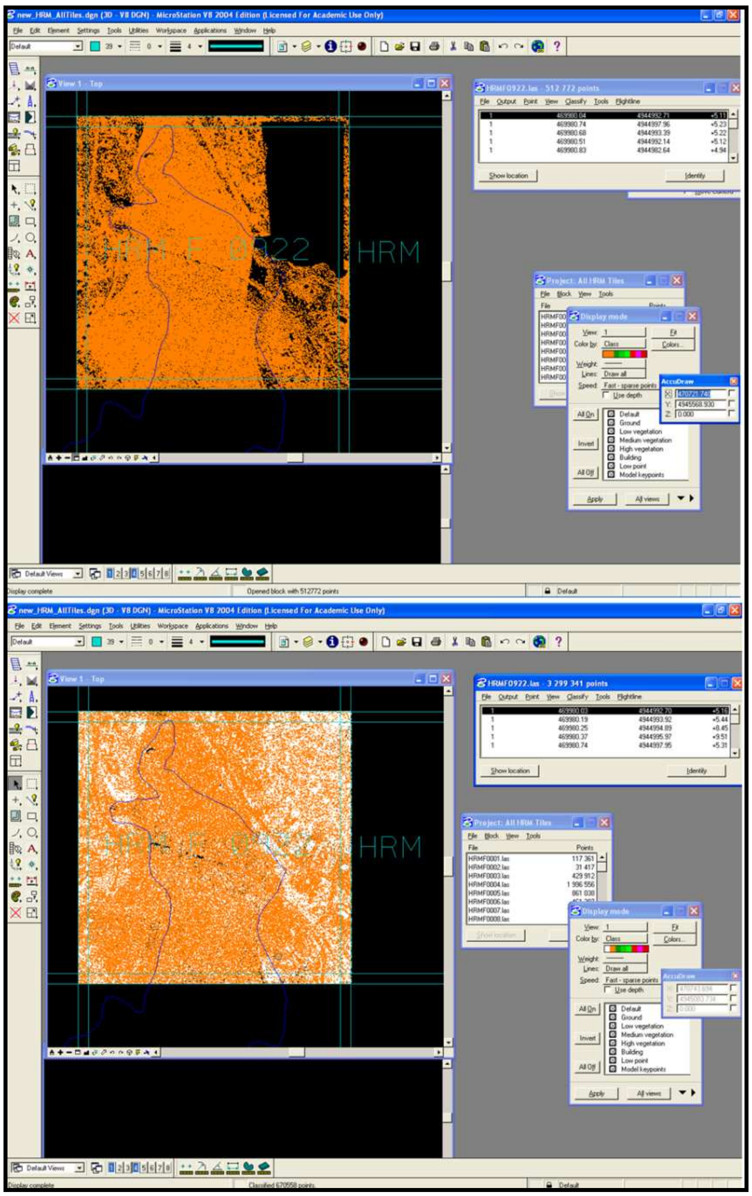


Figure 5 Example of vendor supplied classified "ground" points (top orange points) compared to our classification of "ground" points from the first and last returns (bottom orange points ground, white points non-ground).

The reprocessed DEMs blocks from the misclassified “ground” points were used to mosaic into the DEM again and reconstruct the CSR for another round of inspection (Fig. 6).

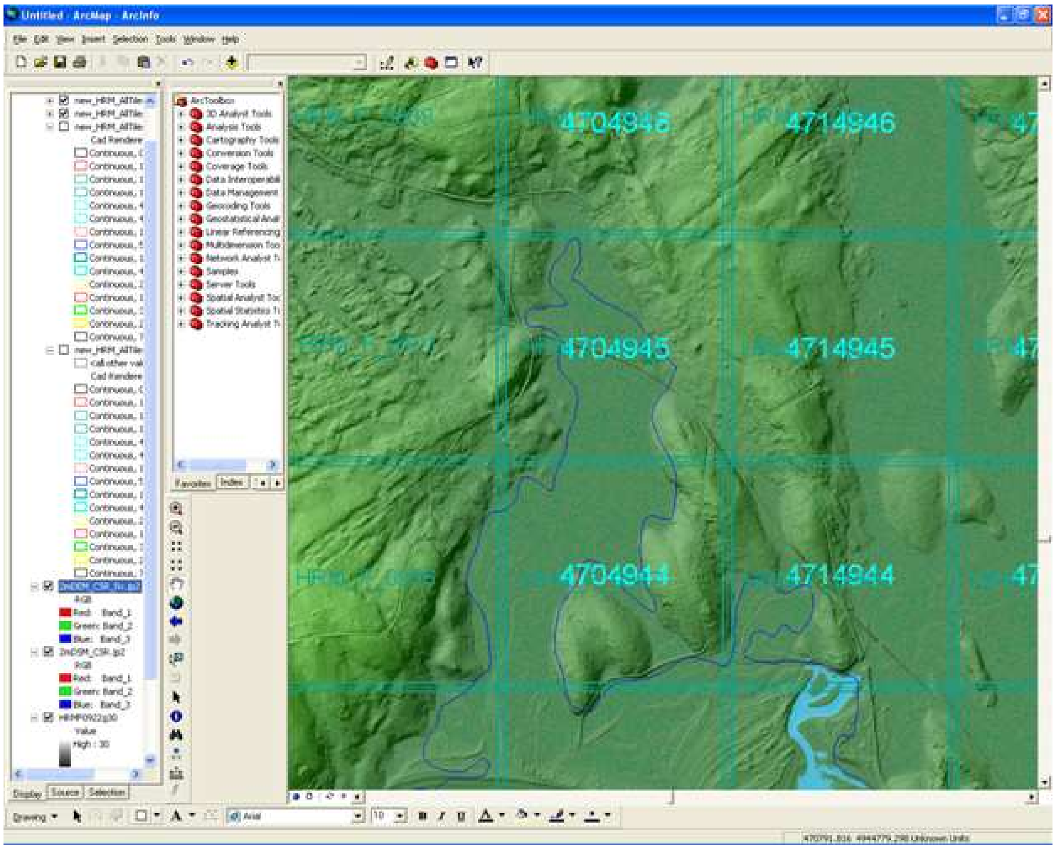


Figure 6 Revised CSR of the revised DEM with the hole fixed.

We construct a CSR for the DSM and observed several artifacts that appeared to be a result of anomalously high elevation values. These appeared to follow the flight lines and occurred near the nadir locations of the scans (Fig. 7). These “air points” were investigated in the point cloud and there typical height above the ground was 1080 m.

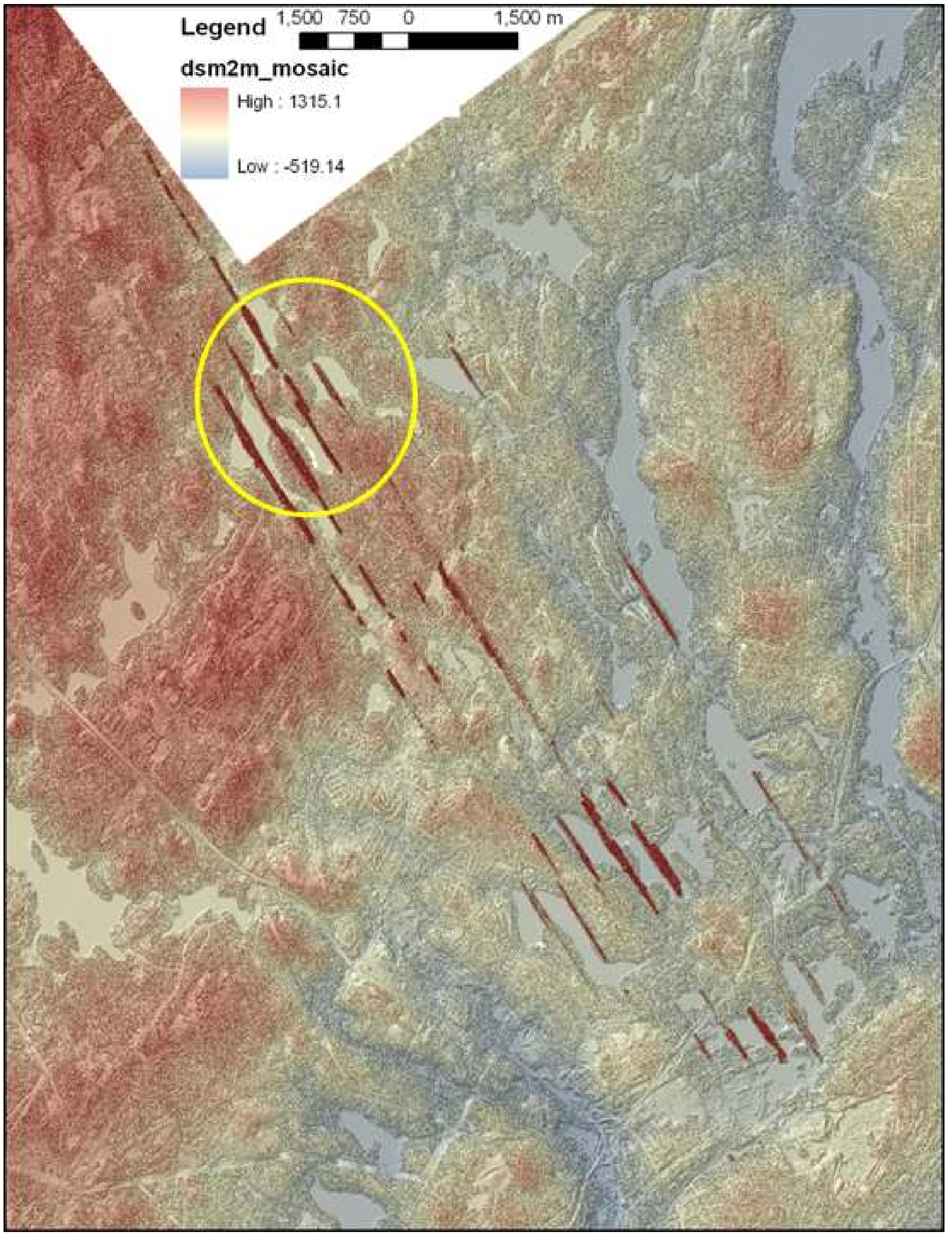


Figure 7 Example of the erroneous areas within the DSM. The yellow circle highlights the anomalous values that are parallel to the flight lines.

The TerraScan™ project that contained the first and last lidar returns was re-processed and these "air points" removed. The resultant LAS files were re-gridded to build a DSM that no longer contained the errors (Fig. 8). These erroneous points should have been detected by the data provider and removed prior to delivery to HRM.

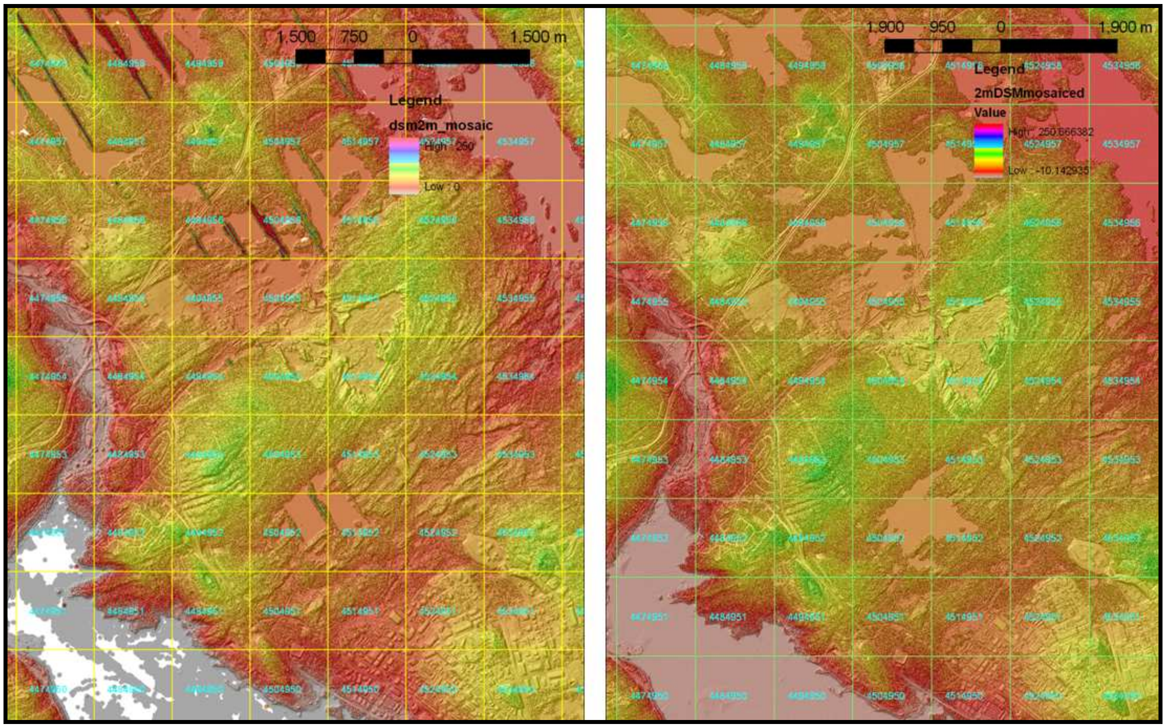


Figure 8 DSM with errors (left) and the revised DSM without errors (right).

As mentioned earlier, we filled in the holes in the DEM in order to have a continuous surface that would facilitate the construction of a normalized height model by subtracting the DEM from the DSM. The holes in the DEM for lakes were a result of the IDW interpolation method (Fig. 9). In the case of the DSM which used a TIN interpolation method, which resulted in a continuous surface without holes, there were triangular artifacts. These sharp triangular facets were a result of the TIN process where a point along the lake edge that may not have been the actual water surface was connected to a point in the water which when interpolated caused these triangular facets to occur around the edges of lakes (Fig. 9).

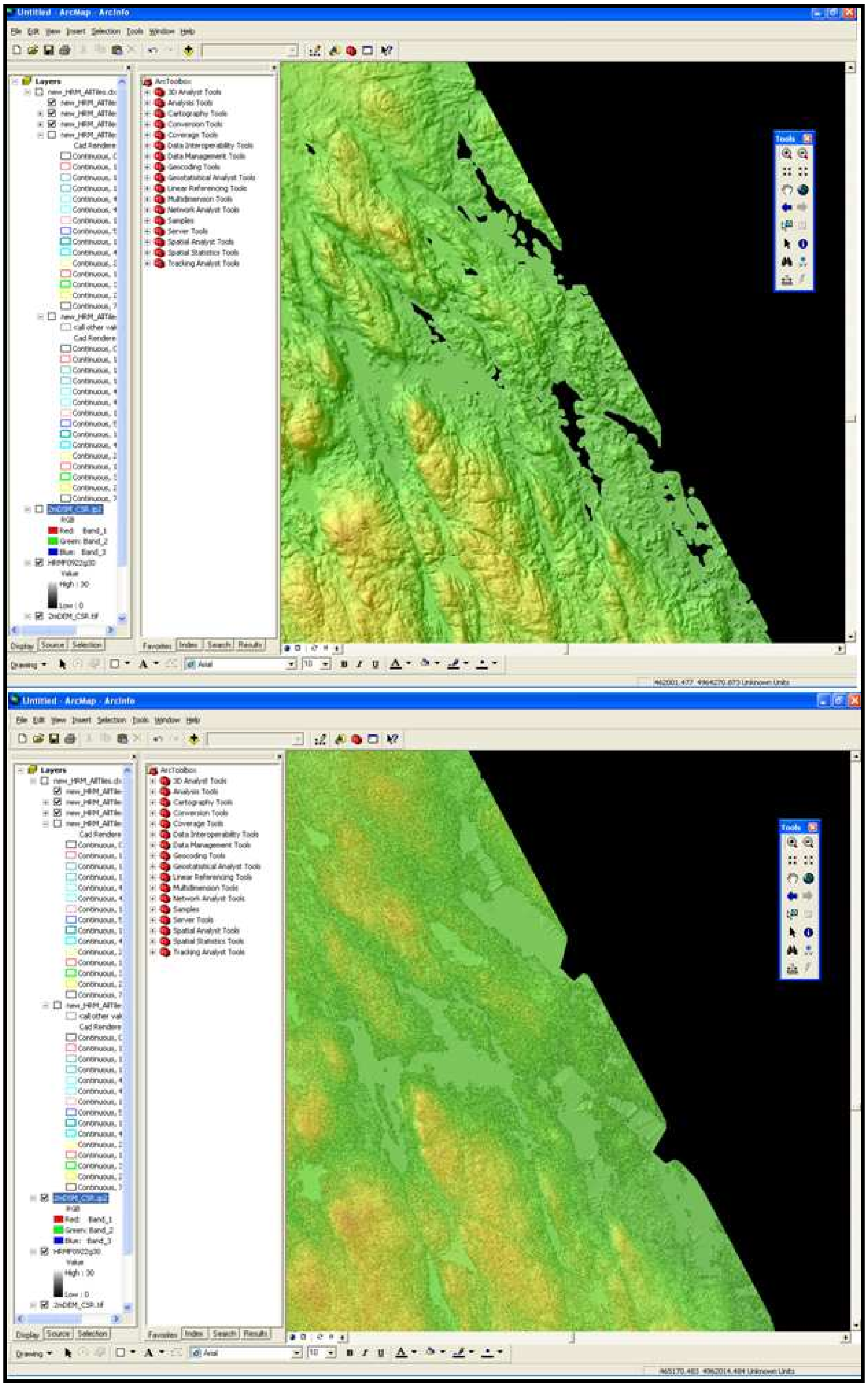


Figure 9 Example of the holes in the lake surface as a result of the IDW interpolation method for the DEM (top). Example of the triangular facet edges visible in the DSM as a result of the TIN interpolation method (bottom).

This resulted in the lake surface not being accurately represented. In other words, instead of a flat lake surface we had an angular surface that was erroneous (Fig. 9). The best automated solution that we could apply to both datasets, DEM and DSM, was to use the 1:10,000 lake polygon and extract the elevation based on the lidar and apply it to each polygon which intern was applied to the surface model. The drawback to this approach is that the positional accuracy of the lake vectors is less than that of the lidar and secondly that only one value can be applied per polygon. In the case of discrete lakes, the one value is not a problem, however in the case of rivers or flowages that connect lakes that may have a gentle slope gradient; we can only apply one value that may bias the results. The lake polygons were overlaid with the lidar DSM and the average elevation was extracted and assigned to the lake polygon which was then superimposed over both surface models. Caution should be taken when using the lake surface elevation from these data. This only makes sense since the water level in each lake will vary in time. An unforeseen circumstance also occurred when examining the result data. We observed a few cases where the lake value clearly overwrote some valid land elevation values or in the case of a power line, overwrote the wires and other structures that were present in the DSM. The situation of lakes covering valid land areas occurred in three situations: 1) where the land had been changed after the lakes was captured, for example a highway was expanded and the lake was partially filled in; 2) areas where the lake polygon crossed a bridge that was represented in the models; and 3) islands within the lakes. In the case of the islands, we extracted them from the 1:10,000 NSTDB and used them to clip the original DSM or DEM and mosaicked these sections over the lake areas to put the islands back. To fix the situation of the lakes overwriting a valid section of land we simply re-mosaiced the appropriate section from the original DEM or DSM back into the final surface models (Fig. 10).

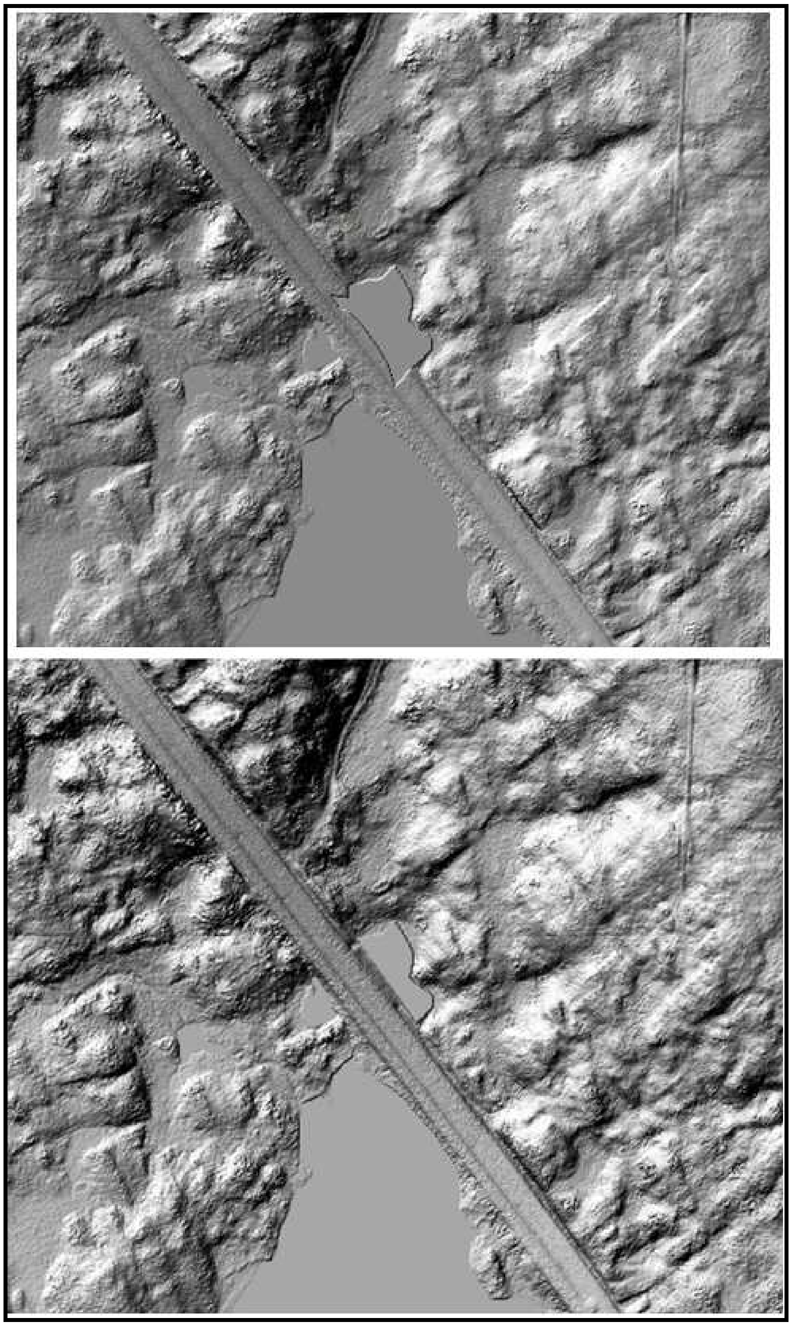


Figure 10 Example of a grey scale shaded relief of the DEM showing the lake polygon and resultant surface extending across the highway (top). The final surface models have the lakes cut back to where we estimated is their correct boundary (bottom).

Once a final DEM and DSM were constructed at 1 m resolution, the normalized height model (NHM) was calculated by subtracting the DEM from the DSM. The final 3 surface models at 1 m resolution, DEM, DSM, NHM were then averaged to form surfaces at 2 m and 5 m. During the averaging process some potential erroneous edge artifacts were introduced, however one should always be cautious of the data near the edge of a grid. These files were then converted to Arc™ grid format and the null data values were set. In the case of the Arc™ grid data layers, both UTM Zone 20 and MTM Zone 5 map projections were constructed. A further product was built to facilitate visualizing the data quickly and for interpreting the terrain. This was represented by constructing colour shaded relief maps of the various data layers. This was only done for the UTM map projection. All of the surfaces were shaded from the northwest at 45 degrees with a 5 times vertical exaggeration applied. The DEM and DSM were linearly scaled from -9 m to 247 m and then pseudo coloured in the process of constructing the CSR. The colours of the terrain were selected to optimize the 3-D characteristics when the data are viewed with the Chromatek™ glasses. The CSR maps are essentially a rendition or picture of the terrain and cannot be used to extract precise elevation. If that is required, one must access the appropriate Arc grid file to obtain the true elevations or derive other products such as slope, aspect or greyscale hill shades from other orientations. The CSR maps were converted into a JPEG2000 format which reduces the file size without compromising the fidelity of the image quality. These maps can be quickly displayed as a backdrop in Arc GIS or most mapping and image analysis software. This is not simply a JPEG image, it is a fully georeference image format that facilitates interpretation and understanding of the terrain, landcover, and height of objects on the landscape from the CSR of the DEM, DSM and NHM respectively.

The Cole Harbor coastal areas were also examined and a preliminary report was delivered to HRM that was used to communicate the issues to the lidar data provider. The analysis of the water levels of the lidar returns clearly showed that some ocean surfaces were ca. 1 m different between flight lines indicating that some were flown near high tide rather than the specified low tide acquisition criteria.

Results and Conclusions

The results of this project will be used for many years into the future by professionals and students and others from many disciplines. The variable resolution Arc grids allow users to access the terrain and height information at three different levels of detail or scales, 1, 2 and 5 m. The construction of the CSR maps will facilitate data exploration because they are quicker to load than the actual surface models and can be easily interpreted in terms of the data quality and level of detail between the different resolutions. An example of the data products is presented for the down town Halifax area (Fig. 11). The data delivered on the hard drive consists of two main types of files: the Arc™ grid data layers, and the CSR JPEG2000 colour shaded relief images. The Arc™ grids have been projected into both UTM and MTM map projections. The CSR JPEG2000 images were only constructed in UTM projection since most mapping systems today can re-project data from one projection to another “on the fly”. In addition to the hard drive and report, a colour plot of the CSR DEM and 3-D glasses was also delivered to show how these maps can aid our understanding of the landscape.

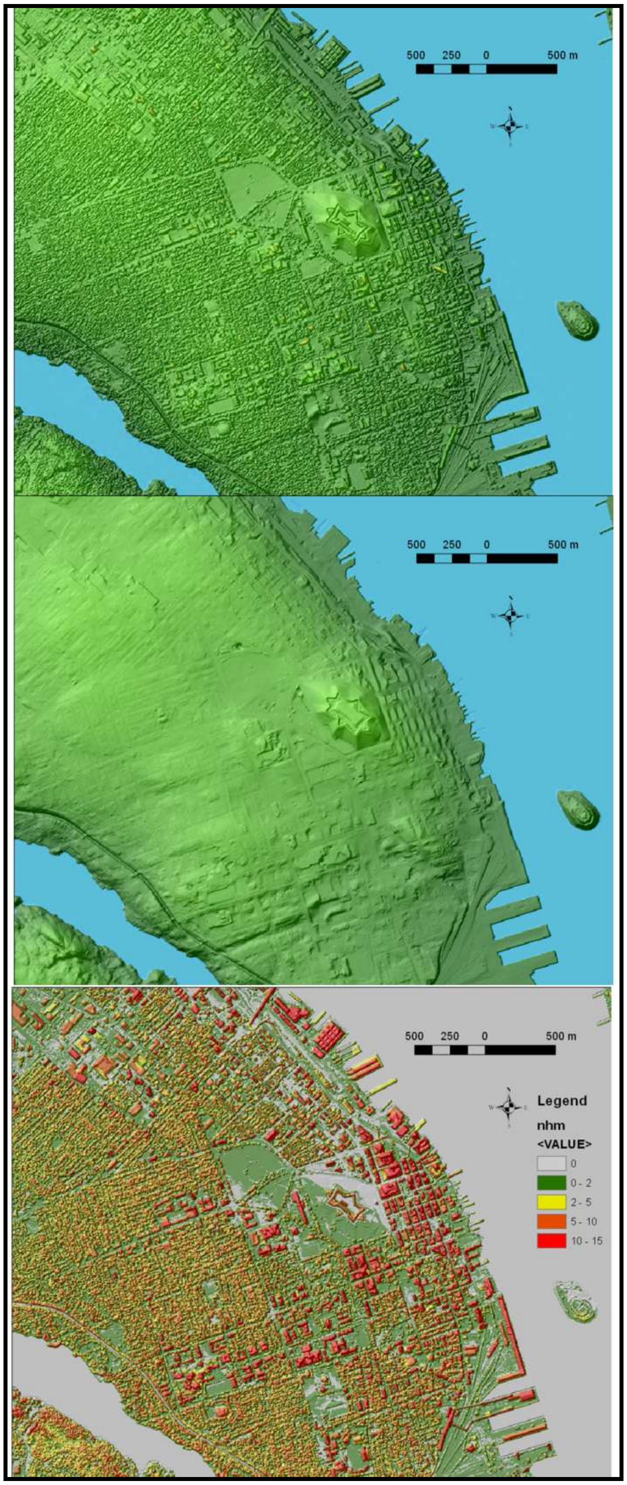


Figure 11 Example of the lidar surface models for down town Halifax. Top image is the DSM showing the buildings and trees as well as ground. The middle image is the DEM of ground only. The bottom image is the NHM showing the height of objects above the ground.

Acknowledgements

We would like to thank John Charles and Roger Wells for the opportunity to work on such a challenging project. At AGRG we would especially like to thank Suzzane Monette for the use of her TerraScan project of the areas as well for sharing past reports and experiences working with these datasets. We would also like to thank Chris Hopkinson, Bob Maher, Kevin McGuigan, and Debbie Hebb for their contributions.

Appendix F

GIS Watershed Modeling

Table of Contents

List of Figures

1. Depressionless DEM

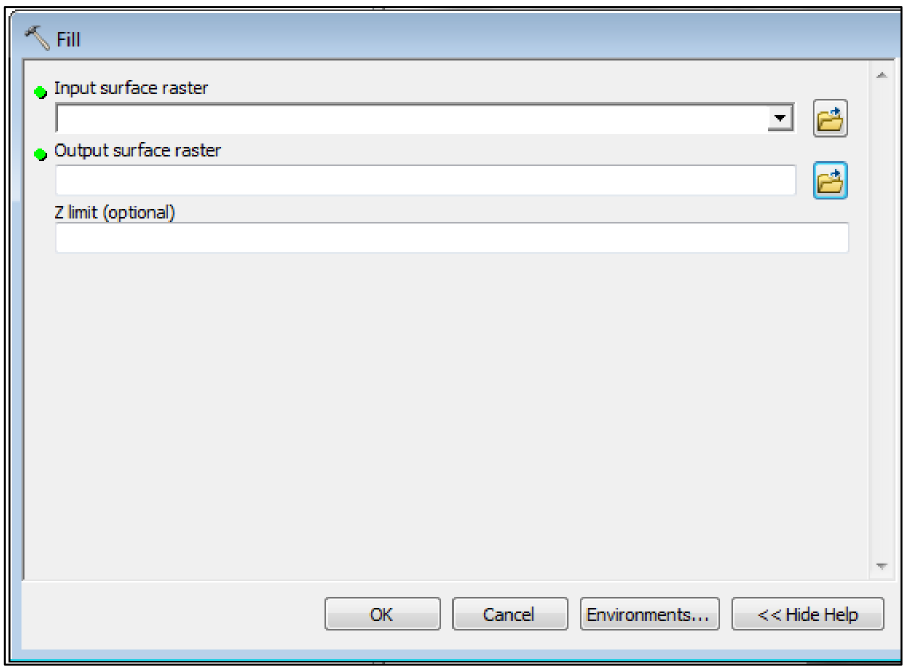
1.1 Steps in ArcGIS

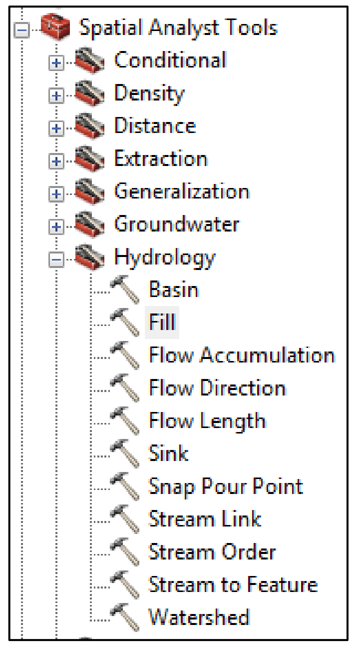
It is important to start with a DEM that has no depressions.

→ Open Arc Toolbox toolset *Spatial Analyst Tools* > *Hydrology.* This is where the surface hydrology tools are found.

→ Open *Fill* tool.

→ The input surface is the DEM. Output is where the files will be saved.





When the Fill tool completes a new layer will be added to the data frame. This is identical to the original DEM raster, but any areas of internal drainage are filled in. To run a quality check on the new DEM, look at the differences in the lowest elevation value between the two DEM's; sink cells in the original will have been filled in.

Remove the original DEM from the mapping.

1.2 Rational

Many watershed models do not work in the presence of depressions, sinks and flat areas. Some sinks are caused by actual ground conditions where no watershed precipitation travels through a river network towards another river network or lake/ocean. However most sinks are caused by data noise and errors in the elevation data. The computation problems arise because cells in depressions, sinks and flat areas do not have any neighbouring cells at a lower elevation to flow into. Under these conditions, the flow might accumulate in a cell and the resulting flow network may not extend to the edge of the grid. Unwanted sinks must be removed prior to starting the watershed analysis by raising the elevation of the cells within the sink to the elevation of its lowest outlet.

1.3 Related to Shubenacadie Lakes

The DEM used in Shubenacadie Lakes was LiDAR derived and produced very few sink locations. The filled DEM was however used for watershed analysis, as literature dictates.

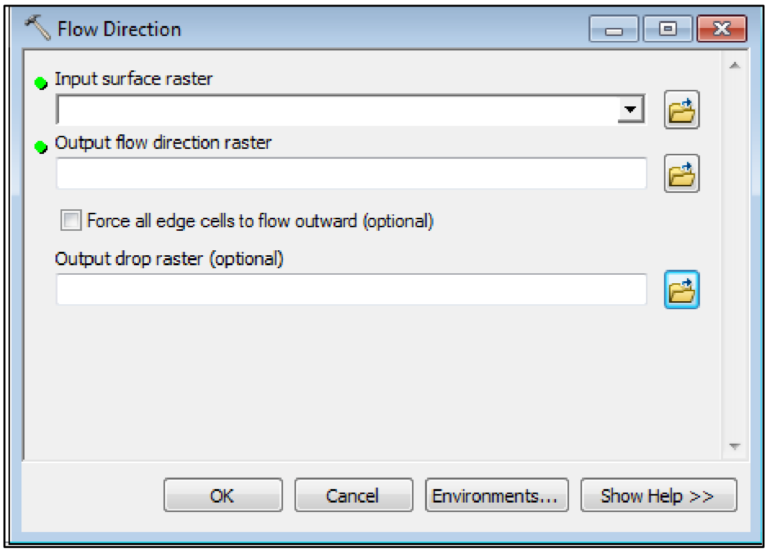
2. Flow Direction

2.1 Steps in ArcGIS

Next create the grid illustrating Flow Direction.

→ Open the *Flow Direction* tool from the Hydrology tools.

→ The input surface is the filled DEM grid. Output is where the files will be saved.



The output of the Flow Direction is an integer raster whose values range from 1 to 255. The values for each direction from the centre are show in Figure 2-1.

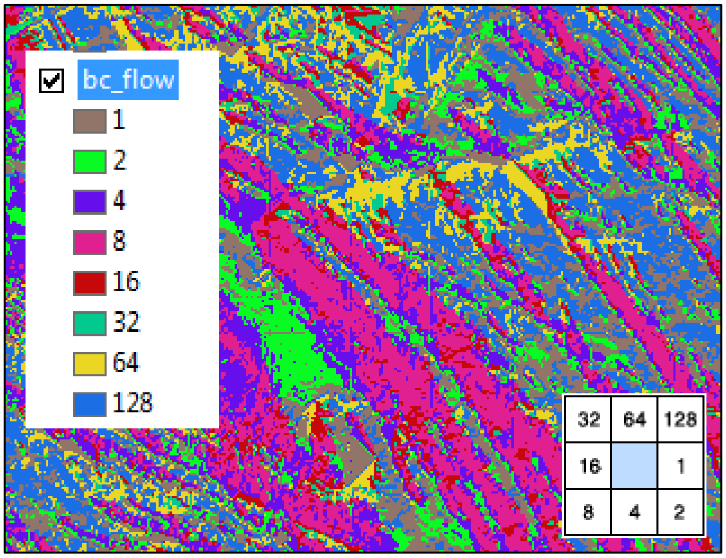


Figure 2-1: Flow Direction Example

2.2 Rational

If a cell is lower than its eight neighbors that cell is given the value of its lowest neighbor and flow is defined toward this cell. If multiple neighbors have the lowest value, the cell is still given this value, but flow is defined with one of the two methods explained below. This is used to filter out one-cell sinks, which are considered noise.

Method 1:
If a cell has the same change in z-value in multiple directions and that cell is part of a sink, the flow direction is referred to as undefined. In such cases, the value for that cell in the output flow direction raster will be the sum of those directions. For example, if the change in z-value is the same both to the right (flow direction = 1) and down (flow direction = 4), the flow direction for that cell is 1 + 4 = 5. Cells with undefined flow direction can be flagged as sinks using the Sink tool.

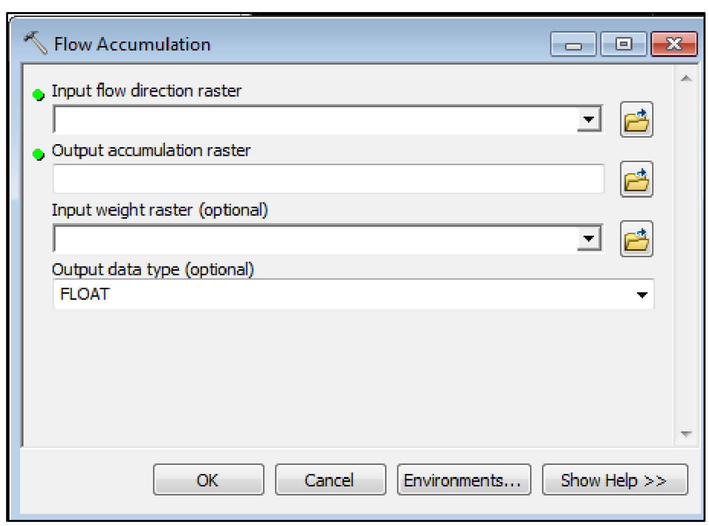
Method 2:
If a cell has the same change in z-value in multiple directions and is not part of a sink, the flow direction is assigned with a lookup table defining the most likely direction.

3. Flow Accumulation

3.1 Steps in ArcGIS

→ Open the *Flow Accumulation* tool from the Hydrology tools.

→ Set the input flow direction raster to the output of the last task. Output is where the files will be saved.



The result of Flow Accumulation is a raster of accumulated flow to each cell, as determined by accumulating the weight for all cells that flow into each downslope cell.

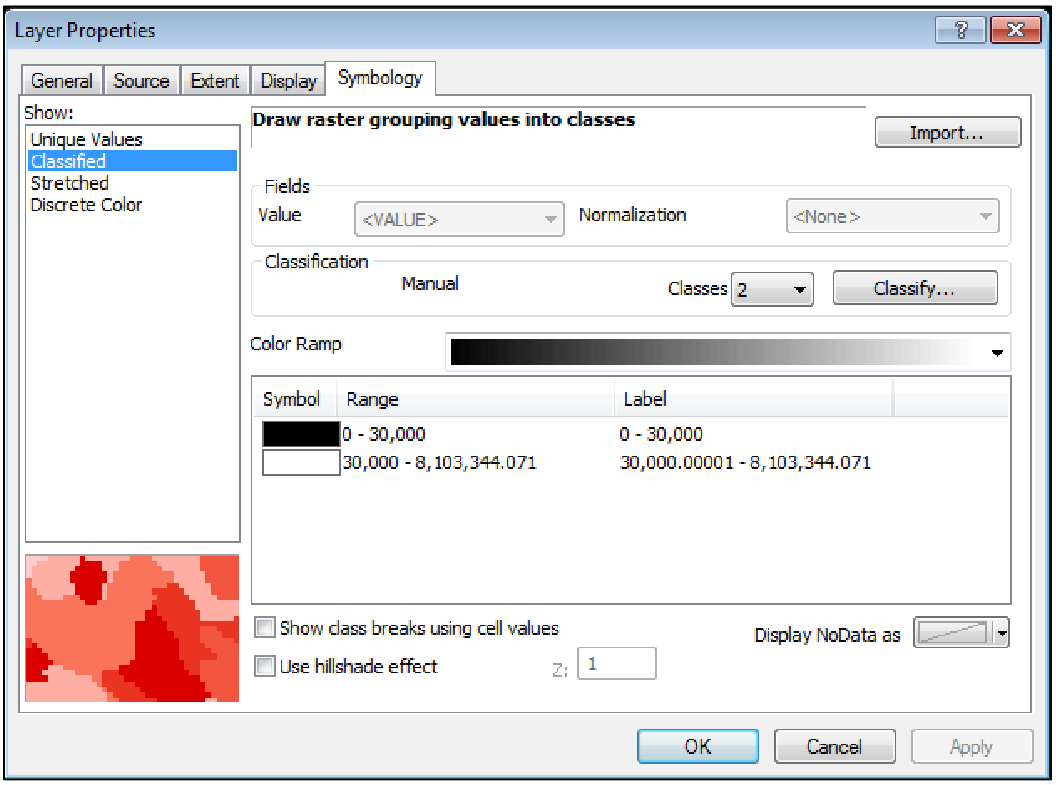
Output cells with a high flow accumulation are areas of concentrated flow and can be used to identify stream channels.

Output cells with a flow accumulation of zero are local topographic highs and can be used to identify ridges.

Change the symbology of the grid to the user defined threshold.

→ Right click on the flow accumulation grid >*Properties* >*Symbology*

→ In the *Show* box: choose *Classified*. Set the number of classifications to 2.



3.2 Rational

Before creating a watershed, users must define the minimum number of upstream cells contributing to flow into a cell to classify that cell as the origin of a stream. This number, referred to as the cells threshold, defines the minimum upstream drainage area necessary to start and maintain a stream. For example if a stream definition value of 10 cells is specified, then for a single grid location of the DEM to be in a stream, it must drain at least 10 cells. The threshold value can be estimated from existing topographic maps or from the hydrographic layer of the real stream network. Selection of an appropriate cell threshold size requires some user judgment. The cell threshold value directly affects the number of subwatersheds in a given watershed. A smaller threshold results in smaller subwatershed sizes.

Flow accumulation is also important because it allows you to locate cells with high cumulative flow. Each watershed must have an outlet called a pour point. Pour points must be located in cells of high cumulative flow.

3.3 Related to Shubenacadie Lakes

A flow accumulation grid was downloaded from the Government of Nova Scotia website to be used as a comparison for the watershed threshold. It was identified that a cell value of 30,000 was comparable to the NSDR file (Figure 3-1) where the blue line is the LiDAR derived flow accumulation, and the orange the NSDR downloaded NSDR file.

Figure 3-1: Comparison of Downloaded and Derived Flow accumulation files.

4. Stream Network

4.1 Steps in ArcGIS

The stream network function takes the raster flow accumulation grid and turns it into a directional vector stream network.

→ Using *Raster Calculator* isolate out the stream network using the command below (Note: **streamnet** is the name of the new file being created):

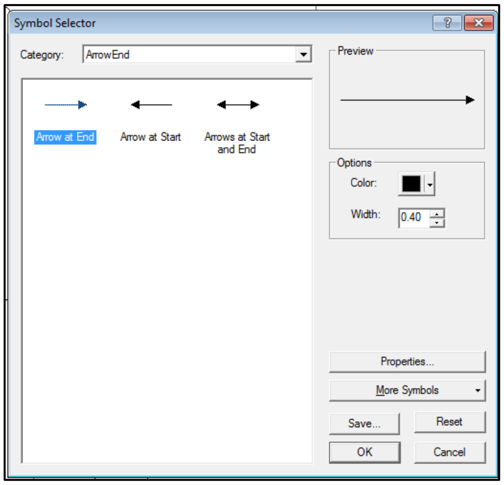
streamnet = con ([Flow_Acc]) > 100, 1)

The above statement creates a stream network by assigning all cells that have 100 cells flowing into them a value of 1, indicating the stream. For a more accurate stream network, experiment with different flow accumulation thresholds.

→ To convert this new file into a vector open *Stream to Feature* open in the Hydrology toolbar.

→ The input is the newly created **streamnet** file, and the input flow direction grid.

To view the direction of the streams, change the symbology of the line output to *Arrow at End*.



4.2 Rational

This step not only provides the ability to view the flow direction of the newly created watercourse but also transfers the raster to a vector making it easier to edit and apply to all mapping and analysis purposes.

4.3 Related to Shubenacadie Lakes

This file is the “Watercourse” layer shown on all figures within this report.

5. Stream Order

5.1 Steps in ArcGIS

In many hydrologic GIS applications, it’s important not just to know the direction of the flow in a stream network, but also the order of the streams. Stream order is a method of classifying streams based upon their number of tributaries.

→ Open the command *Streamorder*

→ Input the stream network layer and the flow direction grid, and choose the method of stream order.

The output and an example of stream order classifications can be seen in Figure 5-1 and 5-2.

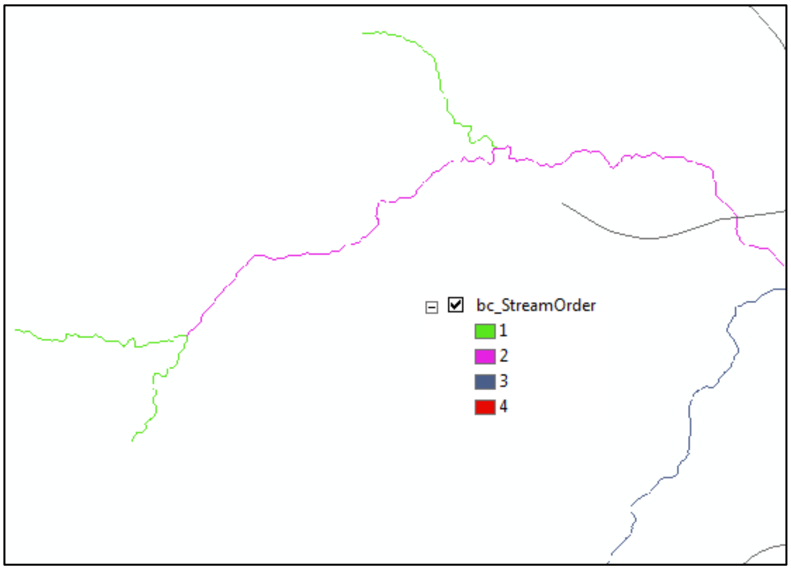


Figure 5-1: Stream Order Results

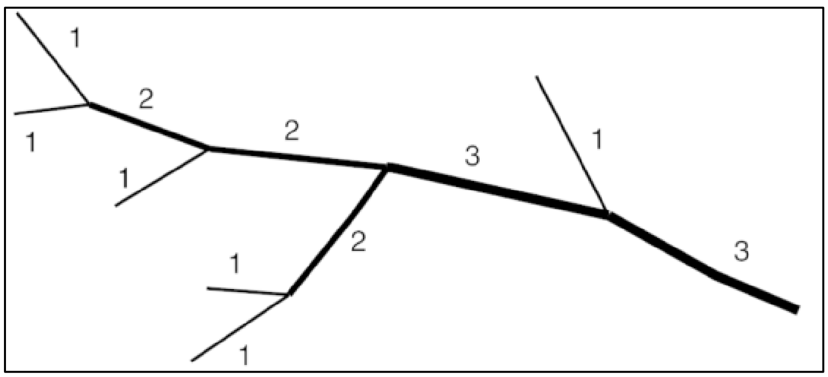


Figure 5-2: Strahler Method Example

5.2 Rational

This step is not imperative to creating a watershed.

5.3 Related to Shubenacadie Lakes

The Strahler method was used to determine stream order within Shubenacadie Lakes subwatershed. This rational identifies streams based on their size, from the smallest 1st order to the largest 12th order streams. A first order stream is the smallest stream, which is typically a tributary to larger streams and rivers. These are the streams that flow into and "feed" larger streams but do not normally have any water flowing into them.

6. Watershed Pour Point

6.1 Steps in ArcGIS

Everything upstream from a pour point will define a single watershed or subwatershed.

→ Start by creating a vector pour point layer in ArcCatalog. Using the creating stream flow and network files, locate positions for the watersheds (Figure 6-1). (Note: Zoom in closely to locate the pour point to ensure it is on the raster grid)

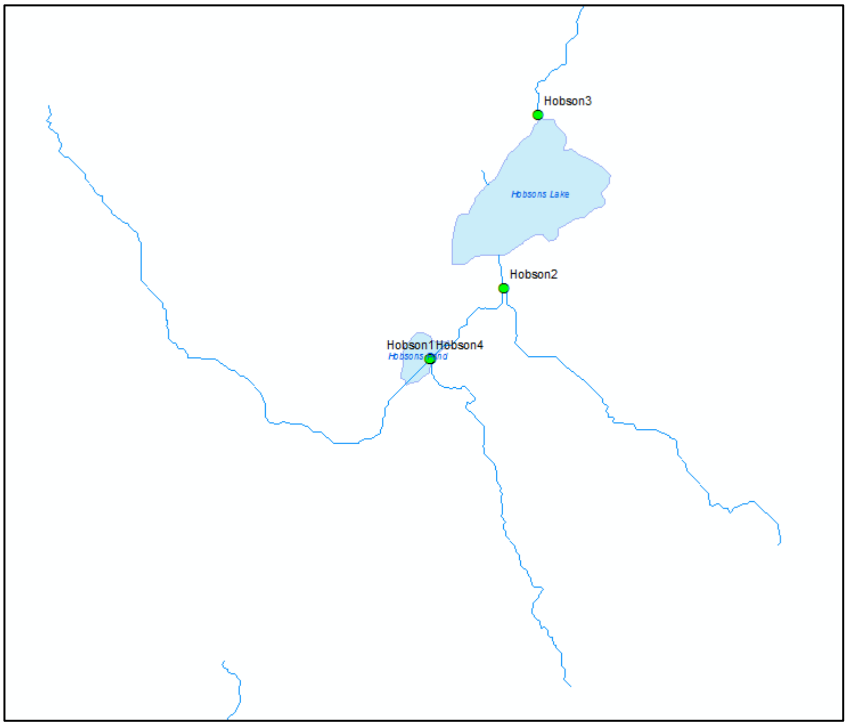
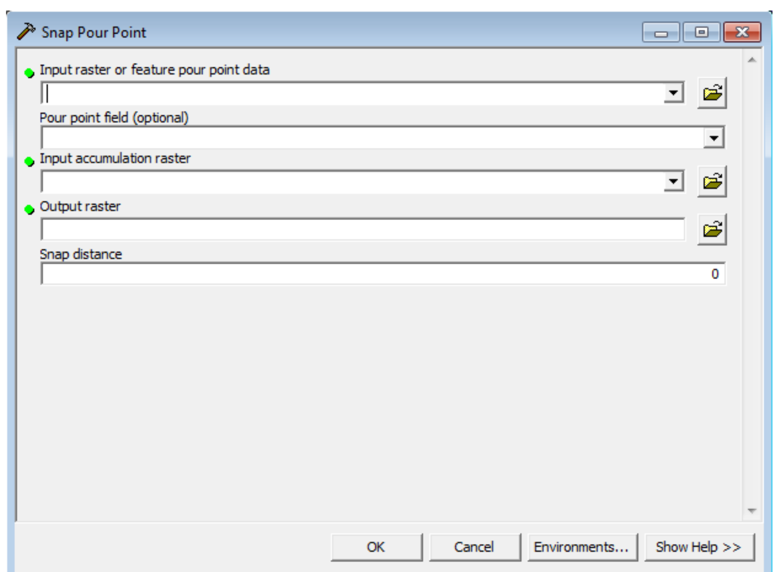


Figure 6-1: Placement of Pour Points

It is best to start by setting the *environment settings* to "same as" the flow accumulation grid. If the Analysis Extent and Cell Size do not match an existing layer, there will be problems of registration between the pour point raster and the other raster layers created during the analysis.

→ In Hydrology toolset use *Snap to Pour Point* to ensure the points are located on the highest flow accumulation cell possible within a specific radius.



The snap to pour point tool will search within a snap distance (m) around the vector pour point for each cell of highest accumulated flow and move the pour point to that location (Figure 6-2).

→ When the tool is complete, the new output will be added to your map.

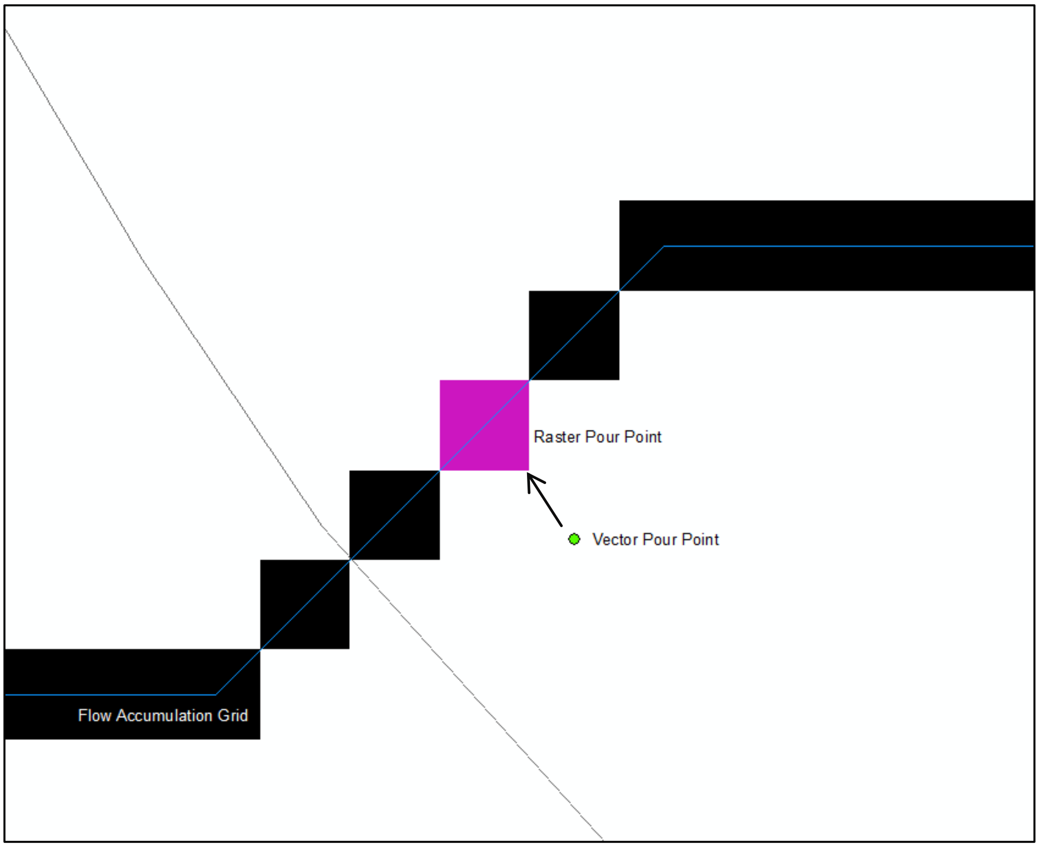


Figure 6-2: Snap to Pour Point Example

6.2 Related to Shubenacadie Lakes

Pour points were located at every major tributary within the Shubenacadie Lakes subwatershed. Once the initial analysis was complete some pour points were taken out due to time restrictions within the hydraulic modeling component. In total 73 pour points were the bases for the subwatersheds within the Shubenacadie Lakes subwatershed.

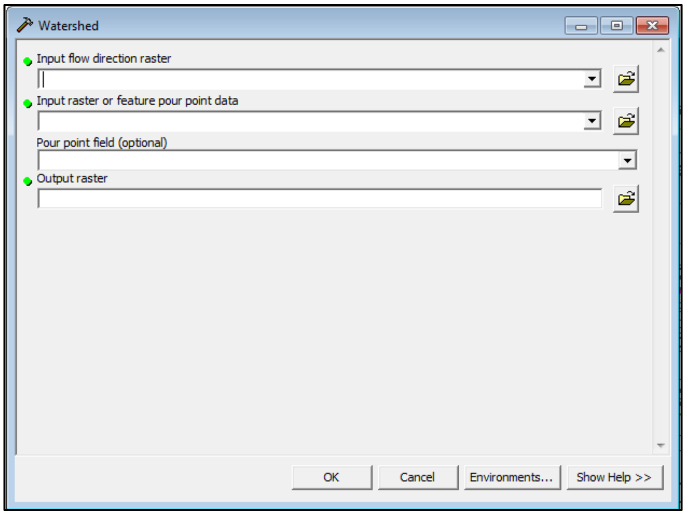
7. Delineate Watersheds

7.1 Steps in ArcGIS

→ Open the Watershed tool in the Hydrology toolset.

→ The input data is the point feature dataset (snapped pour points).

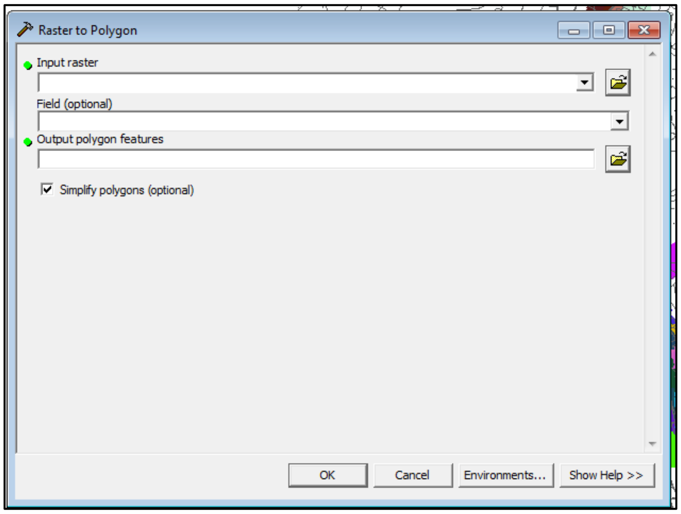
→ Select the flow direction grid as the input flow direction raster.



Note – if the watershed is too small or otherwise not what was expected, it could be because the user located his pour point outside of a high-flow pathway, or the user did not fill the sinks in the input digital elevation model. To correct these errors, return to those steps, correct the error, and follow through all the remaining steps.

To convert the watershed raster to a polygon shapefile for use later use:

→ *ArcToolbox > Conversion Tools > From Raster > Raster to Polygon*



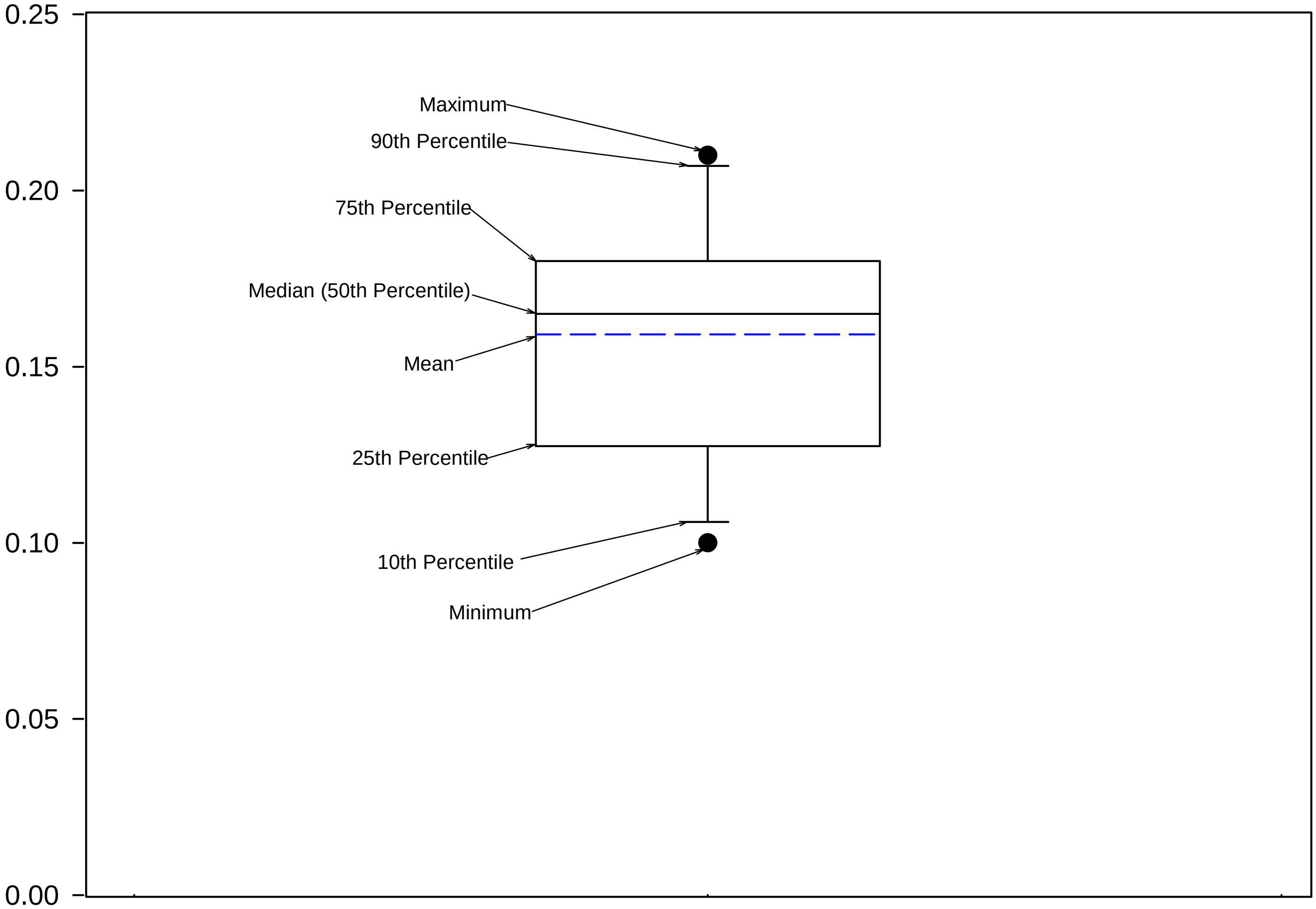
7.2 Related to Shubenacadie Lakes

Once the watershed has been identified, the same process can be applied to identify subwatersheds. These subwatersheds were used in the development of all hydraulic modeling for this project.

Appendix G

Phosphorus Statistics

Guide to Summary Statistics Presented on Box and Whisker Plots



Kruskal-Wallis One Way Analysis of Variance on Ranks Thursday, April 26, 2012, 8:42:32 AM

Data source: Lake Charles TP in Shubie Box plots

Normality Test (Shapiro-Wilk) Failed (P < 0.050)

Group	N	Missing	Median	25%	75%
Lake	22	5	0.00900	0.00450	0.0140
Composite	2	0	0.00700	0.00700	0.00700
Outlet	3	1	0.00850	0.00700	0.01000

H = 0.523 with 2 degrees of freedom. (P = 0.770)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.770)

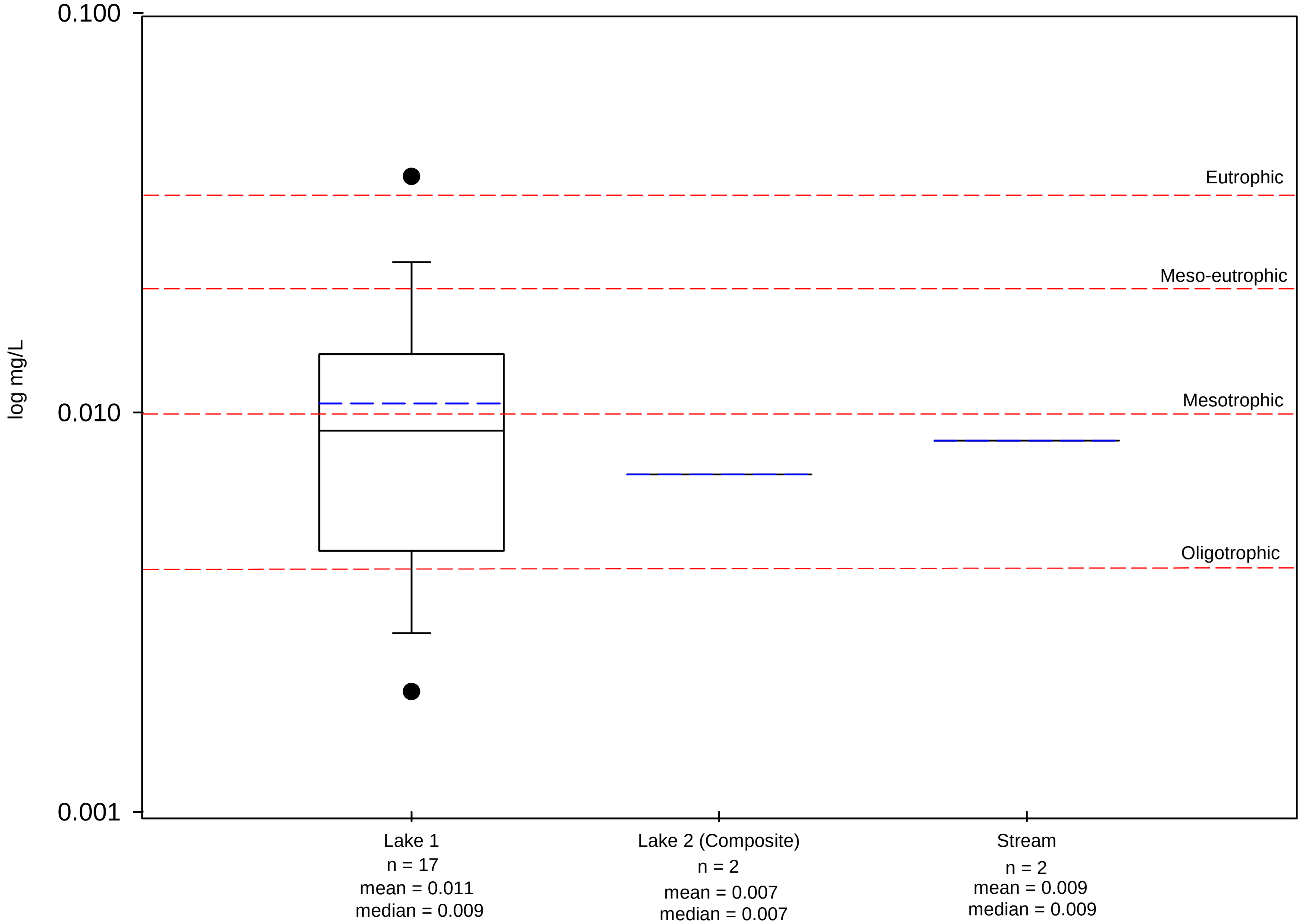
Normality Test (Kolmogorov-Smirnov) Thursday, April 26, 2012, 8:42:16 AM

Data source: Lake Charles TP in Shubie Box plots

Lake:	K-S Dist. = 0.778	P = 0.001	Failed
Composite:	K-S Dist. = 0.000	P < 0.001	Failed
Outlet:	K-S Dist. = 0.260	P > 0.200	Passed

A test that fails indicates that the data varies significantly from the pattern expected if the data was drawn from a population with a normal distribution.
A test that passes indicates that the data matches the pattern expected if the data was drawn from a population with a normal distribution.

A Comparison of Total Phosphorus Results for Lake Charles In-Lake and Stream Samples



Note:

Lake 1 samples were collected by HRM and JW between May 2006 and November 2011.

Lake 2 composite samples were collected by JW in the summer of 2007.

Stream samples were collected by AECOM at the outlet between August 2011 and February 2012.

The results of the Mann-Whitney Rank Sum Test indicate that the difference in the median values among the groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.770).

Kruskal-Wallis One Way Analysis of Variance on Ranks Monday, April 09, 2012, 3:20:20 PM

Data source: TP in Shubie Box plots

Group	N	Missing	Median	25%	75%
Lake 1	1	0	0.00500	0.00500	0.00500
Lake 2	21	2	0.00900	0.00500	0.0120
Stream 1	11	5	0.0300	0.0105	0.112
Stream 2	4	0	0.0300	0.0300	0.0300

H = 11.938 with 3 degrees of freedom. (P = 0.008)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.008)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method) :

Comparison	Diff of Ranks	Q	P<0.05
Stream 2 vs Lake 1	18.500	1.880	No
Stream 2 vs Lake 2	12.474	2.576	Do Not Test
Stream 2 vs Stream 1	2.417	0.425	Do Not Test
Stream 1 vs Lake 1	16.083	1.691	Do Not Test
Stream 1 vs Lake 2	10.057	2.439	Do Not Test
Lake 2 vs Lake 1	6.026	0.667	Do Not Test

Note: The multiple comparisons on ranks do not include an adjustment for ties.

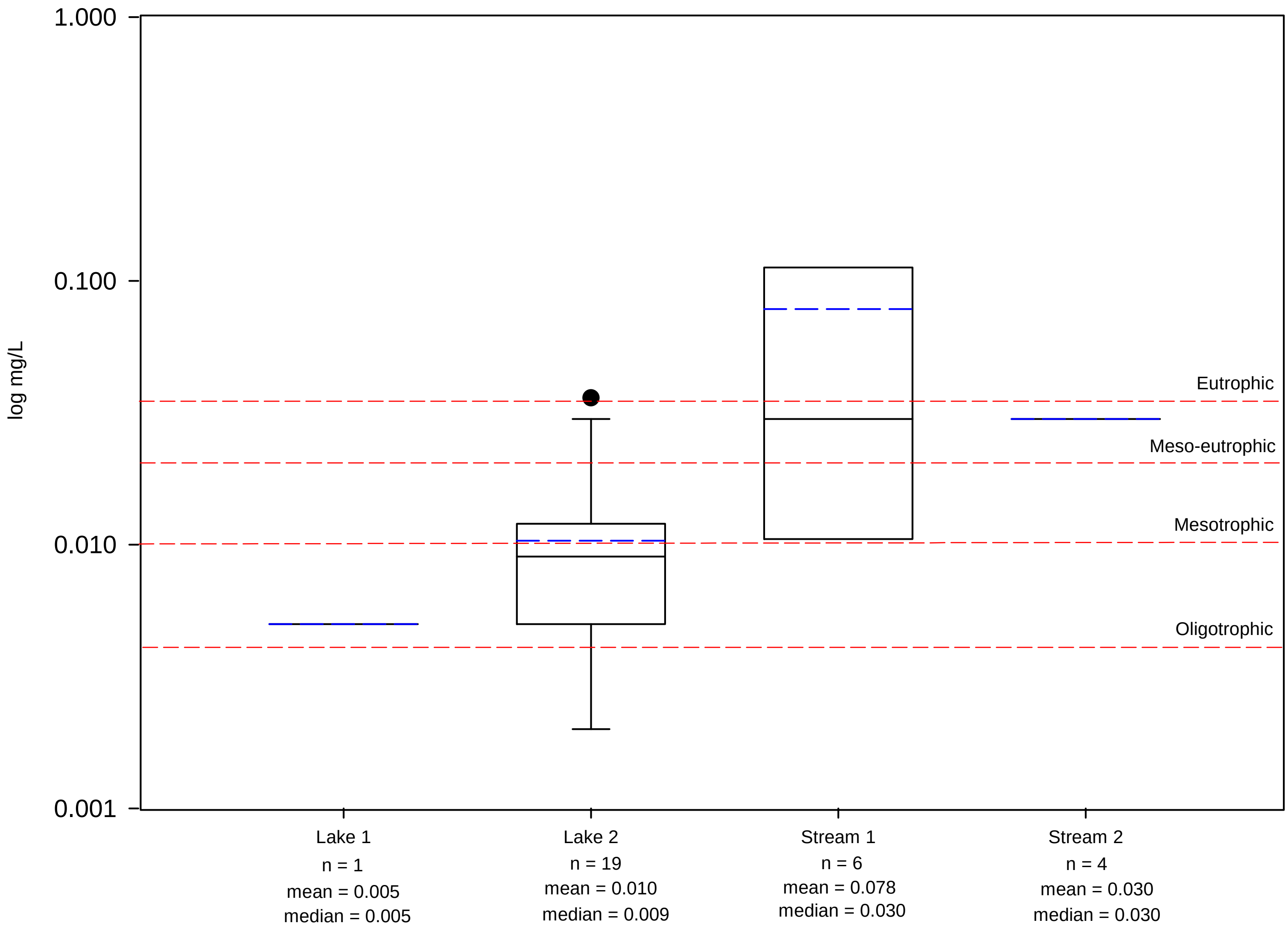
Normality Test (Kolmogorov-Smirnov) Monday, April 09, 2012, 3:19:59 PM

Data source: TP in Shubie Box plots

Lake 1:	K-S Dist. = 0.000	P < 0.001	Failed
Lake 2:	K-S Dist. = 0.268	P < 0.001	Failed
Stream 1:	K-S Dist. = 0.470	P < 0.001	Failed
Stream 2:	K-S Dist. = 0.000	P < 0.001	Failed

A test that fails indicates that the data varies significantly from the pattern expected if the data was drawn from a population with a normal distribution.
A test that passes indicates that the data matches the pattern expected if the data was drawn from a population with a normal distribution.

A Comparison of Total Phosphorus Results for Fletcher In-Lake and Stream samples



Note:

Lake 1 sample was collected by N.S. Lakes Inventory in October 2007.

Lake 2 samples were collected by HRM and JW between May 2006 and November 2011.

Stream 1 samples were collcted by AECOM and MEH downstream of the Welling WWTP between September 2010 and February 2012.

Stream 2 samples were collected by MEH at the inflow from Lake Thomas between September 2010 and September 2011.

The results of the Kruskal-Wallis ANOVA on Ranks test indicate that the difference in median values among groups are greater than would be expected by chance; there is a statistically significant difference (p=0.008). However, when the multiple procedure Dunn's test was run the results indicated that a significant difference did not exist between Lake 1 and Stream 2 samples. Due to the small sample size of Lake 1 and Stream 2 data sets, caution should be used when interpreting these results.

Kruskal-Wallis One Way Analysis of Variance on Ranks Monday, April 09, 2012, 3:34:22 PM

Data source: Grand TP in Shubie Box plots

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Lake 1	18	2	0.00450	0.00225	0.00700
Lake 2	2	0	0.00550	0.00500	0.00600
Lake 3	1	0	0.00700	0.00700	0.00700
Stream 1	11	5	0.0300	0.00550	0.0350

H = 5.309 with 3 degrees of freedom. (P = 0.151)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.151)

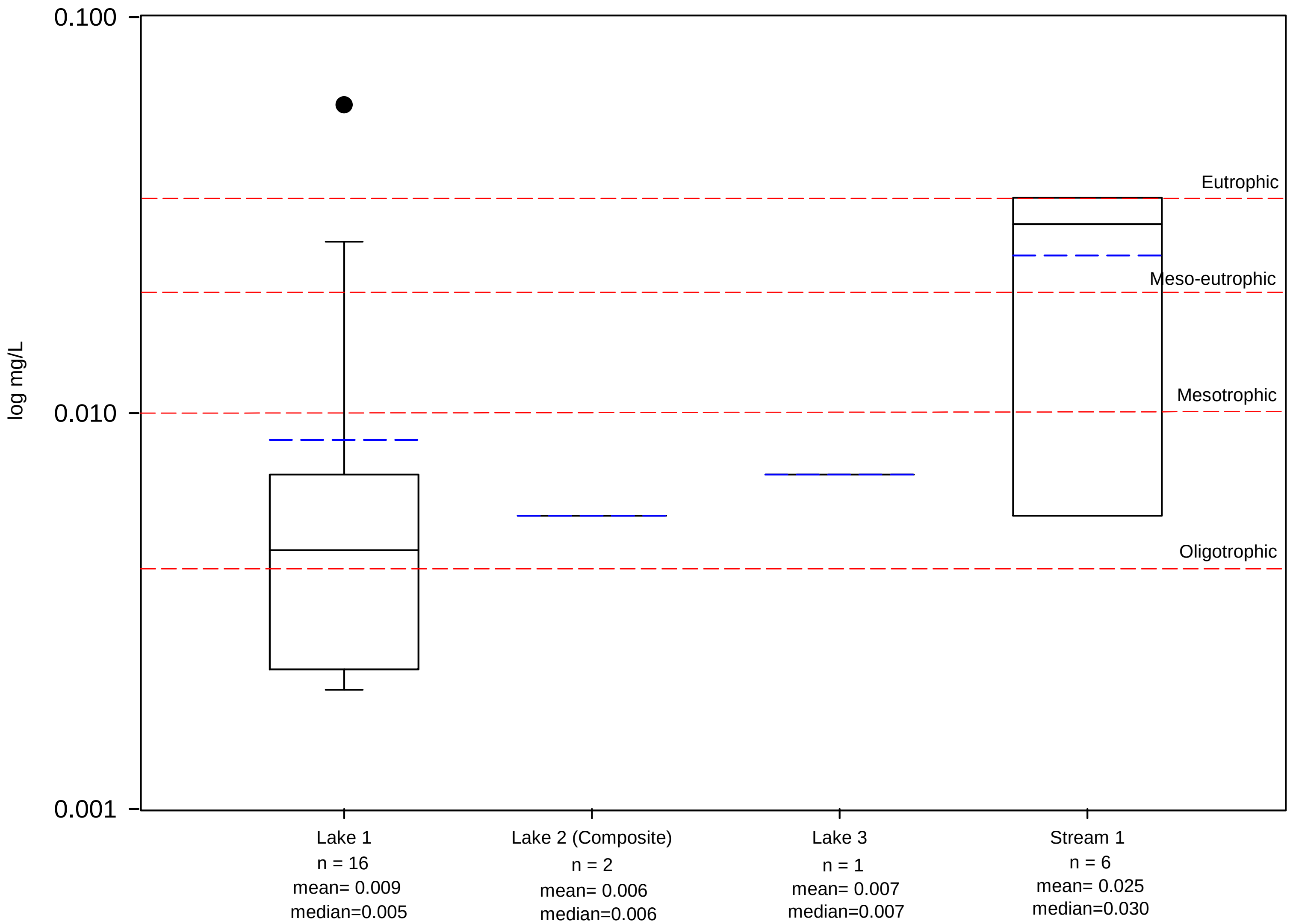
Normality Test (Kolmogorov-Smirnov) Monday, April 09, 2012, 3:34:09 PM

Data source: Grand TP in Shubie Box plots

Lake 1:	K-S Dist. = 0.465	P < 0.001	Failed
Lake 2:	K-S Dist. = 0.260	P > 0.200	Passed
Lake 3:	K-S Dist. = 0.000	P < 0.001	Failed
Stream 1:	K-S Dist. = 0.280	P = 0.149	Passed

A test that fails indicates that the data varies significantly from the pattern expected if the data was drawn from a population with a normal distribution.
A test that passes indicates that the data matches the pattern expected if the data was drawn from a population with a normal distribution.

A Comparison of Total Phosphorus Results for Grand Lake In-Lake and Stream samples



Note:

Lake 1 sample was collected by HRM between October 2006 and November 2011.

Lake 2 composite samples were collected by JW in 2007.

Lake 3 sample was collected by N.S. Lakes Inventory in November 2002.

Stream 1 samples were collected by HRM, AECOM, and MEH between August 2007 and February 2012.

The results of the Kruskal-Wallis ANOVA on Ranks test indicate that the difference in median values among groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is no statistically significant difference (p=0.151).

Mann-Whitney Rank Sum Test Thursday, April 12, 2012, 9:25:26 AM

Data source: Kinsac Lake TP in Shubie Box plots

Normality Test (Shapiro-Wilk) Failed (P < 0.050)

Group	**N**	**Missing**	**Median**	**25%**	**75%**
Lake	18	1	0.0110	0.00783	0.0135
Outlet	12	4	0.0300	0.0132	0.0525

Mann-Whitney U Statistic= 19.500

T = 152.500 n(small)= 8 n(big)= 17 (P = 0.005)

The difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = 0.005)

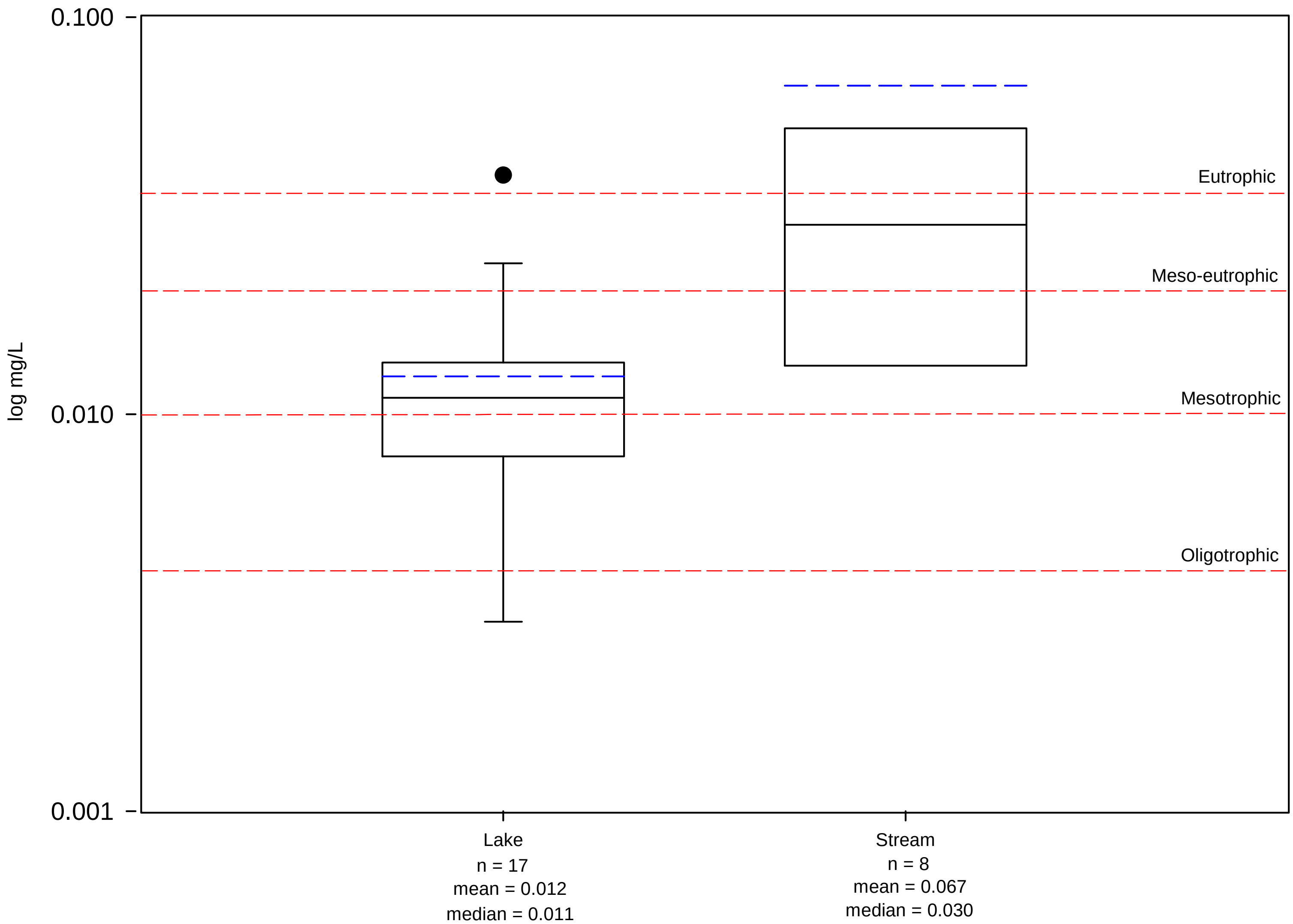
Normality Test (Shapiro-Wilk) Thursday, April 12, 2012, 9:25:14 AM

Data source: Kinsac Lake TP in Shubie Box plots

Lake:	W-Statistic = 0.765	P < 0.001	Failed
Outlet:	W-Statistic = 0.533	P < 0.001	Failed

A test that fails indicates that the data varies significantly from the pattern expected if the data was drawn from a population with a normal distribution.
A test that passes indicates that the data matches the pattern expected if the data was drawn from a population with a normal distribution.

A Comparison of Total Phosphorus Results for Kinsac Lake In-Lake and Stream Samples



Note:

Lake samples were collected by HRM between May 2006 and November 2011.

Stream samples were collected by AECOM and MEH at the outlet between 2010 and 2012.

The results of the Mann-Whitney Rank Sum Test indicate the difference in the median values between the two groups is greater than would be expected by chance; there is a statistically significant difference (P = 0.005)

Kruskal-Wallis One Way Analysis of Variance on Ranks Monday, April 09, 2012, 3:47:26 PM

Data source: Lake Thomas TP in Shubie Box plots

Normality Test (Shapiro-Wilk) Failed ($P < 0.050$)

Group	N	Missing	Median	25%	75%
Lake 1	14	0	0.00850	0.00637	0.0113
Lake 2	19	3	0.00850	0.00725	0.0138
Lake 3	2	0	0.00650	0.00600	0.00700

$H = 1.913$ with 2 degrees of freedom. ($P = 0.384$)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference ($P = 0.384$)

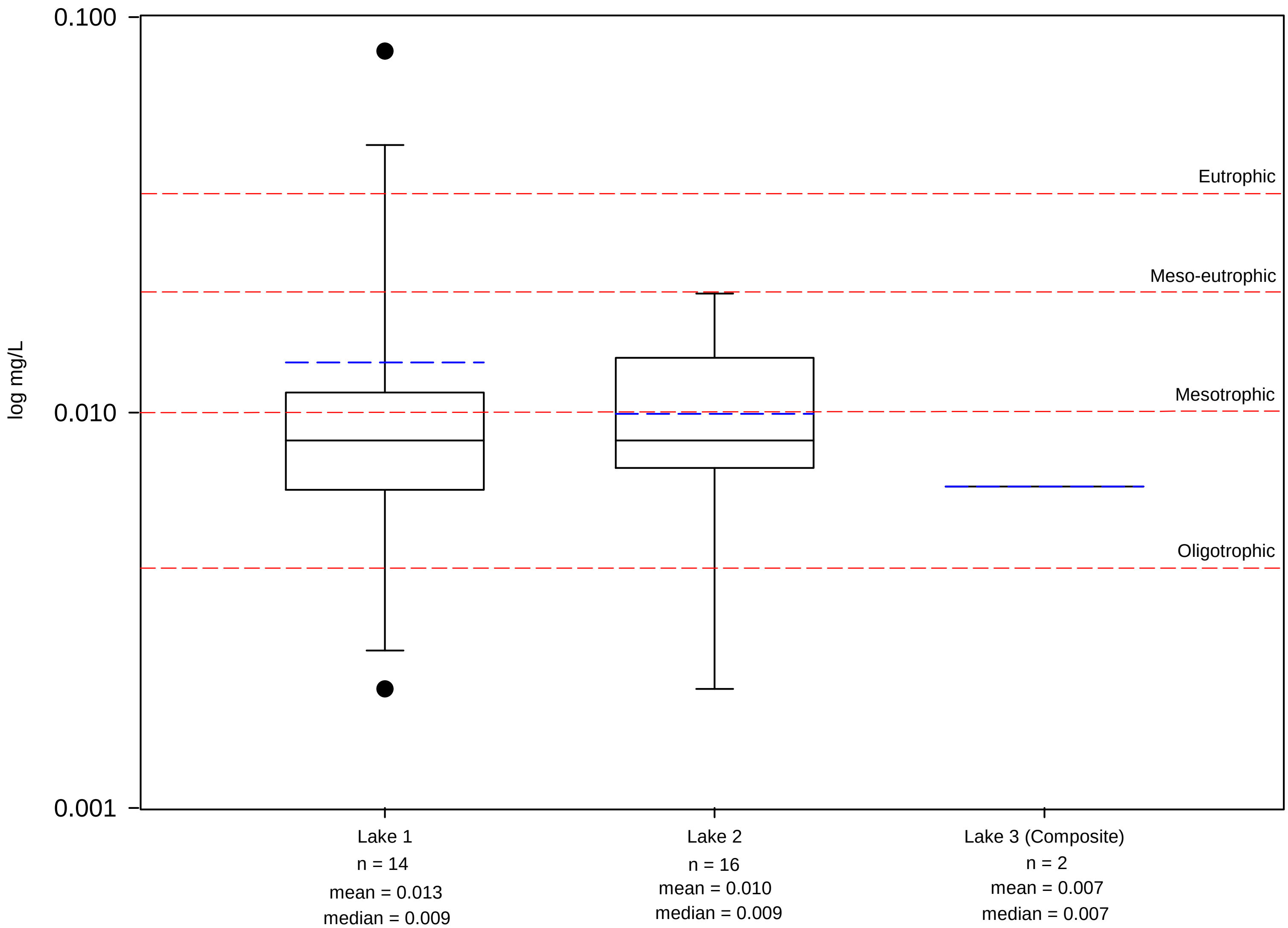
Normality Test (Kolmogorov-Smirnov) Monday, April 09, 2012, 3:47:11 PM

Data source: Lake Thomas TP in Shubie Box plots

Lake 1:	K-S Dist. = 0.449	P < 0.001	Failed
Lake 2:	K-S Dist. = 0.935	P > 0.200	Passed
Lake 3:	K-S Dist. = 0.260	P > 0.200	Passed

A test that fails indicates that the data varies significantly from the pattern expected if the data was drawn from a population with a normal distribution.
A test that passes indicates that the data matches the pattern expected if the data was drawn from a population with a normal distribution.

A Comparison of Total Phosphorus Results for Lake Thomas In-Lake samples



Note:

Lake 1 samples were collected by HRM between May 2006 and November 2011.

Lake 2 samples were collected by HRM between August 2007 and November 2011.

Lake 3 composite samples were collected by JW in 2007.

The results of the Kruskal-Wallis ANOVA on Ranks test indicate that the difference in median values among groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is no statistically significant difference (p=0.384).

Appendix H

Lake Capacity Model Results

Table of Contents

List of Tables and Figures

1. Introduction

A refined version of Ontario's LCM was used to assess potential changes in water quality from proposed development within the Shubenacadie subwatershed. The model, developed by Dillon and Rigler (1975), was calibrated on Canadian Shield lakes in Ontario (Dillon *et al.* 1986; Hutchinson *et al.* 1991) and has since been applied to lakes in Nova Scotia (e.g. Jacques Whitford 2004; Soliman 2008). This is a mass-balance, steady state model that quantifies linkages between natural sources of phosphorus (e.g. atmospheric deposition, in-lake cycling), human inputs from shoreline development (land use), water balance, lake morphometry, and the ice-free TP concentration of a lake (Paterson *et al.* 2006). A mass-balance model calculates a budget of the phosphorus inputs to a lake minus losses to the sediments and the outflow of the lake. The model assumes that the resulting concentration of phosphorus in the lake is equal to that of the outflow, and seasonal fluctuations in hydraulic and phosphorus loadings can be neglected.

For each lake the specific inputs to the model include:

- Surface areas for each land use (e.g. forest, meadow, residential, etc.);
- Phosphorus export coefficient for each land use;
- Hydraulic inputs and hydrology; and
- Point sources (septic systems, waste water treatment plant discharge and sanitary sewer overflows)

Using this information the model calculates:

- Hydraulic budget;
- Phosphorus loads from all land uses, point sources and septic systems; and
- Predicted lake total phosphorus concentration (ice-free).

The model version used for the Shubenacadie watershed was based on that developed by Brylinsky (2004) for Nova Scotia lakes.

1.1 Objective and Modeling Scenarios

The objective of the modeling was to evaluate the long-term impact of development in the Shubenacadie subwatershed on lake phosphorus concentrations. Three land use scenarios were modeled; one current scenario and two future scenarios:

1. Modeling Scenario 1: Existing Conditions
2. Modeling Scenario 2: HRM Authorized Subdivision Agreements
3. Modeling Scenario 3: Scenario 2 plus fully developed Port Wallis Lands

Results from scenarios 2 and 3 were compared to Existing Conditions, Scenario 1.

2. Model Input Parameters

The information needed to construct the model falls into three categories: morphology, hydrology, and phosphorus inputs. The input parameters associated with each of these categories, their values and source are provided below.

2.1 Lakes

The Shubenacadie subwatershed was delineated into 68 subwatersheds (Appendix A). Phosphorus concentrations were modeled for the most downstream lake in each subwatershed. In some instances subwatershed areas were combined and the phosphorus concentration in the most downstream lake was modeled. The land uses areas for the combined watersheds were added, representing the total input from the subwatershed areas upstream. The subwatersheds affected, and the rationale is provided in Table 1. A listing of the lakes modeled is presented in Table 2.

Table 1 Subwatersheds Modelled with Downstream Subwatershed

Watershed	Lake Modeled with	Rational
Tucker 000	Beaverbank	No lake present to model
Cranberry 000	Beaverbank	Development to occur in headwaters of watershed. Lake located in middle reaches of subwatershed
Bennery	Fish	Development to occur downstream of lake
A	Fletchers	Existing water quality data not available
Lizard000	Fletchers	No lake present to model, No development in the watershed,
Kelly	Grand	Development to occur downstream of lake
Kelly Long	Grand	No development in the watershed
Juniper	Soldier	No development in the watershed
Ferry	Ferry	No development in the watershed
Willis	Willis	No development in the watershed

2.2 Morphology

2.2.1 Drainage Basin Area (Ad), Lake Surface Area

The total subwatershed area and lake surface area was calculated for each lake in a Geographic Information System (GIS) environment. Details on the analyses are provided in Appendix I. Drainage basin area for each lake was calculated by subtracting lake surface area from the lake's total subwatershed area. Results are provided in **Error! Reference source not found.**

2.2.2 Lake Bathymetry and Volume

Bathymetric and volume information was available for selected lakes in the Shubenacadie Lakes subwatershed (Table 2). These included the five major lakes: Charles, William, Thomas, Fletcher and Grand Lakes. For these lakes, mean depth and volume were added to the model so it could calculate flushing rate, turnover time, and response time. For all other lakes modeled, this information was not included as the model does not use the values to predict the phosphorus concentrations. Maximum depth was estimated from available bathymetric mapping.

Table 2 Morphology of Lakes in Shubenacadie Watershed

Lake	Drainage Basin (ha)	Surface Area (ha)	Maximum Depth[1] (m)	Average Depth[2] (m)	Volume[3] (m^3)
Micmac	297	104	6		
Banook	169	42	12		
Cranberry South	65	11	3		
Loon	201	77	6		
Charles	1451	141	24	7.9	1.12×10^7
Powder Mill	469	43	13		
William	2196	302	18	11.4	3.44×10^7
First	281	141	23		
Rocky	729	146	3		
Second	579	113	12		
Third	243	85	24		
Soldier	3550	230	n/a		
Miller	472	126	4		
Thomas	801	113	4	3.6	4.06×10^6
Fletcher	1570	101	30	3.7	3.73×10^6
Grand	7734	1877	7	18.4	3.45×10^8
Fish	1230	51	1		
Fenerty	1443	65	2		
Springfield	637	81	1		
Lewis	333	76	2		
Hamilton	2627	30	n/a		
Tucker	153	33	6		
Beaverbank	3882	69	2		
Kinsac	2058	168	5		
Lisle	10	5	n/a		
Barrett	78	9	6		
Duck	70	9	3		
Beaver Pond	481	15	n/a		

Notes: 1. Estimated from available bathymetric mapping 2. Jacques Whitford 2009. 3. Calculated on surface area and mean depth.

2.3 Land Use

The land use areas used in the modeling scenarios were calculated for each lake subwatershed through an analysis of aerial photos, HRM bylaw zoning regulations, parcel fabric delineation, and subdivision agreements using GIS (Appendix F). Twenty five different land use categories were identified under existing and future development scenarios in the Shubenacadie watershed (Table 3). These land use categories were grouped together into a smaller classification list to assist with the selection of export coefficients for modeling (export coefficient are generally derived for coarser scale units). Table 3 presents a description of each land use identified and the classification used for modeling. For each subwatershed, the total area for each land use classification was calculated.

Table 3 Land Use Classifications

Land Use	Description	Model Land Use Classification
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 < .5ha	High Density Residential
Medium Density Residential	Parcel > 0.5 ha <1.5 ha	Medium Density Residential
Low Density Residential	Parcel >1.5 ha	Low Density Residential
Industrial	Industrial	Industrial
Institutional	Schools / library	Institutional
Open Space	Park or inner city open area	Open Space
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	Ponds and rivers	Water
Wetland	Designated wetland by NSDNR	Wetland
Park	Park or inner city open area	Open Space

The areas occupied by each land use classification used for modeling scenarios 1, 2 and 3 are presented in Table 4 and Table 5, and are shown in Figures 24 and 25 n the main body of the report.

Table 4 Modeling Scenario 1: Existing Conditions Land Use Areas (ha)

Watershed	Commercial	Forest	Meadow	High Density Residential	Industrial	Institutional	Low Density Residential	Medium Density Residential	Open Space	Roadway	Water	Wetland	Quarry
Micmac	14.51	62.64	0.00	105.31	0.00	8.75	7.41	14.74	13.85	60.52	9.51	0.00	0.00
Banook	23.72	5.85	0.00	72.54	0.00	7.02	0.00	10.07	19.09	31.12	0.09	0.00	0.00
Cranberry South	1.28	11.59	0.00	38.79	0.00	1.58	0.00	0.00	0.00	11.67	0.00	0.04	0.00
Loon	10.37	64.97	0.00	20.11	0.00	0.00	0.00	42.32	34.27	27.36	0.00	1.78	0.00
Charles	0.84	835.01	2.30	198.77	0.00	11.15	0.00	25.03	0.00	179.32	6.43	52.87	139.23
Powder Mill	19.88	244.67	0.00	65.70	0.50	0.00	0.00	45.55	0.00	44.82	33.96	14.33	0.00
William	8.94	1717.83	0.00	133.75	12.08	0.00	0.00	60.93	0.00	119.21	19.02	123.69	0.00
First	19.22	44.95	0.00	136.63	1.29	19.99	0.00	3.55	3.98	50.82	0.12	0.00	0.00
Rocky	30.42	234.20	0.00	47.44	22.59	2.47	17.12	45.15	10.19	45.08	6.92	40.75	226.56
Second	13.91	364.19	0.00	44.74	0.00	2.45	36.62	54.31	0.82	43.55	0.00	18.03	0.00
Third	1.84	71.17	3.12	13.24	0.45	0.00	15.08	109.20	0.00	27.50	1.84	0.00	0.00
Soldier*	146.99	2830.77	0.66	0.19	33.30	0.00	8.81	35.40	0.00	107.79	76.65	309.12	0.00
Miller	29.88	215.32	0.00	6.94	0.00	0.00	24.60	113.48	1.68	61.75	3.62	14.53	0.00
Thomas*	26.35	343.02	0.00	171.53	0.00	1.08	0.00	101.58	0.44	102.67	14.21	40.29	0.00
Fletcher*	1.38	706.60	0.00	129.41	0.00	29.72	0.00	556.28	0.00	100.62	21.83	23.78	0.00
Grand*	7.71	6718.45	266.89	16.82	2.15	0.00	62.45	272.02	9.95	56.81	59.50	261.50	0.00
Fish*	5.26	804.04	0.00	27.95	4.33	0.00	0.00	147.41	103.60	35.54	58.62	42.99	0.00
Fenerty	0.00	981.35	134.82	0.02	0.00	0.00	0.00	149.85	0.00	39.89	43.16	93.92	0.00
Springfield	3.10	175.11	64.13	107.24	0.00	0.00	0.00	208.43	15.42	50.10	0.71	12.40	0.00
Lewis	0.00	259.31	0.00	0.00	0.00	0.00	54.76	0.00	3.33	6.19	0.00	9.19	0.00
Hamilton	0.00	2004.64	282.90	18.40	0.00	1.60	6.32	3.86	0.00	4.63	96.39	208.09	0.00
Tucker	0.00	25.57	0.00	69.23	0.00	0.00	0.00	26.29	0.00	16.84	0.26	15.23	0.00
Beaverbank*	64.91	2868.75	187.45	66.60	0.00	6.54	0.00	300.55	6.66	63.55	70.08	246.69	0.00
Kinsac	125.61	1322.33	0.00	99.28	0.00	5.31	0.00	335.16	3.41	68.83	12.68	85.24	0.00
Lisle	0.00	2.90	0.00	0.00	0.00	0.00	0.00	6.33	0.00	0.22	0.00	0.51	0.00
Barrett	0.39	33.55	0.00	20.49	0.00	3.24	0.00	11.82	0.00	8.57	0.37	0.00	0.00
Duck	0.00	29.62	0.00	15.53	0.00	0.00	0.00	16.07	0.00	4.51	0.00	3.90	0.00
Beaver Pond	31.07	161.13	0.00	18.57	0.00	4.29	0.00	221.33	0.00	38.47	0.63	5.87	0.00

Notes: * denotes combined watersheds, see Table 1 for details

Table 5 Modeling Scenario 2: HRM Authorized Subdivisions, Land Use Areas (ha)

Watershed	Commercial	Forest	Meadow	High Density Residential	Industrial	Institutional	Low Density Residential	Medium Density Residential	Open Space	Roadway	Water	Wetland	Quarry
Micmac	14.51	62.64	0.00	105.31	0.00	8.75	7.41	14.74	13.85	60.52	9.51	0.00	0.00
Banook	23.72	5.85	0.00	72.54	0.00	7.02	0.00	10.07	19.09	31.12	0.09	0.00	0.00
Cranberry South	1.28	11.59	0.00	38.79	0.00	1.58	0.00	0.00	0.00	11.67	0.00	0.04	0.00
Loon	10.37	64.97	0.00	20.11	0.00	0.00	0.00	42.32	34.27	27.36	0.00	1.78	0.00
Charles[1]	0.84	566.48	2.30	467.30	0.00	11.15	0.00	25.03	0.00	179.32	6.43	52.87	139.23
Powder Mill	19.88	244.67	0.00	65.70	0.50	0.00	0.00	45.55	0.00	44.82	33.96	14.33	0.00
William	8.94	1675.39	0.00	133.75	12.08	0.00	42.44	60.93	0.00	119.21	19.02	123.69	0.00
First	19.22	44.95	0.00	136.63	1.29	19.99	0.00	3.55	3.98	50.82	0.12	0.00	0.00
Rocky	30.42	234.20	0.00	47.44	22.59	2.47	17.12	45.15	10.19	45.08	6.92	40.75	226.56
Second	13.91	340.94	0.00	44.74	0.00	2.45	59.87	54.31	0.82	43.55	0.00	18.03	0.00
Third	1.84	51.39	0.00	13.24	0.45	0.00	34.87	109.20	3.12	27.50	1.84	0.00	0.00
Soldier*	146.99	2819.01	0.66	0.19	33.30	0.00	20.57	35.40	0.00	107.79	76.65	309.12	0.00
Miller	29.88	207.10	0.00	6.94	0.00	0.00	32.83	113.48	1.68	61.75	3.62	14.53	0.00
Thomas*	26.35	343.02	0.00	171.53	0.00	1.08	0.00	101.58	0.44	102.67	14.21	40.29	0.00
Fletcher*	1.38	470.28	0.00	129.41	0.00	25.44	236.24	556.20	0.00	100.62	21.83	28.06	0.00
Grand*	7.71	6665.54	266.89	16.82	2.15	0.00	115.34	271.98	9.95	56.81	59.50	261.50	0.00
Fish*	5.26	791.44	103.60	27.95	4.33	0.00	12.64	147.41	0.00	35.54	58.62	42.99	0.00
Fenerty	0.00	900.93	126.31	0.02	0.00	0.00	88.53	149.85	0.00	41.19	43.16	93.77	0.00
Springfield	3.10	106.93	15.65	107.24	0.00	0.00	113.94	208.43	15.42	50.10	0.71	12.40	0.00
Lewis	0.00	259.31	0.00	0.00	0.00	0.00	54.76	0.00	3.33	6.19	0.00	9.19	0.00
Hamilton	0.00	2004.64	282.90	18.40	0.00	1.60	6.32	3.86	0.00	4.63	96.39	208.09	0.00
Tucker	0.00	10.26	0.00	69.23	0.00	0.00	15.45	26.29	0.00	16.98	0.26	15.23	0.00
Beaverbank*	64.91	2835.77	194.10	66.59	0.00	6.54	32.76	300.55	0.00	63.41	70.09	246.69	0.00
Kinsac	125.60	820.72	0.00	99.26	0.00	5.31	501.61	335.14	3.41	68.83	12.64	85.23	0.00
Lisle	0.00	0.63	0.00	0.00	0.00	0.00	2.27	6.33	0.00	0.22	0.00	0.53	0.00
Barrett	0.39	33.55	0.00	20.50	0.00	3.25	0.00	11.82	0.00	8.56	0.37	0.00	0.00
Duck	0.00	29.63	0.00	15.53	0.00	0.00	0.00	16.08	0.00	4.51	0.00	3.90	0.00
Beaver Pond	31.07	161.14	0.00	18.58	0.00	4.29	0.00	221.33	0.00	38.48	0.66	5.88	0.00

Note: 1. Land use for Charles represents the fully developed Port Wallis Lands: Modeling Scenario 3,* denotes combined watersheds, see Table 1 for details

2.4 Export Coefficient Selection

A review of phosphorus export coefficients from journal articles, thesis, and unpublished reports was conducted (**Table 6**). Much of the available literature is based on studies done in the USA where soils, climate and land use may differ from that in Nova Scotia. As a result, phosphorus export coefficients may not be accurate descriptors of conditions in the Shubenacadie Lakes subwatershed. In addition, much of the original literature and been superseded by more recent studies with more accurate export coefficients. Our primary sources were therefore focussed on recent studies that had been conducted in Halifax (e.g. Jacques Whitford 2004, Jacques Whitford 2009, and Brylinsky 2004) and those used previously in Nova Scotia.

Table 6 Export Coefficients (g/ha/yr) reviewed for Shubenacadie Watershed

Land Use	Location/comment	Export Coefficient	Source
Precipitation	Ontario	167	Paterson et al., 2006
	Nova Scotia	250	Scott et al. 2004
	Nova Scotia-Shubenacadie	173	Underwood, 1984
Wetland	L. Simcoe, ON	160	LSCRA, 2000
	wetlands - Florida	247	Northeast Florida Water Mangament District, 1994
Forest	L. Simcoe, ON	145	LSCRA, 2000
	United Kingdom	20	Johnes, 1996
		100	Rast et al., 1983
		200	Uttormark et al., 1974
		24	Reckhow et al., 1980
	Western Canada	100	Chambers and Dale, 1997
	Grand River	100	Winter and Duthie, 2000
	Sedimentary geology	103-107	Dillon et al., 1986
	Maine, 15% clearcut/10% selective cut	50-75	Main Department of Env. (2000)
	Nova Scotia-Igneous bedrock	69	Scott et al., 2000
	Nova Scotia-Sedimentary bedrock	88	Scott et al., 2000
	Nova Scotia-Igneous: Forest + >15% cleared/wetland	83	Scott et al., 2000
	Nova Scotia-Sedimentary: Forest + >15% cleared/wetland	115	Scott et al., 2000
Residential	Nova Scotia	520	Waller 1977
	Halifax - vegetation/low traffic	1860	Waller and Hart, 1986
	low intensity - L. Simcoe	130	HESL & MOE, 2011
	high intensity - L. Simcoe	1320	HESL & MOE, 2011
	Maine	25-35	Main Department of Env. (2000)
	L. Simcoe-East Holland River Watershed	2010	LSCRA, 2000
	Waterloo, ON (low to mid density)	500	Winter and Duthie, 2001
	Urban	5-125	Reckhow and Simpson, 1980

	low density residential- Minnesota	500	Walker, 1985
	mixed urban and commercial - Minnesota	1200	Walker, 1985
	low density residential- Florida	527	Northeast Florida Water Mangament District, 1994
	multi- density residential- Florida	2208	Northeast Florida Water Mangament District, 1994
	low, Milwaukee	45	Novotny and Olem, 1997
	medium, Milwaukee	583	Novotny and Olem, 1997
	high, Milwaukee	1121	Novotny and Olem, 1997
Impervious	Ontario	45	Waller and Hart, 1986
		932	Waller and Hart, 1986
		2208	Waller and Hart, 1986
		1100	Waller and Hart, 1986
Commercial	light - Nova Scotia - Shubenacadie	400	Waller and Hart, 1986
	Commercial/intuitional - Shubenacadie	2020	Waller and Hart, 1986
	No vegetation/high traffic	2020	Waller and Hart, 1986
	Vegetation/moderately high traffic	3980	Waller and Hart, 1986
	Milwaukee	1491	Novotny and Olem, 1997
	Florida	2298	Northeast Florida Water Mangament District, 1994
	Commercial/intuitional - L. Simcoe	1820	HESL & MOE, 2011
Institutional	Nova Scotia - Shubenacadie	420	Waller and Hart, 1986
	no vegetation/low traffic - Halifax	420	Waller and Hart, 1986
Industrial	Milwaukee	1491	Novotny and Olem, 1997
	Florida	5347	Northeast Florida Water Mangament District, 1994
Parking Lots	Milwaukee	785	Novotny and Olem, 1997
Highway (public road)	Maine	3500	Main Department of Env. (2000)
	Wisconsin, Milwaukee	1042	Novotny and Olem, 1997
	Florida	2802	Northeast Florida Water Mangament District, 1994
Camp/private roads	Maine	3500	Main Department of Env. (2000)
Unpaved road	L. Simcoe , Ontario	830	HESL & MOE, 2011
Open lands	Florida	179	EPA, 2001
Urban development	Halifax, Nova Scotia	430	Waller and Hart, 1986
Quarry	L. Simcoe , Ontario	4-108	HESL & MOE, 2011
	L. Simcoe , Ontario - median value	80	HESL & MOE, 2011

Specific and local export coefficients were not available for every land use in the Shubenacadie Lakes subwatershed, so some were derived from other land uses in the watershed where export coefficients were already developed. Table 7 presents the export coefficients used for the modeling.

Scott *et al.* (2000) carried out an extensive study to determine export coefficients from various combinations of geology, soil type and land use. For igneous bedrock geology forested areas and forested areas with greater than 15% cleared or wetland area they recommended phosphorus export coefficients of 69 and 83 g/ha/yr respectively.

The export coefficient for wetlands was selected equal to that determined by Scott *et al.* (2000) for forested areas with greater than15% cleared or wetland area.

Table 7 Export Coefficients (g/ha/yr) used for Shubenacadie Subwatershed

Land Use Classification	Export Coefficient	Source
Forest	69	Scott *et al.* (2000)
Forest-Meadow	83	Scott *et al.* (2000)
Wetland	83	Scott *et al.* (2000)
Water	173	Jacques Whitford (2004)
Industrial	2020	Waller and Hart (1985)
Institutional	420	Waller and Hart (1985)
Commercial	2020	Waller and Hart (1985)
Quarry	80	HESL & MOE, 2011
Roadway	830	HESL & MOE, 2011
High Density Residential	520	Jacques Whitford (2004)
Medium Density Residential	130	Jacques Whitford (2004)
Low Density Residential	130	HESL & MOE, 2011
Open Space	130	HESL & MOE, 2011

An export coefficient of 2020 g/ha/yr was selected for commercial and industrial land uses in the watershed. This value was taken from the Waller and Hart (1985) export coefficient for commercial areas that have no vegetation and high traffic. This value was used by Jacques Whitford (2004) in their calculations of phosphorus export from commercial and industrial land uses in the Birch Cove watershed. An export coefficient of 830 g/ha/yr was used for roads, after the Ontario phosphorus loading model (HESL and MOE 2011). Most of the roads in the watersheds are residential streets with little traffic. As such, phosphorus export from these areas is expected more similar to unpaved roads than to highways, which have a much higher volume of traffic.

Waller and Hart (1985) derived an export coefficient of 420 g/ha/yr for institutional areas with no vegetation and low traffic. This value was adopted by Jacques Whitford (2004) for institutional areas in their study of Birch Cove and is used here for institutional areas in the Shubenacadie subwatershed.

An export coefficient of 80 g/ha/yr was used for the quarry land use areas located in the Charles and Rocky subwatersheds. This value was selected based on the quarry value used in the Ontario phosphorus loading model (HESL & MOE, 2011). In the absence of any published literature values for export coefficients for quarries, this value was selected to represent the low phosphorus runoff that would be expected from quarry areas.

Phosphorus export coefficients for residential land use were derived from local and Ontario export coefficients. Jacques Whitford (2004) used an export coefficient of 520 g/ha/yr for urban residential areas in the Birch Cove watershed. A review of export coefficients found that values for urban development range from 5 to 2208 g/ha/yr depending on the density of development and the intended use. The value of 520 g/ha/yr was therefore used to represent phosphorus export from high density areas. An export coefficient of 130 g/ha/yr was selected for low and medium density areas, based on that used for low development in the Lake Simcoe watershed in Ontario (HESL &

MOE, 2011). This value was used for both low and medium residential development, the size of the parcel size for medium residential development is between 0.5 and 1.5 ha, which is large for an urbanized area. The export coefficient used for Lake Simcoe is also a more recent value for export coefficients from residential areas.

For ponds and rivers located in the subwatershed the atmospheric export coefficient of 173 g/ha/yr used for lakes was selected, as these features would act to transport phosphorus downstream to the lake. This is the export coefficient value used Jacques Whitford (2004) for atmospheric deposition.

An export coefficient of 130 g/ha/yr was used for open spaces, park and inner city areas. This land use was given the same export coefficient as low and medium density residential, as most of the area would be manicured lawns with little maintenance, and lower runoff, than more intensively maintained or manicured areas.

2.5 Development Inputs

The input from development or the load from septic systems can potentially be a primary source of phosphorus to many lakes. The model requires the following information to calculate the input of phosphorus from development:

- Nd – the number of dwelling units within 300 m of the shoreline of the lake and any tributaries that enter the lake
- Nu – the average number of people occupying the dwellings
- Npc – the average fraction of the year each dwelling is occupied.
- Si – the amount of phosphorus produced per capita
- Rsp – the adsorption capacity of the soils.

For Existing Conditions (Scenario 1) the number of dwelling units within 300 m of the shorelines not serviced by the sanitary sewer system was calculated in a GIS environment. For units that were within 300 m of two modeled lakes units upgradient of the outflow were attributed to the upstream lake. For the HRM Approved Subdivision Agreements Scenario 2, the location of new dwelling units was not available, rather just the total number of units attributed to a residential land use. The number of dwelling units within 300 m of the shoreline was estimated by multiplying the proportion of residential area within 300 m of a shoreline (outside of the sewer shed) by the total number of lots for that area. For Scenario 3 (Port Wallis) all new development will be serviced by the sanitary sewer system. Table 8 presents the number of dwelling units within 300 m of the lakes modelled for Scenarios 1 and 2.

Table 8 The number of dwelling units within 300 m of shorelines

Lake	Scenario 1: Existing Conditions	Scenario 2: HRM Authorized Subdivision Agreements
Charles	70	70
First	53	53
Rocky	147	147
Second	195	209
Third	264	264
Powder Mill	58	58
William	882	884
Soldier	1	1
Miller	133	179

Lake	Scenario 1: Existing Conditions	Scenario 2: HRM Authorized Subdivision Agreements
Thomas	385	385
Fletcher	427	433
Grand	883	889
Fish	79	80
Springfield	135	213
Lisle	14	14
Fenerty	54	187
Lewis	145	145
Tucker	316	339
Beaver- bank	38	38
Barrett	165	165
Duck	121	121
Beaver Pond	73	73
Kinsac	328	544

Notes: Scenario 3 development will be serviced

The average number of persons per dwelling was estimated as 2.6 and the average fraction of year each dwelling is occupied as 1 (occupied at all times). A phosphorus load of 660 g/capita yr was used as the amount of phosphorus produced per capita. This value was taken from a recent review of the LCM (Paterson *et al.* 2006). In the study, 660 g/capita yr is estimated based on the increased water usage in houses and apartments since the early 1970s.

The adsorption capacity is used to infer attenuation of phosphorus in the soils. The adsorption capacity is dependent on the soil type, depth, and distance of the septic system from the shoreline. For Scenario 1 – Existing Conditions, an adsorption capacity of 67% or 0.67 was used. This value was chosen as most of the shoreline lots are large with houses and septic systems located a distance from the shoreline.

For Scenario 2, we assumed that the soil adsorption capacity would decrease as the septic systems aged. With a decreasing capacity to hold phosphorus, the phosphorus mobility will increase. As such, an adsorption capacity of 50% or 0.50 was used for existing septic systems. In instances where the number of new septic systems was 10% or higher than the existing number of septic systems, new septic systems were given an adsorption capacity of 85% (0.85), as it is expected that these would be highly functioning systems allowing little phosphorus mobility. When the number of new septic systems was less than 10% of the number of existing septic systems, an adsorption capacity of 50% was used, as no difference in phosphorus concentrations was observed.

2.6 Point Source Inputs

Point source inputs of phosphorus to lakes include discharge from sewage treatment plants and may also include, for example livestock feedlots and aquaculture operations. Point source inputs to several lakes in the Shubenacadie subwatershed occur from sewage treatment plants. Table 9 presents inputs from sewage treatment plants.

Table 9 Point Source Inputs from Sewage Treatment Plants in Shubenacadie Watershed

Subwatershed Location	Discharge Location	Plant	Flow Capacity[1]		Effluent P[2]	Load
			ML/d	m3/d	mg/L	g/yr
Grand	Grand Lake	Nova Scotia Environmental Health Clinic		9	1.5	4928
Fletcher	Lake Fletcher	Lockview MacPerson (Fall River)	0.45	455	1.5	248565
Fletcher	Grand Lake	Wellington WWTF (Steve's Subdivision)	0.068		1.5	37230
Thomas	Lake Thomas	Inn on the Lake		50	1.5	27375
William	Lake Thomas	Waverley Manor		5	1.5	2738
Miller	Lake Miller	Miller Lake		111	1.5	60773
William	Lake William	Irving Oil		5	1.5	2738
William	Lake William	Frame WWTF	0.08		1.5	43800
Kinsac	Kinsac Lake	Ashburn Golf		26	1.5	14235
Lisle	Lisle Lake	Springfield Lake	0.545	655	1.5	298388

Notes: Only sewage treatment plants that discharge into modelled lakes are presented. 1. Data provided by: W. Regan, compilation of NSE Registered Waste Water Facilities. 2. Effluent phosphorus concentrations are estimated on effluent TP requirements for WWTPs.

2.7 Lake Phosphorus Retention Coefficient

As the amount of phosphorus retained within the lake is equal to that which enters the lake less what is lost to the sediments, a retention coefficient – the amount of phosphorus lost to the sediments - is required. Retention coefficients of 12.4 and 7.2 for lakes with oxic and anoxic hypolimnions, respectively were chosen according to the relationship developed by Dillon *et al.* 1994. A value of 12.4 was used for lakes less than 10 m deep and a value of 7.2 was used for lakes deeper than 10 m, as it is expected that these lakes undergo periods of anoxic conditions during the summer months.

2.8 Precipitation and Evaporation

The Annual Unit Precipitation onto the lakes was estimated as 1.45 m/yr based on Environment Canada's "climate normals" (Table 10) available for the Halifax Stanfield Airport station (8202250) for the most recent meteorological record (1971-2000).

Table 10 Environment Canada Climate Normals (1971-2000) for Halifax Stanfield Airport Station (8202250)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Rainfall (mm)	100.6	69	96.4	96.1	106.2	98.3	102.2	92.7	103.6	126.4	133	114.5	1238.9
Snowfall (cm)	54.6	50.1	41.1	20.9	3.3	0	0	0	0	2.3	14.4	43.9	230.5
Precipitation (mm)	149.2	114.4	134.5	118.3	109.7	98.3	102.2	92.7	103.6	128.7	146	154.8	1452.2
Precipitation (m)													**1.45**

Lake evaporation of 0.0167 m/year was estimated from the Environment Canada's station 8205990, located in Truro Nova Scotia (Table 11).

Table 11 Environment Canada Evaporation Data for Truro Station (8205990)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	Total
Lake Evaporation (mm)	0	0	0	0	2.9	3.4	3.6	3.2	2.3	1.3	0	0	0	16.70
Lake Evaporation (m)														0.0167

3. Model Validation and Calibration

Using existing land use scenarios, a comparison of modeled versus observed lake phosphorus concentrations was conducted to validate the selection of model constants (e.g. export coefficients). Brylinsky (2004) indicated that a model can be considered valid if modeled phosphorus concentrations are within 20% of field measurements. However, field measurements should be collected over a period of 5 to 10 years because the model is constructed using parameter estimates that are the averages of many years and mean annual lake phosphorus concentration can vary considerably from year to year (Brylinsky 2004). For many of the lakes in the Shubenacadie subwatershed, long-term monitoring data is available upon which to calibrate the model. In the instances where current long-term monitoring data is not available (e.g. last 5 years) higher percent differences are expected.

The modeled concentrations for many lakes were 20% outside of their average concentration (Table 11). This was particularly evident for Tucker and Lisle Lakes, whose modeled TP concentrations were more than four times their average TP concentrations. For the lakes with phosphorus concentrations outside of 20%, the model overestimated phosphorus concentrations in most lakes, however for Loon, Rocky and Springfield lakes the model underestimated concentrations.

Table 12 Measured versus Modeled TP Concentrations (µg/L) before Calibration

Lake	Modeled Phosphorus (Scenario 1)	Average Phosphorus [1]	Difference [2]	Median Phosphorus	Number of Measurements
Cranberry South	16	20±13	-19%	11	17
Loon	10	15±12	-37%	8	15
Charles	15	10±8	50%	8	21
Micmac	10	10±12	-3%	8	17
Banook	12	10±11	21%	8	17
First	21	11±10	91%	15	17
Rocky	12	16±12	-23%	8	17
Second	16	12±14	37%	8	16
Third	18	10±11	80%	7	17
Powder Mill	15	10±11	50%	9	17
William	18	9±7	100%	0	19
Soldier	11	n/a		12	
Miller	12	11±4	8%	8	3
Thomas	12	11±14	13%	9	32

Lake	Modeled Phosphorus (Scenario 1)	Average Phosphorus [1]	Difference[2]	Median Phosphorus	Number of Measurements
Fletcher	16	10±9	60%	5	20
Grand	9	8±13	12%	18	19
Fish	13	18±1	-26%	10	2
Springfield	14	14±10	-3%	42	16
Lisle	49	50±26	-3%	21	8
Fenerty	18	22±9	-18%	0	16
Lewis	9	n/a		0	
Hamilton	12	n/a		9	
Tucker	40	10±7	296%	11	17
Beaverbank	11	11±1	2%	11	2
Barrett	58	11±6	428%	30	17
Duck	43	43±39	0%	23	16
Beaver Pond	29	23	26%	11	1
Kinsac	14	12±8	13%	11	17

Notes: 1. Average concentrations ± the standard deviation 2. Shaded values indicate modeled values differing greater than 20% from measured values

The LCM for Halifax uses a relationship between the areal hydraulic load and lake phosphorus retention coefficient to estimate a phosphorus retention factor (Kirchner and Dillon 1975). The value of the retention factor determines how much phosphorus is retained in the lake and how much is moved downstream. Phosphorus retention factors were adjusted for all lakes with modeled concentrations 20% outside of their average concentration, with the exception of Fish and Beaver Pond. Modeled phosphorus concentrations for Fish and Beaver Pond, although outside of their measured concentrations by 20%, were considered reasonable estimates of phosphorus concentrations for these lakes due to the low sample sizes (two and one samples respectively).

After adjusting the retention factors, modeled concentrations were within estimates of measured lake TP concentrations (Table 12). Phosphorus retention coefficients for Loon and Rocky decreased from 0.71 and 0.57 to 0.60 and 0.45 respectively. The lowered retention coefficients in these lakes reduced phosphorus loss due to sedimentation and increased lake concentrations to within 20% of measured concentrations. For all other lakes phosphorus retention coefficients increased. The new retention factors were comparable to other values for lakes in the Shubenacadie subwatershed with the exception of First, Tucker and Barrett lakes. Retention factors for these lakes were 0.80, 0.92 and 0.92 respectively. These values are outside of those found in Shubenacadie lakes, however are necessary for the model to accurately predict total phosphorus concentrations downstream in Kinsac Lake.

Table 13 Measured versus Modeled TP concentrations (µg/L) after Calibration

Lake	Measured TP	Modeled TP	Difference	TP Retention Factor	
				Pre-Calibration	Post Calibration
Cranberry South	20±13	16	-19%	0.63	N/C
Loon*	15±12	13	-14%	0.71	0.60
Charles*	10±8	10	0%	0.33	0.55

Lake	Measured TP	Modeled TP	Difference	TP Retention Factor	
				Pre-Calibration	Post Calibration
Micmac	10±12	10	0%	0.36	N/C
Banook*	10±11	10	0%	0.10	0.30
First*	11±10	10	-5%	0.60	0.80
Rocky*	16±12	15	-6%	0.57	0.45
Second*	12±14	12	0%	0.52	0.65
Third*	10±11	10	0%	0.35	0.65
Powder Mill	10±11	10	0%	0.09	0.40
William*	9±7	9	0%	0.27	0.60
Soldier	n/a	11	n/a	0.42	N/C
Miller	11±4	12	8%	0.25	N/C
Thomas	11±14	12	13%	0.11	N/C
Fletcher*	10±9	9	-7%	0.05	0.45
Grand	8±13	9	12%	0.26	N/C
Fish	18±1	13	-26%	0.32	N/C
Springfield	14±10	14	0%	0.57	N/C
Lisle	50±26	49	-3%	0.08	N/C
Fenerty	22±9	18	-18%	0.25	N/C
Lewis	n/a	9	n/a	0.68	N/C
Hamilton	n/a	12	n/a	0.06	N/C
Tucker*	10±7	9	-5%	0.67	0.92
Beaverbank	11±1	11	0%	0.08	N/C
Barrett*	11±6	11	-0%	0.55	0.92
Duck	43±39	43	0%	0.58	N/C
Beaver Pond	23	29	26%	0.24	N/C
Kinsac	12±8	14	13%	0.14	N/C

Notes: shaded values indicate modeled values differing greater than 20% measured values, * indicated analysis conducted to determine P retention coefficient, N/C = no change from original retention coefficient

4. References

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Appendix I

Lake Capacity Model Worksheets

Lake Name: Banook | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	169.49	ha
Land Use -1 Commercial	23.72	ha
Land Use -2 Forest	5.85	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	72.54	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	7.02	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	10.07	ha
Land Use -9 Open Space	19.09	ha
Land Use -10 Roadway	31.12	ha
Land Use -11 Water	0.09	ha
Land Use -12 Wetland	0.00	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	41.50	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstream Hydraulic Inputs	21903809	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	221081.31	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	0	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.		n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	7.2	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	601750	m^3/yr
Total Evaporation Loss	212480	m^3/yr
Total Hydraulic Surface Runoff	1728837	m^3/yr
Total Hydraulic Input	24234396	m^3/yr
Areal Hydraulic Load	58	m/yr
Total Hydraulic Outflow	24021916	m^3/yr
Total Atmosphosphplugins P Input	7180	g/yr
Total Surface Run Off P Input	118622	g/yr
Total Development P Input	0.00	g/yr
Total P Input	346883	g/yr
Lake P Retention Factor	0.30	n/a
Lake P Retention	104065	g/yr
Predicted Lake P Concentration	**0.010**	mg/L
Lake Phosphours Outflow	242818	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	21903808.74	
Precipitation	601750	
Surface Run Off	1728837	
Evaporation	212480	
Total Outflow	24021916	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	221081.31	
Atmosphere	7180	
Surface Run Off	118622	
Development	0	
Sedimentation	104065	
Total Outflow	242818	
Total Check		
Model Validation		**Units**
Predicted P	0.010	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Micmac | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	297.24	ha
Land Use -1 Commercial	14.51	ha
Land Use -2 Forest	62.64	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	105.31	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	8.75	ha
Land Use -7 Low Density Residential	7.41	ha
Land Use -8 Medium Density Residential	14.74	ha
Land Use -9 Open Space	13.85	ha
Land Use -10 Roadway	60.52	ha
Land Use -11 Water	9.51	ha
Land Use -12 Wetland	0.00	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	104.15	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	17895042	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	184798.44	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	0	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.		n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	1510175	m^3/yr
Total Evaporation Loss	533248	m^3/yr
Total Hydraulic Surface Runoff	3031840	m^3/yr
Total Hydraulic Input	22437057	m^3/yr
Areal Hydraulic Load	21	m/yr
Total Hydraulic Outflow	21903809	m^3/yr
Total Atmosphepheric P Input	18018	g/yr
Total Surface Run Off P Input	148616	g/yr
Total Development P Input	0.00	g/yr
Total P Input	351432	g/yr
Lake P Retention Factor	0.37	n/a
Lake P Retention	130351	g/yr
Predicted Lake P Concentration	**0.010**	mg/L
Lake Phosphours Outflow	221081	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	17895041.60	
Precipitation	1510175	
Surface Run Off	3031840	
Evaporation	533248	
Total Outflow	21903809	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	184798.44	
Atmosphere	18018	
Surface Run Off	148616	
Development	0	
Sedimentation	130351	
Total Outflow	221081	
Total Check		

Model Validation		**Units**
Predicted P	0.010	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Cranberry Lake | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	64.94	ha
Land Use -1 Commercial	1.28	ha
Land Use -2 Forest	11.59	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	38.79	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	1.58	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	0.00	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	11.67	ha
Land Use -11 Water	0.00	ha
Land Use -12 Wetland	0.04	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	11.23	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	0	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	0.00	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	0	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.		n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	162818	m^3/yr
Total Evaporation Loss	57492	m^3/yr
Total Hydraulic Surface Runoff	662430	m^3/yr
Total Hydraulic Input	825248	m^3/yr
Areal Hydraulic Load	7	m/yr
Total Hydraulic Outflow	767756	m^3/yr
Total Atmosphospheric P Input	1943	g/yr
Total Surface Run Off P Input	33907	g/yr
Total Development P Input	0.00	g/yr
Total P Input	35849	g/yr
Lake P Retention Factor	0.64	n/a
Lake P Retention	23108	g/yr
Predicted Lake P Concentration	**0.017**	mg/L
Lake Phosphours Outflow	12742	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	162818	
Surface Run Off	662430	
Evaporation	57492	
Total Outflow	767756	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	1943	
Surface Run Off	33907	
Development	0	
Sedimentation	23108	
Total Outflow	12742	
Total Check		

Model Validation		**Units**
Predicted P	0.017	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Loon | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	201.19	ha
Land Use -1 Commercial	10.37	ha
Land Use -2 Forest	64.97	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	20.11	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	42.32	ha
Land Use -9 Open Space	34.27	ha
Land Use -10 Roadway	27.36	ha
Land Use -11 Water	0.00	ha
Land Use -12 Wetland	1.78	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	76.63	ha
Lake Volume		$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	767756	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	12741.60	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	2020	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	0	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.		n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	1111128	m^3/yr
Total Evaporation Loss	392343	m^3/yr
Total Hydraulic Surface Runoff	2052119	m^3/yr
Total Hydraulic Input	3931004	m^3/yr
Areal Hydraulic Load	5	m/yr
Total Hydraulic Outflow	3538661	m^3/yr
Total Atmosphospheric P Input	13257	g/yr
Total Surface Run Off P Input	101262	g/yr
Total Development P Input	0.00	g/yr
Total P Input	127260	g/yr
Lake P Retention Factor	0.60	n/a
Lake P Retention	76356	g/yr
Predicted Lake P Concentration	**0.014**	mg/L
Lake Phosphours Outflow	50904	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	767756.46	
Precipitation	1111128	
Surface Run Off	2052119	
Evaporation	392343	
Total Outflow	3538661	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	12741.60	
Atmosphere	13257	
Surface Run Off	101262	
Development	0	
Sedimentation	76356	
Total Outflow	50904	
Total Check		
Model Validation		**Units**
Predicted P	0.014	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Charles | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	1450.94	ha
Land Use -1 Commercial	0.84	ha
Land Use -2 Forest	835.01	ha
Land Use -3 Forest - Meadow	2.30	ha
Land Use -4 High Density Residential	198.77	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	11.15	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	25.03	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	179.32	ha
Land Use -11 Water	6.43	ha
Land Use -12 Wetland	52.87	ha
Land Use -13 - Quarry	139.23	ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	141.43	ha
Lake Volume	1117315571	m^3
Hydrology		
Upstrean Hydraulic Inputs	3538661	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	50904.12	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	69	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient - Quarry	80	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	70	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	7.2	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	2050769	m^3/yr
Total Evaporation Loss	724134	m^3/yr
Total Hydraulic Surface Runoff	14799585	m^3/yr
Total Hydraulic Input	20389015	m^3/yr
Areal Hydraulic Load	14	m/yr
Total Hydraulic Outflow	19664881	m^3/yr
Total Atmosphospheric P Input	24468	g/yr
Total Surface Run Off P Input	336267	g/yr
Total Development P Input	39639.60	g/yr
Total P Input	451278	g/yr
Lake P Retention Factor	0.55	n/a
Lake P Retention	248203	g/yr
Predicted Lake P Concentration	**0.010**	mg/L
Lake Phosphours Outflow	203075	g/yr
Lake Mean Depth	7.90	m
Lake Flushing Rate	0.02	/yr
Lake Turnover Time	56.82	yr
Lake Response Time	0.54	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	3538660.61	
Precipitation	2050769	
Surface Run Off	14799585	
Evaporation	724134	
Total Outflow	19664881	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	50904.12	
Atmosphere	24468	
Surface Run Off	336267	
Development	39640	
Sedimentation	248203	
Total Outflow	203075	
Total Check		
Model Validation		**Units**
Predicted P	0.010	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Powder Mill

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	469.40	ha
Land Use -1 Commercial	19.88	ha
Land Use -2 Forest	244.67	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	65.70	ha
Land Use -5 Industrial	0.50	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	45.55	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	44.82	ha
Land Use -11 Water	33.96	ha
Land Use -12 Wetland	14.33	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	43.10	ha
Lake Volume		m^3
Hydrology		
Upstrean Hydraulic Inputs	22674787	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	311607	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	530	520
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	58	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	7.2	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	624913	m^3/yr
Total Evaporation Loss	220659	m^3/yr
Total Hydraulic Surface Runoff	4787928	m^3/yr
Total Hydraulic Input	28087628	m^3/yr
Areal Hydraulic Load	65	m/yr
Total Hydraulic Outflow	27866969	m^3/yr
Total Atmosphospheric P Input	7456	g/yr
Total Surface Run Off P Input	143055	g/yr
Total Development P Input	32844.24	g/yr
Total P Input	494962	g/yr
Lake P Retention Factor	0.40	n/a
Lake P Retention	197985	g/yr
Predicted Lake P Concentration	**0.011**	mg/L
Lake Phosphours Outflow	296977	g/yr
Lake Mean Depth		m
Lake Flushing Rate		/yr
Lake Turnover Time		yr
Lake Response Time		yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	22674786.83	
Precipitation	624913	
Surface Run Off	4787928	
Evaporation	220659	
Total Outflow	27866969	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	311607.38	
Atmosphere	7456	
Surface Run Off	143055	
Development	32844	
Sedimentation	197985	
Total Outflow	296977	
Total Check		
Model Validation		**Units**
Predicted P	0.011	(mg/L)
Measured P	0.010	(mg/L)
% Difference		

Lake Name: William | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	2195.45	ha
Land Use -1 Commercial	8.94	ha
Land Use -2 Forest	1717.83	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	133.75	ha
Land Use -5 Industrial	12.08	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	60.93	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	119.21	ha
Land Use -11 Water	19.02	ha
Land Use -12 Wetland	123.69	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	301.78	ha
Lake Volume	34403266	m^3
Hydrology		
Upstream Hydraulic Inputs	28456915	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	303070	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	530	520
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	882	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1	43800	g/yr
Point Source Input 2	2738	g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	7.2	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	4375854	m^3/yr
Total Evaporation Loss	1545129	m^3/yr
Total Hydraulic Surface Runoff	22393545	m^3/yr
Total Hydraulic Input	55226314	m^3/yr
Areal Hydraulic Load	18	m/yr
Total Hydraulic Outflow	53681185	m^3/yr
Total Atmosphospheric P Input	52208	g/yr
Total Surface Run Off P Input	352294	g/yr
Total Development P Input	545996.46	g/yr
Total P Input	1253569	g/yr
Lake P Retention Factor	0.60	n/a
Lake P Retention	752141	g/yr
Predicted Lake P Concentration	**0.009**	mg/L
Lake Phosphours Outflow	501428	g/yr
Lake Mean Depth	11.40	m
Lake Flushing Rate	1.56	/yr
Lake Turnover Time	0.64	yr
Lake Response Time	0.28	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	28456915.09	
Precipitation	4375854	
Surface Run Off	22393545	
Evaporation	1545129	
Total Outflow	53681185	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	303069.66	
Atmosphere	52208	
Surface Run Off	352294	
Development	545996	
Sedimentation	752141	
Total Outflow	501428	
Total Check		
Model Validation		**Units**
Predicted P	0.009	(mg/L)
Measured P	0.009	(mg/L)
% Difference		

Lake Name: First | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	280.55	ha
Land Use -1 Commercial	19.22	ha
Land Use -2 Forest	44.95	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	136.63	ha
Land Use -5 Industrial	1.29	ha
Land Use -6 Institutional	19.99	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	3.55	ha
Land Use -9 Open Space	3.98	ha
Land Use -10 Roadway	50.82	ha
Land Use -11 Water	0.12	ha
Land Use -12 Wetland	0.00	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	82.70	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	0	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	0.00	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	53	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	7.2	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	1199138	m^3/yr
Total Evaporation Loss	423420	m^3/yr
Total Hydraulic Surface Runoff	2861583	m^3/yr
Total Hydraulic Input	4060721	m^3/yr
Areal Hydraulic Load	4	m/yr
Total Hydraulic Outflow	3637302	m^3/yr
Total Atmosphosphric P Input	14307	g/yr
Total Surface Run Off P Input	167160	g/yr
Total Development P Input	30012.84	g/yr
Total P Input	211480	g/yr
Lake P Retention Factor	0.80	n/a
Lake P Retention	169184	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	42296	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	1199138	
Surface Run Off	2861583	
Evaporation	423420	
Total Outflow	3637302	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0	
Atmosphere	14307	
Surface Run Off	167160	
Development	30013	
Sedimentation	169184	
Total Outflow	42296	
Total Check		

Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Rocky | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	728.88	ha
Land Use -1 Commercial	30.42	ha
Land Use -2 Forest	234.20	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	47.44	ha
Land Use -5 Industrial	22.59	ha
Land Use -6 Institutional	2.47	ha
Land Use -7 Low Density Residential	17.12	ha
Land Use -8 Medium Density Residential	45.15	ha
Land Use -9 Open Space	10.19	ha
Land Use -10 Roadway	45.08	ha
Land Use -11 Water	6.92	ha
Land Use -12 Wetland	40.75	ha
Land Use -13 Quarry	226.56	ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	145.69	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	3637302	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	42296.00	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient - Quarry	80	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	147	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	2112453	m^3/yr
Total Evaporation Loss	745914	m^3/yr
Total Hydraulic Surface Runoff	7434544	m^3/yr
Total Hydraulic Input	13184299	m^3/yr
Areal Hydraulic Load	9	m/yr
Total Hydraulic Outflow	12438384	m^3/yr
Total Atmosphospheric P Input	25204	g/yr
Total Surface Run Off P Input	218489	g/yr
Total Development P Input	83243.16	g/yr
Total P Input	369232	g/yr
Lake P Retention Factor	0.45	n/a
Lake P Retention	166154	g/yr
Predicted Lake P Concentration	**0.016**	mg/L
Lake Phosphours Outflow	203078	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	3637301.53	
Precipitation	2112453	
Surface Run Off	7434544	
Evaporation	745914	
Total Outflow	12438384	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	42296.00	
Atmosphere	25204	
Surface Run Off	218489	
Development	83243	
Sedimentation	166154	
Total Outflow	203078	
Total Check		
Model Validation		**Units**
Predicted P	0.016	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Second | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	578.61	ha
Land Use -1 Commercial	13.91	ha
Land Use -2 Forest	364.19	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	44.74	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	2.45	ha
Land Use -7 Low Density Residential	36.62	ha
Land Use -8 Medium Density Residential	54.31	ha
Land Use -9 Open Space	0.82	ha
Land Use -10 Roadway	43.55	ha
Land Use -11 Water	0.00	ha
Land Use -12 Wetland	18.03	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	112.66	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	0	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	0.00	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	195	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	7.2	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	1633636	m^3/yr
Total Evaporation Loss	576843	m^3/yr
Total Hydraulic Surface Runoff	5901839	m^3/yr
Total Hydraulic Input	7535475	m^3/yr
Areal Hydraulic Load	6	m/yr
Total Hydraulic Outflow	6958632	m^3/yr
Total Atmosphespheric P Input	19491	g/yr
Total Surface Run Off P Input	127084	g/yr
Total Development P Input	110424.60	g/yr
Total P Input	256999	g/yr
Lake P Retention Factor	0.65	n/a
Lake P Retention	167049	g/yr
Predicted Lake P Concentration	**0.013**	mg/L
Lake Phosphours Outflow	89950	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	1633636	
Surface Run Off	5901839	
Evaporation	576843	
Total Outflow	6958632	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	19491	
Surface Run Off	127084	
Development	110425	
Sedimentation	167049	
Total Outflow	89950	
Total Check		
Model Validation		**Units**
Predicted P	0.013	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Third | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	243.45	ha
Land Use -1 Commercial	1.84	ha
Land Use -2 Forest	71.17	ha
Land Use -3 Forest - Meadow	3.12	ha
Land Use -4 High Density Residential	13.24	ha
Land Use -5 Industrial	0.45	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	15.08	ha
Land Use -8 Medium Density Residential	109.20	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	27.50	ha
Land Use -11 Water	1.84	ha
Land Use -12 Wetland	0.00	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	84.71	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	6958632	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	89950	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	264	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	7.2	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	1228348	m^3/yr
Total Evaporation Loss	433734	m^3/yr
Total Hydraulic Surface Runoff	2483156	m^3/yr
Total Hydraulic Input	10670136	m^3/yr
Areal Hydraulic Load	12	m/yr
Total Hydraulic Outflow	10236402	m^3/yr
Total Atmosphospheric P Input	14655	g/yr
Total Surface Run Off P Input	55982	g/yr
Total Development P Input	149497.92	g/yr
Total P Input	310085	g/yr
Lake P Retention Factor	0.65	n/a
Lake P Retention	201555	g/yr
Predicted Lake P Concentration	**0.011**	mg/L
Lake Phosphours Outflow	108530	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	6958632.33	
Precipitation	1228348	
Surface Run Off	2483156	
Evaporation	433734	
Total Outflow	10236402	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	89949.70	
Atmosphere	14655	
Surface Run Off	55982	
Development	149498	
Sedimentation	201555	
Total Outflow	108530	
Total Check		

Model Validation		**Units**
Predicted P	0.011	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Soldier | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	3549.67	ha
Land Use -1 Commercial	146.99	ha
Land Use -2 Forest	2830.77	ha
Land Use -3 Forest - Meadow	0.66	ha
Land Use -4 High Density Residential	0.19	ha
Land Use -5 Industrial	33.30	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	8.81	ha
Land Use -8 Medium Density Residential	35.40	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	107.79	ha
Land Use -11 Water	76.65	ha
Land Use -12 Wetland	309.12	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	230.23	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	0	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	0	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	1	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	3338394	m^3/yr
Total Evaporation Loss	1178798	m^3/yr
Total Hydraulic Surface Runoff	36206592	m^3/yr
Total Hydraulic Input	39544986	m^3/yr
Areal Hydraulic Load	17	m/yr
Total Hydraulic Outflow	38366188	m^3/yr
Total Atmosphosperic P Input	39830	g/yr
Total Surface Run Off P Input	693791	g/yr
Total Development P Input	566.28	g/yr
Total P Input	734188	g/yr
Lake P Retention Factor	0.43	n/a
Lake P Retention	313237	g/yr
Predicted Lake P Concentration	**0.011**	mg/L
Lake Phosphours Outflow	420950	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	3338394	
Surface Run Off	36206592	
Evaporation	1178798	
Total Outflow	38366188	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	39830	
Surface Run Off	693791	
Development	566	
Sedimentation	313237	
Total Outflow	420950	
Total Check		
Model Validation		**Units**
Predicted P	0.011	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Miller | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	471.80	ha
Land Use -1 Commercial	29.88	ha
Land Use -2 Forest	215.32	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	6.94	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	24.60	ha
Land Use -8 Medium Density Residential	113.48	ha
Land Use -9 Open Space	1.68	ha
Land Use -10 Roadway	61.75	ha
Land Use -11 Water	3.62	ha
Land Use -12 Wetland	14.53	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	125.83	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	38366188	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	420950	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	133	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1	60772.50	g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	1824479	m^3/yr
Total Evaporation Loss	644230	m^3/yr
Total Hydraulic Surface Runoff	4812333	m^3/yr
Total Hydraulic Input	45003000	m^3/yr
Areal Hydraulic Load	35	m/yr
Total Hydraulic Outflow	44358770	m^3/yr
Total Atmosphepheric P Input	21768	g/yr
Total Surface Run Off P Input	150070	g/yr
Total Development P Input	136087.74	g/yr
Total P Input	728876	g/yr
Lake P Retention Factor	0.26	n/a
Lake P Retention	189660	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	539216	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	38366188	
Precipitation	1824479	
Surface Run Off	4812333	
Evaporation	644230	
Total Outflow	44358770	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	420950	
Atmosphere	21768	
Surface Run Off	150070	
Development	136088	
Sedimentation	189660	
Total Outflow	539216	
Total Check		
Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Thomas | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	801.16	ha
Land Use -1 Commercial	26.35	ha
Land Use -2 Forest	343.02	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	171.53	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	1.08	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	101.58	ha
Land Use -9 Open Space	0.44	ha
Land Use -10 Roadway	102.67	ha
Land Use -11 Water	14.21	ha
Land Use -12 Wetland	40.29	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	112.89	ha
Lake Volume	4063894	m^3
Hydrology		
Upstrean Hydraulic Inputs	98039955	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	1040644	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	385	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1	27375.0	g/yr
Point Source Input 2	2737.5	g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	1636846	m^3/yr
Total Evaporation Loss	577976	m^3/yr
Total Hydraulic Surface Runoff	8171789	m^3/yr
Total Hydraulic Input	107848591	m^3/yr
Areal Hydraulic Load	95	m/yr
Total Hydraulic Outflow	107270615	m^3/yr
Total Atmosphosphperic P Input	19529	g/yr
Total Surface Run Off P Input	270812	g/yr
Total Development P Input	248130.30	g/yr
Total P Input	1579115	g/yr
Lake P Retention Factor	0.12	n/a
Lake P Retention	182275	g/yr
Predicted Lake P Concentration	**0.013**	mg/L
Lake Phosphours Outflow	1396840	g/yr
Lake Mean Depth	3.60	m
Lake Flushing Rate	26.40	/yr
Lake Turnover Time	0.04	yr
Lake Response Time	0.02	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	98039955.01	
Precipitation	1636846	
Surface Run Off	8171789	
Evaporation	577976	
Total Outflow	107270615	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	1040644	
Atmosphere	19529	
Surface Run Off	270812	
Development	248130	
Sedimentation	182275	
Total Outflow	1396840	
Total Check		
Model Validation		**Units**
Predicted P	0.013	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Fletcher			Watershed: Shubenacadie		
Input Parameters	**Value**	**Units**		**Value**	**Units**
Morphology			**Model Outputs**		
Drainage Basin Area (excl. of lake area)	1569.62	ha	Total Precipitation Input	1459916	m^3/yr
Land Use -1 Commercial	1.38	ha	Total Evaporation Loss	515501	m^3/yr
Land Use -2 Forest	706.60	ha	Total Hydraulic Surface Runoff	16010099	m^3/yr
Land Use -3 Forest - Meadow	0.00	ha	Total Hydraulic Input	124740630	m^3/yr
Land Use -4 High Density Residential	129.41	ha	Areal Hydraulic Load	123	m/yr
Land Use -5 Industrial	0.00	ha	Total Hydraulic Outflow	124225129	m^3/yr
Land Use -6 Institutional	29.72	ha	Total Atmosphospheric P Input	17418	g/yr
Land Use -7 Low Density Residential	0.00	ha	Total Surface Run Off P Input	292906	g/yr
Land Use -8 Medium Density Residential	556.28	ha	Total Development P Input	490366.56	g/yr
Land Use -9 Open Space	0.00	ha	Total P Input	2197531	g/yr
Land Use -10 Roadway	100.62	ha	Lake P Retention Factor	0.45	n/a
Land Use -11 Water	21.83	ha	Lake P Retention	988889	g/yr
Land Use -12 Wetland	23.78	ha	**Predicted Lake P Concentration**	**0.010**	mg/L
Land Use -13		ha	Lake Phosphours Outflow	1208642	g/yr
Land Use -14		ha	Lake Mean Depth	3.70	m
Land Use -15		ha	Lake Flushing Rate	33.35	/yr
Lake Surface Area	100.68	ha	Lake Turnover Time	0.03	yr
Lake Volume	3725303	m^3	Lake Response Time	0.02	yr
Hydrology					
Upstream Hydraulic Inputs	107270615	m^3/yr		**Value**	**% Total**
Annual Unit Precipitation	1.45	m/yr	**Hydraulic Budget (m^3)**		
Annual Unit Evaporation	0.5120	m/yr	Upstream Inflow	107270614.58	
Annual Hydraulic Run Off - veg surf	1.02	m/yr	Precipitation	1459916	
Annual Hydraulic Run Off - urban	1.33	m/yr	Surface Run Off	16010099	
Phosphorus Inputs			Evaporation	515501	
Upstream P Input	1396839.70	g/yr	Total Outflow	124225129	
Annual Atmospheric P Deposition	173	g/(ha*yr)	Total Check		
Export Coefficient - Commercial	2020	g/(ha*yr)	**Phorpshorus Budget (gm)**		
Export Coefficient - Forest	69	g/(ha*yr)	Upstream Inflow	1396840	
Export Coefficient - Forest - Meadow	83	g/(ha*yr)	Atmosphere	17418	
Export Coefficient - High Denisty Residential	520	g/(ha*yr)	Surface Run Off	292906	
Export Coefficient - Industrial	2020	g/(ha*yr)	Development	490367	
Export Coefficient - Instiutional	420	g/(ha*yr)	Sedimentation	988889	
Export Coefficient - Low Density Residential	130	g/(ha*yr)	Total Outflow	1208642	
Export Coefficient - Medium Density Residential	130	g/(ha*yr)	Total Check		
Export Coefficient - Open Space	130	g/(ha*yr)	**Model Validation**		**Units**
Export Coefficient - Roadway	830	g/(ha*yr)	Predicted P	0.010	(mg/L)
Export Coefficient - Water	173	g/(ha*yr)	Measured P		(mg/L)
Export Coefficient - Wetland	83	g/(ha*yr)	% Difference		
Export Coefficient -		g/(ha*yr)			
Export Coefficient -		g/(ha*yr)			
Export Coefficient -		g/(ha*yr)			
No. Dwellings	427	#			
Avg. No. of Pers./Dwelling	2.60	#			
Avg. Yr Frxn Dwelling Occ.	1	/yr			
Phosphorus Load/Capita/Yr	660	g/capita yr			
Septic System Retention Coeff.	0.67	n/a			
Point Source Input 1	248565	g/yr			
Point Source Input 2		g/yr			
Point Source Input 3		g/yr			
Point Source Input 4		g/yr			
Point Source Input 5		g/yr			
Lake Phosphorus Retention Coefficient	7.2	n/a			

Lake Name: Shubenacadie Grand | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	7734.23	ha
Land Use -1 Commercial	7.71	ha
Land Use -2 Forest	6718.45	ha
Land Use -3 Forest - Meadow	266.89	ha
Land Use -4 High Density Residential	16.82	ha
Land Use -5 Industrial	2.15	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	62.45	ha
Land Use -8 Medium Density Residential	272.02	ha
Land Use -9 Open Space	9.95	ha
Land Use -10 Roadway	56.81	ha
Land Use -11 Water	59.50	ha
Land Use -12 Wetland	261.50	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	1877.41	ha
Lake Volume	345442720	m^3
Hydrology		
Upstream Hydraulic Inputs	262580004	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	3110519.41	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	830	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1	4928	g/yr
Point Source Input 2	37230	g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	7.2	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	27222388	m^3/yr
Total Evaporation Loss	9612319	m^3/yr
Total Hydraulic Surface Runoff	78889180	m^3/yr
Total Hydraulic Input	368691572	m^3/yr
Areal Hydraulic Load	19	m/yr
Total Hydraulic Outflow	359079253	m^3/yr
Total Atmosphospheric P Input	324791	g/yr
Total Surface Run Off P Input	638311	g/yr
Total Development P Input	512169.90	g/yr
Total P Input	4585792	g/yr
Lake P Retention Factor	0.27	n/a
Lake P Retention	1254169	g/yr
Predicted Lake P Concentration	**0.009**	mg/L
Lake Phosphours Outflow	3331623	g/yr
Lake Mean Depth	18.40	m
Lake Flushing Rate	1.04	/yr
Lake Turnover Time	0.96	yr
Lake Response Time	0.44	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	262580003.95	
Precipitation	27222388	
Surface Run Off	78889180	
Evaporation	9612319	
Total Outflow	359079253	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	3110519.41	
Atmosphere	324791	
Surface Run Off	638311	
Development	512170	
Sedimentation	1254169	
Total Outflow	3331623	
Total Check		
Model Validation		**Units**
Predicted P	0.009	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Fish | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	1229.76	ha
Land Use -1 Commercial	5.26	ha
Land Use -2 Forest	804.04	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	27.95	ha
Land Use -5 Industrial	4.33	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	147.41	ha
Land Use -9 Open Space	103.60	ha
Land Use -10 Roadway	35.54	ha
Land Use -11 Water	58.62	ha
Land Use -12 Wetland	42.99	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	50.95	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	0	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	0.00	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	2020	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	79	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	738769	m^3/yr
Total Evaporation Loss	260862	m^3/yr
Total Hydraulic Surface Runoff	12543544	m^3/yr
Total Hydraulic Input	13282312	m^3/yr
Areal Hydraulic Load	26	m/yr
Total Hydraulic Outflow	13021451	m^3/yr
Total Atmosphospheric P Input	8814	g/yr
Total Surface Run Off P Input	207530	g/yr
Total Development P Input	44736.12	g/yr
Total P Input	261080	g/yr
Lake P Retention Factor	0.32	n/a
Lake P Retention	83546	g/yr
Predicted Lake P Concentration	**0.014**	mg/L
Lake Phosphours Outflow	177534	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	0	
Precipitation	738769	
Surface Run Off	12543544	
Evaporation	260862	
Total Outflow	13021451	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0	
Atmosphere	8814	
Surface Run Off	207530	
Development	44736	
Sedimentation	83546	
Total Outflow	177534	
Total Check		
Model Validation		**Units**
Predicted P	0.014	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Springfield **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	636.64	ha
Land Use -1 Commercial	3.10	ha
Land Use -2 Forest	175.11	ha
Land Use -3 Forest - Meadow	64.13	ha
Land Use -4 High Density Residential	107.24	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	208.43	ha
Land Use -9 Open Space	15.42	ha
Land Use -10 Roadway	50.10	ha
Land Use -11 Water	0.71	ha
Land Use -12 Wetland	12.40	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	81.28	ha
Lake Volume	0.00	10^6m^3
Hydrology		
Upstream Hydraulic Inputs	0	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	0.00	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	135	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	1178617	m^3/yr
Total Evaporation Loss	416174	m^3/yr
Total Hydraulic Surface Runoff	6493724	m^3/yr
Total Hydraulic Input	7672340	m^3/yr
Areal Hydraulic Load	9	m/yr
Total Hydraulic Outflow	7256167	m^3/yr
Total Atmosphospheric P Input	14062	g/yr
Total Surface Run Off P Input	151264	g/yr
Total Development P Input	76447.80	g/yr
Total P Input	241774	g/yr
Lake P Retention Factor	0.58	n/a
Lake P Retention	140573	g/yr
Predicted Lake P Concentration	**0.014**	mg/L
Lake Phosphours Outflow	101201	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0	
Precipitation	1178617	
Surface Run Off	6493724	
Evaporation	416174	
Total Outflow	7256167	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	14062	
Surface Run Off	151264	
Septics	76448	
Sedimentation	140573	
Total Outflow	101201	
Total Check		

Model Validation		**Units**
Predicted P	0.014	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Lisle | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	9.96	ha
Land Use -1 Commercial	0.00	ha
Land Use -2 Forest	2.90	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	0.00	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	6.33	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	0.22	ha
Land Use -11 Water	0.00	ha
Land Use -12 Wetland	0.51	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	5.36	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	7256167	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	101200.64	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	14	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1	298388	g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	77730	m^3/yr
Total Evaporation Loss	27447	m^3/yr
Total Hydraulic Surface Runoff	101555	m^3/yr
Total Hydraulic Input	7435452	m^3/yr
Areal Hydraulic Load	138	m/yr
Total Hydraulic Outflow	7408005	m^3/yr
Total Atmosphospheric P Input	927	g/yr
Total Surface Run Off P Input	1244	g/yr
Total Development P Input	306315.42	g/yr
Total P Input	409688	g/yr
Lake P Retention Factor	0.08	n/a
Lake P Retention	33735	g/yr
Predicted Lake P Concentration	**0.051**	mg/L
Lake Phosphours Outflow	375953	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	7256167	
Precipitation	77730	
Surface Run Off	101555	
Evaporation	27447	
Total Outflow	7408005	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	101201	
Atmosphere	927	
Surface Run Off	1244	
Development	306315	
Sedimentation	33735	
Total Outflow	375953	
Total Check		
Model Validation		**Units**
Predicted P	0.051	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Fenerty | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	1443.01	ha
Land Use -1 Commercial	0.00	ha
Land Use -2 Forest	981.35	ha
Land Use -3 Forest - Meadow	134.82	ha
Land Use -4 High Density Residential	0.02	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	149.85	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	39.89	ha
Land Use -11 Water	43.16	ha
Land Use -12 Wetland	93.92	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	64.6768	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstream Hydraulic Inputs	7408005	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	375953.22	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Institutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	54	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	937813	m^3/yr
Total Evaporation Loss	331145	m^3/yr
Total Hydraulic Surface Runoff	14718684	m^3/yr
Total Hydraulic Input	23064503	m^3/yr
Areal Hydraulic Load	35	m/yr
Total Hydraulic Outflow	22733358	m^3/yr
Total Atmosphosphric P Input	11189	g/yr
Total Surface Run Off P Input	146767	g/yr
Total Development P Input	30579.12	g/yr
Total P Input	564489	g/yr
Lake P Retention Factor	0.26	n/a
Lake P Retention	147209	g/yr
Predicted Lake P Concentration	**0.018**	mg/L
Lake Phosphours Outflow	417280	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	7408005	
Precipitation	937813	
Surface Run Off	14718684	
Evaporation	331145	
Total Outflow	22733358	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	375953	
Atmosphere	11189	
Surface Run Off	146767	
Development	30579	
Sedimentation	147209	
Total Outflow	417280	
Total Check		
Model Validation		**Units**
Predicted P	0.018	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Lewis

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	332.78	ha
Land Use -1 Commercial	0.00	ha
Land Use -2 Forest	259.31	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	0.00	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	54.76	ha
Land Use -8 Medium Density Residential	0.00	ha
Land Use -9 Open Space	3.33	ha
Land Use -10 Roadway	6.19	ha
Land Use -11 Water	0.00	ha
Land Use -12 Wetland	9.19	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	76.4657	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstream Hydraulic Inputs	0	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	0.00	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	145	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	1108753	m^3/yr
Total Evaporation Loss	391505	m^3/yr
Total Hydraulic Surface Runoff	3394341	m^3/yr
Total Hydraulic Input	4503094	m^3/yr
Areal Hydraulic Load	5	m/yr
Total Hydraulic Outflow	4111589	m^3/yr
Total Atmosphophesric P Input	13229	g/yr
Total Surface Run Off P Input	31341	g/yr
Total Development P Input	82110.60	g/yr
Total P Input	126680	g/yr
Lake P Retention Factor	0.70	n/a
Lake P Retention	88363	g/yr
Predicted Lake P Concentration	**0.009**	mg/L
Lake Phosphours Outflow	38317	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	1108753	
Surface Run Off	3394341	
Evaporation	391505	
Total Outflow	4111589	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	13229	
Surface Run Off	31341	
Development	82111	
Sedimentation	88363	
Total Outflow	38317	
Total Check		
Model Validation		**Units**
Predicted P	0.009	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Tucker | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	153.42	ha
Land Use -1 Commercial	0.00	ha
Land Use -2 Forest	25.57	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	69.23	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	26.29	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	16.84	ha
Land Use -11 Water	0.26	ha
Land Use -12 Wetland	15.23	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	32.65	ha
Lake Volume	0.00	10^6m^3
Hydrology		
Upstream Hydraulic Inputs	0	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	0.00	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	316	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	473394	m^3/yr
Total Evaporation Loss	167157	m^3/yr
Total Hydraulic Surface Runoff	1564885	m^3/yr
Total Hydraulic Input	2038279	m^3/yr
Areal Hydraulic Load	6	m/yr
Total Hydraulic Outflow	1871122	m^3/yr
Total Atmosphospheric P Input	5648	g/yr
Total Surface Run Off P Input	56468	g/yr
Total Development P Input	178944.48	g/yr
Total P Input	241060	g/yr
Lake P Retention Factor	0.92	n/a
Lake P Retention	221775	g/yr
Predicted Lake P Concentration	**0.010**	mg/L
Lake Phosphours Outflow	19285	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	473394	
Surface Run Off	1564885	
Evaporation	167157	
Total Outflow	1871122	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	5648	
Surface Run Off	56468	
Septics and Point Sources	178944	
Sedimentation	221775	
Total Outflow	19285	
Total Check		
Model Validation		**Units**
Predicted P	0.010	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Hamilton | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	2626.83	ha
Land Use -1 Commercial	0.00	ha
Land Use -2 Forest	2004.64	ha
Land Use -3 Forest - Meadow	282.90	ha
Land Use -4 High Density Residential	18.40	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	1.60	ha
Land Use -7 Low Density Residential	6.32	ha
Land Use -8 Medium Density Residential	3.86	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	4.63	ha
Land Use -11 Water	96.39	ha
Land Use -12 Wetland	208.09	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	30.4045	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	26844947	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	455597.10	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings		#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.		n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	440865	m^3/yr
Total Evaporation Loss	155671	m^3/yr
Total Hydraulic Surface Runoff	26793673	m^3/yr
Total Hydraulic Input	54079485	m^3/yr
Areal Hydraulic Load	177	m/yr
Total Hydraulic Outflow	53923814	m^3/yr
Total Atmospheric P Input	5260	g/yr
Total Surface Run Off P Input	211154	g/yr
Total Development P Input	0.00	g/yr
Total P Input	672011	g/yr
Lake P Retention Factor	0.07	n/a
Lake P Retention	43914	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	628097	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	26844947.05	
Precipitation	440865	
Surface Run Off	26793673	
Evaporation	155671	
Total Outflow	53923814	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	455597.10	
Atmosphere	5260	
Surface Run Off	211154	
Development	0	
Sedimentation	43914	
Total Outflow	628097	
Total Check		

Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Beaverbank | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	3881.76	ha
Land Use -1 Commercial	64.91	ha
Land Use -2 Forest	2868.75	ha
Land Use -3 Forest - Meadow	187.45	ha
Land Use -4 High Density Residential	66.60	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	6.54	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	300.55	ha
Land Use -9 Open Space	6.66	ha
Land Use -10 Roadway	63.55	ha
Land Use -11 Water	70.08	ha
Land Use -12 Wetland	246.69	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	68.6190	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	55794937	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	647381.39	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	530	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	38	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	994976	m^3/yr
Total Evaporation Loss	351329	m^3/yr
Total Hydraulic Surface Runoff	39593985	m^3/yr
Total Hydraulic Input	96,383,898	m^3/yr
Areal Hydraulic Load	140	m/yr
Total Hydraulic Outflow	96032568	m^3/yr
Total Atmosphospheric P Input	11871	g/yr
Total Surface Run Off P Input	507278	g/yr
Total Development P Input	21518.64	g/yr
Total P Input	1188049	g/yr
Lake P Retention Factor	0.08	n/a
Lake P Retention	96697	g/yr
Predicted Lake P Concentration	**0.011**	mg/L
Lake Phosphours Outflow	1091352	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	55794936.61	
Precipitation	994976	
Surface Run Off	39593985	
Evaporation	351329	
Total Outflow	96032568	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	647381.39	
Atmosphere	11871	
Surface Run Off	507278	
Development	21519	
Sedimentation	96697	
Total Outflow	1091352	
Total Check		
Model Validation		**Units**
Predicted P	0.011	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Barrett | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	78.43	ha
Land Use -1 Commercial	0.39	ha
Land Use -2 Forest	33.55	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	20.49	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	3.24	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	11.82	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	8.57	ha
Land Use -11 Water	0.37	ha
Land Use -12 Wetland	0.00	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	9.00	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstream Hydraulic Inputs	0	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	0.00	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	165	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	130569	m^3/yr
Total Evaporation Loss	46104	m^3/yr
Total Hydraulic Surface Runoff	799948	m^3/yr
Total Hydraulic Input	930517	m^3/yr
Areal Hydraulic Load	10	m/yr
Total Hydraulic Outflow	884412	m^3/yr
Total Atmospheric P Input	1558	g/yr
Total Surface Run Off P Input	23825	g/yr
Total Development P Input	93436.20	g/yr
Total P Input	118819	g/yr
Lake P Retention Factor	0.92	n/a
Lake P Retention	108720	g/yr
Predicted Lake P Concentration	**0.011**	mg/L
Lake Phosphours Outflow	10100	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	130569	
Surface Run Off	799948	
Evaporation	46104	
Total Outflow	884412	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	1558	
Surface Run Off	23825	
Development	93436	
Sedimentation	108720	
Total Outflow	10100	
Total Check		
Model Validation		**Units**
Predicted P	0.011	(mg/L)
Measured P	0.011	(mg/L)
% Difference		

Lake Name: Duck | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	69.63	ha
Land Use -1 Commercial	0.00	ha
Land Use -2 Forest	29.62	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	15.53	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	16.07	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	4.51	ha
Land Use -11 Water	0.00	ha
Land Use -12 Wetland	3.90	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	9.46	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstream Hydraulic Inputs	0	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	0.00	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	121	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	137170	m^3/yr
Total Evaporation Loss	48435	m^3/yr
Total Hydraulic Surface Runoff	710219	m^3/yr
Total Hydraulic Input	847389	m^3/yr
Areal Hydraulic Load	8	m/yr
Total Hydraulic Outflow	798953	m^3/yr
Total Atmosphospheric P Input	1637	g/yr
Total Surface Run Off P Input	16275	g/yr
Total Development P Input	68519.88	g/yr
Total P Input	86432	g/yr
Lake P Retention Factor	0.59	n/a
Lake P Retention	51414	g/yr
Predicted Lake P Concentration	**0.044**	mg/L
Lake Phosphours Outflow	35018	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	137170	
Surface Run Off	710219	
Evaporation	48435	
Total Outflow	798953	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	1637	
Surface Run Off	16275	
Development	68520	
Sedimentation	51414	
Total Outflow	35018	
Total Check		
Model Validation		**Units**
Predicted P	0.044	(mg/L)
Measured P	0.03	(mg/L)
% Difference		

Lake Name: Beaver Pond

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	481.36	ha
Land Use -1 Commercial	31.07	ha
Land Use -2 Forest	161.13	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	18.57	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	4.29	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	221.33	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	38.47	ha
Land Use -11 Water	0.63	ha
Land Use -12 Wetland	5.87	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	14.98	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	798953	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	35017.89	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	73	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	217199	m^3/yr
Total Evaporation Loss	76694	m^3/yr
Total Hydraulic Surface Runoff	4909859	m^3/yr
Total Hydraulic Input	5926012	m^3/yr
Areal Hydraulic Load	39	m/yr
Total Hydraulic Outflow	5849318	m^3/yr
Total Atmosphepheric P Input	2591	g/yr
Total Surface Run Off P Input	146636	g/yr
Total Development P Input	41338.44	g/yr
Total P Input	225584	g/yr
Lake P Retention Factor	0.24	n/a
Lake P Retention	54140	g/yr
Predicted Lake P Concentration	**0.029**	mg/L
Lake Phosphours Outflow	171444	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	798953.41	
Precipitation	217199	
Surface Run Off	4909859	
Evaporation	76694	
Total Outflow	5849318	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	35017.89	
Atmosphere	2591	
Surface Run Off	146636	
Development	41338	
Sedimentation	54140	
Total Outflow	171444	
Total Check		
Model Validation		**Units**
Predicted P	0.029	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Kinsac | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	2057.84	ha
Land Use -1 Commercial	125.61	ha
Land Use -2 Forest	1322.33	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	99.28	ha
Land Use -5 Industrial	0.00	ha
Land Use -6 Institutional	5.31	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	335.16	ha
Land Use -9 Open Space	3.41	ha
Land Use -10 Roadway	68.83	ha
Land Use -11 Water	12.68	ha
Land Use -12 Wetland	85.24	ha
Land Use -13		ha
Land Use -14 Golf Course		ha
Land Use -15		ha
Lake Surface Area	168.14	ha
Lake Volume	0.00	$10^6 m^3$
Hydrology		
Upstrean Hydraulic Inputs	102766299	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	1272895.16	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	520	g/(ha*yr)
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient - Golf Course		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	328	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.67	n/a
Point Source Input 1	14235	g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	2438074	m^3/yr
Total Evaporation Loss	860892	m^3/yr
Total Hydraulic Surface Runoff	20989944	m^3/yr
Total Hydraulic Input	126194317	m^3/yr
Areal Hydraulic Load	75	m/yr
Total Hydraulic Outflow	125333425	m^3/yr
Total Atmosphospheric P Input	29089	g/yr
Total Surface Run Off P Input	509236	g/yr
Total Development P Input	199974.84	g/yr
Total P Input	2011195	g/yr
Lake P Retention Factor	0.14	n/a
Lake P Retention	286852	g/yr
Predicted Lake P Concentration	**0.014**	mg/L
Lake Phosphours Outflow	1724343	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	102766298.55	
Precipitation	2438074	
Surface Run Off	20989944	
Evaporation	860892	
Total Outflow	125333425	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	1272895.16	
Atmosphere	29089	
Surface Run Off	509236	
Development	199975	
Sedimentation	286852	
Total Outflow	1724343	
Total Check		

Model Validation		**Units**
Predicted P	0.014	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Banook			
Input Parameters	**Symbol**	**Value**	**Units**
Morphology			
Drainage Basin Area (excl. of lake area)		169.49	ha
Land Use -1 Commercial		23.72	ha
Land Use -2 Forest		5.85	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		72.54	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		7.02	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		10.07	ha
Land Use -9 Open Space		19.09	ha
Land Use -10 Roadway		31.12	ha
Land Use -11 Water		0.09	ha
Land Use -12 Wetland		0.00	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		41.50	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		21903809	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		226341.83	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		0	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.			n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

Watershed: Shubenacadie			
	Symbol	**Value**	**Units**
Model Outputs			
Total Precipitation Input		601750	m^3/yr
Total Evaporation Loss		212480	m^3/yr
Total Hydraulic Surface Runoff		1728837	m^3/yr
Total Hydraulic Input		24234396	m^3/yr
Areal Hydraulic Load		58	m/yr
Total Hydraulic Outflow		24021916	m^3/yr
Total Atmosphospheric P Input		7180	g/yr
Total Surface Run Off P Input		118622	g/yr
Total Development P Input		0.00	g/yr
Total P Input		352144	g/yr
Lake P Retention Factor		0.30	n/a
Lake P Retention		105643	g/yr
Predicted Lake P Concentration		**0.010**	mg/L
Lake Phosphours Outflow		246501	g/yr
Lake Mean Depth		#DIV/0!	m
Lake Flushing Rate		#DIV/0!	/yr
Lake Turnover Time		0.00	yr
Lake Response Time		#DIV/0!	yr

		Value	**% Total**
Hydraulic Budget (m^3)			
Upstream Inflow		21903808.74	
Precipitation		601750	
Surface Run Off		1728837	
Evaporation		212480	
Total Outflow		24021916	
Total Check			
Phorpshorus Budget (gm)			
Upstream Inflow		226341.83	
Atmosphere		7180	
Surface Run Off		118622	
Development		0	
Sedimentation		105643	
Total Outflow		246501	
Total Check			
Model Validation			**Units**
Predicted P		0.010	(mg/L)
Measured P			(mg/L)
% Difference			

Lake Name: Micmac

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		297.24	ha
Land Use -1 Commercial		14.51	ha
Land Use -2 Forest		62.64	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		105.31	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		8.75	ha
Land Use -7 Low Density Residential		7.41	ha
Land Use -8 Medium Density Residential		14.74	ha
Land Use -9 Open Space		13.85	ha
Land Use -10 Roadway		60.52	ha
Land Use -11 Water		9.51	ha
Land Use -12 Wetland		0.00	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		104.15	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		17895042	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		193160.60	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		0	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.			n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Symbol	Value	Units
Model Outputs			
Total Precipitation Input		1510175	m^3/yr
Total Evaporation Loss		533248	m^3/yr
Total Hydraulic Surface Runoff		3031840	m^3/yr
Total Hydraulic Input		22437057	m^3/yr
Areal Hydraulic Load		21	m/yr
Total Hydraulic Outflow		21903809	m^3/yr
Total Atmosphospheric P Input		18018	g/yr
Total Surface Run Off P Input		148616	g/yr
Total Development P Input		0.00	g/yr
Total P Input		359794	g/yr
Lake P Retention Factor		0.37	n/a
Lake P Retention		133452	g/yr
Predicted Lake P Concentration		**0.010**	mg/L
Lake Phosphours Outflow		226342	g/yr
Lake Mean Depth		#DIV/0!	m
Lake Flushing Rate		#DIV/0!	/yr
Lake Turnover Time		0.00	yr
Lake Response Time		#DIV/0!	yr

		Value	% Total
Hydraulic Budget (m^3)			
Upstream Inflow		17895041.60	
Precipitation		1510175	
Surface Run Off		3031840	
Evaporation		533248	
Total Outflow		21903809	
Total Check			
Phorpshorus Budget (gm)			
Upstream Inflow		193160.60	
Atmosphere		18018	
Surface Run Off		148616	
Development		0	
Sedimentation		133452	
Total Outflow		226342	
Total Check			
Model Validation			**Units**
Predicted P		0.010	(mg/L)
Measured P			(mg/L)
% Difference			

Lake Name: Cranberry Lake South | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		64.94	ha
Land Use -1 Commercial		1.28	ha
Land Use -2 Forest		11.59	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		38.79	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		1.58	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		0.00	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		11.67	ha
Land Use -11 Water		0.00	ha
Land Use -12 Wetland		0.04	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		11.23	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		0	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.			n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	162818	m^3/yr
Total Evaporation Loss	57492	m^3/yr
Total Hydraulic Surface Runoff	662430	m^3/yr
Total Hydraulic Input	825248	m^3/yr
Areal Hydraulic Load	7	m/yr
Total Hydraulic Outflow	767756	m^3/yr
Total Atmosphospheric P Input	1943	g/yr
Total Surface Run Off P Input	33907	g/yr
Total Development P Input	0.00	g/yr
Total P Input	35849	g/yr
Lake P Retention Factor	0.64	n/a
Lake P Retention	23108	g/yr
Predicted Lake P Concentration	**0.017**	mg/L
Lake Phosphours Outflow	12742	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	162818	
Surface Run Off	662430	
Evaporation	57492	
Total Outflow	767756	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	1943	
Surface Run Off	33907	
Development	0	
Sedimentation	23108	
Total Outflow	12742	
Total Check		
Model Validation		**Units**
Predicted P	0.017	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Loon

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		201.19	ha
Land Use -1 Commercial		10.37	ha
Land Use -2 Forest		64.97	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		20.11	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		42.32	ha
Land Use -9 Open Space		34.27	ha
Land Use -10 Roadway		27.36	ha
Land Use -11 Water		0.00	ha
Land Use -12 Wetland		1.78	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		76.63	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		767756	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		12741.60	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		2020	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		0	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.			n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	1111128	m^3/yr
Total Evaporation Loss	392343	m^3/yr
Total Hydraulic Surface Runoff	2052119	m^3/yr
Total Hydraulic Input	3931004	m^3/yr
Areal Hydraulic Load	5	m/yr
Total Hydraulic Outflow	3538661	m^3/yr
Total Atmospsheric P Input	13257	g/yr
Total Surface Run Off P Input	101262	g/yr
Total Development P Input	0.00	g/yr
Total P Input	127260	g/yr
Lake P Retention Factor	0.60	n/a
Lake P Retention	76356	g/yr
Predicted Lake P Concentration	**0.014**	mg/L
Lake Phosphours Outflow	50904	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	767756.46	
Precipitation	1111128	
Surface Run Off	2052119	
Evaporation	392343	
Total Outflow	3538661	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	12741.60	
Atmosphere	13257	
Surface Run Off	101262	
Development	0	
Sedimentation	76356	
Total Outflow	50904	
Total Check		
Model Validation		**Units**
Predicted P	0.014	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Charles **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		1450.94	ha
Land Use -1 Commercial		0.84	ha
Land Use -2 Forest		835.01	ha
Land Use -3 Forest - Meadow		2.30	ha
Land Use -4 High Density Residential		198.77	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		11.15	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		25.03	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		179.32	ha
Land Use -11 Water		6.43	ha
Land Use -12 Wetland		52.87	ha
Land Use -13 - Quarry		139.23	ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		141.43	ha
Lake Volume		1117315571	m^3
Hydrology			
Upstrean Hydraulic Inputs		3538661	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		50904.12	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		69	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient - Quarry		80	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		70	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	2050769	m^3/yr
Total Evaporation Loss	724134	m^3/yr
Total Hydraulic Surface Runoff	14799585	m^3/yr
Total Hydraulic Input	20389015	m^3/yr
Areal Hydraulic Load	14	m/yr
Total Hydraulic Outflow	19664881	m^3/yr
Total Atmosphospheric P Input	24468	g/yr
Total Surface Run Off P Input	336267	g/yr
Total Development P Input	60060.00	g/yr
Total P Input	471699	g/yr
Lake P Retention Factor	0.55	n/a
Lake P Retention	259434	g/yr
Predicted Lake P Concentration	**0.011**	mg/L
Lake Phosphours Outflow	212264	g/yr
Lake Mean Depth	7.90	m
Lake Flushing Rate	0.02	/yr
Lake Turnover Time	56.82	yr
Lake Response Time	0.54	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	3538660.61	
Precipitation	2050769	
Surface Run Off	14799585	
Evaporation	724134	
Total Outflow	19664881	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	50904.12	
Atmosphere	24468	
Surface Run Off	336267	
Development	60060	
Sedimentation	259434	
Total Outflow	212264	
Total Check		
Model Validation		**Units**
Predicted P	0.011	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: William | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	469.40	ha
Land Use -1 Commercial	19.88	ha
Land Use -2 Forest	244.67	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	65.70	ha
Land Use -5 Industrial	0.50	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	45.55	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	44.82	ha
Land Use -11 Water	33.96	ha
Land Use -12 Wetland	14.33	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	43.10	ha
Lake Volume		m^3
Hydrology		
Upstrean Hydraulic Inputs	22674788	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	372936	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	530	520
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	58	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.50	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	7.2	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	624913	m^3/yr
Total Evaporation Loss	220659	m^3/yr
Total Hydraulic Surface Runoff	4787928	m^3/yr
Total Hydraulic Input	28087629	m^3/yr
Areal Hydraulic Load	65	m/yr
Total Hydraulic Outflow	27866970	m^3/yr
Total Atmosphospheric P Input	7456	g/yr
Total Surface Run Off P Input	143055	g/yr
Total Development P Input	49764.00	g/yr
Total P Input	573211	g/yr
Lake P Retention Factor	0.40	n/a
Lake P Retention	229284	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	343926	g/yr
Lake Mean Depth		m
Lake Flushing Rate		/yr
Lake Turnover Time		yr
Lake Response Time		yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	22674788.28	
Precipitation	624913	
Surface Run Off	4787928	
Evaporation	220659	
Total Outflow	27866970	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	372936.02	
Atmosphere	7456	
Surface Run Off	143055	
Development	49764	
Sedimentation	229284	
Total Outflow	343926	
Total Check		
Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P	0.009	(mg/L)
% Difference		

Lake Name: William | **Watershed: Shubenacadie**

Input Parameters	Value	Units
Morphology		
Drainage Basin Area (excl. of lake area)	2195.45	ha
Land Use -1 Commercial	8.94	ha
Land Use -2 Forest	1675.39	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	133.75	ha
Land Use -5 Industrial	12.08	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	42.44	ha
Land Use -8 Medium Density Residential	60.93	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	119.21	ha
Land Use -11 Water	19.02	ha
Land Use -12 Wetland	123.69	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	301.78	ha
Lake Volume	34403266	m^3
Hydrology		
Upstrean Hydraulic Inputs	28456917	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	350294	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	530	520
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	882	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.50	n/a
Point Source Input 1	43800	g/yr
Point Source Input 2	2738	g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	7.2	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	4375854	m^3/yr
Total Evaporation Loss	1545129	m^3/yr
Total Hydraulic Surface Runoff	22393545	m^3/yr
Total Hydraulic Input	55226316	m^3/yr
Areal Hydraulic Load	18	m/yr
Total Hydraulic Outflow	53681186	m^3/yr
Total Atmosphospheric P Input	52208	g/yr
Total Surface Run Off P Input	354883	g/yr
Total Development P Input	803293.50	g/yr
Total P Input	1560679	g/yr
Lake P Retention Factor	0.60	n/a
Lake P Retention	936408	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	624272	g/yr
Lake Mean Depth	11.40	m
Lake Flushing Rate	1.56	/yr
Lake Turnover Time	0.64	yr
Lake Response Time	0.28	yr
	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	28456916.54	
Precipitation	4375854	
Surface Run Off	22393545	
Evaporation	1545129	
Total Outflow	53681186	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	350294.38	
Atmosphere	52208	
Surface Run Off	354883	
Development	803294	
Sedimentation	936408	
Total Outflow	624272	
Total Check		
Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P	0.009	(mg/L)
% Difference		

Lake Name: First			
Input Parameters	**Symbol**	**Value**	**Units**
Morphology			
Drainage Basin Area (excl. of lake area)		280.55	ha
Land Use -1 Commercial		19.22	ha
Land Use -2 Forest		44.95	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		136.63	ha
Land Use -5 Industrial		1.29	ha
Land Use -6 Institutional		19.99	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		3.55	ha
Land Use -9 Open Space		3.98	ha
Land Use -10 Roadway		50.82	ha
Land Use -11 Water		0.12	ha
Land Use -12 Wetland		0.00	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		82.70	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		53	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

Watershed: Shubenacadie		
	Value	**Units**
Model Outputs		
Total Precipitation Input	1199138	m^3/yr
Total Evaporation Loss	423420	m^3/yr
Total Hydraulic Surface Runoff	2861583	m^3/yr
Total Hydraulic Input	4060721	m^3/yr
Areal Hydraulic Load	4	m/yr
Total Hydraulic Outflow	3637302	m^3/yr
Total Atmosphospheric P Input	14307	g/yr
Total Surface Run Off P Input	167160	g/yr
Total Development P Input	45474.00	g/yr
Total P Input	226941	g/yr
Lake P Retention Factor	0.80	n/a
Lake P Retention	181553	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	45388	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr
	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	1199138	
Surface Run Off	2861583	
Evaporation	423420	
Total Outflow	3637302	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0	
Atmosphere	14307	
Surface Run Off	167160	
Development	45474	
Sedimentation	181553	
Total Outflow	45388	
Total Check		
Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Rocky

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		728.88	ha
Land Use -1 Commercial		30.42	ha
Land Use -2 Forest		234.20	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		47.44	ha
Land Use -5 Industrial		22.59	ha
Land Use -6 Institutional		2.47	ha
Land Use -7 Low Density Residential		17.12	ha
Land Use -8 Medium Density Residential		45.15	ha
Land Use -9 Open Space		10.19	ha
Land Use -10 Roadway		45.08	ha
Land Use -11 Water		6.92	ha
Land Use -12 Wetland		40.75	ha
Land Use -13 Quarry		226.56	ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		145.69	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		3637302	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		45388.23	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient - Quarry		80	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		147	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	2112453	m^3/yr
Total Evaporation Loss	745914	m^3/yr
Total Hydraulic Surface Runoff	7434544	m^3/yr
Total Hydraulic Input	13184299	m^3/yr
Areal Hydraulic Load	9	m/yr
Total Hydraulic Outflow	12438384	m^3/yr
Total Atmosphospheric P Input	25204	g/yr
Total Surface Run Off P Input	218489	g/yr
Total Development P Input	126126.00	g/yr
Total P Input	415207	g/yr
Lake P Retention Factor	0.45	n/a
Lake P Retention	186843	g/yr
Predicted Lake P Concentration	**0.018**	mg/L
Lake Phosphours Outflow	228364	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	3637301.53	
Precipitation	2112453	
Surface Run Off	7434544	
Evaporation	745914	
Total Outflow	12438384	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	45388.23	
Atmosphere	25204	
Surface Run Off	218489	
Development	126126	
Sedimentation	186843	
Total Outflow	228364	
Total Check		
Model Validation		**Units**
Predicted P	0.018	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Second | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		578.61	ha
Land Use -1 Commercial		13.91	ha
Land Use -2 Forest		340.94	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		44.74	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		2.45	ha
Land Use -7 Low Density Residential		59.87	ha
Land Use -8 Medium Density Residential		54.31	ha
Land Use -9 Open Space		0.82	ha
Land Use -10 Roadway		43.55	ha
Land Use -11 Water		0.00	ha
Land Use -12 Wetland		18.03	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		112.66	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		209	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	1633636	m^3/yr
Total Evaporation Loss	576843	m^3/yr
Total Hydraulic Surface Runoff	5901840	m^3/yr
Total Hydraulic Input	7535476	m^3/yr
Areal Hydraulic Load	6	m/yr
Total Hydraulic Outflow	6958634	m^3/yr
Total Atmosphospheric P Input	19491	g/yr
Total Surface Run Off P Input	128502	g/yr
Total Development P Input	179322.00	g/yr
Total P Input	327315	g/yr
Lake P Retention Factor	0.65	n/a
Lake P Retention	212755	g/yr
Predicted Lake P Concentration	**0.016**	mg/L
Lake Phosphours Outflow	114560	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	1633636	
Surface Run Off	5901840	
Evaporation	576843	
Total Outflow	6958634	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	19491	
Surface Run Off	128502	
Development	179322	
Sedimentation	212755	
Total Outflow	114560	
Total Check		
Model Validation		**Units**
Predicted P	0.016	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Third

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		243.45	ha
Land Use -1 Commercial		1.84	ha
Land Use -2 Forest		51.39	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		13.24	ha
Land Use -5 Industrial		0.45	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		34.87	ha
Land Use -8 Medium Density Residential		109.20	ha
Land Use -9 Open Space		3.12	ha
Land Use -10 Roadway		27.50	ha
Land Use -11 Water		1.84	ha
Land Use -12 Wetland		0.00	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		84.71	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		6958634	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		114560	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		264	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	1228348	m^3/yr
Total Evaporation Loss	433734	m^3/yr
Total Hydraulic Surface Runoff	2483156	m^3/yr
Total Hydraulic Input	10670138	m^3/yr
Areal Hydraulic Load	12	m/yr
Total Hydraulic Outflow	10236404	m^3/yr
Total Atmosphospheric P Input	14655	g/yr
Total Surface Run Off P Input	57335	g/yr
Total Development P Input	226512.00	g/yr
Total P Input	413063	g/yr
Lake P Retention Factor	0.65	n/a
Lake P Retention	268491	g/yr
Predicted Lake P Concentration	**0.014**	mg/L
Lake Phosphours Outflow	144572	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	6958633.79	
Precipitation	1228348	
Surface Run Off	2483156	
Evaporation	433734	
Total Outflow	10236404	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	114560.27	
Atmosphere	14655	
Surface Run Off	57335	
Development	226512	
Sedimentation	268491	
Total Outflow	144572	
Total Check		

Model Validation		**Units**
Predicted P	0.014	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Soldier | **Watershed: Shubenacadie**

Input Parameters	**Symbol**	**Value**	**Units**
Morphology			
Drainage Basin Area (excl. of lake area)		3549.67	ha
Land Use -1 Commercial		146.99	ha
Land Use -2 Forest		2819.01	ha
Land Use -3 Forest - Meadow		0.66	ha
Land Use -4 High Density Residential		0.19	ha
Land Use -5 Industrial		33.30	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		20.57	ha
Land Use -8 Medium Density Residential		35.40	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		107.79	ha
Land Use -11 Water		76.65	ha
Land Use -12 Wetland		309.12	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		230.23	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		1	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	3338394	m^3/yr
Total Evaporation Loss	1178798	m^3/yr
Total Hydraulic Surface Runoff	36206592	m^3/yr
Total Hydraulic Input	39544986	m^3/yr
Areal Hydraulic Load	17	m/yr
Total Hydraulic Outflow	38366188	m^3/yr
Total Atmosphospheric P Input	39830	g/yr
Total Surface Run Off P Input	694508	g/yr
Total Development P Input	858.00	g/yr
Total P Input	735197	g/yr
Lake P Retention Factor	0.43	n/a
Lake P Retention	313668	g/yr
Predicted Lake P Concentration	**0.011**	mg/L
Lake Phosphours Outflow	421529	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	3338394	
Surface Run Off	36206592	
Evaporation	1178798	
Total Outflow	38366188	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	39830	
Surface Run Off	694508	
Development	858	
Sedimentation	313668	
Total Outflow	421529	
Total Check		

Model Validation		**Units**
Predicted P	0.011	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Miller

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		471.80	ha
Land Use -1 Commercial		29.88	ha
Land Use -2 Forest		207.10	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		6.94	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		32.83	ha
Land Use -8 Medium Density Residential		113.48	ha
Land Use -9 Open Space		1.68	ha
Land Use -10 Roadway		61.75	ha
Land Use -11 Water		3.62	ha
Land Use -12 Wetland		14.53	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		125.83	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		38366188	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		421529	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings	46	133	#
Avg. No. of Pers./Dwelling	2.60	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	1	/yr
Phosphorus Load/Capita/Yr	660	660	g/capita yr
Septic System Retention Coeff.	0.85	0.50	n/a
Point Source Input 1		60772.50	g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	1824479	m^3/yr
Total Evaporation Loss	644230	m^3/yr
Total Hydraulic Surface Runoff	4812333	m^3/yr
Total Hydraulic Input	45003000	m^3/yr
Areal Hydraulic Load	35	m/yr
Total Hydraulic Outflow	44358770	m^3/yr
Total Atmosphospheric P Input	21768	g/yr
Total Surface Run Off P Input	150572	g/yr
Total Development P Input	175596.25	g/yr
Total P Input	769465	g/yr
Lake P Retention Factor	0.26	n/a
Lake P Retention	200222	g/yr
Predicted Lake P Concentration	**0.013**	mg/L
Lake Phosphours Outflow	569243	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	38366188	
Precipitation	1824479	
Surface Run Off	4812333	
Evaporation	644230	
Total Outflow	44358770	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	421529	
Atmosphere	21768	
Surface Run Off	150572	
Development	175596	
Sedimentation	200222	
Total Outflow	569243	
Total Check		
Model Validation		**Units**
Predicted P	0.013	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Thomas | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		801.16	ha
Land Use -1 Commercial		26.35	ha
Land Use -2 Forest		343.02	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		171.53	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		1.08	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		101.58	ha
Land Use -9 Open Space		0.44	ha
Land Use -10 Roadway		102.67	ha
Land Use -11 Water		14.21	ha
Land Use -12 Wetland		40.29	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		112.89	ha
Lake Volume		4063894	m^3
Hydrology			
Upstrean Hydraulic Inputs		98039956	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		1193515	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		385	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1		27375.0	g/yr
Point Source Input 2		2737.5	g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	1636846	m^3/yr
Total Evaporation Loss	577976	m^3/yr
Total Hydraulic Surface Runoff	8171789	m^3/yr
Total Hydraulic Input	107848592	m^3/yr
Areal Hydraulic Load	95	m/yr
Total Hydraulic Outflow	107270616	m^3/yr
Total Atmosphospheric P Input	19529	g/yr
Total Surface Run Off P Input	270812	g/yr
Total Development P Input	360442.50	g/yr
Total P Input	1844298	g/yr
Lake P Retention Factor	0.12	n/a
Lake P Retention	212885	g/yr
Predicted Lake P Concentration	**0.015**	mg/L
Lake Phosphours Outflow	1631414	g/yr
Lake Mean Depth	3.60	m
Lake Flushing Rate	26.40	/yr
Lake Turnover Time	0.04	yr
Lake Response Time	0.02	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	98039956.46	
Precipitation	1636846	
Surface Run Off	8171789	
Evaporation	577976	
Total Outflow	107270616	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	1193515	
Atmosphere	19529	
Surface Run Off	270812	
Development	360443	
Sedimentation	212885	
Total Outflow	1631414	
Total Check		
Model Validation		**Units**
Predicted P	0.015	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Fletcher

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		1569.45	ha
Land Use -1 Commercial		1.38	ha
Land Use -2 Forest		470.28	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		129.41	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		25.44	ha
Land Use -7 Low Density Residential		236.24	ha
Land Use -8 Medium Density Residential		556.20	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		100.62	ha
Land Use -11 Water		21.83	ha
Land Use -12 Wetland		28.06	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		100.68	ha
Lake Volume		3725303	m^3
Hydrology			
Upstrean Hydraulic Inputs		107270616	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		1631413.54	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		433	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1		248565	g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	1459916	m^3/yr
Total Evaporation Loss	515501	m^3/yr
Total Hydraulic Surface Runoff	16008368	m^3/yr
Total Hydraulic Input	124738901	m^3/yr
Areal Hydraulic Load	123	m/yr
Total Hydraulic Outflow	124223399	m^3/yr
Total Atmosphospheric P Input	17418	g/yr
Total Surface Run Off P Input	305854	g/yr
Total Development P Input	620079.00	g/yr
Total P Input	2574765	g/yr
Lake P Retention Factor	0.45	n/a
Lake P Retention	1158644	g/yr
Predicted Lake P Concentration	**0.011**	mg/L
Lake Phosphours Outflow	1416121	g/yr
Lake Mean Depth	3.70	m
Lake Flushing Rate	33.35	/yr
Lake Turnover Time	0.03	yr
Lake Response Time	0.02	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	107270616.03	
Precipitation	1459916	
Surface Run Off	16008368	
Evaporation	515501	
Total Outflow	124223399	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	1631414	
Atmosphere	17418	
Surface Run Off	305854	
Development	620079	
Sedimentation	1158644	
Total Outflow	1416121	
Total Check		

Model Validation		**Units**
Predicted P	0.011	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Shubie Grand

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		7734.18	ha
Land Use -1 Commercial		7.71	ha
Land Use -2 Forest		6665.54	ha
Land Use -3 Forest - Meadow		266.89	ha
Land Use -4 High Density Residential		16.82	ha
Land Use -5 Industrial		2.15	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		115.34	ha
Land Use -8 Medium Density Residential		271.98	ha
Land Use -9 Open Space		9.95	ha
Land Use -10 Roadway		56.81	ha
Land Use -11 Water		59.50	ha
Land Use -12 Wetland		261.50	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		1877.41	ha
Lake Volume		345442720	m^3
Hydrology			
Upstrean Hydraulic Inputs		262558054	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		3582650.19	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		836	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1		4928	g/yr
Point Source Input 2		37230	g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	27222388	m^3/yr
Total Evaporation Loss	9612319	m^3/yr
Total Hydraulic Surface Runoff	80348117	m^3/yr
Total Hydraulic Input	370128559	m^3/yr
Areal Hydraulic Load	19	m/yr
Total Hydraulic Outflow	360516240	m^3/yr
Total Atmosphospheric P Input	324791	g/yr
Total Surface Run Off P Input	641531	g/yr
Total Development P Input	759445.50	g/yr
Total P Input	5308418	g/yr
Lake P Retention Factor	0.27	n/a
Lake P Retention	1447592	g/yr
Predicted Lake P Concentration	**0.011**	mg/L
Lake Phosphours Outflow	3860826	g/yr
Lake Mean Depth	18.40	m
Lake Flushing Rate	1.04	/yr
Lake Turnover Time	0.96	yr
Lake Response Time	0.43	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	262558054.42	
Precipitation	27222388	
Surface Run Off	80348117	
Evaporation	9612319	
Total Outflow	360516240	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	3582650.19	
Atmosphere	324791	
Surface Run Off	641531	
Development	759446	
Sedimentation	1447592	
Total Outflow	3860826	
Total Check		
Model Validation		**Units**
Predicted P	0.011	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Fish | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		1229.79	ha
Land Use -1 Commercial		5.26	ha
Land Use -2 Forest		791.44	ha
Land Use -3 Forest - Meadow		103.60	ha
Land Use -4 High Density Residential		27.95	ha
Land Use -5 Industrial		4.33	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		12.64	ha
Land Use -8 Medium Density Residential		147.41	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		35.54	ha
Land Use -11 Water		58.62	ha
Land Use -12 Wetland		42.99	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		50.95	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		2020	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		80	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	738769	m^3/yr
Total Evaporation Loss	260862	m^3/yr
Total Hydraulic Surface Runoff	12543902	m^3/yr
Total Hydraulic Input	13282671	m^3/yr
Areal Hydraulic Load	26	m/yr
Total Hydraulic Outflow	13021809	m^3/yr
Total Atmosphospheric P Input	8814	g/yr
Total Surface Run Off P Input	203433	g/yr
Total Development P Input	68640.00	g/yr
Total P Input	280887	g/yr
Lake P Retention Factor	0.32	n/a
Lake P Retention	89884	g/yr
Predicted Lake P Concentration	**0.015**	mg/L
Lake Phosphours Outflow	191003	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr
	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	0	
Precipitation	738769	
Surface Run Off	12543902	
Evaporation	260862	
Total Outflow	13021809	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0	
Atmosphere	8814	
Surface Run Off	203433	
Development	68640	
Sedimentation	89884	
Total Outflow	191003	
Total Check		
Model Validation		**Units**
Predicted P	0.015	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Springfield

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		633.91	ha
Land Use -1 Commercial		3.10	ha
Land Use -2 Forest		106.93	ha
Land Use -3 Forest - Meadow		15.65	ha
Land Use -4 High Density Residential		107.24	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		113.94	ha
Land Use -8 Medium Density Residential		208.43	ha
Land Use -9 Open Space		15.42	ha
Land Use -10 Roadway		50.10	ha
Land Use -11 Water		0.71	ha
Land Use -12 Wetland		12.40	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		81.28	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings	78	135	#
Avg. No. of Pers./Dwelling	2.60	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	1	/yr
Phosphorus Load/Capita/Yr	660	660	g/capita yr
Septic System Retention Coeff.	0.85	0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	1178617	m^3/yr
Total Evaporation Loss	416174	m^3/yr
Total Hydraulic Surface Runoff	6465910	m^3/yr
Total Hydraulic Input	7644527	m^3/yr
Areal Hydraulic Load	9	m/yr
Total Hydraulic Outflow	7228354	m^3/yr
Total Atmospphseric P Input	14062	g/yr
Total Surface Run Off P Input	157348	g/yr
Total Development P Input	116571.75	g/yr
Total P Input	287981	g/yr
Lake P Retention Factor	0.58	n/a
Lake P Retention	167708	g/yr
Predicted Lake P Concentration	**0.017**	mg/L
Lake Phosphours Outflow	120273	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0	
Precipitation	1178617	
Surface Run Off	6465910	
Evaporation	416174	
Total Outflow	7228354	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	14062	
Surface Run Off	157348	
Septics	116572	
Sedimentation	167708	
Total Outflow	120273	
Total Check		
Model Validation		**Units**
Predicted P	0.017	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Lisle | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		9.97	ha
Land Use -1 Commercial		0.00	ha
Land Use -2 Forest		0.63	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		0.00	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		2.27	ha
Land Use -8 Medium Density Residential		6.33	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		0.22	ha
Land Use -11 Water		0.00	ha
Land Use -12 Wetland		0.53	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		5.36	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		7228354	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		120272.95	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		14	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1		298388	g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	77730	m^3/yr
Total Evaporation Loss	27447	m^3/yr
Total Hydraulic Surface Runoff	101738	m^3/yr
Total Hydraulic Input	7407821	m^3/yr
Areal Hydraulic Load	138	m/yr
Total Hydraulic Outflow	7380375	m^3/yr
Total Atmosphospheric P Input	927	g/yr
Total Surface Run Off P Input	1385	g/yr
Total Development P Input	310399.50	g/yr
Total P Input	432985	g/yr
Lake P Retention Factor	0.08	n/a
Lake P Retention	35776	g/yr
Predicted Lake P Concentration	**0.054**	mg/L
Lake Phosphours Outflow	397210	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr
	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	7228354	
Precipitation	77730	
Surface Run Off	101738	
Evaporation	27447	
Total Outflow	7380375	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	120273	
Atmosphere	927	
Surface Run Off	1385	
Development	310400	
Sedimentation	35776	
Total Outflow	397210	
Total Check		
Model Validation		**Units**
Predicted P	0.054	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Fenerty

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		1443.75	ha
Land Use -1 Commercial		0.00	ha
Land Use -2 Forest		900.93	ha
Land Use -3 Forest - Meadow		126.31	ha
Land Use -4 High Density Residential		0.02	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		88.53	ha
Land Use -8 Medium Density Residential		149.85	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		41.19	ha
Land Use -11 Water		43.16	ha
Land Use -12 Wetland		93.77	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		64.6768	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		7380375	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		397209.83	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings	133	54	#
Avg. No. of Pers./Dwelling	2.6	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	1	/yr
Phosphorus Load/Capita/Yr	660	660	g/capita yr
Septic System Retention Coeff.	0.85	0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	937813	m^3/yr
Total Evaporation Loss	331145	m^3/yr
Total Hydraulic Surface Runoff	14726237	m^3/yr
Total Hydraulic Input	23044424	m^3/yr
Areal Hydraulic Load	35	m/yr
Total Hydraulic Outflow	22713279	m^3/yr
Total Atmosphospheric P Input	11189	g/yr
Total Surface Run Off P Input	153086	g/yr
Total Development P Input	80566.20	g/yr
Total P Input	642051	g/yr
Lake P Retention Factor	0.26	n/a
Lake P Retention	167545	g/yr
Predicted Lake P Concentration	**0.021**	mg/L
Lake Phosphours Outflow	474506	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	7380375	
Precipitation	937813	
Surface Run Off	14726237	
Evaporation	331145	
Total Outflow	22713279	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	397210	
Atmosphere	11189	
Surface Run Off	153086	
Development	80566	
Sedimentation	167545	
Total Outflow	474506	
Total Check		

Model Validation		Units
Predicted P	0.021	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Lewis			
Input Parameters	**Symbol**	**Value**	**Units**
Morphology			
Drainage Basin Area (excl. of lake area)		332.78	ha
Land Use -1 Commercial		0.00	ha
Land Use -2 Forest		259.31	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		0.00	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		54.76	ha
Land Use -8 Medium Density Residential		0.00	ha
Land Use -9 Open Space		3.33	ha
Land Use -10 Roadway		6.19	ha
Land Use -11 Water		0.00	ha
Land Use -12 Wetland		9.19	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		76.4657	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		145	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie		
	Value	**Units**
Model Outputs		
Total Precipitation Input	1108753	m^3/yr
Total Evaporation Loss	391505	m^3/yr
Total Hydraulic Surface Runoff	3394341	m^3/yr
Total Hydraulic Input	4503094	m^3/yr
Areal Hydraulic Load	5	m/yr
Total Hydraulic Outflow	4111589	m^3/yr
Total Atmosphospheric P Input	13229	g/yr
Total Surface Run Off P Input	31341	g/yr
Total Development P Input	124410.00	g/yr
Total P Input	168980	g/yr
Lake P Retention Factor	0.70	n/a
Lake P Retention	117868	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	51111	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	1108753	
Surface Run Off	3394341	
Evaporation	391505	
Total Outflow	4111589	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	13229	
Surface Run Off	31341	
Development	124410	
Sedimentation	117868	
Total Outflow	51111	
Total Check		
Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Hamilton | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		2626.83	ha
Land Use -1 Commercial		0.00	ha
Land Use -2 Forest		2004.64	ha
Land Use -3 Forest - Meadow		282.90	ha
Land Use -4 High Density Residential		18.40	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		1.60	ha
Land Use -7 Low Density Residential		6.32	ha
Land Use -8 Medium Density Residential		3.86	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		4.63	ha
Land Use -11 Water		96.39	ha
Land Use -12 Wetland		208.09	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		30.4045	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		26824868	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		525617.70	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings			#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.			n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	440865	m^3/yr
Total Evaporation Loss	155671	m^3/yr
Total Hydraulic Surface Runoff	26793673	m^3/yr
Total Hydraulic Input	54059407	m^3/yr
Areal Hydraulic Load	177	m/yr
Total Hydraulic Outflow	53903736	m^3/yr
Total Atmosphospheric P Input	5260	g/yr
Total Surface Run Off P Input	211154	g/yr
Total Development P Input	0.00	g/yr
Total P Input	742031	g/yr
Lake P Retention Factor	0.07	n/a
Lake P Retention	48507	g/yr
Predicted Lake P Concentration	**0.013**	mg/L
Lake Phosphours Outflow	693525	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	26824868.50	
Precipitation	440865	
Surface Run Off	26793673	
Evaporation	155671	
Total Outflow	53903736	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	525617.70	
Atmosphere	5260	
Surface Run Off	211154	
Development	0	
Sedimentation	48507	
Total Outflow	693525	
Total Check		
Model Validation		**Units**
Predicted P	0.013	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Tucker | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		153.69	ha
Land Use -1 Commercial		0.00	ha
Land Use -2 Forest		10.26	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		69.23	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		15.45	ha
Land Use -8 Medium Density Residential		26.29	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		16.98	ha
Land Use -11 Water		0.26	ha
Land Use -12 Wetland		15.23	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		32.6479	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		339	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	473394	m^3/yr
Total Evaporation Loss	167157	m^3/yr
Total Hydraulic Surface Runoff	1567683	m^3/yr
Total Hydraulic Input	2041077	m^3/yr
Areal Hydraulic Load	6	m/yr
Total Hydraulic Outflow	1873920	m^3/yr
Total Atmosphospheric P Input	5648	g/yr
Total Surface Run Off P Input	57532	g/yr
Total Development P Input	290862.00	g/yr
Total P Input	354042	g/yr
Lake P Retention Factor	0.92	n/a
Lake P Retention	325718	g/yr
Predicted Lake P Concentration	**0.015**	mg/L
Lake Phosphours Outflow	28323	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	473394	
Surface Run Off	1567683	
Evaporation	167157	
Total Outflow	1873920	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	5648	
Surface Run Off	57532	
Septics and Point Sources	290862	
Sedimentation	325718	
Total Outflow	28323	
Total Check		
Model Validation		**Units**
Predicted P	0.015	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Beaverbank

Watershed: Shubenacadie

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		3881.41	ha
Land Use -1 Commercial		64.91	ha
Land Use -2 Forest		2835.77	ha
Land Use -3 Forest - Meadow		194.10	ha
Land Use -4 High Density Residential		66.59	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		6.54	ha
Land Use -7 Low Density Residential		32.76	ha
Land Use -8 Medium Density Residential		300.55	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		63.41	ha
Land Use -11 Water		70.09	ha
Land Use -12 Wetland		246.69	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		68.6190	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		55777655	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		721847.97	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		530	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		38	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	994976	m^3/yr
Total Evaporation Loss	351329	m^3/yr
Total Hydraulic Surface Runoff	39590343	m^3/yr
Total Hydraulic Input	96,362,974	m^3/yr
Areal Hydraulic Load	140	m/yr
Total Hydraulic Outflow	96011645	m^3/yr
Total Atmosphospheric P Input	11871	g/yr
Total Surface Run Off P Input	508835	g/yr
Total Development P Input	32604.00	g/yr
Total P Input	1275158	g/yr
Lake P Retention Factor	0.08	n/a
Lake P Retention	103808	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	1171351	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	55777655.30	
Precipitation	994976	
Surface Run Off	39590343	
Evaporation	351329	
Total Outflow	96011645	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	721847.97	
Atmosphere	11871	
Surface Run Off	508835	
Development	32604	
Sedimentation	103808	
Total Outflow	1171351	
Total Check		
Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Barrett

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		78.45	ha
Land Use -1 Commercial		0.39	ha
Land Use -2 Forest		33.55	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		20.50	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		3.25	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		11.82	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		8.56	ha
Land Use -11 Water		0.37	ha
Land Use -12 Wetland		0.00	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		9.00	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		165	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	130569	m^3/yr
Total Evaporation Loss	46104	m^3/yr
Total Hydraulic Surface Runoff	800148	m^3/yr
Total Hydraulic Input	930718	m^3/yr
Areal Hydraulic Load	10	m/yr
Total Hydraulic Outflow	884613	m^3/yr
Total Atmosphospheric P Input	1558	g/yr
Total Surface Run Off P Input	23831	g/yr
Total Development P Input	141570.00	g/yr
Total P Input	166959	g/yr
Lake P Retention Factor	0.92	n/a
Lake P Retention	152768	g/yr
Predicted Lake P Concentration	**0.016**	mg/L
Lake Phosphours Outflow	14192	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	130569	
Surface Run Off	800148	
Evaporation	46104	
Total Outflow	884613	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	1558	
Surface Run Off	23831	
Development	141570	
Sedimentation	152768	
Total Outflow	14192	
Total Check		
Model Validation		**Units**
Predicted P	0.016	(mg/L)
Measured P	0.011	(mg/L)
% Difference		

Lake Name: Duck | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		69.65	ha
Land Use -1 Commercial		0.00	ha
Land Use -2 Forest		29.63	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		15.53	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		16.08	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		4.51	ha
Land Use -11 Water		0.00	ha
Land Use -12 Wetland		3.90	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		9.46	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		121	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	137170	m^3/yr
Total Evaporation Loss	48435	m^3/yr
Total Hydraulic Surface Runoff	710476	m^3/yr
Total Hydraulic Input	847646	m^3/yr
Areal Hydraulic Load	8	m/yr
Total Hydraulic Outflow	799211	m^3/yr
Total Atmospsheric P Input	1637	g/yr
Total Surface Run Off P Input	16279	g/yr
Total Development P Input	103818.00	g/yr
Total P Input	121734	g/yr
Lake P Retention Factor	0.59	n/a
Lake P Retention	72404	g/yr
Predicted Lake P Concentration	**0.062**	mg/L
Lake Phosphours Outflow	49330	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	137170	
Surface Run Off	710476	
Evaporation	48435	
Total Outflow	799211	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	1637	
Surface Run Off	16279	
Development	103818	
Sedimentation	72404	
Total Outflow	49330	
Total Check		
Model Validation		**Units**
Predicted P	0.062	(mg/L)
Measured P	0.03	(mg/L)
% Difference		

Lake Name: Beaver Pond

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		481.43	ha
Land Use -1 Commercial		31.07	ha
Land Use -2 Forest		161.14	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		18.58	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		4.29	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		221.33	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		38.48	ha
Land Use -11 Water		0.66	ha
Land Use -12 Wetland		5.88	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		14.98	ha
Lake Volume		0.00	10^6m^3
Hydrology			
Upstream Hydraulic Inputs		799211	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		49330.01	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		73	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	217199	m^3/yr
Total Evaporation Loss	76694	m^3/yr
Total Hydraulic Surface Runoff	4910624	m^3/yr
Total Hydraulic Input	5927034	m^3/yr
Areal Hydraulic Load	39	m/yr
Total Hydraulic Outflow	5850340	m^3/yr
Total Atmosphospheric P Input	2591	g/yr
Total Surface Run Off P Input	146664	g/yr
Total Development P Input	62634.00	g/yr
Total P Input	261220	g/yr
Lake P Retention Factor	0.24	n/a
Lake P Retention	62693	g/yr
Predicted Lake P Concentration	**0.034**	mg/L
Lake Phosphorus Outflow	198527	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	799210.93	
Precipitation	217199	
Surface Run Off	4910624	
Evaporation	76694	
Total Outflow	5850340	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	49330.01	
Atmosphere	2591	
Surface Run Off	146664	
Development	62634	
Sedimentation	62693	
Total Outflow	198527	
Total Check		
Model Validation		**Units**
Predicted P	0.034	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Kinsac

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		2057.75	ha
Land Use -1 Commercial		125.60	ha
Land Use -2 Forest		820.72	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		99.26	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		5.31	ha
Land Use -7 Low Density Residential		501.61	ha
Land Use -8 Medium Density Residential		335.14	ha
Land Use -9 Open Space		3.41	ha
Land Use -10 Roadway		68.83	ha
Land Use -11 Water		12.64	ha
Land Use -12 Wetland		85.23	ha
Land Use -13			ha
Land Use -14 Golf Course			ha
Land Use -15			ha
Lake Surface Area		168.14	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		102746598	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		1384069.25	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient - Golf Course			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings	216	328	#
Avg. No. of Pers./Dwelling	2.6	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	1	/yr
Phosphorus Load/Capita/Yr	660	660	g/capita yr
Septic System Retention Coeff.	0.85	0.50	n/a
Point Source Input 1		14235	g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	2438074	m^3/yr
Total Evaporation Loss	860892	m^3/yr
Total Hydraulic Surface Runoff	20989067	m^3/yr
Total Hydraulic Input	126173739	m^3/yr
Areal Hydraulic Load	75	m/yr
Total Hydraulic Outflow	125312847	m^3/yr
Total Atmosphospheric P Input	29089	g/yr
Total Surface Run Off P Input	539802	g/yr
Total Development P Input	351257.40	g/yr
Total P Input	2304217	g/yr
Lake P Retention Factor	0.14	n/a
Lake P Retention	328691	g/yr
Predicted Lake P Concentration	**0.016**	mg/L
Lake Phosphours Outflow	1975526	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	102746598.18	
Precipitation	2438074	
Surface Run Off	20989067	
Evaporation	860892	
Total Outflow	125312847	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	1384069.25	
Atmosphere	29089	
Surface Run Off	539802	
Development	351257	
Sedimentation	328691	
Total Outflow	1975526	
Total Check		
Model Validation		**Units**
Predicted P	0.016	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Banook **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		169.49	ha
Land Use -1 Commercial		23.72	ha
Land Use -2 Forest		5.85	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		72.54	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		7.02	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		10.07	ha
Land Use -9 Open Space		19.09	ha
Land Use -10 Roadway		31.12	ha
Land Use -11 Water		0.09	ha
Land Use -12 Wetland		0.00	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		41.50	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		21903833	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		257541.39	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		0	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.			n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

	Symbol	Value	Units
Model Outputs			
Total Precipitation Input		601750	m^3/yr
Total Evaporation Loss		212480	m^3/yr
Total Hydraulic Surface Runoff		1728837	m^3/yr
Total Hydraulic Input		24234420	m^3/yr
Areal Hydraulic Load		58	m/yr
Total Hydraulic Outflow		24021940	m^3/yr
Total Atmosphospheric P Input		7180	g/yr
Total Surface Run Off P Input		118622	g/yr
Total Development P Input		0.00	g/yr
Total P Input		383343	g/yr
Lake P Retention Factor		0.30	n/a
Lake P Retention		115003	g/yr
Predicted Lake P Concentration		**0.011**	mg/L
Lake Phosphours Outflow		268340	g/yr
Lake Mean Depth		#DIV/0!	m
Lake Flushing Rate		#DIV/0!	/yr
Lake Turnover Time		0.00	yr
Lake Response Time		#DIV/0!	yr
		Value	**% Total**
Hydraulic Budget (m^3)			
Upstream Inflow		21903833.13	
Precipitation		601750	
Surface Run Off		1728837	
Evaporation		212480	
Total Outflow		24021940	
Total Check			
Phorpshorus Budget (gm)			
Upstream Inflow		257541.39	
Atmosphere		7180	
Surface Run Off		118622	
Development		0	
Sedimentation		115003	
Total Outflow		268340	
Total Check			
Model Validation			**Units**
Predicted P		0.011	(mg/L)
Measured P			(mg/L)
% Difference			

Lake Name: Micmac

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		297.24	ha
Land Use -1 Commercial		14.51	ha
Land Use -2 Forest		62.64	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		105.31	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		8.75	ha
Land Use -7 Low Density Residential		7.41	ha
Land Use -8 Medium Density Residential		14.74	ha
Land Use -9 Open Space		13.85	ha
Land Use -10 Roadway		60.52	ha
Land Use -11 Water		9.51	ha
Land Use -12 Wetland		0.00	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		104.15	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		17895066	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		242755.41	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		0	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.			n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Symbol	Value	Units
Model Outputs			
Total Precipitation Input		1510175	m^3/yr
Total Evaporation Loss		533248	m^3/yr
Total Hydraulic Surface Runoff		3031840	m^3/yr
Total Hydraulic Input		22437081	m^3/yr
Areal Hydraulic Load		21	m/yr
Total Hydraulic Outflow		21903833	m^3/yr
Total Atmosphospheric P Input		18018	g/yr
Total Surface Run Off P Input		148616	g/yr
Total Development P Input		0.00	g/yr
Total P Input		409389	g/yr
Lake P Retention Factor		0.37	n/a
Lake P Retention		151848	g/yr
Predicted Lake P Concentration		**0.012**	mg/L
Lake Phosphours Outflow		257541	g/yr
Lake Mean Depth		#DIV/0!	m
Lake Flushing Rate		#DIV/0!	/yr
Lake Turnover Time		0.00	yr
Lake Response Time		#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	17895065.98	
Precipitation	1510175	
Surface Run Off	3031840	
Evaporation	533248	
Total Outflow	21903833	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	242755.41	
Atmosphere	18018	
Surface Run Off	148616	
Development	0	
Sedimentation	151848	
Total Outflow	257541	
Total Check		

Model Validation		Units
Predicted P	0.012	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Cranberry Lake South | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		64.94	ha
Land Use -1 Commercial		1.28	ha
Land Use -2 Forest		11.59	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		38.79	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		1.58	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		0.00	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		11.67	ha
Land Use -11 Water		0.00	ha
Land Use -12 Wetland		0.04	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		11.23	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		0	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.			n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	162818	m^3/yr
Total Evaporation Loss	57492	m^3/yr
Total Hydraulic Surface Runoff	662430	m^3/yr
Total Hydraulic Input	825248	m^3/yr
Areal Hydraulic Load	7	m/yr
Total Hydraulic Outflow	767756	m^3/yr
Total Atmosphepheric P Input	1943	g/yr
Total Surface Run Off P Input	33907	g/yr
Total Development P Input	0.00	g/yr
Total P Input	35849	g/yr
Lake P Retention Factor	0.64	n/a
Lake P Retention	23108	g/yr
Predicted Lake P Concentration	**0.017**	mg/L
Lake Phosphours Outflow	12742	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	162818	
Surface Run Off	662430	
Evaporation	57492	
Total Outflow	767756	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	1943	
Surface Run Off	33907	
Development	0	
Sedimentation	23108	
Total Outflow	12742	
Total Check		
Model Validation		**Units**
Predicted P	0.017	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Loon | **Watershed: Shubenacadie**

Input Parameters	**Symbol**	**Value**	**Units**
Morphology			
Drainage Basin Area (excl. of lake area)		201.19	ha
Land Use -1 Commercial		10.37	ha
Land Use -2 Forest		64.97	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		20.11	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		42.32	ha
Land Use -9 Open Space		34.27	ha
Land Use -10 Roadway		27.36	ha
Land Use -11 Water		0.00	ha
Land Use -12 Wetland		1.78	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		76.63	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		767756	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		12741.60	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		2020	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		0	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.			n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	1111128	m^3/yr
Total Evaporation Loss	392343	m^3/yr
Total Hydraulic Surface Runoff	2052119	m^3/yr
Total Hydraulic Input	3931004	m^3/yr
Areal Hydraulic Load	5	m/yr
Total Hydraulic Outflow	3538661	m^3/yr
Total Atmosphosphedric P Input	13257	g/yr
Total Surface Run Off P Input	101262	g/yr
Total Development P Input	0.00	g/yr
Total P Input	127260	g/yr
Lake P Retention Factor	0.60	n/a
Lake P Retention	76356	g/yr
Predicted Lake P Concentration	**0.014**	mg/L
Lake Phosphours Outflow	50904	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	767756.46	
Precipitation	1111128	
Surface Run Off	2052119	
Evaporation	392343	
Total Outflow	3538661	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	12741.60	
Atmosphere	13257	
Surface Run Off	101262	
Development	0	
Sedimentation	76356	
Total Outflow	50904	
Total Check		
Model Validation		**Units**
Predicted P	0.014	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Charles | **Watershed: Shubenacadie**

Input Parameters	**Symbol**	**Value**	**Units**
Morphology			
Drainage Basin Area (excl. of lake area)		1450.94	ha
Land Use -1 Commercial		0.84	ha
Land Use -2 Forest		566.48	ha
Land Use -3 Forest - Meadow		2.30	ha
Land Use -4 High Density Residential		467.30	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		11.15	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		25.03	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		179.32	ha
Land Use -11 Water		6.43	ha
Land Use -12 Wetland		52.87	ha
Land Use -13 - Quarry		139.23	ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		141.43	ha
Lake Volume		1117315571	m^3
Hydrology			
Upstream Hydraulic Inputs		3538661	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		50904.12	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		69	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient - Quarry		80	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		70	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	2050769	m^3/yr
Total Evaporation Loss	724134	m^3/yr
Total Hydraulic Surface Runoff	14799612	m^3/yr
Total Hydraulic Input	20389041	m^3/yr
Areal Hydraulic Load	14	m/yr
Total Hydraulic Outflow	19664908	m^3/yr
Total Atmospheric P Input	24468	g/yr
Total Surface Run Off P Input	457377	g/yr
Total Development P Input	60060.00	g/yr
Total P Input	592809	g/yr
Lake P Retention Factor	0.55	n/a
Lake P Retention	326045	g/yr
Predicted Lake P Concentration	**0.014**	mg/L
Lake Phosphours Outflow	266764	g/yr
Lake Mean Depth	7.90	m
Lake Flushing Rate	0.02	/yr
Lake Turnover Time	56.82	yr
Lake Response Time	0.54	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	3538660.61	
Precipitation	2050769	
Surface Run Off	14799612	
Evaporation	724134	
Total Outflow	19664908	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	50904.12	
Atmosphere	24468	
Surface Run Off	457377	
Development	60060	
Sedimentation	326045	
Total Outflow	266764	
Total Check		
Model Validation		**Units**
Predicted P	0.014	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: William | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	469.40	ha
Land Use -1 Commercial	19.88	ha
Land Use -2 Forest	244.67	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	65.70	ha
Land Use -5 Industrial	0.50	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	0.00	ha
Land Use -8 Medium Density Residential	45.55	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	44.82	ha
Land Use -11 Water	33.96	ha
Land Use -12 Wetland	14.33	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	43.10	ha
Lake Volume	4913108	m^3
Hydrology		
Upstream Hydraulic Inputs	22674788	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	372936	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	530	520
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	58	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.50	n/a
Point Source Input 1		g/yr
Point Source Input 2		g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	624913	m^3/yr
Total Evaporation Loss	220659	m^3/yr
Total Hydraulic Surface Runoff	4787928	m^3/yr
Total Hydraulic Input	28087629	m^3/yr
Areal Hydraulic Load	65	m/yr
Total Hydraulic Outflow	27866970	m^3/yr
Total Atmosphospheric P Input	7456	g/yr
Total Surface Run Off P Input	143055	g/yr
Total Development P Input	49764.00	g/yr
Total P Input	573211	g/yr
Lake P Retention Factor	0.40	n/a
Lake P Retention	229284	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	343926	g/yr
Lake Mean Depth	11.40	m
Lake Flushing Rate	5.67	/yr
Lake Turnover Time	0.18	yr
Lake Response Time	0.11	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	22674788.28	
Precipitation	624913	
Surface Run Off	4787928	
Evaporation	220659	
Total Outflow	27866970	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	372936.02	
Atmosphere	7456	
Surface Run Off	143055	
Development	49764	
Sedimentation	229284	
Total Outflow	343926	
Total Check		
Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P	0.009	(mg/L)
% Difference		

Lake Name: William | **Watershed: Shubenacadie**

Input Parameters	**Value**	**Units**
Morphology		
Drainage Basin Area (excl. of lake area)	2195.45	ha
Land Use -1 Commercial	8.94	ha
Land Use -2 Forest	1675.39	ha
Land Use -3 Forest - Meadow	0.00	ha
Land Use -4 High Density Residential	133.75	ha
Land Use -5 Industrial	12.08	ha
Land Use -6 Institutional	0.00	ha
Land Use -7 Low Density Residential	42.44	ha
Land Use -8 Medium Density Residential	60.93	ha
Land Use -9 Open Space	0.00	ha
Land Use -10 Roadway	119.21	ha
Land Use -11 Water	19.02	ha
Land Use -12 Wetland	123.69	ha
Land Use -13		ha
Land Use -14		ha
Land Use -15		ha
Lake Surface Area	301.78	ha
Lake Volume	34403266	m^3
Hydrology		
Upstream Hydraulic Inputs	28456917	m^3/yr
Annual Unit Precipitation	1.45	m/yr
Annual Unit Evaporation	0.5120	m/yr
Annual Hydraulic Run Off - veg surf	1.02	m/yr
Annual Hydraulic Run Off - urban	1.33	m/yr
Phosphorus Inputs		
Upstream P Input	351929	g/yr
Annual Atmospheric P Deposition	173	g/(ha*yr)
Export Coefficient - Commercial	2020	g/(ha*yr)
Export Coefficient - Forest	69	g/(ha*yr)
Export Coefficient - Forest - Meadow	83	g/(ha*yr)
Export Coefficient - High Denisty Residential	530	520
Export Coefficient - Industrial	2020	g/(ha*yr)
Export Coefficient - Instiutional	420	g/(ha*yr)
Export Coefficient - Low Density Residential	130	g/(ha*yr)
Export Coefficient - Medium Density Residential	130	g/(ha*yr)
Export Coefficient - Open Space	130	g/(ha*yr)
Export Coefficient - Roadway	830	g/(ha*yr)
Export Coefficient - Water	173	g/(ha*yr)
Export Coefficient - Wetland	83	g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
Export Coefficient -		g/(ha*yr)
No. Dwellings	882	#
Avg. No. of Pers./Dwelling	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	/yr
Phosphorus Load/Capita/Yr	660	g/capita yr
Septic System Retention Coeff.	0.50	n/a
Point Source Input 1	43800	g/yr
Point Source Input 2	2738	g/yr
Point Source Input 3		g/yr
Point Source Input 4		g/yr
Point Source Input 5		g/yr
Lake Phosphorus Retention Coefficient	7.2	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	4375854	m^3/yr
Total Evaporation Loss	1545129	m^3/yr
Total Hydraulic Surface Runoff	22393545	m^3/yr
Total Hydraulic Input	55226316	m^3/yr
Areal Hydraulic Load	18	m/yr
Total Hydraulic Outflow	53681187	m^3/yr
Total Atmospphoric P Input	52208	g/yr
Total Surface Run Off P Input	354883	g/yr
Total Development P Input	803293.50	g/yr
Total P Input	1562314	g/yr
Lake P Retention Factor	0.60	n/a
Lake P Retention	937389	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	624926	g/yr
Lake Mean Depth	11.40	m
Lake Flushing Rate	1.56	/yr
Lake Turnover Time	0.64	yr
Lake Response Time	0.28	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	28456917.35	
Precipitation	4375854	
Surface Run Off	22393545	
Evaporation	1545129	
Total Outflow	53681187	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	351929.37	
Atmosphere	52208	
Surface Run Off	354883	
Development	803294	
Sedimentation	937389	
Total Outflow	624926	
Total Check		
Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P	0.009	(mg/L)
% Difference		

Lake Name: First | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		280.55	ha
Land Use -1 Commercial		19.22	ha
Land Use -2 Forest		44.95	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		136.63	ha
Land Use -5 Industrial		1.29	ha
Land Use -6 Institutional		19.99	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		3.55	ha
Land Use -9 Open Space		3.98	ha
Land Use -10 Roadway		50.82	ha
Land Use -11 Water		0.12	ha
Land Use -12 Wetland		0.00	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		82.70	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		53	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	1199138	m^3/yr
Total Evaporation Loss	423420	m^3/yr
Total Hydraulic Surface Runoff	2861583	m^3/yr
Total Hydraulic Input	4060721	m^3/yr
Areal Hydraulic Load	4	m/yr
Total Hydraulic Outflow	3637302	m^3/yr
Total Atmosphpheric P Input	14307	g/yr
Total Surface Run Off P Input	167160	g/yr
Total Development P Input	45474.00	g/yr
Total P Input	226941	g/yr
Lake P Retention Factor	0.80	n/a
Lake P Retention	181553	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	45388	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	1199138	
Surface Run Off	2861583	
Evaporation	423420	
Total Outflow	3637302	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0	
Atmosphere	14307	
Surface Run Off	167160	
Development	45474	
Sedimentation	181553	
Total Outflow	45388	
Total Check		

Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Rocky | **Watershed: Shubenacadie**

Input Parameters	**Symbol**	**Value**	**Units**
Morphology			
Drainage Basin Area (excl. of lake area)		728.88	ha
Land Use -1 Commercial		30.42	ha
Land Use -2 Forest		234.20	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		47.44	ha
Land Use -5 Industrial		22.59	ha
Land Use -6 Institutional		2.47	ha
Land Use -7 Low Density Residential		17.12	ha
Land Use -8 Medium Density Residential		45.15	ha
Land Use -9 Open Space		10.19	ha
Land Use -10 Roadway		45.08	ha
Land Use -11 Water		6.92	ha
Land Use -12 Wetland		40.75	ha
Land Use -13 Quarry		226.56	ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		145.69	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		3637302	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		45388.23	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient - Quarry		80	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		147	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	2112453	m^3/yr
Total Evaporation Loss	745914	m^3/yr
Total Hydraulic Surface Runoff	7434544	m^3/yr
Total Hydraulic Input	13184299	m^3/yr
Areal Hydraulic Load	9	m/yr
Total Hydraulic Outflow	12438384	m^3/yr
Total Atmosphospheric P Input	25204	g/yr
Total Surface Run Off P Input	218489	g/yr
Total Development P Input	126126.00	g/yr
Total P Input	415207	g/yr
Lake P Retention Factor	0.45	n/a
Lake P Retention	186843	g/yr
Predicted Lake P Concentration	**0.018**	mg/L
Lake Phosphours Outflow	228364	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	3637301.53	
Precipitation	2112453	
Surface Run Off	7434544	
Evaporation	745914	
Total Outflow	12438384	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	45388.23	
Atmosphere	25204	
Surface Run Off	218489	
Development	126126	
Sedimentation	186843	
Total Outflow	228364	
Total Check		
Model Validation		**Units**
Predicted P	0.018	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Second | **Watershed: Shubenacadie**

Input Parameters	**Symbol**	**Value**	**Units**
Morphology			
Drainage Basin Area (excl. of lake area)		578.61	ha
Land Use -1 Commercial		13.91	ha
Land Use -2 Forest		340.94	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		44.74	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		2.45	ha
Land Use -7 Low Density Residential		59.87	ha
Land Use -8 Medium Density Residential		54.31	ha
Land Use -9 Open Space		0.82	ha
Land Use -10 Roadway		43.55	ha
Land Use -11 Water		0.00	ha
Land Use -12 Wetland		18.03	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		112.66	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		209	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	1633636	m^3/yr
Total Evaporation Loss	576843	m^3/yr
Total Hydraulic Surface Runoff	5901840	m^3/yr
Total Hydraulic Input	7535476	m^3/yr
Areal Hydraulic Load	6	m/yr
Total Hydraulic Outflow	6958634	m^3/yr
Total Atmosphospheric P Input	19491	g/yr
Total Surface Run Off P Input	128502	g/yr
Total Development P Input	179322.00	g/yr
Total P Input	327315	g/yr
Lake P Retention Factor	0.65	n/a
Lake P Retention	212755	g/yr
Predicted Lake P Concentration	**0.016**	mg/L
Lake Phosphours Outflow	114560	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	1633636	
Surface Run Off	5901840	
Evaporation	576843	
Total Outflow	6958634	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	19491	
Surface Run Off	128502	
Development	179322	
Sedimentation	212755	
Total Outflow	114560	
Total Check		
Model Validation		**Units**
Predicted P	0.016	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Third **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		243.45	ha
Land Use -1 Commercial		1.84	ha
Land Use -2 Forest		51.39	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		13.24	ha
Land Use -5 Industrial		0.45	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		34.87	ha
Land Use -8 Medium Density Residential		109.20	ha
Land Use -9 Open Space		3.12	ha
Land Use -10 Roadway		27.50	ha
Land Use -11 Water		1.84	ha
Land Use -12 Wetland		0.00	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		84.71	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		6958634	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		114560	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		264	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	1228348	m^3/yr
Total Evaporation Loss	433734	m^3/yr
Total Hydraulic Surface Runoff	2483156	m^3/yr
Total Hydraulic Input	10670138	m^3/yr
Areal Hydraulic Load	12	m/yr
Total Hydraulic Outflow	10236404	m^3/yr
Total Atmospheric P Input	14655	g/yr
Total Surface Run Off P Input	57335	g/yr
Total Development P Input	226512.00	g/yr
Total P Input	413063	g/yr
Lake P Retention Factor	0.65	n/a
Lake P Retention	268491	g/yr
Predicted Lake P Concentration	**0.014**	mg/L
Lake Phosphours Outflow	144572	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	6958633.79	
Precipitation	1228348	
Surface Run Off	2483156	
Evaporation	433734	
Total Outflow	10236404	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	114560.27	
Atmosphere	14655	
Surface Run Off	57335	
Development	226512	
Sedimentation	268491	
Total Outflow	144572	
Total Check		

Model Validation		**Units**
Predicted P	0.014	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Soldier | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		3549.67	ha
Land Use -1 Commercial		146.99	ha
Land Use -2 Forest		2819.01	ha
Land Use -3 Forest - Meadow		0.66	ha
Land Use -4 High Density Residential		0.19	ha
Land Use -5 Industrial		33.30	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		20.57	ha
Land Use -8 Medium Density Residential		35.40	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		107.79	ha
Land Use -11 Water		76.65	ha
Land Use -12 Wetland		309.12	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		230.23	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		1	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	3338394	m^3/yr
Total Evaporation Loss	1178798	m^3/yr
Total Hydraulic Surface Runoff	36206592	m^3/yr
Total Hydraulic Input	39544986	m^3/yr
Areal Hydraulic Load	17	m/yr
Total Hydraulic Outflow	38366188	m^3/yr
Total Atmospheric P Input	39830	g/yr
Total Surface Run Off P Input	694508	g/yr
Total Development P Input	858.00	g/yr
Total P Input	735197	g/yr
Lake P Retention Factor	0.43	n/a
Lake P Retention	313668	g/yr
Predicted Lake P Concentration	**0.011**	mg/L
Lake Phosphours Outflow	421529	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	3338394	
Surface Run Off	36206592	
Evaporation	1178798	
Total Outflow	38366188	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	39830	
Surface Run Off	694508	
Development	858	
Sedimentation	313668	
Total Outflow	421529	
Total Check		
Model Validation		**Units**
Predicted P	0.011	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Miller

Watershed: Shubenacadie

Input Parameters	**Symbol**	**Value**	**Units**
Morphology			
Drainage Basin Area (excl. of lake area)		471.80	ha
Land Use -1 Commercial		29.88	ha
Land Use -2 Forest		207.10	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		6.94	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		32.83	ha
Land Use -8 Medium Density Residential		113.48	ha
Land Use -9 Open Space		1.68	ha
Land Use -10 Roadway		61.75	ha
Land Use -11 Water		3.62	ha
Land Use -12 Wetland		14.53	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		125.83	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		38366188	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		421529	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings	46	133	#
Avg. No. of Pers./Dwelling	2.60	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	1	/yr
Phosphorus Load/Capita/Yr	660	660	g/capita yr
Septic System Retention Coeff.	0.85	0.50	n/a
Point Source Input 1		60772.50	g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	1824479	m^3/yr
Total Evaporation Loss	644230	m^3/yr
Total Hydraulic Surface Runoff	4812333	m^3/yr
Total Hydraulic Input	45003000	m^3/yr
Areal Hydraulic Load	35	m/yr
Total Hydraulic Outflow	44358770	m^3/yr
Total Atmosphospheric P Input	21768	g/yr
Total Surface Run Off P Input	150572	g/yr
Total Development P Input	175596.25	g/yr
Total P Input	769465	g/yr
Lake P Retention Factor	0.26	n/a
Lake P Retention	200222	g/yr
Predicted Lake P Concentration	**0.013**	mg/L
Lake Phosphours Outflow	569243	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	38366188	
Precipitation	1824479	
Surface Run Off	4812333	
Evaporation	644230	
Total Outflow	44358770	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	421529	
Atmosphere	21768	
Surface Run Off	150572	
Development	175596	
Sedimentation	200222	
Total Outflow	569243	
Total Check		
Model Validation		**Units**
Predicted P	0.013	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Thomas

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		801.16	ha
Land Use -1 Commercial		26.35	ha
Land Use -2 Forest		343.02	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		171.53	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		1.08	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		101.58	ha
Land Use -9 Open Space		0.44	ha
Land Use -10 Roadway		102.67	ha
Land Use -11 Water		14.21	ha
Land Use -12 Wetland		40.29	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		112.89	ha
Lake Volume		4063894	m^3
Hydrology			
Upstrean Hydraulic Inputs		98039957	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		1194169	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		385	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1		27375.0	g/yr
Point Source Input 2		2737.5	g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	1636846	m^3/yr
Total Evaporation Loss	577976	m^3/yr
Total Hydraulic Surface Runoff	8171789	m^3/yr
Total Hydraulic Input	107848593	m^3/yr
Areal Hydraulic Load	95	m/yr
Total Hydraulic Outflow	107270617	m^3/yr
Total Atmosphospheric P Input	19529	g/yr
Total Surface Run Off P Input	270812	g/yr
Total Development P Input	360442.50	g/yr
Total P Input	1844952	g/yr
Lake P Retention Factor	0.12	n/a
Lake P Retention	212960	g/yr
Predicted Lake P Concentration	**0.015**	mg/L
Lake Phosphours Outflow	1631992	g/yr
Lake Mean Depth	3.60	m
Lake Flushing Rate	26.40	/yr
Lake Turnover Time	0.04	yr
Lake Response Time	0.02	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	98039957.26	
Precipitation	1636846	
Surface Run Off	8171789	
Evaporation	577976	
Total Outflow	107270617	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	1194169	
Atmosphere	19529	
Surface Run Off	270812	
Development	360443	
Sedimentation	212960	
Total Outflow	1631992	
Total Check		
Model Validation		**Units**
Predicted P	0.015	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Fletcher

Watershed: Shubenacadie

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		1569.45	ha
Land Use -1 Commercial		1.38	ha
Land Use -2 Forest		470.28	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		129.41	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		25.44	ha
Land Use -7 Low Density Residential		236.24	ha
Land Use -8 Medium Density Residential		556.20	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		100.62	ha
Land Use -11 Water		21.83	ha
Land Use -12 Wetland		28.06	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		100.68	ha
Lake Volume		3725303	m^3
Hydrology			
Upstrean Hydraulic Inputs		107270617	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		1631992.05	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		433	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1		248565	g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	1459916	m^3/yr
Total Evaporation Loss	515501	m^3/yr
Total Hydraulic Surface Runoff	16008368	m^3/yr
Total Hydraulic Input	124738901	m^3/yr
Areal Hydraulic Load	123	m/yr
Total Hydraulic Outflow	124223400	m^3/yr
Total Atmospheric P Input	17418	g/yr
Total Surface Run Off P Input	305854	g/yr
Total Development P Input	620079.00	g/yr
Total P Input	2575343	g/yr
Lake P Retention Factor	0.45	n/a
Lake P Retention	1158905	g/yr
Predicted Lake P Concentration	**0.011**	mg/L
Lake Phosphours Outflow	1416439	g/yr
Lake Mean Depth	3.70	m
Lake Flushing Rate	33.35	/yr
Lake Turnover Time	0.03	yr
Lake Response Time	0.02	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	107270616.84	
Precipitation	1459916	
Surface Run Off	16008368	
Evaporation	515501	
Total Outflow	124223400	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	1631992	
Atmosphere	17418	
Surface Run Off	305854	
Development	620079	
Sedimentation	1158905	
Total Outflow	1416439	
Total Check		

Model Validation		**Units**
Predicted P	0.011	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Shubie Grand | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		7734.18	ha
Land Use -1 Commercial		7.71	ha
Land Use -2 Forest		6665.54	ha
Land Use -3 Forest - Meadow		266.89	ha
Land Use -4 High Density Residential		16.82	ha
Land Use -5 Industrial		2.15	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		115.34	ha
Land Use -8 Medium Density Residential		271.98	ha
Land Use -9 Open Space		9.95	ha
Land Use -10 Roadway		56.81	ha
Land Use -11 Water		59.50	ha
Land Use -12 Wetland		261.50	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		1877.41	ha
Lake Volume		345442720	m^3
Hydrology			
Upstrean Hydraulic Inputs		262558055	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		3582968.37	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		836	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1		4928	g/yr
Point Source Input 2		37230	g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		7.2	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	27222388	m^3/yr
Total Evaporation Loss	9612319	m^3/yr
Total Hydraulic Surface Runoff	78888627	m^3/yr
Total Hydraulic Input	368669071	m^3/yr
Areal Hydraulic Load	19	m/yr
Total Hydraulic Outflow	359056751	m^3/yr
Total Atmosphosphric P Input	324791	g/yr
Total Surface Run Off P Input	641531	g/yr
Total Development P Input	759445.50	g/yr
Total P Input	5308736	g/yr
Lake P Retention Factor	0.27	n/a
Lake P Retention	1451954	g/yr
Predicted Lake P Concentration	**0.011**	mg/L
Lake Phosphours Outflow	3856782	g/yr
Lake Mean Depth	18.40	m
Lake Flushing Rate	1.04	/yr
Lake Turnover Time	0.96	yr
Lake Response Time	0.44	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	262558055.23	
Precipitation	27222388	
Surface Run Off	78888627	
Evaporation	9612319	
Total Outflow	359056751	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	3582968.37	
Atmosphere	324791	
Surface Run Off	641531	
Development	759446	
Sedimentation	1451954	
Total Outflow	3856782	
Total Check		
Model Validation		**Units**
Predicted P	0.011	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Fish — **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		1229.79	ha
Land Use -1 Commercial		5.26	ha
Land Use -2 Forest		791.44	ha
Land Use -3 Forest - Meadow		103.60	ha
Land Use -4 High Density Residential		27.95	ha
Land Use -5 Industrial		4.33	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		12.64	ha
Land Use -8 Medium Density Residential		147.41	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		35.54	ha
Land Use -11 Water		58.62	ha
Land Use -12 Wetland		42.99	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		50.95	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		2020	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		80	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	738769	m^3/yr
Total Evaporation Loss	260862	m^3/yr
Total Hydraulic Surface Runoff	12543902	m^3/yr
Total Hydraulic Input	13282671	m^3/yr
Areal Hydraulic Load	26	m/yr
Total Hydraulic Outflow	13021809	m^3/yr
Total Atmospheric P Input	8814	g/yr
Total Surface Run Off P Input	203433	g/yr
Total Development P Input	68640.00	g/yr
Total P Input	280887	g/yr
Lake P Retention Factor	0.32	n/a
Lake P Retention	89884	g/yr
Predicted Lake P Concentration	**0.015**	mg/L
Lake Phosphours Outflow	191003	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0	
Precipitation	738769	
Surface Run Off	12543902	
Evaporation	260862	
Total Outflow	13021809	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0	
Atmosphere	8814	
Surface Run Off	203433	
Development	68640	
Sedimentation	89884	
Total Outflow	191003	
Total Check		

Model Validation		**Units**
Predicted P	0.015	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Springfield | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		633.91	ha
Land Use -1 Commercial		3.10	ha
Land Use -2 Forest		106.93	ha
Land Use -3 Forest - Meadow		15.65	ha
Land Use -4 High Density Residential		107.24	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		113.94	ha
Land Use -8 Medium Density Residential		208.43	ha
Land Use -9 Open Space		15.42	ha
Land Use -10 Roadway		50.10	ha
Land Use -11 Water		0.71	ha
Land Use -12 Wetland		12.40	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		81.28	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings	78	135	#
Avg. No. of Pers./Dwelling	2.60	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	1	/yr
Phosphorus Load/Capita/Yr	660	660	g/capita yr
Septic System Retention Coeff.	0.85	0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	1178617	m^3/yr
Total Evaporation Loss	416174	m^3/yr
Total Hydraulic Surface Runoff	6465910	m^3/yr
Total Hydraulic Input	7644527	m^3/yr
Areal Hydraulic Load	9	m/yr
Total Hydraulic Outflow	7228354	m^3/yr
Total Atmosphospheric P Input	14062	g/yr
Total Surface Run Off P Input	157348	g/yr
Total Development P Input	116571.75	g/yr
Total P Input	287981	g/yr
Lake P Retention Factor	0.58	n/a
Lake P Retention	167708	g/yr
Predicted Lake P Concentration	**0.017**	mg/L
Lake Phosphours Outflow	120273	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0	
Precipitation	1178617	
Surface Run Off	6465910	
Evaporation	416174	
Total Outflow	7228354	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	14062	
Surface Run Off	157348	
Septics	116572	
Sedimentation	167708	
Total Outflow	120273	
Total Check		

Model Validation		**Units**
Predicted P	0.017	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Lisle **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		9.97	ha
Land Use -1 Commercial		0.00	ha
Land Use -2 Forest		0.63	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		0.00	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		2.27	ha
Land Use -8 Medium Density Residential		6.33	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		0.22	ha
Land Use -11 Water		0.00	ha
Land Use -12 Wetland		0.53	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		5.36	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		7228354	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		120272.95	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		14	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1		298388	g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	77730	m^3/yr
Total Evaporation Loss	27447	m^3/yr
Total Hydraulic Surface Runoff	101738	m^3/yr
Total Hydraulic Input	7407821	m^3/yr
Areal Hydraulic Load	138	m/yr
Total Hydraulic Outflow	7380375	m^3/yr
Total Atmospheric P Input	927	g/yr
Total Surface Run Off P Input	1385	g/yr
Total Development P Input	310399.50	g/yr
Total P Input	432985	g/yr
Lake P Retention Factor	0.08	n/a
Lake P Retention	35776	g/yr
Predicted Lake P Concentration	**0.054**	mg/L
Lake Phosphours Outflow	397210	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	7228354	
Precipitation	77730	
Surface Run Off	101738	
Evaporation	27447	
Total Outflow	7380375	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	120273	
Atmosphere	927	
Surface Run Off	1385	
Development	310400	
Sedimentation	35776	
Total Outflow	397210	
Total Check		
Model Validation		**Units**
Predicted P	0.054	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Fenerty

Watershed: Shubenacadie

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		1443.75	ha
Land Use -1 Commercial		0.00	ha
Land Use -2 Forest		900.93	ha
Land Use -3 Forest - Meadow		126.31	ha
Land Use -4 High Density Residential		0.02	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		88.53	ha
Land Use -8 Medium Density Residential		149.85	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		41.19	ha
Land Use -11 Water		43.16	ha
Land Use -12 Wetland		93.77	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		64.6768	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		7380375	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		397209.83	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings	133	54	#
Avg. No. of Pers./Dwelling	2.6	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	1	/yr
Phosphorus Load/Capita/Yr	660	660	g/capita yr
Septic System Retention Coeff.	0.85	0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	937813	m^3/yr
Total Evaporation Loss	331145	m^3/yr
Total Hydraulic Surface Runoff	14726237	m^3/yr
Total Hydraulic Input	23044424	m^3/yr
Areal Hydraulic Load	35	m/yr
Total Hydraulic Outflow	22713279	m^3/yr
Total Atmosphosphelric P Input	11189	g/yr
Total Surface Run Off P Input	153086	g/yr
Total Development P Input	80566.20	g/yr
Total P Input	642051	g/yr
Lake P Retention Factor	0.26	n/a
Lake P Retention	167545	g/yr
Predicted Lake P Concentration	**0.021**	mg/L
Lake Phosphours Outflow	474506	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr
	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	7380375	
Precipitation	937813	
Surface Run Off	14726237	
Evaporation	331145	
Total Outflow	22713279	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	397210	
Atmosphere	11189	
Surface Run Off	153086	
Development	80566	
Sedimentation	167545	
Total Outflow	474506	
Total Check		
Model Validation		**Units**
Predicted P	0.021	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Lewis | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		332.78	ha
Land Use -1 Commercial		0.00	ha
Land Use -2 Forest		259.31	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		0.00	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		54.76	ha
Land Use -8 Medium Density Residential		0.00	ha
Land Use -9 Open Space		3.33	ha
Land Use -10 Roadway		6.19	ha
Land Use -11 Water		0.00	ha
Land Use -12 Wetland		9.19	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		76.4657	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		145	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	1108753	m^3/yr
Total Evaporation Loss	391505	m^3/yr
Total Hydraulic Surface Runoff	3394341	m^3/yr
Total Hydraulic Input	4503094	m^3/yr
Areal Hydraulic Load	5	m/yr
Total Hydraulic Outflow	4111589	m^3/yr
Total Atmosphospheric P Input	13229	g/yr
Total Surface Run Off P Input	31341	g/yr
Total Development P Input	124410.00	g/yr
Total P Input	168980	g/yr
Lake P Retention Factor	0.70	n/a
Lake P Retention	117868	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	51111	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	1108753	
Surface Run Off	3394341	
Evaporation	391505	
Total Outflow	4111589	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	13229	
Surface Run Off	31341	
Development	124410	
Sedimentation	117868	
Total Outflow	51111	
Total Check		
Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Hamilton — **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		2626.83	ha
Land Use -1 Commercial		0.00	ha
Land Use -2 Forest		2004.64	ha
Land Use -3 Forest - Meadow		282.90	ha
Land Use -4 High Density Residential		18.40	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		1.60	ha
Land Use -7 Low Density Residential		6.32	ha
Land Use -8 Medium Density Residential		3.86	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		4.63	ha
Land Use -11 Water		96.39	ha
Land Use -12 Wetland		208.09	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		30.4045	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		26824868	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		525617.70	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings			#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.			n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	440865	m^3/yr
Total Evaporation Loss	155671	m^3/yr
Total Hydraulic Surface Runoff	26793673	m^3/yr
Total Hydraulic Input	54059407	m^3/yr
Areal Hydraulic Load	177	m/yr
Total Hydraulic Outflow	53903736	m^3/yr
Total Atmosphospheric P Input	5260	g/yr
Total Surface Run Off P Input	211154	g/yr
Total Development P Input	0.00	g/yr
Total P Input	742031	g/yr
Lake P Retention Factor	0.07	n/a
Lake P Retention	48507	g/yr
Predicted Lake P Concentration	**0.013**	mg/L
Lake Phosphours Outflow	693525	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	26824868.50	
Precipitation	440865	
Surface Run Off	26793673	
Evaporation	155671	
Total Outflow	53903736	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	525617.70	
Atmosphere	5260	
Surface Run Off	211154	
Development	0	
Sedimentation	48507	
Total Outflow	693525	
Total Check		

Model Validation		**Units**
Predicted P	0.013	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Tucker | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		153.69	ha
Land Use -1 Commercial		0.00	ha
Land Use -2 Forest		10.26	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		69.23	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		15.45	ha
Land Use -8 Medium Density Residential		26.29	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		16.98	ha
Land Use -11 Water		0.26	ha
Land Use -12 Wetland		15.23	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		32.6479	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		339	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	473394	m^3/yr
Total Evaporation Loss	167157	m^3/yr
Total Hydraulic Surface Runoff	1567683	m^3/yr
Total Hydraulic Input	2041077	m^3/yr
Areal Hydraulic Load	6	m/yr
Total Hydraulic Outflow	1873920	m^3/yr
Total Atmosphospheric P Input	5648	g/yr
Total Surface Run Off P Input	57532	g/yr
Total Development P Input	290862.00	g/yr
Total P Input	354042	g/yr
Lake P Retention Factor	0.92	n/a
Lake P Retention	325718	g/yr
Predicted Lake P Concentration	**0.015**	mg/L
Lake Phosphours Outflow	28323	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	473394	
Surface Run Off	1567683	
Evaporation	167157	
Total Outflow	1873920	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	5648	
Surface Run Off	57532	
Septics and Point Sources	290862	
Sedimentation	325718	
Total Outflow	28323	
Total Check		
Model Validation		**Units**
Predicted P	0.015	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Beaverbank

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		3881.41	ha
Land Use -1 Commercial		64.91	ha
Land Use -2 Forest		2835.77	ha
Land Use -3 Forest - Meadow		194.10	ha
Land Use -4 High Density Residential		66.59	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		6.54	ha
Land Use -7 Low Density Residential		32.76	ha
Land Use -8 Medium Density Residential		300.55	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		63.41	ha
Land Use -11 Water		70.09	ha
Land Use -12 Wetland		246.69	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		68.6190	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		55777655	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		721847.97	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		530	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		38	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	994976	m^3/yr
Total Evaporation Loss	351329	m^3/yr
Total Hydraulic Surface Runoff	39590343	m^3/yr
Total Hydraulic Input	96,362,974	m^3/yr
Areal Hydraulic Load	140	m/yr
Total Hydraulic Outflow	96011645	m^3/yr
Total Atmosphospheric P Input	11871	g/yr
Total Surface Run Off P Input	508835	g/yr
Total Development P Input	32604.00	g/yr
Total P Input	1275158	g/yr
Lake P Retention Factor	0.08	n/a
Lake P Retention	103808	g/yr
Predicted Lake P Concentration	**0.012**	mg/L
Lake Phosphours Outflow	1171351	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	55777655.30	
Precipitation	994976	
Surface Run Off	39590343	
Evaporation	351329	
Total Outflow	96011645	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	721847.97	
Atmosphere	11871	
Surface Run Off	508835	
Development	32604	
Sedimentation	103808	
Total Outflow	1171351	
Total Check		
Model Validation		**Units**
Predicted P	0.012	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Barrett | **Watershed: Shubenacadie**

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		78.45	ha
Land Use -1 Commercial		0.39	ha
Land Use -2 Forest		33.55	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		20.50	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		3.25	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		11.82	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		8.56	ha
Land Use -11 Water		0.37	ha
Land Use -12 Wetland		0.00	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		9.00	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		165	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	130569	m^3/yr
Total Evaporation Loss	46104	m^3/yr
Total Hydraulic Surface Runoff	800148	m^3/yr
Total Hydraulic Input	930718	m^3/yr
Areal Hydraulic Load	10	m/yr
Total Hydraulic Outflow	884613	m^3/yr
Total Atmosphospheric P Input	1558	g/yr
Total Surface Run Off P Input	23831	g/yr
Total Development P Input	141570.00	g/yr
Total P Input	166959	g/yr
Lake P Retention Factor	0.92	n/a
Lake P Retention	152768	g/yr
Predicted Lake P Concentration	**0.016**	mg/L
Lake Phosphours Outflow	14192	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	130569	
Surface Run Off	800148	
Evaporation	46104	
Total Outflow	884613	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	1558	
Surface Run Off	23831	
Development	141570	
Sedimentation	152768	
Total Outflow	14192	
Total Check		
Model Validation		**Units**
Predicted P	0.016	(mg/L)
Measured P	0.011	(mg/L)
% Difference		

Lake Name: Duck

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		69.65	ha
Land Use -1 Commercial		0.00	ha
Land Use -2 Forest		29.63	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		15.53	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		0.00	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		16.08	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		4.51	ha
Land Use -11 Water		0.00	ha
Land Use -12 Wetland		3.90	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		9.46	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		0	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		0.00	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		121	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

Watershed: Shubenacadie

	Value	Units
Model Outputs		
Total Precipitation Input	137170	m^3/yr
Total Evaporation Loss	48435	m^3/yr
Total Hydraulic Surface Runoff	710476	m^3/yr
Total Hydraulic Input	847646	m^3/yr
Areal Hydraulic Load	8	m/yr
Total Hydraulic Outflow	799211	m^3/yr
Total Atmosphosphric P Input	1637	g/yr
Total Surface Run Off P Input	16279	g/yr
Total Development P Input	103818.00	g/yr
Total P Input	121734	g/yr
Lake P Retention Factor	0.59	n/a
Lake P Retention	72404	g/yr
Predicted Lake P Concentration	**0.062**	mg/L
Lake Phosphours Outflow	49330	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	0.00	
Precipitation	137170	
Surface Run Off	710476	
Evaporation	48435	
Total Outflow	799211	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	0.00	
Atmosphere	1637	
Surface Run Off	16279	
Development	103818	
Sedimentation	72404	
Total Outflow	49330	
Total Check		

Model Validation		**Units**
Predicted P	0.062	(mg/L)
Measured P	0.03	(mg/L)
% Difference		

Lake Name: Beaver Pond

Watershed: Shubenacadie

Input Parameters	Symbol	Value	Units
Morphology			
Drainage Basin Area (excl. of lake area)		481.43	ha
Land Use -1 Commercial		31.07	ha
Land Use -2 Forest		161.14	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		18.58	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		4.29	ha
Land Use -7 Low Density Residential		0.00	ha
Land Use -8 Medium Density Residential		221.33	ha
Land Use -9 Open Space		0.00	ha
Land Use -10 Roadway		38.48	ha
Land Use -11 Water		0.66	ha
Land Use -12 Wetland		5.88	ha
Land Use -13			ha
Land Use -14			ha
Land Use -15			ha
Lake Surface Area		14.98	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstrean Hydraulic Inputs		799211	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		49330.01	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings		73	#
Avg. No. of Pers./Dwelling		2.60	#
Avg. Yr Frxn Dwelling Occ.		1	/yr
Phosphorus Load/Capita/Yr		660	g/capita yr
Septic System Retention Coeff.		0.50	n/a
Point Source Input 1			g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	Units
Model Outputs		
Total Precipitation Input	217199	m^3/yr
Total Evaporation Loss	76694	m^3/yr
Total Hydraulic Surface Runoff	4910624	m^3/yr
Total Hydraulic Input	5927034	m^3/yr
Areal Hydraulic Load	39	m/yr
Total Hydraulic Outflow	5850340	m^3/yr
Total Atmosphespheric P Input	2591	g/yr
Total Surface Run Off P Input	146664	g/yr
Total Development P Input	62634.00	g/yr
Total P Input	261220	g/yr
Lake P Retention Factor	0.24	n/a
Lake P Retention	62693	g/yr
Predicted Lake P Concentration	**0.034**	mg/L
Lake Phosphours Outflow	198527	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	% Total
Hydraulic Budget (m^3)		
Upstream Inflow	799210.93	
Precipitation	217199	
Surface Run Off	4910624	
Evaporation	76694	
Total Outflow	5850340	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	49330.01	
Atmosphere	2591	
Surface Run Off	146664	
Development	62634	
Sedimentation	62693	
Total Outflow	198527	
Total Check		

Model Validation		**Units**
Predicted P	0.034	(mg/L)
Measured P		(mg/L)
% Difference		

Lake Name: Kinsac | **Watershed: Shubenacadie**

Input Parameters	**Symbol**	**Value**	**Units**
Morphology			
Drainage Basin Area (excl. of lake area)		2057.75	ha
Land Use -1 Commercial		125.60	ha
Land Use -2 Forest		820.72	ha
Land Use -3 Forest - Meadow		0.00	ha
Land Use -4 High Density Residential		99.26	ha
Land Use -5 Industrial		0.00	ha
Land Use -6 Institutional		5.31	ha
Land Use -7 Low Density Residential		501.61	ha
Land Use -8 Medium Density Residential		335.14	ha
Land Use -9 Open Space		3.41	ha
Land Use -10 Roadway		68.83	ha
Land Use -11 Water		12.64	ha
Land Use -12 Wetland		85.23	ha
Land Use -13			ha
Land Use -14 Golf Course			ha
Land Use -15			ha
Lake Surface Area		168.14	ha
Lake Volume		0.00	$10^6 m^3$
Hydrology			
Upstream Hydraulic Inputs		102746598	m^3/yr
Annual Unit Precipitation		1.45	m/yr
Annual Unit Evaporation		0.5120	m/yr
Annual Hydraulic Run Off - veg surf		1.02	m/yr
Annual Hydraulic Run Off - urban		1.33	m/yr
Phosphorus Inputs			
Upstream P Input		1384069.25	g/yr
Annual Atmospheric P Deposition		173	g/(ha*yr)
Export Coefficient - Commercial		2020	g/(ha*yr)
Export Coefficient - Forest		69	g/(ha*yr)
Export Coefficient - Forest - Meadow		83	g/(ha*yr)
Export Coefficient - High Denisty Residential		520	g/(ha*yr)
Export Coefficient - Industrial		2020	g/(ha*yr)
Export Coefficient - Instiutional		420	g/(ha*yr)
Export Coefficient - Low Density Residential		130	g/(ha*yr)
Export Coefficient - Medium Density Residential		130	g/(ha*yr)
Export Coefficient - Open Space		130	g/(ha*yr)
Export Coefficient - Roadway		830	g/(ha*yr)
Export Coefficient - Water		173	g/(ha*yr)
Export Coefficient - Wetland		83	g/(ha*yr)
Export Coefficient -			g/(ha*yr)
Export Coefficient - Golf Course			g/(ha*yr)
Export Coefficient -			g/(ha*yr)
No. Dwellings	216	328	#
Avg. No. of Pers./Dwelling	2.6	2.60	#
Avg. Yr Frxn Dwelling Occ.	1	1	/yr
Phosphorus Load/Capita/Yr	660	660	g/capita yr
Septic System Retention Coeff.	0.85	0.50	n/a
Point Source Input 1		14235	g/yr
Point Source Input 2			g/yr
Point Source Input 3			g/yr
Point Source Input 4			g/yr
Point Source Input 5			g/yr
Lake Phosphorus Retention Coefficient		12.4	n/a

	Value	**Units**
Model Outputs		
Total Precipitation Input	2438074	m^3/yr
Total Evaporation Loss	860892	m^3/yr
Total Hydraulic Surface Runoff	20989067	m^3/yr
Total Hydraulic Input	126173739	m^3/yr
Areal Hydraulic Load	75	m/yr
Total Hydraulic Outflow	125312847	m^3/yr
Total Atmosphspheric P Input	29089	g/yr
Total Surface Run Off P Input	539802	g/yr
Total Development P Input	351257.40	g/yr
Total P Input	2304217	g/yr
Lake P Retention Factor	0.14	n/a
Lake P Retention	328691	g/yr
Predicted Lake P Concentration	**0.016**	mg/L
Lake Phosphours Outflow	1975526	g/yr
Lake Mean Depth	#DIV/0!	m
Lake Flushing Rate	#DIV/0!	/yr
Lake Turnover Time	0.00	yr
Lake Response Time	#DIV/0!	yr

	Value	**% Total**
Hydraulic Budget (m^3)		
Upstream Inflow	102746598.18	
Precipitation	2438074	
Surface Run Off	20989067	
Evaporation	860892	
Total Outflow	125312847	
Total Check		
Phorpshorus Budget (gm)		
Upstream Inflow	1384069.25	
Atmosphere	29089	
Surface Run Off	539802	
Development	351257	
Sedimentation	328691	
Total Outflow	1975526	
Total Check		
Model Validation		**Units**
Predicted P	0.016	(mg/L)
Measured P		(mg/L)
% Difference		

Appendix J

Hydrology, Hydraulic and Water Quality Storm Water Management Model

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1. Introduction

As part of the Shubenacadie Lakes (SL) subwatershed study, a surface water tributary loading model was built using the U.S. Environmental Protection Agency's StormWater Management Model (SWMM). This report summarizes the details of the model setup and results. Much of the background information is contained within other sections or appendices of the SL Subwatershed Report and appropriate sections have been referenced where applicable.

1.1 Design Criteria

Stormwater management (SWM) features include water quantity and quality control strategies for managing stormwater as a result of future development. General SWM design goals and objectives include:

- Minimizing flooding and erosion hazards; and
- Maximizing water quality treatment and environmental benefits.

This watershed study adheres to the local and provincial design standards embodied in the HRM Stormwater Management Guidelines (Dillon Consulting, 2006) and HRM Municipal Design Guidelines (HRM, 2009).

1.2 Modeling Methodology

The U.S. Environmental Protection Agency's StormWater Management Model (SWMM) has been used throughout the world for over four decades and continues to be the standard in the planning, analysis, and design of stormwater management facilities.

In this study, the latest version of SWMM (Build 5.0.022, released April 2011) was used to simulate the stormwater runoff response under existing and proposed land use conditions. SWMM is public-domain software and available for download, along with detailed documentation, at http://www.epa.gov/nrmrl/ wswrd/wq/models/swmm/. Modeling capabilities of SWMM that are useful for this assessment include:

- Hydrology: The hydrologic module of SWMM is used to simulate the surface runoff and abstraction characteristics of land surfaces (i.e., evapotranspiration, infiltration, and surface storage) in response to meteorological inputs. It is a dynamic computer model that uses a non-linear reservoir approximation to represent overland flow. The hydrology module requires input data that describes the characteristics of local rainfall, overland flow, land use, and soil properties. Results include flow hydrographs for subcatchment areas that were used as input to the hydraulic routing module. Additional features include:

  - Time-varying rainfall and continuous simulation
  - Evaporation of standing surface water
  - Snow accumulation and melting
  - Rainfall interception from depression storage
  - Infiltration of rainfall into unsaturated soil layers
  - Percolation of infiltrated water into groundwater layers
  - Interflow between groundwater and the drainage system

- Hydraulics: The hydraulic module of SWMM is used to simulate the conveyance, attenuation, and routing of stormwater and wastewater through the collection system and storage/treatment facilities. It is capable of representing the complex hydraulics of open channel watercourses, piped collection systems, surface storage, overland flow routes, swales, detention/retention ponds, and control structures such as pumps, forcemains, gates, orifices, and weirs. It is a dynamic computer model that accounts for the conservation of mass and momentum using the Saint-Venant equations for gradually varied unsteady flow. Additional features include:

- Can simulate networks of unlimited size;
- Wide variety of standard closed and open conduit shapes including natural (irregular-shaped) channels;
- External flows and water quality inputs: surface runoff, groundwater interflow, RDII, DWF, and user-defined inflows;
- Variety of flow regimes including backwater, surcharging, reverse flow, and ponding; and
- User-defined dynamic control rules for pumps, orifice openings and weir crest levels.

- Water Quality: The quality module of SWMM is used to simulate the generation of pollutants from the various catchment surfaces and subsequent routing/deposition within the collection system and storage/treatment facilities. Features include:

  - Dry-weather pollutant buildup over different land uses;
  - Pollutant washoff from specific land uses during rain;
  - Direct contribution from rainfall deposition;
  - Reduction in dry-weather buildup due to street sweeping;
  - Estimation of dry-weather sanitary flows and user-specified external inflows;
  - Routing of water quality constituents through the drainage system; and
  - Reduction in constituent concentration through treatment in storage units or natural processes in pipes/channels.

2. Model Setup

The SL subwatershed was delineated in 68 subcatchments or “hydrologic units”, the boundaries of which are shown on Figure 2-1 below. Discharge is conveyed to the north through a network of watercourses and lakes that collect runoff from these subcatchments, ultimately discharging to Bay of Fundy. For the purposes of this report the model stops at outlet of Shubenacadie Grand Lake. Historically, the watershed has been altered through the construction of the Shubenacadie Canal System. The Shubenacadie Canal was intended to connect Halifax Harbour with the Bay of Fundy by way of the Shubenacadie River and Shubenacadie Grand Lake. Construction of the canal began in 1826, was completed in 1861 and was closed in 1871. Currently only the lock between Lake Micmac and Charles Lake is operational. The majority of the locks have bypass channels that divert the water around the canal system. Because of the construction of the canal, Charles Lake now discharges to both Lake William (flowing to Grand Lake/the Bay of Fundy) and Micmac Lake which flows to the Bedford Basin. Both of these outlets were represented in the model. Figure 2-1 shows a schematic of the existing conditions model used in this study. The orange circles on the Figure show the model nodes referred to in Table 2-12.

Figure 2-1: Model Schematic

2.1 Land Use

Three land use scenarios were modeled for this project:

- Modeling Scenario 1: Existing Conditions
- Modeling Scenario 2: HRM Authorized Subdivision Agreements
- Modeling Scenario 3: Scenario 2 + Port Wallis Lands

These three scenarios were applied to assess the impacts anticipated within the watershed as a result of the changes of land uses in the watershed. Using the model, SWM improvement alternatives were investigated to mitigate potential impacts. Maps illustrating the three development scenarios have been included in Section 3 of the main body of the Shubenacadie Lakes Subwatershed study.

The existing conditions land uses were interpreted using aerial photography and HRM-provided land use information. The areas were classified into general categorises and then further subdivided into the surface cover parameters described in Section 2.2.5. For example, the land use classifications for high, medium and low density residential were further broken down into surface cover percentages of grass, forest, roofs and pavement. These percentages were derived from an average of sample hydrologic parameters in the SL watershed. Table 2-1 summarizes the breakdown of each land use classification within the watershed that are common to each land use scenario. Table 2-2 summarizes the land use changes in the each subwatershed (i.e., areas tributary to the larger lakes), as characterized by the incremental change in surface cover distribution.

Table 2-1: Breakdown of General Land Uses to Surface Cover Parameters

	Modeled Land Surface Cover									
General Land use	**Forest**	**Grass**	**Meadow**	**Bare**	**Bedrock**	**RegRoof**	**ImpPave**	**Gravel**	**Wetland**	**Water**
Bedrock					100%					
Business Campus		10%				25%	65%			
Commercial		10%				25%	65%			
Commercial and Residential		25%				35%	40%			
Commercial District		10%				25%	65%			
Crown Land	100%									
Forest	100%									
Forest - Meadow	50%		50%							
Forest - Old Growth	100%									
Forest - Sensitive Habitat	100%									
High Density Residential	10%	35%				35%	20%			
Industrial		45%		15%		15%	25%			
Institutional		40%				30%	30%			
Lifestyle Community	10%	35%				35%	20%			
Low Density Residential	70%	20%				5%	5%			
Medium Density Residential	35%	35%				20%	10%			
Mixed Use	10%	35%				35%	20%			
Mixed Use Business Campus		10%				25%	65%			
Open Space	5%	87%					8%			
Park	5%	87%					8%			
Path	50%	25%					25%			
Quarry										
Residential	10%	35%				35%	20%			
Roadway		55%					40%	5%		
Utility	40%	50%								10%
Water										100%
Wetland									100%	

Table 2-2: Percent Changes in Land use

	Forest	Grass	Meadow	Bare	Bedrock	RegRoof	ImpPave	Gravel	Wetland	Water
	Change in Land use from Scenario 1 to Scenario 2									
Barrett Lake	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Beaverbank Lake	-0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bever Pond	-0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Charles Lake	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Cranberry Lake	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Duck Lake	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fenerty Lake	-1.5%	1.2%	-0.3%	0.0%	0.0%	0.3%	0.3%	0.0%	0.0%	0.0%
First Lake	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fish Lake	-0.1%	-0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Fletcher Lake	-4.3%	2.8%	0.0%	0.0%	0.0%	0.6%	0.6%	0.0%	0.3%	0.0%
Grand Lake	-0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Kinsac Lake	-6.6%	4.3%	0.1%	0.0%	0.0%	1.1%	1.1%	0.0%	0.0%	0.0%
Lake William	-0.4%	0.3%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%
Lewis Lake	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lisle Lake	-4.5%	3.0%	0.0%	0.0%	0.0%	0.7%	0.7%	0.0%	0.1%	0.0%
Loon Lake	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Miller Lake	-0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Powder Mill Lake	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rocky Lake	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Second Lake	-1.0%	0.6%	0.1%	0.0%	0.0%	0.2%	0.2%	0.0%	0.0%	0.0%
Springfield Lake	-0.7%	1.4%	-2.3%	0.0%	0.0%	0.8%	0.7%	0.0%	0.0%	0.0%
Third Lake	-1.4%	0.4%	0.5%	0.0%	0.0%	0.3%	0.2%	0.0%	0.0%	0.0%
Thomas Lake	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tucker Lake	-2.4%	1.7%	0.0%	0.0%	0.0%	0.4%	0.4%	0.0%	0.0%	0.0%
	Change in Land use from Scenario 2 to Scenario 3 (Only shown for the Port Wallis Lands)									
Charles Lake	-17.5%	6.8%	0.0%	0.0%	0.0%	6.8%	3.9%	0.0%	0.0%	0.0%

2.2 Hydrology

The hydrologic model was developed using lumped parameters in which average representative values were determined for each subcatchment in the study area. The calculation of area-weighted values is described in detail below for the various hydrologic parameters, which are grouped as follows:

- Overland flow parameters, which describe the slope and length characteristics of shallow surface runoff;
- Surface cover parameters, which describe the imperviousness, roughness and depression storage characteristics; and
- Soil parameters, which characterize the infiltration properties of the underlying surface soil layers.

2.2.1 Rainfall

Environment Canada's intensity duration frequency (IDF) curves for the Halifax Stanfield Int'l Airport (8202250) were applied to determine the design storms for the study. The Chicago type distribution was applied using a time interval of 10 minutes over a 24-hour period. The design storms include the following:

- 2-year return period/24-hour duration: 71.7 mm total depth of rain
- 5- year return period/24-hour duration: 106.9 mm
- 10- year return period/24-hour duration: 128.8 mm
- 25- year return period/24-hour duration: 156.1 mm
- 25- year return period/24-hour duration: 177.3 mm
- 100- year return period/24-hour duration: 197.0 mm

In addition to the design storm events listed above, rainfall records were applied to develop an "average year" continuous simulation. To do this, local archival tipping bucket gage data (with a 1-minute resolution) were compiled to achieve the average rainfall for each month as determined by the Environment Canada "climate normals" available for the Halifax Stanfield Int'l Airport (8202250) for the most recent meteorological record (1971-2000).

To be consistent with the water balance and phosphorus loading models developed as part of this study, the model was simulated for the entire calendar year, from January to December. Snowfall and snow melt however were not incorporated into the SWMM model. As illustrated in Table 2-3, only a small portion of the precipitation received during the winter months is snowfall and rainfall dominates throughout the year. As is characteristic of a maritime climate, the resulting snow pack and spring freshet will have minimal impact on the annual hydrology. As such snowfall observed during the winter months was represented as an equivalent rainfall amount.

Table 2-3: Environment Canada Climate Normals (1971-2000) for Halifax Stanfield Int'l Airport (8202250)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average Temperature (°C)	-6.0	-5.6	-1.4	4.0	9.8	15.0	18.6	18.4	14.1	8.3	3.1	-2.8	6.3
Rainfall (mm)	100.6	69.0	96.4	96.1	106.2	98.3	102.2	92.7	103.6	126.4	133.0	114.5	1238.9
Snowfall (cm)	54.6	50.1	41.1	20.9	3.3	0.0	0.0	0.0	0.0	2.3	14.4	43.9	230.5
Precipitation (mm)	149.2	114.4	134.5	118.3	109.7	98.3	102.2	92.7	103.6	128.7	146.0	154.8	1452.2
Snow Depth at Month-end (cm)	10	13	2	0	0	0	0	0	0	0	1	10	3

2.2.2 Evaporation

Evaporation during the intense, short duration design storm events is negligible and is typically ignored. For continuous simulation however, evaporation is a significant hydrologic variable and cannot be ignored. In this study, evaporation data were input into the hydrologic model as a daily abstraction rate for each calendar month in the continuous simulation runs, including the following values during the simulation period:

- May: 2.9 mm/day
- June: 3.4 mm/day
- July: 3.6 mm/day
- August: 3.2 mm/day
- September: 2.3 mm/day
- October: 1.3 mm/day

These values were collected from the Environment Canada station 8205990, located in Truro and represent a total potential evaporation of 512 mm over the year.

2.2.3 Catchment Delineation

Catchment delineation was completed using LiDAR data available for the watershed. This data was processed using GIS and explained in detail in Appendix F of the SL Watershed Study.

2.2.4 Overland Flow Path Parameters

Representative overland flow paths were identified for each hydrologic unit. The overland flow path length and slope parameters were determined, with the slope taken as the grade difference of the land surface along the overland flow path. Overland flow path lengths were divided into the subcatchment area to give a characteristic width of overland flow, which is a SWMM input parameter. The calculation of these area-weighted parameters was determined using automated processes in GIS by taking the average of the multiple flow path lengths as determined from the DEM.

A slope grid was also created for the watershed using the DEM derived from the LiDAR data. The average slope of each subcatchment was determined by removing the waterbodies (lakes) from the slope grid and calculating the average of the remaining cells.

The results of the analysis are summarized in Table 2-4.

Table 2-4: Overland Flow Path Parameters

Hydrologic Unit	Area (ha)	Area Water (ha)	Slope	Length (m)	Width (m)	Hydrologic Unit	Area (ha)	Area Water (ha)	Slope	Length (m)	Width (m)
A000	428.63	11.07	8.30%	1043	4,005	Grand160	475.34	0	6.80%	4464	1,065
Barrett000	87.45	9.38	6.80%	666	1,172	Grand170	189.1	0	2.80%	2207	857
Beaver000	1167.07	89.01	5.60%	2985	3,612	Grand180	177.84	0.63	5.00%	800	2,215
BeaverP000	496.41	15.44	7.10%	560	8,589	Hamilton000	2657.38	125.08	6.30%	2550	9,930
Bennery000	717.11	52.85	5.60%	1648	4,031	Juniper000	852.96	34.39	4.00%	1895	4,321
Charles000	191.73	0.08	8.60%	1500	1,278	Kelly000	540.03	10.7	7.10%	650	8,143
Charles010	109.4	0.71	9.80%	1800	604	KellyLong000	262.12	10.3	9.70%	500	5,037
Charles020	101.81	0.57	8.90%	1900	533	Kinsac000	1804.83	168.78	7.80%	1350	12,119
Charles030	445.56	135.05	8.50%	1030	3,015	Kinsac010	421.07	5.22	8.50%	1008	4,125
Charles040	111.46	5.67	7.50%	1200	882	Lewis000	408.55	76.47	6.10%	756	4,393
Charles050	54.93	1.11	8.30%	600	897	Lizard000	61.69	3.92	8.70%	668	865
Charles060	576.79	3.81	6.40%	1580	3,626	Loon000	277.82	76.57	5.40%	592	3,402
Cranberry000	2103.94	26.92	4.70%	7996	2,598	Miller000	597.62	129.41	7.20%	1020	4,590
CranSouth000	76.11	7.01	6.80%	379	1,823	Miller010	422.79	0	6.50%	1239	3,413
Duck000	78.94	9.01	3.70%	563	1,243	Rocky000	874.57	151.45	7.40%	1037	6,971
Fenerty000	1507.69	106.61	8.10%	4840	2,895	Second000	690.3	111.37	7.50%	1338	4,328
Fenerty010	15.32	4.51	5.60%	160	676	Soldier000	2504.01	271.8	7.50%	3030	7,367
Ferry000	202.78	10.91	9.30%	815	2,353	Springfield000	715.25	81.99	7.20%	1340	4,726
First000	363.4	82.82	6.20%	831	3,377	Third000	328.16	86.55	6.10%	780	3,098
Fish000	563.58	56.72	8.20%	850	5,963	Thomas000	301.11	46.58	8.90%	742	3,430
Fletchers000	1180.09	107.46	9.90%	1920	5,587	Thomas010	283.17	69.51	11.40%	789	2,707
Grand000	1188.5	2.28	3.30%	3559	3,333	Tucker000	680.71	21.79	8.30%	2222	2,965
Grand010	270.42	0.86	9.20%	1900	1,419	Tucker010	186.34	32.91	10.80%	890	1,724
Grand020	129.03	0.51	8.20%	1723	746	William000	102.12	1.85	8.50%	886	1,132
Grand030	133.11	0.4	6.80%	1000	1,327	William010	686.05	11.98	7.80%	2360	2,856
Grand040	671.34	5.78	5.30%	4800	1,386	William020	60.57	0.26	12.80%	700	862
Grand050	1249.18	9.52	5.30%	6585	1,883	William030	189.67	0.24	11.40%	1435	1,320
Grand060	613.83	3.34	6.50%	2550	2,394	William040	57.99	2.33	11.80%	1124	495
Grand070	292.72	7.98	6.40%	1385	2,056	William050	807.8	2.63	9.20%	2924	2,754
Grand080	135.98	0.69	10.00%	720	1,879	William060	177.02	0.09	14.40%	667	2,653
Grand100	303.03	1.44	5.40%	1148	2,628	William070	108.32	0.78	13.10%	600	1,792
Grand120	82.69	0.71	5.70%	550	1,490	William080	512.5	76.75	8.50%	920	4,736
Grand140	1884.65	1871.77	0.50%	1	1	William090	305.31	300.38	0.10%	1	1
Grand150	1012.8	9.88	6.90%	3980	2,520	Willis000	126.98	0.09	9.10%	1500	846

2.2.5 Surface Cover

In order to reflect the unique hydrologic properties of each subcatchment across the various land use scenarios, a variety of surface cover types were defined. The surface cover types used in this study are described as follows:

- Forest: Forest/meadow, heavy vegetation with high transpiration rates and a deep root zone.
- Grass: Grass/turf, light vegetation, cultivated or landscaped areas with a shallow root zone.
- Meadow: Low lying shrubs and medium vegetation.
- Bare: Un-vegetated soil, loose granular materials, or legacy compacted fill.
- Bedrock: Exposed bedrock out crops.
- RegRoof: Building structures with regular rooftop construction and materials.
- ImpPave: Regular impermeable paved surfaces (i.e., roadways, parking, driveways).
- Gravel: Gravel and compacted granular in traffic areas.
- Wetland: Hydrologic parameters reflect an area that is roughly half open water and half heavily vegetated.
- Water: Open water surface, including SWM detention facilities.

Characteristic hydrologic properties were assigned to each surface cover type as shown in Table 2-5, based on literature values and similar studies throughout North America.

For each surface cover type, the following hydrologic parameters are given:

- Overland flow roughness factors, expressed as Manning's "n" value for both impervious and pervious fractions;
- Initial abstractions (i.e., depression storage losses) for both impervious and pervious fractions;
- Percentage of impervious cover, including any land surface that has been compacted or is covered with a layer of material such that it substantially reduces or prevents the infiltration of stormwater runoff into the ground;
- Subarea routing is a SWMM simulation parameter that designates the internal routing of runoff between pervious and impervious areas (in this case, "Pervious" was selected to indicate a portion of runoff from impervious areas can be discharged onto pervious areas);
- Percent routed indicates the portion of runoff that is routed between subareas (e.g., 100% indicates that all of the impervious area in the subcatchment is routed onto pervious surfaces); and
- The final column indicates the fraction of impervious area that has no depression storage.

Table 2-5: Summary of Hydrologic Properties (by Surface Cover Type)

Surface Cover Type	Manning's "n"		Dep. Storage (mm)		Percent Impervious	Subarea Routing	Percent Routed	Percent Imperv. Without Storage
	Impervious	Pervious	Impervious	Pervious				
Forest	0.030	0.400	10.0	15.0	1	Pervious	100	10
Grass	0.025	0.250	5.0	10.0	2.5	Pervious	75	10
Meadow	0.025	0.350	7.5	17.5	2.5	Pervious	20	5
Bare	0.020	0.150	5.0	7.5	5	Pervious	50	10
Bedrock	0.020	0.150	5.0	7.5	90	Pervious	25	20
RegRoof	0.015	0.150	2.5	5.0	95	Pervious	10	25
ImpPave	0.015	0.150	2.5	5.0	95	Pervious	10	20
Gravel	0.025	0.200	5.0	7.5	90	Pervious	25	20
Wetland	0.015	0.350	0.0	15.0	50	Pervious	50	10
Water	0.015	0.015	0.0	0.0	100	Pervious	0	0

Table 2-6 to Table 2-8 shows the calculation of the surface cover parameters. The top part of the table lists the various surface cover types and the global hydrology parameters shown in Table 2-5. Table 2-6 to Table 2-8 shows the percent of surface cover type for each hydrologic unit on the left. When these proportions are cross-multiplied by the global parameters at the top, the resulting area-weighted surface cover parameters are calculated and shown on the right part of the table.

Table 2-6: Surface cover percentages and parameters for Scenario 1:Existing Conditions Land use

	Percent By Surface Cover Type														Manning's "n"		Dep. Storage (mm)	
Hydrologic Unit Name	Forest	Grass	Meadow	Bare	Bedrock	RegRoof	ImpPave	Gravel	Wetland	Water	Total	% Impervious	% Routed	% Impervious Without Storage	Impervious	Pervious	Impervious	Pervious
A000	44.9%	24.9%	0.0%	0.0%	0.0%	14.5%	11.5%	0.4%	1.2%	2.6%	100.0%	29.3	66.9	13.1	0.024	0.286	6.4	10.7
Beaver000	73.3%	5.0%	3.9%	0.0%	0.0%	2.8%	2.5%	0.1%	4.7%	7.6%	100.0%	16.0	80.8	9.7	0.027	0.345	8.0	13.2
Bennery000	83.0%	2.6%	0.0%	0.1%	0.0%	0.9%	1.4%	0.1%	4.6%	7.4%	100.0%	12.8	87.5	9.5	0.028	0.359	8.5	13.5
Charles000	55.6%	19.5%	0.0%	2.6%	0.0%	9.8%	11.7%	0.4%	0.4%	0.0%	100.0%	22.2	73.9	12.7	0.025	0.309	7.2	11.6
Charles010	64.6%	17.7%	0.0%	0.0%	0.0%	0.0%	12.9%	1.6%	2.5%	0.6%	100.0%	16.7	80.8	11.4	0.027	0.334	7.7	12.6
Charles020	83.9%	7.7%	0.0%	0.0%	0.0%	1.1%	5.4%	0.6%	0.7%	0.6%	100.0%	8.7	90.9	10.7	0.028	0.369	9.0	13.8
Charles030	25.0%	19.9%	0.0%	3.6%	0.0%	7.9%	11.8%	0.4%	1.1%	30.3%	100.0%	50.9	44.4	9.4	0.021	0.194	4.2	7.2
Charles040	20.7%	32.6%	0.0%	0.0%	0.0%	20.6%	19.9%	1.0%	0.0%	5.1%	100.0%	45.5	49.5	14.7	0.021	0.228	4.8	8.5
Charles050	50.9%	22.8%	0.0%	0.0%	0.0%	0.0%	16.6%	2.1%	5.6%	2.0%	100.0%	23.5	73.0	11.7	0.025	0.310	6.7	11.7
Charles060	76.0%	7.6%	0.0%	0.0%	0.0%	3.6%	4.7%	0.3%	7.2%	0.7%	100.0%	13.3	86.2	11.0	0.027	0.361	8.2	13.7
Cranberry000	83.0%	2.8%	2.3%	0.0%	0.0%	1.2%	1.3%	0.1%	8.0%	1.3%	100.0%	8.7	89.8	10.1	0.028	0.379	8.7	14.5
CranSouth000	20.4%	27.2%	0.0%	0.0%	0.0%	18.9%	18.0%	0.8%	5.5%	9.2%	100.0%	48.6	47.5	13.8	0.021	0.227	4.4	8.5
Fenerty000	73.0%	4.9%	4.5%	0.0%	0.0%	2.0%	2.1%	0.1%	6.3%	7.1%	100.0%	15.1	81.2	9.6	0.027	0.350	8.0	13.4
Ferry000	36.2%	24.8%	0.0%	0.0%	0.0%	12.6%	12.8%	0.7%	7.5%	5.4%	100.0%	34.8	61.3	12.7	0.023	0.273	5.5	10.4
First000	16.6%	25.0%	0.0%	0.1%	0.0%	16.4%	18.5%	0.7%	0.0%	22.8%	100.0%	57.3	39.0	12.1	0.020	0.186	3.8	6.8
Fish000	47.7%	27.5%	0.0%	0.0%	0.0%	6.2%	6.6%	0.2%	1.7%	10.1%	100.0%	24.5	70.5	10.6	0.025	0.287	6.5	10.8
Fletchers000	60.0%	15.2%	0.0%	0.0%	0.0%	7.8%	6.2%	0.3%	1.6%	9.1%	100.0%	24.3	73.6	10.9	0.026	0.306	7.1	11.5
Grand000	95.9%	0.0%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	0.2%	100.0%	2.2	97.3	9.9	0.030	0.397	9.7	15.0
Grand010	98.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.3%	100.0%	2.2	98.8	10.0	0.030	0.398	9.8	15.0
Grand020	92.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.9%	0.4%	100.0%	4.8	96.2	10.0	0.029	0.395	9.3	14.9
Grand030	98.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.3%	100.0%	1.9	99.0	10.0	0.030	0.398	9.8	15.0
Grand040	87.5%	0.0%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	0.9%	100.0%	4.6	91.4	9.6	0.029	0.391	9.2	15.0
Grand050	90.4%	0.1%	2.3%	0.0%	0.0%	0.1%	0.0%	0.0%	6.4%	0.8%	100.0%	5.0	94.1	9.8	0.029	0.392	9.2	14.9
Grand060	89.3%	0.2%	1.3%	0.0%	0.0%	0.1%	0.1%	0.0%	8.6%	0.5%	100.0%	5.9	94.0	9.9	0.029	0.392	9.0	14.9
Grand070	91.7%	0.5%	0.0%	0.0%	0.0%	0.3%	0.1%	0.0%	4.7%	2.7%	100.0%	6.4	94.4	9.8	0.029	0.385	9.2	14.5
Grand080	87.0%	6.7%	0.0%	0.0%	0.0%	3.7%	2.0%	0.0%	0.0%	0.5%	100.0%	7.0	92.6	10.7	0.029	0.374	9.2	14.0
Grand100	66.3%	16.8%	0.0%	0.0%	0.0%	8.4%	7.7%	0.3%	0.0%	0.5%	100.0%	17.2	80.6	12.0	0.027	0.332	7.9	12.5
Grand120	81.6%	12.1%	0.0%	0.0%	0.0%	0.0%	2.1%	0.1%	3.3%	0.9%	100.0%	5.7	92.5	10.1	0.028	0.371	8.8	14.0
Grand140	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.3%	100.0%	99.4	0.6	0.1	0.015	0.018	0.1	0.1
Grand150	94.7%	0.6%	3.0%	0.0%	0.0%	0.2%	0.2%	0.0%	0.4%	1.0%	100.0%	2.5	96.0	9.8	0.030	0.393	9.7	14.9
Grand160	99.1%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	100.0%	1.1	99.4	10.0	0.030	0.400	10.0	15.0
Grand170	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	1.0	100.0	10.0	0.030	0.400	10.0	15.0
Grand180	83.0%	9.7%	0.0%	0.0%	0.0%	3.5%	3.3%	0.1%	0.0%	0.4%	100.0%	8.0	91.0	10.8	0.028	0.367	9.0	13.8
Hamilton000	81.1%	0.5%	5.3%	0.0%	0.0%	0.3%	0.3%	0.0%	7.9%	4.7%	100.0%	10.1	86.5	9.3	0.028	0.373	8.5	14.3
Juniper000	65.4%	3.8%	0.0%	0.5%	0.0%	4.1%	10.8%	0.1%	11.4%	4.0%	100.0%	24.7	75.6	11.3	0.025	0.335	7.1	12.7
Kelly000	73.4%	10.6%	0.0%	0.1%	0.0%	4.6%	4.8%	0.3%	4.4%	2.0%	100.0%	14.3	84.5	11.0	0.027	0.350	8.1	13.2
KellyLong000	92.9%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.1%	3.9%	100.0%	6.4	94.5	9.6	0.029	0.383	9.3	14.4
Kinsac000	66.9%	8.4%	0.0%	0.0%	0.0%	5.1%	6.0%	0.1%	4.0%	9.4%	100.0%	22.9	76.4	10.4	0.026	0.321	7.4	12.1
Kinsac010	56.8%	13.3%	0.0%	0.0%	0.0%	10.4%	13.4%	0.2%	4.7%	1.2%	100.0%	27.2	71.6	12.8	0.025	0.313	7.0	11.8
Lewis000	72.8%	4.2%	0.0%	0.0%	0.0%	0.7%	1.3%	0.1%	2.2%	18.7%	100.0%	22.6	77.3	8.4	0.026	0.315	7.5	11.8
Lizard000	23.9%	34.6%	0.0%	0.0%	0.0%	19.2%	15.3%	0.6%	0.0%	6.3%	100.0%	40.8	53.4	13.8	0.022	0.236	5.0	8.8
Loon000	30.1%	24.4%	0.0%	0.0%	0.0%	6.5%	10.3%	0.5%	0.7%	27.6%	100.0%	45.2	50.5	9.3	0.022	0.214	4.7	7.9
Miller000	45.7%	14.3%	0.0%	0.0%	0.0%	5.7%	9.7%	0.5%	2.4%	21.7%	100.0%	38.8	59.3	9.7	0.023	0.254	5.7	9.5

	Percent By Surface Cover Type														Manning's "n"		Dep. Storage (mm)	
Hydrologic Unit Name	Forest	Grass	Meadow	Bare	Bedrock	RegRoof	ImpPave	Gravel	Wetland	Water	Total	% Impervious	% Routed	% Impervious Without Storage	Impervious	Pervious	Impervious	Pervious
Rocky000	30.6%	21.2%	0.0%	4.3%	0.0%	8.3%	13.3%	0.3%	4.8%	17.3%	100.0%	41.5	53.2	10.9	0.022	0.234	4.9	8.8
Second000	59.9%	10.0%	0.0%	0.0%	0.0%	4.7%	6.3%	0.3%	2.7%	16.1%	100.0%	29.1	69.9	9.8	0.025	0.293	6.8	11.0
Soldier000	77.0%	2.1%	0.0%	0.0%	0.0%	0.5%	1.9%	0.1%	7.4%	10.9%	100.0%	17.8	82.6	9.2	0.027	0.345	7.9	13.0
Springfield000	40.6%	21.1%	4.5%	0.0%	0.0%	11.1%	9.1%	0.3%	1.7%	11.4%	100.0%	32.9	60.4	11.3	0.024	0.270	6.0	10.3
Third000	37.0%	19.5%	0.0%	0.0%	0.0%	8.5%	8.2%	0.4%	0.0%	26.4%	100.0%	43.4	53.5	9.5	0.023	0.227	5.1	8.4
Thomas000	28.1%	22.7%	0.0%	0.0%	0.0%	15.8%	17.4%	0.6%	0.0%	15.5%	100.0%	48.4	48.5	12.6	0.022	0.222	4.8	8.2
Thomas010	51.4%	11.3%	0.0%	0.0%	0.0%	4.6%	7.5%	0.6%	0.1%	24.5%	100.0%	37.4	61.2	9.0	0.024	0.257	6.0	9.5
Tucker000	69.5%	8.8%	0.0%	0.0%	0.0%	6.3%	8.4%	0.1%	3.6%	3.2%	100.0%	20.0	79.5	11.5	0.026	0.336	7.8	12.6
William000	39.2%	17.3%	0.0%	0.0%	0.0%	12.2%	14.7%	0.6%	14.1%	1.8%	100.0%	35.8	62.2	13.2	0.023	0.292	5.5	11.1
William010	76.7%	7.3%	0.0%	0.0%	0.0%	2.3%	4.4%	0.4%	7.2%	1.7%	100.0%	13.0	86.5	10.7	0.027	0.361	8.2	13.7
William020	90.6%	4.9%	0.0%	0.0%	0.0%	0.0%	3.6%	0.4%	0.0%	0.4%	100.0%	5.3	94.8	10.4	0.029	0.381	9.4	14.3
William030	96.3%	0.8%	0.0%	0.1%	0.0%	0.1%	0.5%	0.0%	2.0%	0.1%	100.0%	2.8	98.0	10.1	0.030	0.395	9.7	14.9
William040	92.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.9%	0.1%	1.7%	4.0%	100.0%	6.8	93.9	9.7	0.029	0.379	9.3	14.2
William050	90.2%	1.6%	0.0%	0.2%	0.0%	0.2%	1.1%	0.1%	6.3%	0.3%	100.0%	5.7	94.8	10.1	0.029	0.389	9.1	14.7
William060	48.5%	22.9%	0.0%	0.0%	0.0%	15.2%	12.5%	0.5%	0.5%	0.0%	100.0%	28.0	68.8	13.6	0.025	0.295	6.7	11.0
William070	68.9%	12.4%	0.0%	0.0%	0.0%	5.3%	9.1%	0.7%	2.9%	0.7%	100.0%	17.5	81.3	11.7	0.027	0.340	7.9	12.8
William080	52.1%	12.8%	0.0%	0.0%	0.0%	7.2%	9.5%	0.4%	2.9%	15.0%	100.0%	33.5	65.0	10.6	0.024	0.279	6.3	10.4
William090	1.4%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	98.4%	100.0%	98.5	1.5	0.2	0.015	0.021	0.1	0.2
Willis000	72.9%	3.7%	0.0%	0.0%	0.0%	0.7%	2.6%	0.3%	19.7%	0.1%	100.0%	14.2	85.9	10.4	0.026	0.375	7.6	14.4
Barrett000	45.4%	19.9%	0.0%	0.0%	0.0%	12.1%	11.4%	0.5%	0.0%	10.7%	100.0%	34.4	62.8	11.9	0.024	0.269	6.1	10.0
BeaverP000	48.5%	22.1%	0.0%	0.0%	0.0%	12.1%	12.6%	0.4%	1.2%	3.1%	100.0%	28.5	68.3	12.8	0.025	0.292	6.6	10.9
Duck000	46.6%	17.2%	0.0%	0.0%	0.0%	11.0%	8.3%	0.3%	5.3%	11.4%	100.0%	33.5	64.1	11.4	0.024	0.279	6.0	10.5
Fenerty010	33.4%	15.2%	0.0%	0.0%	0.0%	8.3%	4.7%	0.1%	8.8%	29.4%	100.0%	47.0	50.6	8.8	0.022	0.227	4.4	8.5
Miller010	85.9%	4.3%	0.0%	0.0%	0.0%	0.4%	2.8%	0.3%	6.2%	0.0%	100.0%	7.4	92.7	10.4	0.028	0.382	8.9	14.4
Tucker010	22.4%	22.9%	0.0%	0.0%	0.0%	15.8%	12.5%	0.5%	8.2%	17.7%	100.0%	49.9	46.7	11.9	0.021	0.222	4.1	8.3
Area Weighted Average	**68.1%**	**7.6%**	**1.2%**	**0.2%**	**0.0%**	**3.6%**	**4.4%**	**0.2%**	**4.3%**	**12.0%**	**100.0%**	**22.5**	**75.9**	**9.7**	**0.026**	**0.320**	**7.4**	**12.1**

Table 2-7: Surface cover percentages and parameters for Scenario 2:HRM Authorized Subdivisions

	Percent By Surface Cover Type														Manning's "n"		Dep. Storage (mm)	
Hydrologic Unit Name	Forest	Grass	Meadow	Bare	Bedrock	RegRoof	ImpPave	Gravel	Wetland	Water	Total	% Impervious	% Routed	% Impervious Without Storage	Impervious	Pervious	Impervious	Pervious
A000	39.7%	27.9%	0.0%	0.0%	0.0%	15.1%	12.1%	0.4%	2.2%	2.6%	100.0%	30.9	64.6	13.2	0.024	0.278	6.1	10.5
Beaver000	73.3%	5.0%	4.0%	0.0%	0.0%	2.8%	2.5%	0.1%	4.7%	7.6%	100.0%	16.1	80.7	9.7	0.027	0.345	8.0	13.2
Bennery000	82.8%	2.4%	0.3%	0.1%	0.0%	1.0%	1.5%	0.1%	4.6%	7.4%	100.0%	12.9	87.2	9.5	0.028	0.359	8.5	13.5
Charles000	55.6%	19.5%	0.0%	2.6%	0.0%	9.8%	11.7%	0.4%	0.4%	0.0%	100.0%	22.2	73.9	12.7	0.025	0.309	7.2	11.6
Charles010	64.6%	17.7%	0.0%	0.0%	0.0%	0.0%	12.9%	1.6%	2.5%	0.6%	100.0%	16.7	80.8	11.4	0.027	0.334	7.7	12.6
Charles020	83.9%	7.7%	0.0%	0.0%	0.0%	1.1%	5.4%	0.6%	0.7%	0.6%	100.0%	8.7	90.9	10.7	0.028	0.369	9.0	13.8
Charles030	25.0%	19.9%	0.0%	3.6%	0.0%	7.9%	11.8%	0.4%	1.1%	30.3%	100.0%	50.9	44.4	9.4	0.021	0.194	4.2	7.2
Charles040	20.7%	32.6%	0.0%	0.0%	0.0%	20.6%	19.9%	1.0%	0.0%	5.1%	100.0%	45.5	49.5	14.7	0.021	0.228	4.8	8.5
Charles050	50.9%	22.8%	0.0%	0.0%	0.0%	0.0%	16.6%	2.1%	5.6%	2.0%	100.0%	23.5	73.0	11.7	0.025	0.310	6.7	11.7
Charles060	76.0%	7.6%	0.0%	0.0%	0.0%	3.6%	4.7%	0.3%	7.2%	0.7%	100.0%	13.3	86.2	11.0	0.027	0.361	8.2	13.7
Cranberry000	82.6%	3.0%	2.3%	0.0%	0.0%	1.3%	1.3%	0.1%	8.0%	1.3%	100.0%	8.8	89.7	10.1	0.028	0.379	8.7	14.4
CranSouth000	20.4%	27.2%	0.0%	0.0%	0.0%	18.9%	18.0%	0.8%	5.5%	9.2%	100.0%	48.6	47.5	13.8	0.021	0.227	4.4	8.5
Fenerty000	71.6%	6.1%	4.2%	0.0%	0.0%	2.3%	2.3%	0.1%	6.3%	7.1%	100.0%	15.7	80.6	9.7	0.027	0.347	7.9	13.3
Ferry000	36.2%	24.8%	0.0%	0.0%	0.0%	12.6%	12.8%	0.7%	7.5%	5.4%	100.0%	34.8	61.3	12.7	0.023	0.273	5.5	10.4
First000	16.6%	25.0%	0.0%	0.1%	0.0%	16.4%	18.5%	0.7%	0.0%	22.8%	100.0%	57.3	39.0	12.1	0.020	0.186	3.8	6.8
Fish000	47.7%	27.5%	0.0%	0.0%	0.0%	6.2%	6.6%	0.2%	1.7%	10.1%	100.0%	24.5	70.5	10.6	0.025	0.287	6.5	10.8
Fletchers000	55.8%	18.0%	0.0%	0.0%	0.0%	8.5%	6.9%	0.3%	1.6%	9.1%	100.0%	25.7	71.6	11.1	0.025	0.298	6.9	11.2
Grand000	95.9%	0.0%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	0.2%	100.0%	2.2	97.3	9.9	0.030	0.397	9.7	15.0
Grand010	98.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.3%	100.0%	2.2	98.8	10.0	0.030	0.398	9.8	15.0
Grand020	92.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.9%	0.4%	100.0%	4.8	96.2	10.0	0.029	0.395	9.3	14.9
Grand030	98.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.3%	100.0%	1.9	99.0	10.0	0.030	0.398	9.8	15.0
Grand040	87.5%	0.0%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	0.9%	100.0%	4.6	91.4	9.6	0.029	0.391	9.2	15.0
Grand050	90.4%	0.1%	2.3%	0.0%	0.0%	0.1%	0.0%	0.0%	6.4%	0.8%	100.0%	5.0	94.1	9.8	0.029	0.392	9.2	14.9
Grand060	89.3%	0.2%	1.3%	0.0%	0.0%	0.1%	0.1%	0.0%	8.6%	0.5%	100.0%	5.9	94.0	9.9	0.029	0.392	9.0	14.9
Grand070	91.7%	0.5%	0.0%	0.0%	0.0%	0.3%	0.1%	0.0%	4.7%	2.7%	100.0%	6.4	94.4	9.8	0.029	0.385	9.2	14.5
Grand080	87.0%	6.7%	0.0%	0.0%	0.0%	3.7%	2.0%	0.0%	0.0%	0.5%	100.0%	7.0	92.6	10.7	0.029	0.374	9.2	14.0
Grand100	62.0%	19.7%	0.0%	0.0%	0.0%	9.1%	8.4%	0.3%	0.0%	0.5%	100.0%	18.6	78.5	12.2	0.026	0.324	7.6	12.2
Grand120	81.6%	12.1%	0.0%	0.0%	0.0%	0.0%	2.1%	0.1%	3.3%	0.9%	100.0%	5.7	92.5	10.1	0.028	0.371	8.8	14.0
Grand140	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.3%	100.0%	99.4	0.6	0.1	0.015	0.018	0.1	0.1
Grand150	94.7%	0.6%	3.0%	0.0%	0.0%	0.2%	0.2%	0.0%	0.4%	1.0%	100.0%	2.5	96.0	9.8	0.030	0.393	9.7	14.9
Grand160	99.1%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	100.0%	1.1	99.4	10.0	0.030	0.400	10.0	15.0
Grand170	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	1.0	100.0	10.0	0.030	0.400	10.0	15.0
Grand180	83.0%	9.7%	0.0%	0.0%	0.0%	3.5%	3.3%	0.1%	0.0%	0.4%	100.0%	8.0	91.0	10.8	0.028	0.367	9.0	13.8
Hamilton000	81.1%	0.5%	5.3%	0.0%	0.0%	0.3%	0.3%	0.0%	7.9%	4.7%	100.0%	10.1	86.5	9.3	0.028	0.373	8.5	14.3
Juniper000	65.4%	3.8%	0.0%	0.5%	0.0%	4.1%	10.8%	0.1%	11.4%	4.0%	100.0%	24.7	75.6	11.3	0.025	0.335	7.1	12.7
Kelly000	72.8%	10.9%	0.0%	0.1%	0.0%	4.7%	4.9%	0.3%	4.4%	2.0%	100.0%	14.5	84.2	11.0	0.027	0.349	8.1	13.2
KellyLong000	92.9%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.1%	3.9%	100.0%	6.4	94.5	9.6	0.029	0.383	9.3	14.4
Kinsac000	59.8%	13.1%	0.1%	0.0%	0.0%	6.3%	7.2%	0.1%	4.0%	9.4%	100.0%	25.2	73.0	10.7	0.025	0.308	7.0	11.6
Kinsac010	52.6%	16.3%	0.0%	0.0%	0.0%	11.0%	14.1%	0.2%	4.5%	1.2%	100.0%	28.5	69.6	13.0	0.025	0.305	6.7	11.5
Lewis000	72.8%	4.2%	0.0%	0.0%	0.0%	0.7%	1.3%	0.1%	2.2%	18.7%	100.0%	22.6	77.3	8.4	0.026	0.315	7.5	11.8
Lizard000	23.9%	34.6%	0.0%	0.0%	0.0%	19.2%	15.3%	0.6%	0.0%	6.3%	100.0%	40.8	53.4	13.8	0.022	0.236	5.0	8.8
Loon000	30.1%	24.4%	0.0%	0.0%	0.0%	6.5%	10.3%	0.5%	0.7%	27.6%	100.0%	45.2	50.5	9.3	0.022	0.214	4.7	7.9

	Percent By Surface Cover Type														Manning's "n"		Dep. Storage (mm)	
Hydrologic Unit Name	Forest	Grass	Meadow	Bare	Bedrock	RegRoof	ImpPave	Gravel	Wetland	Water	Total	% Impervious	% Routed	% Impervious Without Storage	Impervious	Pervious	Impervious	Pervious
Rocky000	30.6%	21.2%	0.0%	4.3%	0.0%	8.3%	13.3%	0.3%	4.8%	17.3%	100.0%	41.5	53.2	10.9	0.022	0.234	4.9	8.8
Second000	58.9%	10.6%	0.1%	0.0%	0.0%	4.9%	6.5%	0.3%	2.7%	16.1%	100.0%	29.4	69.4	9.8	0.025	0.292	6.7	10.9
Soldier000	77.0%	2.1%	0.0%	0.0%	0.0%	0.5%	1.9%	0.1%	7.4%	10.9%	100.0%	17.8	82.6	9.2	0.027	0.345	7.9	13.0
Springfield000	40.0%	22.5%	2.2%	0.0%	0.0%	12.0%	9.8%	0.4%	1.7%	11.5%	100.0%	34.3	60.4	11.6	0.024	0.265	5.8	10.0
Third000	35.6%	19.9%	0.5%	0.0%	0.0%	8.8%	8.4%	0.4%	0.0%	26.4%	100.0%	43.9	52.5	9.5	0.022	0.225	5.0	8.3
Thomas000	28.1%	22.7%	0.0%	0.0%	0.0%	15.8%	17.4%	0.6%	0.0%	15.5%	100.0%	48.4	48.5	12.6	0.022	0.222	4.8	8.2
Thomas010	51.4%	11.3%	0.0%	0.0%	0.0%	4.6%	7.5%	0.6%	0.1%	24.5%	100.0%	37.4	61.2	9.0	0.024	0.257	6.0	9.5
Tucker000	69.9%	8.3%	0.3%	0.0%	0.0%	6.4%	8.3%	0.1%	3.5%	3.2%	100.0%	19.9	79.4	11.5	0.026	0.336	7.8	12.6
William000	39.2%	17.3%	0.0%	0.0%	0.0%	12.2%	14.7%	0.6%	14.1%	1.8%	100.0%	35.8	62.2	13.2	0.023	0.292	5.5	11.1
William010	74.8%	8.5%	0.0%	0.0%	0.0%	2.7%	4.7%	0.4%	7.2%	1.7%	100.0%	13.6	85.6	10.7	0.027	0.358	8.1	13.6
William020	90.6%	4.9%	0.0%	0.0%	0.0%	0.0%	3.6%	0.4%	0.0%	0.4%	100.0%	5.3	94.8	10.4	0.029	0.381	9.4	14.3
William030	96.3%	0.8%	0.0%	0.1%	0.0%	0.1%	0.5%	0.0%	2.0%	0.1%	100.0%	2.8	98.0	10.1	0.030	0.395	9.7	14.9
William040	92.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.9%	0.1%	1.7%	4.0%	100.0%	6.8	93.9	9.7	0.029	0.379	9.3	14.2
William050	90.2%	1.6%	0.0%	0.2%	0.0%	0.2%	1.1%	0.1%	6.3%	0.3%	100.0%	5.7	94.8	10.1	0.029	0.389	9.1	14.7
William060	48.5%	22.9%	0.0%	0.0%	0.0%	15.2%	12.5%	0.5%	0.5%	0.0%	100.0%	28.0	68.8	13.6	0.025	0.295	6.7	11.0
William070	68.9%	12.4%	0.0%	0.0%	0.0%	5.3%	9.1%	0.7%	2.9%	0.7%	100.0%	17.5	81.3	11.7	0.027	0.340	7.9	12.8
William080	52.1%	12.8%	0.0%	0.0%	0.0%	7.2%	9.5%	0.4%	2.9%	15.0%	100.0%	33.5	65.0	10.6	0.024	0.279	6.3	10.4
William090	1.4%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	98.4%	100.0%	98.5	1.5	0.2	0.015	0.021	0.1	0.2
Willis000	72.9%	3.7%	0.0%	0.0%	0.0%	0.7%	2.6%	0.3%	19.7%	0.1%	100.0%	14.2	85.9	10.4	0.026	0.375	7.6	14.4
Barrett000	45.4%	19.9%	0.0%	0.0%	0.0%	12.1%	11.4%	0.5%	0.0%	10.7%	100.0%	34.4	62.8	11.9	0.024	0.269	6.1	10.0
BeaverP000	48.4%	22.1%	0.0%	0.0%	0.0%	12.1%	12.6%	0.4%	1.2%	3.1%	100.0%	28.6	68.2	12.8	0.025	0.292	6.6	10.9
Duck000	46.6%	17.2%	0.0%	0.0%	0.0%	11.0%	8.3%	0.3%	5.3%	11.4%	100.0%	33.5	64.1	11.4	0.024	0.279	6.0	10.5
Fenerty010	28.9%	18.2%	0.0%	0.0%	0.0%	9.0%	5.4%	0.1%	8.9%	29.4%	100.0%	48.4	48.5	9.0	0.021	0.219	4.2	8.2
Area Weighted Average	**67.1%**	**7.9%**	**1.5%**	**0.2%**	**0.0%**	**3.8%**	**4.5%**	**0.2%**	**4.4%**	**12.1%**	**100.0%**	**23.3**	**76.4**	**9.9**	**0.026**	**0.323**	**7.4**	**12.2**

Table 2-8: Surface cover percentages and parameters for Scenario 3:Authorized Subdivisions and Development of the Port Wallis Lands

	Percent By Surface Cover Type														Manning's "n"		Dep. Storage (mm)	
Hydrologic Unit Name	Forest	Grass	Meadow	Bare	Bedrock	RegRoof	ImpPave	Gravel	Wetland	Water	Total	% Impervious	% Routed	% Impervious Without Storage	Impervious	Pervious	Impervious	Pervious
A000	39.7%	27.9%	0.0%	0.0%	0.0%	15.1%	12.1%	0.4%	2.2%	2.6%	100.0%	30.9	64.6	13.2	0.024	0.278	6.1	10.5
Beaver000	73.3%	5.0%	4.0%	0.0%	0.0%	2.8%	2.5%	0.1%	4.7%	7.6%	100.0%	16.1	80.7	9.7	0.027	0.345	8.0	13.2
Bennery000	82.8%	2.4%	0.3%	0.1%	0.0%	1.0%	1.5%	0.1%	4.6%	7.4%	100.0%	12.9	87.2	9.5	0.028	0.359	8.5	13.5
Charles000	55.6%	19.5%	0.0%	2.6%	0.0%	9.8%	11.7%	0.4%	0.4%	0.0%	100.0%	22.2	73.9	12.7	0.025	0.309	7.2	11.6
Charles010	64.6%	17.7%	0.0%	0.0%	0.0%	0.0%	12.9%	1.6%	2.5%	0.6%	100.0%	16.7	80.8	11.4	0.027	0.334	7.7	12.6
Charles020	83.9%	7.7%	0.0%	0.0%	0.0%	1.1%	5.4%	0.6%	0.7%	0.6%	100.0%	8.7	90.9	10.7	0.028	0.369	9.0	13.8
Charles030	19.7%	21.9%	0.0%	3.6%	0.0%	10.0%	12.9%	0.4%	1.1%	30.3%	100.0%	53.9	40.9	9.8	0.020	0.183	3.8	6.8
Charles040	20.7%	32.6%	0.0%	0.0%	0.0%	20.6%	19.9%	1.0%	0.0%	5.1%	100.0%	45.5	49.5	14.7	0.021	0.228	4.8	8.5
Charles050	50.9%	22.8%	0.0%	0.0%	0.0%	0.0%	16.6%	2.1%	5.6%	2.0%	100.0%	23.5	73.0	11.7	0.025	0.310	6.7	11.7
Charles060	38.2%	22.2%	0.0%	0.0%	0.0%	18.3%	13.1%	0.3%	7.2%	0.7%	100.0%	35.2	61.7	14.0	0.023	0.281	5.7	10.6
Cranberry000	82.6%	3.0%	2.3%	0.0%	0.0%	1.3%	1.3%	0.1%	8.0%	1.3%	100.0%	8.8	89.7	10.1	0.028	0.379	8.7	14.4
CranSouth000	20.4%	27.2%	0.0%	0.0%	0.0%	18.9%	18.0%	0.8%	5.5%	9.2%	100.0%	48.6	47.5	13.8	0.021	0.227	4.4	8.5
Fenerty000	71.6%	6.1%	4.2%	0.0%	0.0%	2.3%	2.3%	0.1%	6.3%	7.1%	100.0%	15.7	80.6	9.7	0.027	0.347	7.9	13.3
Ferry000	36.2%	24.8%	0.0%	0.0%	0.0%	12.6%	12.8%	0.7%	7.5%	5.4%	100.0%	34.8	61.3	12.7	0.023	0.273	5.5	10.4
First000	16.6%	25.0%	0.0%	0.1%	0.0%	16.4%	18.5%	0.7%	0.0%	22.8%	100.0%	57.3	39.0	12.1	0.020	0.186	3.8	6.8
Fish000	47.7%	27.5%	0.0%	0.0%	0.0%	6.2%	6.6%	0.2%	1.7%	10.1%	100.0%	24.5	70.5	10.6	0.025	0.287	6.5	10.8
Fletchers000	55.8%	18.0%	0.0%	0.0%	0.0%	8.5%	6.9%	0.3%	1.6%	9.1%	100.0%	25.7	71.6	11.1	0.025	0.298	6.9	11.2
Grand000	95.9%	0.0%	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	2.1%	0.2%	100.0%	2.2	97.3	9.9	0.030	0.397	9.7	15.0
Grand010	98.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.3%	100.0%	2.2	98.8	10.0	0.030	0.398	9.8	15.0
Grand020	92.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.9%	0.4%	100.0%	4.8	96.2	10.0	0.029	0.395	9.3	14.9
Grand030	98.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	0.3%	100.0%	1.9	99.0	10.0	0.030	0.398	9.8	15.0
Grand040	87.5%	0.0%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	0.9%	100.0%	4.6	91.4	9.6	0.029	0.391	9.2	15.0
Grand050	90.4%	0.1%	2.3%	0.0%	0.0%	0.1%	0.0%	0.0%	6.4%	0.8%	100.0%	5.0	94.1	9.8	0.029	0.392	9.2	14.9
Grand060	89.3%	0.2%	1.3%	0.0%	0.0%	0.1%	0.1%	0.0%	8.6%	0.5%	100.0%	5.9	94.0	9.9	0.029	0.392	9.0	14.9
Grand070	91.7%	0.5%	0.0%	0.0%	0.0%	0.3%	0.1%	0.0%	4.7%	2.7%	100.0%	6.4	94.4	9.8	0.029	0.385	9.2	14.5
Grand080	87.0%	6.7%	0.0%	0.0%	0.0%	3.7%	2.0%	0.0%	0.0%	0.5%	100.0%	7.0	92.6	10.7	0.029	0.374	9.2	14.0
Grand100	62.0%	19.7%	0.0%	0.0%	0.0%	9.1%	8.4%	0.3%	0.0%	0.5%	100.0%	18.6	78.5	12.2	0.026	0.324	7.6	12.2
Grand120	81.6%	12.1%	0.0%	0.0%	0.0%	0.0%	2.1%	0.1%	3.3%	0.9%	100.0%	5.7	92.5	10.1	0.028	0.371	8.8	14.0
Grand140	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	99.3%	100.0%	99.4	0.6	0.1	0.015	0.018	0.1	0.1
Grand150	94.7%	0.6%	3.0%	0.0%	0.0%	0.2%	0.2%	0.0%	0.4%	1.0%	100.0%	2.5	96.0	9.8	0.030	0.393	9.7	14.9
Grand160	99.1%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	100.0%	1.1	99.4	10.0	0.030	0.400	10.0	15.0
Grand170	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	1.0	100.0	10.0	0.030	0.400	10.0	15.0
Grand180	83.0%	9.7%	0.0%	0.0%	0.0%	3.5%	3.3%	0.1%	0.0%	0.4%	100.0%	8.0	91.0	10.8	0.028	0.367	9.0	13.8
Hamilton000	81.1%	0.5%	5.3%	0.0%	0.0%	0.3%	0.3%	0.0%	7.9%	4.7%	100.0%	10.1	86.5	9.3	0.028	0.373	8.5	14.3
Juniper000	65.4%	3.8%	0.0%	0.5%	0.0%	4.1%	10.8%	0.1%	11.4%	4.0%	100.0%	24.7	75.6	11.3	0.025	0.335	7.1	12.7
Kelly000	72.8%	10.9%	0.0%	0.1%	0.0%	4.7%	4.9%	0.3%	4.4%	2.0%	100.0%	14.5	84.2	11.0	0.027	0.349	8.1	13.2
KellyLong000	92.9%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.1%	3.9%	100.0%	6.4	94.5	9.6	0.029	0.383	9.3	14.4
Kinsac000	59.8%	13.1%	0.1%	0.0%	0.0%	6.3%	7.2%	0.1%	4.0%	9.4%	100.0%	25.2	73.0	10.7	0.025	0.308	7.0	11.6
Kinsac010	52.6%	16.3%	0.0%	0.0%	0.0%	11.0%	14.1%	0.2%	4.5%	1.2%	100.0%	28.5	69.6	13.0	0.025	0.305	6.7	11.5
Lewis000	72.8%	4.2%	0.0%	0.0%	0.0%	0.7%	1.3%	0.1%	2.2%	18.7%	100.0%	22.6	77.3	8.4	0.026	0.315	7.5	11.8
Lizard000	23.9%	34.6%	0.0%	0.0%	0.0%	19.2%	15.3%	0.6%	0.0%	6.3%	100.0%	40.8	53.4	13.8	0.022	0.236	5.0	8.8
Loon000	30.1%	24.4%	0.0%	0.0%	0.0%	6.5%	10.3%	0.5%	0.7%	27.6%	100.0%	45.2	50.5	9.3	0.022	0.214	4.7	7.9
Miller000	45.4%	14.3%	0.1%	0.0%	0.0%	5.7%	9.8%	0.5%	2.4%	21.7%	100.0%	38.9	59.1	9.7	0.023	0.254	5.7	9.4

	Percent By Surface Cover Type														Manning's "n"		Dep. Storage (mm)	
Hydrologic Unit Name	**Forest**	**Grass**	**Meadow**	**Bare**	**Bedrock**	**RegRoof**	**ImpPave**	**Gravel**	**Wetland**	**Water**	**Total**	**% Impervious**	**% Routed**	**% Impervious Without Storage**	**Impervious**	**Pervious**	**Impervious**	**Pervious**
Rocky000	30.6%	21.2%	0.0%	4.3%	0.0%	8.3%	13.3%	0.3%	4.8%	17.3%	100.0%	41.5	53.2	10.9	0.022	0.234	4.9	8.8
Second000	58.9%	10.6%	0.1%	0.0%	0.0%	4.9%	6.5%	0.3%	2.7%	16.1%	100.0%	29.4	69.4	9.8	0.025	0.292	6.7	10.9
Soldier000	77.0%	2.1%	0.0%	0.0%	0.0%	0.5%	1.9%	0.1%	7.4%	10.9%	100.0%	17.8	82.6	9.2	0.027	0.345	7.9	13.0
Springfield000	40.0%	22.5%	2.2%	0.0%	0.0%	12.0%	9.8%	0.4%	1.7%	11.5%	100.0%	34.3	60.4	11.6	0.024	0.265	5.8	10.0
Third000	35.6%	19.9%	0.5%	0.0%	0.0%	8.8%	8.4%	0.4%	0.0%	26.4%	100.0%	43.9	52.5	9.5	0.022	0.225	5.0	8.3
Thomas000	28.1%	22.7%	0.0%	0.0%	0.0%	15.8%	17.4%	0.6%	0.0%	15.5%	100.0%	48.4	48.5	12.6	0.022	0.222	4.8	8.2
Thomas010	51.4%	11.3%	0.0%	0.0%	0.0%	4.6%	7.5%	0.6%	0.1%	24.5%	100.0%	37.4	61.2	9.0	0.024	0.257	6.0	9.5
Tucker000	69.9%	8.3%	0.3%	0.0%	0.0%	6.4%	8.3%	0.1%	3.5%	3.2%	100.0%	19.9	79.4	11.5	0.026	0.336	7.8	12.6
William000	39.2%	17.3%	0.0%	0.0%	0.0%	12.2%	14.7%	0.6%	14.1%	1.8%	100.0%	35.8	62.2	13.2	0.023	0.292	5.5	11.1
William010	74.8%	8.5%	0.0%	0.0%	0.0%	2.7%	4.7%	0.4%	7.2%	1.7%	100.0%	13.6	85.6	10.7	0.027	0.358	8.1	13.6
William020	90.6%	4.9%	0.0%	0.0%	0.0%	0.0%	3.6%	0.4%	0.0%	0.4%	100.0%	5.3	94.8	10.4	0.029	0.381	9.4	14.3
William030	96.3%	0.8%	0.0%	0.1%	0.0%	0.1%	0.5%	0.0%	2.0%	0.1%	100.0%	2.8	98.0	10.1	0.030	0.395	9.7	14.9
William040	92.0%	1.3%	0.0%	0.0%	0.0%	0.0%	0.9%	0.1%	1.7%	4.0%	100.0%	6.8	93.9	9.7	0.029	0.379	9.3	14.2
William050	90.2%	1.6%	0.0%	0.2%	0.0%	0.2%	1.1%	0.1%	6.3%	0.3%	100.0%	5.7	94.8	10.1	0.029	0.389	9.1	14.7
William060	48.5%	22.9%	0.0%	0.0%	0.0%	15.2%	12.5%	0.5%	0.5%	0.0%	100.0%	28.0	68.8	13.6	0.025	0.295	6.7	11.0
William070	68.9%	12.4%	0.0%	0.0%	0.0%	5.3%	9.1%	0.7%	2.9%	0.7%	100.0%	17.5	81.3	11.7	0.027	0.340	7.9	12.8
William080	52.1%	12.8%	0.0%	0.0%	0.0%	7.2%	9.5%	0.4%	2.9%	15.0%	100.0%	33.5	65.0	10.6	0.024	0.279	6.3	10.4
William090	1.4%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	98.4%	100.0%	98.5	1.5	0.2	0.015	0.021	0.1	0.2
Willis000	72.9%	3.7%	0.0%	0.0%	0.0%	0.7%	2.6%	0.3%	19.7%	0.1%	100.0%	14.2	85.9	10.4	0.026	0.375	7.6	14.4
Barrett000	45.4%	19.9%	0.0%	0.0%	0.0%	12.1%	11.4%	0.5%	0.0%	10.7%	100.0%	34.4	62.8	11.9	0.024	0.269	6.1	10.0
BeaverP000	48.4%	22.1%	0.0%	0.0%	0.0%	12.1%	12.6%	0.4%	1.2%	3.1%	100.0%	28.6	68.2	12.8	0.025	0.292	6.6	10.9
Duck000	46.6%	17.2%	0.0%	0.0%	0.0%	11.0%	8.3%	0.3%	5.3%	11.4%	100.0%	33.5	64.1	11.4	0.024	0.279	6.0	10.5
Fenerty010	28.9%	18.2%	0.0%	0.0%	0.0%	9.0%	5.4%	0.1%	8.9%	29.4%	100.0%	48.4	48.5	9.0	0.021	0.219	4.2	8.2
Area Weighted Average	**67.1%**	**7.9%**	**1.5%**	**0.2%**	**0.0%**	**3.8%**	**4.5%**	**0.2%**	**4.4%**	**12.1%**	**100.0%**	**23.3**	**76.4**	**9.9**	**0.026**	**0.323**	**7.4**	**12.2**

2.2.6 Soils and Infiltration Parameters

Infiltration parameters were determined for the Green-Ampt method based on soil texture properties. Characteristic hydrologic properties were assigned to each soil texture as shown in Table 2-9, which are literature values taken from the Handbook of Hydrology (Maidment 1993). Infiltration parameters include:

- Capillary tension, a measure of how tightly water is held within the soil pore space;
- Saturated hydraulic conductivity, a measure of how quickly the water can be drained vertically; and
- Porosity (or initial soilwater deficit), the volumetric fraction of water within the soil pore space under initially dry conditions.

Table 2-9: Infiltration Properties (by Soil Texture)

Texture	Capillary Tension	Saturated Hydraulic Conductivity		Porosity	
	(mm)	(mm/hr)	(cm/s)	wet clim.	dry clim.
Sand	49.5	235.6	6.54E-03	0.346	0.404
Sandy Loam	110.1	21.8	6.06E-04	0.246	0.358
Loam	88.9	13.2	3.67E-04	0.193	0.346
Silt Loam	166.8	6.8	1.89E-04	0.171	0.368
Sandy Clay Loam	218.5	3.0	8.33E-05	0.143	0.250
Clay Loam	208.8	2.0	5.56E-05	0.146	0.267
Silty Clay Loam	273.0	2.0	5.56E-05	0.105	0.263
Clay	316.3	0.6	1.67E-05	0.079	0.203

Soils were determined based on the Soil Survey of Halifax County and Hants County. The soils report for the Halifax County lists the following soil formations: Aspotogan, Bridgewater, Castley, Chaswood, Cumberland, Danesville, Elmsdale, Gibraltar, Halifax, Hantsport, Hebert, Mahone, Middlewood, Lawencetown, Peat, Queens, Riverpoint, Rockland, Wolfville, and Swampy land. These were further broken down based on their properties and descriptions, and a texture description of each is included in Table 2-10.

Table 2-10: Soil Descriptions

Soil Series	Soil Description		Soil Series	Soil Description		Soil Series	Soil Description
Aspotogan	Sandy Loam		**Gibraltar**	Sandy Loam		**Peat**	Clay
Bridgewater	Loam		**Halifax**	Sandy Loam		**Queens**	Sandy Clay Loam
Castley	Clay		**Hantsport**	Sandy Clay Loam		**Riverpoint**	Loam
Chaswood	Silt Loam		**Hebert**	Sandy Loam		**Rockland**	Clay
Cumberland	Sand		**Mahone**	Loam		**Wolfville**	Sandy Clay Loam
Danesville	Sandy Loam		**Middlewood**	Clay Loam		**Swampy Land**	Clay
Elmsdale	Sandy Loam		**Lawencetown**	Silty Clay Loam			

Table 2-11 summarizes the infiltration parameters determined for the model. The top part of the table lists the various soil texture types and global infiltration properties derived from Table 2-9. Table 2-11 shows the proportions of soil texture for each hydrologic unit. When these proportions are cross-multiplied by the global properties in Table 2-9, the resulting area-weighted infiltration parameters are calculated and shown on the right side of Table 2-11.

Table 2-11: Soil Types and Calculated Infiltration Parameters

Hydrologic Unit	Sand	Sandy Loam	Loam	Silt Loam	Sandy Clay Loam	Clay Loam	Silty Clay Loam	Clay	Capillary Tension (mm)	Saturated Hydrualic Cond. (mm/hr)	Initial Moisture Deficit
A000	0%	16%	17%	0%	39%	0%	0%	27%	204.3	7.2	0.2
Beaver000	3%	33%	0%	0%	64%	0%	0%	0%	177.1	17.1	0.2
Bennery000	0%	28%	22%	0%	44%	0%	0%	6%	165.0	10.4	0.2
Charles000	0%	89%	0%	0%	11%	0%	0%	0%	121.6	19.8	0.2
Charles010	0%	100%	0%	0%	0%	0%	0%	0%	110.1	21.8	0.2
Charles020	0%	93%	0%	0%	7%	0%	0%	0%	117.9	20.4	0.2
Charles030	0%	98%	0%	0%	0%	0%	0%	2%	113.5	21.4	0.2
Charles040	0%	61%	22%	0%	18%	0%	0%	0%	124.7	16.6	0.2
Charles050	0%	100%	0%	0%	0%	0%	0%	0%	110.1	21.8	0.2
Charles060	0%	82%	4%	0%	6%	0%	0%	7%	130.8	18.8	0.2
Cranberry000	0%	37%	3%	2%	49%	0%	0%	8%	181.6	10.1	0.2
CranSouth000	0%	0%	0%	0%	100%	0%	0%	0%	218.5	3.0	0.1
Fenerty000	0%	33%	11%	0%	46%	5%	0%	5%	173.9	10.1	0.2
Ferry000	0%	67%	33%	0%	0%	0%	0%	0%	103.1	18.9	0.2
First000	0%	1%	0%	0%	98%	0%	0%	0%	217.6	3.2	0.1
Fish000	0%	0%	0%	0%	100%	0%	0%	0%	218.5	3.0	0.1
Fletchers000	0%	9%	8%	0%	53%	0%	0%	29%	226.4	4.9	0.1
Grand000	5%	0%	0%	0%	85%	0%	0%	10%	219.8	14.4	0.1
Grand010	0%	4%	0%	0%	96%	0%	0%	0%	214.0	3.8	0.1
Grand020	0%	76%	0%	0%	24%	0%	0%	0%	135.7	17.4	0.2
Grand030	0%	100%	0%	0%	0%	0%	0%	0%	110.1	21.8	0.2
Grand040	0%	69%	0%	0%	31%	0%	0%	0%	143.3	16.0	0.2
Grand050	0%	56%	0%	0%	36%	0%	0%	8%	166.3	13.3	0.2
Grand060	0%	69%	0%	0%	30%	0%	0%	1%	144.8	15.9	0.2
Grand070	0%	0%	0%	0%	100%	0%	0%	0%	218.5	3.0	0.1
Grand080	0%	0%	0%	0%	100%	0%	0%	0%	218.5	3.0	0.1
Grand100	0%	0%	0%	0%	99%	0%	0%	1%	218.9	3.0	0.1
Grand120	0%	0%	0%	0%	100%	0%	0%	0%	218.5	3.0	0.1
Grand140	0%	59%	0%	0%	41%	0%	0%	0%	154.7	14.1	0.2
Grand150	0%	70%	0%	0%	30%	0%	0%	0%	142.6	16.2	0.2
Grand160	0%	60%	0%	0%	30%	0%	0%	10%	163.2	14.0	0.2
Grand170	0%	0%	0%	0%	80%	0%	0%	20%	238.1	2.5	0.1
Grand180	0%	45%	0%	0%	55%	0%	0%	0%	169.7	11.5	0.2
Hamilton000	0%	65%	0%	0%	35%	0%	0%	1%	149.3	15.1	0.2
Juniper000	0%	20%	30%	0%	5%	0%	0%	45%	202.0	8.7	0.1
Kelly000	0%	4%	0%	0%	90%	0%	0%	6%	220.4	3.5	0.1
KellyLong000	0%	40%	21%	0%	38%	0%	0%	0%	147.2	12.7	0.2
Kinsac000	0%	16%	10%	0%	49%	0%	0%	25%	211.7	6.5	0.1
Kinsac010	0%	0%	0%	0%	97%	0%	0%	3%	221.4	2.9	0.1
Lewis000	0%	100%	0%	0%	0%	0%	0%	0%	110.1	21.8	0.2
Lizard000	0%	0%	0%	0%	100%	0%	0%	0%	218.5	3.0	0.1

Hydrologic Unit	Sand	Sandy Loam	Loam	Silt Loam	Sandy Clay Loam	Clay Loam	Silty Clay Loam	Clay	Capillary Tension (mm)	Saturated Hydraulic Cond. (mm/hr)	Initial Moisture Deficit
Loon000	0%	58%	0%	0%	42%	0%	0%	0%	155.4	13.9	0.2
Miller000	0%	39%	6%	0%	33%	0%	0%	22%	190.7	10.4	0.2
Miller010	0%	41%	59%	0%	0%	0%	0%	0%	97.7	16.7	0.2
Rocky000	0%	56%	0%	0%	14%	0%	0%	30%	187.6	12.7	0.2
Second000	0%	1%	0%	0%	95%	0%	0%	4%	221.0	3.1	0.1
Soldier000	0%	44%	30%	0%	2%	0%	0%	24%	155.4	13.8	0.2
Springfield000	0%	26%	35%	0%	36%	0%	0%	2%	146.0	11.5	0.2
Third000	0%	27%	13%	0%	57%	0%	0%	3%	176.2	9.3	0.2
Thomas000	0%	0%	54%	0%	46%	0%	0%	0%	148.2	8.5	0.2
Thomas010	0%	31%	11%	0%	58%	0%	0%	0%	170.7	10.0	0.2
Tucker000	8%	9%	0%	0%	83%	0%	0%	0%	195.7	23.1	0.2
William000	0%	83%	0%	0%	0%	0%	0%	17%	146.0	18.1	0.2
William010	0%	100%	0%	0%	0%	0%	0%	0%	110.3	21.8	0.2
William020	0%	62%	0%	0%	0%	0%	0%	38%	189.0	13.7	0.2
William030	0%	14%	0%	0%	0%	0%	0%	86%	286.5	3.7	0.1
William040	0%	47%	0%	0%	0%	0%	0%	53%	220.0	10.5	0.2
William050	0%	87%	0%	0%	0%	0%	0%	13%	136.5	19.1	0.2
William060	0%	100%	0%	0%	0%	0%	0%	0%	110.1	21.8	0.2
William070	0%	100%	0%	0%	0%	0%	0%	0%	110.1	21.8	0.2
William080	0%	90%	0%	0%	5%	0%	0%	5%	125.5	19.8	0.2
William090	0%	97%	0%	0%	0%	0%	0%	3%	116.9	21.1	0.2
Willis000	0%	87%	0%	0%	13%	0%	0%	0%	123.7	19.4	0.2
Barrett000	0%	0%	0%	0%	100%	0%	0%	0%	218.5	3.0	0.1
BeaverP000	0%	0%	0%	0%	100%	0%	0%	0%	218.5	3.0	0.1
Duck000	0%	0%	0%	0%	100%	0%	0%	0%	218.5	3.0	0.1
Fenerty010	0%	0%	45%	0%	55%	0%	0%	0%	160.2	7.6	0.2
Tucker010	0%	0%	0%	0%	100%	0%	0%	0%	218.5	3.0	0.1

2.3 Hydraulics

The hydraulic model was developed using topographical data to characterize the conveyance and routing of stormwater throughout the existing drainage network. The drainage network was represented by a link-node system of conduits (i.e., culverts, dams, and open watercourses) and junctions (i.e., storage areas/lakes, connecting nodes, and outfalls).

2.3.1 Model Junctions

The hydraulic model schematic for the subject site was shown on Figure 2-1. Modeled conduits are described in Section 0. Modeled junctions are labelled and shown in red with the following symbols:

- Storage junctions (lakes) are represented by squares;
- Linking junctions (i.e., without storage) are represented by circles; and
- The model outfall is represented by a triangle.

The hydraulic model system includes a total of 58 junctions and the input data are shown in Table 2-12. For each junction the table shows the name, invert elevation, node type, ground surface elevation, and corresponding maximum flow depth at the junction. The maximum flow elevation is was generally set to 1 m for the storage nodes and the depth of the channel cross sections.

A free outfall was applied as the boundary condition for all design storm events and land use scenarios for both outlets. Table 2-13 shows the surface storage that was assigned to the junctions that represent lake or pond features in the watershed. As detailed bathymetry was not available for each lake, the initial lake elevation was entered for the normal water surface elevation as determined by the DEM. For each storage junction, a description is given along with the characteristic elevation-stage-volume data derived from available topographic mapping. Depth and surface area are the input parameters in SWMM.

Table 2-12: Nodes included in the Hydraulic Model

Junction Name	Invert Elevation (m-datum)	Junction Type	Surface / Overtop Elevation (m-datum)	Maximum Flow Depth (m)	Junction Name	Invert Elevation (m-datum)	Junction Type	Surface / Overtop Elevation (m-datum)	Maximum Flow Depth (m)
j_Beaver001	92.40	Junction	94.40	2.00	s_KellyLong001	96.26	Storage	97.26	1.00
j_Bennery001	98.89	Junction	100.89	2.00	s_Kinsac001	25.11	Storage	26.11	1.00
j_Charles001	32.45	Junction	34.45	2.00	s_Lewis001	150.67	Storage	151.67	1.00
j_Charles011	27.66	Junction	29.66	2.00	s_Loon001	67.80	Storage	68.80	1.00
j_Charles021	29.12	Junction	31.12	2.00	s_Miller001	51.39	Storage	52.39	1.00
j_Charles061	34.43	Junction	36.43	2.00	s_Rocky001	38.65	Storage	39.65	1.00
j_Charles062	50.64	Junction	52.64	2.00	s_Second001	35.44	Storage	36.44	1.00
j_Fenerty001	138.47	Junction	140.47	2.00	s_Soldier001	63.28	Storage	64.28	1.00
j_Grand062	69.45	Junction	71.45	2.00	s_Spring001	105.45	Storage	106.45	1.00
j_Kinsac011	31.99	Junction	33.99	2.00	s_Third001	34.37	Storage	35.37	1.00
j_Lizard001	18.08	Junction	20.08	2.00	s_Thomas001	18.39	Storage	19.39	1.00
j_Soldier001	84.68	Junction	86.68	2.00	s_Thomas011	18.39	Storage	19.39	1.00
j_SRiver012	13.25	Junction	16.25	3.00	s_Tucker001	68.98	Storage	69.98	1.00
j_SRiver013	13.10	Junction	16.10	3.00	s_William081	27.45	Storage	28.45	1.00
j_Tucker001	41.45	Junction	43.45	2.00	s_William091	19.16	Storage	20.16	1.00
j_William001	70.63	Junction	72.63	2.00	s_Duck001	63.03	Storage	64.03	1.00
j_William051	28.07	Junction	30.07	2.00	s_Barrett001	83.16	Storage	84.16	1.00
j_William093	20.24	Junction	22.24	2.00	s_BeverP001	31.85	Storage	32.85	1.00
j_Tucker003	49.51	Junction	51.51	2.00	s_Tucker011	51.18	Storage	52.18	1.00
j_Miller011	110.16	Junction	112.16	2.00	s_Fenerty001	96.44	Storage	97.44	1.00
j_Charles041	31.30	Outfall	n/a	n/a	s_Fenerty002	74.87	Storage	75.87	1.00
j_SRiver014	12.79	Outfall	n/a	n/a	s_First001	50.48	Storage	51.48	1.00
s_A001	50.65	Storage	51.65	1.00	s_Fish001	18.34	Storage	19.34	1.00
s_Beaver001	39.77	Storage	40.77	1.00	s_Fletchers001	15.52	Storage	16.52	1.00
s_Bennery001	60.67	Storage	61.67	1.00	s_Grand071	44.49	Storage	45.49	1.00
s_Charles031	28.28	Storage	29.28	1.00	s_Grand111	13.30	Storage	14.30	1.00
s_CranSouth001	72.74	Storage	73.74	1.00	s_Hamilton001	72.35	Storage	73.35	1.00
s_Hamilton003	145.70	Storage	146.70	1.00	s_Hamilton002	143.56	Storage	144.56	1.00
s_Juniper001	104.60	Storage	105.60	1.00	s_Kelly001	55.71	Storage	56.71	1.00

Table 2-13: Storage Junction Rating Curves

Description	Storage Junction	Elevation (m)	Depth (m)	Surface Area (m^2)
A Lake	s_A001	50.65	0.00	153,763
		51.65	1.00	238,581
Beaverbank Lake	s_Beaver001	39.77	0.00	686,628
		40.77	1.00	799,160
Bennery Lake	s_Bennery001	60.67	0.00	504,523
		61.67	1.00	576,092
Charles Lake	s_Charles031	28.28	0.00	1,415,301
		29.28	1.00	1,702,637
Cranberry Lake	s_CranSouth001	72.74	0.00	112,368
		73.74	1.00	133,519
Lisle Lake	s_Fenerty001	96.44	0.00	53,828
		97.44	1.00	89,875
Fenerty Lake	s_Fenerty002	74.87	0.00	647,165
		75.87	1.00	726,669
First Lake	s_First001	50.48	0.00	827,520
		51.48	1.00	872,320
Fish Lake	s_Fish001	18.34	0.00	509,840
		19.34	1.00	559,498
Fletchers Lake	s_Fletchers001	15.52	0.00	1,006,838
		16.52	1.00	1,132,425
Golden Lake	s_Grand071	44.49	0.00	79,324
		45.49	1.00	127,725
Shubenacadie Grand Lake	s_Grand111	13.30	0.00	18,840,316
		14.30	1.00	18,990,316
Square Lake	s_Hamilton001	72.35	0.00	361,538
		73.35	1.00	389,571
Nicholson Lake	s_Hamilton002	143.56	0.00	400,117
		144.56	1.00	430,117
Savage Lake	s_Hamilton003	145.70	0.00	184,400
		146.70	1.00	214,400
King Lake	s_Juniper001	104.60	0.00	97,780
		105.60	1.00	368,190
Kelly Lake	s_Kelly001	55.71	0.00	132,766
		56.71	1.00	393,350
Kelly Long Lake	s_KellyLong001	96.26	0.00	102,600
		97.26	1.00	142,906
Kinsac Lake	s_Kinsac001	25.11	0.00	1,682,515
		26.11	1.00	1,717,826
Lewis Lake	s_Lewis001	150.67	0.00	765,105
		151.67	1.00	795,105
Loon Lake	s_Loon001	67.80	0.00	766,841
		68.80	1.00	843,985
Miller Lake	s_Miller001	51.39	0.00	1,259,106
		52.39	1.00	1,431,486
Rocky Lake	s_Rocky001	38.65	0.00	740,714
		39.65	1.00	1,077,795
Second Lake	s_Second001	35.44	0.00	1,127,372
		36.44	1.00	1,252,668
Soldier Lake	s_Soldier001	63.28	0.00	2,303,912
		64.28	1.00	2,326,568
Springfield Lake	s_Spring001	105.45	0.00	813,330
		106.45	1.00	826,216
Third Lake	s_Third001	34.37	0.00	848,503
		35.37	1.00	895,312
Lake Thomas (North)	s_Thomas001	18.39	0.00	437,454
		19.39	1.00	450,291
Lake Thomas (South)	s_Thomas011	18.39	0.00	692,155
		19.39	1.00	702,365
Hamilton Lake	s_Tucker001	68.98	0.00	304,233
		69.98	1.00	336,583

Description	Storage Junction	Elevation (m)	Depth (m)	Surface Area (m^2)
Powder Mill Lake	s_William081	27.45	0.00	431,260
Powder Mill Lake		28.45	1.00	530,369
Lake William	s_William091	19.16	0.00	3,023,936
Lake William		20.16	1.00	3,444,742
Duck Lake	s_Duck001	63.03	0.00	94,652
Duck Lake		64.03	1.00	172,418
Barrett Lake	s_Barrett001	83.16	0.00	90,048
Barrett Lake		84.16	1.00	106,639
Beaver Pond	s_BeverP001	31.85	0.00	149,792
Beaver Pond		32.85	1.00	212,083
Tucker Lake	s_Tucker011	51.18	0.00	326,479
Tucker Lake		52.18	1.00	371,551

2.3.2 Model Conduits

The hydraulic model of the proposed collection system includes a total of 54 watercourse reaches as shown in Figure 2-1. For each conduit, Table 2-14 shows the name, inlet (i.e., upstream junction name) and outlet (i.e., downstream junction name), length, shape, transect name, roughness coefficient (i.e., Manning “n”) of the main channel, slope, and upstream and downstream invert elevations (expressed as an offset above the corresponding junction invert). As these were represented in the model as open channels, cross sections were developed using the DEM.

Design or as-built information describing stream crossing structures such as bridges and culverts was unavailable during the development of the model. As such these structures were not represented in the model. Results therefore reflect a conservative approach in which peak flows are not attenuated by the conveyance capacity of the structures. Although this affects the timing of surface water loading to the receiving water bodies, the total routed volume is not affected by omitting the structures.

Table 2-14: Modelled Conduits

Name	Model Junctions		Length (m)	Conduit Shape	Transect Name	Roughness Coefficient (Manning "n")	Invert Offset		Slope
	Inlet	Outlet					Inlet (m)	Outlet (m)	
w_A001	s_A001	j_Lizard001	1352	IRREGULAR	c_A001	0.045	0	0	2.4%
w_Beaver001	j_Beaver001	s_Beaver001	3437	IRREGULAR	c_Beaverbank001	0.045	0	0	1.5%
w_Beaver002	s_Beaver001	s_Kinsac001	1214	IRREGULAR	c_Kinsac002	0.045	0	0	1.2%
w_Bennery001	j_Bennery001	s_Bennery001	1702	IRREGULAR	c_Bennery001	0.045	0	0	2.2%
w_Charles031	j_Charles061	s_Charles031	151	IRREGULAR	c_Charles031	0.045	0	0	4.1%
w_Charles051	j_Charles021	j_Charles011	434	IRREGULAR	c_Charles021	0.045	0	0	0.3%
w_Charles061	s_Loon001	j_Charles062	2039	IRREGULAR	c_Charles061	0.045	0	0	0.8%
w_Charles062	j_Charles062	j_Charles061	1230	IRREGULAR	c_Charles062	0.045	0	0	1.3%
w_Fenerty001	s_Fenerty001	s_Fenerty002	676	IRREGULAR	c_Fenerty001	0.045	0	0	3.2%
w_Fenerty002	j_Fenerty001	s_Fenerty002	6614	IRREGULAR	c_Fenerty002	0.045	0	0	1.0%
w_Fish001	s_Fish001	s_Grand111	358	IRREGULAR	c_Fish001	0.045	0	0	1.4%
w_Fish002	s_Bennery001	s_Fish001	2894	IRREGULAR	c_Fish002	0.045	0	0	1.5%
w_Fletchers002	s_Fletchers001	s_Grand111	1309	IRREGULAR	c_Fletchers001	0.045	0	0	0.2%
w_Grand061	j_Grand062	s_Grand111	3204	IRREGULAR	c_Beaverbank002	0.045	0	0	1.8%
w_Grand071	s_Grand071	s_Grand111	1140	IRREGULAR	c_Grand071	0.045	0	0	2.7%
w_Grand112	s_Grand111	j_SRiver012	3891	IRREGULAR	c_SRiver001	0.045	0	0	0.0%
w_Hamilton001	s_Lewis001	s_Hamilton003	198	IRREGULAR	c_Hamilton001	0.045	0	0	2.5%
w_Hamilton004	s_Hamilton003	s_Hamilton002	726	IRREGULAR	c_Hamilton001	0.045	0	0	0.3%
w_Hamilton006	s_Hamilton002	s_Hamilton001	9847	IRREGULAR	c_Hamilton001	0.045	0	0	0.7%
w_Hamilton007	s_Hamilton001	s_Tucker001	553	IRREGULAR	c_Hamilton001	0.045	0	0	0.6%
w_Juniper001	s_Juniper001	j_Soldier001	6243	IRREGULAR	c_Soldier001	0.045	0	0	0.3%
w_Kelly001	s_Kelly001	s_Grand111	1640	IRREGULAR	c_Kelly002	0.045	0	0	2.6%
w_KellyLong001	s_KellyLong001	s_Kelly001	2910	IRREGULAR	c_Kelly001	0.045	0	0	1.4%
w_Kinsac001	s_Kinsac001	s_Grand111	3314	IRREGULAR	c_Kinsac001	0.045	0	0	0.4%
w_Kinsac002	j_Kinsac011	s_Kinsac001	751	IRREGULAR	c_Kinsac011	0.045	0	0	0.9%
w_Lizard001	j_Lizard001	s_Fletchers001	686	IRREGULAR	c_Lizard001	0.045	0	0	0.4%
w_Loon001	s_CranSouth001	s_Loon001	676	IRREGULAR	c_Loon001	0.045	0	0	0.7%
w_Miller001	s_Soldier001	s_Miller001	1104	IRREGULAR	c_Miller001	0.045	0	0	1.1%

Name	Model Junctions		Length (m)	Conduit Shape	Transect Name	Roughness Coefficient (Manning "n")	Invert Offset		Slope
	Inlet	Outlet					Inlet (m)	Outlet (m)	
w_Rocky001	s_First001	s_Rocky001	1441	IRREGULAR	c_Rocky001	0.045	0	0	0.8%
w_Soldier001	j_Soldier001	s_Soldier001	1598	IRREGULAR	c_Soldier002	0.045	0	0	1.3%
w_Springfield001	s_Springfield001	s_Fenerty001	1443	IRREGULAR	c_Springfield001	0.045	0	0	0.7%
w_Third001	s_Second001	s_Third001	860	IRREGULAR	c_Third001	0.045	0	0	0.1%
w_Thomas001	s_Thomas001	j_Lizard001	603	IRREGULAR	c_Thomas001	0.045	0	0	0.0%
w_Thomas011	s_William091	s_Thomas011	357	IRREGULAR	c_Thomas011	0.045	0	0	0.1%
w_Tucker001	j_Tucker001	s_Beaver001	1930	IRREGULAR	c_Tucker001	0.045	0	0	0.1%
w_William011	j_William001	s_William091	1671	IRREGULAR	c_William011	0.045	0	0	0.2%
w_William051	j_William051	s_William091	1523	IRREGULAR	c_William051	0.045	0	0	0.1%
w_William071	j_Charles011	s_William091	871	IRREGULAR	c_William071	0.045	0	0	3.1%
w_William081	s_William081	s_William091	686	IRREGULAR	c_William081	0.045	0	0	0.6%
w_William082	s_Rocky001	s_William081	1129	IRREGULAR	c_William082	0.045	0	0	1.0%
w_William083	s_Third001	s_William081	1570	IRREGULAR	c_William083	0.045	0	0	1.2%
w_Miller011	s_Miller001	s_Thomas001	769	IRREGULAR	c_Thomas002	0.045	0	0	1.0%
w_DuckTOBev	s_Duck001	s_BeverP001	3382	IRREGULAR	c_Kinsac011	0.045	0	0	0.4%
w_BevTOkin	s_BeverP001	j_Kinsac011	684	IRREGULAR	c_Kinsac011	0.045	0	0	4.3%
w_BarTOkin	s_Barrett001	j_Kinsac011	3378	IRREGULAR	c_Kinsac011	0.045	0	0	0.9%
w_TucTOTuc	s_Tucker011	j_Tucker003	311	IRREGULAR	c_Tucker002	0.045	0	0	0.0%
w_HamTOTuc	s_Tucker001	j_Tucker003	1548	IRREGULAR	c_Tucker002	0.045	0	0	1.5%
w_Tuc3TOTuc1	j_Tucker003	j_Tucker001	1029	IRREGULAR	c_Tucker002	0.045	0	0	0.5%
w_MilTOSold	j_Miller011	s_Soldier001	2014	IRREGULAR	c_Soldier001	0.045	0	0	1.3%

2.4 Water Quality

The water quality module of SWMM was used to simulate the generation of total suspended solids (TSS) loadings from each subcatchment, including pollutant buildup during dry weather periods and washoff during rainfall events. The pollutographs were subsequently routed through the collection system and the deposition of particulate solids in the lakes was simulated in the lakes.

Total phosphorous (TP) loadings were estimated based on an empirical relationship between TSS and TP. The process for simulating TSS loading into the collection system first required the categorization of surface cover types to generate the pollutant loads. Next, the appropriate parameters were assigned to the buildup and washoff functions that determine the pollutant loadings from each surface cover type. The only source of TSS represented in the model is from surface washoff. That is, contributions from rainfall, groundwater or other sources were not considered.

2.4.1 Total Suspended Solids

The surface cover types that were defined for the hydrologic model were used to represent TSS loadings. The land use categories (such as high medium and low density residential) were selected to correspond with the land use given in Halifax Regional Municipality Stormwater Management Guidelines, Table 5-5. This table presents mean pollutant concentration generated by different land uses.

No local TSS measurements were available to calibrate the buildup and washoff functions as the samples collected as part of the monitoring plan did not focus on collecting TSS measurements during the storm events nor were they meant to characterize the particle size distributions of TSS generated from the source areas. Therefore, parameters were estimated from the range of values reported in the literature.

The buildup of TSS that accumulates within each land use category was represented using the power function option in SWMM. With this function, the pollutant buildup is expressed by a rate that increases proportionally by the number of preceding dry weather days until a maximum accumulation mass is achieved. Input parameters for the power buildup function include:

- Maximum buildup, expressed as a limiting mass per unit subcatchment area;
- Buildup rate constant, expressed as a mass per unit area per day; and
- Time exponent.

The buildup rate constant (1.9 kg/ha/day) and time exponent (1.5) were applied equally to all surface cover types. The maximum TSS buildup values were defined individually by cover type, including:

- Forested wetland: 1,200 kg/ha
- Urban open: 4,800 kg/ha
- Communication and utilities: 1,200 kg/ha
- Low-density residential: 1,200 kg/ha
- Medium-density residential: 1,200 kg/ha
- High-density residential: 1,200 kg/ha
- Institutional: 4,800 kg/ha
- Multifamily residential: 1,200 kg/ha
- Highways: 4,800 kg/ha
- Commercial: 4,800 kg/ha

- Industrial: 4,800 kg/ha

The buildup of accumulated TSS becomes available for washoff into the collection system. Washoff of TSS was represented using the Event Mean Concentration (EMC) option in SWMM. With this option, the pollutant washoff is expressed as a constant washoff pollutant concentration in mass per liter. During wet weather events, these concentrations are sustained until the accumulated buildup mass is depleted at which time washoff ceases. The washoff EMC rates were defined individually by surface cover type, based event mean pollutant concentrations listed in Table 5-5 HRM Stormwater Management Guidelines (Dillion 2006). The following values were applied:

- Forested wetland: 19.0 mg/L
- Urban open: 20.0 mg/L
- Communication and utilities: 20.7 mg/L
- Low-density residential: 22.1 mg/L
- Medium-density residential: 30.5 mg/L
- High-density residential: 47.7 mg/L
- Institutional: 41.9 mg/L
- Multifamily residential: 47.7 mg/L
- Highways: 57.8 mg/L
- Commercial: 54.2 mg/L
- Industrial: 57.8 mg/L

In SWMM, particulate settling is represented by a characteristic settling velocity distribution. No local stormwater settling velocity measurements were available and so empirical data from other regions were used. Stormwater particle size distributions and settling velocities were taken from the Nationwide Urban Runoff Program (NURP, U.S. EPA, 1983 Final Report) and are shown in Table 2-15.

Table 2-15: Total Suspended Solids Particle Size Distribution (PSD) and Settling Velocities

	PSD % Finer Than	Average Velocity (m/s)	Equiv. Size µm	Approximate NURP Size µm	Settling Equation
TSS 1	20%	0.0000025	2	3	C = TSS_1 * EXP(-0.00000254/(DEPTH)*DT)
TSS 2	30%	0.0000130	4	4	C = TSS_2 * EXP(-0.00001300/(DEPTH)*DT)
TSS 3	40%	0.0000254	5	6	C = TSS_3 * EXP(-0.00002540/(DEPTH)*DT)
TSS 4	60%	0.0001270	12	12	C = TSS_4 * EXP(-0.00012700/(DEPTH)*DT)
TSS 5	80%	0.0005927	26	35	C = TSS_5 * EXP(-0.00059267/(DEPTH)*DT)
TSS 6	100%	0.0055033	103	500	C = TSS_6 * EXP(-0.00550333/(DEPTH)*DT)

Because the settling or removal equations (given in Table 2-15) require depth as a function of settling, the depth was calculated as the depth of water plus the mean lake depth. Where bathymetry data was available, it was incorporated into the model. For the remaining lakes in the watershed where no bathymetry data was available, a lake depth of 2.2 m was assumed for water quality treatment given the range of lake depths in the sounding areas. A brief sensitivity analysis was completed to ensure that this value would be acceptable. The parameter was found to be not very sensitive as a change in depth of 2 m resulted in a water quality change of 1 mg TSS/L.

For the average year water quality simulations, baseflow was incorporated to improve numerical stability during the dry periods in the summer months. This method also more realistically represents the hydrology of the system. Baseflow was not included for the design storm event simulations. Baseflow quantities were derived from the observed hydrometric monitoring. At the time of the analysis, however summer flows had not yet been collected.

2.4.2 Total Phosphorus

The TP was calculated as a ratio for each size fraction of TSS. There is some variation in the literature based on the ratio of TP to TSS. Based on a literature review, the initial ratio of TP to TSS was taken from Stone and English (1993). This paper looked at forms of phosphorus with various size fractions of suspended sediment for two watersheds on Lake Erie, Ontario. The correlation between the modeled water quality using the Stone and English ratios with the measured average values provided a good fit for the data. The TP:TSS ratios are presented in Table 2-16 and a summary of values are presented in
Table 2-17. Septic was incorporated into the model based on the development loading contributions from the LCM model. The breakdown of TP load is presented in
Table 2-17.

Table 2-16: Ratio of TP to TSS

	Equiv. Size Fraction (µm)			Co-pollutant Correlation	
	Lower	Upper	Mean	TP:TSS Ratio	Equiv. Size Fraction (µm)
TSS 1	0	3	2	0.0011	<5
TSS 2	3	5	4	0.0011	<5
TSS 3	5	7	6	0.0009	5 – 7
TSS 4	7	17	12	0.0006	7 – 17
TSS 5	17	35	26	0.0006	17 – 35
TSS 6	35	171	103	0.0001	35 – 60

Table 2-17: Comparison of Measure and Modeled TP values (µg/l)

Lake	Measured	Scenario 1: Existing Conditions			Difference
		SWMM Runoff	Septic from LCM	Total	
Cranberry (south)	20±13	2	9	24	19%
Loon	15±12	4	0	15	-3%
Charles	10±8	5	5	10	3%
First	11±10	9	1	10	-9%
Rocky	16±12	24	0	24	53%
Second	12±14	9	34	12	-2%
Third	10±11	6	1	11	12%
William	9±7	9	1	12	32%
Miller	11±4	8	2	10	-7%
Thomas	11±14	6	1	11	-2%
Fletcher	10±9	3	0	10	-4%
Shubenacadie Grand	8±13	5	1	7	-18%
Fish	18±1	1	6	17	-7%
Springfield	14±10	8	36	14	1%
Lisle	50±26	15	0	44	-12%
Fenerty	22±9	8	2	7	-68%
Lewis	8±2	21	3	7	-14%
Tucker	10±7	5	0	12	24%
Beaverbank	11±1	10	4	5	-58%
Barrett	11±6	7	5	10	-6%

Duck	43±39	9	2	42	-1%
Beaver Pond	23	5	7	24	-54%
Kinsac	12±8	9	3	15	-47%

2.5 Stormwater Management Facilities

It is important to note that the proposed development scenarios were modeled with and without stormwater management facilities, although development in the Port Wallis lands would be required to include stormwater management (SWM) facilities. The other low density development occurring in the subwatershed would not be required to incorporate SWM facilities. Given the large scale of the watershed model development, it was not practical to incorporate these small, distributed stormwater management facilities for Modeling Scenario 3 into the model. As a result, we have used a spreadsheet based calculation to estimate the treatment performance of SWM facilities.

The long-term treatment performance and potential removal rates of stormwater management facilities with respect to water quality have been well studied and documented. The HRM Stormwater Management Guidelines (2006) includes the maximum removal rates for a wet pond of 80% TSS removal and 50% TP removal. These removal rates were applied to the modeled data to quantify the potential treatment efficiency of the SWM facilities.

The water quantity results show the changes to the flow regime as a result of unmitigated flow inputs. Water quantity can be controlled within the watershed though the use of wet ponds to match post-development conditions to pre-development conditions. The effects of the stormwater management facilities on water quantity were not estimated.

There are opportunities within the watershed to control the unmitigated stormwater inputs using stormwater management and best management practices. The HRM Stormwater Management Guidelines (2006) contains an extensive review of stormwater management best practices and quantity/quality controls that can be implemented in conjunction with the development plan.

3. Model Results

The water quality model results are presented in the main body of the report.

The focus of the SWMM modeling effort for the Shubenacadie subwatershed was the accurate representation of the water *quality* results. Due to the large size of many of the lakes in the system, the water *quantity* results for the design storm based events was not accurately represented in the model. This appears to be caused by a limitation in the SWMM model related to lake size. For the design storms, the large lakes reduce the peak flows resulting in the design storms for the system being under estimated. As such, only the water quality modeling results are presented in the main body of the report.

4. References

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