HALIFAX REGIONAL MUNICIPALITY

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Item No. 9
Halifax Regional Council
May 18, 2010

TO: Mayor Kelly and Members of Halifax Regional Council

SUBMITTED BY: [signature]
For Phillip Townsend, Director, Infrastructure and Asset Management

DATE: April 9, 2010

SUBJECT: **Final Report: Water Quality Monitoring Functional Plan**

INFORMATION REPORT

ORIGIN

This Report originates from Staff.

BACKGROUND

As a Functional Plan requirement of the Halifax Regional Municipal Planning Strategy (Regional Plan), the municipality is required to adopt a Water Quality Monitoring Functional Plan.

In order to work in an integrated manner, Sustainable Environment Management staff (the lead on this Functional Plan) intend to sequence the final consultation with the Watershed Advisory Boards and Regional Planning Advisory Committee and final recommendation to Regional Council with the Stormwater Management Functional Plan.

The intent of this report is simply to make the Stantec Final Report: Water Quality Monitoring Functional Plan a document of public record.

DISCUSSION

In August 2008, Stantec (formerly Jacques Whitford) was awarded the contract from Request for Proposal 08-056 to develop a Water Quality Monitoring Functional Plan. Staff received the final report from Stantec in Spring 2009 and commenced a committee to prepare a recommendation, ultimately for Regional Council, with representation from stakeholders and the three Watershed Advisory Boards. This committee work was suspended to sequence the Service Review, presented on April 27th, first.

Since that time, it has become clear that a recommendation on the Water Quality Monitoring Functional Plan should be integrated with the recommendations flowing from the work and strategies that will be presented in the Stormwater Management Functional Plan, and both will be framed according to the completion of the Provincial Water Resources Management Strategy. The logical sequencing of decisions has clarified.

The Watershed Advisory Boards have participated in the creation of and seen this document.

In order to prevent further delay with this document, staff are providing this information report to make this Stantec Report a document of public record.

There is some excellent information in this report which will help inform stakeholders and citizens.

BUDGET IMPLICATIONS

There are no budget implications of this information report.

FINANCIAL MANAGEMENT POLICIES/BUSINESS PLAN

This report complies with the Municipality's Multi-Year Financial Strategy, the approved Operating, Capital and Reserve budgets, policies and procedures regarding withdrawals from the utilization of Capital and Operating reserves, as well as any relevant legislation.

ATTACHMENTS

The Stantec Report, Water Quality Monitoring Functional Plan
http://www.halifax.ca/environment/documents/HRM.Water.Quality.Monitoring.Functional.Plan.Jan2010.pdf

A copy of this report can be obtained online at http://www.halifax.ca/council/agendasc/cagenda.html then choose the appropriate meeting date, or by contacting the Office of the Municipal Clerk at 490-4210, or Fax 490-4208.

Report Prepared by: Richard MacLellan, Manager, Sustainable Environment Management Office, 490-6056

FINAL REPORT: Water Quality Monitoring Functional Plan

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File: 1043788.

May 2009

Notice of Addendum

The Water Quality Monitoring Functional Plan (WQMFP) was originally published in May 2009. In January 2010, an addendum was issued to the Halifax Regional Municipality by Stantec. The addendum included an updated Appendix C (Budget Information) and updates to the associated cost table (Table 5.1) in Section 5 of the main document. In addition, text on page 5.2 was revised to reflect that cost estimates were based on preferred laboratory rates.

Executive Summary

The Water Quality Monitoring Functional Plan (WQMFP) is one of a series of functional plans mandated by the HRM Regional Municipal Planning Strategy (August, 2006). Functional Plans are considered to be management guides considering the detailed elements of policy programming. These plans assist HRM in developing a framework for implementation, considering budgetary requirements, the ongoing management of strategic initiatives, partnerships and demonstration projects.

Recognizing that "environmental features within a watershed all are connected and land-use activities in one part of the watershed can adversely affect quality and quantity of water in another", the Regional Municipal Planning Strategy (RMPS) in Policy E-18 identifies the need for the WQMFP to assist in the sustainable management land use and water resources. The overarching goals of water quality management in HRM are to strive to meet body contact recreation standards for lakes, waterways and coastal waters where feasible and stem the decline of lakes from the accelerated process of eutrophication, sedimentation and other inputs from urban runoff by managing development on a watershed basis.

Jacques Whitford Stantec Limited worked in association with Dalhousie University's Centre for Water Resources Studies to complete this report. The project team undertook an integrated management approach to ensure a focused and comprehensive process in developing recommendations of options for watershed management and land development in the study area which encompassed watershed within the HRM boundary. The program provides a basis for re-evaluating watershed management controls and future development potential.

The WQMFP consists of an HRM-wide monitoring program for selected lakes and rivers to determine the state of water resources and to detect changes over time. This program will act as a performance measure to assess the adequacy of water quality and mitigation measures and to detect long-term water quality impacts on receiving waters. The WQMFP also includes a development-oriented monitoring program, which focuses on short-term, development-specific monitoring activities occurring over the course of construction. This development-oriented program is linked into the HRM-wide program so monitoring results are transferrable and inform the broader program.

To inform the management and implementation of the WQMFP, a summary of the ongoing HRM surface water monitoring programs are provided, with recommendations for modification or clarification, as appropriate. A review of water quality monitoring strategies used by four other municipal jurisdictions is presented, with recommendations for elements that can be effectively incorporated into HRM Functional Plan. Standard operating procedures (SOPs) were reviewed and the most appropriate identified for monitoring of applicable developments (either by proponents or HRM and its agents) regulated under HRM development agreements, including sampling procedures, locations, frequency and duration, parameters, analytical requirements, data management procedures, and data assessment criteria and procedures. Finally, budgetary requirements for the proposed monitoring program are itemized in detail, along with a series of potential funding options.

The water quality monitoring program described in the WQMFP will enable identification of trends, identify problem areas and establish relationships between water quality monitoring and land development trends. Over the long-term, the program will provide a performance measurement and aid in identifying priorities for development and infrastructure upgrades (sewers, pumping stations, treatment plants), including the effectiveness of storm and wastewater management measures. It will help to inform the municipality on the effects of land uses on water quality within watersheds and provide a future performance measure for planning and development controls intended to preserve or protect water resources.

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1.0 Introduction

The HRM Water Quality Monitoring Functional Plan (WQMFP) is intended to establish a comprehensive water quality monitoring program. The objective of the WQMFP is to guide Halifax Regional Municipality's (HRM's) decision-making process relative to the ongoing monitoring of water resources, such that water quality in lakes, rivers and streams remain safe for body contact recreation; and to assist HRM in establishing effective, watershed-based monitoring controls to assist in the prevention of the decline of water quality in these same surface water systems resulting from eutrophication, sedimentation and other inputs from runoff typically caused by development activities.

The WQMFP consists of an HRM-wide monitoring program for selected lakes and rivers to determine the state of water resources and to detect changes over time. This program will act as a performance measure to assess the adequacy of water quality and mitigation measures and to detect long-term water quality impacts on receiving waters. The WQMFP also includes a development-oriented monitoring program, which focuses on short-term, development-specific monitoring activities occurring over the course of construction. This development-oriented program is linked into the HRM-wide program so monitoring results are transferrable and inform the broader program.

The water quality monitoring program described in the WQMFP will enable identification of trends, identify problem areas and establish relationships between water quality monitoring and land development trends. The WQMFP is not intended to be a monitoring or sampling program for all lakes currently experiencing recreational use in HRM. Over the long-term, the program will provide a performance measurement and aid in identifying priorities for development and infrastructure upgrades (sewers, pumping stations, treatment plants), including the effectiveness of storm and wastewater management measures. It will help to inform the municipality on the effects of land uses on water quality within watersheds and provide a future performance measure for planning and development controls intended to preserve or protect water resources.

1.1 REGIONAL MUNICIPAL PLANNING STRATEGY

The Regional Municipal Planning Strategy (RMPS) identifies the framework for integrated land use planning and long-term coordination to be implemented through four broad policy types: land use regulations; secondary planning strategies; background studies; and functional plans. Functional Plans are considered to be management guides considering the detailed elements of policy programming. These plans assist HRM in developing a framework for implementation, considering budgetary requirements, the ongoing management of strategic initiatives, partnerships and demonstration projects.

The basis for the WQMFP is enabled under policy E-18 in the RMPS. The two long-term goals of the WQMFP identified in the Regional Plan detailed in the RMPS are:

- To meet body contact recreation standards for our lakes, waterways and coastal waters where feasible; and
- To stem the decline of lakes from the accelerated process of eutrophication, and sedimentation and inputs from other urban runoff by managing development on a watershed basis.

This section also identifies the requirements for this functional plan which include the following:

- Specifying the duration of monitoring for the pre-construction, construction and post-construction phases of development;
- Specifying the physical and chemical water quality indicators to be measured, the location and frequency of testing and the format of submissions to the municipality in each phase of development;
- Assessing lake water quality against the water quality objectives established under policy E-17 to detect changes such as eutrophication, which would be used as a basis for re-evaluating watershed management controls and future development potential within the area;
- Conforming with all water quality policies, specifications, protocols and review and approval procedures established by regional council; and
- Establishing an on-going monitoring program for selected lakes and rivers to determine the state of water resources and to detect changes over time.

The information resulting from the implementation of the WQMFP is expected to inform watershed management and land use regulations. The RMPS identifies HRM's intention to plan on a watershed basis and protect environmental features and functions which sustain the 'desired objectives for water quality in urban, suburban and rural areas'. Water quality monitoring is a critical element of watershed planning and will act as the technical basis for the development of knowledge relating to watershed management over the long-term.

1.2 FUNCTIONAL PLAN STUDY FRAMEWORK

1.2.1 Study Area

The study area (Figure 1.1) encompasses all of HRM, which covers an area of approximately 5,600 square kilometres. Emphasis in the Water Quality Monitoring Functional Plan is on the monitoring and protection of surface water resources, specifically lakes, rivers and streams in areas proposed for development in HRM.

HRM Water Quality Functional Plan

HALIFAX
Regional Municipality

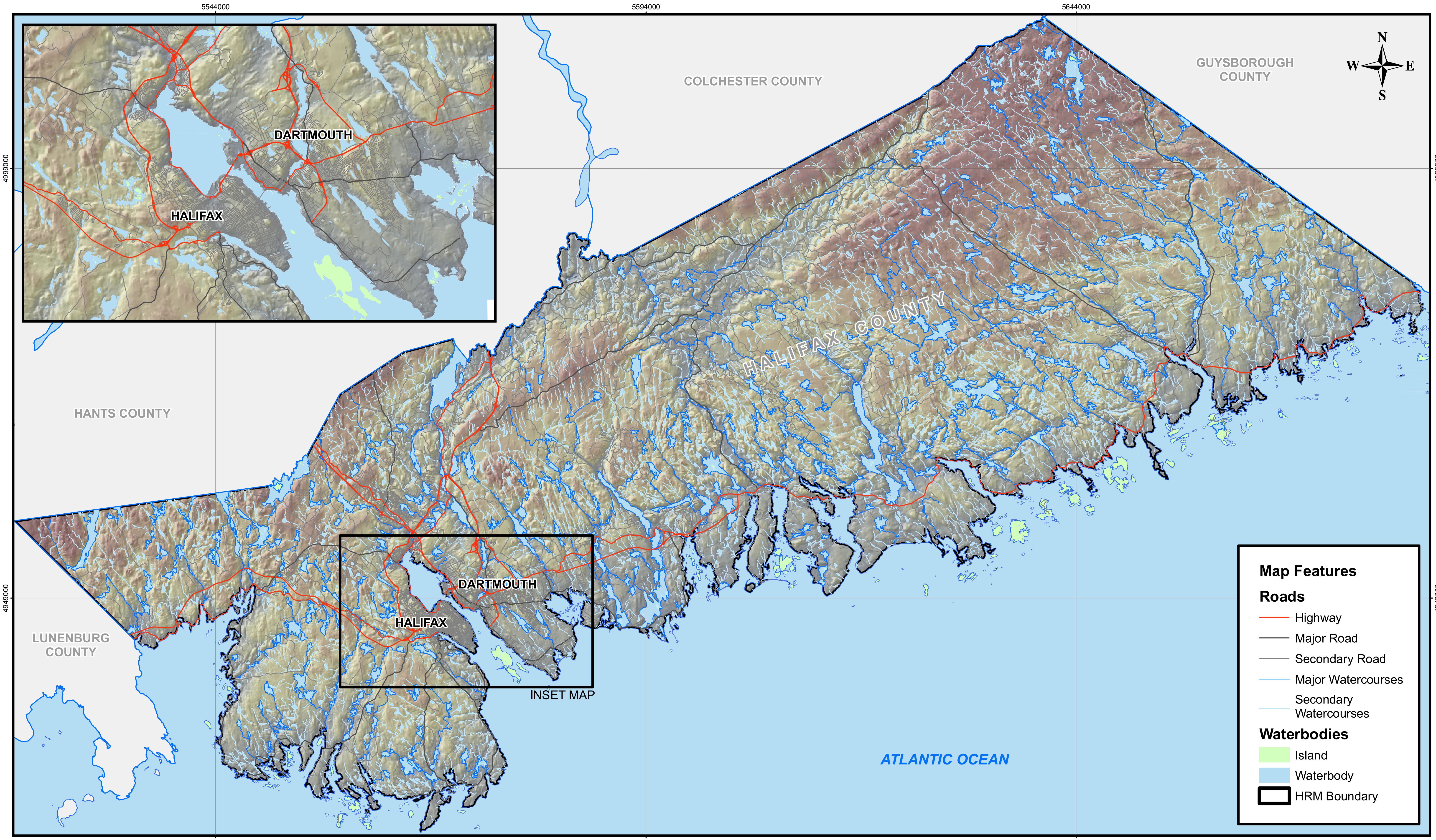


Figure 1.1
Study Area Map

0 10 20 40
Kilometers

Map Parameters
Projection: UTM-NAD83-Z20
Scale 1:400,000
Date: April 2009
Project No.: 1037606.

Stantec

1.2.2 Project Scope

The scope of the project is to develop a Water Quality Monitoring Functional Plan for HRM, establishing a framework for a broad-based monitoring program within the Municipality, along with specific controls and procedures for development activity. To develop the WQMFP, the project team identified key environmental and development water quality influences occurring within HRM. Development influences included the land use designation (*e.g.,* urban settlement or rural commuter) and presence of servicing, while environmental influences included region-specific factors such as acid rock presence-absence. Within key watersheds experiencing a high degree of vulnerability due to water quality influences, water quality and water chemistry parameters (and associated sampling timeframes) were identified specific to the water quality pressures associated with that watershed. CCME Guidelines and other federal and provincial standards for quality, collection, analyses and assessment were referenced to develop a monitoring program that helps to identify trends and changes in water quality that may be indicative of impacts such as sedimentation or eutrophication.

To inform the management and implementation of the WQMFP, a summary of the ongoing HRM surface water monitoring programs are provided, with recommendations for modification or clarification, as appropriate. A review of water quality monitoring strategies used by four other municipal jurisdictions is presented, with recommendations for elements that can be effectively incorporated into the HRM Functional Plan. Standard operating procedures (SOPs) were reviewed and the most appropriate identified for monitoring of applicable developments (either by proponents or HRM and its agents) under HRM development agreements, including sampling procedures, locations, frequency and duration, parameters, analytical requirements, data management procedures, and data assessment criteria and procedures. Finally, budgetary requirements for the proposed monitoring program are itemized in detail, along with a series of potential funding options.

1.2.3 Methodology and Approach

Jacques Whitford Stantec Limited worked in association with Dalhousie University's Centre for Water Resources Studies to complete this report. The project team undertook an integrated management approach to ensure a focused and comprehensive process in developing recommendations for watershed management related to land development in the study area. The program provides a basis for re-evaluating watershed management controls and future development potential.

The study approach allowed the team to develop a monitoring framework capable of producing data that can be analyzed in a variety of ways, including modeling and the potential use of indices (*e.g.,* Canadian Council of Ministers of the Environment (CCME) Water Quality Index). Rather than trying to interpret water quality values on a variable by variable basis, a water quality index can be calculated and used to provide a convenient means of summarizing complex water quality data.

Using a dynamic geographic information system the study team identified key influences on water quality on a watershed basis. By identifying development and environmental influences, a water quality monitoring framework was developed specific to the pressures within each watershed. Select water bodies and flowing water systems were identified using additional community-based information. The project was completed as a series of objective-based tasks to produce a comprehensive and logical report for ease of use in watershed management.

The WQMFP was developed in four parts that dealt with:

- A review of existing conditions and the identification of appropriate procedures used by other regulatory jurisdictions;
- Monitoring and assessment framework and procedures for on-going baseline surface water quality monitoring by HRM staff;
- State-of-the-art technology (*e.g.,* automated samplers) and procedures that may be used for monitoring; and
- Recommendations surrounding procedures or strategies for financing the monitoring plan components.

The specific tasks associated with the development of the WQMFP included:

- Data compilation and desktop review of existing data sources;
- Collection of relevant information from other jurisdictions (*i.e.,* other municipalities, governments);
- Development of the parameters for a Water Quality Monitoring program in select lakes and rivers;
- Geospatial analysis to identify development constraints and opportunities as they relate to the protection of groundwater, surface water and ecological resources;
- Identification of select phosphorus models compatible with existing data;
- Provide methods and protocols to assess current monitoring of selected lakes or rivers;
- Identification of opportunities for refinement or improvement of selected programs;
- Identification of standard operating procedures and technical equipment and procedures for monitoring; and
- Recommendation of options to finance the HRM monitoring program (*e.g.,* Policy E-18).

The key steps of the approach to these tasks are summarized in Table 1.1.

Table 1.1 High Level Project Outline

<table>
<tr><th>Key Steps</th><th>Key Project Tasks</th><th colspan="2">Description</th></tr>
<tr><td>Step 1: Background Review</td><td>Background Review</td><td colspan="2">• Document Review
• Municipal Best Practices Review
• Key Stakeholder Interviews
• Monitoring Program/Procedures Review</td></tr>
<tr><td rowspan="2">Step 2: Watershed Prioritization</td><td>Select Key Watersheds</td><td colspan="2">• Watershed Management Level Established
• GIS Mapping Used to Integrate:
o Watershed Area
o Water Surface Area
o Regional Plan Land Use Designation
o Percentage of Serviced Land
o Percentage of Watershed Underlain by Halifax Formation Geologic Unit
o Soil Type Breakdown</td></tr>
<tr><td>Vulnerability Assessment</td><td colspan="2">• Level of Vulnerability of Watersheds Established:
o Tier One (High Vulnerability)
o Tier Two (Moderate Vulnerability)
o Tier Three (Low Vulnerability)</td></tr>
<tr><td rowspan="2">Step 3: Water Body Prioritization</td><td>Identify Community Layers</td><td colspan="2">• GIS Mapping Used to Integrate:
o Greenfield/Master Plan Areas
o Commercial/Industrial Zoning
o Watershed Advisory Board Areas of Concern
o Public Beach/Swimming Designation
o Public Drinking Supply
o Areas of Engineering Concern (Known issues)
o Existing Monitoring Program</td></tr>
<tr><td>Establish Key Water Bodies</td><td colspan="2">• Key Water Bodies in each Secondary Watershed for Tier I and II Identified
• High Priority Water Bodies Identified
• High Priority Flowing Water Systems Identified</td></tr>
<tr><td rowspan="3">Step 4 Establish Monitoring Program</td><td>Tier I WQM Program</td><td>• Identify at Least One Tier One Watershed for Phase I Water Quality Management Project.
• Establish Overall Watershed Monitoring Programs for Tier One Watersheds
• Identify Development-Specific Program</td><td rowspan="2">Monitoring intensity (spatial, temporal, no. of parameters) will depend on the Tier.</td></tr>
<tr><td>Tier II / III WQM Program</td><td>• Establish Overall Monitoring Program for Tier Two and Three Watersheds.
• Identify Development Specific Program.</td></tr>
<tr><td>Review Development-Specific Monitoring</td><td colspan="2">• Suggest Monitoring Specific to Key Uses of Concern: Golf Courses, Heavy Industrial Uses
• Suggestions for Water Quality Monitoring/ Management Specific to Key Planning Processes (Master Planning/Secondary Planning/Open Space Subdivisions/Development Agreements)</td></tr>
<tr><td rowspan="2">Step 4: Establish Management Framework</td><td>Establish WQM Technical Inputs/ Outputs</td><td colspan="2">• Suggest Sampling Procedures for Key Parameters
• Examine Relationship Between Annual Reporting /Data Collection Methods/Inputs</td></tr>
<tr><td>Establish Funding Program</td><td colspan="2">• Establish Current HRM WQM Available Funds (Current Monitoring System of Approximately 70 Lakes)
• Establish Yearly Costs Based on Monitoring Elements Outlined (Level of Effort/Frequency) Tier I, Tier II, Tier III
• Funding Program Should Support Baseline Monitoring as well as Mitigation/Response to Issues</td></tr>
</table>

Table 1.1 High Level Project Outline

Key Steps	Key Project Tasks	Description
	Implementation and Monitoring	• Recommendations Toward Management/Response Framework - We Have the Data – So Now What? • Suggest Program Phasing • Suggest Additional Areas for Study/Future Monitoring
Step 5: Review Period	Watershed Advisory Board Review	• Presentations Provided to all Three Watershed Advisory Boards During Regular Meeting Time. • Project Concepts Identified and Reviewed. • Receive Verbal and Written (Consolidated) Input from WABs/LAB on Project Direction
	HRM Staff Review	• Progress Meetings Held Throughout Project with HRM/Halifax Water Staff • Final document submitted to HRM May 2009

1.3 STUDY LIMITATIONS

There were a number of limitations related to the development of a detailed WQMFP that affected the level of analysis within the report. The development and implementation of a comprehensive watershed-level monitoring plan is an iterative process in which specific program details and components undergo continual evaluation. As such, the program evolves with time, as more data are collected and analyzed. With a few exceptions, this study relied on existing regional information and knowledge of the study area using information provided by HRM or key stakeholders. Specialized studies and further investigation, as outlined in Section 4, are necessary to more fully understand the biophysical context of the watershed and to fine-tune the biomonitoring program, continuous monitoring potential, analytical approach and modeling options. This report provides the framework for an effective, watershed-level, WQMFP and includes detailed recommendations for certain technical program components. The document is not intended to provide prescriptive planning advice.

There were some specific limitations associated with the technical development of the program components. Specifically, no other similar lake-based municipal monitoring programs were found to draw comparisons with and therefore stream-based municipal programs were reviewed instead. The lack of a current provincial strategy for water resources management was also a limitation in the development of recommendations. An additional limitation was the inaccuracy in some of the provincial secondary watershed data used in the assessment. As discussed in Section 4.1 (Watershed Prioritization), the secondary scale of watershed delineation produced a practical number of watersheds that could be screened and assessed for the purposes of the WQMFP. Therefore, the secondary scale of watershed delineation was used despite known limitations.

2.0 CURRENT SITUATION

The current situation relating to water quality monitoring and management in HRM is detailed in this background review which outlines the relevant context for water quality monitoring in HRM. Key stakeholder interviews were conducted to establish the community context surrounding the Water Quality Monitoring Program. Interviews were conducted with the Watershed Advisory Board Chairs, HRM Staff, Developers and the Province. Current monitoring programs in HRM, sampling methods, land use, and relevant regulations and best practices from other municipalities were reviewed to develop a solid framework and the background context needed for the development of a comprehensive WQMFP for HRM. This information was then compared to the broader E-18 Functional Plan objectives and a gap analysis between the current water quality monitoring framework and identified long-term goals was undertaken to establish key areas of focus for the development of the WQMFP.

The background research for the WQMFP identified several existing gaps associated with the two priorities that HRM identified for the development of a WQMFP. These limitations have been summarized in the Table 2.1 below. An overview of each of the background research areas contributing to this summary is provided in the subsequent sections.

Table 2.1 HRM Priority Limitations

Priority	Limitations
HRM WQMFP Priority 1: To meet body contact recreation standards for lakes and watercourses where feasible	• Limited consistent, comprehensive bacterial monitoring in non-supervised lakes and watercourses
	• Inability to predict lake and watercourse closures
	• Delay in reporting results of those lakes and watercourses that are tested as a result of process (*i.e.,* samples collected, lab analysis, results provided to consultant and/or developer, notification of HRM, notification of the public)
	• Use of fecal coliform testing instead of *E. coli*
	• Inability to mitigate problems and respond to water quality issues as they arise because of lack of a comprehensive management and response framework
HRM WQMFP Priority 2: To stem the decline of lakes from the accelerated process of eutrophication, sedimentation and inputs from other urban runoff by managing development on a watershed basis.	• Limited consistent, comprehensive water quality monitoring on a watershed scale
	• Lack of biomonitoring and flow measurement throughout HRM
	• Lack of sufficient integration and communication of existing data collected through individual monitoring programs
	• Lack of leadership role in water quality monitoring from the Province
	• Lack of consistent financial backing of large-scale monitoring programs (at HRM and Development level)
	• Lack of a consistent approach to water quality monitoring at the development-scale
	• Inability to enforce adherence to water quality standards
	• Inability to mitigate problems and respond to water quality issues as they arise because of lack of a comprehensive management and response framework

2.1 ASSESSMENT OF POLICY AND REGULATORY FRAMEWORK

The regulatory framework around water quality in Nova Scotia is supported by the municipal, provincial and federal governments. The HRM Water Resource Management Study (Dillon 2002) includes a comprehensive review of regulations related to water resource management for the municipality. Specifically, it presents the detailed roles and responsibilities of municipal, provincial and federal government agencies, applicable Acts, and HRM mandates. The information presented in that report as well as updates to the regulatory framework since 2002 have been considered in the preparation of this report. A list of relevant Acts and government departments with jurisdiction over surface water is provided in Table 2.2.

Table 2.2 Summary of Jurisdiction Related to Surface Water[1]

Act and Department of Authority	Surface Water Details (freshwater)
NS Environment Act, 1994-95, Nova Scotia Environment	Jurisdiction over watercourses broadly defined; includes requirement for Water Approvals (permit for work in a watercourse)
NS Crown Lands Act, 1989, Nova Scotia Department of Natural Resources	Jurisdiction over bed of watercourse as Crown Land
NS Beaches Act, 1989 Nova Scotia Department of Natural Resources	Marine waters protections may be applied to shores of lakes
NS Municipal Government Act, 1998, replaced by Halifax Regional Municipality Charter, 2008, Service Nova Scotia and Municipal Relations	No jurisdiction over waters; Planning and Development, and Subdivision parts of Act include watercourses; planning authority given for lands adjacent to watercourse
Canada Fisheries Act, 1985, Fisheries and Oceans Canada	Jurisdiction of fisheries; applies to fish and fish habitat (containing fish or not)
Canada Navigable Waters Protection Act, 1985, Transport Canada	Approval may be required for structures over, across, through or under navigable waters
Canadian Environmental Protection Act, 1999, Environment Canada	Establishment of environmental standards, codes of practice and environmental quality guidelines protective of water resources

[1] adapted from Dillon 2002

2.1.1 Provincial Regulatory Update

Several regulatory advances in water quality monitoring have been made since 2002. At the provincial level, a Water Resources Management Strategy is being developed. The process of developing the Strategy began in March, 2007 and is anticipated to take three years. Nova Scotia Environment (NSE) is leading the preparation of a comprehensive Water Resources Management Strategy to facilitate government decisions concerning water resources by answering key questions that address water use, water quality and water quantity, as well as protection of water resources (NSE 2009). Development of this strategy is overseen by an Interdepartmental Water Management Committee consisting of ten government departments and chaired by the Deputy Minister of Environment. The participating departments are: Agriculture, Energy, Environment, Fisheries and Aquaculture, Health Promotion and Protection, Natural Resources, Nova Scotia Economic and Rural Development, Service Nova Scotia and Municipal Relations, Transportation and Infrastructure Renewal, and Tourism, Culture and Heritage (NSE 2009).

The provincial Water Resources Management Strategy is still under development and is not yet complete for consideration in the HRM WQMFP. The first round of public comments is currently being considered by NSE and it is anticipated that a draft Strategy will be available for review by stakeholders in the fall of 2009 (D. Briggins, pers. comm. February 2009). There are two municipal/provincial working groups that meet on a quarterly basis to discuss the Strategy: the Municipal/Provincial Joint Advisory Group on Water and Wastewater Management in Nova Scotia and the Municipal Public Works Association of Nova Scotia and Nova Scotia Environment Stakeholder Committee. These groups focus on provincial issues, but may also consider municipal issues that arise. Municipal representation on the first of the two working groups is limited to Union of Nova Scotia Municipalities (UNSM) and Association of Municipal Administrators of Nova Scotia (AMANS) members; however, sub-groups or working groups with other municipal representatives may be established to address specific issues. It is recommended that HRM participate in at least one of the two working groups by having a WQMFP staff member attend the meetings and represent HRM's interests related to watershed-level monitoring. There are likely to be other opportunities to comment on the draft Strategy when it is published. It will also be important for HRM to be involved in this process to ensure that specific feedback is provided concerning roles and responsibilities of the municipality versus the province, funding needs, communication, and data sharing.

2.1.2 Municipal Regulatory Update

At the municipal level, there have been a few regulatory developments since 2002. A Regional Plan became effective in 2006 which lead to the identification of the need for individual Functional Plans, some of which directly affect water quality. The Regional Plan represents integrated land use planning and long-term coordination of the municipality's growth and development. This report presents a proposed functional plan for water quality monitoring at the municipal level specifically related to development projects within HRM. Additional functional plans recommended in the Regional Plan are also related to water quality. For example, it is necessary to consider stormwater management when preparing a development-specific water quality monitoring plan. Therefore, the HRM Stormwater Management Functional Plan to be developed will need to complement the HRM Water Quality Monitoring Functional Plan. Both of the functional plans should be consulted for water quality management in HRM. At this time, preparation of the Stormwater Management Functional Plan has been assigned within HRM but the plan has not been developed.

Wastewater management in HRM is similarly tied to water quality management. There is great potential for wastewater management to influence watershed water quality and development-specific water quality. As such, the Wastewater Management Functional Plan will complement the Stormwater Management and Water Quality Monitoring Functional Plans. The Wastewater Management Functional Plan has been assigned to Halifax Water for preparation and is currently in progress. Aquatic ecosystem health is subject to multiple controlling factors, some of which are natural processes and some of which are heavily related to anthropogenic inputs. This results in the need for comprehensive management of the anthropogenic inputs (*e.g.,* runoff, stormwater and wastewater) into freshwater resources within HRM boundaries.

Halifax Water has begun to manage water quality monitoring on a watershed scale. More specifically, Halifax Water has begun the development and implementation of Source Water Protection Plans on a watershed scale. The development of these Plans includes an assessment of land uses in the watershed (*e.g.,* forestry), existing contaminant sources (*e.g.,* highways, railroad tracks, residential development), and hydrology. Water quality monitoring programs are currently being undertaken on Tomahawk Lake and Pockwock Lake source water components (*i.e.,* streams feeding the lakes). Additional watershed-specific Source Water Protection Plans are currently being implemented for other potable water sources within HRM, starting with Lake Major (B. Geddes, pers. comm., 2009).

2.2 ASSESSMENT OF LAND USE AND COMMUNITY CONTEXT

As a municipality, HRM conducts activities in two areas which affect water quality: approval of land development, and operation of municipal stormwater and wastewater infrastructure. Through the development approvals process, HRM requires developers to implement stormwater and wastewater management plans including mitigative measures and infrastructure to reduce water quality impacts. In operating municipal infrastructure, HRM and the Halifax Regional Water Commission (Halifax Water) may affect water quality through overflows and accidental releases, leaks, and cross-connections. In August 2007, the HRM transferred the responsibility of sewer and stormwater assets, including collection systems, treatment facilities and pumping stations, to Halifax Water. Water quality testing has occasionally been required under development agreements for major subdivisions, but has been temporally and spatially limited.

The RMPS establishes the basis for integrated land use planning and water quality management. The RMPS identifies watershed analysis as a key component of land use management, in order to sustain water quality over the long-term. It is expected that over the course of the Regional Plan, watershed management will play an increasingly larger role in planning processes; in particular the secondary planning strategies. At a broader level, the RMPS integrates various components of water quality management, by implementing strategies for watershed management, stormwater management and open space management, each of which contribute to sustainable management of water resources.

Water quality issues typically arise when a development is in close proximity to a lake of community concern. Requirements for water quality monitoring are detailed only through development agreement processes. There has been significant involvement of the Watershed Advisory Boards in the management of water quality. The Advisory Boards typically influence development applications that require public approval and have the potential to impact surface water resources. Generally however, the approach to management of surface water quality varies significantly and there is a requirement for greater continuity and consistency.

2.2.1 Watershed Advisory Board Summary

Presentations were made at the March 2009 meetings of the Bedford Watershed Advisory Board, Halifax Watershed Advisory Board and Dartmouth Lakes Advisory Board to outline the approach to preparing the WQMFP. Written, consolidated comments were solicited from each Board for consideration in the WQMFP. The preliminary comments provided at the meetings on broader water quality monitoring issues in HRM were consistent among the boards. These high-level comments are summarized below and were taken into consideration during the preparation of the WQMFP draft report:

- Consistent, prescriptive sampling procedures are needed;
- Sampling should be carried out by qualified individuals;
- There should be strong science behind the choice of parameters and frequency of sampling;
- It is important to secure sufficient funding to ensure that the monitoring program will function on a continuing basis. It was felt that the lowest practical level of effort for a worth-while program would result in monitoring the water bodies recommended in this report for the high and medium vulnerability watersheds and a minimum of one water body in each of the lowest vulnerability watersheds (see Section 4).
- The data collected must be consolidated, accessible, and used in the decision-making process;
- Data analyses and modeling must be backed by strong science; and
- Improved communication among HRM and the Advisory Boards to increase awareness of potentially complementary monitoring programs being carried out in HRM.

2.2.2 Community Development Staff Summary

Three representatives from HRM Community Development Staff were contacted for input to the HRM WQMFP, and were asked to detail the current framework, issues experienced under the current system, and recommendations moving forward. The representatives contacted were Richard Harvey, Planner, Sean Audas, Development Officer and Mark McGonnell, Development Engineer. All three of these individuals have had significant experience with the development process and protection of freshwater resources and represented three different but related perspectives: development; planning; and engineering.

The messaging from all three staff was consistent. An overall summary of key feedback is provided below. All comments by HRM Staff were taken into consideration during the development of the HRM WQMFP.

- There is a need to create a standardized process to create consistency for developers and for HRM staff; however it was generally felt that a standardized process is difficult to create given the large variations in development, water bodies, and the existing regulatory processes in place.

- There is general concern that water quality falls under provincial jurisdiction and that HRM doesn't have the power to effectively regulate.
- It was also suggested that HRM has no mechanism for enforcement, in so far as the municipality can require developers through the development agreement process to undertake water quality monitoring, there is no real means to enforce compliance or apply fines, particularly once construction has been completed.
- It was considered important to differentiate between monitoring the impacts and managing the form of new development versus managing the impacts of existing development on water quality. It is difficult to do anything to change water quality impacts from existing development.
- When there are problems with water quality, there are no real resources or mechanisms in place to address the problems. For example, it is difficult to determine what the actual cause of the change in water quality is, which creates problems assigning responsibility.
- It was felt the HRM-wide program was needed to establish a water quality baseline over the long-term so developers know the water quality trends. One year of data is insufficient to create a baseline; the information being collected through development agreements cannot really show changes in water quality.
- Insufficient expertise at the municipal level to adequately evaluate monitoring programs and understand the requirements for water quality monitoring.
- Need for timely consideration of applications from water quality perspective when negotiating development agreements.

2.2.3 Developer Summary

Representatives from three development companies in HRM were contacted for input to the HRM WQMFP based on issues experienced under the current system and ideas for moving forward. The representatives contacted were Brad Harnett of United Gulf Developments, Scott MacCallum of Clayton Developments, and Kevin Riley of Riley Management. All three of these individuals have had significant experience with the development process and protection of freshwater resources in consultation with HRM and the Advisory Boards.

The messaging from all three developers was quite consistent. An overall summary of key feedback is provided. All comments by the developers were taken into consideration during the development of the HRM WQMFP.

- Clearly defined roles and responsibilities of all stakeholders are essential (*e.g.,* each HRM staff department involved in the development process, the Watershed Advisory Boards, the province, and the developers);

- Effective division of responsibility *i.e.,* determine responsibility for monitoring during the different phases of construction (developer, general contractor, sub-contractor);
- Integrated management at the watershed scale is needed, including management of the overlap between watercourse and wetland protection measures and other integrated management programs within HRM such as “HRM By Design” (*e.g.,* can credits be given for development in one area that creates green space or improves hydrology or habitat quality, to off-set work in other areas?);
- Clarification of watercourse designation/definition;
- Clarification of responsibility for maintenance costs for stormwater management and water quality maintenance infrastructure (*e.g.,* HRM versus the development company);
- Important for private companies to maintain the ability to control timelines and be vigorous in the market (*e.g.,* be able to carry out their own monitoring programs);
- Use of qualified individuals and companies for monitoring program implementation;
- Would like to see prescriptive approach to monitoring program parameters, frequency and methods to minimize inconsistency in level of effort among programs;
- Improve consistency at Watershed Advisory Board level, or minimize “case-by-case” recommendations;
- Development companies will pay for certainty and the current process includes many uncertainties at multiple stages; and
- It should also be noted that there were consistent comments related to fecal coliform and *E. coli* issues on construction sites. This is outlined in greater detail in Section 4.10, Development-Specific Water Quality Monitoring Plan.

2.3 ASSESSMENT OF EXISTING WATER QUALITY MANAGEMENT

A selection of existing water monitoring programs was assessed to determine typical parameters, timeframe, location and extent of sampling within HRM and surrounding communities. Table 2.3 summarizes a number of water quality monitoring programs currently or previously carried out in the HRM but is not an exhaustive list of all historical or ongoing sampling programs.

Table 2.3 Summary of Select Local Water Quality Monitoring Programs

Monitoring Plan	Location	Duration	Water State
HRM Lakes Water Quality Sampling Program	HRM (70 Lakes and Streams)	2006- present	Freshwater Lakes
Development-Specific	Russell Lake, Morris Lake, Papermill Lake,	1997-2008	Freshwater Lakes
Halifax/Dartmouth Lakes Decadal Survey (HRM)	HRM (51 Lakes)	1980,1991,2000	Freshwater Lakes
Municipal Beaches (HRM- NSE)	24 Lakes and 10 Beachfronts in HRM	Ongoing	Marine and Freshwater
Potable water (Pockwock & Lake Major) HWRC	Pockwock Lake and Lake Major	Pockwock 1977-Present Major 1999-Present	Freshwater Lakes
HRM Receiving Water Baseline Sampling Program	HRM (64 Sites)	2001-2006	Freshwater Lakes
Harbour Solutions Project for Marine Waters in HRM	50+ locations in Bedford Basin, Halifax Harbour, North-West Arm and Eastern Passage	2003-Present	Marine Waters
NSE Lake Survey Data	All NS	1960-present	Freshwater Lakes
Nova Scotia Automated Surface Water Quality Program	5 sites throughout NS Pockwock Lake in HRM	2003-Present	Freshwater Lakes
Flowing Water Bodies	Sackville River, Nine Mile River, MacIntosh Run	Ongoing (intermittent)	Freshwater Rivers
TEAM – Trends in Eutrophication and Acidification in the Maritimes	Individual Lakes throughout Nova Scotia	2003-2004	Freshwater Lakes
Site-specific Monitoring	Individual Lakes in HRM	Various	Freshwater Lakes

Each of the above-listed water quality monitoring plans is described in more detail below.

2.3.1 HRM Lakes Water Quality Sampling Program

This program was initiated in 2006 with 50 Lakes which were sampled twice a year (spring/fall) for RCAp-30 (general chemistry suite), total suspended solids (TSS), chlorophyll *a* and fecal coliform. *In situ* field measurements included: pH, conductivity, temperature, dissolved oxygen (DO), salinity and Secchi depth. Lakes were chosen in consultation with HRM staff and the Watershed Advisory Boards, based on degree of risk from development, municipal infrastructure, water uses and stakeholder interest. Sampling by HRM staff during the 2007 program expanded to 70 lakes; the additional 20 lakes were the remainder from the 2001 baseline sampling (see Section 2.3.6 *Baseline Sampling*). In 2007 the sampling frequency also increased to 3 times per year (spring/summer/fall).

2.3.2 Development-Specific Monitoring

As part of the development agreement process, developers may be required to undertake a water quality monitoring program if the proposed development is anticipated to produce a change in the aquatic environment. Water monitoring programs are developed with the aid of the local Watershed Advisory Board and municipal planners. Development-specific water quality monitoring programs are assessed in more detail in Section 2.5 of this report.

2.3.3 Halifax Dartmouth Decadal Survey

In March 2000, water samples were collected by helicopter and small boat from 51 Metro Area lakes, repeating the synoptic surveys of the same lakes conducted in 1980 and 1991. Samples were analyzed for temperature, pH, conductivity, sodium, calcium, magnesium, potassium, aluminum, chloride, sulphate, alkalinity, ammonia, nitrate, phosphate, silicate, total nitrogen, total phosphorous, chlorophyll *a*, dissolved organic carbon, colour, and trace elements (cadmium, lead and uranium). The goal of the survey is to provide water quality data on the lake as a whole, as this time of year water temperature is least likely to be stratified and samples will most likely represent whole lake averages.

2.3.4 Municipal Beaches (HRM)

Nova Scotia Environment (NSE) tests 24 supervised lakes within the province every week, between the dates of July 1 – September 1. This testing has been done exclusively for HRM. The results are forwarded to the designated municipal contact and closure signs are posted if the *E. Coli* count reaches >2000/L based on a geometric mean of at least five samples collected within 30 days. NSE has recently announced their intent to stop performing this service for HRM. HRM intends to continue the monitoring program by providing the sampling services (and associated funding for laboratory analysis) in-house.

2.3.5 Potable Water

Halifax Water undertakes a comprehensive water testing program. Bacteriological testing is done twice per week at 48 locations within the urban core, and weekly at each of the small systems. These samples are collected by the HRWC's Water Sampler and delivered to the QEII Pathology Lab for analysis. The reports from the QEII Lab are communicated to Halifax Water and the Nova Scotia Environment (NSE) simultaneously.

Additional testing includes: use of continuous flow-through sensors to monitor chlorine residual, pH, and turbidity of treated water leaving each treatment plant as well as locations within the plant, to monitor and optimize the treatment process; bi-annual sampling of Lake Major and Pockwock Lake raw and treated water for all parameters in the Guidelines for Canadian Drinking Water Quality; and bi-annual testing and sampling for *Giardia* cysts and *Crytosporidium* for treated and raw water for all surface water systems.

2.3.6 HRM Receiving Water Baseline Sampling Program

The HRM Receiving Water Baseline Sampling Program began in August 2001 with the objective of establishing a baseline level of fecal coliform counts in lakes and watercourses that are in proximity to HRM's wastewater infrastructure. The data also provided a potential indication of a wastewater release from HRM or from a private sewer. Water samples were collected and analyzed three times per year, typically during the spring, summer and fall seasons, from the outlet of 62 lakes. The bacterial sampling program was merged with the lake sampling program in 2007.

2.3.7 Harbour Solutions

As a condition of approval for the Harbour Solutions Project under the *Canadian Environmental Assessment Act*, HRM has undertaken a water quality sampling program for Halifax Harbour. Between June 2004 and September 2006, weekly samples were collected for fecal coliform bacterial analysis, and bi-weekly samples for more extensive chemical analyses including TSS, Ammonia (Nitrogen), and 25 metals. Since October 2006, sampling has been bi-weekly for both bacteria and chemistry. Samples are collected at the surface and at a 10-metre depth.

2.3.8 NSE Lake Survey Data

The Nova Scotia Lake Survey program is a partnership initiative between NSE and Nova Scotia Fisheries and Aquaculture (NSFA) to inventory lakes throughout the province and determine baseline water quality, in support of both sport fisheries and water resource management.

NSFA staff collect water samples along with fisheries related information from lakes, generally during the summer months. Water quality samples are taken according to standard NSE protocols at varying lake depths, depending upon thermal stratification. NSE funds the analytical costs, and data are shared and used by both departments. Parameters tested include pH, conductivity, sodium, magnesium, potassium, calcium, alkalinity, total dissolved solids, TSS, sulphate, chloride, silica, orthophosphate, total phosphate, nitrate/nitrite, ammonia, total organic carbon, colour, turbidity, chlorophyll *a* and phaeophytin. Temperature and dissolved oxygen profiles are recorded in the field and bathymetric or bottom contour maps have been produced.

2.3.9 NS Automated Surface Water Quality Program

The Nova Scotia Automated Surface Water Quality Monitoring Network was started in 1999. It currently includes 5 active stations located across the province. The network is used to assess ambient water quality in lakes and streams throughout the province. Automated water quality probes, or sondes, are co-located with existing Hydrometric (stream flow gauging) sites to provide near real-time flow and quality data. Water samples are also collected by departmental staff at varying lake and stream locations and submitted to a laboratory for analysis.

Automated equipment records water quality parameters on an hourly basis. These parameters include: dissolved oxygen, temperature, transparency, pH, and conductivity. Grab sampling for nutrients, chlorophyll *a*, alkalinity, colour, major ions, and selected metals, occurs at a frequency of every 4 to 6 weeks during equipment maintenance visits over the ice-free season.

2.3.10 Flowing Water Bodies

Within HRM, flowing water systems (*i.e.,* rivers, streams and brooks) are affected by past and present developments. While short-term monitoring does exist, it is usually related to assessing impacts from construction activities or effluent from stormwater and industrial operations. There is a lack of monitoring programs focused on establishing trends on the health of the stream and river systems in HRM. Within HRM four flowing water bodies were reviewed: the Sackville River, Nine Mile River, MacIntosh Run and Musquodoboit Harbour.

Within the Sackville River system there are currently no comprehensive water quality monitoring programs in place. The Sackville Rivers Association has been involved in numerous sampling events related to water quality, but often these events are limited to the summer months. A hydrometric gauging station is present within the River and has been active since 1970, providing continuous measurements of depth and discharge. At the direction of DFO, Sandy Lake, through which the Sackville River runs, was limed to increase pH; monitoring was performed for multiple years at the lake inlet and outlet. Environment Canada has recently established a continuous water quality monitoring station on the Little Sackville River, and is now measuring temperature, pH, DO, conductivity and turbidity on a continuous basis at this location.

The area surrounding the Nine Mile River is expected to experience increased development pressures in the future and as such, an upgrade to the current Waste Water Treatment Plant (WWTP) was proposed. An assimilation study was conducted by Dillon Consulting in 2002 which included six months of water quality monitoring in relation to the feasibility of upgrades to the WWTP and corresponding effects on the surface water.

MacIntosh Run also faced pressures from increased development. Water quality was sampled in 2002 for identification of sewage loading effects. In 2004, pH and temperature were measured during the summer months as part of a Trout Nova Scotia conservation strategy. The MacIntosh Run Watershed Association has been involved in water quality sampling events although the extent of the program could not be confirmed.

At this time, no monitoring programs could be confirmed within the Musquodoboit River.

2.3.11 TEAM – Trends in Eutrophication and Acidification in the Maritimes

A five-year NSERC Strategic Grant to Researchers at Queen's and Trent Universities was provided to study the development and application of water quality assessment tools in Nova Scotia and Southern New Brunswick using paleoecological and modeling techniques. Recent relevant publications from this research program include:

Jeziorski, A., Yan, N.D., Paterson, A.M., DeSellas, A.M., Turner, M.A., Jeffries, D.S., Keller, W., Weeber, R.C., McNicol, D.K., Palmer, M.E., McIver, K., Arseneau, K., Ginn, B.K., Cumming, B.F., and Smol, J.P. 2008. The widespread threat of calcium decline in fresh waters. Science 322: 1374-1377.

Gerber, A.M., Ginn, B.K., Whitfield, C.J., Dillon, P.J., Cumming, B.F., and Smol, J.P. 2008. Glasgow Lake: an early warning sentinel of lake acidification in Cape Breton Highlands National Park (Nova Scotia, Canada). Hydrobiologia 614: 299-307.

Tropea, A.E., Ginn, B.K. Cumming, B.F., and Smol, J.P. 2007. Environmental changes in the Halifax municipal water supply (Pockwock Lake) related to acidic deposition. Lake and Reservoir Management 23: 279-286.

Ginn, B.K., Cumming, B.F., and Smol, J.P. 2007. Assessing pH changes since pre-industrial times in 51 low-alkalinity lakes in Nova Scotia, Canada. Canadian Journal of Fisheries and Aquatic Science 64: 1043-1054.

Ginn, B.K., Cumming, B.F., and Smol, J.P. 2007 Long-term acidification trends in high- and low-sulphate deposition regions in Nova Scotia, Canada. Hydrobiologia 586: 261-275.

2.4 ASSESSMENT OF EXISTING MONITORING PROCEDURES/PROTOCOLS

Multiple guidance documents were reviewed to determine the best approach for the development of a HRM WQMFP (*e.g.,* Brown *et al.* 2000, CCME 2006, Cervoni *et al*. 2008, Dillon 2002, Government of British Columbia 2008, HRM 2006, and HWAB 1999). One of these documents was the *Canada-wide Framework for Water Quality Monitoring*, published by the Canadian Council of the Ministers of the Environment (CCME) in 2006. The goal of CCME is to enhance water resource management across the country through the establishment of a national framework for water quality monitoring programs. The *Canada-wide Framework for Water Quality Monitoring* report presents high level recommendations for improving the cross-country consistency and strength of water quality monitoring. The document identifies the priority of maintaining consistency in all aspects of a water quality monitoring program including sampling, data management, and reporting. It also focuses on improving the accessibility of data, making data from one monitoring program available to all with the exception of proprietary data.

Several of the CCME recommended principles for inclusion in new water quality monitoring programs were taken into consideration during the development of the HRM WQMFP including:

- The need to communicate data in a timely manner and to multiple stakeholders;
- The requirement for support from and shared responsibility among multiple government levels, industry and academia;
- The effectiveness and efficiency (monetary) of a new program;
- Cost recovery potential;

- The need for monitoring and reporting standards as well as standardization of data sets;
- Accountability and transparency of the program components; and
- The flexibility to adapt to changes in water quality (CCME 2006).

Using the guidance provided by CCME (2006), Dillon (2002), and HRM (2006), an approach was developed that would produce a WQMFP encompassing the various components identified in the scope of work. This approach followed ten key steps (see Table 1.1) and resulted in the development of a comprehensive WQMFP for HRM.

Based on the information collected regarding the aforementioned monitoring programs, it is apparent that although a variety of monitoring programs are in place, there is not a consistent surface water monitoring program in HRM. The monitoring programs are often limited in duration and/or spatial boundaries and only a few basic parameters are consistently measured (pH, temperature, DO). Protocols are not uniform among individual groups or departments however there is an increased attempt to improve data compilation and availability within HRM (*e.g.,* HRM Lakes monitoring program database and the Harbour Solutions WaterTrax database). Interpretation of the resulting data is often absent or limited in scope. Generally interpretation is on a site by site basis with the exception of the decadal survey which attempts to assess water quality trends in multiple lakes over a 30 year period from 3 days of monitoring. Water quality monitoring programs have been designed by a number of individuals including consultants, academics, various levels and departments of government, Watershed Advisory Boards and non-government organizations (NGOs). These monitoring programs are often complex in nature and offer results based on differing issues within and between watersheds.

2.4.1 Halifax Watershed Advisory Board Ad-Hoc Subcommittee Sampling Recommendations

The Halifax Watershed Advisory Board (HWAB) ad-hoc subcommittee (AHS) formed in 1998 and published recommendations for water quality monitoring in HRM. The AHS considered the physical, chemical and biological indicators of water quality, the nature, methodology and costs of monitoring water quality, and the potential users of the resulting data. Approaches taken in other jurisdictions were examined and adopted where applicable.

As a result of its deliberations, the AHS recommended the consolidation of water quality monitoring policy throughout HRM, and that an ad-hoc Technical Subcommittee (TSC) be formed to provide scientific and technical advice, on request, to all water advisory groups in HRM. It was further recommended that any proposed development, arising from a development agreement, be classified as one of three categories in terms of potential impact on freshwater quality in any stream or lake: (i) substantial, (ii) moderate, or (iii) unlikely to impact to any significant extent. Where impact of development is potentially substantial, the AHS recommended that initial baseline monitoring be carried out, followed by on-going monitoring of a shortlist of key indicator parameters. A base list of parameters is presented in the AHS document for each of these phases, together with a schedule for the shortlist program.

Where potential for impact is moderate, the AHS recommended that sampling for only the shortlist of key parameters be carried out by trained volunteers under a part-time coordinator. It was suggested that developer and construction organizations be approached to provide the necessary support funding, in return for which they would have the right to advertise their patronage and to use the results for promotional purposes. Further it suggested that all data must have quality assurance, be assessed within a reasonable period, and that the data and assessment be readily accessible to all interested parties.

2.4.2 CCME Canada-wide Framework for Water Quality Monitoring

As previously noted, the CCME published the *Canada-wide Framework for Water Quality Monitoring* in 2006. While this is currently a set of high level recommendations for the development of nation-wide water quality monitoring programs, it was proposed that numerous technical documents detailing each element of water quality monitoring would be developed. Topics of interest identified for these documents included the following (CCME 2006):

- Water quality monitoring program design;
- Field sampling;
- Automated sampling;
- Laboratory analysis;
- Quality assurance/quality control;
- Data analysis and interpretation;
- Statistical methods;
- Data processing and management;
- Data reporting; and
- New/innovative techniques and equipment for water quality monitoring, analysis (*e.g.,* neural networks for QA of automated data) and reporting.

At this time, none of the above-listed documents have been published by the CCME. However, HRM should keep abreast of CCME updates that address this technical document list, as many of the topics cover key elements of the WQMFP. The mandate of the CCME 2006 Canada-wide framework document is the introduction of concepts within water quality monitoring that can lead to national consistency. It is recommended that HRM carefully review published technical documents released under the CCME Canada-wide framework prior to adoption or implementation given some of the unique characteristics of water quality in this region (*e.g.,* low pH waters).

2.4.3 Government-based Water Sampling Protocols

Current water quality monitoring procedures within HRM are based on internal protocols or Environment Canada's report: *Sampling for Water Quality* (1983). While the Environment Canada manual is adequate for illustrating the procedures, techniques, and equipment involved in sampling, as well as the specific requirements of individual parameters, it does not take into account that sample bottles are frequently supplied by the laboratory providing the analysis. The United States Environmental Protection Agency (USEPA) has written a sampling manual reflective of the *Environmental Protection Act* (EPA). This manual does not cover specifics for individual parameters. It is recommended that protocols be derived from the methods detailed in *Standard Methods for the Examination of Water and Wastewater 21st Ed*. (Eaton *et al.* 2005) and Environment Canada's *Field Inspectors Sampling Manual* (2005). Additional information concerning these two recommended resources is provided in Section 4.9, Water Quality Sampling Procedures and Protocols.

2.5 ASSESSMENT OF DEVELOPMENT-SPECIFIC MONITORING PROGRAMS

There are numerous development-specific monitoring programs underway in HRM related to construction on previously undeveloped lands. It is standard practice to engage in water quality monitoring during construction and post-construction, but consistency is lacking in relation to data collection and the timing of sampling events. As such, a cursory review of three key current monitoring programs was undertaken to assess target areas for refinement and improved consistency.

The three monitoring programs reviewed take into account different phases of development. Russell Lake West Development is a development along the western shore of Russell Lake in Dartmouth, Nova Scotia. The development is primarily single unit dwellings and townhouses. Morris Lake Estates, a completed development in Dartmouth, Nova Scotia, is adjacent to Morris Lake and consists of single unit housing. A water quality monitoring program was initiated with pre-, current-, and post-development monitoring. Due to ongoing development in the area surrounding Morris Lake, HRM has included the lake in the Lakes Water Quality Plan and as such monitoring continues. Bedford West is a third example of an existing development-specific water quality monitoring program. The development is located north of Paper Mill Lake and Kearney Run, a watercourse which flows from Kearney Lake into Paper Mill Lake. The monitoring program involves monitoring water quality at multiple locations, depending on the stage of development.

2.5.1 Russell Lake Development West

The water quality monitoring program consists of pre-construction, construction and post-construction monitoring. Pre-construction (baseline) analysis included TSS, total phosphorus, chlorophyll *a*, fecal coliforms and Maxxam's Rapid Chemistry Analytical Package with metals scan (RCAp-MS). The RCAp-MS package includes: sodium, potassium, calcium and magnesium concentrations, which determine water hardness and total dissolved solids (TDS).

Also included are: alkalinity, sulfide, chloride, reactive silica, orthophosphate, nitrate/nitrite, ammonia, iron, copper, zinc, colour, dissolved organic carbon, turbidity as well as analysis of 25 prevalent metals. *In situ* measurements of temperature, pH, conductivity, dissolved oxygen (DO) and Secchi depth were also taken. These samples and measurements were taken at four locations corresponding with the hydrological inputs and outputs of the lake as well as one in-lake station. These parameters were adopted for the sampling program which occurred monthly during the first year of development. Upon reassessment of the monitoring program, the sampling frequency was reduced for the second year to four events, which is currently maintained: spring, early summer, late summer and fall. The number of parameters being tested were also reduced at this time; dissolved phosphorous and the metals scan were removed. During the initial two years of development, the extent of exposed soil resulted in rain-based monitoring; any rain event greater than 25 mm/day triggered a sampling event. Rain event samples were collected for TSS, fecal coliform, and RCAp-30, which is similar to RCAp-MS analysis but without the scan of 25 metals.

In the case of Russell Lake, results are forwarded from the consultant who collects the data to the developer, then to HRM and finally, to other interested or affected parties. This sequence of communication occurs in the event that:

- The geometric mean of at least five fecal coliform measurements within 30 days exceeds 200 counts per 100 ml , or a onetime exceedance of 400 counts per 100 ml; or

- Where total phosphorous (TP) results at the In Lake station exceed the 15 microgram per litre (µg/L) HRM Threshold Value (based on TP lake capacity modeling completed by Jacques Whitford in 2006).

2.5.2 Morris Lake

The water quality monitoring plan consists of pre-construction (baseline), construction and post-construction analysis of TSS, total organic phosphorus, ortho-phosphate, meta and poly-phosphorus, total phosphorus, chlorophyll a, fecal coliforms and Maxxam's Rapid Chemistry Analytical Package (RCAp-30). *In situ* measurements of temperature, pH, conductivity, dissolved oxygen (DO) and Secchi disk depth are also completed. Temperature profiling is also carried out at the in-lake stations. Sampling for the aforementioned parameters and *in situ* measurements occurs at seven locations corresponding to the hydrological inputs and outputs of Morris Lake as well as two in-lake stations to identify stratification. Sampling occurs in the spring, summer, and fall at all seven locations. Parameters were altered in 2006 to include phaeophytin while reducing phosphorous analysis to a measure of total phosphorous only. The alteration of parameters in 2006 was carried out to allow the inclusion of Morris Lake in HRM's Lake Quality monitoring program. The results obtained by the consultant carrying out the sampling are provided to HRM, who then communicates the results to the developer and other interested or affected parties.

2.5.3 Papermill Lake

The water quality monitoring plan consists of pre-construction (baseline), construction and post-construction analysis of: RCAp, total phosphorous, TSS, fecal coliform and chlorophyll *a.* The monitoring is to be conducted in Kearney Lake at two locations in the north and south end of the lake. Additional sampling is to be conducted in the spring, summer and fall during the construction period, at two locations along Kearney run. Summer sampling includes the aforementioned parameters with the addition of a metals scan which provides concentrations for 25 metals. Field measurements collected during sampling include: pH, temperature, dissolved oxygen and conductivity.

In the case of Papermill Lake, results will be forwarded immediately to the designated municipal contact in the event that:

- The geometric mean of at least five fecal coliform measurements within 30 days exceeds 200 counts per 100 ml , or a onetime exceedance of 400 counts per 100ml; or
- Where total phosphorous from any sample location exceeds 10 micrograms per litre

3.0 Best Practices Review

Four other municipalities or areas have been selected for review of watershed management and water quality monitoring practices. The four regions selected for comparison of best practices are the City of Waterloo, the Town of Richmond Hill, the Toronto and Region Conservation Authority and the Province of New Brunswick. To complete the review, key contacts were identified and an interview was conducted. Following this, available documentation was collected and the information obtained was reviewed and summarized. The best practices review offers lessons learned and key points that can be applied to the HRM-wide monitoring program and the ongoing management of the program through the WQMFP.

3.1 CITY OF WATERLOO

The City of Waterloo implemented a proactive stream-based watershed management plan through which they lead the development of a three-part monitoring program remarkably similar to the plan being proposed for HRM. As such, some care was taken to detail the City of Waterloo's Watershed Monitoring program and the process through which it was developed. Lessons learned over the twelve years of the City's program will also be presented.

3.1.1 City of Waterloo Monitoring Program Key Points

Several key points can be used to summarize the City of Waterloo's Laurel Creek Watershed Monitoring Program, as presented below:

- Watershed study focused on streams, which began more than ten years ago;
- Use of a three-part monitoring program;
- System Monitoring (carried out by the municipality to establish long-term baseline conditions and identify trends within the watershed);
- During Development Monitoring (carried out by the developers to regularly monitor and maintain environmental conditions and facilities, and to determine mitigation measures where indicator targets and objectives are not being achieved; continues until two years after 90% of the land development is complete);
- Post-Development Monitoring (carried out by the municipality to regularly monitor and maintain environmental conditions and facilities, and to determine mitigation measures where indicator targets and objectives are not being achieved);

- Carry out water chemistry and bacterial testing, as well as biological monitoring (invertebrates); tie this sampling to flow measurement;
- Use priority criteria for site selection; and
- Use three-stage, 10-year plan for data collection to assess natural variation in baseflow and total flow.

3.1.2 City of Waterloo Monitoring Program Development

The Laurel Creek Watershed monitoring program currently in place was developed through a series of steps, starting with the recommendation to develop a monitoring plan based on an initial study of the Watershed. Following this recommendation, the City agreed to develop the program through the City Official Plan and an inter-agency team was assembled that included representatives from various municipalities, the provincial Ministry of Natural Resources and Ministry of Environment and Energy, the Grand River Conservation Authority and the University of Waterloo. In the Province of Ontario, the protection, rehabilitation, and enhancement of the environment is supported by provincial policy, but monitoring is not a requirement of provincial legislation. Policy specific to watershed management does exist at other levels of government which lends strong support and justification to watershed monitoring. As such, it is the City of Waterloo's Official Plan and District Plans that support watershed monitoring.

Once the purpose and structure of the program were established, key issues were determined (*i.e.,* technical, communication and financial) and task teams developed (*i.e.,* Indicator Team, Data Team, Education Team and Report Team). A critical step was then the implementation of a one-year Pilot Study (1996) to develop a sampling protocol for the System Monitoring Program, including a statistical analysis of the sample size, frequency and locations required for monitoring of water quality and quantity indicators. Following the pilot study sampling, an open house was held to increase community awareness and to solicit feedback. An analysis of potential statistical sampling methods was carried out to ascertain the best methods that could be used to improve accuracy and derive accurate conclusions from data that would be collected. Long-term recommendations, the management plan and an appropriate database were all developed which then allowed for the final step, the implementation of the Laurel Creek Watershed monitoring program in 1997.

3.1.3 City of Waterloo Monitoring Program Description

The primary watershed for the City of Waterloo is the Laurel Creek Watershed, which covers approximately 74 square kilometres in the Regional Municipality of Waterloo (City of Waterloo 1997). The majority of the Watershed (80%) falls within the City. A watershed study was implemented in 1991 in response to increasing concern from many stakeholders (*e.g.,* community, government, public and private agencies), largely resulting from negative impacts from past and present land use development, both urban and rural. A report on the findings of the study (1993) concluded that a comprehensive strategy for the future management of the watershed was needed. A key recommendation of the study was to develop and implement a long-term environmental monitoring program. It was also recognized that the study should function as a springboard for action, as it was not intended to be an endpoint.

The three-part monitoring program Waterloo has developed includes 1/ System Monitoring, carried out by the municipality, 2/ During Development Monitoring, carried out by developers, and 3/ Post-Development Monitoring, and carried out by the municipality. The System Monitoring provides long-term baseline environmental conditions, which will help to identify future trends throughout the watershed and will allow a comparison against future indicator levels. Indicators and targets were selected to provide an opportunity for the establishment of baseline conditions and the subsequent detection of deterioration during and after development has occurred. The three-part program addresses the need for the environmental monitoring in the Laurel Creek Watershed to serve as a critical means of ensuring that the carrying capacity of the watershed is not being exceeded by approved development. HRM faces this same need to prevent an exceedance of carrying capacity resulting from development; however, HRM needs to address a large number of watersheds, rather than just one.

The City of Waterloo's watershed management program has four primary objectives, as follows:

- To detect on an ongoing basis and as development occurs, changes in environmental health of the watershed;
- To maintain and improve the health of the watershed (terrestrial features, water quality, hydrology, wildlife, aquatic habitat, groundwater, *etc.*);
- To develop a comprehensive database for future comparison and analysis; and
- To increase public awareness and encourage community stewardship.

The City of Waterloo set out to address several goals and objectives which had been outlined in the initial watershed study of 1991, including those focused on flooding, water quality, terrestrial features, groundwater, amenity enhancement and public education. By addressing these goals and objectives, the approach to watershed management became an ecosystem approach, which emphasized the functions of various watershed components as a connected, rather than disconnected system. The city recognized that in order to maintain connectivity, the monitoring program also had to be observant of the ecosystem approach so that it too could be viewed in the context of the system as a whole.

The watershed study set out environmental constraint levels which are imposed on all lands to identify the kinds of development and land use activities that may occur in order to protect sensitive areas of the watershed. This establishment of three "Environmental Constraint Levels" with corresponding action recommendations is a very similar approach to the three-tiered system of vulnerability being proposed for HRM.

The System Monitoring Plan includes four ecosystem components and related indicators including:

- Hydrology (storm flow, baseflow, temperature and precipitation);
- Aquatic Habitat (benthic organisms);
- Water Quality (phosphorus, suspended sediments, temperature, dissolved oxygen and bacteria); and
- Terrestrial Features (green space size and green space health).

Targets and objectives were set for each ecosystem approach. The Hydrology component of the program indicated that natural variation in baseflow and total flow is difficult to define; therefore the hydrological monitoring component was divided into three stages: a one year (*i.e.,* year 1), long-term pilot study to assess seasonal variation, followed by four years (*i.e.,* years 2 – 5) of monitoring to establish baseline conditions including one “wet” and one “dry” year. Assuming baseline conditions were established in the first five years of monitoring, the final stage of the hydrological monitoring would be five years of data collection (*i.e.,* years 6 - 10) to assess change in baseflow at particular locations, which would indicate an impact had occurred. Data were obtained via historical stream flow records and meteorological data, as well as field-based measurements. This ten-year approach to hydrological monitoring presents a comprehensive option to facilitate gaining an understanding of the relationship between hydrologic conditions and changes to land use and/or development activities in a particular area. The pilot study was used to help identify target areas for flow monitoring.

Discussion with Denise McGoldrick, the Environmental Project Manager for Water Resources at the City of Waterloo municipal office revealed several lessons that have been learned over the more than ten years that the program has been running. These lessons may be important to consider during the development and implementation of the HRM Water Quality Functional Plan and have therefore been provided below.

- Documented support for watershed monitoring needs to be established in the municipality’s Official Plan (or equivalent municipal policy);
- Early consultation with land developers and other stakeholders is essential;
- Instead of having each developer responsible for undertaking the development monitoring portion of the program, have the developer provide funds for the municipality to undertake the work. This will help encourage consistent data collection, level of effort, QA/QC, reporting, *etc.*;
- Provide a dedicated staff person to coordinate the monitoring program;

- At the City of Waterloo municipal office, there is one coordinator of the water resource portions of the monitoring program (only 5% of overall workload), but each development engineer in the Development Services department is responsible for reviewing the submitted developer reports. This creates a gap between the municipality's System Monitoring program and the Development Monitoring program;

- Collaboration with local university experts was very valuable during the program set-up phase;

- Identification of benthic invertebrate to the lowest taxonomic level possible increases the sensitivity of the assessments:

    - The City of Waterloo has employed the services of a benthic invertebrate expert (Dr. D. Barton) at the University of Waterloo to undertake the benthic sampling and analysis for the program. This expert has compared the results of the benthic summary indices using both family level and genus/species level in his analysis. Results indicate that a higher taxonomic level of identification can skew the results. This skewing is most notable in urban and developing catchment areas.

- Active participant in the National Water and Wastewater Benchmarking Initiative (http://www.nationalbenchmarking.ca/).

3.2 TOWN OF RICHMOND HILL

The Town of Richmond Hill contains the headwaters and tributaries of three watershed systems, the Humber River, Rouge River and Don River. It is one of Canada's fastest growing municipalities and is estimated to reach a population size of 200,000 by the year 2021 (Town of Richmond Hill 2009). The Town's Official Plan will direct future land use changes and how land is used in Richmond Hill.

The Town of Richmond Hill is focused on maintaining a healthy environment, and preserving and protecting the Town's natural features from the Oak Ridges Moraine to hundreds of parks and trails. A variety of programs including the Clean Air and Energy Efficiency initiatives, waste management, stormwater management, natural heritage and stewardship programs, and being the first municipality in Ontario to obtain ISO 14001 registration, demonstrates the Town's continued leadership in the management of the environment (Town of Richmond Hill 2009).

Information concerning the municipality's water quality monitoring program (including development-specific monitoring) was provided through an interview with the Manager of Water Resources, John Nemeth. The Town of Richmond Hill has taken an approach to municipal and development-specific monitoring that is very similar to that taken by the City of Waterloo. The senior municipal staff members responsible for the water quality monitoring plan in each of these cities work closely together to help refine programs and learn from each other. These individuals have expressed interest in maintaining communication with the senior staff member at HRM responsible for the continued development and implementation of the WQMFP.

Additionally, it was suggested that HRM become an active member of the National Water and Wastewater Benchmarking Initiative.

3.2.1 Town of Richmond Hill Key Points

There are several key strategies and lessons that can be taken from the Town of Richmond Hill's approach to water quality and quantity monitoring, which are summarized below:

- Allowing developers to pay the municipality for development monitoring has had many benefits for the Town of Richmond Hill:
  - Eliminates inconsistencies in data collection resulting from many different consultants being involved;
  - Can be cost-saving to developers in the long-run as they are not managing the logistics and reporting associated with data collection;
  - Municipal-run monitoring serves as a watch-dog for the design engineering consultants hired by the developers to design and build stormwater ponds (*i.e.,* water quality monitoring can reveal if the stormwater ponds are not working properly; municipality can then put a hold on the development project until the problem is fixed, and design engineer consultants are held accountable for cost);
  - Important Note: The municipal framework is different in the Town of Richmond Hill compared to HRM therefore, some of the benefits described above may be difficult to realize within the HRM system.
- The watershed water quality is integrally tied to stormwater management:
  - Stormwater holding ponds are the primary means of managing stormwater on a site-by-site basis;
- Water quality and water quantity are viewed with equal importance:
  - Stream gauges monitor flow and water quantity within the watershed and related to specific development sites.
- The Town of Richmond Hill has fine-tuned their program over 10 years (*i.e.,* a comprehensive program can take time to implement).
- Active participant in the National Water and Wastewater Benchmarking Initiative (http://www.nationalbenchmarking.ca/).

3.2.2 Town of Richmond Hill Monitoring Program Development

The Richmond Hill Plan focuses on water quality and quantity within the municipal boundaries and has been evolving over the past 15 – 20 years. Water quality and quantity monitoring was initially monitored through the stormwater management process. More specifically, the program has focused on stormwater ponds, which are prevalent in developments in the region and have the potential to affect water quality in the aquatic environments to which they discharge.

Over the years, the Town's sampling program has broadened to include lake and stream monitoring as well, resulting in a watershed scale water quality and quantity monitoring program. The overall goal of the municipality is to maintain the environment at the highest possible level of quality and to prevent any deleterious contribution to downstream environments.

As part of the monitoring program, the municipality has built a considerable inventory of water quality monitoring equipment which is now integrated into the program throughout the watersheds. The Town owns and operates multiple weather stations and has stream gauges at more than fifteen watercourses. The stream gauges were originally used to monitor water quantity discharge to the downstream environment at the watershed boundaries. The gauges have now been moved to key locations throughout the watersheds to contribute to a more comprehensive water quality monitoring program.

The equipment procurement process adopted by the municipality has been facilitated through the development-specific component of the monitoring plan. Whenever a development-specific monitoring program is required, any equipment required for the monitoring program agreed upon is purchased and used specifically for that program. This results in the overall growth of municipal-owned monitoring equipment over the long-term, rather than resulting in a strain on limited resources.

The primary difference between the monitoring approaches taken by the City of Waterloo (described above) and the Town of Richmond Hill is related to the funding strategy. Both municipalities have an overall watershed monitoring program as well as development-specific programs that are designed on a project-by-project basis. The City of Waterloo enforces mandatory development-specific monitoring whereby the developers facilitate and pay for monitoring, typically by hiring consultants to implement the required sampling programs. In the Town of Richmond Hill, developers provide funding to the municipality to carry out the agreed-upon, site-specific monitoring plan.

The Town of Richmond Hill uses a single consultant to conduct all of the field work for the site monitoring, allowing them to eliminate the inconsistency associated with each developer hiring a consultant for the monitoring. By feeding all of the work through the municipal office, the municipality is able to maintain control and consistency concerning training and experience of those involved in the program, level of effort, laboratory choice, data reporting and communication. This has resulted in a more robust and efficient system.

The municipality uses its own permanent staff members for program facilitation and results analysis, including model development and use. Graduate students from a local relevant program at the University of Toronto are used in the office in the summer to help address the seasonal increase in workload. The municipality has expanded the number of staff members over the years to meet the growing demands related to increasing development projects in the area.

3.3 CITY OF TORONTO (TORONTO AND REGION CONSERVATION AUTHORITY) WATERSHED MONITORING

The Toronto and Region Conservation Authority (TRCA) is one of 36 Conservation Authorities (CAs) in Ontario formed as a result of the *Conservation Authorities Act* and overseen by the Ontario Minister of Natural Resources (Cervoni *et al*. 2008). In 2000, the TRCA began the development of a Regional Watershed Monitoring Network that would address several monitoring indicators. In 2001, TRCA's Regional Watershed Monitoring Program (RWMP) began and has been monitoring a wide range of watershed components since, including aquatic habitat and species, surface water quality, stream flow and precipitation, groundwater quality and quantity, and terrestrial natural heritage (TRCA 2008). The surface water quality monitoring components of the RWMP were reviewed in detail for best practices that could be implemented in the HRM Water Quality Monitoring Functional Plan.

3.3.1 TRCA Watershed Monitoring Program Key Points

Despite some of the key differences in the TRCA system compared to the HRM environment, there are many ideas and recommendations from the TRCA's review of their Regional Watershed Monitoring Program that can be applied to the development of HRM's WQMFP. Specifically, the following ideas from the TRCA program were considered in the development of the HRM plan:

- Use partnerships to provide in-kind services for monitoring, analyzing, managing data and interpreting results;
- The inclusion of winter-based sampling is an improvement over three-season sampling to better understand the water quality picture in a watershed;
- Standardize laboratory techniques and detection limits;
- Volunteer based programs can generate issues such as biased, unrepeatable, sporadic results, and limited participation;
- Beach monitoring should be integrated with the larger water quality monitoring program (health departments of the City of Toronto run the beach monitoring program);
- Develop user-friendly databases and interfaces that capture all surface water quality data generated; include adequate QA/QC protocols and a mechanism for all network partners and interested outside groups to gain access to the data;
- Flow measurement should be integrated with water sampling in terms of sampling locations and times (both the TRCA and City of Toronto have flow monitoring programs,

but they are not coordinated with the other surface water sampling programs and as such, flow data cannot be integrated with water sampling data);

- Allow a minimum of three years of data to be collected per program component before completing an overall review of findings;
- Further define stress/pressure and response/management indicators and monitoring protocols to measure/monitor these indicators; and
- Be mindful of the costs and benefits associated with benthic invertebrate monitoring programs (*e.g.,* what sampling interval is appropriate, what level of identification should be used?); it has been suggested that genus/species level identification may be required for benthic invertebrate monitoring to be an effective tool for impact assessment.

3.3.2 TRCA Watershed Monitoring Program Development

As is common in other jurisdictions, several different organizations and government branches in the Toronto region were monitoring various aspects of the natural environment for a variety of purposes, which lead to both monitoring overlap and data gaps. There was also a lack of communication between many of the different groups and as such, opportunities for sharing results and resources were missed. The TRCA decided that a network approach bringing together cooperative organizations to collect, store, distribute and report on environmental monitoring data would be the best approach for the Toronto region (TRCA 2008). This is an advantageous approach that can be applied within HRM as well, although on a smaller scale.

The network approach allows the TRCA to broaden its monitoring program through several other existing large-scale monitoring programs ongoing in various regions of their jurisdiction. As such, surface water quality is monitored through collaboration of the following groups: the provincial Ministry of the Environment (MOE), the TRCA, Regional Health Units, private laboratories, volunteers, the City of Toronto, and a Great Lakes program related to herring gull egg tissue chemistry monitoring. These organizations and government groups play varying roles depending on the specific monitoring program (*e.g.,* field sampling, laboratory analysis, data management, data interpretation, *etc.*).

3.3.3 TRCA Watershed Monitoring Program Description

The primary issue facing the Toronto region in relation to surface water quality is flooding and urban-influenced runoff. The substantial increase in paved surfaces through urbanization has led to serious flooding issues following rain events. The runoff that leads to these floods is carrying contaminants related to the urban environment (*e.g.,* garbage, salt, grease, fertilizers, *etc.*). The main receiving waters for this runoff and associated flooding are streams of varying sizes and flow. There is very little lake-based monitoring being carried out, outside of the work being done on the Great Lakes. This represents a substantial difference between the TRCA-based surface water monitoring program as well as the Town of Richmond Hill and City of

Waterloo programs and that being developed and proposed for HRM. Within the boundaries of HRM, lakes make up the vast majority of the aquatic environment.

3.4 NEW BRUNSWICK WATERSHED MONITORING

The City of Moncton, the Petitcodiac Watershed Alliance (PWA) and the Province of New Brunswick work together in a partnership that results in comprehensive monitoring of two New Brunswick watersheds. This partnership is similar to the network approach used by the TRCA, but on a smaller scale. Several components of the New Brunswick system may be transferable to Nova Scotia, where community and provincial scale is more comparable than in Ontario.

The Petitcodiac and Memramcook Watersheds are located in southeastern New Brunswick and cover approximately 2400 km^2. The area stretches from the Village of Petitcodiac to the Village of Dorchester and includes the Greater Moncton area (*i.e.,* Moncton, Riverview, and Dieppe). Approximately 111,000 people inhabit both watersheds (PWA 2008). A description of the three groups and the role each plays in the partnership is described below.

3.4.1 New Brunswick System Key Points

There are several key points that can be summarized from the review of the New Brunswick system involving a partnership between the province, a city municipality and a watershed alliance group.

- Identify and involve stakeholders: In NB, there is strong partnership between the Province of New Brunswick and regional watershed groups (run as non-profit organizations). The City of Moncton Forest Management Program works closely with local residents as well as Irving Pulp and Paper products;

- Gather water quality information: It is important to develop a baseline from which to measure results. All improvements or habitat decline can be measured against the baseline data. In addition, assemble land and water use information;

- Set goals for water quality: Determine how the data will be used (*e.g.,* for policy making decisions, to control land use, to advise the public of issues) to evaluate what data are important. Is this a science project or a public health and safety project? The use of key indicators is important for limiting costs;

- Ensure quality assurance/quality control: Data will then be useful to all stakeholders including developers, the province, consulting firms;

- Prepare and implement action plans;

- One point of contact for all watershed groups, municipal, provincial and possibly federal water-based data (*i.e.,* all reports and information can be funnelled through one person or small group). New Brunswick has the NB Aquatic Data Warehouse as a model;

- Provide yearly easy-to-read, short and simple status reports to the public and all stakeholders (Indicator Report from the Petitcodiac Watershed Alliance is provided in Appendix A for reference). This will 'keep the project alive'; and

- Regular, dependable funding is key to ensuring program continuity and success.

3.4.2 New Brunswick's Watershed Classification Program

The *Water Classification Regulation* is a regulation administered under the New Brunswick *Clean Water Act* by the New Brunswick Department of Environment (NBENV). The purpose of water classification is to set goals for surface water quality and promote management of water on a watershed basis (NBENV 2002). The *Water Classification Regulation* establishes water quality classes, and associated water quality standards, and outlines administrative processes and requirements related to the classification of water.

Water classification places the water of lakes and rivers or segments of rivers into categories or classes based on water quality goals. Each class is then managed according to the goal. The goals associated with a specific class are set according to the intended uses of the water, and the water quality and quantity required to be protective of the intended uses.

Public involvement is a cornerstone of the *Water Classification Regulation.* The Water Classification Program has been developed to help watershed and other multi-stakeholder community groups plan and set goals for surface water quality, and to help achieve water quality goals through the establishment of water quality standards, action planning and watershed management.

The process of water classification has several important steps. First, stakeholders are identified and involved early in the process, so that groups can build understanding and work to make decisions together. Stakeholders include various landowners, residents and those who come from outside the watershed to use or enjoy the water. Stakeholders can also include various groups of land users: farmers, foresters, industry (including those in the mining, pulp and paper, and aquaculture industries), anglers, canoeists, residential and recreational users, and others. Other stakeholders are the various levels of government: aboriginal, federal, provincial and municipal. Each of these groups has an interest in the water and, potentially, an influence on water quality.

Another important early step is measurement and interpretation of existing water quality. Historical information and newly collected data on water quality are used to build a picture of how the water quality may have changed in a watershed. Knowing the existing water quality helps a group make realistic decisions about the future of the watershed.

The next step is mapping of land and water information. Understanding the topography, geology, soils and vegetation cover in an area helps to explain water quality characteristics. Often ecological land classification can help to integrate the interpretation of these features.

Land use and geological mapping helps to explain water quality changes from the natural system, and shows where sources of pollutants occur.

Once the information is assembled, stakeholders are involved in setting water quality goals for waters in the watershed. The various stakeholders who have an interest in a watershed and its water are encouraged to work together to build consensus on water quality issues and goals.

By involving stakeholders early in the water classification process, everyone can understand why the water quality is the way it is, and what will result from actions to maintain, protect or restore that quality. This includes the economic, social and environmental consequences of decisions that are made and goals that are set. There are numerous non-profit watershed groups that have undertaken the water classification process (*e.g.,* Petitcodiac and Memramcook Watershed, Tantramar River, Nashwaak River, and Cap-Pelé, Eastern-Charlotte waterways).

There is one staff person at the provincial government level that works full-time to coordinate this program, although all data is collected by the Watershed Alliance groups. Work within the watersheds is funded through various funding agencies such as the NB Environmental Trust Fund, NB Wildlife Trust Fund, Shell Environmental Fund, Mountain Equipment Co-op Fund, TD Bank Environment Fund, *etc.*

3.4.3 City of Moncton Watershed Monitoring Program Description

The City of Moncton began monitoring 35 sites for *E. coli* and total coliform bacteria inside its designated watershed area in 1987 and subsequently expanded the program. The City's Forest Management Program Coordinator and summer students sample at each site once per month from the beginning of April to the end of September. Sampling frequency is increased if there is a major activity occurring within the watershed (*e.g.,* installation of the Kent Hills Wind Farm, major forestry operations). The intent of the monitoring program is to identify point and non-point sources of pollution rapidly so that management of these sources is effected as soon as possible.

The program began prior to installation of a full water treatment facility. The monitoring program enabled the sampling technicians to notify the City of Moncton about high suspended sediment concentrations (SSC), nitrate or phosphate problems and coliform bacteria issues in streams feeding the drinking water reservoir. The City of Moncton would react by adjusting water treatment (*i.e.,* addition of chlorine) to ensure the safety of the drinking water supply. Concurrently, the Forest Management Program (FMP) would locate the source of the problem and seek to manage it. The furthest site is approximately 24 km from the drinking water intake pipe. In 2000, a full water treatment facility was commissioned.

At the outset of the water monitoring program, forestry operations within the Turtle Creek watershed were believed to be the source of most point source pollution. After several years of water quality monitoring, improperly installed or leaking septic tanks and agricultural inputs were identified as the greatest sources of pollution. The City of Moncton was able to re-direct management efforts to repairing septic systems and land owner education.

Currently, the FMP continues to work in collaboration with the City of Moncton and has, over time, developed relationships with other watershed users. Each year, a workplan is developed by the FMP and City of Moncton and shared with the other watershed users to advise them of upcoming activities in the watershed. This process is particularly important for the forestry operators, primarily Irving Pulp and Paper Ltd., who can adjust their cutting schedule and locations based on FMP plans or vice versa. A Community Stewardship Committee comprised of 12 community members meets regularly to discuss relevant watershed topics. The FMP meets with all landowners once per year to advise them of activities as well. A sense of stewardship has spread to the landowners within the Turtle Creek watershed and the FMP coordinator is often called with reports regarding water quality issues or concerns.

Since 2000, the water quality monitoring program has expanded to other major streams in the Moncton area, outside of Turtle Creek watershed. This lead to the creation of an engineered wetland in Centennial Park to deal with siltation issues from a nearby project and a reduction in sewer cross-connections.

The FMP coordinator notes that developing a solid set of baseline data has opened avenues to other opportunities with the provincial Department of Health, Department of Agriculture, the New Brunswick Department of Environment and Environment Canada. These government bodies have committed to helping with any issues that arise under their jurisdiction. For example, a manure management problem will be directed to the Department of Agriculture who in turn works with the farmer to fix the problem. Environment Canada has provided instruction on the appropriate use of sediment stabilization techniques to the forest industry and residents.

The program is funded through the City of Moncton’s Engineering Department budget. There are a number of provincial and federal programs that can be tapped into for financial assistance if a university student is being hired (*e.g.,* Canada Summer Jobs program).

Funding from the NB Environmental Trust Fund was sought to fix sewer cross-connections and faulty septic tanks.

3.4.4 Petitcodiac Watershed Alliance Program Description

The Petitcodiac Watershed Alliance (PWA) was found in 1997. PWA is a non-profit environmental science and education organization that works to enhance and maintain the Petitcodiac and Memramcook Rivers and tributaries. PWA promotes watershed awareness, encourages the community to take part in identifying environmental problems and follows through with actions to restore and protect the watershed. The PWA is highly involved with the *New Brunswick Water Classification Regulation.*

Each year, since 1997, from April to October, PWA monitors 25 sites in the freshwater streams and rivers that enter the Petitcodiac and Memramcook Rivers. The estuarine portions of each river are not monitored by PWA due to time and equipment limitations. The water is analyzed *in situ* for dissolved oxygen content, pH, salinity and temperature. Water samples are analyzed in a laboratory for bacteria concentrations and suspended sediment levels. A partnership with the

Université de Moncton permits PWA to use equipment (*e.g.,* sterilization oven, incubation oven) for bacteria testing. A partnership with Department of Fisheries and Oceans, Gulf Region permits PWA to use water filtering equipment and lab space to conduct suspended sediment measurements.

The PWA does not monitor within the Turtle Creek Watershed to avoid overlap with the City of Moncton's Forest Management Program. The PWA works collaboratively with various stakeholders, including the City of Moncton, to manage issues within the Petitcodiac and Memramcook watershed. Seen as a non-political, independent entity, this science-based organization is able to bring a wide variety of stakeholders to the table. The organization's current focus is on education.

In 2008, the PWA published its first indicator report on the Status of the Watershed (see Appendix A). Each year, the PWA publishes a detailed water quality report, but these reports were too long and complex for the general public. Therefore, the indicator report was developed in an easy to read format to generate more public interest in watershed issues and the organization. The indicators included were: dissolved oxygen levels, bacteria, suspended sediments, water usage, salinity, forest cover, and urbanization levels. The level of 'health' for each of these indicators was indicated on a coloured (red to green) spectrum bar. The reception of this report has been very positive.

All of the above mentioned funding sources provide support for the PWA. The indicator report was funded by the NB Environmental Trust Fund and the Shell Environmental Fund. A local design company was hired to produce the report.

4.0 Water Quality Monitoring Program Development

To develop the water quality monitoring program the background context and known pressures on water quality in HRM (*e.g.,* development, acid rock, land use, combined stormwater and sewer systems) were used to develop a long-term water quality monitoring program at the HRM scale, in addition to development-specific monitoring requirements. An analysis of the appropriate watershed scale, local environmental and development-based pressures allowed for the formulation of a comprehensive monitoring program specific to HRM.

A framework for performance measurement was developed to include objectives, indicators, measurable parameters and targets. This traditional target-setting approach was used in combination with modern GIS techniques and local expert knowledge to devise a multi-tiered system of water quality monitoring. This procedure has been developed to characterize and screen all major water features within HRM.

4.1 WATERSHED PRIORITIZATION

The Nova Scotia Watershed Series is a system used to index watersheds in Nova Scotia that was created by the Water Resources Branch of the Water Survey of Canada which was adopted from that developed by the Dominion Water Power Branch of Canada, Department of the Interior in 1914. Nova Scotia "Primary" watersheds represent one or more major watersheds and a number of smaller coastal streams that empty directly into the ocean. For example, all drainage entering Halifax Harbour south along the coast to Tantallon belong to the primary watershed with the designation 1EJ. Within this grouping there are 13 secondary watersheds. Secondary watersheds are a subdivision of the primary watersheds. Each sub-catchment draining to the main drainage channel of a secondary watershed constitutes a tertiary watershed.

The objective of the screening process was to prioritize the watersheds and water bodies within HRM using the background context and known pressures on water quality in the municipality. A phased approach was used to prioritize watersheds and water bodies within HRM. The ultimate goal of this exercise was to target monitoring activities towards water systems that: (i) currently are potentially impacted due to existing development, or (ii) could be impacted in the future because of proposed development. Due to the number of watersheds and water bodies in HRM, a GIS-based risk model was developed to first characterize all watersheds within HRM based on physical characteristics that could influence water quality. The risk characterization process was designed to assign vulnerability rankings to watersheds as a function of landscape and hydrologic parameters that could be readily generated from existing databases, similar to the DRASTIC model for assessing groundwater vulnerability (Aller et al. 1987). For the initial physical screening process, the water features were screened at the scale of the provincial secondary watershed delineations. While there are limitations associated with using the provincial secondary watershed level of delineation (*e.g.,* known information gaps in the database), this scale of watershed delineation produced a practical number of watersheds which could be screened and assessed. There are approximately 100 secondary watersheds located within HRM. The project team then identified all readily available digital datasets that could be used to physically characterize the secondary watersheds. A physical risk index was developed and applied to the secondary watersheds, and the watersheds were divided into three vulnerability categories. In the second phase of the targeting process, vulnerable watersheds identified in the initial targeting phase were further assessed in greater detail, considering a number of community, development and infrastructure related factors.

4.1.1 GIS Process

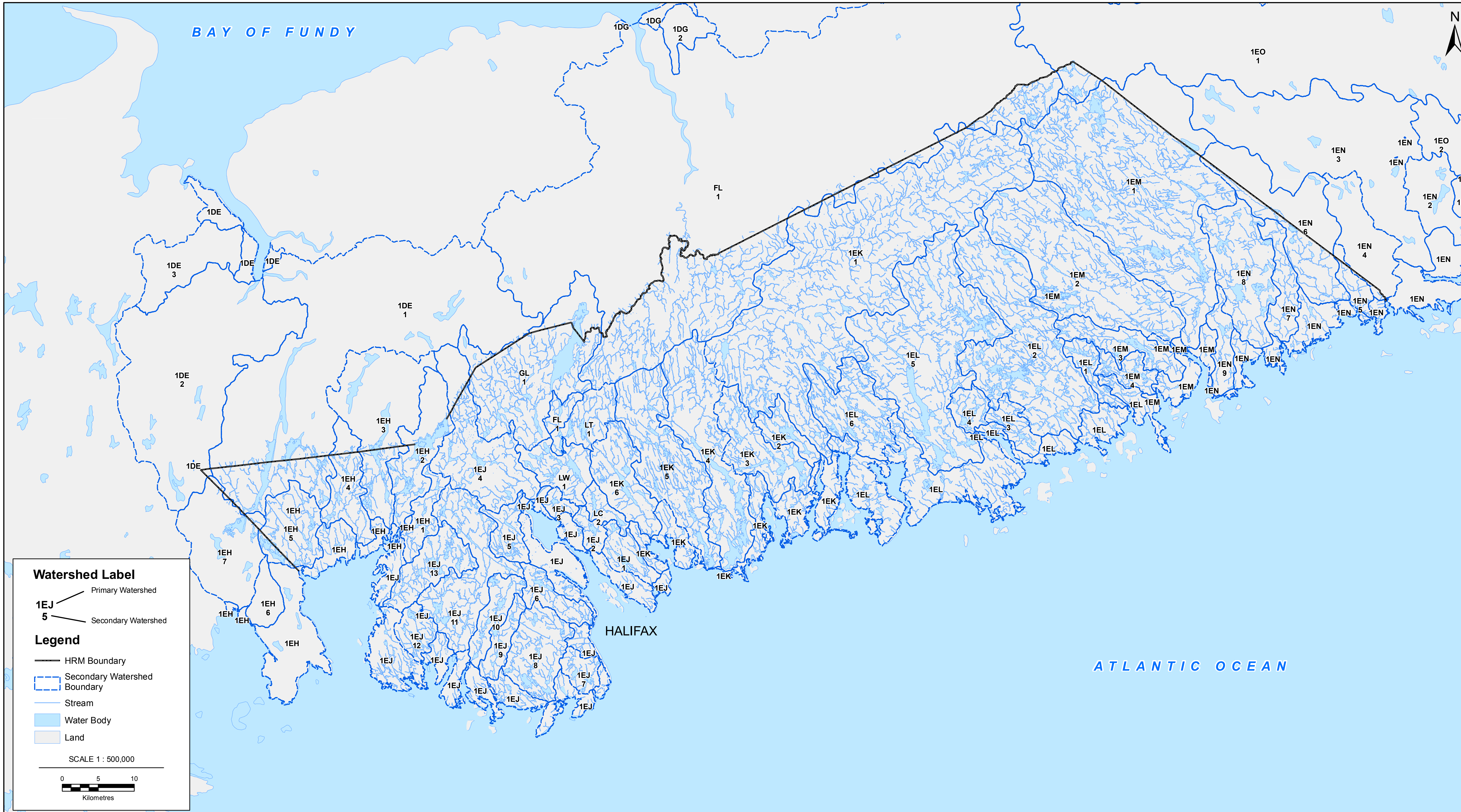
To facilitate the analysis of the water quality influences and to delineate key water bodies, GIS-based project data were acquired from Halifax Regional Municipality as well as various Federal and Provincial government agencies. The following datasets were used to establish the water quality monitoring framework during the two phases of the process:

- Nova Scotia Watershed Series, Nova Scotia Geomatics Centre - classifies drainage areas at the Primary, Secondary, Tertiary, Sub-tertiary levels, and Shoreline direct into saltwater areas. 1:50,000 scale, compilation circa 1980;
- NS Water bodies, Nova Scotia Geomatics Centre – Nova Scotia Topography Data Base (NSTDB), 1:10,000 scale;
- Generalized Future Land Use (GFLUM), Halifax Regional Municipality – 1:10,000 Scale;
- HRM Service Requirements, Halifax Regional Municipality – 1:10,000 Scale;
- Bedrock Geology, Nova Scotia Department of Natural Resources – DP ME 43, Version 2, 2006, Digital Version of Nova Scotia Department of Natural Resources Map ME 2000-1, Geological Map of the Province of Nova Scotia, scale 1:500 000, Compiled by J. D. Keppie, 2000;
- Nova Scotia Detailed Soil Survey, Agriculture and Agri-Food Canada – CanSIS NSDB Detailed Soil Survey of Halifax County. 1:10,000 to 1:250,000 scales;
- HRM Settlement & Transportation Centres (Land Use), Halifax Regional Municipality – 1:10,000 Scale;
- Public Beaches, Halifax Regional Municipality – 1:10,000 Scale;
- Designated Water Supply Areas, Nova Scotia Department of Natural Resources – Restricted and Limited Use Land Database 2007. Various Scales;
- Greenfield Areas, Halifax Regional Municipality – 1:10,000 Scale; and

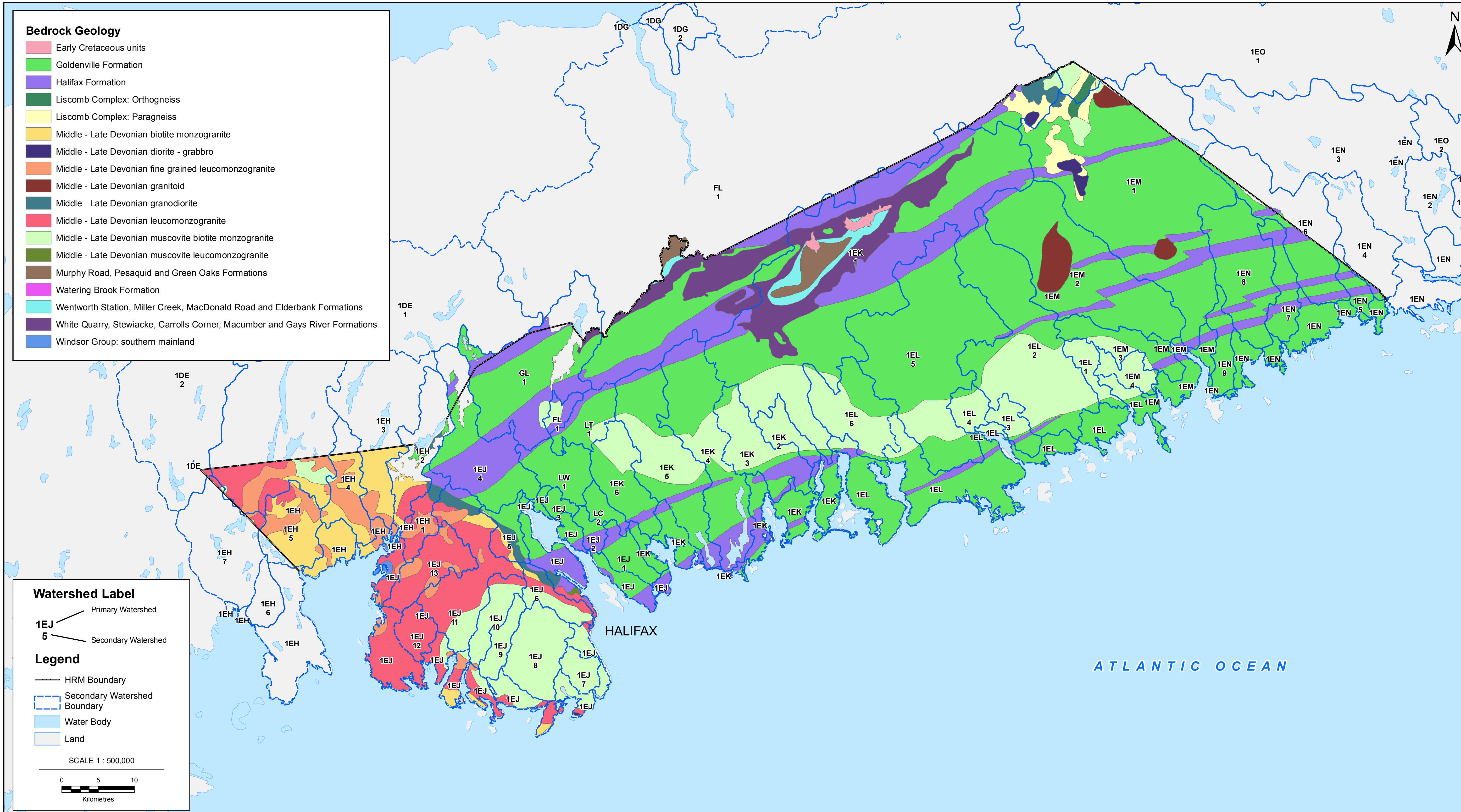
- Land Zoning, Halifax Regional Municipality – 1:10,000 Scale.

Watershed delineations were determined by selecting all "secondary level" polygons from the Nova Scotia Watershed Series that intersected the Halifax Regional Municipality boundary. A new "Secondary Watershed Boundary" data set was then created based on this selection and used as the "Study Area". Areas for each secondary watershed boundary were then recalculated in hectares.

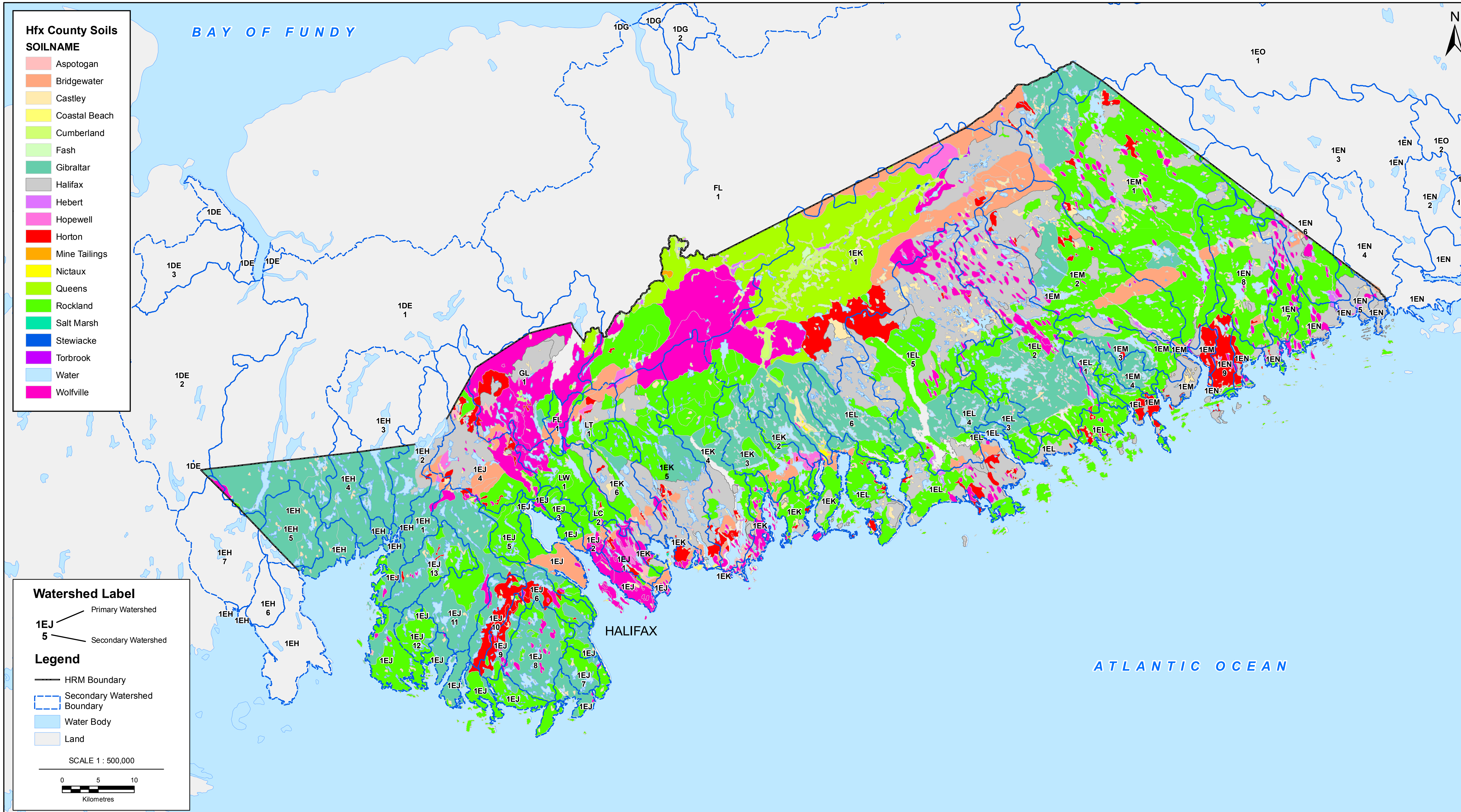
The "Secondary Watershed Boundary" data set was intersected (spatially joined) with the additional data layers (Water bodies, Geology, Soils, Services and GFLUM (See Figures 4.1-4.5)) to determine the total area, in hectares, of each within the study area. The tabular information for each data layer was exported to a tab delimited text file for import into MS Excel. Pivot tables were created in Excel and provided to watershed experts at the Centre for Water Resources Studies (Dalhousie University) for use in the screening process.



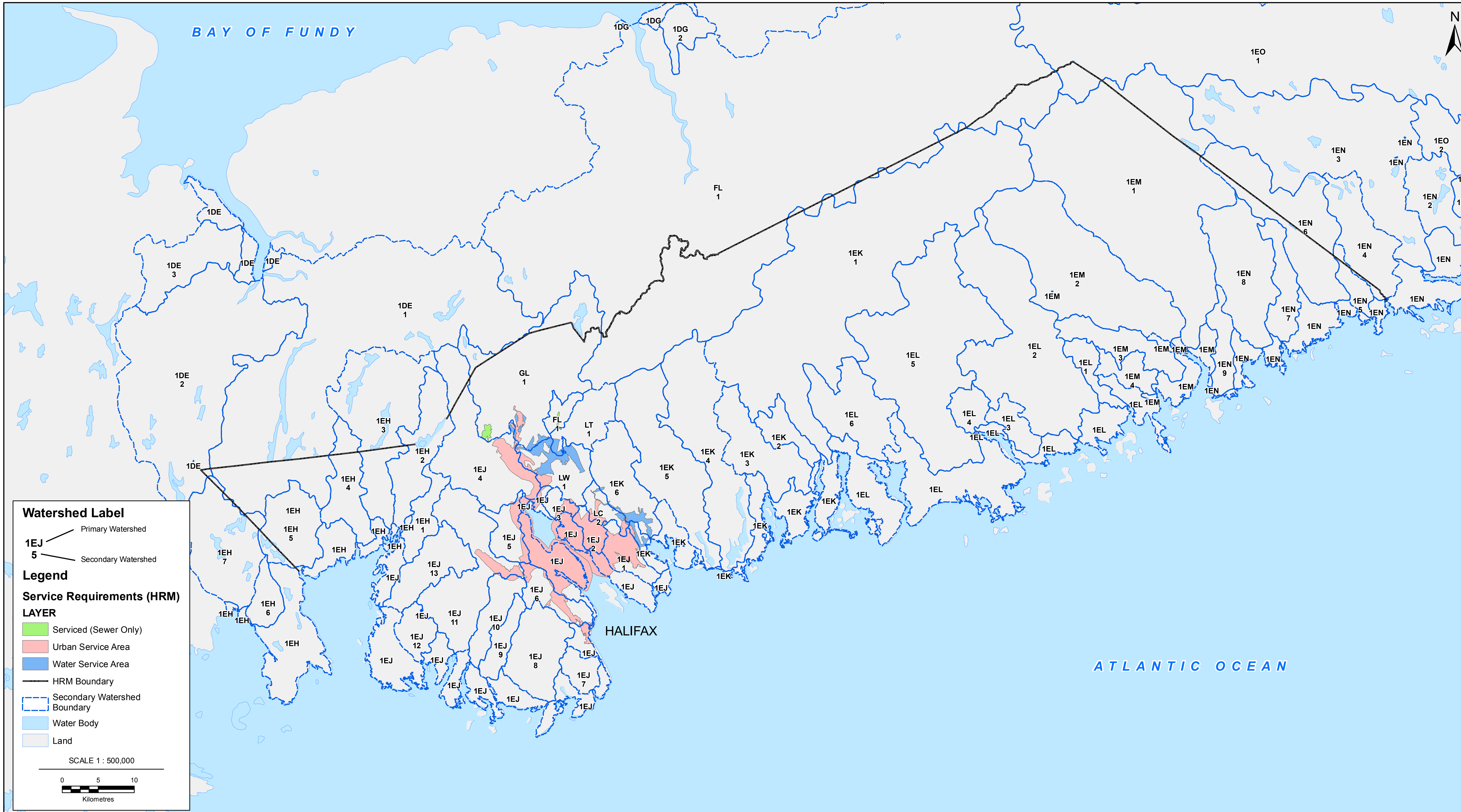
DATE: APRIL 16, 2009	Water Quality Monitoring Functional Plan	FIGURE NO.: Figure 4.1
PREPARED BY: G. MESHEAU		
HALIFAX REGIONAL MUNICIPALITY	**HRM WATER BODIES USED FOR INITIAL SCREENING AND PRIORITIZATION**	Stantec



DATE: APRIL 16, 2009	Water Quality Monitoring Functional Plan	FIGURE NO.: Figure 4.2
PREPARED BY: G. MESHEAU		
HALIFAX REGIONAL MUNICIPALITY	**HRM GEOLOGICAL CHARACTERIZATION USED FOR INITIAL SCREENING AND PRIORITIZATION**	Stantec



DATE: APRIL 16, 2009	Water Quality Monitoring Functional Plan	FIGURE NO.: Figure 4.3
PREPARED BY: G. MESHEAU		
HALIFAX REGIONAL MUNICIPALITY	**HRM SOILS CHARACTERIZATION USED FOR INITIAL SCREENING AND PRIORITIZATION**	Stantec



DATE: APRIL 16, 2009

PREPARED BY: G. MESHEAU

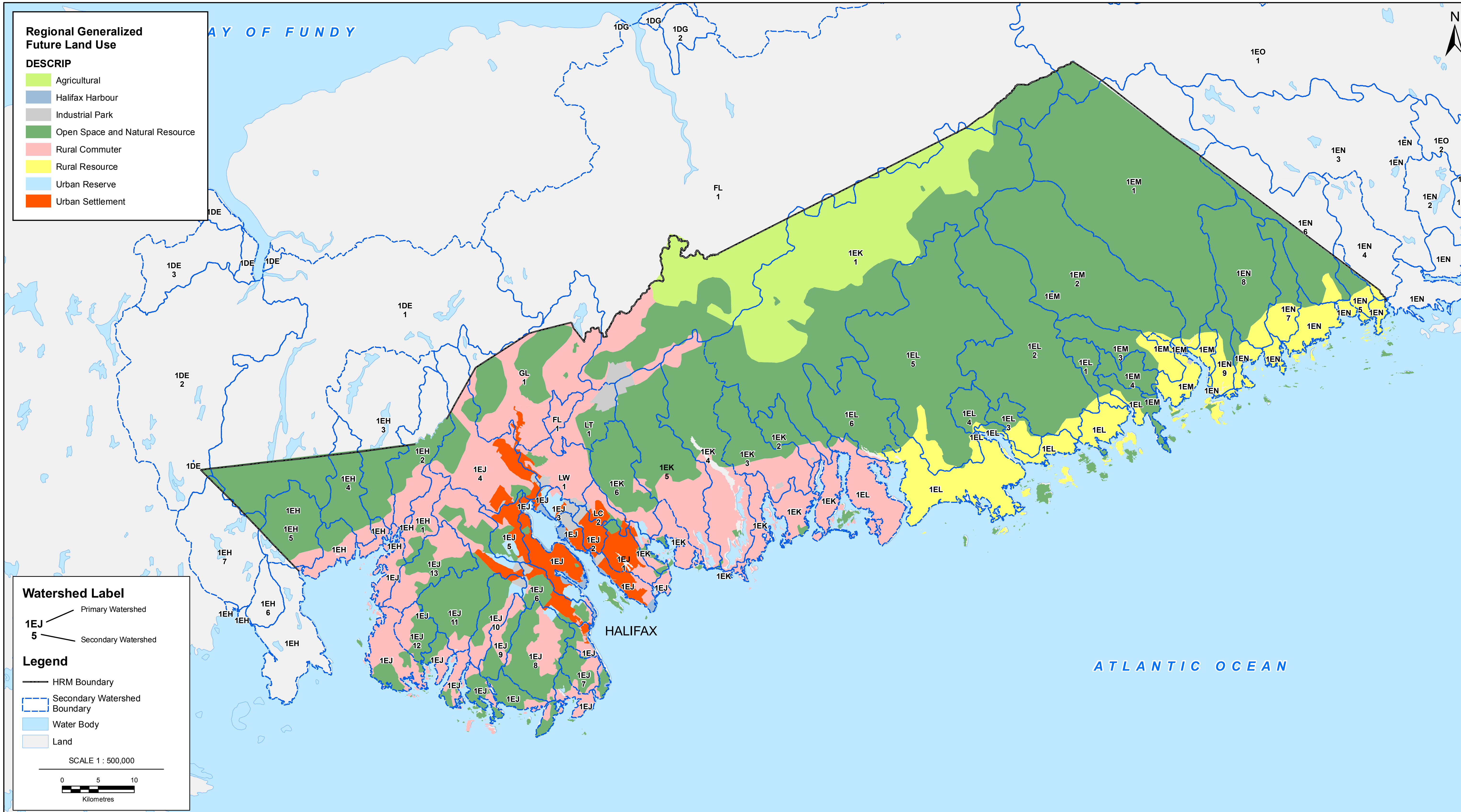
Water Quality Monitoring Functional Plan

FIGURE NO.: **Figure 4.4**

HALIFAX REGIONAL MUNICIPALITY

HRM SERVICING INFRASTRUCTURE USED FOR INITIAL SCREENING AND PRIORITIZATION

Stantec



DATE: APRIL 16, 2009 PREPARED BY: G. MESHEAU	Water Quality Monitoring Functional Plan	FIGURE NO.: Figure 4.5
HALIFAX REGIONAL MUNICIPALITY	**HRM GENERALIZED FUTURE LAND USE USED FOR INITIAL SCREENING AND PRIORITIZATION**	Stantec

4.1.2 Phase 1: Physical Watershed Screening

The two primary physical characteristics that were used to assign the initial vulnerability rankings were: (i) the ratio of water surface area to watershed area, and (ii) the land use distribution. The land use distribution within each watershed, specifically the percentage of drainage area used for urban settlements, commercial or industrial use, or rural residences, was assumed to be the primary factor which would cause changes in water quality. Sub-watersheds which possessed large percentages of urban settlements, or industrial land-uses (*e.g.,* the Stanfield International Airport), would be classified as the most vulnerable.

Another important watershed characteristic that was mapped and examined was the amount of developed land that was serviced by centralized sewage collection and treatment facilities. However, it was found that the sewered land use distribution corresponded closely to the urban settlement spatial distribution, and therefore this risk factor was incorporated within the land use risk layer. The ratio of water surface area to drainage area was used to characterize the relative vulnerability of a water body to land use changes within the drainage basin. This parameter was used due to the fact that bathmetry, and thus volume and retention time characteristics are not available for many water bodies within HRM. A simple risk index was developed using these two datasets. First, for each secondary watershed, a Land-use Risk Factor was computed.

$$LRF = ((F_u + F_c + F_i) \times 10) + (F_r \times 5) + (F_{un} \times 0)$$

Where:

- LRF= landuse risk factor
- F_u = fraction of watershed that is urban settlement
- F_c = fraction of watershed that is commercial
- F_i = fraction of watershed that is industrial
- F_r = fraction of watershed that is rural commuter/rural resource
- F_{un}= fraction of watershed that is undeveloped (undeveloped land is assigned a risk value of 0)

The LRF is scaled from 0 - 10. If a watershed was comprised of only undeveloped land it would be assigned an LRF equal to 0, as illustrated in the above equation. A value of 10 would represent the worst case scenario, where the entire drainage area is Urban Settlement, Commercial or Industrial land use. The relative pollution factors for each land use category were adapted from Akan and Houghtalen (2003). A Water body Vulnerability Factor (WVF) was then computed, which represents the vulnerability of a water body to landscape pollutant loadings. The watershed which possessed the highest ratio of drainage area to water body area was assigned a WVF of 10. This would represent a scenario in which the majority of water entering the receiving water system was interacting with the landscape. All other watersheds were ranked relative to this watershed.

$$WVF = \frac{DWR}{DWR_{\max}} \times 10$$

Where:

- WVF = water body vulnerability factor
- DWR = drainage area to water body area ratio
- DWR_{max} = maximum drainage area to water body ratio

A combined vulnerability factor (VF) was then computed for each secondary watershed as:

$$VF = LRF + WVF$$

Based on the VF all secondary watersheds were placed into one of three Tiers:

- Tier I: High Vulnerability;
- Tier II: Moderate Vulnerability; and
- Tier III: Low Vulnerability.

Two additional physical factors, soil type and bedrock geology, were characterized for each secondary watershed. A Soil Erosion Risk Factor (SERF) was generated for each secondary watershed. All major soil types within HRM watersheds were classified as possessing low, moderate, or high susceptibility to erosion, based on the relative magnitude of their Universal Soil Loss Equation (USLE) soil erodibility factor (Schwab et al. 1981). An integrated SERF was then computed, using GIS, for each secondary watershed:

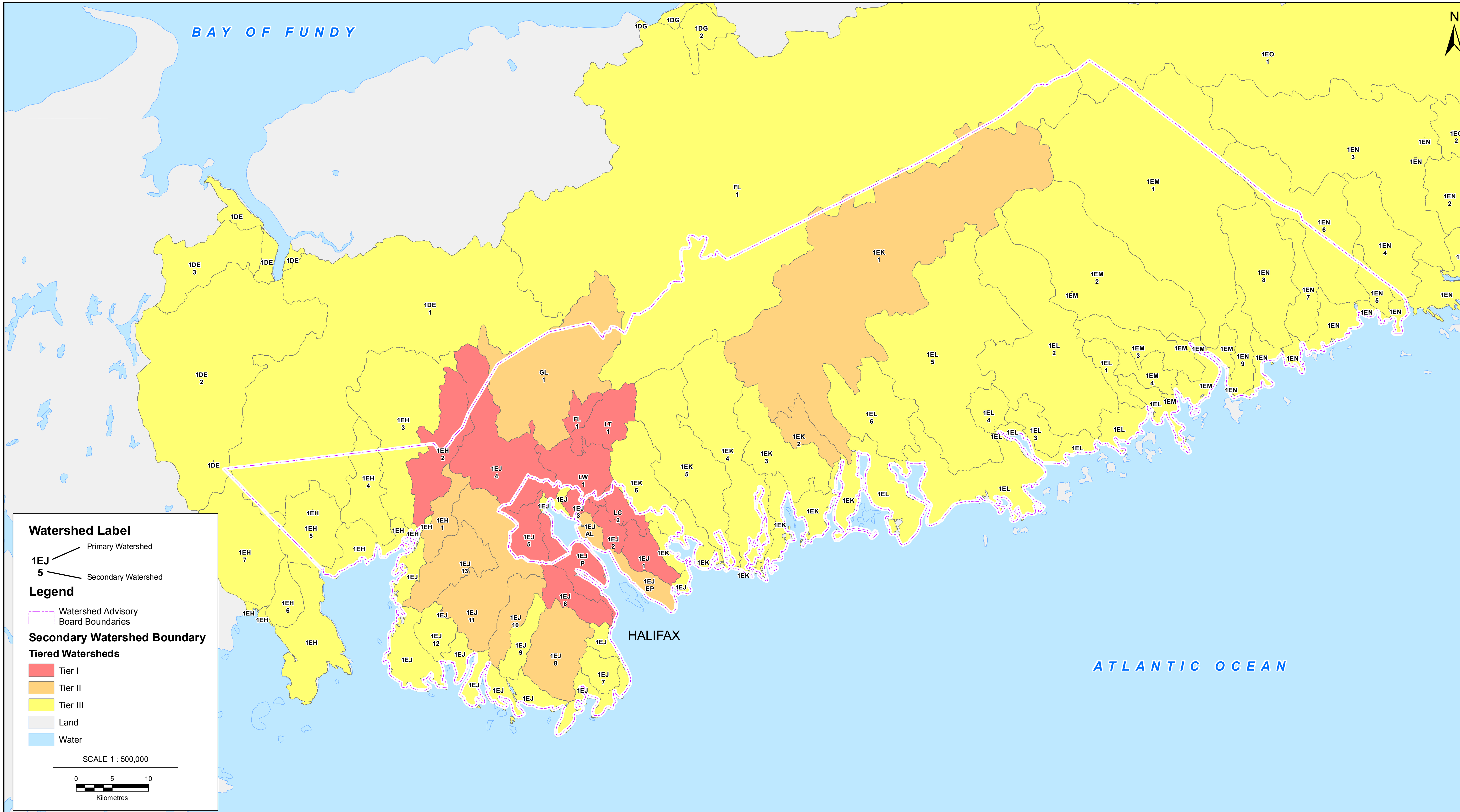
$$SERF = (F_L \times 1) + (F_M \times 2) + (F_H \times 3)$$

Where:

- SERF = Soil Erosion Risk Factor
- F_L = fraction of watershed with low erosion risk soils
- F_M = fraction of watershed with moderate erosion risk soils
- F_H = fraction of watershed with high erosion risk soils

The SERF characterizes the relative erosion risk for each secondary watershed on a scale from 1 – 3. With respect to bedrock geology, the presence of pyritic slates (Halifax Formation), and the potential for acid drainage, is a known issue within HRM. Therefore, the fraction of each secondary watershed underlain by the Halifax Formation bedrock group was also determined. After dividing the secondary watersheds into the three tiers using the VF, these two additional characteristics (SERF and the fraction of each secondary watershed underlain by Halifax Formation) were examined to determine if the tier classification of any of the secondary watersheds should be changed to account for either high erosion potential or susceptibility to acid rock drainage impacts (*i.e.,* if a secondary watershed was ranked as Tier II but had either (i) a high SERF or (ii) large fraction of land underlain by the Halifax Formation, it would be re-assigned as a Tier I watershed. The Shubenacadie Headwater Lake watersheds (Lake Charles, Lake William, Lake Thomas, Lake Fletcher, and Grand Lake) were considered separately. Water quality models had been developed for this chain of watersheds in a previous study (Jacques Whitford 2009). These modeling results were used to assess the vulnerability of these watersheds.

A map representing the three Tiers of secondary watersheds can be found in Figure 4.6.



DATE: MAY 13, 2009	Water Quality Monitoring Functional Plan	FIGURE NO.: Figure 4.6
PREPARED BY: G. MESHEAU		
HALIFAX REGIONAL MUNICIPALITY	**WATERSHED PRIORITIZATION**	Stantec

4.2 WATER BODY PRIORITIZATION

The physical risk assessment procedure outlined in Section 4.1.2 served to narrow the focus of the water body targeting process. The second phase of the water body targeting process involved prioritizing individual water bodies within each Tier I and II watershed, taking into account the community context and known area-specific pressures on water quality. An analysis of community and development-based pressures supported the formulation of a comprehensive monitoring program specific to the community-scale. Before initiating this process the project team included a qualitative verification step, examining land use distributions within each secondary watershed to determine if any key water bodies had been missed during the initial watershed screening process.

A complete inventory of major water bodies was developed for each sub-watershed falling into the Tier I and Tier II categories. A secondary community-oriented screening process was conducted to identify watersheds and/or water features that have specific development pressures, land use designations, water use designations (*e.g.,* beaches, drinking supply), historical water quality data, and/or community concerns. The inputs used include the following (see Appendix B for illustration of some of these inputs on Tier I and Tier II watershed scale maps):

- Greenfield/Master Plan Areas;
- Commercial/Industrial Zoning;
- Watershed Advisory Board Areas of Concern;
- Public Beach/Swimming Designation;
- Public Drinking Supply;
- Areas of Engineering Concern (*e.g.* identified sewer and stormwater overflow areas); and
- Existing Monitoring Program.

These additional inputs were used to reclassify, as needed, the Tier I, II, and III categorizations on an individual basis as well as generate a list of water bodies recommended for monitoring within Tier I and Tier II watersheds (see Table 4.1). Each Tier I and II watershed was examined on an individual basis. One or more water bodies within each watershed were chosen for inclusion in the monitoring program based on surrounding land use, position within the hydrologic drainage network, and the existence of known community or engineering issues. Using this approach, some lakes previously monitored within the HRM Lakes Monitoring Program have not been included in the current recommendations as a result of one or more of the conditions listed (*i.e.,* land use, hydrology, or community/engineering issues). For example, while Lake Echo and Porter's Lake are undergoing development pressure (*i.e.,* land use condition), the hydrologic drainage network they are part of is not likely to be vulnerable to development pressure at the scale proposed. Further consideration was also given to the physical features of a lake to determine if it could or should be included in the WQMFP. That is, it can be inappropriate to sample one site and claim that it is representative of the full lake when a lake is large and includes several basins (*e.g.,* Porters Lake). This is not to suggest that larger-scale, lake-specific research programs should not be considered by HRM if there is sufficient community interest in a specific area; any research-based monitoring could be carried out in conjunction with the WQMFP.

Recognizing that the number of lakes recommended for monitoring represents a substantial increase in level of effort compared to existing monitoring (because of frequency of sampling), the highest priority watersheds were re-evaluated and a short-list of lakes requiring monitoring was developed (see Table 4.2). These lakes are found in the areas expected to experience significant change in the foreseeable future, *i.e.,* located within Master Plan areas or are influenced by existing approved large-scale subdivisions in key watersheds. However, one lake system on the list represents an exception to this criterion. Lake Banook and Lake MicMac are on the list of recommended high priority Tier I water bodies because of the highly valued nature of the lakes on a community level. The lake system is used by aquatic sport athletes (*e.g.,* kayakers, rowers, triathletes) from the local community through to the international competitive sport community. The lake system also experiences heavy recreational use throughout the year.

In addition to the lake monitoring recommendations, four flowing water systems were identified for inclusion in the monitoring program: the Sackville River system (including the Little Sackville River), MacIntosh Run, Musquodoboit River and Nine Mile River. The Musquodoboit and Nine Mile Rivers are the only recommended water bodies for monitoring within their respective secondary watersheds. It is recommended that these flowing water systems be given the same priority in the monitoring program as the high priority, top 11 lakes listed in Table 4.2.

The full inventory of key water bodies, high priority water lakes and flowing water systems is shown in Tables 4.1, 4.2 and 4.3 below. Figures 4.7 and 4.8 provide mapping depicting this information, organized based on Watershed Advisory Board boundaries.

Table 4.1 Key Lake Water Bodies included in WQM Program

Water Body	Secondary Watershed	Existing HRM Lakes Monitoring	Tier
Albro Lake	1EJ-AL	Yes	II
Anderson Lake	1EJ-3	No	I
Barrett Lake	GL-1	Yes	II
Bayers Lake	1EJ-6	No	I
Beaver Pond	GL-1	No	II
Beaverbank Lake	GL-1	No	II
Bell Lake	1EJ-1	Yes	I
Bissett Lake	1EJ-1	Yes	I
Black Point Lake	1EJ-13	Yes	II
Brand Lake	GL-1	No	II
Chocolate Lake	1EJ-P	Yes	II
Cranberry Lake	LC-2	Yes	I
De Said Lake	1EJ -EP	Yes	II

Table 4.1 Key Lake Water Bodies included in WQM Program

Water Body	Secondary Watershed	Existing HRM Lakes Monitoring	Tier
Drain Lake	1EJ-4	Yes	I
Elbow Lake	1EH-1	No	II
Fenerty Lake	GL-1	Yes	II
Fiddle Lake	1EJ-10	No	II
First Chain Lake	1EJ-6	Yes	I
First Lake	LW-1	Yes	I
Five Island Lake	1EJ-13	No	II
Flat Lake	1EH-1	No	II
Fletchers Lake	FL-1	Yes	I
Frenchman Lake	1EJ-2	Yes	I
Governor's Lake	1EJ-P	Yes	I
Hubley Big Lake	1EJ-13	Yes	II
Hubley Mill Lake	1EH-1	No	II
Kearney Lake	1EJ-5	Yes	I
Kelly Lake	GL-1	No	II
Kidston Lake	1EJ-6	Yes	I
Kinsac Lake	GL-1	Yes	II
Lake Banook	1EJ-2	Yes	I
Lake Charles	LC-2	Yes	I
Lake downstream of De Said (unnamed)	1EJ -EP	No	II
Lake MicMac	1EJ-2	Yes	I
Lake Thomas	LT-1	Yes	I
Lake William	LW-1	Yes	I
Lamont Lake	1EJ-1	No	I
Lisle Lake	GL-1	Yes	II
Little Lake	1EJ-3	No	I
Long Lake	1EJ-6	Yes	I
Long Pond	1EJ-6	Yes	I
Loon Lake	LC-2	Yes	I
Maynard Lake	1EJ-2	Yes	I
McCabe Lake	1EJ-4	Yes	I
McQuade Lake	1EJ-5	No	I
Mill Lake	1EH-2	No	I
(The) Mill Pond (Three Mile Pond)	1EK-2	Yes	II
Miller Lake	LT-1	No	I
Moody Lake	1EJ-8	Yes	II
Morris Lake	1EJ-1	Yes	I
Oathill Lake	1EJ-2	Yes	I
Paces Lake	1EK-2	No	II
Paper Mill Lake	1EJ-5	Yes	I
Penhorn Lake	1EJ-2	Yes	I
Powder Mill Lake	LW-1	Yes	I
Quarry Lake	1EJ-5	No	I
Red Bridge Pond	1EJ-2	Yes	I
Rocky Lake	LW-1	Yes	I
Russell Lake	1EJ-1	Yes	I
Sandy Lake (Bedford)	1EJ-4	Yes	I
Sandy Lake (Glen Arbour)	1EJ-4	Yes	I
Scots Lake	1EK-2	No	II
Scots Pond	1EK-2	No	II
Second Lake	LW-1	Yes	I

Table 4.1 Key Lake Water Bodies included in WQM Program

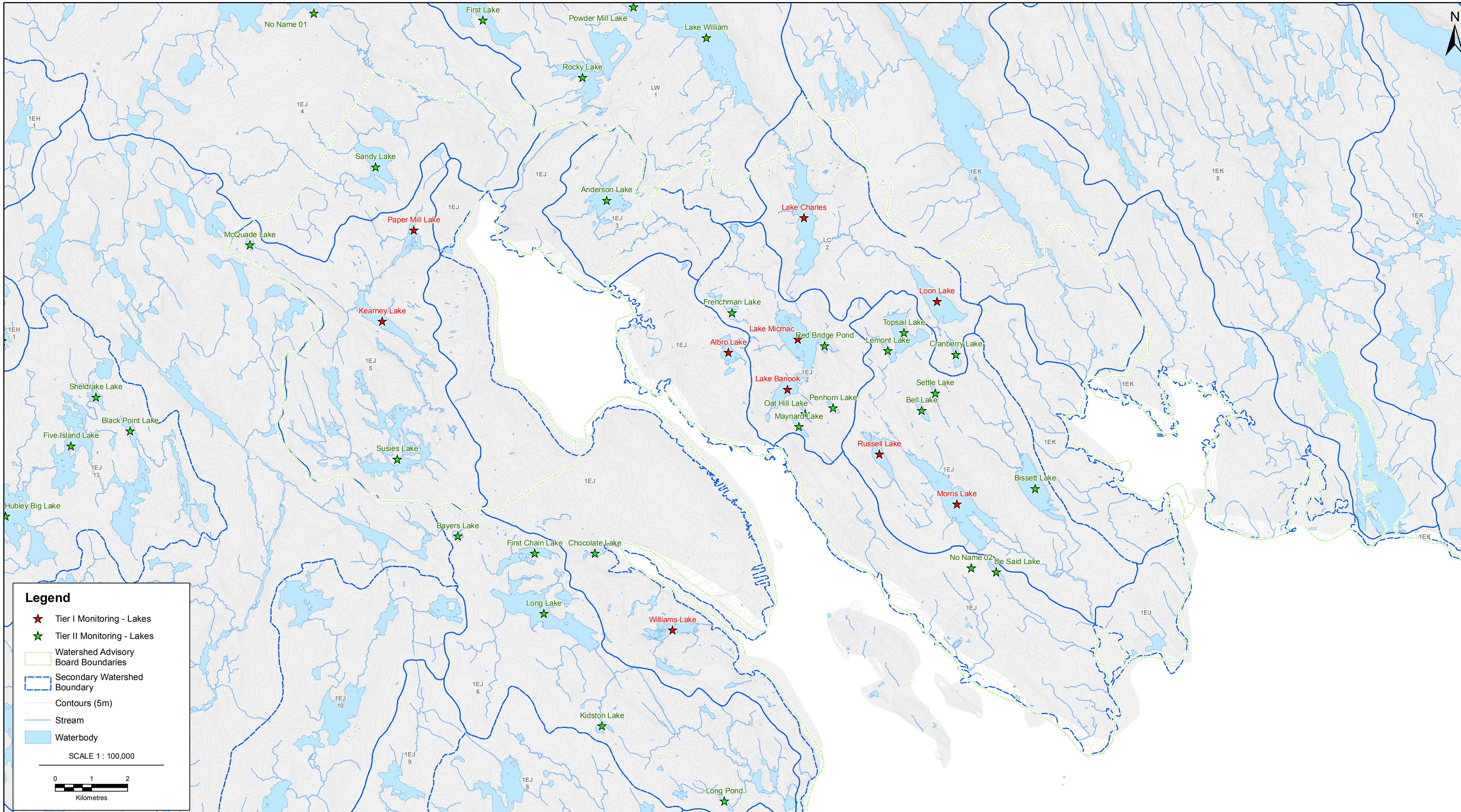
Water Body	Secondary Watershed	Existing HRM Lakes Monitoring	Tier
Settle Lake	1EJ-1	Yes	I
Sheldrake Lake	1EJ-13	Yes	II
Springfield Lake	GL-1	Yes	II
Stillwater Lake	1EH-1	Yes	II
Susies Lake	1EJ-5	No	I
Third Lake	LW-1	Yes	I
Topsail Lake	1EJ-1	No	I
Tucker Lake	GL-1	Yes	II
Unnamed Lake below McCabe Lake	1EJ-4	No	I
Whites Lake	1EJ-10	No	II
Williams Lake (Spryfield)	1EJ-P	Yes	I
Wrights Lake	1EH-2	No	I

Table 4.2 Tier 1 High Priority Lake Water Bodies

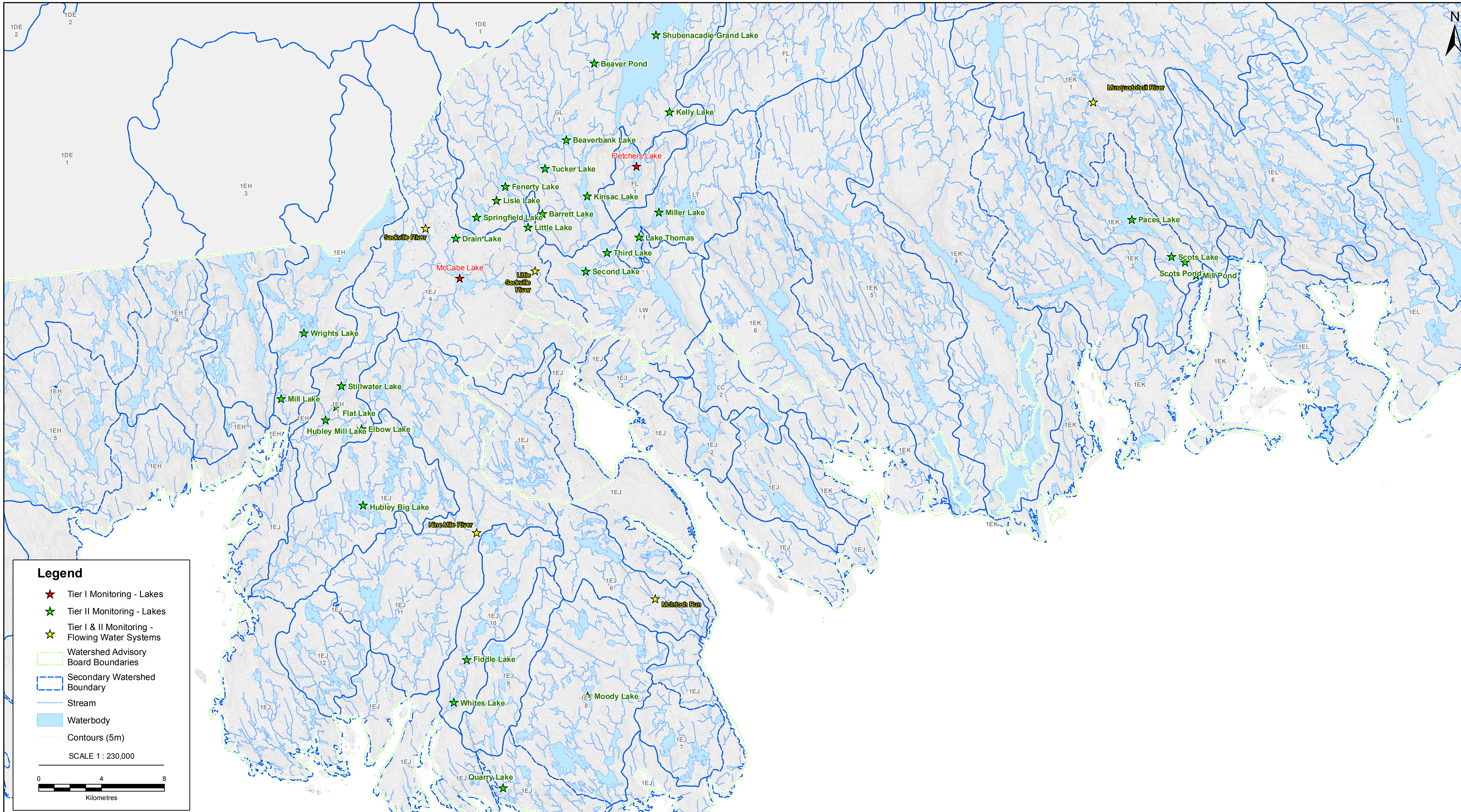
Water Body	Secondary Watershed
Morris Lake	1EJ-1
Russell Lake	1EJ-1
Paper Mill Lake	1EJ-5
Kearney Lake	1EJ-5
Loon Lake	LC-2
Lake Charles	LC-2
Lake Banook	1EJ-2
Lake MicMac	1EJ-2
Williams Lake	1EJ (Pen)
McCabe Lake	1EJ-4
Lake Fletcher	FL-1

Table 4.3 Flowing Water Systems

Flowing Water System	Secondary Watershed	Tier
Little Sackville River (including Sackville)	1EJ-4	I
McIntosh Run	1EJ-6	I
9-Mile River	1EJ-11	II
Musquodoboit River	1EK-1	II



DATE: May 14th, 2009	Water Quality Monitoring Functional Plan	FIGURE NO.: Figure 4.7
PREPARED BY: G. MESHEAU		
HALIFAX Regional Municipality	**PROPOSED TIER I & TIER II WQMFP WATER BODIES - MAP A**	Stantec



DATE: MAY 14, 2009	Water Quality Monitoring Functional Plan	FIGURE NO.: Figure 4.8
PREPARED BY: G. MESHEAU		
HALIFAX REGIONAL MUNICIPALITY	**PROPOSED TIER I & TIER II WQMFP WATER BODIES - MAP B**	Stantec

4.3 HRM MONITORING PROGRAM ELEMENTS AND RECOMMENDED ACTIONS

The key elements of the overall HRM-wide monitoring program are the ecosystem indicators, key monitoring objectives, duration of monitoring, physical and chemical indicator parameters, and sampling frequency. The broad objective of the monitoring program outlined is to gather empirical data that would be used to document seasonal and long-term variability in lake water quality attributable to natural and anthropogenic influences.

The WQMFP program addresses the key objectives of the water quality functional plan: nutrient loading/eutrophication impacts; sedimentation impacts; microbial water quality; and acid drainage impacts. In the aim to develop a more robust monitoring program, the proposed program is structured around specific ecosystem components and indicator parameters. Overall, it is designed to provide the information needed to develop, and validate, predictive water quality tools, and to track key development-related impacts to water quality and overall watershed management. The development of databases necessary for calibrating and validating predictive water quality models should be considered a key objective of the WQMFP. Reliable and tested water quality models will help minimize monitoring requirements and could serve as important planning tools.

4.3.1 Ecosystem Indicators and Key Water Quality Monitoring Objectives

Aquatic ecosystems are naturally complex, making it difficult to understand the interconnected processes that shape lake and stream environments. It is valuable to break apart the aquatic ecosystem as a whole, and identify the individual components of the key ecosystem relationship(s) under study. In the case of the WQMFP, it is important to understand how specific ecosystem components are related to human land use and the associated impacts of human activities. Therefore, water quality, hydrology, physical aquatic habitat and terrestrial features need to be considered. Following the identification of the key ecosystem components, tangible indicators were established (see Table 4.4). These ecosystem component indicators can be used to monitor and assess the health of each ecosystem component.

The ability of a lake or stream to respond to anthropogenic pressure is dependent upon the existing hydrological, biological, ecological and physical conditions of the water body. To better track aquatic ecosystem response to changes in land use and other human activities, specific objectives and working targets were set for the WQMFP (see Table 4.5). To effectively monitor and protect complex aquatic ecosystems, clearly defined objectives and targets are needed. Setting these objectives within an ecosystem indicator framework will improve HRM’s ability to detect changes within the municipality’s aquatic systems over the long-term. This type of ecosystem science approach to studying relationships and interactions in the environment is considered the foundation for the science needed for integrated management of diverse human activities that affect the natural environment (DFO 2007).

The key ecosystem component indicators are as outlined in Table 4.4, while key objectives are outlined in Table 4.5.

Table 4.4 Ecosystem Component Indicators

Water Quality	Phosphorous, Suspended Solids, Temperature, Dissolved Oxygen, Bacteria, Chlorophyll *a*, CCME Aesthetic Parameters, Fish, Oil, Grease, Hydrocarbons, Metals, Salt
Hydrology	Streamflow partitioning (Baseflow vs. Stormflow)
Physical Aquatic Habitat	Benthic Organisms
Terrestrial Features	Green Space Size, Green Space Health

Table 4.5 Water Quality Monitoring Program Objectives and Working Targets

Track trophic status as a means of assessing the presence or absence of nutrient loading (*e.g.,* eutrophication)	• No change in frequency of events (*e.g.,* "green water") • Phosphorus management in accordance with CCME guideline • Determine existing trophic status and track potential shift in trophic status • Validate and run a predictive phosphorus model in all priority watersheds
Maintain water quality and improve public notification to allow for safe recreational use (*i.e.,* safe body contact)	• Data meeting the CCME requirements for Recreational Use Guidelines • No increased frequency of lake closures • Zero delayed lake closures • Sufficient bacterial data in focus lakes (collected over a minimum of two years) to produce a predictive model to forecast microbial water quality in freshwater recreational systems
Track long-term trends in the occurrence of sedimentation and associated impacts	• No change in benthic community or habitat status from baseline • Trend detection and ability to assess effectiveness of mitigation measures via: o Benthic community status (*e.g.,* EPT:Total ratio) o Physical habitat status
Monitor acid drainage impacts	• Sufficient data to detect acidification of lakes • Avoidance of increased acidification • Identify potential treatment options
Track relationship between overall watershed health and green space	• Tracking of data relative to tree/ pervious cover and health
Track the relationship between stormwater quality/quantity and overall watershed health	• Better understand how stormwater impacts hydrology, water quality, and overall aquatic ecosystem health

4.3.2 Physical and Chemical Water Quality Parameters

Once the high level WQMFP program components and objectives were determined, the physical and chemical parameters used to measure these objectives were identified. A complete list of parameters selected for testing purposes is provided in Table 4.6. In addition to these four groups of parameters, the amount of pervious cover should be tracked in each Tier I and Tier II watershed. Water quality sampling locations, surveillance frequency and groups of tests to be performed, specific to each tier classification, are described in detail in sections to follow.

Table 4.6 Grouped Listing of Physical and Chemical Water Quality Parameters

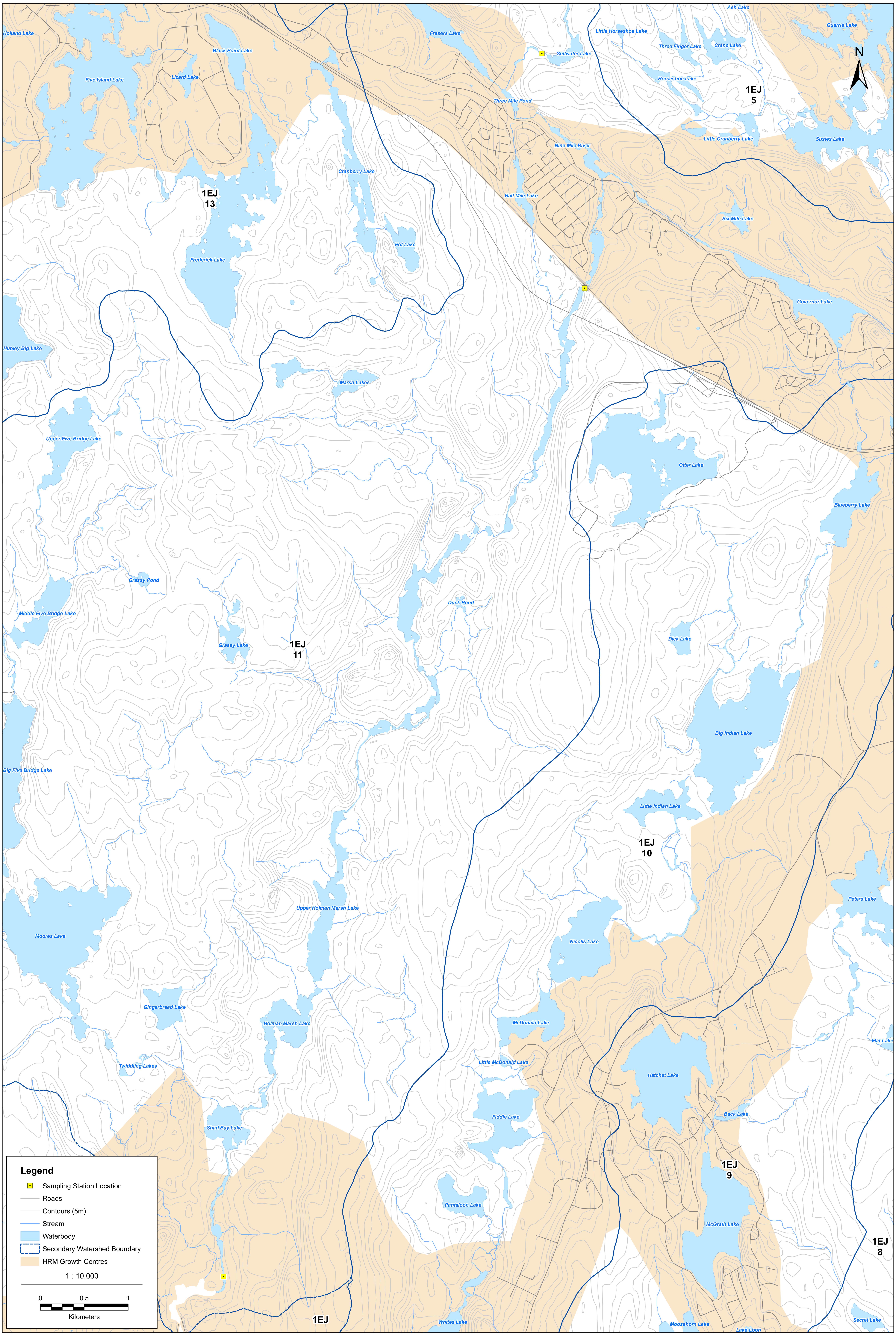
Group 1	Group 2 *(RCAp-30)*	Group 3 *("MS" portion of RCAp-MS)*	Group 4
pH	Sodium	Aluminum	*E. coli*
Conductivity	Potassium	Antimony	Colour/turbidity
Temperature Profile	Calcium	Arsenic	Total phosphorus (low level)
Dissolved Oxygen Profile	Magnesium	Barium	Total suspended solids
Secchi Depth	Hardness as mg $CaCO_3$	Beryllium	Water Temperature
Air Temperature	TDS (calculated)	Bismuth	
Cloud Cover	Alkalinity as mg $CaCO_3$	Boron	
Ice Depth	Bicarbonate as mg $CaCO_3$	Cadmium	
Time	Carbonate as mg $CaCO_3$	Chromium	
Total Phosphorus (low level)	Sulfate	Cobalt	
Chlorophyll a	Chloride	Lead	
E. coli	Reactive Silica	Molybdenum	
Turbidity	Nitrate-Nitrite (as N)	Nickel	
Colour	Ammonia (as N)	Selenium	
Incidental wildlife sightings (*e.g.,* frogs, dragonflies, ducks, *etc.*)	Total Organic Carbon	Silver	
	Iron	Strontium	
	Copper	Thallium	
	Manganese	Tin	
	Zinc	Titanium	
		Uranium	
		Vanadium	

4.3.3 Sample Frequency

The monitoring intensity (spatial, temporal, and number of parameters) for each watershed will depend on the level of vulnerability of the watershed (Tier I or II). See Tables 4.7 and 4.8 for the proposed schedule of analyses for each Tier level.

4.3.4 Water Sampling Locations

Depending on the size and number of lake basins, a sampling station(s) is to be established at the deepest point in each of the main basins of a lake. In-lake station selection is based on the assumption that water quality at any site is representative of average basin conditions. Sampling station locations have been recommended for the four flowing water systems as well (see Figures 4.9 through 4.12). The recommended proposed lakes and corresponding site locations have not been confirmed with field visits and may need some adjustment to facilitate adequate access and appropriate sampling conditions (*e.g.,* the sites should be representative of the stream or river area and should be of minimum depth to allow sample collection year-round). The sampling sites located at the mouth of the river or stream (*i.e.,* draining into the Halifax Harbour) should be established upstream of backwater effects.



DATE: April 16th, 2009

PREPARED BY: G MESHEAU

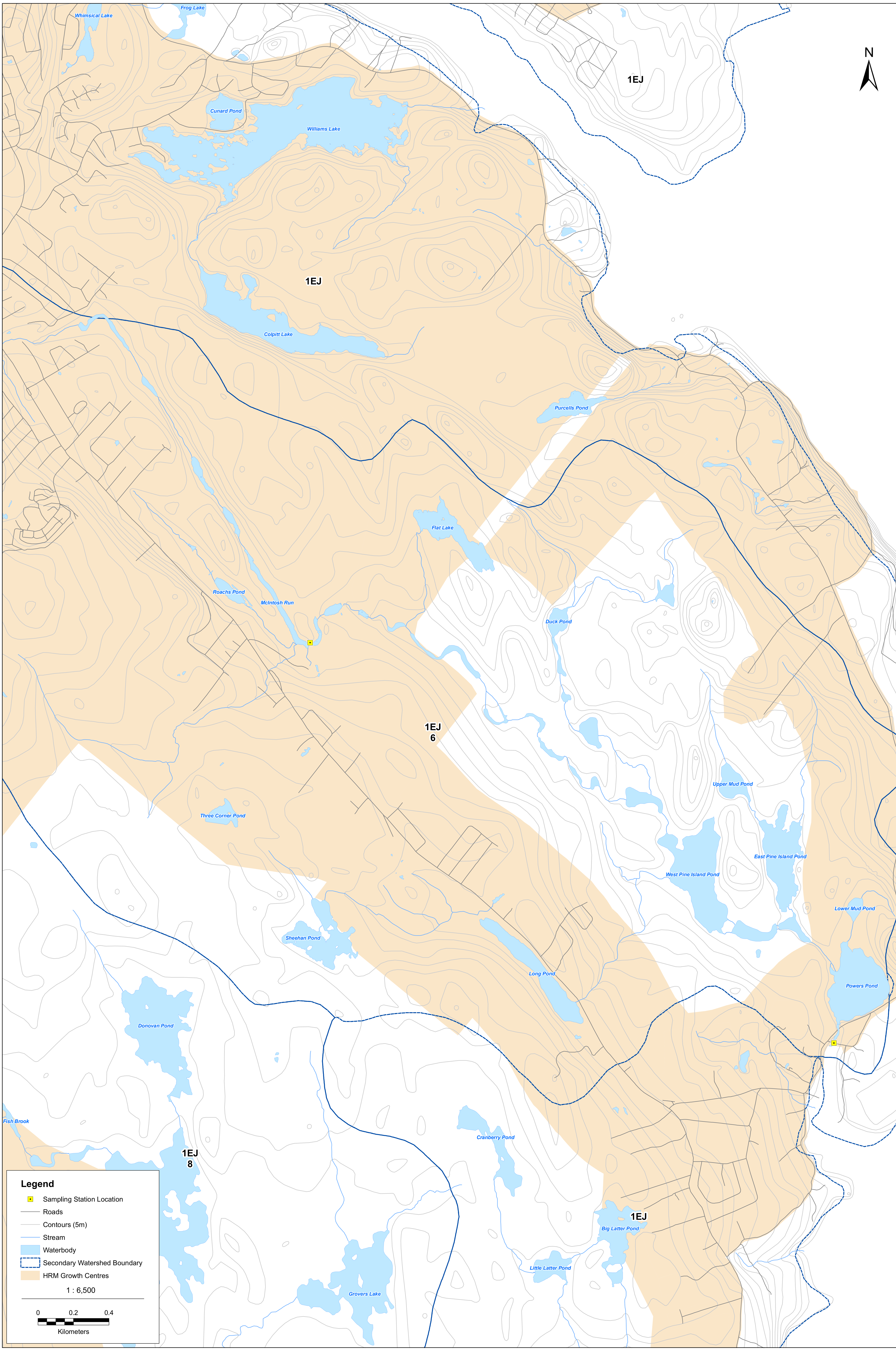
HALIFAX REGIONAL MUNICIPALITY

HRM Water Quality Functional Plan

NINE MILE RIVER - PROPOSED SAMPLING STATIONS

FIGURE NO: **Figure 4.9**

Stantec



DATE: April 16th, 2009

PREPARED BY: G MESHEAU

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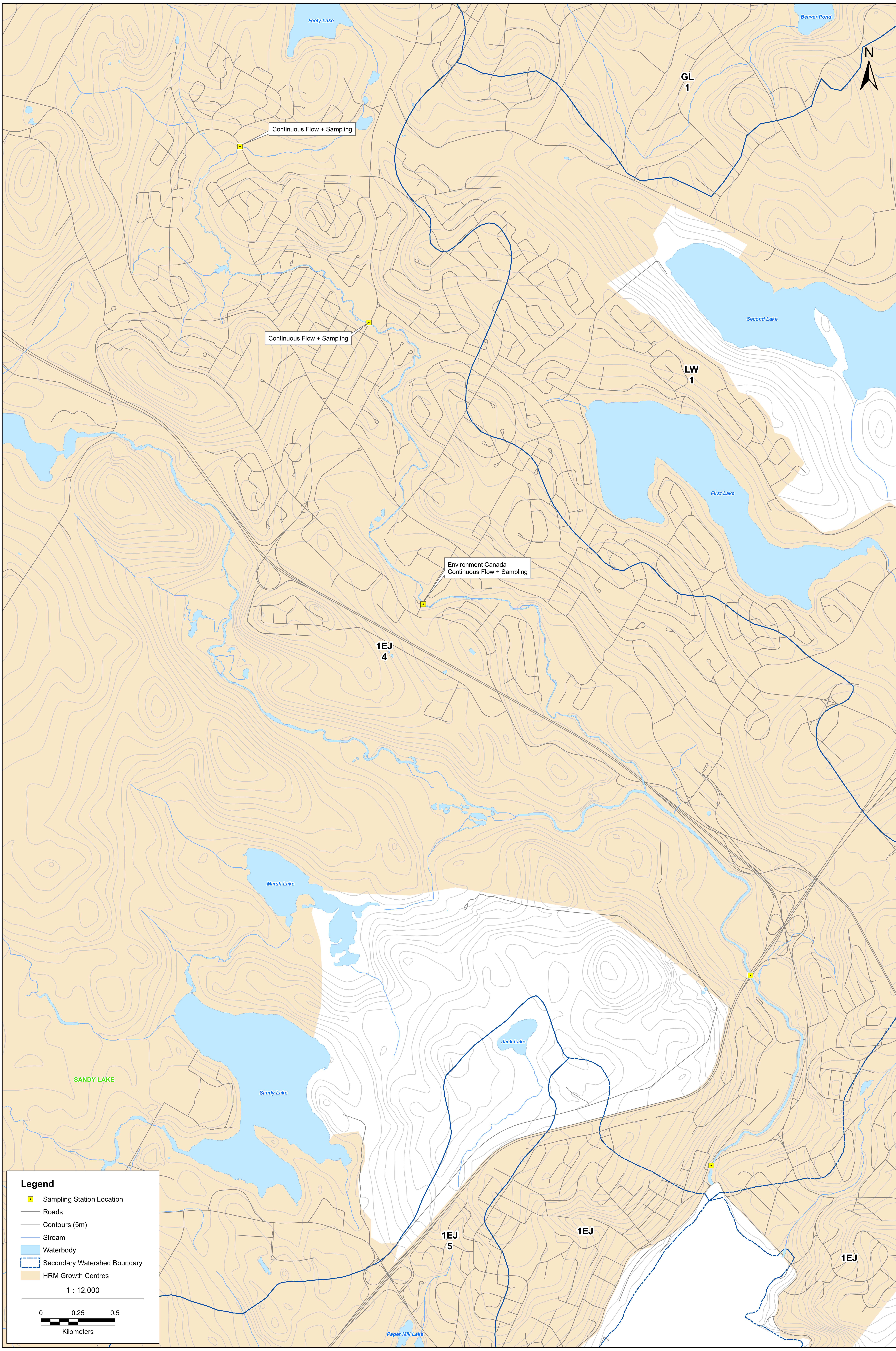
HRM Water Quality Functional Plan

MACINTOSH RUN - PROPOSED SAMPLING STATIONS

FIGURE NO: **Figure 4.10**

Stantec



DATE:
April 16th, 2009

PREPARED BY:
G MESHEAU

HALIFAX REGIONAL MUNICIPALITY

HRM Water Quality Functional Plan

LITTLE SACKVILLE RIVER - PROPOSED SAMPLING STATIONS

FIGURE NO:
Figure 4.11

Stantec

DATE:
April 14th, 2009

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G MESHEAU

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REGIONAL MUNICIPALITY

HRM Water Quality Functional Plan

MUSQUODOBOIT RIVER - PROPOSED SAMPLING STATIONS

FIGURE NO:
Figure 4.12

Stantec

4.3.5 Profiling and Water Sample Depths

Temperature and dissolved oxygen profiles should be collected during every water chemistry sampling event; additionally the profiles, in general, should be generated using information collected at 1 m intervals. During periods of thermal mixing, intervals can be increased to 3 m. For lakes with a maximum depth greater than 20 m, profiling intervals can be increased to up to 3 m below the 20 m level.

Discrete water samples should be collected 0.5 m below the lake surface, at mid-depth, and 1 m above the lake bottom. During periods of thermal stratification, the mid-depth sample should try to be retrieved from the mid-point of the thermocline (metalimnion), if present.

4.3.6 Sampling Flowing Water Systems

Grab samples and *in situ* measurements should be obtained mid-channel, approximately 0.3 m below the water surface, depending on the water depth. At each sample location temperature, DO, pH, and conductivity should be measured *in situ*. Total suspended solids should be sampled using a depth-integrating sampling procedure (Edwards and Glysson 1999) using a standard sediment sampling device (*i.e.,* DH-48 suspended sediment sampler for wadeable streams). At each sampling location a staff gauge should be installed to allow for a consistent measurement of stage height during each sampling event. During the first year of the monitoring program, the flow should be measured at each sampling location during every sampling event. Flow should be measured in accordance with standard methodologies (*i.e.,* Canadian General Standards Board (1991; *Liquid flow measurement in open channels Velocity-Area Methods. National Standard of Canada. CAN/CGSB-157.6-M/ISO 1088.* Ottawa, ON). The concurrent measurement of stage and flow will allow for the development of a stage-discharge relationship at each location. Once this relationship is established, only stage will have to be measured to obtain a flow estimate. For assessing water quality trends in flowing water systems, it is crucial to have concurrent flow measurements.

4.3.7 Water Quality Analysis

Two types of water samples – discrete and volume-weighted – should be analyzed at each lake station. Total phosphorus and chlorophyll *a* testing must be performed on all discrete water samples (*i.e.,* samples taken from the top, middle and bottom of the water column when thermal stratification is observed as described in the profiling section above). *E. coli* need only be measured for the 0.5 metre (top) water sample. Volume-weighted samples made up of top, middle and bottom water samples are to be tested for the remaining grouped analytical parameters specified in Table 4.6. Lake specific volume weighting requires bathymetric data to be available. Bathymetry studies have been carried out on only a limited number of lakes in HRM; as such, it is recommended that opportunities for bathymetric evaluation of the identified lakes to be sampled be pursued. Bathymetric data will also be required for water quality modeling activities.

4.4 TIER I PROGRAM DETAILS

The in-lake water sampling program is to consist of monthly collections during the ice-free season (April – December) and at least one sampling date occurring during the period of ice cover (January - March), conditions permitting. If for safety reasons, only a single wintertime sampling is possible, it should be scheduled as close to the time of ice break-up as possible in order to document the maximum effect of the presence of ice cover. If HRM determines that winter sampling is unsafe and even a single wintertime sampling event is not possible, sampling should occur during open water conditions as close to ice-in and ice-out as possible. That is, the lake should be sampled immediately before ice cover in the late fall or early winter, and immediately following the ice melt in the late winter or early spring. This sampling period will change in timing each year with the temporal variation in annual ice-over conditions.

The list of parameters identified in Group 1 (Table 4.6) should be measured at each sampling location during each sampling event. Group 2 parameters (*i.e.,* RCAp-30 suite from Maxxam Analytics) should be analyzed on volume-weighted samples 4 times per year (Spring turnover – April/May; peak-summer stratification – August/September; Fall turnover – October/November; peak-winter stratification – February/March). Group 3 parameters (*i.e.,* the metals scan, MS, portion of Maxxam Analytics RCAp-MS) should be analyzed on volume-weighted samples twice per year (Spring turnover – April/May; Fall turnover – October/November). A scheduling summary is provided in Table 4.7. For months when both Group 2 and Group 3 parameters are measured, a single RCAp-MS suite from Maxxam Analytics will include all required parameters.

All flowing water system sampling locations should be sampled on a monthly basis. The list of parameters identified in Group 1 (Table 4.6) should be measured at each sampling location during each sampling event. Group 2 parameters (*i.e.,* RCAp-30 suite from Maxxam Analytics) should be performed 4 times per year (Spring- April/May; summer – August/September; Fall – October/November; winter – February/March). Group 3 parameters (*i.e.,* the metals scan, MS, portion of Maxxam Analytics RCAp-MS) should be analyzed on volume-weighted samples twice per year (Spring – April/May; Summer (during low flow period) – July/August).

Table 4.7 Scheduling of Analyses for Tier I Water Bodies

<table>
<tr><th>April</th><th>May</th><th>June</th><th>July</th><th>Aug</th><th>Sept</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan-Mar</th></tr>
<tr><td>Group 1</td><td>Group 1</td><td>Group 1</td><td>Group 1</td><td>Group 1</td><td>Group 1</td><td>Group 1</td><td>Group 1</td><td>Group 1</td><td>Group 1</td></tr>
<tr><td colspan="2">Group 2</td><td></td><td></td><td colspan="2">Group 2</td><td colspan="2">Group 2</td><td></td><td>Group 2</td></tr>
<tr><td colspan="2">Group 3</td><td></td><td></td><td></td><td></td><td colspan="2">Group 3</td><td></td><td></td></tr>
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4.5 TIERS II AND III PROGRAM DETAILS

Water sampling will take place on a quarterly basis for water bodies identified as Tier II and follows the seasonal thermal regime exhibited by many temperate lakes: Spring turnover (April-May); peak Summer stratification (August- mid-September), Fall turnover (October-December), and peak Winter stratification (February-March). Should HRM decide to monitor Tier III watersheds in the future, the same program as Tier II would be followed.

For each of the four sampling dates, Groups 1 and 2 parameters are to be measured. Group 3 parameters will be measured during the Fall and Spring mixed periods only, October – December and April - May, respectively. Volume-weighted samples are used for Groups 2 and 3 analyses. Table 4.8 presents a scheduling summary.

Table 4.8 Scheduling of Analyses for Tiers II and III Water Bodies

<table>
<tr><th>April</th><th>May</th><th>June</th><th>July</th><th>Aug.</th><th>Sept</th><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan-Mar</th></tr>
<tr><td colspan="2">Group 1</td><td></td><td></td><td colspan="2">Group 1</td><td colspan="2">Group 1</td><td></td><td>Group 1</td></tr>
<tr><td colspan="2">Group 2</td><td></td><td></td><td colspan="2">Group 2</td><td colspan="2">Group 2</td><td></td><td>Group 2</td></tr>
<tr><td colspan="2">Group 3</td><td></td><td></td><td></td><td></td><td colspan="2">Group 3</td><td></td><td></td></tr>
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4.6 BENTHIC MONITORING PROGRAM

Benthic macroinvertebrates are long-term indicators of environmental quality and biodiversity as they integrate water, sediment, and habitat qualities (USEPA 1989; 1990). In addition, macroinvertebrate species have sensitive life stages that react to stressors, both on the short- and long-term. These organisms are relatively long-lived and are present year-round, and are often abundant, yet not very motile, allowing for monitoring of temporal variability. There are more than 4000 species of mites and insects reported from Canadian lakes and streams (benthic invertebrates also include worms, molluscs, and amphipods). This highly diverse group can represent an important component in monitoring changes in biodiversity.

Benthic invertebrates are often used for aquatic biological assessments and environmental effects monitoring programs in lake and flowing water systems. Particularly sensitive to sediment deposition, toxicity, organic enrichment, prey species, and fluctuations in dissolved oxygen, these invertebrates are easy to monitor and are an important component of energy movement through the food chain (*e.g.,* bacteria, fish, and birds). Benthic invertebrates react to a broader range of human influences than will chemical criteria. Monitoring of these organisms allows for documentation of changes in the chemical/physical environment of the lake, helps identify areas of sediment accumulation, and track recovery. They represent the sum of effects over the year as opposed to one point in time.

4.6.1 Study Sites

Study areas should be relatively homogeneous with respect to major habitat type and level of exposure to potential impacts. Sampling locations should be situated in areas with similar bottom substrate, depth, velocity (in the case of streams), and cover to help reduce the natural inter-annual variations. Information for lake sites should include bathymetry, location of inlets and outlets, areas of thermal stratification and oxygen depletion.

Individual sites in the lake and flowing water systems should be established near high exposure areas (near-field) and away from exposure areas (far-field). Multiple sites within the near- and far-field areas will assist with determining spatial variation. All sites must be designed to allow for multiple sample events. Reference areas should be sampled and would represent far-field areas. These sites will be similar in nature to the study areas but be situated beyond any actual or potential exposure (industrial/municipal). Reference areas on lakes may be located on a separate lake, provided limnological features are the same. Benthic invertebrate samples are often taken in close proximity to water quality sites to allow for incorporation of water quality parameters in benthic habitat assessments. For the flowing water systems, it is recommended that the invertebrate samples be taken in the vicinity of the water quality sampling sites.

There are three wide-scale lake habitats; littoral, sublittoral and profundal. The *littoral* zone is related to the shoreline and includes the riparian vegetation. The *sublittoral* zone can be considered that area which lies above the thermocline and is generally free of rooted vegetation. The *profundal* zone is below the thermocline; generally considered the deepest part of the lake. The littoral habitat is highly variable due to seasonal influences, land use patterns, riparian variation, and direct climatic effects producing high-energy areas. Determination of benthic invertebrates can be difficult, however, due to the number of invertebrates, areal extent, and growth of the macrophyte beds (weeds and grasses). The sublittoral habitat, lacks the biodiversity of the littoral habitat, but is less subject to habitat variation. The sublittoral habitat is rarely exposed to severe hypoxia (but might also lack the sensitivity to toxic effects that may be found in the sediment of the profundal zone). The sublittoral habitat supports diverse infaunal populations, and standardized sampling is easy to implement because a constant depth and substrate can be selected for sampling. While the sublittoral habitat is often the preferred habitat for surveying the benthic assemblage in most regions, the many rocky lakes in Nova Scotia means that the littoral zone very often is the preferable study area. It is recommended that the sublittoral zone be the target sampling area in each lake within the monitoring program; however, when this zone is not able to be effectively sampled on a repeat basis, littoral-based sampling sites may be used. This may result in a lake have a mix of sublittoral and littoral zone benthic sampling sites, which is acceptable. However, once a zone is chosen for sampling for a specific site, the same zone must be sampled at that site during each repeat sampling event.

It is suggested that benthic sampling be conducted once a month during the growing season for Tier I lakes, and twice per growing season for Tier II and III lakes. In flowing water systems, it is recommended that benthic sampling be conducted twice per growing season. Growing season is generally considered to run from early spring (April) to late fall (October).

4.6.2 Biological Criteria

Biocriteria provide the standard by which a lake may be assessed and managed for biological integrity. Biocriteria are developed from biological parameters and together with the water quality parameters represent the qualities which must be present for a healthy watershed. These criteria are based on the number and type of organisms present in the water body and are measured using standard metrics.

Specific biocriteria can be developed following the first two to three years of data collection through the WQMFP (see Phase 1 description in Section 4.8) and will be based on conditions of the reference sites. HRM would need to work with an invertebrate specialist to develop these region-specific biocriteria. Dr. D. Barton at the University of Waterloo has worked closely with the City of Waterloo on their biomonitoring program. Guidance on these criteria may be sought from local specialists or from Dr. Barton through Denise McGoldrick, the Environmental Project Manager for Water Resources at the City of Waterloo.

4.7 CONTINUOUS FLOW AND WATER QUALITY MONITORING PROGRAM

The discrete sampling program outlined in the previous sections will allow for tracking of general trends in water quality and ecosystem health. A discrete sampling program cannot be used to assess trends in pollutant loading and, specifically within flowing water systems, will not capture short-term, event-based water quality dynamics. Continuous water quality and flow monitoring is required to adequately measure the total loading of pollutants in flowing water systems, as well as characterize water quality parameters that could be changing on a daily, or hourly, basis (*e.g.,* dissolved oxygen). In particular, the quantification of stormwater impacts will require a continuous monitoring approach.

It is recommended that HRM establish a targeted, continuous watershed monitoring program within the Little Sackville River drainage basin. The Little Sackville River is one of the few streams not intersected by lakes in HRM, and is significantly impacted by urban development and stormwater discharges. In addition, Environment Canada currently operates a real-time water quality monitoring station where the Little Sackville River crosses Sackville Cross Road (Figure 4.11). It is suggested that an additional two continuous monitoring stations be established where the Little Sackville River intersects Millwood Drive and where the stream crosses Old Beaverbank Road. With these three stations water quality, and pollutant loading, can be tracked from the headwater of the stream to near the watershed outlet. At each station a Sonde should be installed, and should be equipped to measure temperature, pH, DO, turbidity, and conductivity. An automated sampler should be installed at each location to collect samples for other parameters such as total phosphorus, total nitrogen, and total suspended solids. A flow monitoring system will be required at each location.

The data obtained from this sampling program would then allow for the calibration and validation of an urban watershed modeling system, such as PCSWMM or QUALHYMO. A validated model could then be used to assess potential stormwater impacts in existing developed watersheds, and develop stormwater management strategies for proposed developments. This study should be conducted in partnership with local research institutions, which would be able to provide in-kind services to help reduce the costs of this initiative. This component of the WQMFP would need to be strongly linked to the future stormwater management functional plan.

4.8 PHASED APPROACH FOR FULL PROGRAM IMPLEMENTATION

In reviewing water quality monitoring programs in other municipalities, it was clear that there were substantial benefits to the long-term success of programs when a pilot study was run for two to three years prior to the implementation of the larger sampling program. This phased approach is proposed for the HRM, as the WQMFP represents a substantial shift in organization and scale. It is recommended that the Phase 1 program be run on three Tier I watersheds (*e.g.,* Russell/Morris Lakes (1EJ-1), Little Sackville River (1EJ-4) and Bedford West(1EJ-5)) for a minimum of two years and include a minimum of one reference lake representative of all three watersheds, if possible. It may be necessary to chose one reference water body within each of the three Phase 1 watersheds if a single water body does not exist to provide reference conditions for all three watersheds. Phase 1 will be used to test the methodology, sampling frequency, lake access, funding strategy and relevant policies and protocols required to support the implementation of the plan. Phase 1 should also be used to complete a detailed study design for the benthic invertebrate biological monitoring, to develop an effective database, and to determine what trends can be detected on a statistically significant basis with the data that is obtained from the water quality monitoring. It is recommended that HRM work with a statistician to assess and fine-tune opportunities for data interpretation.

Testing the WQMFP using a phased approach and adjusting the larger-scale program (as needed) prior to implementation will contribute to more relevant and effective future monitoring.

4.9 WATER QUALITY SAMPLING PROCEDURES AND PROTOCOLS

To maximize effectiveness of a watershed level monitoring program, it is essential that in-field protocols be consistent across time and space. The same methods should be followed every time a field sample is collected. Existing HRM water quality monitoring procedures and other available references for sampling protocols were reviewed during the development of the HRM WQMFP (see Section 2). This review resulted in the recommendation of two publications to address specific procedures related to the collection, preservation, transportation and analysis of water quality samples collected as part of the HRM WQMFP. The two recommended publications are the Environment Canada *Inspector's Field Sampling Manual* (2005) and the American Public Health Association (APHA) *Standard Methods for the Examination of Water and Wastewater 21st Ed.* (2005). These publications cover in detail the procedures that should be followed from the start of a water quality sampling program (*e.g.,* site selection) through to the end (*e.g.,* lab-based analyses of samples collected). The documents are detailed, well organized, and have been reviewed within National government bodies making them valuable resources for training and implementation.

The Environment Canada *Inspector's Manual* (2005) is a guide to field-based sample collection. It relates more to the sample collection phase than the analytical component of water quality monitoring. The manual provides protocols for the sampling of water, sediment, and soil for numerous parameters. Sections on documentation, site selection, sources of contamination, and QA/QC procedures are included to aid in field preparations. It describes common QA/QC practices in terms of sample collection and identification, tool and sample container decontamination, and field QC samples. The manual also includes the instructions on the various water sampler types such as autosamplers, composite samplers, depth samplers, and the grab sampler. Sample protocols are separated based on specific parameter groupings (*i.e.,* nitrogen compounds, with specific protocols detailed for nitrate/nitrite, ammonia and total

Kjeldahl nitrogen). Included in the appendix of the manual are numerous checklists, flow calculations, and conversion factors (Environment Canada 2005). The *Inspectors Field Sampling Manual* can be downloaded from Environment Canada's web-site.

The APHA *Standard Methods for the Examination of Water and Wastewater* (Eaton *et al*. 2005) is the largest single reference for the process of analysis and interpretation of water and wastewater sampling. The document includes basic accounts of sampling procedures and preservation, including holding time for samples. Descriptions of the procedures and reagents required for the analysis of over 400 parameters are provided including equipment and materials lists. Guidelines on the basic interpretation of results are provided for each parameter; detailed results interpretation is highly dependent on specific site conditions.

APHA protocols are separated by parameters and further divided into differentiated tests. For example, there is a Microbiological Examination Section (section 9000) under which there are subsections covering Fungi (section 9610), Protozoa (section 9711), *Enterococcus* and *Streptococcus* (section 9230), as well as Coliform (section 9220). Within the Coliform subsection, there are fourteen procedures related to the enumeration of coliform bacteria.

It is essential that consistency be maintained in laboratory analytical methods across sites, seasons and years. It is mandatory that a long-term monitoring program use consistent analytical methods for water sample processing to allow trend detection. Laboratories in HRM and nationally have a history of changing analytical protocols without notification being provided to clients, and sometimes without a guarantee that the change in methods will not affect results. As such, it is critical that the HRM WQMFP coordinator take ownership over communication with the lab and ensure that the lab contact HRM prior to any change in analysis methodology. HRM should in turn ensure there is a guarantee that results will be not affected by the procedural changes prior to agreeing to them (and record any change in procedures in the database). If the lab cannot guarantee that results will not be affected, HRM should not allow the lab analysis procedures to change.

In addition to the use of well-defined protocols such as those provided in the Environment Canada and APHA documents described above, it is critical that appropriate laboratories be used for water chemistry analysis. The CCME *Canada-wide Framework for Water Quality Monitoring* recommends accreditation from the Canadian Association for Laboratory Accreditation (CALA). The laboratories used by HRM for the WQMFP should be accredited by CALA at a minimum.

In addition to the field and laboratory procedures outlined in the references named above, there are a few region-specific recommendations that will help improve consistency of data analysis. Those recommendations are:

- Always request that phosphorus be measured at "low level". A minimum detection limit of 0.002 mg/L must be used to obtain data of value for interpretation of local conditions; and

- Every Chain of Custody (COC) submitted with water samples should include a list of guidelines against which the results will be compared (*e.g.,* CCME guidelines for the protection of freshwater aquatic life, CCME guidelines for recreational use of freshwater, *etc.*). This will ensure appropriate detection limits are used by the laboratory during the analyses, so that results can be directly compared to the guidelines.

- It is recommended that *E. coli* be used for assessing the microbial quality of fresh waters within HRM. The fecal coliform group is comprised of several different bacterial species, some of which are not associated with fecal matter (e.g. thermotolerant *Klebsiella* species). Epidemiological studies have shown that E. coli levels have a higher degree of association with disease outbreaks in recreational waters, as opposed to fecal coliforms (USEPA, 1986). The USEPA now recommends that all states use E. coli to monitor recreational water systems. Additionally, the CCME guidelines for recreational use provide an *E. coli* recommendation.

4.9.1 Benthic Sampling Procedures and Protocols

As with water quality sampling, consistent procedures and protocols must be used during benthic invertebrate collection and processing to ensure that a robust data set is created using the long-term monitoring data being collected. Inconsistent sample collection or processing will result in an inability to use the data to detect trends in the benthic invertebrate community structure.

Sampling of benthic invertebrates should be carried out in the sublittoral zone where dissolved oxygen levels are greater than 5mg/L (above thermocline) and preferably between 1 and 5 metres in depth. Samples should be taken with a grab (*e.g.,* ponar or Eckman dredge), depending on bottom sediments. If lake morphology or substrate type prevent adequate sublittoral sampling, then shoreline assessments should be made in the littoral zone with D-nets (500 µm mesh) instead.

Tier I lakes should contain between 3 and 5 sampling sites, as well as at least one reference site. The exact number of sampling sites in a lake can be determined by the spatial variability of nutrients, turbidity, and chlorophyll, the size of the lake(s), the size of the inlet and outlets to the lake(s), human use of the lake(s), and historical parameters (*e.g.,* industrial uses). These factors will need to be determined during the initiation of study design on a lake-by-lake basis. Inlet, and possibly outlet streams may also need to be sampled near the confluence with the lake, if variations in invertebrate populations require additional data on source impacts.

A composite of 3 grabs should be standard for each sampling site, when grabs are used. To create a composite, the full grab sample from each of three grabs are consolidated. The one composite sample for each site is then sub-sampled, either collecting a set number of invertebrates (*e.g.,* 100) from each composite site sample, or sampling a set volume of the composite site sample. Composite samples characterize the lake better than a single sample and save field and analysis costs. The principal disadvantage of composite samples is that they do not allow estimation of spatial variability within a lake; however, with more than one sampling site, spatial variability can be minimized.

Detailed sample procedures for shore-line invertebrate sampling using D-nets, is provided in the *Ontario Benthos Biomonitoring Network (OBBN) Protocol Manual* (Jones *et al.* 2005). It is recommended that the “Near-Shore Lake Sampling Methods” be used when grab sampling from the sublittoral zone is not possible.

All samples collected should be preserved in 90% alcohol in the field and returned to the lab as soon as possible. Formalin will dissolve the hard parts of many organisms and is a safety concern to users, therefore it is not recommended.

Recording additional physical parameters should be included in the sampling procedures as well. These include, but are not limited to, dissolved oxygen, depth, temperature, sediment type, and Secchi depth. Habitat evaluations similar to those used in the OBBN program (Jones *et al.* 2005) should be completed for shoreline (littoral) samples.

4.9.1.1 Sample Processing

Lab processing and analysis of benthic invertebrates will consist of washing the samples through a sieve (mesh size = 500 microns) to remove fines and preservative, and subsampling if required to obtain a minimum of 100 organisms. Invertebrate identifications should be made to lowest possible level (usually to rank of genus or species) using standard reference materials. A reference collection for each lake should also be made. These should be properly labelled and stored in 70% ethanol with a drop of glycerine. Biomass measurements of groups of individuals (*i.e.,* mayflies, oligochaetes, amphipods, *etc.*) should be made.

The benthic sample analysis processing can be facilitated by the hiring of an invertebrate specialist within HRM, or through contracting the work to an external specialist capable of identifying benthic invertebrates to the level of genus and potentially species. It is recommended that HRM WQMFP staff correspond directly with the invertebrate specialist used by the City of Waterloo in the development of their biomonitoring program to benefit from the lessons they have learned. The Environmental Project Manager, Water Resources at the City of Waterloo can facilitate this contact.

All data should be fully recorded on standard lab forms for subsequent inputting to a database.

4.10 DEVELOPMENT-SPECIFIC WATER QUALITY MONITORING PROGRAM

Development-specific monitoring programs will still have to be evaluated on a case-by-case basis. However, a general framework for monitoring at each Tier during the pre-construction, construction and post-construction phases is recommended (see Tables 4.9 and 4.10). In addition to the framework provided below, development projects will have to be evaluated for supplementary testing to monitor the specific environmental pressures of each development type. That is, additional nitrate testing may be needed for golf course development, industrial sites will prompt the addition of Total Petroleum Hydrocarbons and the major constituents of gasoline, Benzene, Toluene, Ethylbenzene and Xylene (TPH/BTEX) and metals testing, commercial sites containing large parking lots should also add TPH/BTEX to their monitoring programs, while gas stations, car washes and dry cleaning facilities may also induce very project-specific supplementary water chemistry testing.

A benthic sampling program is recommended for the littoral zone of lakes during the construction phase of development projects in Tier I watersheds. On a project-by-project basis, the need for a benthic monitoring program can be evaluated for Tier II and Tier III lakes.

4.10.1 Pre-Construction Monitoring Program

For water bodies that are not currently part of the HRM-wide Water Quality Program, frequency of sampling should be carried out as follows (see Table 4.9): 3 times per year (Spring turnover – April/May; peak-summer stratification – August/September; and Fall turnover – October/November).

Table 4.9 Scheduling of Analyses for Tier I, II, III Water Bodies Not Already Being Monitored During the Pre-Construction Phase of Development

April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan-Mar
Group 1 Group 2 Group 3				Group 1 Group 2		Group 1 Group 2 Group 3			

For water bodies that are already part of the HRM-wide Water Quality Program, pre-construction monitoring requirements will be addressed by the Tier-specific monitoring being carried out by HRM. No additional pre-construction monitoring will be required for lakes already being monitored by HRM under the WQMFP. Instead, the Tier-specific monitoring program should continue until the start of the construction phase.

4.10.2 Construction Phase Monitoring Program

During construction at all Tier levels, construction-specific parameters (*i.e.,* Group 4, Table 4.6) should be monitoring in lakes. In lotic environments (*e.g.,* streams and rivers), an increased frequency of monitoring is required to capture potential sediment loading effects; sampling frequency would need to be increased above one sample per season. This will be applicable to the Sackville River systems, for example.

Construction-specific parameters should be sampled bi-weekly in lakes that are already being monitoring under the HRM monitoring program. During this time, standard Tier-specific monitoring should continue uninterrupted, simultaneous to the additional construction-specific monitoring (see Table 4.10).

Development projects impacting water bodies that are not part of the HRM Wide-Program should continue to monitor Group 1, 2 and 3 parameters 4 times per year over the course of construction in addition to biweekly sampling of Group 4 parameters. The 4 sampling events per year should correspond to the following timeframes: Spring turnover (April-May); peak Summer stratification (August- mid-September), Fall turnover (October-December), and peak Winter stratification (February-March).

Table 4.10 Scheduling of Analyses for Tier I, II, III Water Bodies During the Construction Phase of Development

April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan-Mar
Group 4 (x2)	Group 4 (x2)	Group 4 (x2)	Group 4 (x2)	Group 4 (x2)	Group 4 (x2)	Group 4 (x2)	Group 4 (x2)	Group 4 (x2)	Group 4 (x2)
Group 1				Group 1		Group 1			Group 1
Group 2				Group 2		Group 2			Group 2
Group 3						Group 3			

4.10.3 Post-Construction Phase Monitoring Program

Following the construction phase, monitoring should return to the Tier II and III level of sampling (see Table 4.8) for a period of two years for all water bodies that are not part of the HRM-wide program.

4.10.4 Mitigative Action Recommendations and Monitoring

Measuring water quality impacts associated with construction phase activities presents significant challenges. Pollutant transport from construction sites is episodic and largely driven by precipitation events. Depending on the size of the development the time scales of these loading events will be on the order of minutes to hours. Continuous monitoring systems for turbidity and/or suspended sediments would need to be implemented in order to ensure the complete measurement of a rainfall-induced pollutant transport event. This type of monitoring approach would not be practical for most development projects. The bi-weekly sampling program recommended in Section 4.10.2 is needed to determine if significant changes in receiving water systems are occurring during the construction phase of a project. This monitoring program will not allow for the quantification of contaminant inputs from construction sites to receiving waters. It is suggested that, in addition to bi-weekly monitoring, HRM implement a consistent set of regulations for mitigating pollutant transport from construction sites. This would include specific criteria for sizing and maintaining stormwater treatment structures such as retention basins.

It should also be noted that there were consistent comments related to fecal coliform and *E. coli* issues on construction sites. The suggestion was that development activities are not the source of bacterial issues and as such, developers should not have to continue (or increase) monitoring efforts based on increases in bacterial levels in adjacent water bodies. However, the report authors would like to stress that as the potential for soil erosion increases, the potential for bacterial (*e.g., E. coli*) transport is also increased. As such, while development activities may not be a “source” of *E. coli*, they are facilitating the transport of microbial contaminants that are present within the soil environment, due to a host of other sources such as pets and wildlife. HRM may need to help improve education within the development community related to bacterial issues. Improved education would in turn reduce frustration within the development community and thereby improve their commitment to appropriate, effective sedimentation and erosion mitigation and monitoring.

5.0 Future Water Quality Management

5.1 PROGRAM COSTS AND FUNDING

To develop an understanding of the potential costs associated with the proposed monitoring program framework, the basic program elements were detailed, including costs for sample collection (personnel and equipment) and lab analysis. This information was then applied to potential variations of the overall water quality monitoring program. The different options for the potential monitoring program varied the number of water bodies being monitored and the types of parameters being assessed. By developing a range of potential program costs, the project team was able to depict various cost options for the proposed monitoring program. The proposed water quality monitoring funding was developed, and some of the potential mechanisms for obtaining ongoing funding for the water quality monitoring program were reviewed and relative strengths and weaknesses were established.

5.1.1 Program Cost Options

The study team developed an overview of the costs associated with running each of the variations of the monitoring program over the course of one year. This information is detailed in Appendix C. Four basic water body monitoring programs for lakes and one for flowing waters were considered. The first assumed that HRM would monitor all of the Tier I and Tier II water bodies identified in this report, along with one lake in each of the Tier III watersheds. The second assumed that HRM would monitor all of the Tier I and Tier II water bodies identified in this report. The third assumed that HRM would monitor all Tier I water bodies identified in this report. The fourth option assumed that HRM would only monitor the High Priority water bodies identified in this report. Finally, the costs to monitor the identified flowing water systems were also developed. A summary of the different options is provided in Table 5.1.

Table 5.1 Monitoring Program Cost Option Summary

Monitoring Program Description	Number of Tier I Water Bodies	Number of Tier II Water Bodies	Number of Tier III Water Bodies	Number of Flowing Water Systems	Personnel and Equipment	Lab Analysis Fees	Total Program Costs
Tier I, II & III	47	27	46	0	$84,000 $15,300	$299,664	$398,964
Tier I & II	47	27	0	0	$53,200 $9,690	$196,900	$259,790
Tier I	47	0	0	0	$33,600 $6,120	$136,582	$176,302
High Priority Water Bodies	11	0	0	0	$8,400 $1,530	$31,966	$41,896

Table 5.1 Monitoring Program Cost Option Summary

Monitoring Program Description	Number of Tier I Water Bodies	Number of Tier II Water Bodies	Number of Tier III Water Bodies	Number of Flowing Water Systems	Personnel and Equipment	Lab Analysis Fees	Total Program Costs
Flowing Water Systems	0	0	0	4	$2,800 $3,900	$34,872	$66,772

5.1.2 Costing Assumptions

An overview of each of the elements built into the various monitoring program options is outlined in Appendix C. An outline of the lab rates for the Group 1-4 parameters is also provided in Appendix C. In order to develop the information in Table 5.1, the team built a number of assumptions into the costing. The budget numbers assigned to personnel costs assume that all field work will be contracted out and standard rates applied on an hourly basis. The budget numbers also assume preferred lab rates were assigned at a third party lab since it is likely that if HRM continues with the monitoring program, a reduction in lab rates would be likely based on sample volume. The costing assumes that there is one water quality station per lake, which allows depth profiling. The benthic program assumes that there are three benthic invertebrate stations per lake. In some instances HRM may want to have more than one water quality station in a lake, therefore these numbers may be understated. Without the information necessary to determine which water bodies would require more than one water quality station, the team applied the minimum required stations to each water body. Each flowing water system has been assessed and the number of stations per system is specific to the watercourse. This information can be found in Appendix C, and the proposed sampling locations are presented on Figures 4.9-4.12. Of note, the costing program included above does not include HRM staff costs for data management, analysis, reporting and overall management of the program.

5.1.3 Funding for Ongoing Program Management

The proposed costs as outlined in section 5.1.1 and 5.1.2 represent the very basic components of a monitoring program. There will be overhead and management costs associated with the development of a full-scale water quality monitoring program, such as database management, data interpretation by qualified persons, and the establishment of regular reporting. For example to establish a more comprehensive program, HRM may wish to hire additional personnel to assist in the management of the program and water quality analysis. In addition to the costs above, the study team recommends that funds be established to assist HRM in dealing with known problems. For example, once a lake reaches a water quality objective threshold, or once a problematic water quality trend is established in a given water body, HRM will likely want to take steps to understand the issue in greater detail, and potentially take steps to remedy the situation, as is feasible. In order to do this, appropriate funding should be set aside for ongoing water quality management, response and mitigation. Finally, as the program moves forward and is developed, there were likely be areas of study that HRM will need to pursue on an ongoing basis. Examples of these types of study can be found in Section 6.0 of this report. We would further recommend that budget be set aside to provide ongoing development and research in the establishment of the program.

At the outset of the project, the request for proposals (HRM 2008) indicated that the ideal funding model will make the costs incurred for required monitoring and reporting a part of the development process, and that the program will either be funded in-whole or in part by developers proposing large-scale developments. The RMPS identifies the expectation that funding would be obtained through large-scale developments, which could have a significant impact on lakes, using a Master Planning or Development Agreement process. While these processes represent a method for funding a portion of the program, it is likely that other funding sources will need to be pursued in order to develop a comprehensive, well-managed program. The strengths and weaknesses of potential methods are explored in greater detail below.

Master Planning

There are six master planning sites listed in the Regional Plan. These include, Bedford South, Morris-Russell Lake, Bedford West, Port Wallis, Sandy Lake, and the Highway 102 west corridor. These are all located in the Urban Settlement Designation, which is expected to accommodate a significant portion of HRM's growth over the next 25 years. Water quality monitoring can be required through the Development agreement process as required through the Master Planning process. Some of the strengths and weaknesses of this method are:

Strengths:

- Master Planning is an existing mechanism in place through which HRM can request funding for overall program in place of developer being required to do ongoing monitoring; and

- Large-Scale developments in which there are already expectations that developers will be required to contribute financially through water quality monitoring and management based on the Master Planning Process.

Weaknesses

- Some of the existing Master Plan areas have already been developed and policy framework and monitoring programs have already been established;

- Represents a short-term source of funding where since monitoring is tied into the construction and development agreement process;

- Difficult to determine how long developers should fund the water quality monitoring program; and

- Funding obtained will likely not be sufficient to offset the full extent of the costs of a comprehensive overall monitoring program.

Development Agreement

At present, development agreements are the key planning processes HRM is using to require developers to address development-specific water quality monitoring. As previously noted, the level of funding and involvement in water quality monitoring varies significantly depending on the use proposed, policy requirements, water body involved, Watershed Advisory Board recommendations, and development pressures on the water body concerned.

Strengths

- Development agreements are an existing mechanism through which HRM can request funding for overall program in place of requiring the developer to do ongoing monitoring; and

- There are already expectations that developers will be required to contribute financially through water quality monitoring and management based on the Master Planning Process.

Weaknesses

- Difficult to establish a consistent level of funding from development agreements, since development agreements are dependent on policy environment, public approval process and vary significantly in scope;

- Funding level associated with water quality monitoring through the development agreement is erratic; tied to water body, sampling locations and monitoring parameters; and

- HRM would need to develop a consistent method for determining how much a developer should contribute to the HRM-wide water quality monitoring through the development agreement process, otherwise funding contribution would be managed on a case-by-case basis.

Permitting Processes

HRM requires a variety of permit and application fees through municipal development, planning and building permit processes. These fees differ depending on the type of use being proposed, the size and location of the use, and servicing requirements. The Future Settlement Charge, Sewer Redevelopment Charge, Sewage Treatment Charge, and Solid Waste Charge all represent means for collecting revenue to assist with ongoing municipal costs. If a permit fee could be established to assist in funding water quality, this could assist in the ongoing maintenance of the program. For example, at a rate of $100 per permit, assuming 4000 permits a year, HRM could fund the program in the amount of $400,000.

Strengths

- Establishes a more consistent method for obtaining funding; and
- Is more representative of the relationship between development and water quality; large-scale developments tend to be targeted for water quality monitoring because they represent a significant change to watershed, however all development contributes to degradation of water quality and contributes to the need for an overall water quality monitoring program.

Weaknesses

- Municipal jurisdiction over water quality within the *Halifax Regional Municipality Charter (2008)* would need to be studied in greater detail before establishing a funding mechanism. Amendments to the Act may be required; and
- Represents a change in application and standard HRM fees therefore requires approval from HRM management and Regional Council.

Provincial Funding

The study team would strongly recommend the establishment of a partnership with the provincial government for funding in whole or in part of the water quality monitoring program. While the management of inland lakes is a provincial responsibility, municipalities are on the front line of managing impacts to water quality through the development approval and infrastructure process. The new provincial Water Resources Management Strategy could also significantly impact HRM's involvement in water quality management. By developing a direct link between the provincial government and HRM through the funding of this water quality monitoring program, a new framework for water quality management in the province could be established.

Strengths

- Better reflects current alignment of jurisdiction over water quality issues, but allows local governments the resources needed to implement effective water quality management at the local level.

Weaknesses

- If the municipality takes on responsibility of monitoring water quality, funding may not be received from the provincial government at a level representative of the level of effort required to engage in this type of programming. Responsibility could be downshifted, while responsibility for costs and funding changed or shifted over time with the municipality having little influence or control; and

- There is a lack of certainty regarding provincial commitment to provide any level of funding for water quality monitoring.

5.1.4 In-Kind Service Arrangements

Partnership programs (also known as in-kind services) can be established to help offset the cost of a large-scale municipal water quality monitoring program. These partnerships involve setting up an arrangement which will allow both partners to obtain the required data with costs being absorbed by both parties. For example, honours or graduate university students often require data which is expensive and time-consuming for the student to both collect and analyse. An in-kind service could be arranged to allow the collection of data done by one group (HRM) to be analysed and provided back to the municipality by the student. The data could then also be used for the student's particular study project. In-kind service arrangements may also be possible with Non-Government-Organizations (NGOs) that have stakeholder interest in water quality protection within HRM. An example is the Sackville Rivers Association. See Section 5.3 for a more detailed discussion of potential community engagement opportunities.

Listed below are some areas where in-kind services could be developed. In-kind service arrangements are used to help manage costs of water quality monitoring programs in other municipalities across the country. In Tables 5.2 through 5.5 below, the following certification acronyms are used: CALA – Canadian Association for Laboratory Accreditation; SCC – Standards Council of Canada; and NSE- Nova Scotia Environment. Some labs may have additional accreditation not listed here.

Table 5.2 Summary of Academic Institutions, Organizations and Groups with the Potential to Support In-Kind-Service Arrangement Opportunities

Name	City	Area of Expertise	Contact
Saint Mary's University	Halifax	Aquatic habitat assessment/remediation	C. Conrad, Dept. of Geography cconrad@smu.ca 902-420-5737
Dalhousie University	Halifax	Watershed assessment, modeling	R. Jamieson, Process Engineering and Applied Science jamiesrc@dal.ca 902-494-6791
Acadia University	Wolfville	Aquatic ecosystem energy flows, modeling, acidification	M. Brylinsky, Centre for Estuarine Research mike.brylinsky@acadiau.ca 602-585-1509
Nova Scotia Agricultural College	Truro	Aquatic ecology	C. Enright, Dept. of Plant and Animal Studies cenright@nsac.ca 902-893-3827

Table 5.2 Summary of Academic Institutions, Organizations and Groups with the Potential to Support In-Kind-Service Arrangement Opportunities

Name	City	Area of Expertise	Contact
Nova Scotia Community College	Dartmouth	Limnology/water chemistry	J. Kerr, Environmental Engineering waterfront.info@nscc.ca 902-491-1100
Halifax Water	HRM	Water Quality	John Sheppard, Environmental Services 902-490-6958
Nova Scotia Museum of Natural History	(Andrew Hebda: HEBDAAJ@gov.ns.ca)	Halifax, NS	Biological support (*e.g.,* taxonomic identification) 902-424-7353

Table 5.3 Small to Medium Private Labs (regional)

Name	City	Type of Analysis	Certification
Envirosphere Consultants Limited Patrick Stewart enviroco@ns.sympatico.ca	Box 290,6 Unit 5 120 Morrison Dr. Windsor NS 902-798-4022	Bacterial; some chemical	NSE, CALA
Ecowater Nova Scotia Gary Slater info@ecowaterns.com	1679 Hammonds Plains Rd Halifax NS 902 832-7873	Bacterial	unknown
Evolution Water Testing Ltd. Tracey Giodani tracey@evowater.ca	2400 Sackville Dr Upper Sackville NS 902-252-3363	Bacterial	unknown

Table 5.4 Large Private Labs (national)

Name	City	Type of Analysis	Certification
AGAT info@agatlabs.com	11 Morris Dr Unit 122 Dartmouth, NS 902-468-8718	Bacterial; chemical	CALA, SCC
Maxxam Analytics Inc. info@maxxamanalytics.com	200 Bluewater Rd Bedford NS 902-420-0203	Bacterial; chemical	CALA, SCC

Table 5.5 Hospitals

Name	City	Type of Analysis	Certification
QEII- Environmental Services Lab livelyf@cdha.nshealth.ca	5788 University Ave. Halifax NS 902-473-8466	Bacterial; chemical	CALA
Aberdeen Hospital	835 East River Rd New Glasgow NS 902-875-7600	Bacterial	NSE
Colchester Regional Hospital	207 Willow St. Truro NS 902-893-5517	Bacterial	NSE
St. Martha's Hospital	25 Bay St. Antigonish NS 902-863-2830	Bacterial	NSE

Table 5.6 Other

Name	City	Type of Analysis/Service	Certification
NS Dept of Agriculture sparrowmm@gov.ns.ca	Harlow Institute College Rd Bible Hill NS 902-893-7740	Bacterial; some chemical	SCC
Volunteer groups, such as Boy/Girl Scouts, Young Naturalists, Duke of Edinburgh's Award candidates, high school students, river associations (*e.g.,* Sackville Rivers Association), *etc.*		Sample collection, sorting	N/A

5.2 DATA MANAGEMENT

One of the most comprehensive means of managing large volumes of data is through the establishment of a database. Establishing the structure and design of a database is an integral component of running an effective and efficient data-intense water quality monitoring program. Database design must consider the volume and type of data to be stored, the end use of the database (*e.g.,* presentation, statistical analysis, and/or storage, *etc.*), need for compatibility with other programs, frequency of data input and manipulation, and timeframe of the project. It is recommended that the finer details of database design be developed during Phase I of the WQMFP program, using that timeframe to test and fine-tune the design. Recommended categories for database inclusion are:

- Site name and location (including GPS coordinates);
- Sample date, time and weather (including precipitation in previous 24 hours);
- Collection depth of water sample (including whether or not the sample was a composite);
- All water chemistry parameters (including full name, units of measure, detection limits, and results);
- Relevant water quality guidelines (project-specific targets and/or national guidelines);
- All in situ water quality parameters (including full name, units of measure and results);
- Field treatment (*e.g.,* filtering), storage time, preservative type;
- Lab methodology;
- QA/QC procedures for data verification (*e.g.,* 10% of the data to be checked by someone other than the individual who entered it); and
- Ability to detect and identify outliers in the data.

The intended functions of a HRM WQFP database management system were reviewed and discussions were held with other municipalities concerning their own water-based data management experience. This lead to the identification of several key requirements for a HRM WQFP database, as listed below:

- Accessible to all stakeholders;
- Allows queries to be run to extract focused data sets;
- User friendly interface;
- Integrated (or at least compatible) with GIS mapping system;
- Compatible with mainstream data management software for the purposes of exporting and sharing with the public (*e.g.,* Microsoft Excel); and
- Allow basic statistical analyses, or be compatible with programs that include statistics packages (*e.g.,* Microsoft Excel, Systat).
- Potential database systems that HRM can consider for implementation: WaterTrax, Access, Oracle, ENVIRODAT (CCME 2006).

5.2.1 Water Quality Data Analysis

Effectively managing a large database is the first step in successful data management for a project like the HRM WQMFP. The second step in data management is to effectively use the data collected through the monitoring program to improve understanding of the system and subsequently to improve decision making. Data collected and stored in a comprehensive database can become a powerful tool in watershed management, public awareness, health and safety, development approval and city planning. Communication of findings is an essential part of the data analysis process. Water quality monitoring results should be interpreted by qualified persons and findings should be communicated in scientific and layman's terms to make the data more accessible to a wide range of users. CCME (2006) recommends that watershed monitoring should include analyses of data trends over long periods of time, relationships between parameters, and comparisons to published guidelines or regulations. Given the monitoring program proposed for HRM, it is strongly suggested that the water quality data be used for any or all of the following purposes:

- Development of HRM-specific water quality objectives;
- Trophic status assessment, including the validation and running of a predictive model;
    - *e.g.,* using water quality indicators such as total phosphorus and chlorophyll a in a phosphorus model (*i.e.,* lake capacity modeling);

- CCME Water Quality Index (WQI) classification;
  - *e.g.,* provides an overall water quality status that can likely be used in an indicator or status report to track annual changes in water quality; can be linked to a colour-coded indicator scale;
- Statistical-based trend detection for all ecosystem component indicators and subsequent identification of potential causes and treatment options (work with a statistician to develop options);
  - *e.g.,* an increased frequency of "green water" events tied to changing trend in phosphorus and/or chlorophyll a levels; identification of nutrient loading source;
  - *e.g.,* an increase in acidity of lakes prompts identification and implementation of treatment options;
- Identification of problem sources for the purpose of taking corrective action.
  - *e.g.,* use of benthic invertebrate biocriteria leads to indication of sedimentation effects from development project;
- Relationship tracking to implement improved community planning decision making;
  - *e.g.,* relating water quality changes to changes in amount and/or distribution of pervious/impervious cover;
  - *e.g.,* relating water quality to storm flow using continuous flow;
- Development of a predictive tool for bacterial-based lake closures;
  - *e.g.,* collection of *E. coli* and flow data over a minimum of two years; subsequent identification of conditions that lead to bacterial spikes resulting in ability to monitor for those conditions and predict spikes (and close lakes/beaches) before they occur;
- Public and stakeholder education;
  - *e.g.,* indicator reports addressing the status of the monitoring program and the health of watershed, including yearly results (max, min, mean, *etc.*) and trends for key parameters such as dissolved oxygen, total suspended solids, total phosphorus and bacteria; and
  - *e.g.,* indicator reports can relate annual findings to priority actions that the public can take.

5.2.2 Benthic Invertebrate Data Analysis

It is recommended that the standard biometric measurements be calculated for each benthic invertebrate sample collected. The results can then be compared among sites within the same lake, as well as among lakes in the same watershed, as appropriate. The biometric measurements recommended are:

- Species abundance;
- Species richness;
- EPT:Total ratio (see additional note below);
- % Chironomidae;
- % Oligochaetes;
- % filter feeders; and
- Simpson's Diversity index.

The EPT:Total ratio is a commonly used water quality assessment index that is based on the abundance of three pollution-sensitive orders of macroinvertebrates (Ephemeroptera (E) or mayflies, Plecoptera (P) or stoneflies, and Trichoptera (T) or caddisflies) present in water bodies. The numbers of these three taxa are compared to the abundance of other macroinvertebrates in the water body to calculate the EPT to total ratio index.

Optional analyses:

- Total abundance (excluding Chironomidae and Tubificidae);
- Community assemblages;
- Co-variance (*e.g.,* richness vs lake size);
- Carlsen's index (needs nutrient measurements);
- Number of long-lived taxa (*Corbicula*, *Hexagenia*, mussel, snails);
- Cluster analysis (*e.g.,* Bray-Curtis);
- Hilsenoff Biotic Index; and
- As discussed in Section 4.6.2, region-specific biocriteria should also be developed and employed to maximize interpretive potential of benthic invertebrate results.

5.2.3 Contractor Qualification or Certification

The review of best practices in other municipalities and discussion with multiple stakeholders confirmed the importance of consistency in data collection. Some municipalities have addressed the need for consistency in water sampling by having all developers pay into a fund controlled by the municipality so that the municipality can carry out all of the water sampling, including development-specific monitoring. This approach prevents each developer from hiring their own consultant or carrying out the sampling themselves, which can result in very different levels of effort and methodology.

All of the stakeholders consulted during the development of the WQMFP recognized the need for improved consistency of data collection within HRM water quality monitoring programs. However, many expressed concern that a funding program that sees developers pay the municipality for all monitoring is not appropriate.

It is recommended that the responsibility for conducting monitoring stay with the developer, but in an effort to improve consistency of sampling, HRM should establish a qualification process for those carrying out water quality monitoring. That is, only individuals who have been deemed qualified by HRM can be hired to carry out sampling under the HRM WQMFP, including the development-specific monitoring programs. This approach will improve consistency of data collection (identified as a priority by all stakeholders) while giving developers the opportunity to maintain control over resourcing and timelines. Developers would simply have to choose from an approved source-list of contractors who had been through the HRM WQMFP qualification process.

The following recommendations are presented for consideration in developing a certification/qualification program:

- Only pre-qualified individuals will be permitted to carry out sampling under the WQMFP, including HRM-specific or Development-specific monitoring programs;
- Prequalification could require the following: a science degree or water resources/environmental college diploma held by the individual; and /or
- Completion of a training session held by HRM;
- The training session would consist of a 4-8 hour session which would include an overview of the WQMFP as well as detailed instruction on the procedures and protocols used for water and benthic invertebrate sampling, data reporting, lab COC requirements, *etc.* A take-away training manual is recommended;
- It is recommended that the training session be delivered on a semi-annual basis and would be reasonably priced to not exclude qualified independents;

- It is recommended that the qualification program would authorize an individual, not a company, for participation in the WQMFP program. However upon successful completion of the session, HRM could authorize the individual to train an “alternate” within the same company provided the “alternate” holds the required science degree/diploma; and
- Documentation would be provided to HRM to communicate the name, education, and training and qualification (*i.e.,* knowledge transfer of WQMFP specifics) of the new individual.

5.2.4 Stormwater Management

Stormwater management is required within a municipality because development activities change land use and can increase stormwater runoff. More specifically, development and urbanization typically increase impervious surfaces, which do not allow percolation of rainwater. This excess water follows the path of least resistance down gradient and typically, eventually drains into a water body. Stormwater management is the control of the quality and the volume, or quantity, of water. The management and mitigation of this flow comes in numerous forms including those presented below (Dillon 2006).

Source control - these control devices are placed before the entrance of a conveyance method (*i.e.,* channel or pipe) and consist generally of erosion control measures, pesticide/herbicide limitations and measures to control the volume of water that enters the pipe.

Conveyance control - these control devices are placed within the method of conveyance and can vary from vegetated swales to Continuous Displacement Units (CDU), a method of centrifugally removing detritus in the stormwater.

End of pipe controls – Located at the end of the conveyance system (*i.e.,* “treatment” ponds). These ponds do not generally have treatment methods or equipment associated with them. They allow for the detention of surface water runoff; with the increased detention time, the velocity decreases allowing the sediment to fall out of suspension. These ponds do not aid in removing soluble chemical constituents that may be present in the stormwater.

Downstream of the control devices the developer is required (through the development agreement) to monitor the quality of the released stormwater. A list of parameters and the frequency of sampling is decided upon with the aid of the local governing Watershed Advisory Board. The most commonly tested parameters are pH, TSS and Total Oil and Grease.

It is recommended that TSS be a key indicator for the performance of stormwater management systems (Dillon 2006). Development can double TSS levels and runoff volume under some conditions which leads to TSS impacts four times greater than were present during the previous vegetated conditions (Dillon 2006).

As discussed in Section 4.7, a continuous flow sampling program would produce data that would allow for the calibration and validation of an urban watershed modeling system. A validated model could then be used to assess potential stormwater impacts in existing developed watersheds, and develop stormwater management strategies for proposed developments. This component of the WQMFP would need to be strongly linked to the future stormwater management functional plan

5.3 COMMUNITY ENGAGEMENT AND EDUCATION

As many of the sources of impacts to water quality are the result of human development pressures, education surrounding pollution, watershed management, and watershed stewardship are important to maintaining watershed health. Continuing community engagement is another management component of a water quality monitoring strategy. Examples of possible programs are listed below.

5.3.1 Watershed Stewardship Projects

Successful examples of these types of programs include the Sackville River Watershed and the Clean Annapolis River Project. In the instance where a watershed has been urbanized to the point that water quality is deteriorating, municipalities can focus on developing subwatershed restoration projects. These projects are often derived from results of water quality monitoring and testing, which can assist in identifying ‘hot spots’ or particular events or areas which may be causing stress to receiving water quality.

Another example of a similar stewardship program is the Adopt-a-Stream program. Youth groups (*e.g.,* church groups, scouts, guides, and young naturalists), and Senior Centres can become involved through this program. Students or individuals may go out to a chosen stream to conduct water quality analyses and bug sampling. While this activity is primarily educational, these groups can report their findings to HRM. A yearly clean-up can be conducted as part of this Program. There are numerous successful examples of the Adopt-a-Stream program available online (*e.g., http://www.adopt-a-stream.org/; http://www.kelowna.ca/CM/Page454.aspx; http://www.gmbservices.ca/Eco/AdoptAStreamCrossing.htm*). Recognition from HRM can be a certificate to the group and a yearly meet-and-greet for participants. This could coincide with the Indicator Report.

5.3.2 Watershed Citizens Group

An important step toward management of a healthy watershed is to engage citizens living in the watershed. The City of Moncton has developed a very strong sense of stewardship in the Turtle Creek watershed by engaging the local citizens and watershed users at regular meetings of a consistent volunteer group. The City also reports the water quality monitoring information to this group. The City also has a very open relationship with JD Irving Limited. Forest harvesting plans are discussed before the beginning of the season to ensure the City is not harvesting in the same areas as the forestry company, to build common access roads, and to inform the public about seasonal cutting plans. Through years of monitoring, it was determined that septic tank malfunctions were more closely linked to poor water quality than forestry practices. The City has fully paid to replace faulty septic tanks throughout the watershed. As a benefit, citizens feel comfortable calling the City to report any water quality changes (colour, smell) or questionable activities. A similar citizen volunteer group is used in the Municipality of the County of Kings. This group meets on a yearly basis to provide technical and community guidance into the management and direction of the Kings County water quality monitoring program.

5.3.3 Publication of an Annual Indicator/Status Report

An annual watershed indicator report can be a very effective tool to reach a large number of watershed residents and promote the HRM water quality program. There are many examples of this kind of reporting, particularly in the Province of Ontario. A colour coded indicator scale has worked successfully in several watersheds (see Petitcodiac Watershed Alliance example, Appendix A). Success stories can easily be published within the Indicator Report or as another mailout or insert. This is a way to demonstrate the effectiveness of the water quality program and get ‘buy-in’ from the public.

5.3.4 Water Quality Issue Reporting Hot Line

As part of stewardship development, a well-publicized contact number or hotline for residents to report water quality changes or suspicious activity may be helpful. Often, suspicious or illegal activities are witnessed but individuals do not know where or who to call. An anonymous hotline may be an effective method to reach those witnesses. An example is the Petitcodiac Riverkeeper, *Report a Polluter* hotline.

5.3.5 Partnerships with Universities and Government Departments

Long-term, reliable data sets will be helpful to university research programs if made public. Projects can then be developed by University researchers to determine pollution sources, and develop indicator or modeling methodology, as introduced earlier in this report. These types of projects would be highly beneficial to the HRM water quality program and low-cost alternatives to developing similar programs in-house.

Experience has shown that government departments are also more likely to partner with municipalities or organizations that have reliable data sets. In addition, funding bodies often seek concrete methods to determine success, and improved water quality as demonstrated through reliable data, will meet this requirement.

6.0 Areas for Future Study and Report Recommendations Summary

Development of the HRM WQMFP involved consultation with a variety of stakeholders and experts including HRM and Halifax Water staff, the Watershed Advisory Boards and representatives of various municipalities. Through the course of these discussions and other research conducted to develop the plan, areas of potential interest for further study were identified and several recommendations were made in support of the WQMFP. The areas for further study are summarized below and are followed by a summary table of report recommendations. It is noted that the complete set of comments received from the Halifax and Bedford Watershed Advisory Boards is presented along with responses in a disposition document included in Appendix D. Comments received from HRM that could not be addressed directly are also included in the disposition document. Due to member availability constraints, comments from the Dartmouth Lakes Advisory Board were not available for inclusion in the HRM WQMFP.

The following areas were identified for future study and analysis during the iterative process of the functional plan development and implementation:

- Specific reference sites, lakes or watersheds have not been included in the recommendations, as reference water bodies must be chosen specifically in response to the lakes selected for inclusion in the WQMFP. To be of value for scientific comparison of results, reference lakes must mimic sample lakes in terms of their bathymetry, substrate type, water chemistry, hydraulics, and watershed characteristics (soils, geology, and vegetation);

- Biocriteria must be developed, as they provide the standard by which a lake may be assessed and managed for biological integrity. Biocriteria are developed from biological parameters and together with the water quality parameters represent the qualities which must be present for a healthy watershed. These criteria are based on the number and type of organisms present in the water body and are measured using standard metrics;

- Specific biocriteria can be developed following the first two to three years of data collection through the WQMFP and will be based on conditions of the reference sites;

- HRM WQMFP staff will need to work closely with a biostatistician to assess the best analytic methods to use for statistical-based trend detection. Data may need to be collected for two – three years to determine which statistical options can be pursued. A biostatistician can assess the timeframe needed to build a sufficiently robust data set, can recommend the analyses that are appropriate for the type of data being collected, and can define the questions that can be answered using those analyses;

- The Stormwater Management Functional Plan will need to be integrated with the WQMFP. Stormwater management and surface water quality management are closely related but the scope of the current project did not allow for detailed stormwater management recommendations. The WQMFP should be designed to produce data that can be used for calibrating and validating stormwater planning tools. Section 5.2 provides recommendations for data management based on experience and input from various stakeholders;

- Development of an orientation program for developers and contractors that would present an overview of the WQMFP and the associated development-specific requirements including sampling and mitigation;

- There are several large water bodies within HRM that were not specifically included within the monitoring program. Porter's Lake and Musquodoboit Harbour are two water systems that are expected to experience increasing pressures due to residential development. Because of their size, these two water systems would require a more sophisticated and intensive sampling strategy, as compared to the lakes which were indentified in this document. Individual water quality studies should be undertaken within these two watersheds.

- Climate change impacts have not been considered as part of this study, but it is recognized that extreme weather events and flooding can cause significant impacts to water quality. Further study may be warranted to better understand how climate change may impact both hydrology and water quality within HRM watersheds;

- It is recognized that the Province of Nova Scotia has jurisdiction over inland waters. This study does not address the different roles and responsibilities of the various levels of government. Cooperation in delivering elements of the recommendations between all levels of government is required, in particular the Province of Nova Scotia;

- The development and validation of models for predicting water quality processes in HRM watersheds should be an on-going part of the WQMFP. Water quality models, such as the Nova Scotia Phosphorus Model (NSPM), have been used in HRM, and other municipalities, for planning purposes for several years. However, there is still a level of uncertainty associated with predictions provided by the NSPM; continued validation of phosphorus loading models will reduce this level of uncertainty and increase acceptance of the model as a planning tool. To start, the NSPM should be applied, using a consistent calibration and validation methodology, to the 11 Tier I High Priority Water bodies listed in Table 4.2. This model validation exercise should be conducted three years after implementation of the WQMFP. This exercise should be used to produce a consistent phosphorus modeling approach that can be applied to future developments. A consistent phosphorus modeling approach would involve specific guidelines for selecting export coefficients, determining phosphorus loading from on-site wastewater systems, determining hydraulic parameters, and incorporating uncertainty analyses; and

- Several other types of models should be developed and tested with data collected within the WQMFP. Maintenance and assessment of the microbial quality of recreational waters is an important issue within HRM. Attempts should be made to develop a predictive tool for forecasting microbial water quality within freshwater bathing waters. A focused study, within 3 to 5 lakes used heavily for recreational purposes, during the first two years of the monitoring program could be used to provide data for the development of this type of tool. This study could be completed in collaboration with local research institutions.

Table 6.1 presents a summary of report recommendations.

Table 6.1 Summary of Report Recommendations

Ref. #	Page #	TOC Item #	Topic	Recommendation
1	2.3	2.1.1 Provincial Regulatory Update	Water Resources Management Strategy	• It is recommended that HRM participate in at least one of the two working groups by having a WQMFP staff member attend the meetings and represent HRM's interests related to watershed-level monitoring.
2	2.3	2.1.1 Provincial Regulatory Update	Water Resources Management Strategy	• There are likely to be other opportunities to comment on the draft Strategy when it is published.
3	2.5	2.2.1 Watershed Advisory Board Summary	Watershed Advisory Boards consistent comments on broad water quality issues	Preliminary comments provided at the meetings on broader water quality monitoring issues in HRM were consistent among the Advisory Boards and are summarized below: • Consistent, prescriptive sampling procedures are needed; • Sampling should be carried out by qualified individuals; • There should be strong science behind the choice of parameters and frequency of sampling; • The data collected must be consolidated, accessible, and used in the decision-making process; • Data analyses and modeling must be backed by strong science; and • Improved communication among HRM and the Advisory Boards to increase awareness of potentially complementary monitoring programs being carried out in HRM.
4	2.6	2.2.2 Community Planning Staff Summary	General comments regarding development of the HRM WQMFP	• It was felt the HRM-wide program was needed to establish a water quality baseline over the long-term so developers know the water quality trends. One year of data is insufficient to create a baseline; the information being collected through development agreements cannot really show changes in water quality.
5	2.6	2.2.2 Community Planning Staff Summary	General comments regarding development of the HRM WQMFP	• Need for timely consideration of applications from water quality perspective when negotiating development agreements.
6	2.6	2.2.3 Developer Summary	Roles and responsibilities under the HRM WQMFP	• Clearly defined roles and responsibilities of all stakeholders are essential (*e.g.,* HRM , watershed advisory boards, province, and developers); • Effective division of responsibility for monitoring during the different phases of construction (developer, general contractor, sub-contractor); and • Clarification of responsibility for maintenance costs for stormwater management and water quality maintenance infrastructure (HRM/developer).

Table 6.1 Summary of Report Recommendations

Ref. #	Page #	TOC Item #	Topic	Recommendation
7	2.6	2.2.3 Developer Summary	Integrated management approach	• Integrated management at the watershed scale is needed, including management of the overlap between watercourse and wetland protection measures and other integrated management programs within HRM such as “HRM By Design” (*e.g.,* can credits be given for development in one area that creates green space or improves hydrology or habitat quality, to off-set work in other areas?).
8	2.6	2.2.3 Developer Summary	Developer monitoring	• Important for private companies to maintain the ability to control timelines and be vigorous in the market (*e.g.,* be able to carry out their own monitoring programs).
9	2.6	2.2.3 Developer Summary	Consistency in monitoring program	• Use of qualified individuals and companies for monitoring program implementation; • Would like to see prescriptive approach to monitoring program parameters, frequency and methods to minimize inconsistency in level of effort among programs; and • Improve consistency at Watershed Advisory Board level, or minimize “case-by-case” recommendations.
10	2.13	2.4.2 CCME Canada-wide Framework for Water Quality Monitoring	Technical documents proposed for development by CCME in the 2006 Canada-wide Framework for Water Quality Monitoring	• It is recommended that HRM carefully review published technical documents released under the CCME Canada-wide framework prior to adoption or implementation given some of the unique characteristics of water quality in this region (*e.g.,* low pH waters).
11	2.14	2.4.3 Government-based water Sampling Protocols	Sampling protocols	• It is recommended that protocols be derived from the methods detailed in *Standard Methods for the Examination of Water and Wastewater 21st Ed*. (Eaton et al. 2005) and Environment Canada’s *Field Inspectors Sampling Manual* (2005).
12	3.4	3.1.3 City of Waterloo Monitoring Program Description	City of Waterloo recommendations for municipal support	• Documented support for watershed monitoring needs to be established in the municipality’s Official Plan (or equivalent municipal policy); and • Provide a dedicated staff person to coordinate the monitoring program with development engineer responsible for reviewing the submitted developer reports.
13	3.4	3.1.3 City of Waterloo Monitoring Program Description	City of Waterloo recommendations for program set up	• Early consultation with land developers and other stakeholders is essential; and • Collaboration with local university experts during the program set-up phase.
14	3.4	3.1.3 City of Waterloo Monitoring Program Description	City of Waterloo recommendations for program funding	• Have developers provide funds for municipality to undertake monitoring - encourages consistent data collection, level of effort, QA/QC, reporting, *etc.*

Table 6.1 Summary of Report Recommendations

Ref. #	Page #	TOC Item #	Topic	Recommendation
15	3.4	3.1.3 City of Waterloo Monitoring Program Description	City of Waterloo recommendations for benthic invertebrate program	• Identification of benthic invertebrate to the lowest taxonomic level possible increases the sensitivity of the assessments.
16	3.5	3.2 Town of Richmond Hill	Inter-municipal senior staff collaboration on water quality program development	• It was suggested that HRM become an active member of the National Water and Wastewater Benchmarking Initiative.
17	3.5	3.3.1 TRCA Watershed Monitoring Program Key Points	TRCA program in kind support	• Use partnerships to provide in-kind services.
18		3.3.1 TRCA Watershed Monitoring Program Key Points	TRCA program recommendations	• Inclusion of winter-based sampling is an improvement to better understand water quality in a watershed; • Beach monitoring should be integrated with the larger water quality monitoring program; • Flow measurement should be integrated with water sampling locations and times to integrate flow and sampling data; and • Further define stress/pressure and response/management indicators and monitoring protocols to measure/monitor these indicators.
19	3.8	3.3.1 TRCA Watershed Monitoring Program Key Points	TRCA data quality and data access recommendations	• Standardize laboratory techniques and detection limits; • Volunteer based programs can generate issues such as biased, unrepeatable, sporadic results, and limited participation; • Develop user-friendly databases and interfaces that capture all data and provide access to data; • Allow at least three years of data to be collected before completing an overall review of findings; • Genus/species identification may be required for benthic invertebrate monitoring to be effective for impact assessment.
20	3.9	3.4.1 New Brunswick System Key Points	New Brunswick program stewardship recommendations	• Identify and involve stakeholders such as the Province, regional watershed groups, industry and local residents; • Provide yearly easy-to-read, short and simple status reports to the public and all stakeholders (see Appendix A for reference); • Regular, dependable funding is key to ensuring program continuity and success.

Table 6.1 Summary of Report Recommendations

Ref. #	Page #	TOC Item #	Topic	Recommendation
21	3.9	3.4.1 New Brunswick System Key Points	New Brunswick program recommendations	• Gather baseline water quality information to measure improvements or habitat decline; • Assemble land and water use information; • Set goals for water quality and determine how the data will be used (*e.g.,* policy, land use, public advisement); • The use of key indicators is important for limiting costs; and • Prepare and implement action plans.
22	3.9	3.4.1 New Brunswick System Key Points	New Brunswick data quality and access recommendations	• Ensure quality assurance/quality control to ensure its usefulness to stakeholders; and • One point of contact for water-based data for reports and information (*e.g.,* NB Aquatic Data Warehouse).
23	4.14	4.2 Water Body Prioritization	Equal priority for flowing water systems and top 11 lakes	• It is recommended that these flowing water systems be given the same priority in the monitoring program as the high priority, top 11 lakes listed in Table 4.2.
24	4.19	4.3 HRM Monitoring Program Elements and Recommended Actions	Development of databases for water quality models	• The development of databases necessary for calibrating and validating predictive water quality models should be considered a key objective of the WQMFP.
25	4.20	4.3.2 Physical and Chemical Water Quality Parameters	Tracking pervious cover in Tier II and Tier II watersheds	• A complete list of parameters selected for testing purposes is provided in Table 4.6. In addition to these four groups of parameters, the amount of pervious cover should be tracked in each Tier I and Tier II watershed.
26	4.26	4.3.6 Sampling Flowing Water Systems	Water quality and flow measurement in flowing waters	• During the first year of the monitoring program, the flow should be measured at each sampling location during every sampling event. For assessing water quality trends in flowing water systems, it is crucial to have concurrent flow measurements.
27	4.26	4.3.7 Water Quality Analysis	Bathymetric data for water quality modeling	• It is recommended that opportunities for bathymetric evaluation of the identified lakes to be sampled be pursued.
28	4.27	4.4 Tier I Program Details	Monitoring frequency and parameters for lakes	• The in-lake water sampling program is to consist of monthly collections during the ice-free season (April – December) and at least one sampling date occurring during the period of ice cover (January - March), conditions permitting. Consult Tables 4.6 and 4.7 for parameters and sampling schedules or Group 1, 2 and 3 parameters.
29	4.27	4.4 Tier I Program Details	Monitoring frequency and parameters for flowing water systems	• All flowing water system sampling locations should be sampled on a monthly basis. Consult Tables 4.6 and 4.7 for parameters and sampling schedules or Group 1, 2 and 3 parameters.

Table 6.1 Summary of Report Recommendations

Ref. #	Page #	TOC Item #	Topic	Recommendation
30	4.27	4.5 Tiers II and III Program Details	Monitoring frequency and parameters for Tier II and Tier III water bodies	• Water sampling will take place on a quarterly basis for Tier II water bodies and will follow the seasonal thermal regimes for turnover and stratification. Should HRM decide to monitor Tier III watersheds, the Tier II program would be followed. Consult Tables 4.6 and 4.8 for parameters and sampling schedules or Group 1, 2 and 3 parameters.
31	4.28	4.6.1 Study Sites	Benthic invertebrate monitoring program	• Site selection criteria for benthic invertebrate monitoring should be consistent with direction provided in Section 4.6.1 .
32	4.29	4.6.1 Study Sites	Benthic invertebrate monitoring frequency for lakes and moving waters	• It is suggested that benthic sampling be conducted once a month during the growing season for Tier I lakes, and twice per growing season for Tier II and III lakes. In flowing water systems, it is recommended that benthic sampling be conducted twice per growing season
33	4.30	4.7 Continuous Flow and Water Quality Monitoring Program	Continuous flow monitoring	• It is recommended that HRM establish a targeted, continuous watershed monitoring program within the Little Sackville River drainage basin. Sondes and automated samplers should be installed at each location.
34	4.30	4.8 Phased Approach for Full Program Implementation	Phased approach to monitoring program	• It is recommended that the Phase 1 program be run on three Tier I watersheds for a minimum of two years and include a minimum of one reference lake representative of all three watersheds, if possible.
35	4.32	4.9 Water Quality Sampling Procedures and Protocols	Analytical details	• Always request "low level" phosphorus analysis (detection limit of 0.002 mg/L); • Every Chain of Custody submitted with water samples should list the guidelines against which the results will be compared; and • E. coli analysis is recommended for assessing microbial quality of freshwater.
36	4.33	4.9.1 Benthic Monitoring Procedures and Protocols	Number of benthic invertebrate sampling sites	• Tier I lakes should contain between 3 and 5 sampling sites, as well as at least one reference site.
37	4.33	4.9.1.1 Sample Processing	Benthic invertebrate identification	• Invertebrate identifications should be made to lowest possible level (genus or species) using standard reference materials. A reference collection for each lake should also be made.
38	4.33	4.9.1.1 Sample Processing	Consultation with Waterloo on benthic invertebrate program	• It is recommended that HRM WQMFP staff correspond directly with the invertebrate specialist used by the City of Waterloo in the development of their biomonitoring program to benefit from the lessons they have learned.
39	4.34	4.10 Development-Specific Water Quality Monitoring Program	General recommendations for development-specific monitoring	• A general framework for monitoring at each Tier during the pre-construction, construction and post-construction phases is recommended as described in Tables 4.9 and 4.10. A benthic sampling program is recommended for the littoral zone of lakes during the construction phase of development projects in Tier I watersheds.

Table 6.1 Summary of Report Recommendations

Ref. #	Page #	TOC Item #	Topic	Recommendation
40	4.35	4.10.1 Pre-Construction Monitoring Program	Monitoring frequency and parameters for pre-construction	• For water bodies not currently in the HRM-wide Water Quality Program, sampling should be carried out 3 times per year as per Table 4.9; and • For water bodies that are already part of the HRM-wide Water Quality Program, pre-construction monitoring requirements will be addressed by the Tier-specific monitoring being carried out by HRM.
41	4.35	4.10.2 Construction Phase Monitoring Program	Monitoring frequency and parameters for the construction phase	• During construction at all Tier levels, construction-specific parameters (*i.e.,* Group 4, Table 4.6) should be monitoring in lakes while lotic environments (*e.g.,* streams and rivers), will require an increased frequency (above one sample per season) to capture potential sediment loading effects; sampling should be scheduled in accordance with Table 4.10 .
42	4.36	4.10.3 Post-Construction Phase Monitoring Program	Monitoring frequency and parameters for the post-construction phase	• Following the construction phase, monitoring should return to the Tier II and III level of sampling (see Table 4.8) for a period of two years for all water bodies that are not part of the HRM-wide program.
43	4.37	4.10.4 Mitigative Action Recommendations and Monitoring	Regulations for pollutant transport from construction sites	• It is suggested that, in addition to bi-weekly monitoring, HRM implement a consistent set of regulations for mitigating pollutant transport from construction sites including specific criteria for sizing and maintaining stormwater treatment structures such as retention basins.
44	4.37	4.10.4 Mitigative Action Recommendations and Monitoring	Developer concerns around E. Coli monitoring	• HRM may need to help improve education within the development community related to bacterial issues.
45	5.2	5.1.3 Funding for Ongoing Program Management	Additional funding requirements	• To establish a more comprehensive program, HRM may wish to hire additional personnel to assist in the management of the program and water quality analysis; • In addition to funds required to support sampling costs, the study team recommends that funds be established to assist HRM in dealing with known problems; and • It is further recommended that budget be set aside to provide ongoing development and research in the establishment of the program.
46	5.4	5.1.3 Funding for Ongoing Program Management	Permit fee funding opportunities	• If a permit fee could be established to assist in funding water quality, this could assist in the ongoing maintenance of the program.
47	5.5	5.1.3 Funding for Ongoing Program Management	Provincial funding opportunities	• The study team would strongly recommend the establishment of a partnership with the provincial government for funding in whole or in part of the water quality monitoring program.
48	5.6	5.1.3 Funding for Ongoing Program Management	In-kind service arrangements	• Partnership programs (also known as in-kind services) can be established to help offset the cost of a large-scale municipal water quality monitoring program.

Table 6.1 Summary of Report Recommendations

Ref. #	Page #	TOC Item #	Topic	Recommendation
49	5.8	5.2 Data Management	Design and refinement of water quality database	• It is recommended that the finer details of database design be developed during Phase I of the WQFP program, using that timeframe to test and fine-tune the design; and • The database should meet a number of criteria with respect to accessibility, interface and compatibility, searchability *etc.*
50	5.9	5.2.1 Water Quality Data Analysis	Interpretation and use of water quality data	• Water quality monitoring results should be interpreted by qualified persons and communicated in scientific and layman's terms to make the data more accessible to a wide range of users. The HRM WQMFP data can be used for a variety of purposes as described in Section 5.2.1.
51	5.10	5.2.2 Benthic Invertebrate Data Analysis	Recommended biometric measurements	• It is recommended that the standard biometric measurements be calculated for each benthic invertebrate sample collected at a minimum.
52	5.12	5.2.3 Contractor Qualification or Certification	Qualification standards for water quality sampling personnel	• It is recommended that the responsibility for conducting monitoring stay with the developer, but in an effort to improve consistency of sampling, HRM should establish a qualification process, including the elements described in Section 5.2.3, for those carrying out water quality monitoring.
53	5.14	5.3 Community Engagement and Education	Programs for community engagement	• A variety of avenues are available to promote community engagement such as: watershed groups, indicator/status reports, water quality hotline, and partnerships with government and academia.

7.0 Closure

This report has been prepared for the sole benefit of Halifax Regional Municipality. The report may not be used by any other person or entity without the express written consent of Halifax Regional Municipality.

Any uses that a third party makes of this report, or any reliance on decisions made based on it, are the responsibility of such third parties. Jacques Whitford Stantec Limited accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made, or actions taken, based on this report.

The information and conclusions contained in this report are based upon work undertaken by trained professional and technical staff in accordance with generally accepted engineering and scientific practices current at the time the work was performed. Conclusions and recommendations presented in this report should not be construed as legal advice.

The conclusions presented in this report represent the best technical judgment of Jacques Whitford Stantec Limited based on the data obtained from the work. If any conditions become apparent that differ significantly from our understanding of conditions as presented in this report, we request that we be notified immediately to reassess the conclusions provided herein.

Yours very truly,

JACQUES WHITFORD STANTEC LIMITED

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Shannan Murphy, B.Sc.
Project Manager

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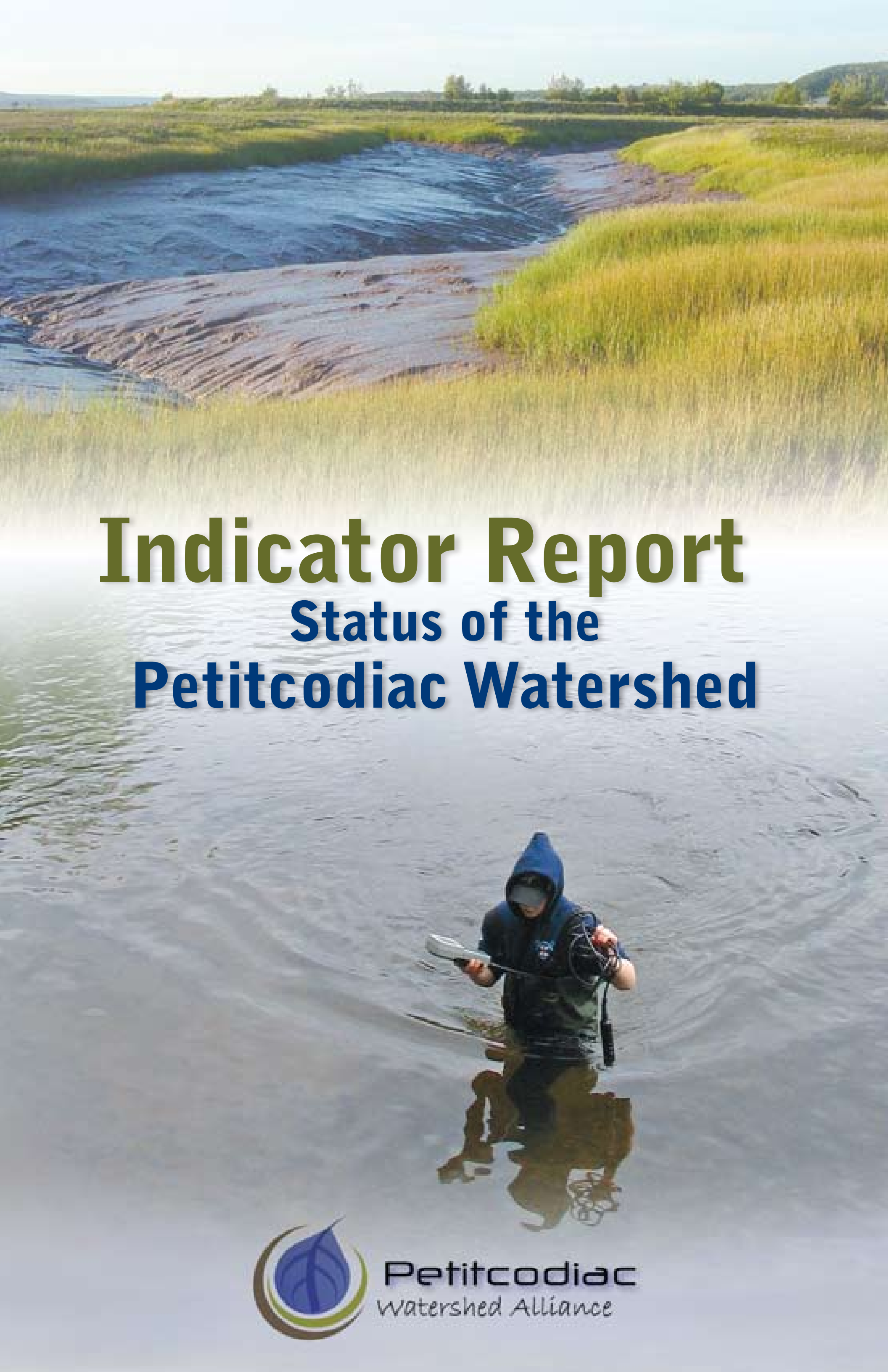
9.0 Appendices

APPENDIX A	Indicator/Status Report Example
APPENDIX B	Watershed Maps (Tier I and Tier II)
APPENDIX C	Budget Information
APPENDIX D	Disposition Document for Watershed Advisory Board Comments and Select HRM Comments

APPENDIX A
Indicator/Status Report Example



Indicator Report

Status of the Petitcodiac Watershed

Petitcodiac
Watershed Alliance

Petitcodiac Watershed Alliance

The Petitcodiac Watershed Alliance (PWA) was founded in 1997. We are a non-profit environmental science and education organization that works to enhance and maintain the Petitcodiac and Memramcook Rivers and their tributaries. Our actions are guided by what we want to leave behind for future generations.

Our vision

To achieve a healthy environment for the greater good of the Petitcodiac and Memramcook watersheds (hereafter referred to as Petitcodiac Watershed).

Our purpose

The Petitcodiac Watershed Alliance promotes watershed awareness, encourages the community to take part in identifying environmental problems and follows through with actions to restore and protect the watershed.

Example of a watershed

Wherever you are, you are in a watershed. A watershed (or drainage basin) refers to a geographical area where water, including rain, snow melts and groundwater, drains downhill into a body of water, such as a river, lake, dam, estuary, wetland, sea or ocean. The watershed encompasses the streams and rivers that convey the water as well as the land surface from which the water drains.

Watershed illustration reproduced with the permission of the Minister of Public Works and Government Services Canada 2008, courtesy of Natural Resources Canada

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Description of the Petitcodiac Watershed

The Petitcodiac and Memramcook Rivers have many small streams that flow into them. Both rivers empty into Shepody Bay, which drains into the Bay of Fundy. The watershed is located in South East New Brunswick, covering approximately 2400 km^2. This area stretches from the Village of Petitcodiac to the Village of Dorchester, including the Greater Moncton area.

The Petitcodiac Watershed lies within the Acadian forest, which is characterized by a mix of conifers and deciduous trees. Approximately 111, 000 people inhabit the Petitcodiac Watershed.

The watershed's claim to fame is its tidal bore, which comes up the Petitcodiac River twice a day. The bore is the result of immense tidal action that characterises the Bay of Fundy, which is home to the highest tides in the world.

The Petitcodiac Watershed is part of the newly appointed UNESCO Fundy Biosphere Reserve (United Nations Educational, Scientific and Cultural Organization). It has the distinction of being the first such reserve in New Brunswick.

Why is the Petitcodiac Watershed important?

Watersheds are an integral part of our environment because they support habitat for plant and animal life, they provide drinking water and they provide recreational areas to enjoy nature and play.

Turtle Creek, part of the Petitcodiac Watershed provides drinking water for the residents of Moncton, Riverview and Dieppe.

With our first Indicator Report, the PWA hopes to increase public awareness on the health of the Petitcodiac Watershed. Seven environmental indicators have been used to assess the health of the Petitcodiac Watershed.

Long term water quality trends

The PWA has been analysing water samples collected from the Petitcodiac Watershed since 1997. Our focus is on freshwater streams and rivers.

Each year, twenty-five sites are monitored from April to October. Monitoring is important because it allows us to quickly identify possible problems. It also helps us evaluate the effectiveness of our rehabilitation and pollution reduction programs.

The water samples are analyzed for a wide range of parameters that help us determine if the stream is healthy. These include, dissolved oxygen content, bacteria levels, pH, salinity and suspended sediment concentrations.

Dissolved Oxygen

Dissolved Oxygen (DO) is the most important parameter in aquatic ecosystems because it allows all aquatic species to breathe and to digest food. Therefore, the amount of DO present in an aquatic ecosystem is an important measure of water quality.

High levels of DO generally indicate a healthy and stable ecosystem that is able to support many different kinds of plants and animals. Different organisms require varying levels of DO; trout and salmon require high levels of DO (7-14 mg/L) while carp and catfish flourish in waters with low levels of DO (below 7 mg/L).

The Canadian Environmental Quality Guidelines state that 5.5 mg/L is the lowest acceptable DO concentration for the protection of all life stages of aquatic organisms in freshwater systems.

There are several factors that influence the amount of DO in freshwater:

- Temperature
- The level of photosynthesis
- Degree of light penetration (turbidity and water depth)
- The level of turbulence
- Amount of decaying organic matter and nutrients

How are we doing?

Overall, the DO levels in all streams and rivers in the Petitcodiac Watershed have been at or above the level required for a healthy aquatic habitat. However, there are a few instances every year where the DO levels fall below the healthy level of 5.5 mg/L.

What is being done?

The PWA is re-establishing indigenous plants and shrubs along streams and rivers. This "riparian vegetation" provides shade for the stream, which helps to lower water temperature (Riparian vegetation refers to the green ribbons of lush vegetation adjacent to water courses). Fish like cooler water that consequently has higher DO levels. Increased riparian vegetation also helps reduce the erosion of stream banks. Furthermore, the vegetation helps filter out sediment, organic matter and pollutants from water runoff from streets, housing lots and businesses.

Bacteria

In order to assess the microbiological quality of the water, *E.coli* levels are measured. *E.coli* is a form of bacteria that is found only in human or animal faecal waste. Studies have shown that certain illnesses, such as gastroenteritis, eye infections, skin rashes, ear, nose and throat infections and respiratory illnesses can result from exposure to high levels of faecal bacteria. A high *E.coli* count signifies the presence of human and/or animal waste, and possibly the presence of other, more serious, disease-producing pathogens. The main sources of *E.coli* are municipal sewage discharges running directly into a watercourse, runoff from failing septic systems and livestock and agricultural operations. The bacteria level in the water is often highest immediately following a rainstorm. The CCME (Canadian Council of Ministers of the Environment) environmental quality guidelines state that *E.coli* levels should not exceed 200 *E.coli* / 100 mL of water in any watercourse where people could be swimming or boating.

How are we doing?

High levels of *E.coli* are very common in the Petitcodiac Watershed. Median yearly *E.coli* concentrations in Rabbit Brook and Jonathan Creek are consistently over 200 *E.coli* / 100 mL, making the water unsafe for humans and animals to live and play in. All other rivers and streams that we study have also had *E.coli* levels greater than 200 *E.coli* / 100 mL.

There are many sources that can lead to elevated *E.coli* levels. In the case of Rabbit Brook, high *E.coli* levels are caused by sewage cross-connections, where raw sewage from households accidentally flows directly into the stream. Sewage cross-connections and large amounts of dirty storm-water runoff from surrounding commercial parking lots have given Rabbit Brook the dubious distinction of being the most polluted stream in the Petitcodiac Watershed.

What is being done?

Prior to the creation of the Greater Moncton Sewarage Commission in 1983, wastewater flowed untreated into the Petitcodiac River. Since 1983, our high-tech, internationally recognized wastewater treatment plant has helped to stop most raw, untreated sewage from entering the Petitcodiac River.

In 2004, the PWA built fences along farmland streams. The goal was to stop cows and other livestock from stirring up bottom sediments and from directly contaminating the stream. This project helped to raise awareness regarding agricultural sources of pollution and resulted in the reduction in the amount of faecal waste entering local watercourses.

Since 2005, the PWA has been working actively with the City of Moncton to identify the most problematic sewage cross-connections. The City of Moncton fixes numerous sewage cross-connections each year.

What else can be done?

- Rural residents should maintain their septic tanks through regular inspections, at least every three years
- Riparian vegetation should be protected
- Livestock should be excluded from streams. The proper collection, storage, transportation, and application of animal waste on the farm can significantly reduce bacteria loss from runoff (Best Management Practices available from Agricultural Alliance)
- Clean up after your pets. Pet waste contains nutrients and pathogens that can contaminate surface water
- The PWA will continue to educate the public, so that we can all reduce our impact on the watershed

Suspended Sediments

Suspended sediments are the floating particles that cloud our streams.

They are primarily clays, silts and fine sands, which require only low velocities and minor turbulence to remain suspended. Suspended sediments cause streams to appear dark brown after a rainstorm. High suspended sediment concentrations are very harmful to fish and other aquatic life.

The negative effects include:

- Abrasion and damage to fish gills, increasing risk of infection and disease
- Loss of sensitive or threatened fish species
- Reduces light penetration causing a reduction in plankton and aquatic plant growth
- Adversely impacts aquatic insects, which are the base of the food chain
- Turbid water increases the probability of boating, swimming and diving accidents
- Increased water treatment costs to meet drinking water standards

The CCME`s Canadian Water Quality Guidelines for the Protection of Aquatic Life states that in clear flow conditions long term increases (1-30 days) of more than 5 mg/L and short term increases (24 hours) of 25 mg/L will be detrimental to aquatic life.

How are we doing?

The urban streams of the Petitcodiac Watershed are very susceptible to sediment loading during and after rain events. For instance, Rabbit Brook and Jonathan Creek remain turbid for up to a week following a heavy rainfall. This is bad for fish, aquatic plants and insects that live in these streams.

There are also many construction projects that cause more sediment to enter the streams. The PWA has observed numerous situations where silt fences, built to trap sediment, were improperly installed. If they are not installed correctly, they can not trap sediment. For example, after a rain event during the summer of 2007, we measured a 460 mg/L increase in suspended sediments in Humphrey's Brook. This significant increase was caused, in part, by improperly installed silt fences along a construction site.

The good news is that suspended sediment concentrations in our rural streams remain relatively low in all weather conditions. We must keep working to maintain these clean flowing streams.

What is being done?

The PWA and the NB Department of Environment as well as the Department of Fisheries and Oceans have been working together to make sure that silt fences are properly installed on construction sites.

The PWA is planting trees and shrubs along rivers and streams in order to stabilize their banks. This riparian vegetation will also filter sediments from runoff before it enters and damages the streams.

What else can be done?

- Support the PWA in their efforts to educate residents and developers on sediment reduction strategies
- Re-establish trees and shrubs on your own property, especially along riparian zones
- Plant a roof-top garden

Salinity

The rising level of salinity in our watersheds is alarming. Salt is a natural component of our landscape, being deposited from a variety of sources over millions of years. Salt enters our waterways from groundwater, from the weathering of rocks or from the atmosphere. In Canada, de-icing salt has become a major source of anthropogenic salt in our rivers and streams. Improperly stored road salt, snow disposal and roadway salt application are contaminating our waterways.

Recent studies have shown that salt concentrations in surface freshwaters are frequently at levels that have, or may have, immediate or long-term effects on the environment and its biological diversity. Increased salt concentrations are leading to the loss of soil stability, which in turn increases soil erosion. In addition, high salt concentrations are damaging plants and provoking negative effects on fish communities that are poorly adapted to the elevated salt concentrations. Toxicity occurs at concentrations as low as 210 mg/L, these concentrations have been observed in numerous urban creeks and streams.

How are we doing?

In 2007, the PWA started measuring salinity levels in the Petitcodiac Watershed. Most streams had acceptable levels of salinity. However, median salinity levels in Fox Creek and Rabbit Brook were well above the 210 mg/L guideline. Therefore, initial measurements suggest that salinity levels at these sites are toxic to aquatic organisms.

What is being done?

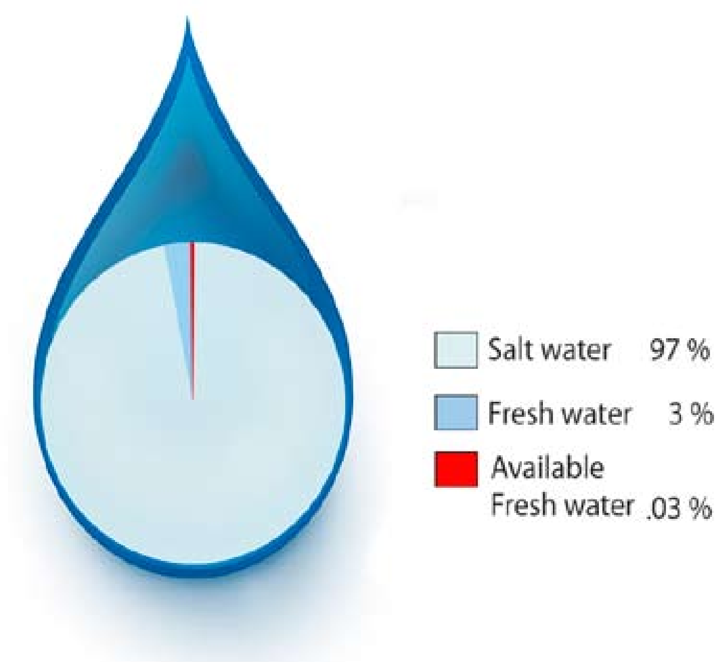
The City of Moncton is currently using a pre-wetting technique during road salt application. This technique reduces the amount of salt applied by 15%.

What else can be done?

- "Best Management Practices" need to be applied to road-salt storage
- Salt application needs to be minimised in ecologically sensitive areas
- Snow dump locations need to be carefully chosen, to minimise environmental damage
- The use of new salt application technologies and alternative de-icing chemicals need to be investigated

Water Usage

Water is an important part of our daily life. It covers 71% of the earth's surface and is essential for all living things. Water is found in oceans, seas, lakes, rivers, aquifers, ice caps, glaciers, swamps and in air vapours. Freshwater only accounts for 3% of the Earth's water, while salt water makes up the other 97%. Humans can only use 0.3% of the world's freshwater for drinking because the rest is "locked up" in the ground or in glaciers and ice caps.



Humans tend to treat this natural resource as if it's limitless, but it is not. Population growth has dramatically increased water demand and man-made pollution has contaminated many of our freshwater resources. In Canada, we have more freshwater than any other country in the world (20% of the earth's freshwater). However, we only possess 7% of the earths renewable freshwater. Despite our relatively vast water resource, the growing Canadian metropolitan population and the rising water demands are stressing available water supplies. More than half of our water resources are located north of the Arctic Circle, while 84% of the Canadian population inhabit the southern part of the country, making access to this water supply difficult and expensive.

How are we doing?

Canadians consume on average 343 L of clean drinking water per person per day. We are some of the highest water users in the world. Water is used for cleaning, drinking, cooking, lawn watering, etc. To compare, our friends in Britain and France only use 150 L a day!

The residents of Greater Moncton obtain their drinking water from the Turtle Creek reservoir. On average, Greater Moncton consumes 17 751 000 m^3 of water per year (this is enough water to fill 7 100 Olympic sized swimming pools). Industrial, commercial and institutional organizations use 30 % of this water while residential homes use the rest. Residents of Greater Moncton on average consume 340 L of clean drinking water per day. All our water is eventually cycled back to the Petitcodiac Watershed.

What is being done?

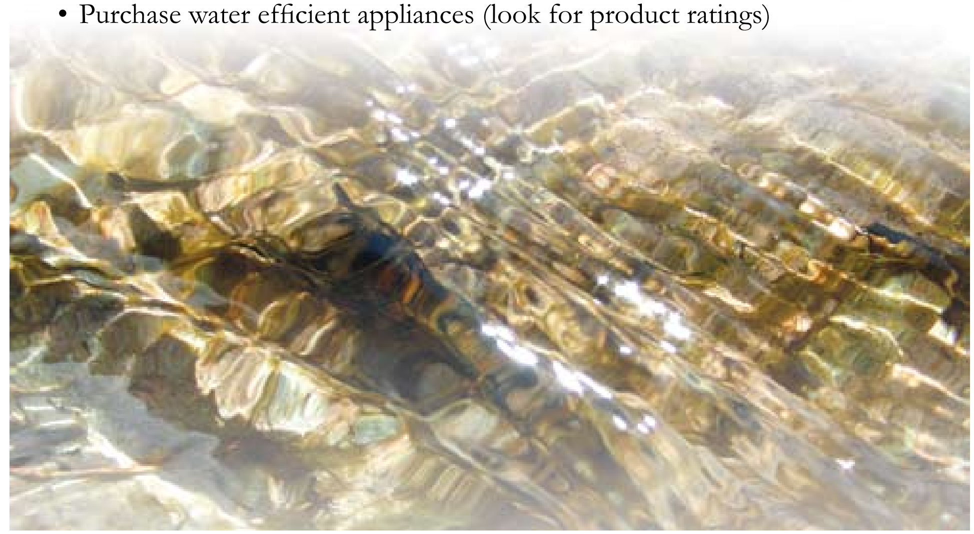
In spite of the ever-increasing metropolitan population, water consumption has remained consistent over the past 7 years. Our stable water consumption is most likely a benefit associated to the implementation of residential water meters. When consumers are asked to pay for a resource, they usually curb their usage. The City of Moncton is also one of the first municipalities in the Atlantic Provinces to implement a lawn watering by-law.

What else can be done?

Although water consumption seems to have levelled off in recent years, the amount of water being extracted from the Petitcodiac Watershed is still high. Reducing the amount of water you use is an important step towards protecting this precious resource. Reduced water bills are an added bonus associated with reduced water consumption!

The following tips will help you protect our freshwater resource:

- Follow the municipal lawn watering by-law. " Even numbered houses can water their lawn/garden for a maximum of two hours a day on even numbered calendar days, while odd numbered houses can water on odd numbered calendar days. There is no watering permitted between 08h00 and 18h00".
- Install water efficient (dual flush) toilets and low flow shower heads and faucets
- Take shorter showers
- Turn the water off while brushing your teeth, shaving, or washing your face
- Fix leaky faucets and toilets (a leaky toilet can waste 200 000 L of water in a year)
- Install grey water systems (used water from laundry, sinks, etc.)
- Install rainwater tank or rain barrel. This water can be used for garden and lawn watering.
- Use water-wise plants. Native and adaptive plants will use less water and be resistant to local plant diseases and pests
- Put a layer of mulch around trees and plants. Chunks of bark, peat moss or gravel slows down evaporation
- When washing a car, use a bucket and sponge (this can save 300 L)
- Only use the washing machine and dishwasher when they're full
- Purchase water efficient appliances (look for product ratings)



Forest Cover

All watersheds have two major ecosystems that are continually interacting: a terrestrial ecosystem and an aquatic ecosystem. Human land based activities can affect water quality and cause the loss of important wildlife habitats. For example, water quality is negatively affected by forest clear cutting.

The detrimental effects associated with deforestation:

- Loss of wildlife habitat
- Increased erosion that results in an increase in sediment entering watercourses
- Increased rainwater runoff
- Shade provided by forest cover is lost, which leads to the warming of streams
- Non-porous surfaces, such as pavement and buildings, reduce the amount of water infiltration, which leads to lower groundwater levels. This can cause critically low summer and winter flows that cannot support aquatic life.

The benefits of forest cover are numerous:

- Removes air pollution
- Produces oxygen
- Conserves energy by providing shade in summer and acting as a windbreak in winter
- Reduces stormwater runoff and improves water quality
- Provides wildlife habitat
- Increases property values
- Improves appearance of a community

How are we doing?

Environment Canada states that 30% forest cover is needed to maintain a healthy watershed. Currently the Petitcodiac Watershed has approximately 68% forest cover. Despite the relatively high forest cover in our watershed, some human activities continue to degrade and threaten the health of the forest in our watershed. Heavy deforestation has occurred in ecologically sensitive areas, such as the immediate vicinity of most rivers and streams (riparian zones), where people like to live and build houses. The ongoing development in the Moncton and Dieppe areas is drastically decreasing forest cover.

Type of land use	Petitcodiac River (km^2)	Memramcook River (km^2)
Forest	1445.2	178.24
Residential developments	194.6	118.28
Farms	143	31.32
Recreational	121.2	62.68
Wetlands	58	-
Institutional	15.8	5.04
Industrial	14.6	3.56
Commercial	7.6	0.88
Total	2000	400

Land use in the Petitcodiac Watershed, (see center spread for detailed map)

What is being done?

The PWA has been involved in planting projects to help increase urban forest cover. Also, the cities of Dieppe, Moncton and Riverview all employ arborists (tree specialists) to protect and maintain the remaining forest. These municipalities also allocate money for tree planting. In 2007, the City of Moncton allocated $100,000 for tree planting in our community.

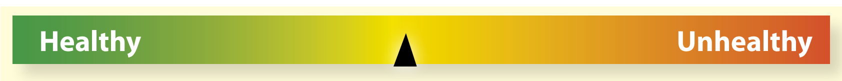
What else can be done?

- The municipalities have a role to play in maintaining and re-establishing forest cover in the Petitcodiac Watershed. They must plan properly to protect the remaining forest cover. They must also work hard to reconnect patches of forests so that animals have a corridor in which to move.
- New developments need to focus on keeping as many trees as possible and limiting the amount of pavement in their designs, particularly in ecologically sensitive areas.
- We need to continue to re-establish vegetative cover where it has been lost.
- We need to educate residents and developers on the benefits associated with forest cover.

Increased Urbanization

When more people move into an area a host of support facilities must be built. Growing cities mean more sewage flowing through treatment plants, more construction projects, more roads, more cars on the road, more housing and more shopping developments. Also, the need for more food can lead to agricultural intensification. In rural areas, agricultural activities intensify to meet the growing food demand. This means that there are more natural or manufactured fertilisers used to increase crop production. We can also expect an increase in the concentration of farm animals. It is inevitable that an increasing population creates unique challenges and stresses on the streams and rivers flowing through our watershed.

How are we doing?



The urban areas within the Petitcodiac Watershed, especially Moncton and Dieppe are currently experiencing high levels of growth and development. Greater Moncton is the only census metropolitan area in the Atlantic Provinces whose growth rate surpassed the national average between 2001 and 2006. It now has a larger population than any other urban area in New Brunswick (Statistics Canada, 2007). The total population of the Petitcodiac Watershed has increased by nearly 12,000 residents since 1991.

Municipality	1991	2001	2006
Moncton	59,313	61,046	64,128
Dieppe	12,496	14,951	18,565
Riverview	16,684	17,010	17,832
Memramcook	4,904	4,719	4,638
Salisbury	1,882	1,954	2,036
Petitcodiac	1,425	1,444	1,368
Hillsborough	1,272	1,288	1,292
Dorchester	1,179	954	1,119
Total	99,155	103,366	110,978

Population in the Petitcodiac Watershed

What is being done?

- The Greater Moncton Sewerage Commission assures that the wastewater returning to the watershed is properly treated
- The installation of water meters has lowered the per capita consumption of water in the Petitcodiac Watershed
- The PWA continues to educate local residents on how to minimize their impact on the watershed. We will continue our school education programs, teaching students to be responsible watershed citizens.

What else can be done?

To minimize the effects or urbanization on our watershed, we should:

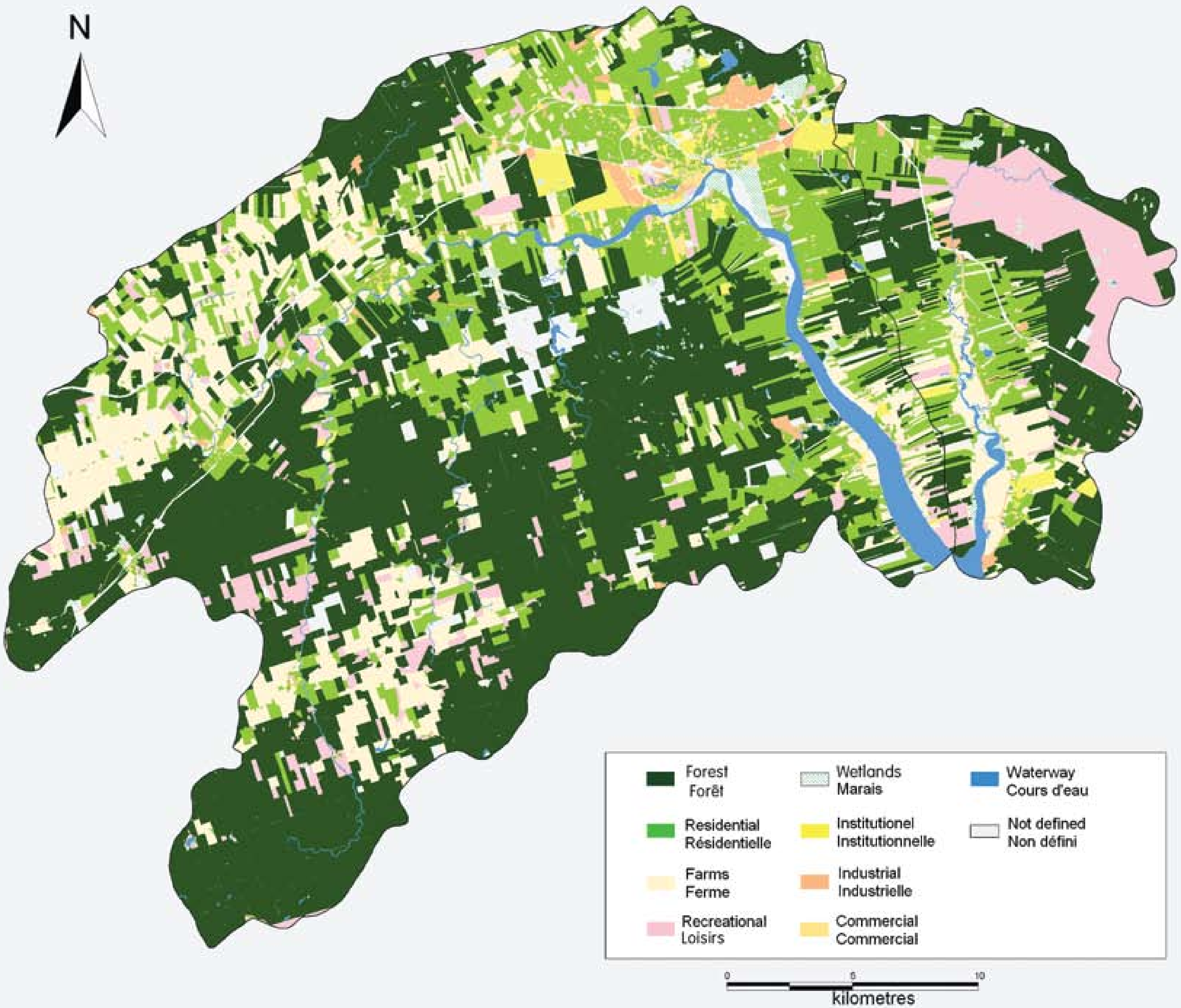
- Reduce our water consumption
- Increase the value associated to green spaces and vegetation, especially near watercourses, as these areas have shown to alleviate some of stresses associated to human activities
- Support organic farms, because they don't use manufactured fertilizers and pesticides
- Educate developers and residents on the importance of proper planning in minimizing runoff from developed areas
- Install wood decking, bricks or interlocking stones instead of impervious cement walkways
- Stop the use of cosmetic pesticides
- Store and dispose of chemicals correctly
- Choose indigenous plants that have low requirements for water, fertilizers and pesticides
- Compost yard and food waste

Summing up: what does it all mean?

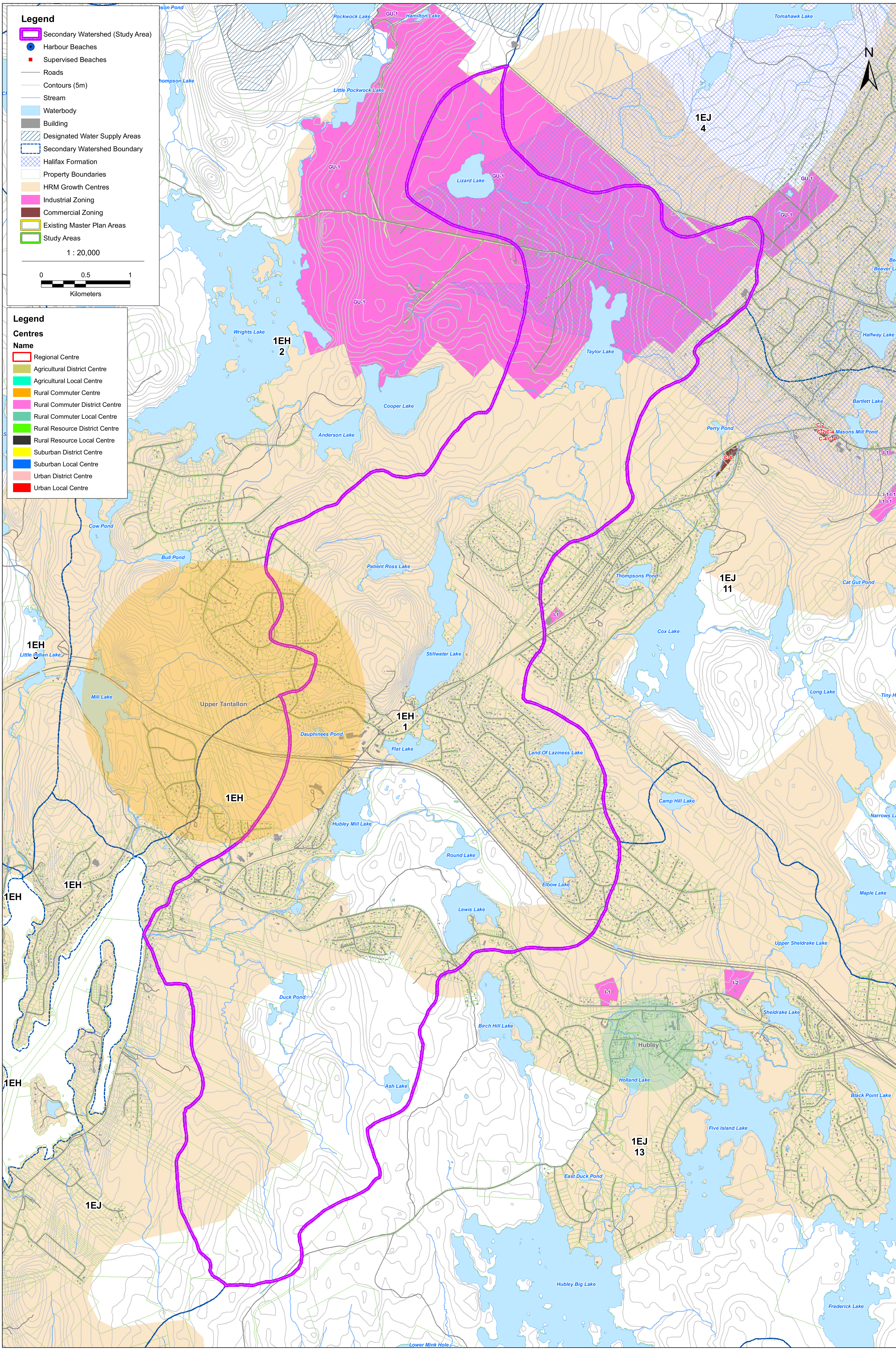
How healthy is the Petitcodiac Watershed? In terms of overall health, the Petitcodiac Watershed is in "fair" health. The evaluation of the seven environmental health indicators revealed that bacteria and suspended sediment concentrations are currently at unhealthy levels, while salinity, water usage and urbanization are at "fairly" healthy levels. Finally, dissolved oxygen and forest cover are at healthy levels.

Although the Petitcodiac Watershed seems to be in "fair" health, we must continue our efforts to minimize the effects of our actions on the watershed. Working together we can achieve a healthy Petitcodiac Watershed that is livable, sustainable and prosperous. By being responsible watershed citizens we can ensure that the beauty of the Petitcodiac Watershed will be passed on to future generations.

LAND USE WITHIN THE PETITCODIAC WATERSHED
UTILISATION DES TERRES DANS LE BASSIN VERSANT PETITCODIAC



APPENDIX B
Watershed Maps (Tier I and Tier II)



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HALIFAX Regional Municipality

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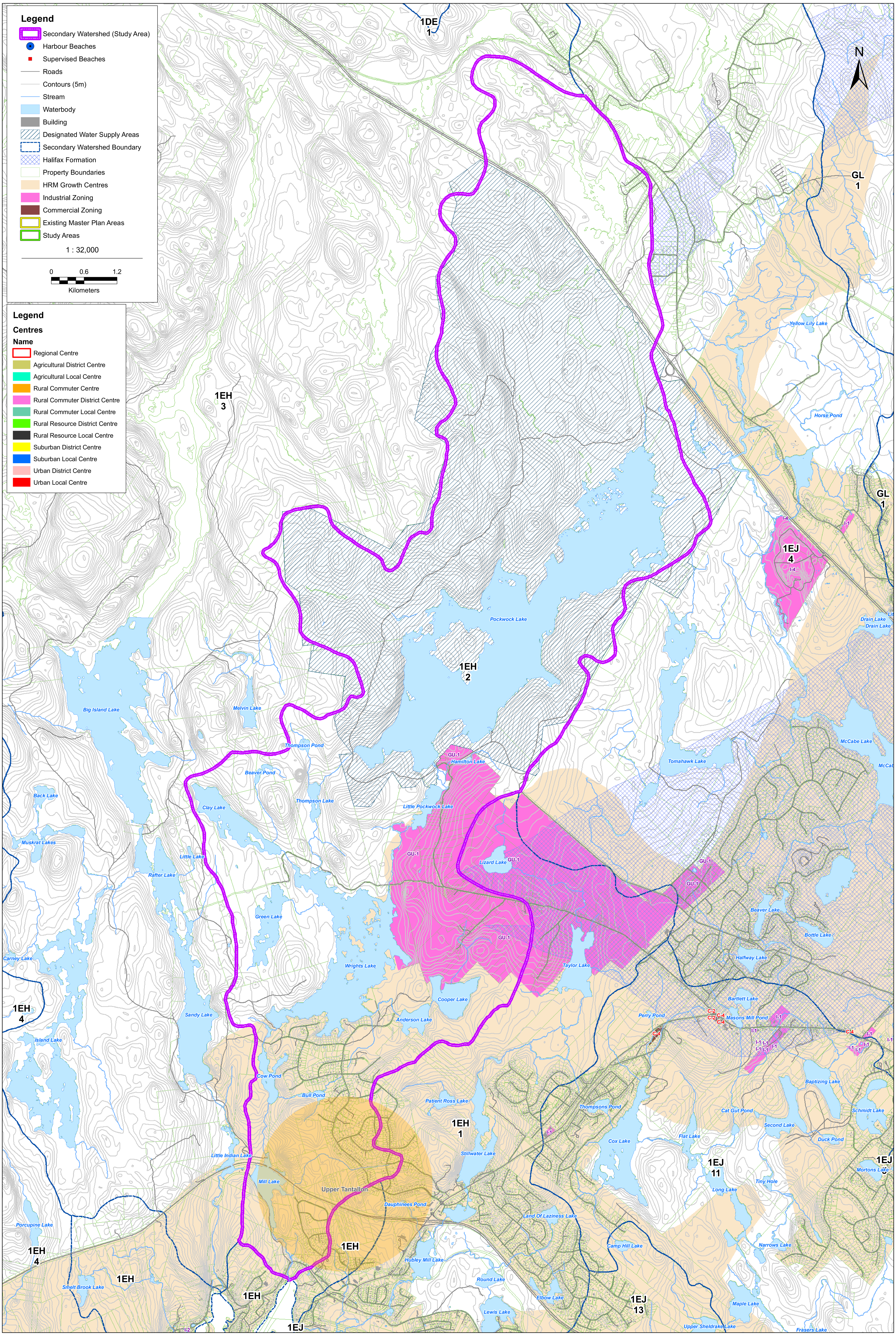

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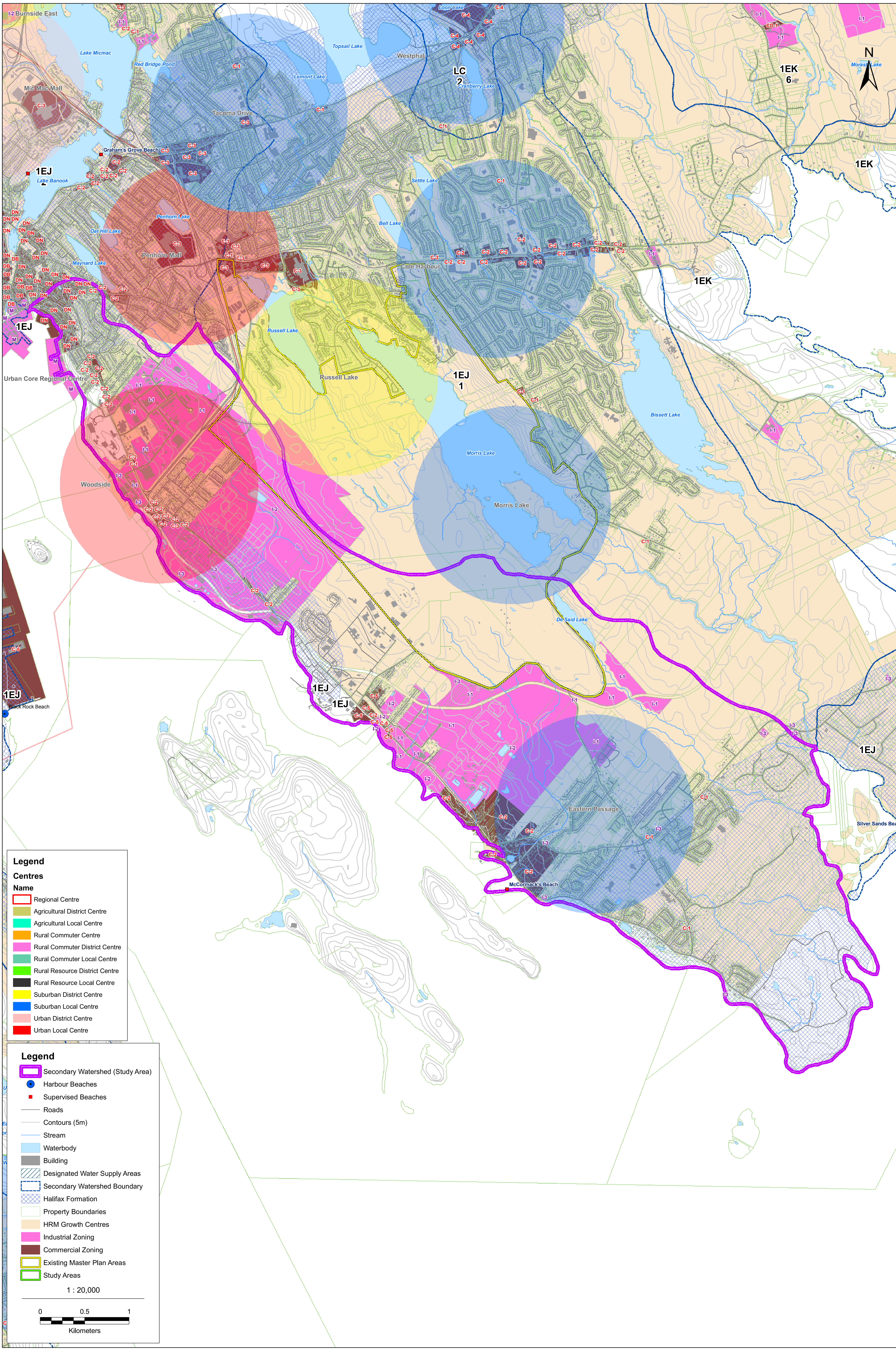

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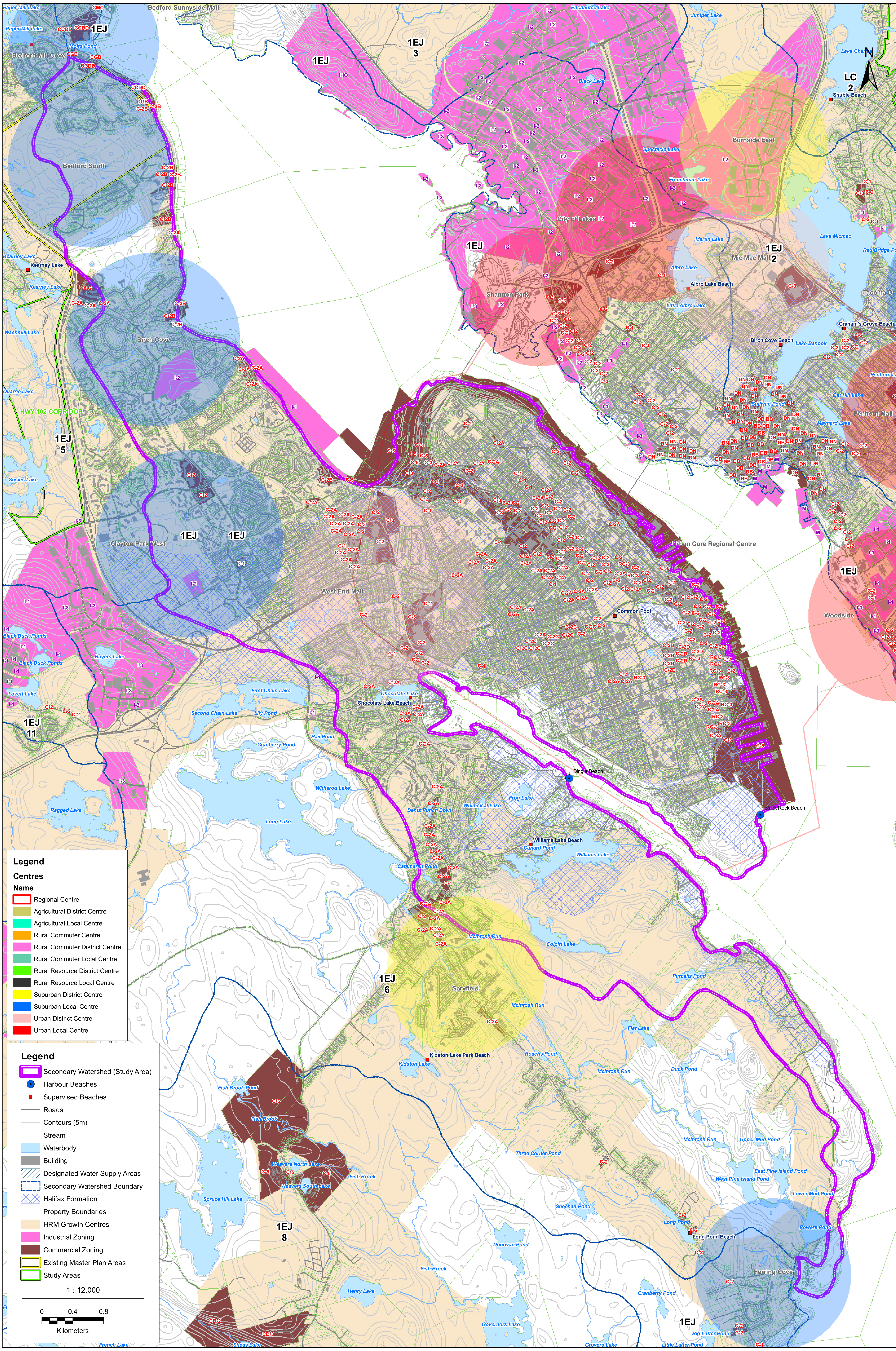
HALIFAX Regional Municipality	SUBWATERSHED 1EJ (EASTERN PASSAGE)



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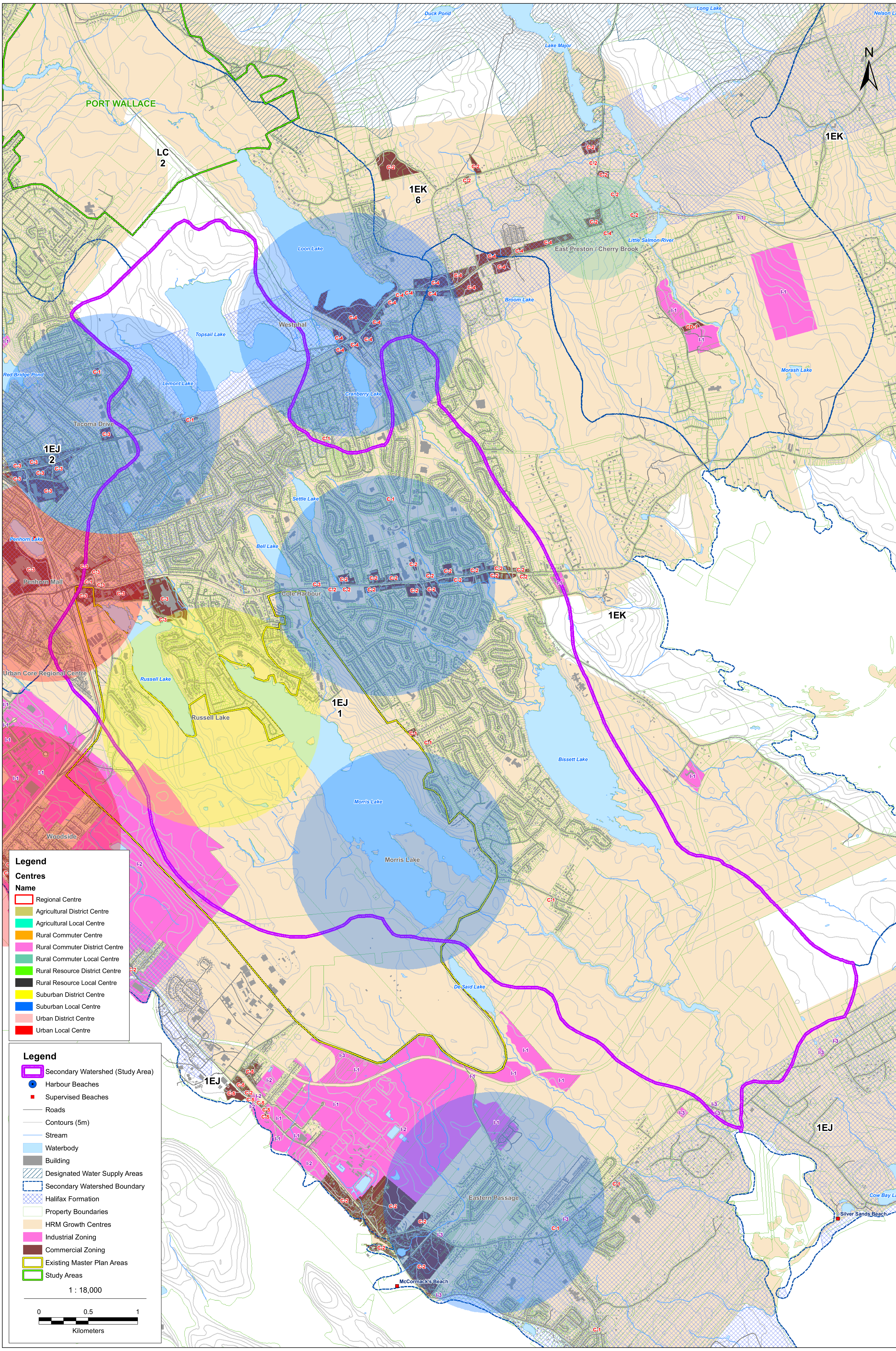

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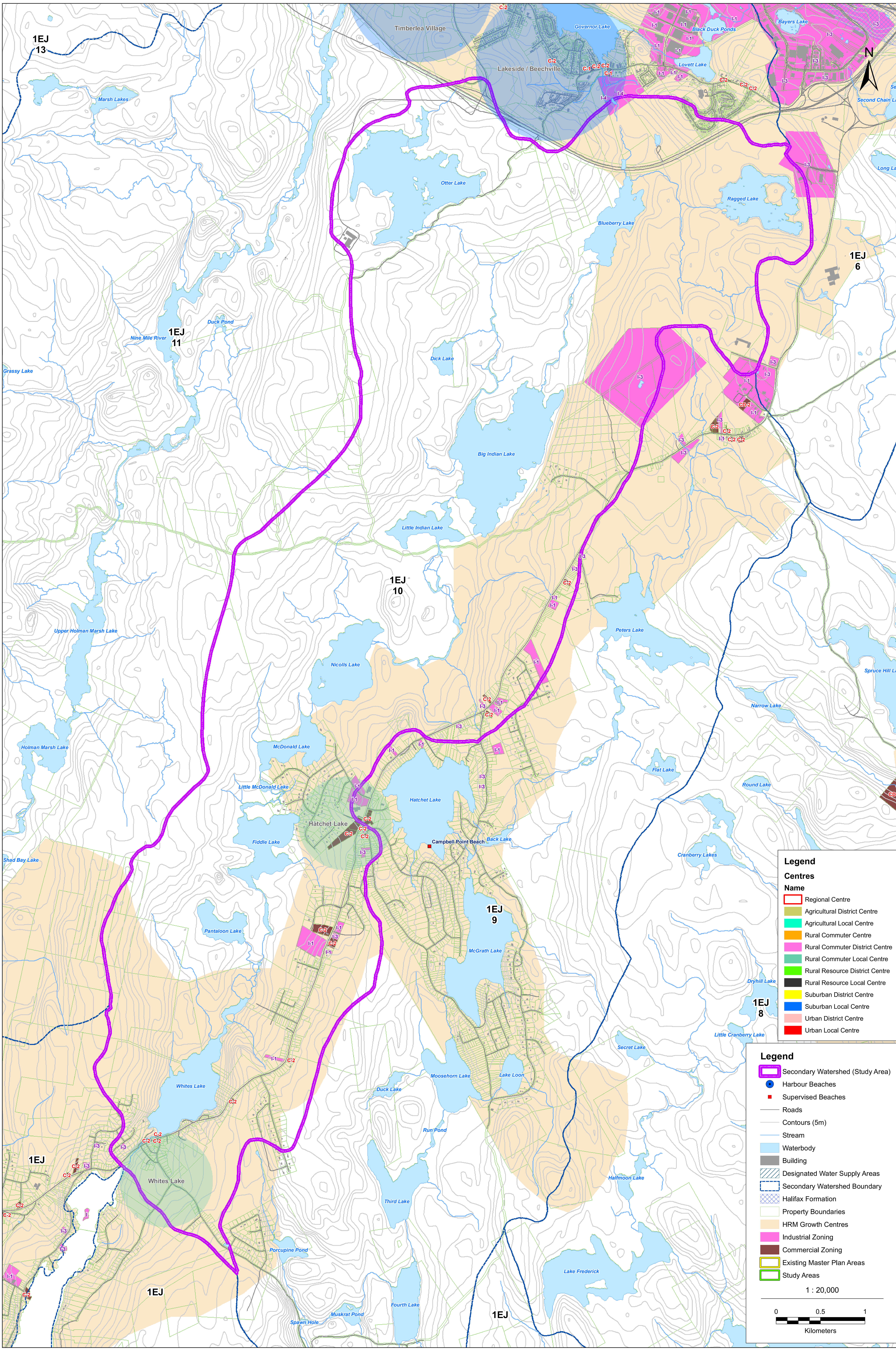

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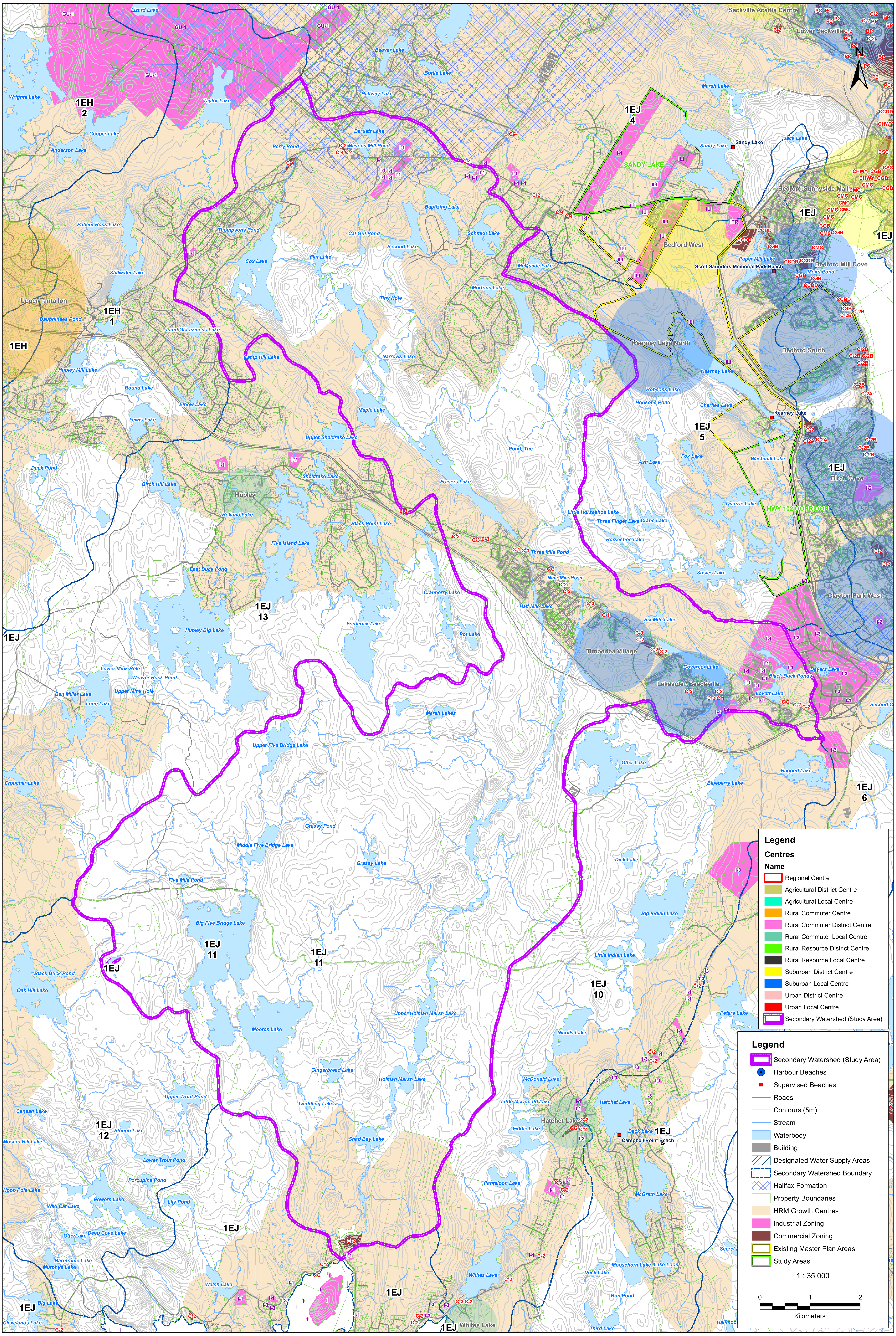

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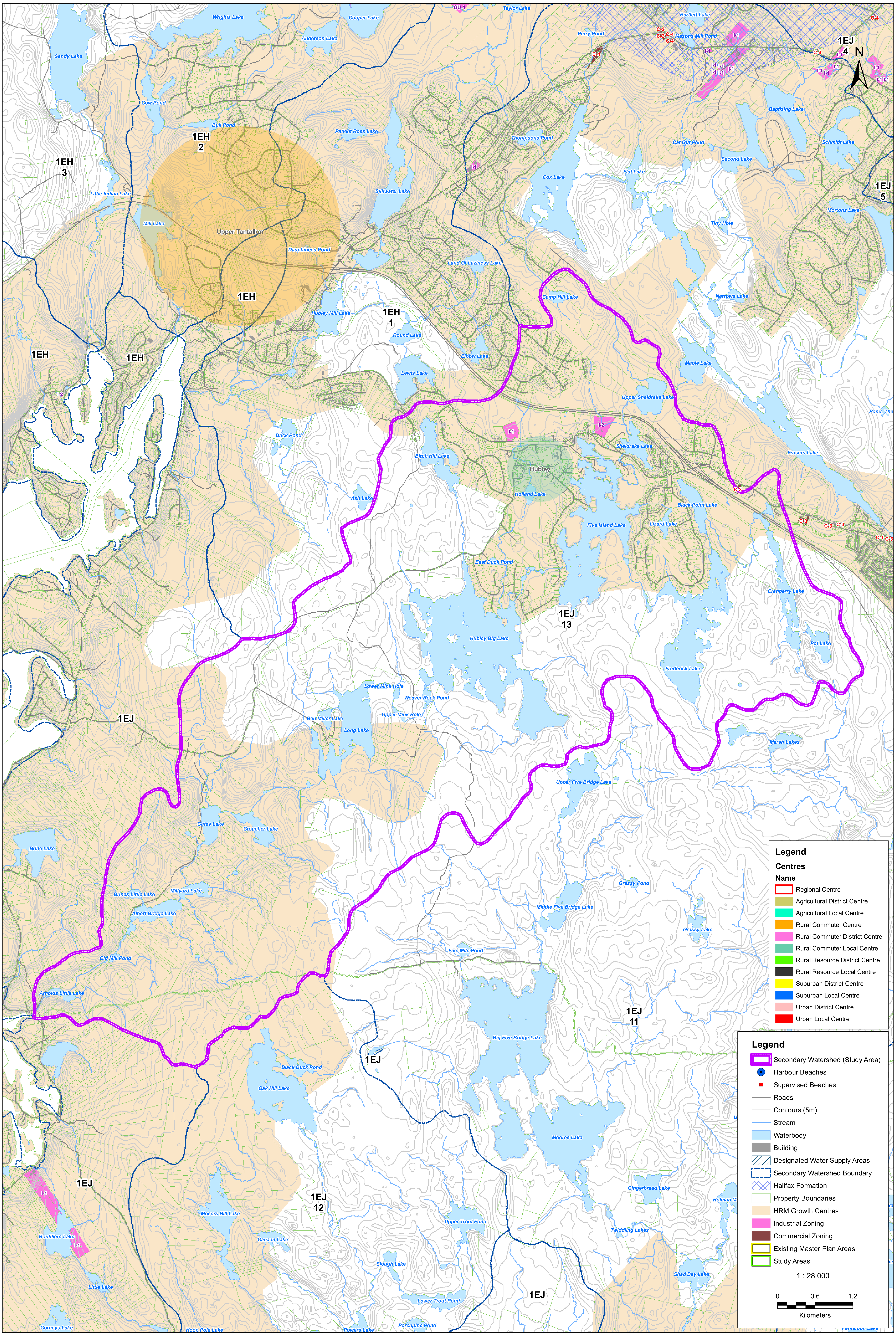

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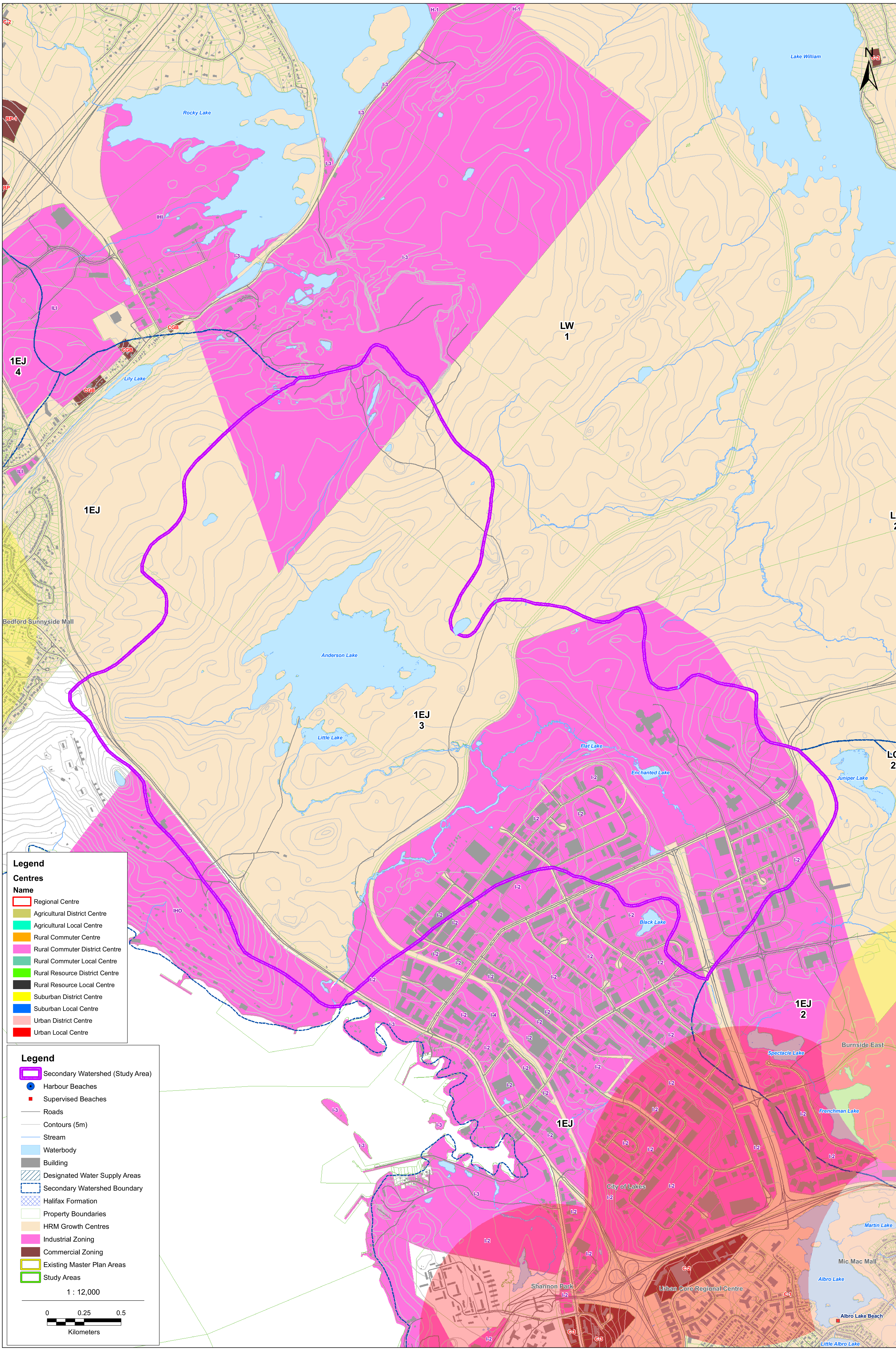

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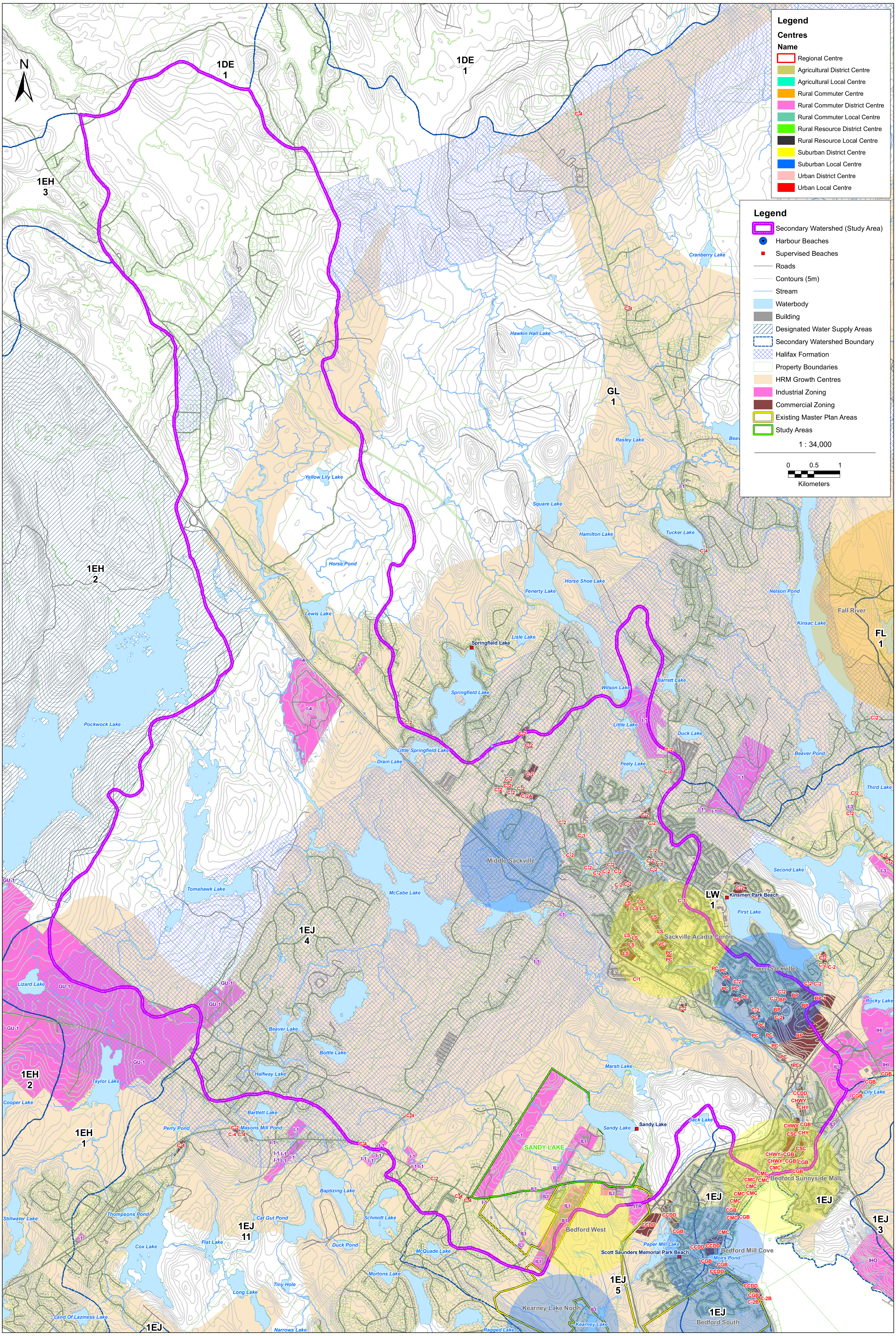

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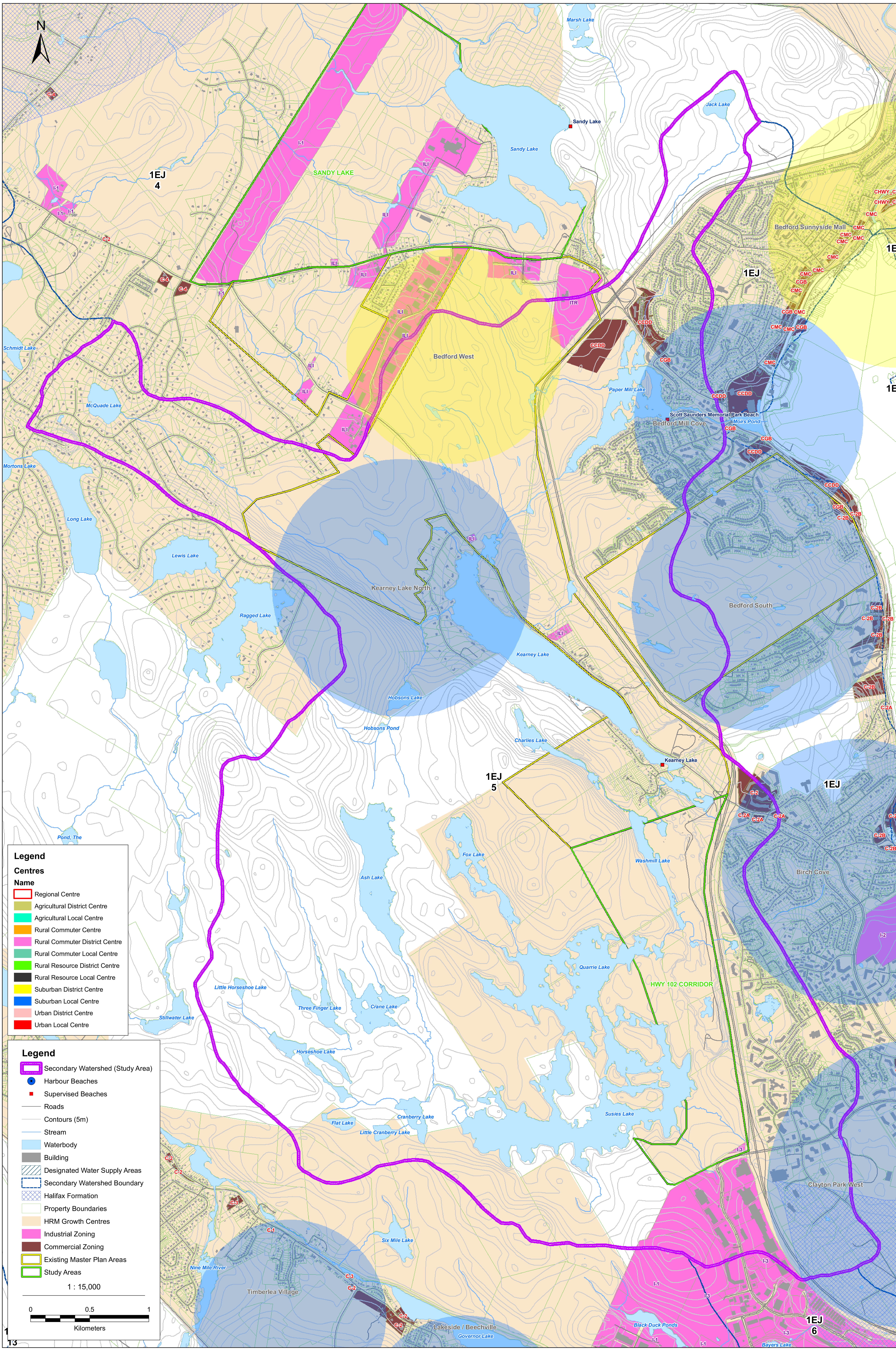

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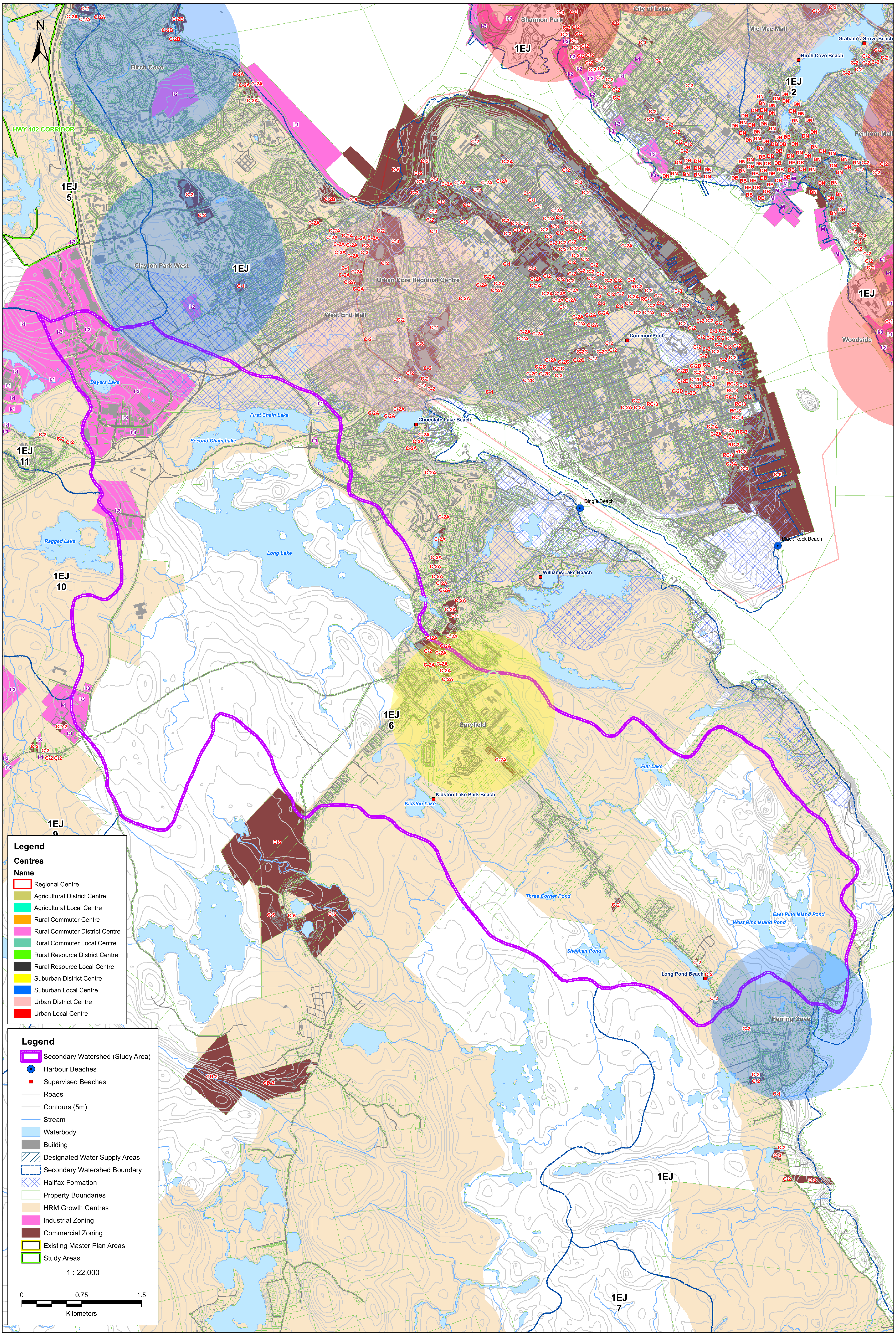

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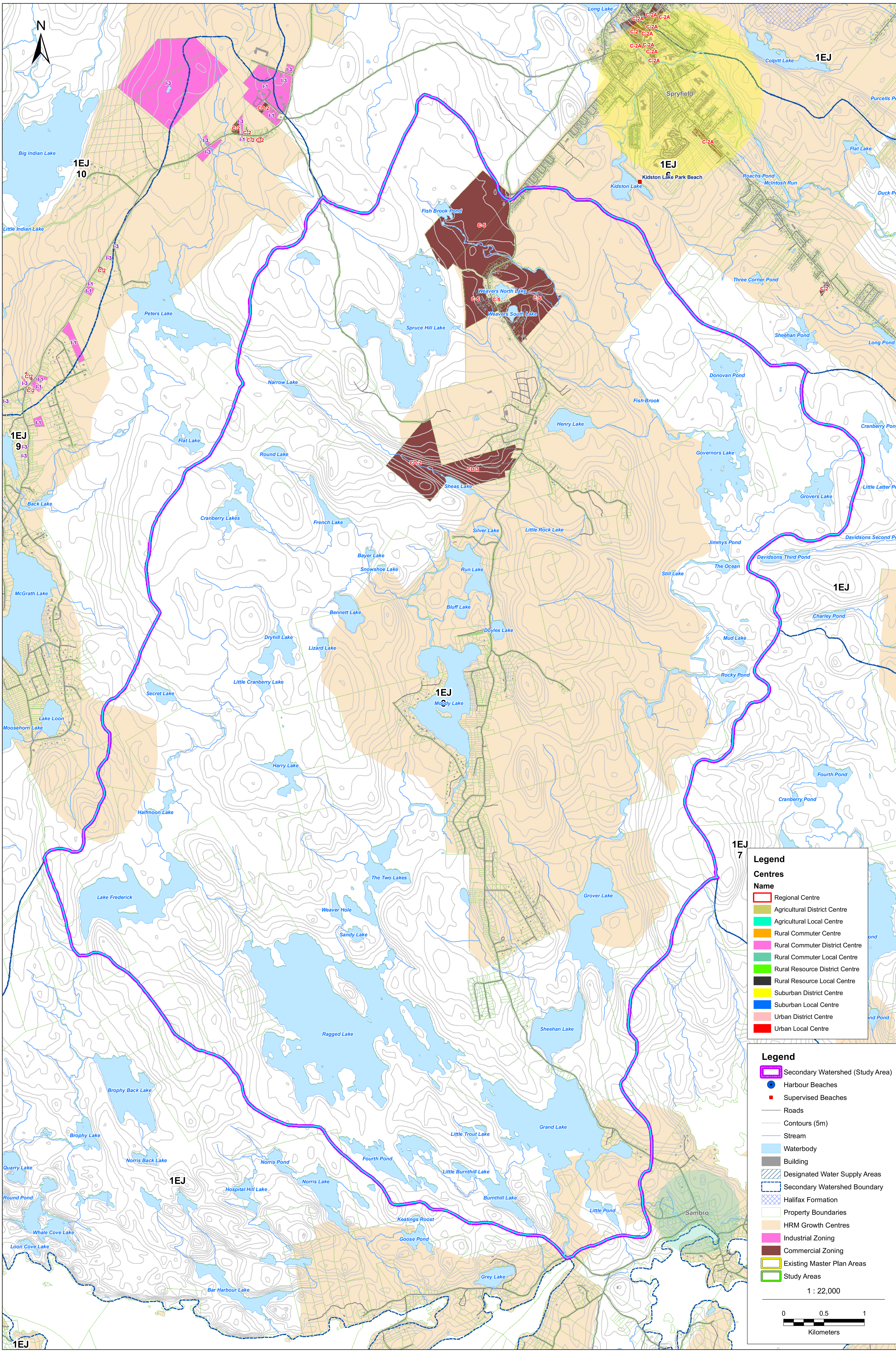

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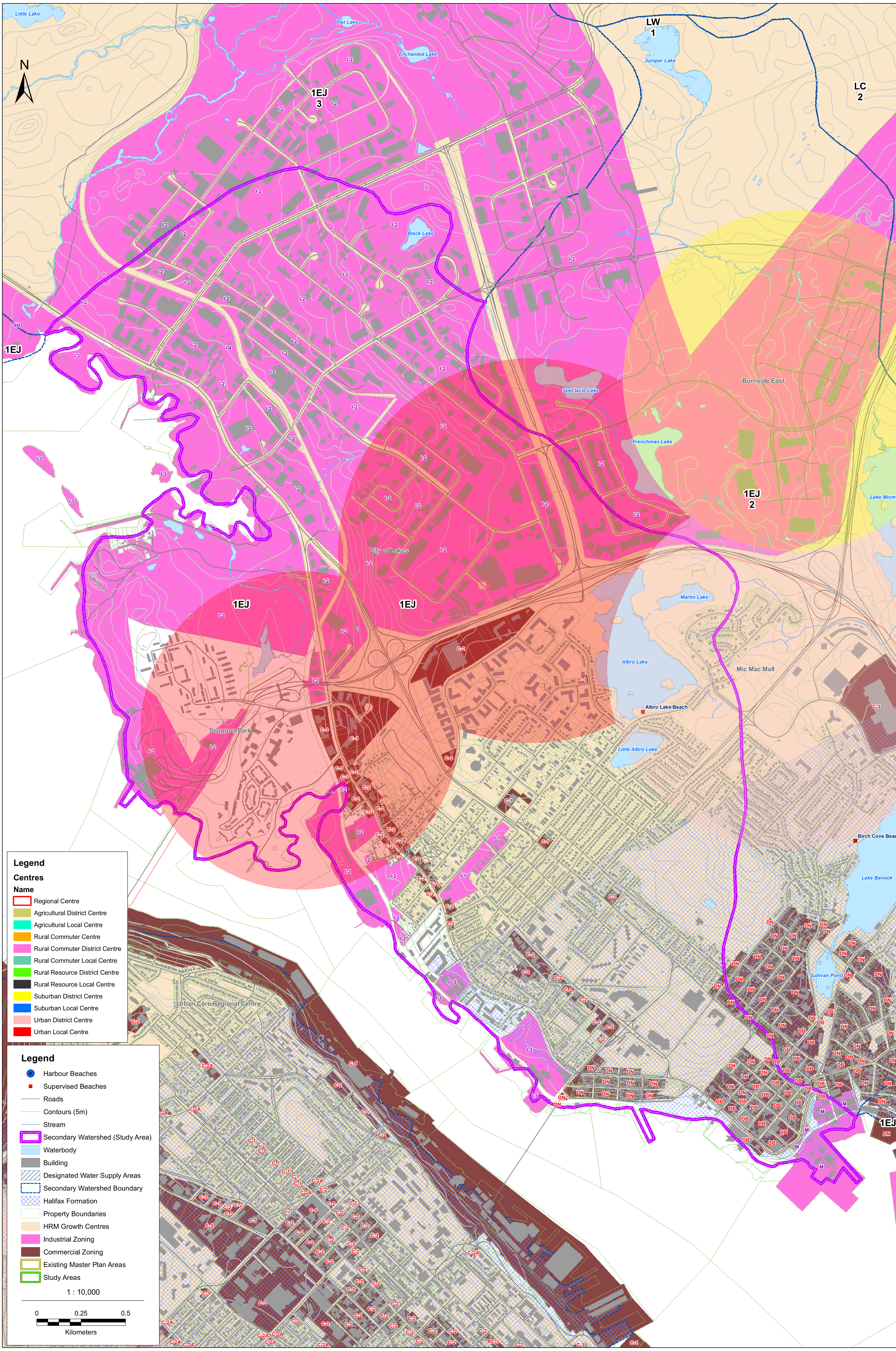

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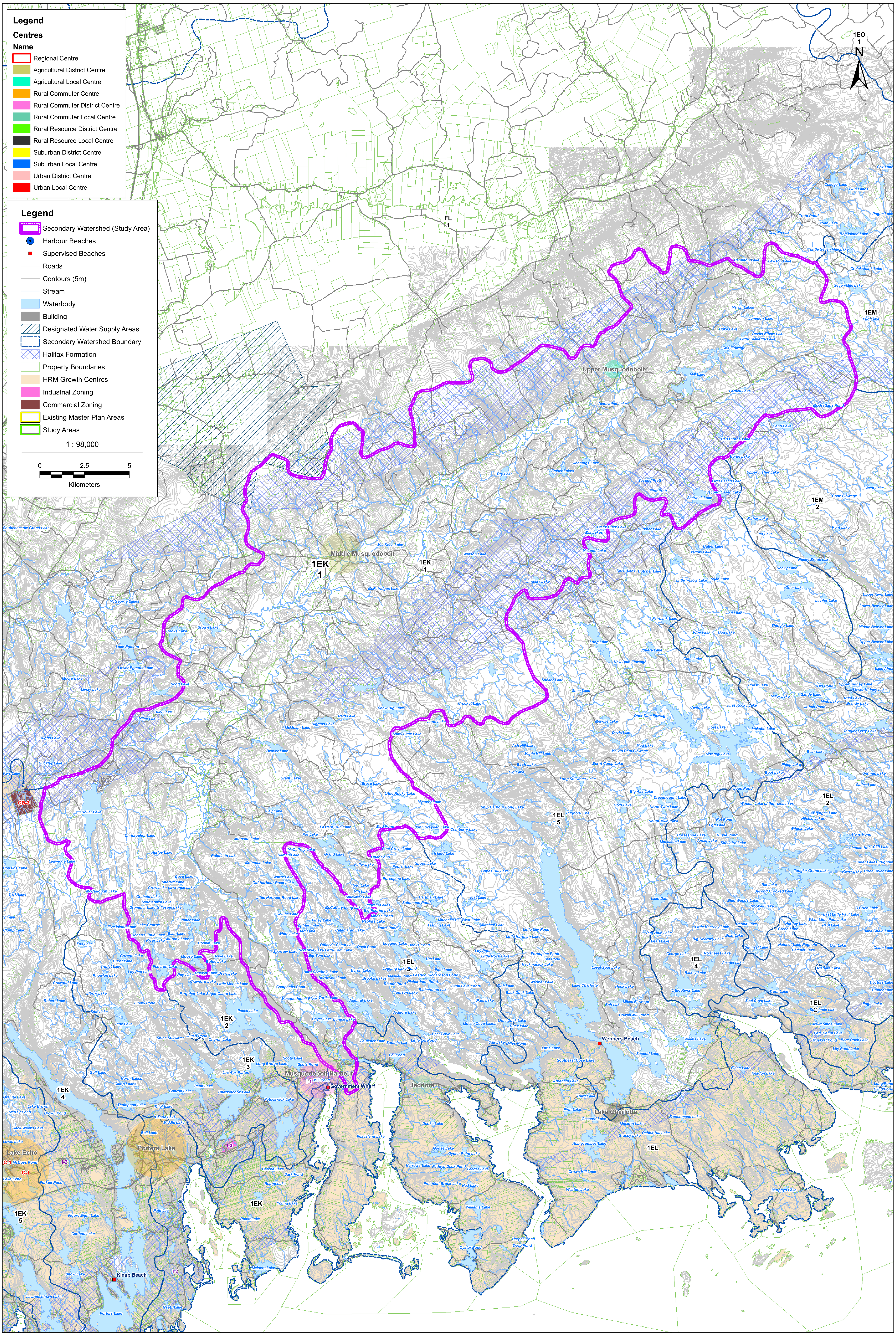

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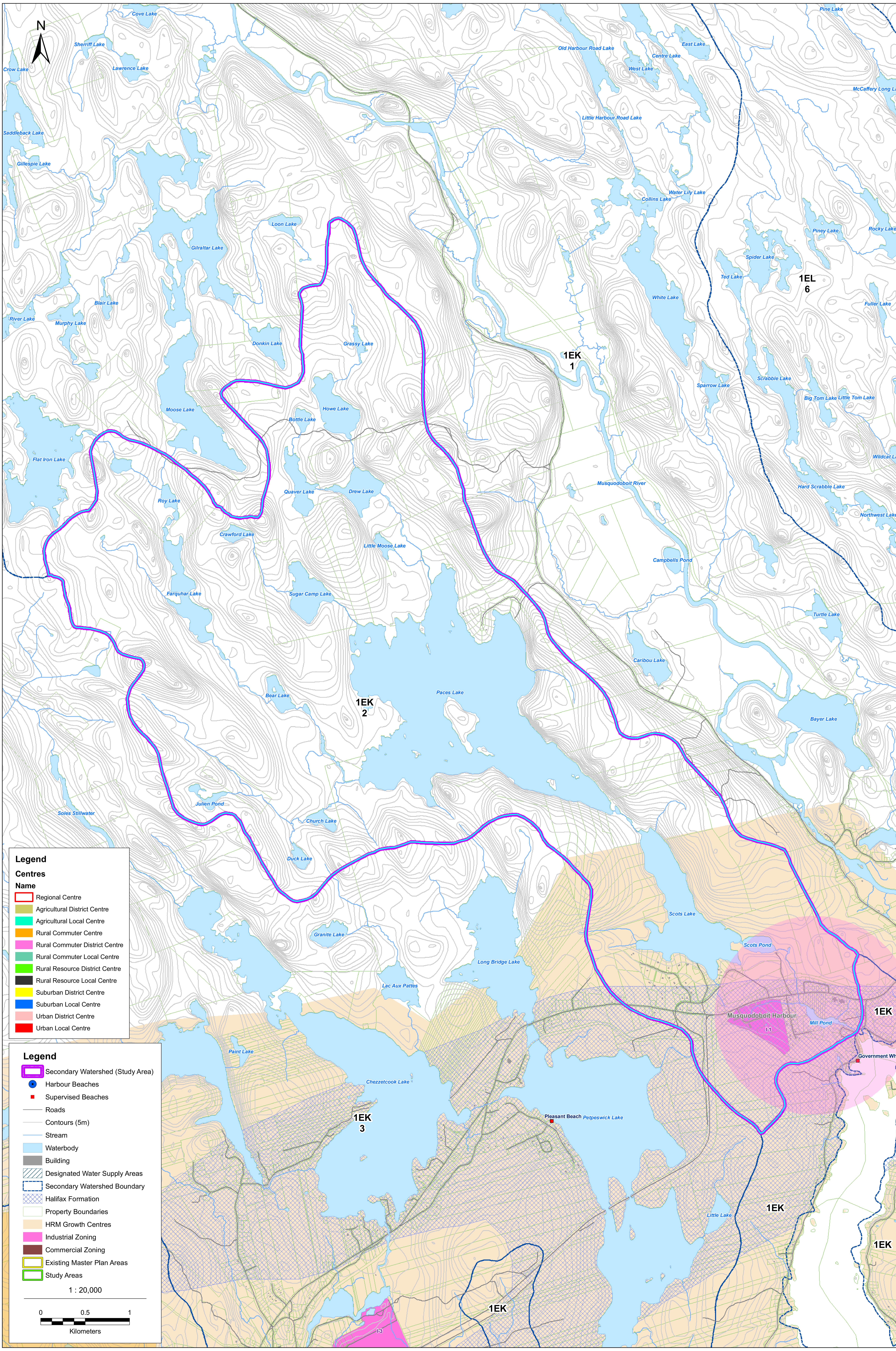

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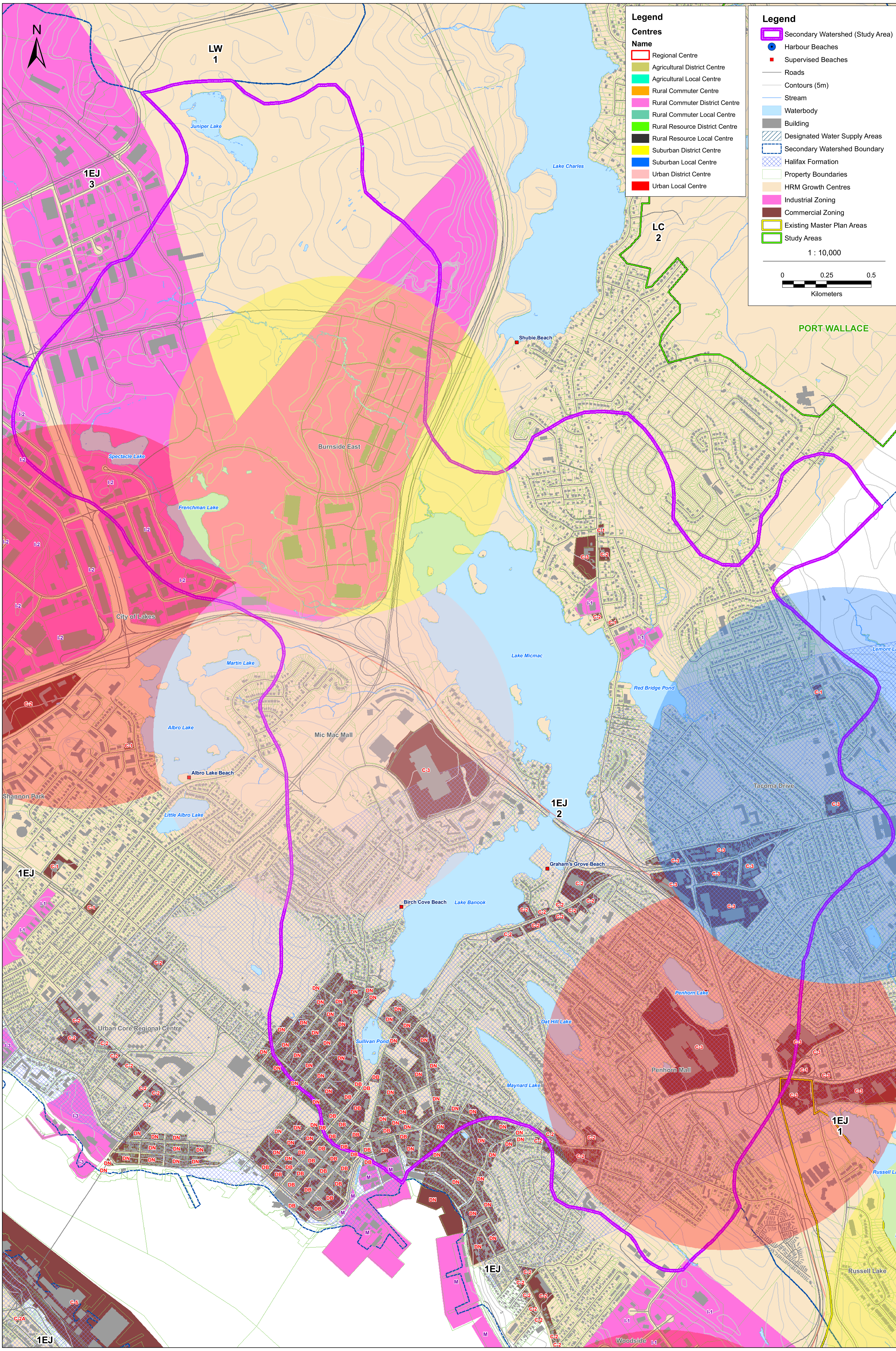

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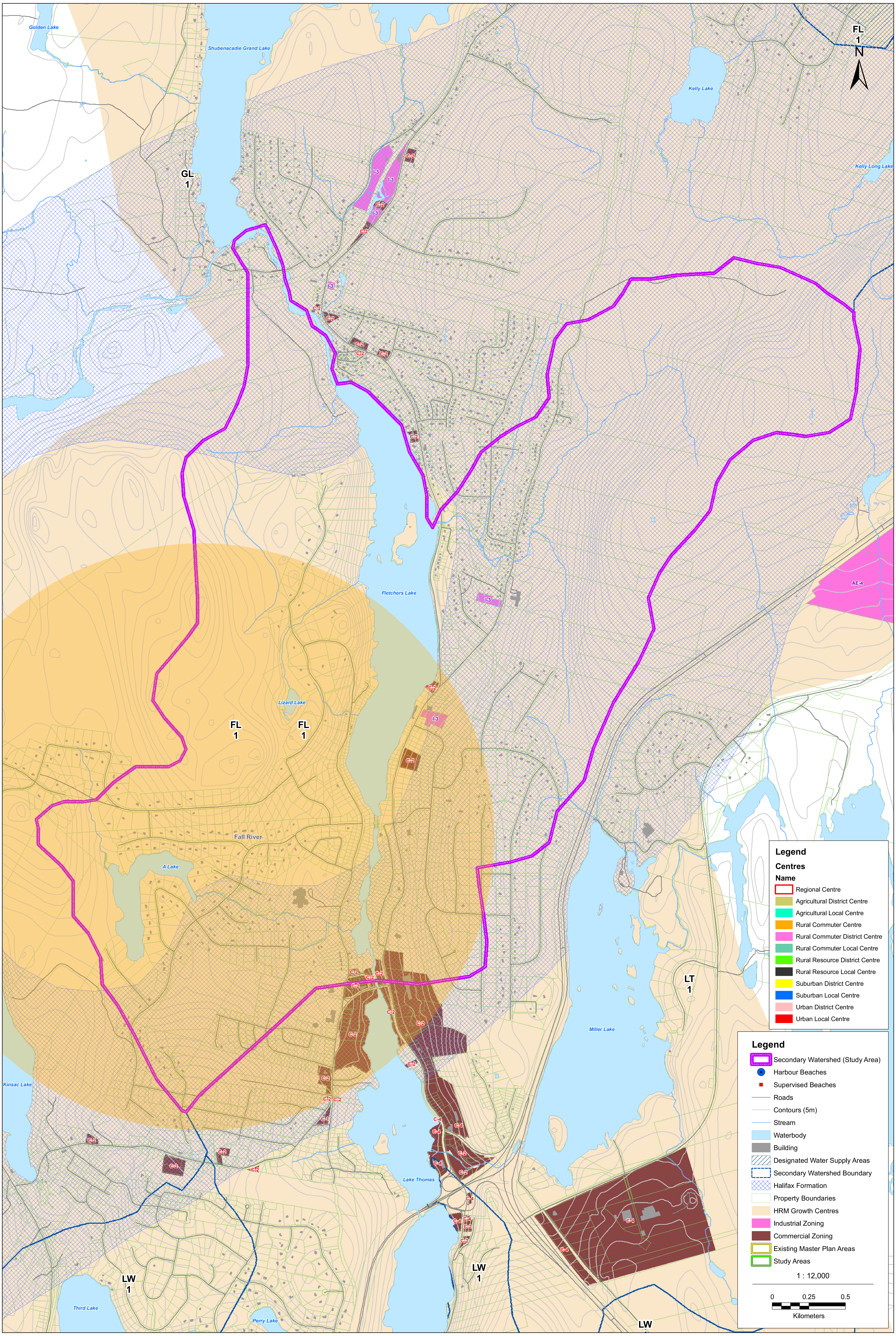

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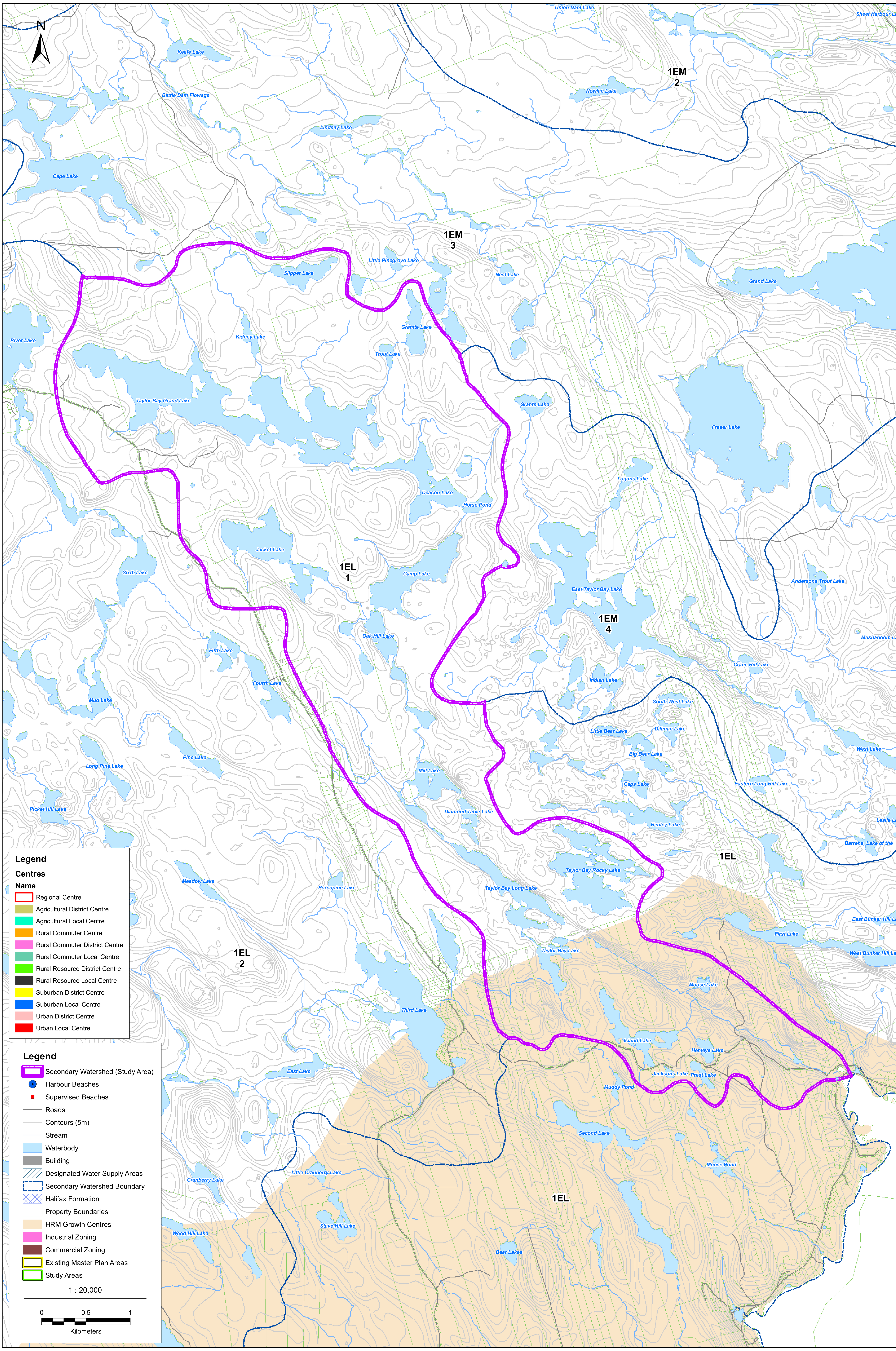

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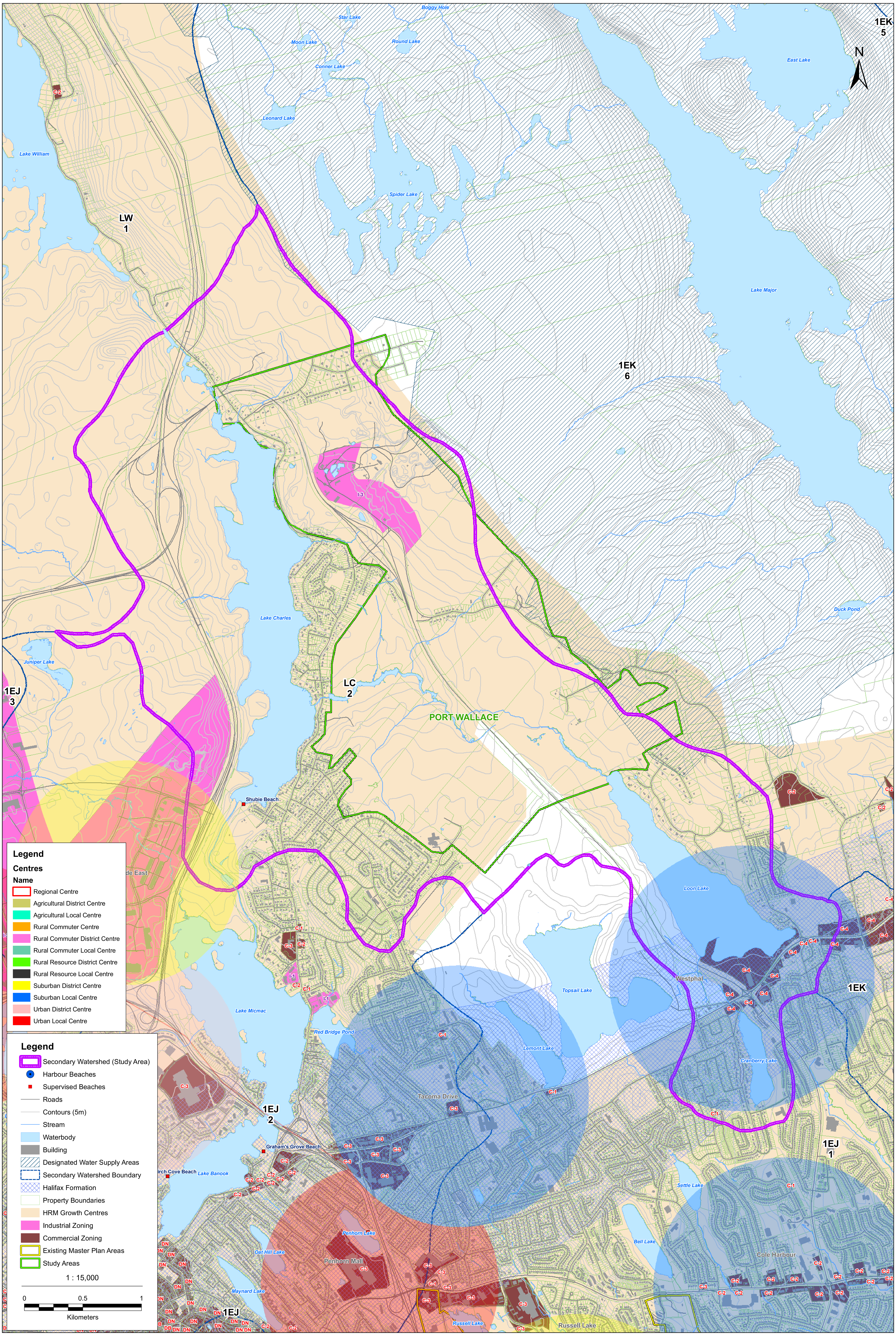

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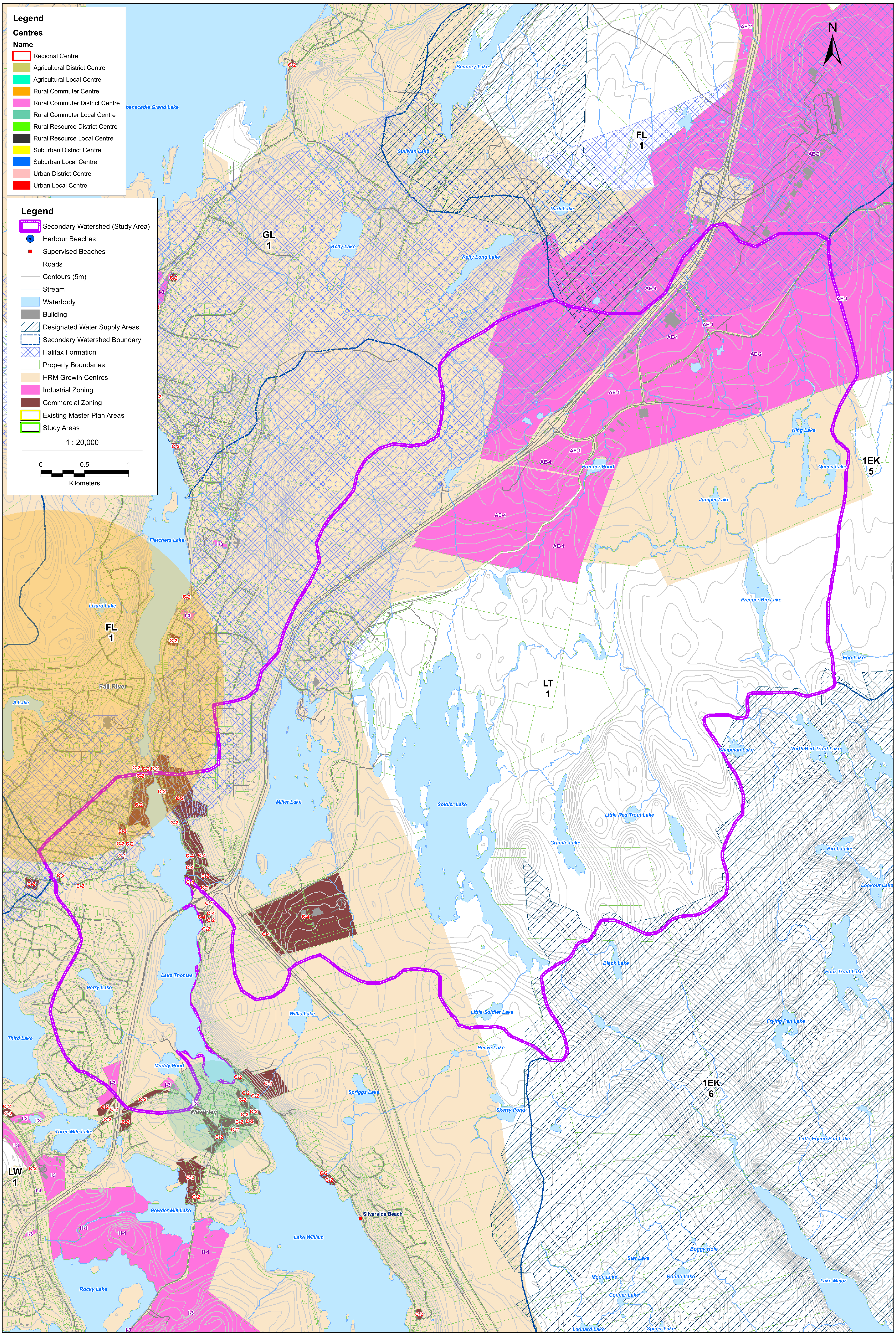

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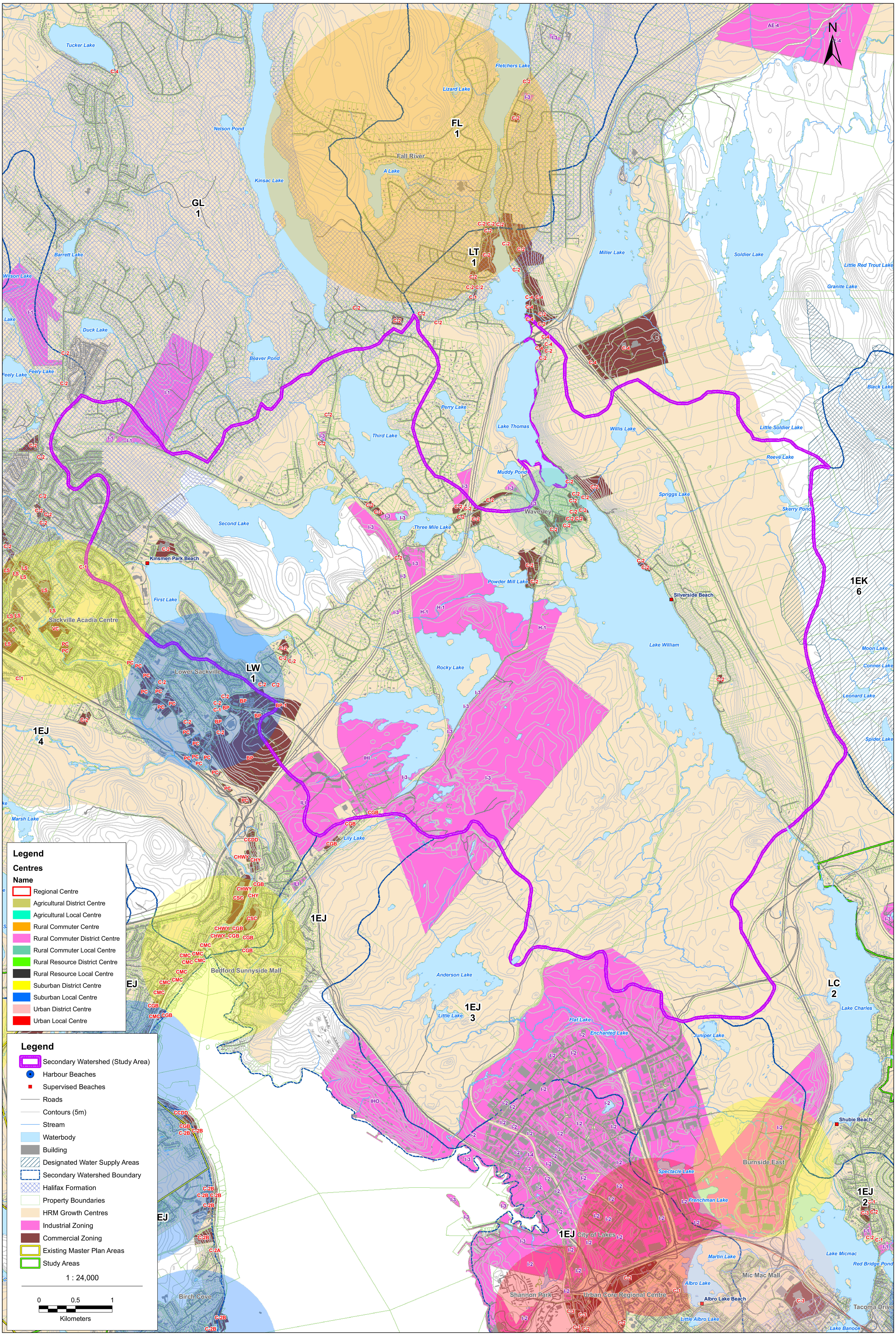

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HRM Water Quality Functional Plan

SUBWATERSHED LW-1

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APPENDIX C
Budget Information
(revised January 2010)

Table C.1 Lab Analysis Budget

Group 1 Parameters

Parameter	Cost	Samples	Total Cost
Total Phosphorus	$23.00	1	$23
Chlorophyll a	$41.25	1	$41
Escherichia coli bacteria	$19.50	1	$20
Turbidity	$12.00	1	$12
Colour	$15.75	1	$16
Total Cost per Lake			$112

Group 2 Parameters

Parameter	Cost	Samples	Total Cost
RCAp-30	$115.00	1	$115
Total Cost per Lake			$115

Group 3 Parameters[1]

Parameter	Cost	Samples	Total Cost
RCAp-MS	$153.00	1	$153
Total Cost per Lake			$153

[1] RCAp MS includes RCAp 30 plus metals scan

Benthic Analysis

Parameter	Cost	Samples	Total Cost
Shoreline Sample	$125.00	1	$125.00
Lake Sample	$150.00	2	$300.00
QC samples	$0.00	1	$0.00
[2]Consumables	$25.00	1	$25.00
Data analysis	$800.00	1	$800.00
Total Cost Per Lake			**$1,250.00**

[2] Includes preservative, bottles, collection supplies

Table C.2 Moving Waters

(This Budget is based on the following number of Rivers, Stations and Level of Effort)

	Rivers	Stations	Rivers/Day	Working Days
Tier 1	4	12	2	20
Total	**4**	**12**		**20**

Personnel Costing	Daily Rate	Days	Personnel Costs
Technician[1]	$700	20	$14,000
Technician[1]	$700	20	$14,000
Total	**$1,400**		**$28,000**

[1] Personnel costing includes two field personnel for sampling in moving waters to meet Health & Safety requirements.

Equipment	Cost
YSI Rental	$75
Field Supplies	$10
Mileage (100km @ $0.50/km)	$50
Benthic Consumables	$60
Disbursements per Day	$195
Working Days	20
Total Disbursements per Year	**$3,900**

Lab Fees	Stations	Lab Fees
Tier 1	12	$19,872
Benthic	12	$15,000
Total Lab Fees per Year		**$34,872**

Total Moving Waters Budget	**$66,772**

Table C.3 Tier 1,2 &3 Lakes with benthic component

(This Budget is based on the following number of Watersheds, Lakes and Level of Effort)

	Watershed	Lakes	Lakes/Day	Working Days
Tier 1	11	47	2	24
Tier 2	7	27	2	14
Tier 3	46	46	2	23
Total	**64**	**120**	**2**	**60**

Personnel Costing	Daily Rate	Days	Personnel Costs
Technician[1]	$700	60	$42,000
Technician[1]	$700	60	$42,000
Total	**$1,400**		**$84,000**

[1] Personnel costing includes two field personnel for sampling on open water to meet Health & Safety requirements.

Equipment	Cost
YSI Rental	$75
Secchi	$10
Boat	$50
Field Supplies	$10
Mileage (100km @ $0.50/km)	$50
Benthic Consumables	$60
Disbursements per Day	**$255**
Working Days	60
Total Disbursements per Year	**$15,300**

	Lakes	Lab Fees
Tier 1	47	$77,832
Tier 2	27	$26,568
Tier 3	46	$45,264
Benthic	120	$150,000
Total Lab Fees per Year		**$299,664**

Total Program Cost	**$398,964**

Table C.4 Tier 1,2 & 3 Lakes without benthic component

(This Budget is based on the following number of Watersheds, Lakes and Level of Effort)

	Watershed	Lakes	Lakes/Day	Working Days
Tier 1	11	47	3	16
Tier 2	7	27	3	9
Tier 3	46	46	3	15
Total	**64**	**120**	**3**	**40**

Personnel Costing	Daily Rate	Days	Personnel Costs
Technician[1]	$700	40	$28,000
Technician[1]	$700	40	$28,000
Total	**$1,400**		**$56,000**

[1] Personnel costing includes two field personnel for sampling on open water to meet Health & Safety requirements.

Equipment	Cost
YSI Rental	$75
Secchi	$10
Boat	$50
Field Supplies	$10
Mileage (100km @ $0.50/km)	$50
Disbursements per Day	$195
Working Days	40
Total Disbursements per Year	**$7,800**

	Lakes	Lab Fees
Tier 1	47	$77,832
Tier 2	27	$26,568
Tier 3	46	$45,264
Total Lab Fees per Year		**$149,664**

Total Program Cost	**$213,464**

Table C.5 Tier 1 & 2 Lakes with benthic component

(This Budget is based on the following number of Watersheds, Lakes and Level of Effort)

	Watershed	Lakes	Lakes/Day	Working Days
Tier 1	11	47	2	24
Tier 2	7	27	2	14
Total	**18**	**74**	**6**	**38**

Personnel Costing	Daily Rate	Days	Personnel Costs
Technician[1]	$700	38	$26,600
Technician[1]	$700	38	$26,600
Total	**$1,400**		**$53,200**

[1] Personnel costing includes two field personnel for sampling on open water to meet Health & Safety requirements.

Equipment	Cost
YSI Rental	$75
Secchi	$10
Boat	$50
Field Supplies	$10
Mileage (100km @ $0.50/km)	$50
Benthic Consumables	$60
Disbursements per Day	**$255**
Working Days	38
Total Disbursements per Year	**$9,690**

	Lakes	Lab Fees
Tier 1	47	$77,832
Tier 2	27	$26,568
Benthic	74	$92,500
Total Lab Fees per Year		**$196,900**

Total Program Cost	**$259,790**

Table C.6 Tier 1 & 2 Lakes without benthic component

(This Budget is based on the following number of Watersheds, Lakes and Level of Effort)

	Watershed	Lakes	Lakes/Day	Working Days
Tier 1	11	47	3	16
Tier 2	7	27	3	9
Total	**18**	**74**		**25**

Personnel Costing	Daily Rate	Days	Personnel Costs
Technician[1]	$700	25	$17,500
Technician[1]	$700	25	$17,500
Total	**$1,400**		**$35,000**

[1] Personnel costing includes two field personnel for sampling on open water to meet Health & Safety requirements.

Equipment	Cost
YSI Rental	$75
Secchi	$10
Boat	$50
Field Supplies	$10
Mileage (100km @ $0.50/km)	$50
Disbursements per Day	**$195**
Working Days	25
Total Disbursements per Year	**$4,875**

	Lakes	Lab Fees
Tier 1	47	$77,832
Tier 2	27	$26,568
Total Lab Fees per Year		**$104,400**

Total Program Cost	**$144,275**

Table C.7 Tier 1 Lakes with benthic component

(This Budget is based on the following number of Watersheds, Lakes and Level of Effort)

	Watershed	Lakes	Lakes/Day	Working Days
Tier 1	11	47	2	24
Total	**11**	**47**		**24**

Personnel Costing	Daily Rate	Days	Personnel Costs
Technician[1]	$700	24	$16,800
Technician[1]	$700	24	$16,800
Total	**$1,400**		**$33,600**

[1] **Personnel costing includes two field personnel for sampling on open water to meet Health & Safety requirements.**

Equipment	Cost
YSI Rental	$75
Secchi	$10
Boat	$50
Field Supplies	$10
Mileage (100km @ $0.50/km)	$50
Benthic Consumables	$60
Disbursements per Day	**$255**
Working Days	24
Total Disbursements per Year	**$6,120**

	Lakes	Lab Fees
Tier 1	47	$77,832
Benthic	47	$58,750
Total Lab Fees per Year		**$136,582**

Total Program Cost	**$176,302**

Table C.8 Tier 1 Lakes without benthic component

(This Budget is based on the following number of Watersheds, Lakes and Level of Effort)

	Watershed	Lakes	Lakes/Day	Working Days
Tier 1	11	47	3	16
Total	**11**	**47**		**16**

Personnel Costing	Daily Rate	Days	Personnel Costs
Technician[1]	$700	16	$11,200
Technician[1]	$700	16	$11,200
Total	**$1,400**		**$22,400**

[1] Personnel costing includes two field personnel for sampling on open water to meet Health & Safety requirements.

Equipment	Cost
YSI Rental	$75
Secchi	$10
Boat	$50
Field Supplies	$10
Mileage (100km @ $0.50/km)	$50
Disbursements per Day	**$195**
Working Days	16
Total Disbursements per Year	**$3,120**

	Lakes	Lab Fees
Tier 1	47	$77,832
Total Lab Fees per Year		**$77,832**

Total Program Cost	**$103,352**

Table C.9 11 Priority Lakes with benthic component

(This Budget is based on the following number of Watersheds, Lakes and Level of Effort)

	Watershed	Lakes	Lakes/Day	Working Days
Tier 1	7	11	2	6
Total	**7**	**11**		**6**

Personnel Costing	Daily Rate	Days	Personnel Costs
Technician[1]	$700	6	$4,200
Technician[1]	$700	6	$4,200
Total	**$1,400**		**$8,400**

[1] Personnel costing includes two field personnel for sampling on open water to meet Health & Safety requirements.

Equipment	Cost
YSI Rental	$75
Secchi	$10
Boat	$50
Field Supplies	$10
Mileage (100km @ $0.50/km)	$50
Benthic Consumables	$60
Disbursements per Day	$255
Working Days	6
Total Disbursements per Year	**$1,530**

	Lakes	Lab Fees
Tier 1	11	$18,216
Benthic	11	$13,750
Total Lab Fees per Year		**$31,966**

Total Program Cost	**$41,896**

Table C.10 11 Priority Lakes without benthic component

(This Budget is based on the following number of Watersheds, Lakes and Level of Effort)

	Watershed	Lakes	Lakes/Day	Working Days
Tier 1	7	11	3	4
Total	**7**	**11**		**4**

Personnel Costing	Daily Rate	Days	Personnel Costs
Technician[1]	$700	4	$2,800
Technician[1]	$700	4	$2,800
Total	**$1,400**		**$5,600**

[1] Personnel costing includes two field personnel for sampling on open water to meet Health & Safety requirements.

Equipment	Cost
YSI Rental	$75
Secchi	$10
Boat	$50
Field Supplies	$10
Mileage (100km @ $0.50/km)	$50
Disbursements per Day	$195
Working Days	4
Total Disbursements per Year	**$780**

	Lakes	Lab Fees
Tier 1	11	$18,216
Total Lab Fees per Year		**$18,216**

Total Program Cost	**$24,596**

APPENDIX D
Disposition Document for Watershed Advisory Board Comments and Select HRM Comments

KEY COMMENTS ARISING FROM HRM AND WATERSHED ADVISORY BOARD REVIEW OF THE PROPOSED HRM WATER QUALITY MONITORING FUNCTIONAL PLAN AND PROPONENT RESPONSES

Halifax Regional Municipality Comments

The majority of comments received from HRM were addressed directly by updating the text in the Final report. Responses are provided below for the remaining balance of comments which were not addressed directly in the text of the Final report.

Comment:

HRM-03	Tony Blouin	2.3 - Table - it would be useful to know the number of lakes involved in some of the programs such as the NSE Lake Survey - how many of these were in HRM?

Response:

The NSE Lakes survey database format does not make it easy to determine which lakes are within HRM boundaries and which are not. It would take a considerable level of effort to confirm the number within HRM, which is outside the scope of the WQMFP report.

Comment:

HRM-07	Tony Blouin	3.1, 3.2, 3.3, 3.4.3 - is there any estimate of the annual budget (developers, consultants, municipal) devoted to water quality monitoring in these jurisdictions, for comparison to the present and proposed programs for HRM?

Response:

Given differing costs of the same services in other provinces, this would not be a valuable comparison for HRM-bases costs.

Comment:

HRM-10	Tony Blouin	4.6 - are there local labs competent in benthic taxonomy to the required level? Genus or species level identification is recommended (P. 4.32) which requires significant expertise.

Response:

Local competency and resourcing for genus level identification of benthic invertebrates was confirmed prior to making the recommendation.

Comment:

HRM-30	Cameron/Maureen	Re 3.1.3 (Waterloo Program Description, page 3.4), did D. McGoldrick discuss how the gap between the municipality's System program and the Development Monitoring Program is addressed?

Response:

In previous conversation with D. McGoldrick concerning the working relationship between their two programs, it was suggested that it is an ongoing process to maximize the effectiveness of both programs, and minimize gaps.

Comment:

HRM-31	Cameron/Maureen	Re 3.1.3 (continued); did McGoldrick or others make it clear that the National Water and Wastewater Benchmarking Initiative is relevant to freshwater monitoring programs not oriented towards provision of potable water or treatment of waste water (i.e. sewage)? The NWWBI appears to be exclusively utility-oriented.

Response:

While the NWWBI is utility-oriented, the close relationship between utilities and surface water quality results in the opportunity for many lessons to be learned from utility-based monitoring and effects detection.

Comment:

HRM-40	Cameron/Maureen	Re Section 4.9 (Sampling procedures & protocols). Please provide commentary on the utility of the CABIN protocol for benthic invertebrate monitoring vs. the discussed OBBN protocol. My understanding is that CABIN is intended for both lentic & lotic waters.

Response:

The CABIN protocol is typically only used for stream and river system sampling. OBBN and other protocols are used and accepted within Nova Scotia for lake-based benthic invertebrate sampling.

<u>Halifax Watershed Advisory Board (HWAB) Comments</u>

All comments received from HWAB are provided below. Corresponding responses are provided for all comments.

Comment:

HWAB-01	Board	It is important to secure sufficient funding to ensure that the monitoring program will function on a continuing basis. Concern was expressed over the wide range of funding options. It was felt that the high cost option would, in fact, prove to be the lowest practical level of funding for a worth-while program.

Response:

Final report text updated (Section 2.2.1) to reflect HWAB's recommendation for minimum acceptable level of monitoring effort.

Comment:

HWAB-02	Board	Include: Black Lake, Moose River, Muddy Lake

Response:

Black Lake has already undergone substantial physical change (fully surrounded by HRM works department. It was a headwater lake but the outlet has been piped by HRM and cut off) and as such is not a strong candidate for the proposed WQMFP. Moose River and Muddy Pond were requested for addition to the program because of gold mining effects. The proposed WQMFP was not designed to detect mining effects specifically; additionally, mines are subject to independent regulatory controls to monitor environmental effects of mining activity.

Comments:

HWAB-03	Board	Include: Feeley Lake (Sackville) and Sandy Lake (Bedford). Both to be included in Regional Parks.

Response:

Sandy Lake (Bedford) was already included in the proposed lake list. Feeley Lake is upstream of the Little Sackville River system; monitoring downstream in Little Sackville River is sufficient to address potential effects in the upstream Feeley Lake area.

Comments:

HWAB-04	Board	A lake in the Sheet Harbour area that could potentially serve as the water supply for Sheet Harbour

Response:

Out of scope.

Comments:

HWAB-05	Board	Include: All lakes which have supervised swimming beaches and lakes with recreational or paddling clubs. Among these are: Lake Echo, Petpeswick Lake, Conrod Lake.
HWAB-06	Board	Include: Lawrencetown Lake and Porters Lake (brackish); recreational use.
HWAB-07	Board	Include: Lakes with campgrounds (e.g. Lake Charlotte)

Response:

Added clarification to Section 1 introductory text: "The WQMFP program will not serve the purpose of being a monitoring or sampling program for all lakes currently experiencing recreational use in HRM." Supervised swimming areas are monitored under the Municipal Beaches Monitoring Program. Campgrounds and paddling clubs do engage in recreational use of the waterways but the objective of the WQMFP was not to develop a recreational use monitoring program. Rather the purpose was to facilitate long-term decision making concerning land use and surface water quality changes within HRM. Recreational land use in the form of beaches, campgrounds and paddling clubs is anticipated to have less of an effect on water quality over time than industrial or residential land use.

Comment:

HWAB-08	Board	None of the lakes (neither primary nor back-up) supplying the HRM municipal water system should be included in the monitoring program. They are the responsibility of Halifax Water and are monitored separately. However, it would be useful to have the Halifax Water results attached to the Water Quality Monitoring Functional Plan Reports as information.

Response:

Pockwock Lake and Tomahawk Lakes were removed from the proposed lake list, taking comment HWAB-08 into consideration. The Project Team was in agreement. No other lakes currently included in Halifax Water's Source Water Protection Plan were on the proposed WQMFP list (i.e. Bennery Lake, Lake Major). Halifax Water is considering the addition of Fletchers Lake and Lake Lamont to the Source Water Protection Plan. However, given that they were only being considered for addition by Halifax Water at the time of publication of the WQMFP, both lakes were left in the WQMFP lake list.

Comment:

HWAB-09	Board	Lakes used for drinking water by private operators, often mobile home parks, should be traced and included in the monitoring program. (e.g. Little Springfield Lake in Sackville) (Perhaps a testing system could be developed for private operators.)

Response:

Out of scope.

Comment:

HWAB-10	Board	A group of pristine lakes (not likely to be affected by development) should be included in the program as a control group in order to monitor natural effects and for reference purposes

Response:

Recommendation made in the final report to choose reference water bodies specifically in response to the lakes selected by HRM for inclusion in the WQMFP.

Comment:

HWAB-11	Board	River flows should be gauged

Response:

Recommendation for continuous flow monitoring included in the final report.

Comment:

HWAB-12	Board	Although it comes under the jurisdiction of the Province, groundwater should not be forgotten as an important aspect of the water resources of any area. All wells should be tested for water quantity and quality when they first become operational in order to provide a nase line report c/w civic address

Response:

Out of scope.

Comment:

HWAB-13	Board	Airport run-off, the presence of pyritic slates, and any other similar problems should be referenced.

Response:

Text in final report updated as requested.

Comment:

HWAB-14	Board	The location of all landfills, and C & D debris disposal facilities both old and new, should be included in the report.

Response:

Landfills and C&D sites are subject to independent regulatory control for environmental effects monitoring. The locations of known C&D sites were taken into consideration during the community-based evaluation of topographic layers to determine water body prioritization.

Comment:

HWAB-19	Board	In order to assist in the planning of future development, it would be helpful to overlay the watershed map with the development plan showing district/regional growth centres and include in the monitoring program those watershed likely to be developed first

Response:

Growth centre mapping was overlaid with watershed mapping and heavily influenced both watershed and water body prioritization.

Comment:

HWAB-15	Board	All lakes and other water bodies that receive sewage discharges should be included. e.g. Shubie Lake, Drain Lake, Halifax Harbour

Response:

Added clarification to Section 4.2 list that "areas of engineering concern" included stormwater and sewer overflow locations.

Comment:

HWAB-16	Board	A study should be undertaken to identify all sources of discharges into water bodies from point sources such as sewage treatment plants and water supply plants, and non-point sources such as sedimentation or septic tanks, including those of schools, trailer parks and hospitals.

Response:

Out of scope.

Comment:

HWAB-17	Board	Incidental wildlife sightings (particularly of sensitive species such as frogs and dragonflies) should be included as a measure of health for lakes in the monitoring program.

Response:

Wildlife sighting observations added as a Group 1 Parameter to Table 4.6

Comment:

HWAB-18	Board	The monitoring program should provide enough information to assign water quality objectives

Response:

Added to Section 5.2.1 as first goal of data analysis.

Comment:

HWAB-19	Board	In order to assist in the planning of future development, it would be helpful to overlay the watershed map with the development plan showing district/regional growth centres and include in the monitoring program those watershed likely to be developed first

Response:

Already addressed in community GIS layer of mapping assessment. Top 11 lake recommendations are from areas anticipated to have most development pressure in near future.

Comment:

HWAB-20	Board	Water quality monitoring results should be interpreted by qualified persons to make the data more accessible to a wide range of users

Response:

Added the comment to text in Section 5.2.1.

Comment:

HWAB-21	Board	The HWAB would like to receive the final report on the Water Quality Monitoring Functional Plan for review and comment at the same time it goes to staff.

Response:

HRM's decision.

Comment:

HWAB-22	Board	Either the work "demonstration" or "pilot" should be included in the title to describe this project.

Response:

Project team does not agree with this recommendation.

Comment:

HWAB-23	Board Chair (E. Williams)	the titles of the two maps, involving the Watershed Advisory Boards, were a bit confusing – partly because some of the lakes under one of the board's jurisdiction were included on the map of the other – i.e. some HWAB lakes were included on the BWAB/DLAB map - and some the other way round. Also, there is quite a possibility that the Watershed Boards will be merged, reassigned, taken over by someone else, when the results of a study on volunteer boards due this summer come out – so the map titles would be a bit of an anachronism anyway.

Response:

Map titles updated.

Bedford Watershed Advisory Board (BWAB) Comments

All comments received from BWAB are provided below. Corresponding responses are provided for all comments.

Comment:

BWAB-01	Board	Page 2-1 – Where do the HRM WQM priorities come from - Is this a statement of council, staff, DOE ??? I agree with them, The bulleted list appears to be an instantiation of the 2 priorities and the observed deficiencies. Might be a bit easier to understand if you identify the deficiencies as one of scientific, policy or organizational. Address what you mean by WQ – scientific definition, what is the HRM policy – what standard do we wish to meet – CCME, WHO, our own, etc, and then organizational – who is in charge of the testing, who is in charge of the remediation, what tools do we have to manage and control WQ issues, what are the reporting responsibilities - to council only, to Dept of Health, to public, etc

Response:

Additional level of detail provided in Final report compared to the Watershed Advisory Board WQMFP Review Document helps to provide context for or directly addresses many of these comments (*e.g.* recommendation for development of HRM-specific water quality objectives).

Comment:

BWAB-02	Board	There would seem to be a normal separation in the WQ environment of permanent influences and thereby non-controllable and anthropogenic/variable influences that may be controllable. The ration of these influences should determine the amount of testing that a watershed would need to have. We would normally just baseline the lakes that have little or no variable factors, and monitor on a sliding scale those lakes/watersheds that have significant human contact. The report reflects this in the discussion of watershed prioritization, but what the weighting for the different factors is not defined. It would seem to me that Watershed area, water surface area, soil type and geologic formation would put each Watershed areas on a equitable comparison. The second factor would then be how much interaction does it have with humans: is there a beach, swimming, fishing. Do homes abut? How many septic systems are abutting? Industries? Part of a housing development with or without septic/ water. Where does the water go? Are there any ground water wells?

Response:

Additional level of detail provided in Final report compared to the Watershed Advisory Board WQMFP Review Document helps to provide context for or directly addresses many of these comments. The watershed and water body prioritization process was evidence-informed and consideration was given to all of the variables listed above that were within the scope of the project.

Comment:

BWAB-03	Board	I plotted the number of sample points in each watershed that the report recommends, and it is instructive to look at - my summary is that there seems to be an all or nothing approach. No Tier 3 watershed are sampled, not even as a baseline. Most of the Tier2 have some samples, although the two largest are not recommended for sampling - 1EJ11 and 1EK1. There is one split watershed - 1EJ3. This should not be allowed since the jurisdiction and sharing of information between the WAB's (BWAB is one of them) has not happened. And unless there is a lake in the Watershed, no sampling is done, not even on the streams that may flow through the area. What happens to 1EJ at Eastern Passage? This doesn't make sense. And some of the smaller watersheds have a very large number of sampling locations: 1EJ2 has 7, as does 1EJ1. How does 1EK1 and 1EL1 get to be tier 2 watershed yet have no testing done on them? Why is Albro Lake a Tier 3? It even has a beach!!!!

Response:

Watersheds 1EJ-11 and 1EK-1 are dominated by major river systems (Nine Mile River and Musquodoboit River, respectively) and as such, monitoring efforts are focused on these flowing water systems. Watershed 1EL-1 was re-evaluated and designated as Tier III. Albro Lake watershed was re-evalutated and designated as Tier II, with monitoring recommended for Albro Lake. The rationale for some large watersheds (with substantial unimpacted surface water area) not being designated with as high a vulnerability ranking as some small watersheds (with less surface water area but potential for higher impact) was rooted in scientific rationale and was evidence-informed.

Comment:

BWAB-04	Board	Specifically for BWAB regions, which is 1EJ5, there are few areas that should be tested for local effects: Belchers Pond - This is a small lake completely surrounded by development, and should be a good indicator of eutrophication but it doesn't seem to have happened??? Kearney Lake is noted as measured, but it is abutted by Kearney Lake Road and receives considerable salt run off. There are also many aged septic systems around Kearney Lake that will influence the microbial readings. . Selection of the measurement : point and frequency will require some care. The third area to be checked is McQuade Lake. This lake is also bounded by many aged septic systems. There are a few areas that I am at a loss to understand why they are vulnerable - specifically 1EH2, (This is Pockwock and part of the Halifax Water system - they do there own testing and monitoring I thought). I would have thought that IEJ 11 would be Tier 1 and have at least a couple of lakes - Ragged , Lewis, Morton - There is something definitely wrong with the way you have assigned vulnerabilities 1EJ 11 should be Tier 1!!!!!

Response:

McQuade Lake and Kearney Lake are included in the program. Pockwock and Tomahawk Lakes have been removed from the proposed list of lakes to undergo monitoring under the WQMFP, but the watershed itself supports several other water bodies that are not potable water sources. It is recommended that monitoring within watershed 1EJ-11 be focused on the Nine Mile River system, as the watershed is dominated by very small lakes and the river system. In some Tier II watersheds, the location of lakes was such that they would not receive runoff or it was determined that there would not be much to gain from monitoring small systems with short retention times. Belchers Pond has a small surface area and is shallow, likely flushing with every rain event (*i.e.,* functioning as a stormwater pond instead of a lake). It was determined that there was likely no opportunity to have a positive impact on water quality through land development.

Comment:

BWAB-05	Board	Eco system measurement parameters I think can be simplified. Although we may need a baseline for all of the metals for example, unless there is active development in the area, then they should only be done occasionally and revisited on a long term basis. The population of watersheds to be sampled should not be restricted to Tier 1 Watersheds.In my mind, we should look at the 4 effects that are anthropogenically related: Phosphorus loading, sedimentation, microbial, and acid run off. There may be a requirement to look at nitrite loading to determine which is the inhibiting chemical. (15:1 ratio etc). These tests are reasonably simple, and can generate the trophic status changes that is the prime directive. It would also be instructive to set up the modeling tools for a couple of watersheds to see if the predicted and actual phosphorus numbers track over time (2-3 years). If the modeling capability matches, then the requirement to sample may be further reduced. BWAB will provide a copy of the model which we have developed for PML system.

Response:

The proposed WQMFP program was evidence informed. Additional modeling recommendations were made in the Final report, including the use of the publically available Nova Scotia Phosphorus Model (NSPM). Known limitations and further recommendations for calibration and validation of the NSPM as related to the WQMFP are presented in the Final report (Section 6.0).

Comment:

BWAB-06	Board	You cannot tie vulnerability to testing intensity. If the reason that a lake is a Tier 1 lake, is because it has a beach and swimming, then the testing should reflect this concern. There would normally be no requirement to test for heavy metals – Group 3, other than initially as a baseline. If the reason a lake was a tier 1 was because it is beside an industrial site, then testing for heavy metals - group 3 - on a frequent basis would be reasonable. You should identify why each watershed has its priority to fit the testing to it.

Response:

The program recommendations related to vulnerability and testing frequency (and testing parameters) were based on scientific rationale, program objectives, and discussion with relevant technical water quality experts.

Comment:

BWAB-07	Board	Agree with Table 6.4 subject to comments above.

Response:

See response to BWAB-06.

Comment:

BWAB-08	Board	Table 6.5 from a scheduling point of view is likely OK. I still have trouble applying the full suite of tests twice a year.

Response:

See response to BWAB-06.

Comment:

BWAB-09	Board	Benthic Monitoring - I have my doubts that sampling 3 times a year randomly in a lake will get you any information.

Response:

The benthic monitoring program recommendations arose out of expert discussions and are evidence-informed.

Comment:

BWAB-10	Board	Requirement for Water quality testing in a development area. BWAB has been very steadfast in requiring that a full baseline WQ study be done, tailored to the development and the nearby Water bodies pre, during and post development. This is Group 1,2 and 3. It is now expected in the development community and should be placed firmly into the Municipal rules for Developers. This document should emphasize this. I would expect that the area under consideration would now be upgraded to a Tier 1 watershed because of the development.

Response:

Clarification provided in Final report concerning requirement for monitoring during all construction-related phases.

Comment:

BWAB11	Board	Chapter 7 is a very good start to getting this information into the public domain. It should be downloadable on something simple like EXCEL, and there should be pre formatted reports. Links to the other WQ sites will be needed eg CCME, Environment Canada, CWRS etc. Ability to access and run the WQ tools that are used inside HRM.

Response:

Recommendation for actively linking data to other water quality resources can be considered by HRM once data sharing options have been determined.

Comment:

BWAB-12	Board	Program phasing - Good idea. Not sure what region you mean by Bedford West - I Assume that you mean Paper Mill Lake Watershed. We already have the predictor model done.

Response:

Bedford West (Secondary Watershed 1EJ-5) is a Suburban District Centre (anticipated growth area); see map 1EJ-5 in Appendix B of Final report.

Comment:

BWAB-13	Board	This report has brought a lot of relevant information together. My main criticism is that approach used to fit defined protocols (group 1,2 or 3) into rigid situations: Tier 1,2 and 3 watersheds. I am of the opinion that there are certainly broad levels of vulnerabilities, but the protocols used to monitor each site should be personalized to the specific vulnerabilities. By phasing in the WQ program, we should be able to show value for testing money spent, and by giving public access to the data immediately, we should be able to engage and make more aware the public of this valued resource. The process of determining which watersheds fit a particular level of vulnerability does not seem to fit my understanding of these areas and some are definitely wrong. This should be reviewed.

Response:

The process of determining the vulnerability of each watershed arose from scientific rationale, expert discussions and stakeholder feedback. Additional context and supporting information concerning the scientific approach, findings and recommendations are presented in the Final report.

Dartmouth Lakes Watershed Advisory Board Comments

As a result of board member availability constraints, comments were not received from the Dartmouth Lakes Watershed Advisory Board prior to the end of the Project.