Approved Quinte Region Assessment Report

Version 6.1

Prepared by:

Quinte Region Source Protection Committee

July 17, 2023

Preface

The Preface and Executive Summary sections of this document provide readers with introductory information on the Assessment Report.

Authority to Establish the Report

The authority for the Source Protection Committee to establish the Report comes from the *Clean Water Act, 2006*.

Purpose of Report

The purpose of the Assessment Report is to present the current known scientific knowledge related to all aspects of water in the Quinte region. This scientific foundation will form the basis for the planning stage of the Quinte Region Source Protection Committee to protect existing and future sources of municipal drinking water. The Assessment Report has been prepared to meet the requirements of the Ontario *Clean Water Act, 2006*. It is a highly technical report.

Report Objectives

The *Clean Water Act, 2006* establishes the following objectives for the Assessment Report:

(a) Identify all the watersheds in the source protection area;
(b) Characterize the quality and quantity of water in each watershed;
(c) Set out a water budget for each watershed, which describes how water enters and leaves the watershed and describes the groundwater and surface water flows in the watershed and how water is used;
(d) Identify all significant groundwater recharge areas and highly vulnerable aquifers that are in the source protection area;
(e) Identify all surface water intake protection zones and wellhead protection areas for municipal drinking water sources that are in the source protection area;
(f) Describe the drinking water issues relating to the quality and quantity of water in each of the vulnerable areas identified under clauses (d) and (e);
(g) List activities that are or would be drinking water threats, and conditions that result from past activities and that are drinking water threats; and
(h) Identify the areas where an activity listed under clause (g) is or would be a significant drinking water threat, and the areas where a condition listed under clause (g) is a significant drinking water threat.

Explanatory Note

This report was written under the Ontario *Clean Water Act, 2006* through a provincially-funded and directed drinking water source protection initiative. The initial findings and comments herein were approved by the Ontario government in 2011. This version is updated to reflect new technical work including a new Wellhead Protection Area for the Village of Madoc drinking water system and an expanded Intake Protection Zone 2 for the City of Belleville and Town of Picton. Version 6 was approved in September, 2019.

Summary of Previous Report Approvals

The Proposed Assessment Report was endorsed by the Quinte Region Source Protection Committee on June 24, 2010 and published for local review on July 13, 2010.

The final Proposed Assessment Report was submitted to the Minister of the Environment in August, 2010. Comments on the report were received in February 2011 and revisions were approved by the Quinte Source Protection Committee on February 24, 2011. That report was submitted on March 4, 2011 to the Ministry of the Environment and received approval on April 5, 2011.

The report was updated and approved in October 2011.

This report was updated again in 2014 based on additional technical work and threats verification carried out in 2013.

The report was updated in 2019 to amend the mapping of the intake protection zones for the City of Belleville and the Town of Picton municipal surface water intakes. This amendment also conveys information about a new groundwater-based municipal drinking water system in the Village of Madoc, updates the mapping of the wellhead protection area for the Village of Madoc municipal well system, and provides this new system with the same level of protection as the other municipal drinking water systems in the Quinte Region Source Protection Plan. This new system was required to replace an existing well that had been experiencing quantity and quality concerns.

The report was updated in 2022 under Section 34 of the Clean Water Act, 2006 to establish an issue contributing area to address rising levels of nitrates in the raw water of the groundwater-based municipal drinking water system in the Municipality of Tweed. The amendment updated:

- the mapping of the wellhead protection area for Tweed to include the issue contributing area
- the methodology for identifying issues in Chapter 4
- The write-up on the Tweed drinking water system and related vulnerable areas and threats identification in Chapter 5
- Key outcomes related to Issues in Chapter 9
- Appendix G to include consultation requirements related to the Issues Contributing Area.
- An addendum to the Tweed Well Issues and Threat Report included in Appendix E-6.

The updated report was approved by the Ministry of the Environment, Conservation and Parks July 11, 2023.

Source Protection Committee

The Quinte Region Source Protection Committee was formed in 2007. Original members included:

MEMBER	REPRESENTING
Max Christie	Chairman
Ron Hamilton	Local Municipalities
Sandy Latchford	Local Municipalities
Garnet Thompson	Local Municipalities
Clarence Zieman	Local Municipalities
Jo-Anne Albert	Local Municipalities
Angela Genereaux	Small Business/Industry
Rahumathulla Marikkar	Large Business/Industry
Gary Fox	Agriculture
Heather Lang	Agriculture
Terry Shea	Tourism And Recreation
Terry Kennedy	Environmental Associations
Mel Plewes	General Public
Doug Parker	General Public
Eric Bauer	General Public
Phillip Norton	General Public
Todd Kring	Bay of Quinte Mohawks
Curtis Maracle	Bay of Quinte Mohawks
Roger Cole/ Mike Kerby	Source Protection Authority Liaison
Andrew Landy	Health Units Liaison
Wendy Lavender	Ministry of the Environment Liaison

The Quinte Region Source Protection Committee was renewed in 2018-2019 to comply with Ontario Regulation 288/07. The committee members include:

MEMBER	REPRESENTING
Max Christie	Chairman
Ron Hamilton	Local Municipalities
Ernie Margetson	Local Municipalities
Pat Culhane	Local Municipalities
Roger Cole	Local Municipalities
Jo-Anne Albert	Local Municipalities
Jack Alexander	Economic
Bryon Keene	Economic
Gary Fox	Agriculture (Economic)
Heather Lang	Agriculture (Economic)
Sandy Latchford	Economic

Terry Kennedy	General Public
Mel Plewes	General Public
Gillian Ward	General Public
Josh Powles	General Public
Phillip Norton	General Public
Nicole Storms	Bay of Quinte Mohawks
Curtis Maracle	Bay of Quinte Mohawks
Mike Kerby	Source Protection Authority Liaison
Andrew Landy	Health Units Liaison
Mary Wooding	Ministry of the Environment Liaison

For More Information

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Acknowledgements

Conservation Authority Staff
The Quinte Region Source Protection Committee wishes to acknowledge the contribution of the following Quinte Conservation staff towards the preparation of this report and subsequent updates:

Keith Taylor	Lucille Fragomeni
Bryon Keene	Mark Boone
Julie Munro	Amy Dickens
Lynette Lambert	Nancy Marshall
Terry Murphy	Kirsten Geisler
Brad McNevin	Curtis Vance

Numerous other Conservation Authority staff supported the effort between 2005 and 2019.

Consultants and Study Partners
The findings in this report were developed in part through the contributions of the following consultants and partners:

- Dillon Consulting Ltd.
- XCG Consultants Ltd
- Golder Associates

- Schlumberger Water Services
- Dr. Harold Schroeter
- Greer Galloway Consulting Engineers
- Environment Canada – Canada
- Centre for Inland Waters
- Natural Resources Canada
- Ontario Ministry of Natural Resources
- Ontario Ministry of the Environment
- Trent Conservation Coalition Source Protection Region
- Cataraqui Source Protection Area
- Mississippi Rideau Source Protection Region

The three local counties, local municipalities, Mohawks of the Bay of Quinte and two public health units in the Quinte Source Protection Region provided advice, knowledge, and data towards the preparation of this report. We acknowledge and appreciate their assistance.

This report was prepared with funding from the Ontario Ministry of the Environment and the Ontario Ministry of Natural Resources.

Executive Summary

The original approved Assessment Report (March 2011) compiled available knowledge in the Quinte watershed related to the sources of drinking water and presented the findings of various technical studies undertaken by Quinte Conservation and others. This report was updated in 2014 to reflect the findings of additional technical work on the issues based threat approach and threats verification.

Extensive efforts to consult with the public and other agencies and stakeholders were made by the Quinte Source Protection Region during the development of this document. This provided an opportunity to gain local knowledge and explain the findings of our research. Comments were received from various agencies and members of the public and changes, where appropriate, were included in the current document.

Although the primary focus has been on sources for the 11 municipal drinking water systems in the region, some of the technical work has been based on the entire watershed area. Studies include a characterization of the human and physical geography of the watershed, various levels of water budget and water quantity stress assessment, an assessment of groundwater and surface water vulnerability, land use activities that could pose threats to drinking water sources, and an evaluation of existing water quality contamination issues.

Never before has so much scientific work related to drinking water been compiled in the Quinte Region. Ultimately this science-based work provided the foundation to support the initiatives of a Source Protection Plan.

Chapter 1 provides an understanding of why this work was done and the process followed. Critical to the process is the number of partners and the opportunity for stakeholder and public involvement.

Chapter 2 describes the watershed in detail and the drinking water systems within the region. It is a snap-shot of the known information about the area, particularly the information related to water resources and factors that affect water.

Chapter 3 outlines the Water Budget methodology and the detailed results for the Quinte Region. This work was completed to determine if the quantities of water available for the drinking water systems are sufficient for present and future use. It was determined through this exercise that there is an adequate supply of water for all the municipal systems. However, this work did reveal the potential for seasonal shortages in some areas serviced by private wells.

Chapter 4 explains how the four main types of vulnerable areas were determined and how the risk to water quality was assessed within these zones. Highly Vulnerable Aquifers, Significant Groundwater Recharge Areas, Wellhead Protection Areas and Intake Protection Zones are explained. The system of vulnerability scoring and evaluating a list of prescribed threats is also outlined in what is called a Threats Approach. This provides the Source Protection Committee with the background to determine where threats to drinking-water sources are significant, moderate or low. In addition to the Threats Approach further study on water quality issues identified for the Village of Madoc wells is explained. This work looked at any unexplained water quality concerns not related to previously identified activities based specific threats.

Chapter 5 presents the results of the threats and issues found in the groundwater resources of the area. These findings include the Highly Vulnerable Aquifers and Significant Groundwater Recharge Areas. There are four municipal drinking water systems in the Quinte Region that are considered to have groundwater as the primary source of water. Wellhead Protection Areas have been delineated for these systems and the threats and issues work is presented.

Chapter 6 outlines the delineation of the Intake Protection Zones around the seven surface water drinking water systems in the Quinte Region. The threats and issues assessment is also provided.

Chapter 7 discusses the emerging issue of climate change. At this stage it is difficult to determine with certainty how climate change will affect water resources but certainly the topic cannot be ignored. It will be necessary to continually monitor and study climate change over time to see how it will change the current state of our water resources.

Chapter 8 initiates a discussion about emerging issues and additional research requirements. Science is continuously advancing and there are current knowledge gaps that will need to be addressed in the future as more is learned. Source protection planning initiatives will evolve and adapt over time as new information becomes available.

Chapter 9 summarizes the key outcomes of the Assessment Report.

A tremendous amount of technical work and numerous scientific studies were completed to arrive at this point. The technical rules provided by the Province of Ontario were followed and wide-ranging consultation has occurred and will continue throughout the source protection planning process. An extensive set of appendices has been compiled to complement and support the Assessment Report. This Assessment Report presents the findings but the appendices are available if more detail is required.

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Map Listing for Assessment Report

Maps are located in the accompanying Map Booklet

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Common Acronyms

<u>Lengths</u>

mm	millimetres
m	Metres
km	Kilometres
masl	Metres above sea level

<u>Area</u>

km^2	Square Kilometres
ha	Hectares

<u>Volume</u>

m^3	Cubic Metres	
ha.m	Hectare Metres	(used for stating storage in large reservoirs)

<u>Flow</u>

m^3/s	Cubic Metres per Second
L/s	Litres per Second

<u>Flux (Groundwater Flow)</u>

cm/s	Centimetres per Second
m/d	Metres per Day

<u>Velocity</u>

m/s	Metres per Second

Special Acronyms

IPZ	Intake Protection Zone
PDWT	Prescribed Drinking Water Threat
SGRA	Significant Groundwater Recharge Area
WHPA	Wellhead Protection Area
DNAPL	Dense Non-Aqueous Phase Liquids have densities greater than that of water. Trichloroethylene, methylene chloride, trichloroethane, dichlorobenzene are examples of DNAPLs. DNAPLs sink to the bottom of the aquifer, and since they are toxic at low concentrations the entire aquifer is easily contaminated. Because of this, DNAPLs are usually a very serious problem

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1 Introduction

"The health of our waters is the principal measure of how we live on the land"
– Luna Leopold

1.1 Drinking Water Source Protection and the Ontario Clean Water Act, 2006

The reality of what can happen to our sources of drinking water became all too apparent after the tragedy that occurred in Walkerton, Ontario in May 2000. A groundwater source of drinking water became contaminated and a treatment system failed, ultimately causing the death of seven people and illness in thousands.

The Walkerton Commission of Inquiry (also commonly referred to as the Walkerton Inquiry) conducted by Justice O'Connor studied the Walkerton tragedy and determined that one of the causes was contaminated groundwater. In his report Justice O'Connor recommended that sources of drinking water should be protected from contamination and overuse. This would be considered the first step in a multi barrier approach to ensure safe drinking water. The Ontario government responded by funding an intensive Drinking Water Source Protection Program and by proclaiming the *Clean Water Act, 2006.* The *Act* sets out the process required to develop locally driven, science-based assessment reports and source protection plans. While the primary focus of the work to-date has been the source water for municipal residential systems, the *Act* allows for future work to consider other types of drinking water systems.

The outcome was the development of a comprehensive plan that identifies what needs to be done locally to protect sources of drinking water. The plan also provides a list of tools to ensure that threats to drinking water sources are reduced or eliminated. This Assessment Report is intended to provide much of the scientific basis for the forthcoming Quinte Region Source Protection Plan.

1.2 The Source Protection Planning Process

The source protection planning process is intended to continue over the long-term, similar to activities by the provincial government and municipalities under the Ontario *Planning Act, 1990*. Source protection is one component of watershed management and involves the following steps: scientific research, planning, monitoring, and the evaluation of success. This Assessment Report is the culmination of many years of scientific research and data gathering.

The Ontario Ministry of the Environment is the lead agency for drinking water source protection activities across the province. The Ontario Ministry of the Natural Resources assisted with project management and aspects related to protecting quantities of water from overuse.

The settled parts of Ontario were divided into watershed-based source protection areas and regions. Locally, the Quinte Source Protection Region was defined to include the jurisdiction of Quinte Conservation Authority plus waters in Lake Ontario.

Conservation Authorities across Ontario serve as source protection authorities to coordinate the local work. The Quinte Source Protection Authority is composed of the staff and the 26-member board of the Quinte Region Conservation Authority. The Quinte Source Protection Authority managed the technical studies that are summarized in this report, and in 2007 it formed the Quinte Source Protection Committee to oversee the work.

The provincially-appointed Chair of the Source Protection Committee is Mr. Max Christie of Napanee; Mr. Christie is an engineer specializing in water treatment issues. Each Source Protection Committee has municipal, economic, and community members, and representation from First Nations. The 17-member Quinte Source Protection Committee includes: municipal councilors; economic representatives from agriculture, industry, and tourism and recreation; and community representatives from environmental groups and the public. There are two members from the Mohawk Tyendinaga Territory (Mohawks of the Bay of Quinte) representing the interests of that First Nation community. The Committee also has three non-voting liaison members representing: the Ministry of the Environment, Health Units (Hastings Prince Edward Health Unit and Kingston Frontenac Lennox and Addington Public Health), and the Quinte Source Protection Authority.

The Source Protection Committee was required to complete three tasks outlined in the *Clean Water Act, 2006*:

- Write a Terms of Reference to identify what work needs to be done and who is responsible to complete that work;
- Compile an Assessment Report that brings together the science and technical information required to develop a source protection plan; and
- Produce a source protection plan that will outline measures necessary to reduce or eliminate the threats identified in the Assessment Report.

The Source Protection Plan was submitted August 2012. It includes polices that make use of implementation tools such as public education, incentives, municipal land use planning and by-laws, risk management plans and in some circumstances source protection plans may prohibit certain activities. It also includes requirements for monitoring local progress on source protection. Municipalities are involved in implementing the source protection plans, in part through updates to their municipal official plans and zoning by-laws.

The Source Protection Committee consulted with municipalities, stakeholder groups and the public so that the Assessment Report and Source Protection Plan are developed through an open and transparent process. Information related to the work has been shared at public open houses and municipal council meetings, and is posted on the Internet at www.quintesourcewater.ca.

1.3 Participants in the Process

Everyone has an interest in drinking water source protection. The future of our communities depends on access to clean and plentiful supplies of water. For these reasons, source protection in Ontario is being led locally, with source protection committees established on a watershed basis. There were many different participants in the process. Stakeholders and partners include municipalities, federal and provincial government agencies, community groups, businesses, and permanent and seasonal residents.

1.3.1 Municipalities

All or part of the municipalities listed below fall within the Quinte Source Protection Region.

Name of Municipality

- The Corporation of the County of Prince Edward
- The Corporation of the City of Belleville
- The City of Quinte West
- The Corporation of the Municipality of Centre Hastings
- The Townships of Tudor and Cashel
- The Town of Deseronto
- The Municipality of Marmora and Lake
- The Municipality of Tweed
- The Corporation of the Township of Madoc
- The Township of Tyendinaga
- The Township of Stone Mills
- The Township of Stirling-Rawdon
- The Township of North Frontenac

The Township of Central Frontenac
The Township of South Frontenac
The Corporation of the Township of Addington Highlands
The Town of Greater Napanee
The County of Frontenac
The Corporation of Loyalist Township
The County of Lennox and Addington
The County of Hastings

1.3.2 Provincial Government

There are a number of provincial agencies closely involved in water management. These include:

- Ministry of Environment;
- Ministry of Natural Resources;
- Ministry of Municipal Affairs and Housing; and
- Ministry of Agriculture, Food, and Rural Affairs.

Two local health units were involved: the Hastings Prince Edward Health Unit and Kingston Frontenac Lennox and Addington Public Health.

1.3.3 Federal Government

The federal government has many interests in the Quinte Source Protection Region. The federal government is involved in issues related to First Nation reserves. The Mohawk Tyendinaga Territory is located in the Quinte Watershed. (Map 2.19 Federal and Protected Lands)

1.3.4 Mohawks of the Bay of Quinte

The Quinte Region Source Protection Authority and Committee are working with the Mohawks of the Bay of Quinte. A partnership was arranged to monitor both surface and groundwater at several test sites in the Mohawk Tyendinaga Territory. Quinte Conservation also coordinated and delivered several workshops on the Mohawk Tyendinaga Territory aimed at helping people understand groundwater issues.

1.3.5 Adjacent Source Protection Regions

The Quinte Region Source Protection Authority and Committee coordinated their efforts with the three neighbouring source protection regions, including the Cataraqui, Mississippi - Rideau, and Trent Conservation Coalition. This built on a long tradition of cooperation between conservation authorities. These regions have worked together on common communications, mapping, technical products, and used a coordinated approach when sharing information with municipalities. The intent is to provide a consistent level of information, wherever possible, for the benefit of those municipalities that fall into more than one source protection area.

1.3.6 Interested Stakeholders, Engaged Public and Non Governmental Organizations

There are many stakeholders and non-governmental organizations in the Quinte region that have an interest in supplies of clean and plentiful water. The agricultural community, tourism and recreation sector, lake and river associations and the manufacturing sector are well represented in the area. Each of these sectors is represented on the Quinte Source Protection Committee. Quinte Conservation also has a long history of interaction with many stakeholder groups and these established relationships benefit the source protection process.

1.4 Scope and Purpose of the Assessment Report

1.4.1 Scope of the Report

The scope of this Assessment Report is defined by the Terms of Reference: Quinte Source Protection Region (Appendix A-1). Currently, the focus of the Assessment Report is on 11 local drinking water systems in the “municipal residential” category that is defined by the Ontario Ministry of the Environment (Map 2.3 Drinking Water System Locations & Areas Serviced). Chapter 5 of the Assessment Report also includes information about the general state of groundwater resources across the entire Quinte area. Future versions of the Assessment Report may also include technical findings related to other public drinking water systems and/or ‘clusters of six or more’ of private intakes or wells. These systems would only be considered if they were added to the Terms of Reference through a municipal resolution, or at the direction of the Ontario Minister of the Environment.

1.4.2 Purpose of the Report

The main purpose of this report is to provide data, information and analyses to assist the prioritization of drinking water issues and threats within the vulnerable areas that are described in Chapters 4 through 7. This information assisted the community, led by the Quinte Source Protection Committee, to prepare the Quinte Source Protection Plan. Drinking water issues and threats that are prioritized in this document were the subject of extensive discussion during the development of the plan.

This report also serves as a summary of technical findings. For more detailed findings about a specific location, reference should be made to the individual technical reports, each of which is listed in the References section and held by Quinte Conservation at its Administration Office in Belleville. The Assessment Report includes a DVD with digital copies of the pertinent studies and reference material.

1.4.3 Objectives of the Report

The *Clean Water Act, 2006* establishes the following minimum objectives for the Assessment Report:

a) identify all the watersheds in the source protection area;
b) characterize the quality and quantity of water in each watershed;
c) set out a water budget for each watershed, which describes how water enters and leaves the watershed and describes the groundwater and surface water flows in the watershed including how water is used;
d) identify all significant groundwater recharge areas and highly vulnerable aquifers that are in the source protection area;
e) identify all surface water Intake Protection Zones and Wellhead Protection Areas that are in the source protection area;
f) describe the drinking water issues relating to the quality and quantity of water in each of the vulnerable areas identified under clauses (d) and (e);
g) list activities that are or would be drinking water threats, and conditions that result from past activities and that are drinking water threats; and
h) identify the areas where an activity listed under clause (g) is or would be a Significant drinking water threat, and the areas where a condition listed under clause (g) is a Significant drinking water threat.

This Assessment Report includes detailed local information in support of each of the above objectives.

1.4.4 Methods of Technical Work

The Source Protection Program in Ontario is based on the best available science. The scientific methods used to carry out the technical work are described in Ontario Regulation 287/07 General, the Technical Rules: Assessment Report (Appendix A-2), and related guidance materials. These documents were developed by the provincial government in consultation with scientists from various fields and representatives from stakeholder groups such as agriculture and industry. Similar methods were used across Ontario, so that there is a reasonable degree of consistency in the preparation of Assessment Reports.

This Assessment Report includes findings from many technical studies that were completed for the Quinte Source Protection Region since 2005. The studies were completed under the supervision of Quinte Conservation's technical staff, with assistance from municipalities, public health units, consultants and others. The water budget studies were peer reviewed by qualified neutral third parties. The Source Protection Committee hosted many municipal and public meetings and open houses to share the findings with the community for all these studies, and to seek feedback and local knowledge. The findings were carefully reviewed by Conservation Authority staff and were received by the Source Protection Committee for inclusion in this document.

Additional information about the technical methods used is presented in subsequent chapters of this report.

1.4.5 Statement Regarding the Science within the Assessment Report

A guiding principle of the Walkerton Inquiry recommendations related to source protection is that decisions be based on the best available science and knowledge. A concerted effort was made to compile the information for this Assessment Report using the best current available information and methods of analyzing that information. However, it was apparent throughout this exercise there are data and knowledge gaps in some parts of the document that need to be addressed in future versions.

For example, Chapter 7 explains what is known about Climate Change. This is an area where there will be a considerable amount of new research carried out in the near future. Climate Change has the potential to impact both water quality and quantity but it is impossible to say to what extent at this point. There will be revised Assessment Reports developed over time that will include new information as it becomes available. Data gaps are summarized in Chapter 8.

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2 The Quinte Source Protection Region

2.1 Watersheds in the Source Protection Region

The Quinte Source Protection Region is an area of approximately 6,600 square kilometres (including water and islands) that borders the Bay of Quinte and Lake Ontario in eastern Ontario. It includes the lands that drain into the Moira, Salmon and Napanee Rivers as well as the Prince Edward Peninsula and coincides with the jurisdiction of Quinte Conservation.

This chapter is an overview of the character of the Quinte Region. It provides background information and describes the physical setting in which the surface and groundwater resources and the 11 municipal drinking water systems in the Quinte Region have been studied.

For further information about the Quinte Source Protection Region the reader is directed to the Watershed Characterization (Appendix B1). Similarly, for more details on the water resources of the region please see the Conceptual Water Budget (Appendix C1) and Tier 1 Water Budget (Appendix C2).

2.1.1 Watershed Boundaries

The Quinte Region watershed boundaries are illustrated by Map 2.1. A watershed is an area of land that contributes water to one lake, river or stream. There are four large watersheds within the Quinte Source Protection Region: Moira River, Salmon River, Napanee River and the Prince Edward Peninsula. These have been further subdivided into 25 subwatersheds for the purpose of this report.

2.1.2 Subwatersheds

The Moira, Napanee and Salmon Rivers drain an area of approximately 2772, 818, and 925 square kilometres respectively. The Moira River has eight subwatersheds; the Salmon River, three; and the Napanee River, four. Ten subwatersheds with numerous small streams and creeks drain either into Lake Ontario or the Bay of Quinte off the Prince Edward Peninsula. Subwatersheds are described further in Chapter 3 of this report and shown on Map 2.2.

2.1.2.1 Moira River Watershed

The Moira River is the largest of the four large watersheds in the Quinte Region at over 2,700 square kilometres. It originates on the well forested Canadian Shield and descends 383 metres through the Limestone Terrane to the Bay of Quinte. The two major northern tributaries are the Black and Skootamatta Rivers. The large lakes in the watershed are Lingham, Skootamatta, Deerock, Moira and Stoco Lakes. South of Stoco Lake the physical and human geography of the Moira River watershed changes. Forests, wetlands and lakes of the Canadian Shield give way to a predominately agricultural landscape of pastures and cultivated fields. Population density increases too as the river travels south from Stoco Lake onto the Limestone Terrane. Other tributary streams enter the Moira River as it flows south to the City of Belleville on the Bay of Quinte. Over 80 percent of the watershed is covered by woodlands, water bodies and permanent wetlands (Section 2.2.3).

2.1.2.2 Salmon River Watershed

The Salmon River has a watershed area of over 900 square kilometres and originates on the Canadian Shield. It descends 267 metres through the Limestone Terrane to the Bay of Quinte. The Salmon River’s headwaters are in the Township of Addington Highlands and the river flows through Central Frontenac and Stone Mills townships. Kennebec, Big Clear, Horseshoe, Beaver and White Lakes support both seasonal and permanent residences. The Salmon River flows south from the Canadian Shield onto the limestone plain. In this section the river passes through villages and hamlets like Croydon, Roblin, Forest Mills and Kingsford on its way to the Village of Shannonville and the Bay of Quinte. Eighty-two percent of the watershed is covered by woodlands, water bodies and permanent wetlands (Section 2.2.3)**.**

2.1.2.3 Napanee River Watershed

The Napanee River has a watershed area of over 800 square kilometres and originates on the Canadian Shield descending 172 metres through the Limestone Terrane to the Bay of Quinte. The river flows from its headwaters in the Depot Lakes system in the Township of Central Frontenac south to the Town of Greater Napanee at the Bay of Quinte. Over 63 percent of the watershed is covered by woodlands, water bodies and permanent wetlands (Section 2.2.3).

2.1.2.4 Prince Edward County Watershed

The peninsula of Prince Edward County is over 1,000 square kilometres with many small creeks and streams that drain into Lake Ontario and the Bay of Quinte. The area is characterized by limestone bedrock, and extensive shoreline with picturesque limestone bluffs, and pebble and sand beaches. Agriculture is the predominant land use in Prince Edward County. The area has been designated a wine growing region by the Province of Ontario. The largest population centres are the Town of Picton and Villages of Wellington and Bloomfield. Woodlands, water bodies and permanent wetlands cover over 41 percent of the peninsula.

2.1.3 Neighbouring Source Protection Regions

Map 2.1 shows the source protection regions/areas and conservation authorities that border the Quinte Source Protection Region and Table 2-1 lists them. There is a small portion (approximately a 20 kilometres stretch) of the northern border of Quinte Region that is not within the jurisdiction of another source protection region. This small portion is within the Township of Addington Highlands and the Townships of Tudor and Cashel. The Ministry of Natural Resources is responsible for source protection planning in areas that are not covered by source protection areas or regions.

Table 2-1: Neighbouring Source Protection Regions/Areas and Conservation Authorities

Border	Source Protection Region or Area	Conservation Authority
East – Southeast	Cataraqui Source Protection Area	Cataraqui Region Conservation Authority
East - Central	Mississippi Rideau Source Protection Region	Rideau Valley Conservation Authority
East - Northeast	Mississippi Rideau Source Protection Region	Mississippi Valley Conservation Authority
West – Southwest	Trent Conservation Coalition Source Protection Region	Lower Trent Conservation
West – Northwest	Trent Conservation Coalition Source Protection Region	Crowe Valley Conservation Authority

2.1.4 Drinking Water Systems

There are 11 municipal drinking water systems in the Quinte Region. Seven of these systems have their source from surface water and the remaining four from groundwater. Table 2-2 summarizes all 11 systems, including system classification and number of users served by the system. Map 2.3 shows the locations of drinking water systems and their intakes or wells.

2.1.5 Other Drinking Water Systems

At the time of the writing of this report there were no additional Regulated Drinking Water Systems identified to be included in this Assessment Report.

Table 2-2: Locations and Classification of Quinte Region Municipal Drinking Water Systems

Drinking Water System Name (Operating Authority)	Classification	Drinking Water Source	Community Served	Population Served	Drinking Water System Location	Water Intake & Well Location
Great Lakes						
Gerry O'Connor Water Treatment Plant (City of Belleville)	Large Municipal Residential	Surface water of the Bay of Quinte	City of Belleville Cannifton Sidney Township Rossmore Fenwood Gardens	40,000 people	2 Sidney St., Belleville, County of Hastings	430 metres of intake pipe extending from the treatment plant into the Bay of Quinte. A second intake at 490 metres into the Bay of Quinte. Both at 5.5 metres deep
Point Anne Hamlet Water Treatment Plant (City of Belleville)	Small Municipal Residential	Surface water of the Bay of Quinte and groundwater	Point Anne, Hamlet of	55 people (22 connections) and a small fire hall	32 Thurlow Lane Ave, City of Belleville, County of Hastings	105 metres of intake pipe at 2.5 metres deep connecting to an on-shore intake well. Lot 24, Concession Broken Front, City of Belleville.
Deseronto Water Treatment Plant (Greater Napanee Utilities)	Large Municipal Residential	Surface water of the Bay of Quinte	Deseronto, Town of	1,700 people	322 Water Street, Town of Deseronto, County of Hastings. Intake: Lot A, Plan 162, Town of Deseronto, County of Hastings	480 metres of intake pipe extending from the treatment plant into the Bay of Quinte to a depth of 6 metres.
Picton Water Treatment Plant (Prince Edward County)	Large Municipal Residential	Surface water of Picton Bay in the Bay of Quinte	Town of Picton and Village of Bloomfield	5,905 people in Picton and 643 people in Bloomfield	30 Spencer Street, Prince Edward County.	Two separate intakes: 305 metres long north intake pipe (not currently used) and 91 metres long south intake pipe extending from the treatment plant into Picton Bay to a depth of 3.3 metres.
Wellington Water Treatment Plant (Prince Edward County)	Large Municipal Residential	Surface water of Lake Ontario	Village of Wellington	1,743 people	459 Main St., Wellington	1,475 metres of intake pipe in 10 metres water depth of Lake Ontario.
Inland Waters						
A.L. Dafoe Drinking Water System Backup (Greater Napanee Utilities)	Large Municipal Residential	Surface water of Napanee River	Napanee, Town of Greater	8,500 people	A.L. Dafoe Water Treatment Plant, 75 East Street, Napanee	Backup intake pipe in the Napanee River extending from the treatment plant to the top of Napanee Falls

Drinking Water System Name (Operating Authority)	Classification	Drinking Water Source	Community Served	Population Served	Drinking Water System Location	Water Intake & Well Location
Ameliasburgh Hamlet Water Treatment Plant (Prince Edward County)	Small Municipal Residential	Surface water	Hamlet of Ameliasburgh and Roblin Lake residents	175 people (57 connections)	73 Coleman St. Hamlet of Ameliasburgh; Lot 82, Concession 3, Ameliasburgh Ward	115 metres of intake pipe extending from the treatment plant into Roblin Lake to an unknown depth
Groundwater						
Madoc Waterworks (OCWA*)	Large Municipal Residential	Groundwater, GUDI †	Madoc, Village of	1,250	Pumphouse and Well #1 (Rollins Well), 95 Rollins Street at 49 metres deep	
					Pumphouse and Well #2 (Whytock Well), 4 Whytock Avenue at 90 metres deep	
Tweed Waterworks (OCWA*)	Large Municipal Residential	Groundwater, GUDI †	Tweed, Village of	1,800	Pumphouse: Crookston Rd (County Rd 38)	Well #3 (Crookston Well) in the plant is Crookston Rd (County Rd 38) at 122 metres deep
						Well #1 (Main well - backup), located off Hungerford Rd. Municipality of Tweed, Hastings County (not a GUDI) at 132 metres deep
						Well #2 was decommissioned in 1995
Deloro Well Supply (Municipality of Marmora & Lake)	Small Municipal Residential	Groundwater, GUDI †	Deloro, Village of	160	Pumphouse, Reservoir, and Well: Lot 109, Village of Deloro, County of Hastings (Municipality of Marmora & Lake) at 30 metres deep	
Peats Point Subdivision Well Supply (Prince Edward County)	Small Municipal Residential	Groundwater, GUDI †	Peat's Point Subdivision in Prince Edward County	19 residential connections	Pumphouse and Well #2: 55 Howard Cres, Peats Point Subdivision; Lot 54, Concession 2, Ameliasburgh Ward, Prince Edward at 37 metres deep	
					Well #1 was decommissioned in 2005.	

† Groundwater Under the Direct Influence of Surface Water
* Ontario Clean Water Agency (OCWA)

2.2 Physical Geography

2.2.1 Physiography

The physiography of the Quinte Source Protection Region may be understood generally by considering three prominent zones: Northern Area, Limestone Terrane and the Prince Edward Peninsula. These are shown on Map 2.1 and described below.

More details on physiography are provided in Chapter 3.

Northern Area

The northern area may be described as the rocky highlands of the region containing the head waters of the Moira, Napanee, and Salmon Rivers. This area is characterized by steep to rolling topography, Precambrian bedrock, numerous lakes and forested lands. Due to irregular topography many lakes, bogs and wetlands have formed in the depressions and are intermixed with large tracts of forested land. See Figure 2-1 below. The soils are generally shallow and stony with the exception of deposits of organic soils which are found in large bogs and wetlands. This region is used extensively for forestry and mining, as well as recreation with many cottages located on the numerous small lakes. In view of the ruggedness of this terrain there are few roads and minimal agriculture. Areas of settlement are located along the southern fringe of this region including the communities of Deloro, Madoc and Tweed.

Quinte Conservation Photo

Figure 2-1: A Precambrian Landscape in the Northern Area

Limestone Terrane

South of the Canadian Shield (Northern Area) lies the Limestone Terrane; an area of more subdued topography, greater soil depth and fertile agricultural land. This zone extends to the south along the shore of the Bay of Quinte and encompasses numerous glacial soil deposits in the form of drumlins, eskers, and a large kame moraine; interpreted as an extension of the Oak Ridges Moraine. The soils in some of these landforms have been reported as extending to depths in excess of 60 metres, however the majority of this region exhibits shallow soil over limestone bedrock, as illustrated by Figure 2-2 below, and the overburden thickness map (Map 2.5). Land use is primarily agricultural with rural residential development becoming popular due to aesthetic appeal and the attraction of the rural landscape.

Quinte Conservation Photo

Figure 2-2: Limestone Bedrock near Napanee

Prince Edward Peninsula

The third region includes all of Prince Edward County which is a peninsula extending into Lake Ontario characterized by limestone bedrock with thin soil cover and relatively flat topography. The peninsula exhibits an irregular shoreline defined in some areas by steep bedrock escarpments, rocky shorelines and other areas of bay mouth sand bars. See Figure 2-3 below. Numerous small water courses provide drainage for this area, leading from inland plateaus to the surrounding water bodies of the Bay of Quinte and Lake Ontario. This area is not drained by a single large water course but numerous small water courses. Land use is predominantly agricultural and rural residential.

Quinte Conservation Photo

Figure 2-3: Fractured Limestone Shoreline on the Prince Edward Peninsula

2.2.2 Overall Topography

The topography of the Quinte Region ranges from rugged in the rocky highlands of the Canadian Shield to areas of flat, low relief along the shores of the Bay of Quinte and Lake Ontario. Elevations range from a maximum of 458 metres above sea level in the extreme north of the Moira Watershed to 75 metres above sea level along the shore of the Bay of Quinte and Lake Ontario. Mapping of topography, illustrated by Map 2.6, using a digital elevation model illustrates areas of steep slope concentrated in the Canadian Shield portion of the Moira, Salmon, and Napanee watersheds. To the south, there is a predominance of low slopes with the exception of steep bedrock escarpments which are found throughout the Prince Edward Peninsula.

2.2.3 Geology

To describe the geology of the region, this section has been divided into Bedrock Geology and Surficial Geology.

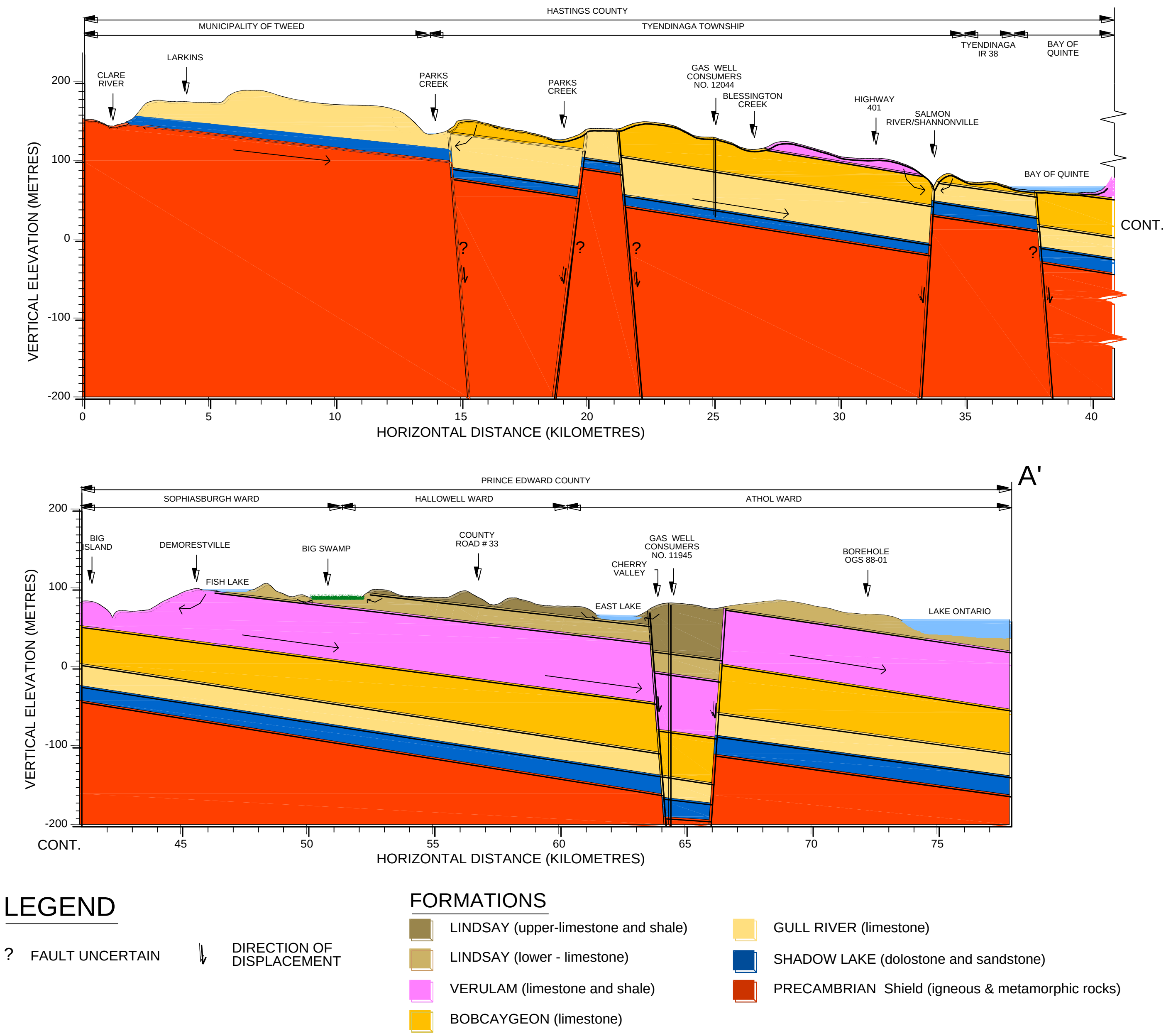
Bedrock Geology

In the absence of significant soil deposits the bedrock geology has a large influence on the physical landscape and flow of water in the Quinte Region. The bedrock found in this area consists of both Precambrian and Paleozoic formations with distribution illustrated by Map 2.7 showing the Precambrian rock in the northern area and Paleozoic at the south. A generalized regional cross section of the study area is shown in Figure 2-4. The Precambrian rocks, the oldest in the area, underlie the entire region and are exposed near the surface in the Northern area. This rock is comprised of igneous (cooled from lava) and metamorphic rock that was later heated and reformed while still below the surface. The Paleozoic rocks, found throughout the southern area (Limestone Terrane and Prince Edward Peninsula), are reported to be above the Precambrian bedrock at depths of as much as 300 metres in the extreme south and tapering to zero at the north. These rocks consist predominantly of limestone that was formed after the area was inundated by an ocean and sediments accumulated on the bottom consolidating over time into sedimentary rocks. The limestone rocks are predominantly flat-lying with the surface sloping in a southerly direction similar to the overall trend of the rugged Precambrian rock. The slope of the bedrock surface (both types), as illustrated by Map 2.8 is to the south, serves to direct the regional flow of both ground and surface water in a southerly direction.

Surficial Geology

Soils in the Quinte Region, depicted in Map 2.9, are the result of the most recent glacial period which ended approximately 10,000 years ago. During this period the glaciers scraped and deposited soils throughout leaving often only a thin cover (1 metre and less) of material over bedrock. However, in some areas thick deposits of soil were left behind in the form of moraines, drumlins and eskers. The areas of greater soil depth are, illustrated by Map 2.5, found throughout the Limestone Terrane and in isolated areas of the Prince Edward Peninsula in the vicinity of West and East Lakes.

Soils in the Quinte Region developed in relation to the underlying bedrock formations. Given the bedrock geology, there are numerous different soil types in the region (Map 2.10). In general, all soils are thin and well drained; however, there is variability in composition. In the Northern area the bedrock is resistant to erosion; the soils are granular, not well developed and are generally not well suited for agriculture. In the southern area of the Limestone Terrane and the Prince Edward Peninsula the underlying limestone bedrock is softer and the soil building process has resulted in well developed soils which are favourable for agricultural activities.



(Source: Quinte Regional Groundwater Study, October 2004)

Figure 2-4: Generalized Bedrock Geology Cross Section

2.2.4 Natural Vegetative Cover

A large portion of the Quinte Region is naturally vegetated. Over 70 percent is considered wetlands and woodlands (Table 2-3) and 69 percent of riparian areas along streams in the region are naturally vegetated.

Woodlands and wetlands are distributed throughout the Quinte Region, but most are preserved in the Canadian Shield region where pressure from human development has been limited (Map 2.11). Some of these woodlands and wetlands are designated as Areas of Natural and Scientific Interest (ANSI) in the Life Science category which is an Ontario Ministry of Natural Resources designation for the purpose of protecting lands that are provincially or regionally significant and are representative of significant ecological features. These designated areas are protected under the *Environmental Assessment Act*, 1990, Ontario Regulation 282/98. Some wetlands in the Quinte Region are designated as evaluated wetlands through the Ontario Ministry of Natural Resources Ontario Wetland Evaluation System. Those designated as Provincially Significant Wetlands because of their unique ecosystems are protected by Provincial Policy Statement under the *Planning Act*, 1990 and through policies in municipal official plans. Full lists of Provincially Significant Wetlands and Areas of Natural and Scientific Interest for Life Science are provided in Appendix 4 and 5 of the Watershed Characterization Report (Appendix B1).

Table 2-3: Natural Vegetative Cover per Watershed †

Watershed	Moira River		Salmon River		Napanee River		Prince Edward Peninsula		Total	
	ha	%	ha	%	ha	%	ha	%	ha	%
Total Area (ha)	284,804		91,801		104,157		108,147		588,909	
Woodlands	189,611	66.6	60,167	65.5	50,538	48.5	35,224	32.6	335,540	57
Waterbodies	15,311	5.4	5,149	5.6	6,321	6.1	2,989	2.8	29,770	5.1
Permanent Wetlands	24,619	8.6	9,942	10.8	9,335	9	7,004	6.5	50,900	8.6
TOTAL	**229,541**	**80.6**	**75,258**	**82**	**66,194**	**63.6**	**45,216**	**41.8**	**416,209**	**70.7**
OMNR Wetlands *	8,411	3		0	12,478	12	8,796	8.1	29,685	5
ANSI Life Science **	18,616	6.5		0	13,972	13.4	6,705	6.2	39,293	6.7

† modified table from McNevin 2005; Prince Edward Peninsula values include the entire peninsula, not just the portion that drains into the Bay of Quinte (McNevin 2005).

* Evaluated by Ontario Ministry of Natural Resources using the Ontario Wetland Evaluation System (NHIC 2005).

** Areas of Natural and Scientific Interest (ANSI) for Life Science evaluated by Ontario Ministry of Natural Resources as having provincially or regionally significant representative ecological features (NHIC 2005).

2.2.5 Aquatic Habitats

2.2.5.1 Fisheries

The Quinte Source Protection Region has a wide variety of lake and river fish habitats that support both cold and warm water fisheries. Map 2.12 shows the water body temperatures based on sensitive fish populations in the region.

Loss of cold water streams can be an indication of the impact of human activities. Some examples are straightening of stream channels, increased erosion due to deforestation and removal of riparian vegetation that allows sunlight to warm the waters. There have been stream improvements in the Quinte region as a result of initiatives of local stewardship groups like:

- Palliser Creek Improvement Association that was very active in the 1980s and early 1990s;
- Waring's Creek Improvement Association, active in the early 1990s, and
- Bay of Quinte Remedial Action Plan; and

Loss of fish and wildlife habitat has been identified by the Bay of Quinte Remedial Action Plan in 1993 as a concern.

Although most streams in the Quinte Region are warm water, cool and cold water streams are an indication of groundwater discharge. These discharge areas are important to both human activities and aquatic habitats as these areas help to maintain water levels and provide potential sources of fresh drinking water. In 2006 and 2007 Quinte Region streams were surveyed to identify cold water streams following the Ontario Stream Assessment Protocol by the Ontario Ministry of Natural Resources and were classified by their temperature regimes (Stanfield 2005, Coker 2001). Table 2-4 is the list of cold and cool water stream reaches across the Quinte region surveyed in 2006 and 2007 based on this protocol. No warm water streams were included in the survey. Generally, cold water streams can be found in headwater streams in the upper reaches of watersheds (Map 2.12). Where there is a cold water stream, there is a groundwater discharge area and therefore there is a groundwater recharge area nearby. Groundwater recharge areas are valuable because they supply aquifers with fresh water but can easily be contaminated by runoff or spills.

Table 2-4: Stream Temperature Classes (based on measurements in 2006 and 2007)

Station ID	Watercourse	Year	Temperature Regime
Moira River Watershed			
BSC01	Blessington Creek	2006	cool
CHC05	Chrysal Creek	2006	cold
GOC03	Goose Creek	2006	cool
		2007	cool
MOR01	Moira River	2006	cool
		2007	cool
MOR02	Moira River	2006	cool
		2007	cool
MOR03	Moira River	2006	cool
		2007	cool
MOR09	Moira River	2006	cool
NTC02	Number Ten Creek	2006	cold
		2007	cold
PAC06	Palliser Creek	2006	cold
PKC10	Parks Creek	2006	cold
		2007	cold
POC01	Potter Creek	2006	cool
UNC03	Noname Creek	2006	cool
		2007	cool
Napanee Region Watershed*			
CRC01	Crooked Creek	2006	cool
DPC01	Depot Creek	2006	cool
FIC02	Fisher Creek	2006	cool
NPR07	Napanee River	2006	cool
OTC01	Otter Creek	2006	cool
PNC01	Pennels Creek	2006	cool
Prince Edward Peninsula			
BLC01	Bloomfield Creek	2006	cool
HBC02	Hubbs Creek	2006	cool
HLC02	Slab (Hillier) Creek	2006	cool
WAR2	Waring's Creek	2006	cool
		2007	cold
WAR3	Waring's Creek	2006	cold
WAR4	Waring's Creek	2006	cold
		2007	cold

* Napanee Region Watershed includes data from the Napanee and Salmon Rivers combined.
Water temperatures measured in 2006 and 2007 used to classify temperature regimes based on preferred temperature of fish (<19°C cold, 19 to 25°C cool, >25°C warm water) (Coker 2001).

2.2.5.2 Aquatic Macroinvertebrates

Benthic macroinvertebrates are aquatic invertebrates (organisms without a backbone) that live on the bottom of streams and lakes and are large enough to be seen with the naked eye. Since these organisms spend most, if not all, of their lives on the stream bottom, their community composition indicates the general health of the stream.

The Hilsenhoff Biotic Index is used to interpret the benthic macroinvertebrates which is a weighted average for a set of organism groups that are assigned tolerant values based on how the general group reacts to nutrient enrichment (Stanfield 2005). As identified in the Watershed Characterization Report (Appendix B1), monitoring stations that had a high index should be monitored closely in future as they could be nutrient enriched according to the 2003 to 2007 surveys. In the Moira River Watershed, Chrysal Creek, Palliser Creek, Parks Creek, and Potter Creek had Hilsenhoff Biotic Indices showing signs of possible impairment. In the Napanee Region Watershed, Selby Creek also had a Hilsenhoff Biotic Index showing signs of possible impairment. In Prince Edward Watershed, Demorestville Creek, Hillier Creek and Waring’s Creek also show signs of impairment (Map 2.13).

2.2.6 Species and Habitats at Risk

Ontario's original *Endangered Species Act, 2007* prohibits willful harm to endangered species that are listed in regulations under the Act and the willful destruction of, or interference with, their habitats. The main threats to species at risk in Ontario are habitat loss, pollution, invasive species, and over-harvesting of the species. It is important to identify rare species, particularly populations of aquatic species, because populations may be dwindling due to impaired water quality or quantity conditions. The occurrence of rare aquatic species can also suggest the presence of rare or unique habitat characteristics which may be important to note during the formulation of a source protection plan.

There are two accepted authorities on endangered species in Ontario. They are the Ontario Committee on the Status of Species at Risk reporting to the Ontario Ministry of Natural Resources and the federal Committee on the Status of Endangered Wildlife in Canada.

The Ontario Ministry of Natural Resources is a good source of the provincial rare species list. The distribution data of the rare species is based on the number of occurrences in 1 kilometre square boxes (Map 2.14). The reason for the generalized reporting is to protect the populations from further risk of becoming extinct by human interference. Most of the rare species in the Quinte Source Protection Region were located in the lower portion of the Salmon and the

Napanee River watersheds. These rare species occurrences were associated with natural areas of shorelines along lakes, rivers, wetlands and forested areas. In addition, there were some located in urban areas, such as Tweed, Belleville, and Picton.

The national list of rare species published by the Committee on the Status of Endangered Wildlife in Canada and the provincial list of Ontario Ministry of Natural Resources was gathered for the Quinte region from the Natural Heritage Information Centre (NHIC) without revealing their specific locations (NHIC 2005). The list includes mammals, amphibians, fish, birds, and plants of both terrestrial and aquatic species. As of 2005, there were 17 rare species in the Moira River Watershed, 17 in Napanee Region Watershed, and 11 identified on the Prince Edward Peninsula. There are five species at risk common to all three watersheds: Black Tern, Blandings Turtle, Henslow Sparrow, Least Bittern, Loggerhead Shrike. See Table 2-5 below. The list is periodically updated with changes of status.

Table 2-5: Rare species identified by the Natural Heritage Information Centre in the Quinte Region (NHIC 2005).

Common Name	Scientific Name	Committee on the Status of Endangered Wildlife in Canada †	Ontario Ministry of Natural Resources ††
Moira River Watershed			
Black Tern	Chlidonias niger	Not At Risk	Special Concern
Blanding's Turtle	Emydoidea blandingii		Threatened
Central Stoneroller	Campostoma anomalum	Not At Risk	Not At Risk
Channel Darter	Percina copelandi	Threatened	Threatened
Dwarf Hackberry	Celtis tenuifolia	Threatened	Threatened
Eastern Hog-nosed Snake	Heterodon platirhinos	Threatened	Threatened
Five-lined Skink	Eumeces fasciatus	Special Concern	Special Concern
Grey Fox	Urocyon cinereoargenteus	Threatened	Threatened
Henslow's Sparrow	Ammodramus henslowii	Endangered	Endangered-R
Least Bittern	Ixobrychus exilis	Threatened	Threatened
Loggerhead Shrike	Lanius ludovicianus	Endangered	Endangered-R
Louisiana Waterthrush	Seiurus motacilla	Special Concern	Special Concern
Macoun's Shining Moss	Neomacounia nitida	Extinct	Extinct
Prairie Warbler	Dendroica discolor	Not At Risk	Not At Risk
Red-shouldered Hawk	Buteo lineatus	Special Concern	Special Concern
Small White Lady's-slipper	Cypripedium candidum	Endangered	Endangered-R
Southern Flying Squirrel	Glaucomys volans	Special Concern	Special Concern
Napanee Region Watershed			
Black Tern	Chlidonias niger	Not At Risk	Special Concern
Blanding's Turtle	Emydoidea blandingii		Threatened
Butternut	Juglans cinerea	Endangered	Endangered

Common Name	Scientific Name	Committee on the Status of Endangered Wildlife in Canada †	Ontario Ministry of Natural Resources ††
Cerulean Warbler	Dendroica cerulea	Special Concern	Special Concern
Dwarf Hackberry	Celtis tenuifolia	Threatened	Threatened
Eastern Prairie Fringed-orchid	Platanthera leucophaea	Endangered	Endangered
Five-lined Skink	Eumeces fasciatus	Special Concern	Special Concern
Henslow's Sparrow	Ammodramus henslowii	Endangered	Endangered-R
Juniper Sedge	Carex juniperorum	Endangered	Endangered-R
King Rail	Rallus elegans	Endangered	Endangered-R
Least Bittern	Ixobrychus exilis	Threatened	Threatened
Loggerhead Shrike	Lanius ludovicianus	Endangered	Endangered-R
Louisiana Waterthrush	Seiurus motacilla	Special Concern	Special Concern
Prairie Warbler	Dendroica discolor	Not At Risk	Not At Risk
Red-shouldered Hawk	Buteo lineatus	Special Concern	Special Concern
Toothcup	Rotala ramosior	Endangered	Endangered
Yellow-breasted Chat	Icteria virens	Special Concern	Special Concern
Prince Edward Peninsula			
Black Tern	Chlidonias niger	Not At Risk	Special Concern
Blanding's Turtle	Emydoidea blandingii		Threatened
Butternut	Juglans cinerea	Endangered	Endangered
Cerulean Warbler	Dendroica cerulea	Special Concern	Special Concern
Climbing Prairie Rose	Rosa setigera	Special Concern	Special Concern
Deepwater Sculpin	Myoxocephalus thompsoni	Threatened	Threatened
Henslow's Sparrow	Ammodramus henslowii	Endangered	Endangered-R
King Rail	Rallus elegans	Endangered	Endangered-R
Least Bittern	Ixobrychus exilis	Threatened	Threatened
Loggerhead Shrike	Lanius ludovicianus	Endangered	Endangered-R
Swamp Rose-mallow	Hibiscus moscheutos	Special Concern	Special Concern

Note:

* Napanee Region Watershed includes both the Salmon and Napanee Rivers.

† **Endangered:** A species facing imminent extirpation or extinction throughout its range.
Extirpated: A species no longer existing in the wild in Canada, but occurring elsewhere in the wild.
Extinct: A species that no longer exists.
Indeterminate: A species for which there is insufficient information to support a status designation.
Not At Risk: A species that has been evaluated and found to be not at risk.
Special Concern: A species of special concern because of characteristics that make it particularly sensitive to human activities or natural events, but do not include an extirpated, endangered or threatened species.
Threatened: A species likely to become endangered if nothing is done to reverse the factors leading to its extirpation or extinction.

†† Extinct: A species that no longer exists anywhere.
Extirpated: A species that no longer exists in the wild in Ontario but still occurs elsewhere.
Endangered-R (Regulated): A species facing imminent extinction or extirpation in Ontario which has been regulated under Ontario's Endangered Species Act (ESA).
Endangered (Not Regulated): A species facing imminent extinction or extirpation in Ontario which is a candidate for regulation under Ontario's ESA.

Threatened: A species that is at risk of becoming endangered in Ontario if limiting factors are not reversed.
Special Concern: (formerly Vulnerable) A species with characteristics that make it sensitive to human activities or natural events.
Not at Risk: A species that has been evaluated and found to be not at risk.
Data Deficient: (formerly Indeterminate) A species for which there is insufficient information for a provincial status recommendation.

2.3 Water Quality and Quantity

The purpose of this section is to provide a general description of current surface water and groundwater quality and quantity as outlined in the Quinte Region Watershed Characterization Report (Appendix B1). The Watershed Characterization Report contains information on data sources, methods of analysis and limitations for this section.

2.3.1 Surface Water Quality

Surface water quality in the Quinte Source Protection Region is generally considered good and has shown improvement over the last 40 years (the period for which data are available). Lakes and rivers are enjoyed by residents and tourists for recreation. These same lakes and rivers are used as municipal and private drinking water sources. Table 2-6 summarizes water quality problems that include Arsenic, Phosphorous, Organic Nitrogen, Taste and Odour, Water Clarity and *E.coli* as identified in the Watershed Characterization Report. Occasionally some of these parameters still have concentrations greater than the Provincial Water Quality Objectives (Ministry of Environment 1999) that are benchmarks used to protect aquatic life and recreational uses.

The Bay of Quinte has a history of being nutrient enriched or hyper-eutrophic due to phosphorous loading which results in algae blooms and taste and odour problems for drinking water. Local swimming beach closures are also common due to elevated *E.coli* counts. Some improvements have resulted due to the upgrades of the sewage treatment plants, the reduction of industrial waste discharges into the Bay, and landowner stewardship programs of the Bay of Quinte Remedial Action Plan initiative and partners' activities. Other changes that have not been beneficial are the introduction of invasive species, such as the zebra mussels that changed the physical, chemical, and biological integrity of the Bay. The main data source used to characterize the surface water quality in the region was collected through the Provincial Water Quality Monitoring Network (Map 2.15). Other data sources are listed in the fifth column of Table 2-6.

Municipal drinking water systems with surface water intakes supply safe drinking water. Occasionally, some parameters have exceeded the Ontario Drinking Water Standards in the raw-untreated water, reflecting the water quality of the source water. The evaluation to the water quality Issues Approach for all municipal drinking water system intakes are discussed in Chapter 6. Recent concerns for drinking water sources and recreational use of water are algal toxins brought on by the die off of cyanobacteria (also called blue-green algae); and pharmaceuticals and personal care products with man-made chemicals and endocrine disruptors. These concerns are discussed from the drinking water perspective under Chapter 8.

Table 2-6: Surface Water Quality Problems in the Quinte Source Protection Region

Water Quality Concern	Implications	Known Sources of Contamination	Geographic Extent	Water Quality Data Source
Arsenic	• Acutely or chronically toxic to humans and a threat to aquatic biota • Arsenic has settled out along the Moira River downstream from Deloro, therefore could be released back into the water when sediment is disturbed	• Arsenic is naturally occurring in the Precambrian Shield • Former Deloro Mine site (closed in 1961). Contaminated substrate in the Moira River and outflow into the Bay of Quinte • Clean up of contaminants by the Ontario Ministry of the Environment since 1979 has improved conditions in the Moira River system	• High concentrations have been found in the Moira River downstream from the Village of Deloro, in Moira Lake and Bay of Quinte. • Concentration of arsenic diminishes with distance from Deloro and has improved over time	• Provincial Water Quality Monitoring Network • Drinking Water Surveillance Program • Bay of Quinte Remedial Action Plan
Phosphorous	• May lead to increased growth of aquatic plants and algal blooms resulting in eutrophic conditions	• Runoff of fertilizers, sewage plant effluent, and waste water from industrial, agricultural, and domestic sources including septic systems located throughout the Quinte Region	• Many streams monitored in Quinte Region exceeded the provincial objective. • 3 of 22 Lake Partner Program inland lakes are considered eutrophic • Bay of Quinte was hyper-eutrophic in the 1950s and concentrations have improved	• Provincial Water Quality Monitoring Network • Lake Partner Program, • Drinking Water Surveillance Program • Great Lakes Index Station Network • Municipal / Industrial Strategy for Abatement • Bay of Quinte Remedial Action Plan • Quinte Conservation's Ontario Benthos Biomonitoring Network program

Water Quality Concern	Implications	Known Sources of Contamination	Geographic Extent	Water Quality Data Source
Organic Nitrogen	• High levels may lead to eutrophic conditions and increased growth of aquatic plants and algal blooms	• Organic Nitrogen is found naturally in detritus at bottom of lakes and rivers • Organic Nitrogen is from runoff of sewage, septic systems, and farmyards found in agricultural and rural areas; stormwater systems and sewage treatment • Ammonia in urea from barn yard runoff • Airport runoff with de-icing agent	• Many streams monitored in Quinte Region had high concentrations compared to typical Canadian waters • Belleville, Deseronto, and Picton drinking water intakes have levels in raw water higher than typical levels	• Provincial Water Quality Monitoring Network • Drinking Water Surveillance Program • Great Lakes Index Station Network • Municipal / Industrial Strategy for Abatement • Quinte Conservation Ontario Benthos Biomonitoring Network program
Taste and Odour	• Measured as Geosmin • Leads to aesthetic problems of drinking water • Associated with high amounts of organic materials, aquatic plant and algae growth	• Detritus formed from high nutrient levels • Nutrient enrichment is often caused by runoff from sewage, septic systems, and farm yards found in agricultural and rural areas; stormwater systems and sewage treatment plants in urban areas of the Quinte Region	• Bay of Quinte waters • High in raw water at Belleville, Deseronto, and Picton drinking water systems	• Drinking Water Surveillance Program • Bay of Quinte Remedial Action Plan
Clarity of water	• Murky conditions impede light and gas diffusion into water • Measured as turbidity (ultrafine dispersions in water) • Measured as clarity in lakes • Dissolved or suspended materials that contain algae may be hazardous if algae toxins are present	• Runoff of eroded soils and fine sediments during rain events • Municipal/industrial effluent runoff and spills, nutrient runoff, and aerosol fallout • Water bodies that do not have adequate vegetated riparian buffers	• Riparian buffer strips less than 30 m wide are found throughout the Quinte Region • Most monitored streams in Quinte Region exceeded the provincial standard for turbidity. • Some monitored streams exceeded the provincial standard for total residue • 3 of 22 Lake Partner Program lakes had poor clarity	• Provincial Water Quality Monitoring Network • Drinking Water Surveillance Program • Great Lakes Index Station Network

Water Quality Concern	Implications	Known Sources of Contamination	Geographic Extent	Water Quality Data Source
E.coli	• Hazardous to humans and animals • Indicators of fecal contamination including bacteria and viruses • Beaches closed for swimming	• Runoff of animal farm yards and crop land spread by agricultural source material • Stormwater systems, septic systems • Bird, wildlife and pet droppings at beaches and parks, etc.	• Many monitored streams in the Quinte Region had *E.coli* counts exceeding the Provincial Water Quality Objective • Bay of Quinte has elevated *E.coli* counts at inflows and swimming beaches	• Provincial Water Quality Monitoring Network • Drinking Water Information System • Bay of Quinte Remedial Action Plan • Local Health Units

Source: Watershed Characterization (Appendix B1)

2.3.2 Groundwater Quality

Groundwater quality in the Quinte Region is generally considered good with most wells intercepting water of fresh quality suitable for domestic and agricultural use. However there are a number of natural groundwater quality concerns that include chloride, sodium, methane gas, hydrogen sulphide, hardness, uranium, fluoride and sulphate (Table 2-7). These natural water quality problems are quite often associated with the limestone aquifers and wells that are drilled to depths in excess of 30 metres. Fewer water quality problems are reported for wells drilled in the Precambrian bedrock. Some other groundwater quality concerns have developed as a result of human activity relating to *E.coli*, total coliform, sodium, chloride, nitrates, and hydrocarbons (Table 2-8). A good source of data used to characterize the groundwater quality in the region was from the Provincial Groundwater Monitoring Network (Map 2.16). Other sources of information on groundwater quality include municipal and regional hydrogeologic reports and the Ontario Water Well Records. More detail on groundwater quality is available in the Watershed Characterization Report (Appendix B1). Water quality issues identified at the municipal well supplies are discussed in Chapter 5 of this report.

Table 2-7: Natural Groundwater Quality Problems in the Quinte Source Protection Region

Parameter	Aquifer	Source	Implications	Location
Chloride	Limestone	Leaching from rocks	Salty taste to water Corrosive to plumbing	Deep aquifers in southern Quinte Region
Sodium	Limestone	Leaching from rocks	Important to people on sodium restricted diets	Deep aquifers in southern Quinte Region
Methane gas	Limestone	Decay of organic matter	Potential explosion hazard	Southern Quinte Region
Hydrogen Sulphide	Limestone and Overburden	Decay of organic matter chemical reaction	At low levels unpleasant odour in water	Deep aquifers in southern Quinte Region
Hardness	All	Leaching of calcium & magnesium from rock.	Aesthetic difficult to lather soap Residue on pipes and fixtures	Throughout the Region
Uranium	Precambrian Bedrock	Leaching from rocks	Health hazard - Toxic	Canadian Shield Village of Tweed
Fluoride	Precambrian Bedrock	Leaching from rocks	High concentrations can be toxic	Canadian Shield Village of Tweed
Sulphate	Limestone	Leaching from rocks	Objectionable taste Potential laxative	Deep aquifers in southern Quinte Region

Source: Watershed Characterization (Appendix B1)

Table 2-8: Human Sources of Groundwater Contamination in the Quinte Source Protection Region

Parameter	Source	Implications	Potential Areas of Concern
E.coli and total coliform	Septic Systems Livestock waste	Health related – water borne diseases	Throughout the Quinte Region
Nitrates and Nitrites	Septic Systems Fertilizers Livestock Waste	Health related – especially toxic to infants and pregnant women	Throughout the Quinte Region
Sodium & Chloride	Septic Systems Road Salt	Health related for people on sodium restricted diets Corrosive to plumbing Salty taste	Along major highways, intersections, and municipal salt storage facilities
Hydrocarbons	Fuel Storage Tanks	Health related	Former and active gas stations and tank farms

Source: Watershed Characterization (Appendix B1)

2.3.3 Water Quantity

Water in the Quinte Region is used as a source of drinking water and also for irrigation, agricultural livestock watering, industry, manufacturing and recreation. This water comes from both ground and surface water sources. Water use and water demand in the region is typically focused around developed areas and hamlets. Water use greater than 50,000 litres per day falls under the Permit to Take Water Process. Details on water use by permit holders may be found in Chapter 3 of this document and Chapter 4 of the Watershed Characterization (Appendix B1). The average monthly and annual water demand for the municipal drinking water systems are listed in Table 2-9.

Table 2-9: Summary of Water Demand at Municipal Drinking Water Systems

System	Water Source	Average	
		Monthly (m^{3*})	Annual (m^{3*})
Tweed	Groundwater	17370	211335
Madoc	Groundwater	17460	212430
Deloro	Groundwater	2040	24820
Peats Point	Groundwater	404	5086
Picton	Surface Water	109288	1312430
Wellington	Surface Water	25931	311345
Ameliasburgh	Surface Water	2018	24217
Napanee**	Surface Water	176353	2102378
Deseronto	Surface Water	30672	368124
Belleville	Surface Water	752347	8840081
Point Anne	Combined	481	5619

*cubic metres
**This use is based on taking from the Lake Ontario intake.

In the Quinte Region today 52 percent of the population obtains their drinking water from municipal sources (49 percent from surface water and 3 percent from municipal wells). Private water systems are the source of water for the remaining 48 percent of residents. These systems include private water wells and intakes. The location of water wells (of which there are 22,000 in the Quinte Region) are illustrated by Map 3-5. A summary of the population distribution in the Quinte Region with water use by municipality is provided by Table 2-10.

The Conceptual Water Budget, 2009 identified that about two thirds of the water coming into the collective watersheds of the Quinte Region is lost through evaporation and transpiration. On average the equivalent of about 1 metre of precipitation falls in the area but only one third of that is available to recharge aquifers, replenish lakes and rivers and supply water for the range of uses throughout the region.

Stress on water quantity, particularly from groundwater sources tends to be seasonal. In the usually dry months of summer and early fall the aquifers may become stressed but typically rebound almost immediately, once precipitation increases or snow melt occurs. There are some locations on the Limestone Terrane and Prince Edward peninsula where an inadequate water supply in private wells has been reported. One of the municipal wells on the Precambrian Shield at Madoc has run dry in the past. See Chapter 5.

Five of the region's seven intakes draw their water from the Bay of Quinte or Lake Ontario (see Table 2-2). These two bodies of water are interconnected and represent an enormous volume of water. Lake Ontario and the Bay of Quinte water levels have been regulated since 1960, primarily through the Moses-Saunders power dam near Cornwall, Ontario and Massena, New York. It is not anticipated that water quantity will be an issue for this source; however climate change could have a long term effect. Climate Change is discussed in Chapter 7.

More information and details on water quantity in the Quinte Region may be found in Chapters 3 and 5 and in the Watershed Characterization Report (Appendix B1) and the Conceptual Water Budget (Appendix C1).

Table 2-10: Municipal Population Distribution on Ground and Surface Water Supplies

Lower or Single Tier Municipality *	Total Population	Population Served			% Population Supplied by Groundwater		
		Municipal Groundwater	Municipal Surface Water	Private Wells/ Intakes	Total	Municipal Wells	Private wells
Municipality of Tweed	5612	1539	0	4073	100	27.4	72.6
City of Belleville	45986	0	38306	7680	16.7	0	16.7
Township of Tyendinaga	3769	0	0	3769	100	0	100
Town of Deseronto	1796	0	1796	0	0	0	0
Township of Stone Mills	7337	0	0	7337	100	0	100
Township of Madoc	2044	0	0	2044	100	0	100

Lower or Single Tier Municipality *	Total Population	Population Served			% Population Supplied by Groundwater		
		Municipal Groundwater	Municipal Surface Water	Private Wells/ Intakes	Total	Municipal Wells	Private wells
Township of South Frontenac	3447	0	0	3447	100	0	100
Municipality of Centre Hastings	3127	1730	0	1397	100	55.3	44.7
Township of Addington Highlands	1056	0	0	1056	100	0	100
Town of Greater Napanee	11667	0	7760	3907	33.5	0	33.5
Township of North Frontenac	18	0	0	18	100	0	100
Township of Central Frontenac	2096	0	0	2096	100	0	100
Municipality of Marmora & Lake	527	50	0	477	100	9.5	90.5
City of Quinte West	3528	0	0	3528	100	0	100
Township of Stirling Rawdon	465	0	0	465	100	0	100
Township of Tudor & Cashel	319	0	0	319	100	0	100
Loyalist Township	238	0	0	238	100	0	100
County of Prince Edward	24901	50	9901	14950	60.2	0.2	60
Totals	**117933**	**3369**	**57763**	**56801**	**51**	**2.9**	**48.2**

Source: Statistics Canada and Municipal Affairs and Housing (2006)

* Upper Tier municipalities are not listed to eliminate double counting population

2.4 Overview of Human Geography: Including Interactions Between Physical and Human Geography

The physical geography of the Quinte Region has had a strong influence on human activity and water usage.

The Quinte Region's location, bordering Lake Ontario and its close proximity to larger population centres in Canada and the United States has influenced its development. It is a popular travel and cottage destination due to its location on the water, many lakes and natural splendor. Industry on Lake Ontario benefits from the Great Lake location that allows shipping to international destinations. The region is on established transportation corridors, and near major population and commercial centres in eastern Canada and the northeastern United States. This continues to positively influence development and the local economy.

Additional information on Human Geography in the Quinte Region including details on human economic activities like mining and aggregate extraction, forestry, and transportation is available in the Watershed Characterization Report (Appendix B1).

2.4.1 Settlement Areas

Settlement and development in the region evolved around the land and water resources and this legacy continues to be reflected on the landscape in the Quinte Region today.

First Nations people were in the area when the Europeans arrived in the 1600s. Following exploration, settlements sprang up along rivers and shorelines. The local waterways provided power for mills and transportation for the inhabitants, their goods and products. Valuable timber, fertile arable soil on the limestone plains, and later, minerals on the Canadian Shield all played a part in the evolution of the human geography in Quinte Region. Exploration, settlement and development have led to a subsequent population increase that has placed demands on local water resources and established the need to protect water for the future.

Reflecting the area's settlement history, urban centres in the region are situated on or at the confluence of local waterways (Map 2.17). Most population centres are in the southern part of the region on the shores of the Bay of Quinte or Lake Ontario. The largest urban centre, Belleville, is at the mouth of the Moira River on the Bay of Quinte. Like the City of Belleville, the Towns of Napanee, Deseronto, and Picton and the Village of Wellington are also located on the water. Even the smaller villages on the edge of the Canadian Shield, like Tweed and Madoc, have a connection to water resources as early sites of grist and saw mills. These villages, with active ties to forestry and mining, now also serve as recreational hubs for tourism and cottagers.

There are also numerous small villages and hamlets in the region. Many of these like Milford, Colebrook, Yarker, Forest Mills, Flinton and Queensboro became established surrounding some of the region’s first mills. Still other settlements sprang up at crossroads, for example; Huffs Corners, Sharps Corners.

Rural settlement clusters have developed throughout the region. Today, there may be both water quantity and quality concerns that have developed in these clusters. Often rural clusters are linear in nature, having sprung up along popular waterfront or on roads leading into villages and towns. Many of these clusters developed before adequate municipal planning controls were in place. Some clusters are around lakes where seasonal homes have since been converted to permanent residences. These conversions place more demand on water sources and increase concern about potential contamination from inadequately designed or maintained septic systems. In some of these areas existing lot sizes are now considered inadequate to handle both a private well and septic system without creating concerns for contamination of water sources.

For some existing rural settlement areas, the solution has been to provide municipal water. The Village of Rossmore and Hamlet of Fenwood Gardens in Prince Edward County are examples. Municipal water was piped under the Bay of Quinte from the City of Belleville in 1991 to supply Rossmore and was extended later to Fenwood Gardens. Water for the residents of the Hamlet of Carrying Place, also in Prince Edward County, was provided in the mid 1990s by the City of Quinte West. That source is in the Trent Conservation Coalition Source Protection Region.

Some municipalities in the Quinte Region now require a minimum lot size of one hectare (two acres) to protect local water resources and to reduce the likelihood of the need for the future provision of municipal water.

2.4.2 Municipal Boundaries

Within the Quinte Source Protection Region there are three upper tier, three single tier and 15 lower tier municipalities. The municipalities are shown on Map 2.18. These municipalities are represented by five members on the Quinte Region Source Protection Committee.

Upper Tier municipalities are the County of Hastings, County of Frontenac, and

County of Lennox and Addington. Single Tier municipalities are Corporation of the County of Prince Edward, Corporation of the City of Belleville, and City of Quinte West. Lower Tier municipalities are: Township of Stirling/Rawdon, Corporation of the Municipality of Centre Hastings, Corporation of the Township of Madoc, Municipality of Marmora and Lake, Municipality of Tweed, Townships of Tudor and Cashel, Town of Deseronto, Township of Tyendinaga, Corporation of the Township of Addington Highlands, Township of Stone Mills, Town of Greater Napanee, Corporation of Loyalist Township, Township of North Frontenac, Township of Central Frontenac, and Township of South Frontenac.

2.4.3 Federal Lands and Protected Lands

Data for the Federal Lands in the Quinte Region was incomplete and is an identified data gap. Map 2.19 does not show all federal lands. The crown land data layer used to create the map was limited and incomplete. The data showed no distinction between provincial crown land and federal crown land. While the data did show the Mohawk Territory as federal land, there were large areas of known crown land in the north and other areas in Prince Edward County that were not shown. This data gap is discussed in Chapter 8.

In order to provide some representation of Federal Lands in the region information from the Protected Lands Map in the Watershed Characterization, 2006 was used. Protected Lands are areas considered valuable habitat, for example Areas of Natural and Scientific Interest or Provincially Significant Wetlands (see Section 2.2.4 Natural Vegetative Cover). Some Protected Lands, as described in the Watershed Characterization, 2006, are those that have been put aside for environmental or aboriginal use. Most of the Protected Lands in the Quinte Source Protection Region are lands administered by the Ministry of Natural Resources. However, some Protected Lands fall under the control of the federal government, including aboriginal territory, harbours and canal systems.

Two provincial parks, Sandbanks and North Beach, located on the Lake Ontario shoreline in Prince Edward County are shown on Map 2.19 as Protected Lands. In addition to provincial crown land and federal land Map 2.19 also shows Quinte Conservation’s substantial land holdings of over 12,000 hectares, some of which are developed as conservation areas.

2.4.4 Population

There are 117,933 (Statistics Canada 2006) people living in the Quinte Region with an almost equal distribution between urban (49 percent) and rural (51 percent) dwellers. The distribution and density of the population is shown on Map 2.18.

The City of Belleville, Towns of Napanee and Picton as well as the Villages of Wellington, Madoc and Tweed and the Town of Deseronto have population densities ranging from 41 to 1250 people per square kilometre as shown in Map 2.18. This map shows the highest densities are in those municipalities located south of the Canadian Shield in the Limestone Terrane and Prince Edward peninsula. Northern and some eastern municipalities in the Quinte region are less densely populated, having less than 10 people per square kilometre. Rural municipalities in the northern headwater areas are largely forested (Map 2.11) including substantial tracts of crown land. In the rural areas of the southern municipalities the population density is typically in the range of 11 to 40 people per square kilometre. The Township of Tyendinaga and Township of Stone Mills are the only southern municipalities with population densities of less than 10 people per square kilometre.

First Nations Population

Map 2.18 shows that the Tyendinaga Mohawk Territory, population 2,037 as of December 2004, has a density that ranges from 21 to 40 people per square kilometre (Kring 2005). The Mohawks of the Bay of Quinte came to the area in May 1784 when Captain John Deserontyon, a Mohawk serving in the British army, brought 20 families and landed on the shores of the Bay of Quinte. Today, the Tyendinaga Mohawk Territory, bordering the Bay of Quinte, east of the City of Belleville, is the only First Nation territory in the region (Map 2.19).

2.4.5 Managed Lands

Managed Lands, for the purpose of this report, means lands to which agricultural source material, commercial fertilizer or non-agricultural source material is applied. Managed lands are discussed in more detail in Chapter 4.

Agriculture is a large industry in the Quinte region and the major land use in the southern half of the area. Map 2.20 depicts the distribution of agricultural land. Agriculture in the region includes orchards, corn, beef and dairy and is located predominately on the Limestone Terrane south of the Canadian Shield, where physical conditions such as soil type and depth are more conducive to farming than on the Canadian Shield. On the Prince Edward Peninsula, in addition to traditional agriculture, there is a burgeoning viticulture and wine industry thanks to the well-drained rocky soils and the moderating influence of Lake Ontario on the local climate. Overall, agriculture is changing in the Quinte region to increased intensity over smaller areas. The Watershed Characterization Report (Appendix B1) identified that waste and water management plans will need to have regard for this shift; and that agriculture is an important factor to be considered when planning for ground and surface water resources.

There are approximately one dozen golf courses in the Quinte region that may apply agricultural source material, commercial fertilizer or non-agricultural source material. Most of these recreational sites are located in the southern portion of the region, on the limestone plain, close to population centres.

2.4.6 Livestock Production

The density of livestock raised in the region, including beef and dairy cows, chickens, pigs, sheep and lambs is shown in Map 2.21 where density is expressed as nutrient units per acre. See the definition of a Nutrient Unit in Table 2-11 below. Livestock density is used as a way to measure the potential for generating, storing and land applying agricultural source material as a source of nutrients within a defined area. See Chapter 4 or Table 2-11 below for more details.

Table 2-11: Percent Managed Lands and Livestock Density

Census Subdivision	Managed Lands (Percent)	Livestock Density (Nutrient Units*/acre)
South Frontenac	29	2.8
Central Frontenac	15	1.6
Loyalist	21	9.7
Greater Napanee	56	2.3
Stone Mills	39	2.7
Addington Highlands	2	1.6
Tyendinaga	44	2.8
Belleville	37	2.4
Quinte West	41	2.4
Stirling-Rawdon	62	2.3
Centre Hastings	42	2.8
Tweed	19	3.2
Madoc	37	2.9
Marmora and Lake	8	3.0
Prince Edward	25	2.7

*A Nutrient Unit is the number of animals housed, or pastured, at one time on a Farm Unit, that generate enough manure to fertilize the same area of crop landbase under the most limiting of either nitrogen or phosphorous as determined by the Ontario Ministry of Agriculture Food and Rural Affairs Nutrient Management (NMAN) Software. OR in the case where no animals are housed: the Weight or volume of manure or other biosolids used annually on a Farm Unit, that fertilizes the same area of crop landbase under the most limiting of either nitrogen or phosphorous as determined by Ontario Ministry of Agriculture Food and Rural Affairs Nutrient Management (NMAN) software. One dairy cow is equivalent to one nutrient unit.

2.4.7 Impervious Surfaces

As a result of development in urban areas, large areas of land surface become impervious to water. Impervious surfaces of buildings, roads, roofs and parking lots reduce the infiltration of water and increase runoff with the resulting concerns for both water quantity and quality. Paved areas are subject to salt applications and snow removal that may impact water quality. See Map 2.22. Impervious area percentages have been calculated and mapped for each vulnerable area within the Quinte Region watershed and none are near the significant impervious percentage threshold; that is, none are greater than 80 percent impervious. More details are available in Section 4.7.6.

2.5 The Quinte Source Protection Region and the Great Lakes

The watersheds of the Quinte Source Protection Region including the Moira, Salmon and Napanee Rivers, and smaller streams on the Prince Edward Peninsula drain into Lake Ontario via the Bay of Quinte, and some on the Peninsula drain directly into Lake Ontario. This section addresses the requirements of the *Clean Water Act, 2006* that are applicable to the source protection regions that drain into the Great Lakes.

2.5.1 Consideration of the Great Lakes Agreements

The *Clean Water Act, 2006* requires that the Terms of Reference for the Preparation of an Assessment Report and Source Protection Plan for Source Protection Areas that contain water that flows into the Great Lakes or the St. Lawrence River, must consider the Great Lakes Agreements. These include the following plus any other agreement to which the Government of Ontario or the Government of Canada is a party that relates to the Great Lakes Basin and that is prescribed by the regulations (there are currently no other documents prescribed by the regulations).

Water Quality and Quantity Agreements:

- **Canada-US Great Lakes Water Quality Agreement** (GLWQA), 1978 – outlines Areas of Concern and goals between the two countries. Amendments are currently being negotiated.
- **Canada-Ontario Agreement** (COA) Respecting the Great Lakes Basin Ecosystem, 2007 – helps the Government of Canada deliver on its commitments under the GLWQA building on actions through the previous agreements. It is an overarching framework agreement that sets out the vision, goals, principles and administration of the COA, and four Annexes that outline the goals, results and commitments of the signatories.

- **Annex 1: Areas of Concern Annex** focuses on efforts to complete the actions necessary to restore the degraded ecosystems in four Areas of Concern (AOCs) and to make significant progress towards recovery in the remaining 11 Areas of Concern. The Bay of Quinte is one of 43 Areas of Concern and is an area in recovery. The Lakewide Management Plans (LaMPs) focus on the ecosystem health of an individual Great Lake as a whole. Remedial Action Plans focus on Areas of Concern.
- **Annex 2: Harmful Pollutants Annex** focuses on virtually eliminating persistent toxic substances, reducing other pollutants that have significant environmental impacts, with an enhanced focus on human health, and improving our knowledge and ability to manage harmful pollutants.
- **Annex 3: Lake and Basin Sustainability Annex** focuses on protection, restoration and sustainability of aquatic ecosystem and water resources and encourages the integration of these practices into every day activities. It includes commitments to promote sustainable lifestyles and uses, reduce pollutants, restore and protect fish and wildlife species and habitat, address issues of aquatic invasive species, understand climate change and protect the Great Lakes as sources of drinking water.
- **Annex 4: Coordination of Monitoring, Research and Information** Annex coordinates scientific monitoring, research and information sharing to track environmental change and progress in order to make informed management decisions regarding policies and programs.

- **Great Lakes-St Lawrence River Basin Sustainable Water Resources Agreement**, 2005 – a good faith agreement between the Great Lakes provinces and states that agreed on seven rules. Addresses concerns on exporting large quantities of water (withdrawals and consumption uses)
  - **Great Lakes Charter**, 1985 – 10 principles
  - **Great Lakes Charter Annex Supplementary Agreement**, 2001 – directives that further the principles of the charter

Further, the Technical Rules required that a written description of how these agreements were considered in the work undertaken must be included in the Assessment Report.

During the development of the work plan and preparation of the draft Assessment Report, organizations involved in the delivery of programs associated with these agreements were consulted through the following representatives:

- Canada-Ontario Agreement/Great Lakes Divisional Project Manager, Lake Ontario Lakewide Management Plan
- Implementation Manager, Bay of Quinte Remedial Action Plan
- Lakewide Management Plans Coordinator, Environment Canada
- Remedial Action Plan Liaison, U.S. Environmental Protection Agency
- Remedial Action Plan Program Officer, Environment Canada

Data made available through broader Great Lakes monitoring programs (e.g. the Drinking Water Surveillance Program of the Ontario Ministry of Environment) were also used in the development of this Assessment Report.

Although the prescribed documents share common goals with the source protection process, the Great Lakes Water Quality Agreement is the only prescribed document that has specific links to the preparation of this Assessment Report. The following sections describe the prescribed documents and indicate how they were considered during the preparation of this Assessment Report.

2.5.1.1 Canada-US Great Lakes Water Quality Agreement

The Great Lakes Water Quality Agreement, first signed in 1972 and renewed in 1978, is an agreement between the governments of Canada and the United States of America that expresses their commitment to restore and maintain the chemical, physical, and biological integrity of the Great Lakes Basin Ecosystem. It also reaffirms the rights and obligations of these two countries under the Boundary Waters Treaty. The Agreement outlines provisions for the development of cooperative programs and research and includes a number of objectives and guidelines to achieve its goals (Environment Canada 2004a). In 1987, the governments signed Annex 2 adding provisions to incorporate the development and implementation of Remedial Action Plans for Areas of Concern and Lakewide Management Plans to control critical pollutants (International Joint Commission 2009). The governments of Canada and the U.S. are currently in the process of negotiating amendments to this Agreement.

2.5.1.2 Canada-Ontario Agreement Respecting the Great Lakes Ecosystem

The Canada-Ontario Agreement Respecting the Great Lakes Ecosystem is an agreement between the governments of Canada and the Province of Ontario that supports the restoration and protection of the Great Lakes Basin Ecosystem. It outlines how the two governments will cooperate and coordinate their efforts to restore, protect, and conserve the Great Lakes basin ecosystem, and it contributes to meeting Canada's obligations under the Great Lakes Water Quality Agreement (Environment Canada 2004b). The current Canada Ontario Agreement, signed in 2007, was set to expire on March 31, 2010. As an interim measure while the Canada-US Great Lakes Water Quality Agreement amendments are being negotiated, Ontario and Canada are proposing a one year extension of the term of the current Canada Ontario Agreement to a new end date of March 31, 2011. Technical information applicable to the preparation of this Assessment Report was gathered through the Bay of Quinte Remedial Action Plan and Lake Ontario Lakewide Management Plan as outlined below.

Bay of Quinte Remedial Action Plan:

A provision of the Agreement that is specifically relevant to the Quinte Source Protection Region is the development and implementation of Remedial Action Plans. These are management plans that are designed to address environmental issues in areas around the Great Lakes that fail to meet the objectives set out in the Agreement (where such failure has caused or is likely to cause impairment of the beneficial use of these areas or its ability to support aquatic life). These problem areas are established by the Agreement as Areas of Concern. The entire Moira River, Salmon River, and Napanee River watersheds and the northern portion of the Prince Edward Peninsula that drains into the Bay of Quinte are located within the Bay of Quinte Area of Concern.

The Bay of Quinte Remedial Action Plan was initiated to mitigate pollution problems in the Bay of Quinte Area of Concern. These problems included a loss of diversity of plant and animal life and their habitats (especially wetlands), human health risks, and a "mix of toxic contaminants, bacterial and nutrient overloads that led to great imbalances in the aquatic ecosystem" (Bay of Quinte Remedial Action Plan 2009a). In 1986, a federal, provincial, and local cleanup partnership was created to draft the Bay of Quinte Remedial Action Plan.

The Bay of Quinte Remedial Action Plan endeavors to address specific Impaired Beneficial Uses, which represents degraded ecological functions and features of the Bay that include: restrictions on drinking water consumption, fish consumption, and dredging activities (due to contaminated sediment); drinking water taste and odour problems; loss of fish and wildlife habitat; degraded aesthetics, benthos, plankton, and fish and wildlife populations; eutrophication or undesirable algae; and beach closures (International Joint Commission, 2006). The restoration effort follows a multi-year work plan that identifies cleanup actions intended to correct these Impaired Beneficial Uses and ultimately result in the delisting of the Bay of Quinte as an Area of Concern.

The cleanup actions in the latest work plan include: protection of significant natural areas in partnership with municipalities and landowners; protection of fish habitats through the development of a Bay of Quinte fish habitat management plan; monitoring of wildlife to track trends in environmental conditions through a volunteer community wildlife watchers program; reduction of urban pollution to the Bay through the implementation of municipal pollution prevention and control planning studies; and a review of the progress made to date on lowering toxic inputs to the Bay (Bay of Quinte Remedial Action Plan 2009b). Some of these cleanup actions will serve to improve the quality of source water for the municipal drinking water intakes (Gerry O'Connor in Belleville, Point Anne Hamlet, Deseronto, and Picton intakes), which are located in the Bay of Quinte.

The Bay of Quinte Remedial Action Plan was an important consideration in the development of this Assessment Report. The document was considered in the following ways:

1. During the preparation of technical studies that are components of this Assessment Report, data and reports made available through the Bay of Quinte Remedial Action Plan were reviewed, including:
    a) An inventory of potential sources of contamination in the Bay of Quinte (Lower Trent Conservation 2004)
    b) Water quality reports on algal toxins and taste and odour compounds (e.g. Project Quinte Annual Report (Watson et. al. 2009))
    c) Modelling Phosphorous Management in the Bay of Quinte, Lake Ontario in the Past, 1972 to 2001, and in the Future (Minns and Moore 2004)
2. Bay of Quinte Remedial Action Plan staff was consulted regarding the shared concern of drinking water taste and odour, which is both an impaired beneficial use in the Bay of Quinte Remedial Action Plan and a potential drinking water issue.
3. Cyanobacterial toxins (harmful algal blooms) also known as blue-greens are identified as an emerging issue in the Project Quinte Annual Report 2007 (Bay of Quinte Restoration Council 2009). Microcystin is a cyanobacterial toxin which is one of the parameters that can be considered for identification of drinking water issues under the *Clean Water Act, 2006*.
4. Source protection staff has attended meetings and made presentations to the various Bay of Quinte Remedial Action Plan meetings to provide updates and solicit input in preparing the Terms of Reference and Assessment Report.

Lake Ontario Lakewide Management Plans:

Another provision of the Agreement that is relevant to the Quinte Source Protection Region is the development and implementation of the Lake Ontario Lakewide Management Plan. The Lakewide Management Plan for each Great Lake is a cooperative effort between Canada and the United States of America to restore and protect the health of Lake Ontario by reducing chemical pollutants entering the lake and addressing the biological and physical factors impacting the lake (Lake Ontario Lakewide Management Plan Status 2008).

Building on the Lake Ontario Toxics Management Plan (1989, 1991, 1993), the Lake Ontario Lakewide Management Plan focuses on:

- Restoring lakewide beneficial use impairments, as defined in the Great Lakes Water Quality Agreement;
- Virtually eliminating critical pollutants that, due to their toxicity, persistence in the environment and their ability to accumulate in organisms, are likely to contribute to these impairments despite past application of regulatory controls; and
- Improving physical and biological integrity of the waters of Lake Ontario and water dependent resources that have been impaired by human activities. (Lake Ontario Lakewide Management Plan Status 2008).

Lakewide Management Plans for each of the Great Lakes are updated at least once every two years (Lake Ontario Lakewide Management Plan Status 2008). The Lake Ontario Lakewide Management Plan report contains new and updated information on the state of Lake Ontario, Lake Ontario Lakewide Management Plan indicators, habitat, and public involvement and communication. The report is a comprehensive compilation of existing reports and provides an update on work plan actions and progress and next steps. The report covers a great geographic extent of the Lake Ontario basin and the scale was not always applicable to the development of the Assessment Report. The monitoring program required that the Great Lakes Index Station Network collects surface water chemistry data which was reviewed for Belleville Drinking Water System issues evaluation in Chapter 6. The Municipal/Industrial Strategy for Abatement (MISA) compliance reports that address the quality of treated wastewater were reviewed for potential sources. Some studies were produced by Quinte Conservation such as the Pollution Prevention and Control initiatives for local Sewage Treatment Plants which analyzed data collected at stormwater outfalls. The water chemistry data at outfalls in Picton Bay for the Pollution Prevention and Control study of the Picton Sewage Treatment Plant was used in the Picton Drinking Water System issues evaluation in Chapter 6.

2.5.1.3 Great Lakes-St Lawrence River Basin Sustainable Water Resources Agreement and the Great Lakes Charter

The Great Lakes Charter is a series of agreements between the Provinces of Ontario, Quebec, and the eight Great Lakes States that set out broad principles for the joint management of the Great Lakes (Environment Canada 2005). The original Charter was developed in 1985 in response to the growing use of water and proposals to divert large quantities of water out of the Great Lakes Basin (Ministry of Natural Resources 2005). The purposes of the Charter are "to conserve the levels and flows of the Great Lakes and their tributary and connecting waters; to protect and conserve the environmental balance of the Great Lakes Basin ecosystem; to provide for cooperative programs and management of the water resources of the Great Lakes Basin by the signatory States and Provinces; to make secure and protect present developments within the region; and to provide a secure foundation for future investment and development within the region" (Council of Great Lakes Governors 1985).

The Great Lakes Charter was supplemented in 2001 by the Great Lakes Charter Annex, which reaffirmed the principles of the Charter and committed the Governors and Premiers of the Great Lakes States and Provinces to "developing an enhanced water management system that…protects, conserves, restores, and improves the Waters and Water-Dependent Natural Resources of the Great Lakes Basin" (Council of Great Lakes Governors 2001). The Great Lakes Charter Annex implementing agreements including the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement, attempt to provide this water management system (Environment Canada 2005). The Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement provides a framework for each province and state to pass laws putting in place new safeguards for the waters of the Great Lakes-St. Lawrence River Basin. Although this Agreement and Charter is geared towards the protection of water quantity, it does not contain any specific technical information that was applicable to the preparation of this Assessment Report.

2.5.2 Great Lakes Targets

The *Clean Water Act* allows for the Minister of the Environment to establish targets relating to the use of the Great Lakes as a source of drinking water for any of the Source Protection Areas that contribute water to the Great Lakes. If targets are set, policies and steps would need to be established to achieve these targets. No targets have been set at this time.

2.5.3 Lake Ontario Working Group

The Source Protection Regions and Areas draining into Lake Ontario (Niagara, Halton-Hamilton, CTC (Credit Valley, Toronto and Region, and Central Lake Ontario), Trent Conservation Coalition, Quinte, and Cataraqui) have formed a Lake Ontario Lake-by-Lake Working Group (comprised of Source Protection Committee Chairs and Project Managers) to discuss and address common issues, share knowledge and engage in broader discussions on Great Lakes issues from a drinking water perspective.

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3. Summary of Quinte Region Water Budget

This chapter provides an overview of the results of water budget activities completed by Quinte Conservation. Detailed information on these activities can be obtained from the following reports that were produced from this work. These may be viewed in Appendix C:

- Quinte Conservation Conceptual Water Budget Final Draft, December 8, 2006;
- Quinte Conservation Tier 1 Water Budget Final Draft, April 14, 2009;
- Quinte Conservation Tier 2 Water Budget Village of Madoc Quinte Source Protection Region Draft Report Feb 2, 2010; and
- Quinte Conservation Report Draft Tier 2 Water Budget – Ameliasburgh Subcatchment, Quinte Source Protection Region (March, 2010).

The purpose of this chapter is to introduce the water budget, to describe the water budget process, and to provide the results.

3.1 What is a Water Budget?

A water budget is a scientific method of accounting for the amount of water in a watershed and how it travels through this area. Water budgets account for water entering the watershed (such as precipitation), water leaving (rivers flowing out of the watershed), changes in water storage (changes in lake and groundwater levels) and how it is used. This understanding is crucial for the management and protection of existing and future water resources.

The various components of a water budget are best understood through a review of the hydrologic cycle, Typically, the water cycle, (illustrated by Figure 3-1), begins with water entering a watershed in the form of precipitation (rain or snow). Some of this precipitation is returned to the atmosphere by evaporation or transpiration (water vapour lost to the atmosphere from plants). The combined loss to the atmosphere is referred to as evapotranspiration. Water that does not evaporate or transpire remains for either travel overland into rivers, lakes, and streams, or for seepage into the ground to become part of the groundwater system. Once in the ground, the water continues to move and may eventually discharge to surface water bodies, which is important for maintaining water levels and temperatures in our rivers and streams. When more water comes into the watershed than leaves, the levels in our lakes, wetlands, and groundwater rise. This increases the amount of water storage. In the opposite situation when more water leaves than enters, a deficit exists and the levels in storage decline. In the Quinte Region this phenomenon occurs over the course of a year with high water levels in the spring after snow melt and decreasing levels in the dry summer months.

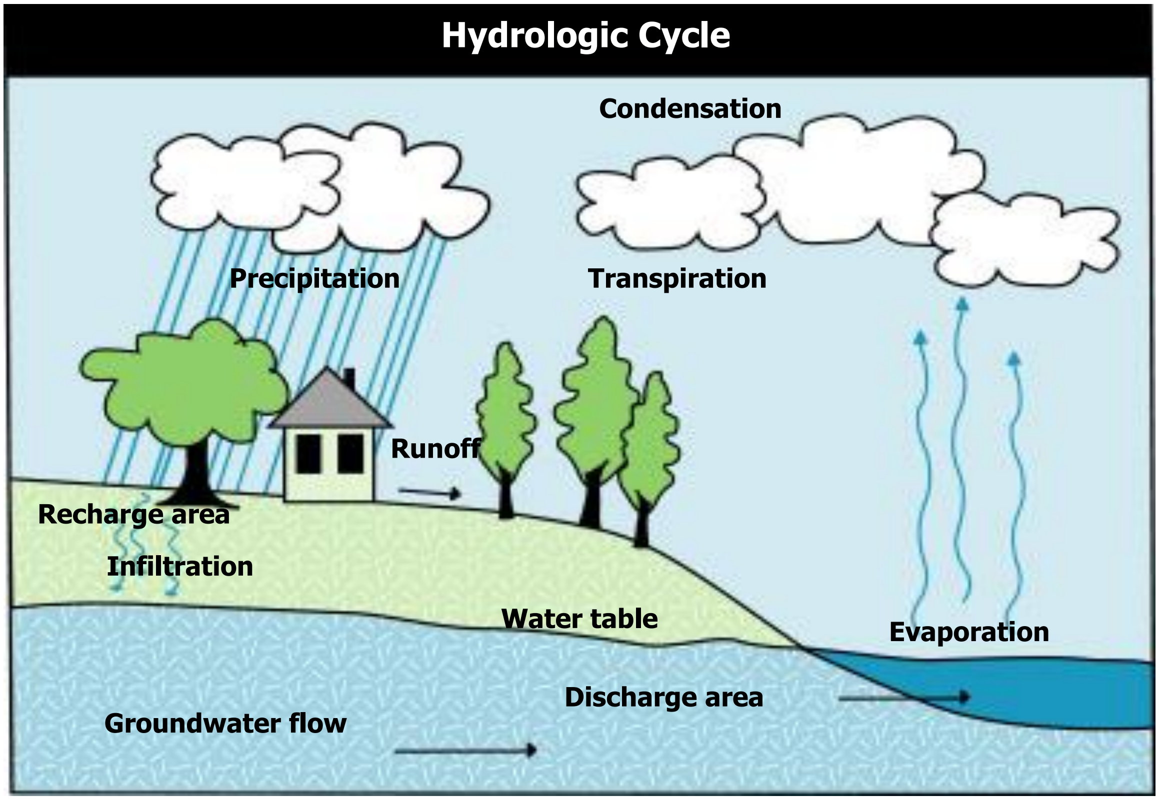


Figure 3-1: Hydrologic Cycle

To prepare a water budget, data is gathered and analysis is required. Climate information as well as data on land cover, geology, groundwater and surface water is used to build a conceptual understanding of where the water is located and how it moves through the watershed. Depending on the quality of the data, it may be used in simple calculations or complex models to calculate water budget parameters (such as evaporation and groundwater recharge).

3.2 The Approach

The water budget process, prescribed by the Province of Ontario, is a stepped or tiered approach. Starting at a simple scale (time and spatial) the process can include up to four levels, getting more complex at each level if there is concern about the availability of water in a given area. These four levels, illustrated by Figure 3-2, are called: Conceptual, Tier 1, Tier 2 and Tier 3 Water Budgets. The purpose of moving from one step (tier) to another is to provide an increased understanding of the water budget process and to focus on areas of the watershed where water shortages may be occurring. This allows the more complex work to be completed in areas where deemed necessary.

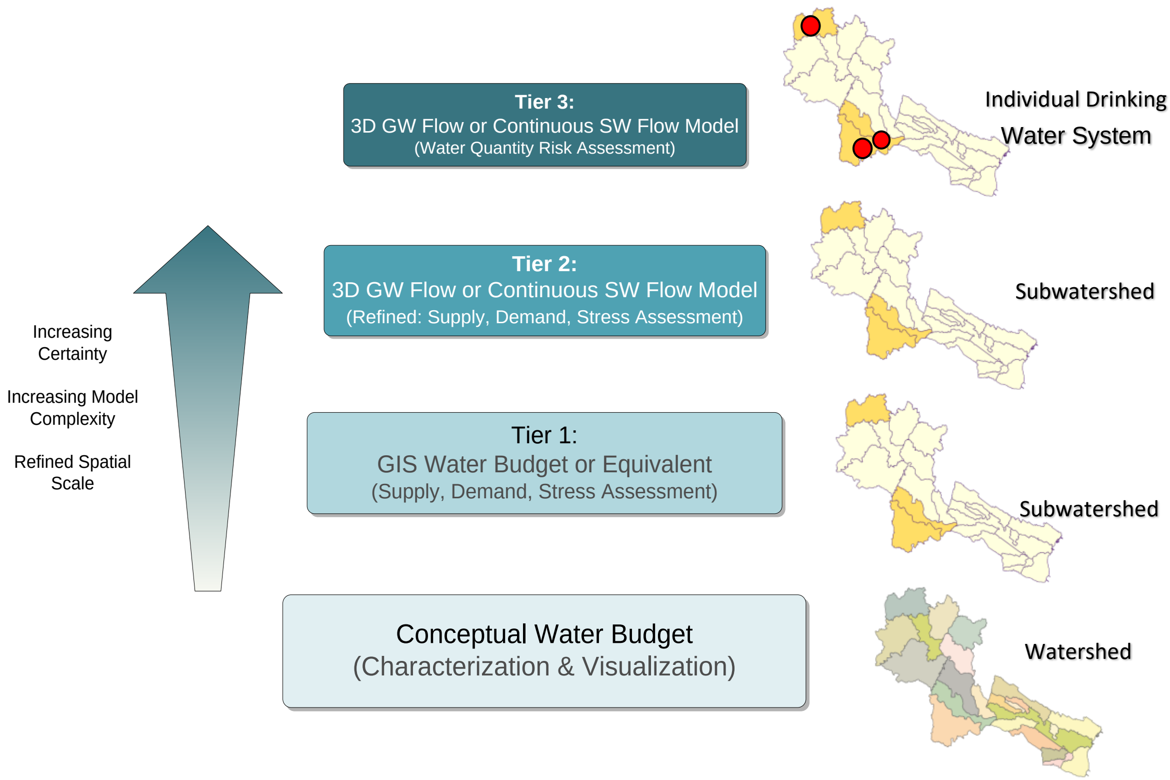


Figure 3-2: Water Budget Tier Diagram

3.2.1 Conceptual Water Budget

The Conceptual Water Budget (Appendix C1) builds on the Watershed Characterization Report (Appendix B1). It describes the hydrologic processes in the Quinte Source Protection Region and shows annual estimates of water budget parameters at the regional watershed level. This provides an understanding of where the water is located, how it moves through the watershed and how much water is available annually for consumption.

3.2.2 Tier 1 Water Budget

A Tier 1 water budget builds on data and information gathered at the conceptual water budget stage. The spatial scale increases from the watershed level to subwatershed areas and the time scale is monthly versus annual. Through this process the potential for water quantity stress is evaluated by comparing the amount of water use with the amount of water available in each subwatershed. Subject to this ratio the level of hydrologic stress is then assigned as Significant, Moderate or Low based on predetermined thresholds provided by the Province of Ontario. Subwatersheds that are assigned a Low stress level do not move forward in the process. Any subwatershed assigned a Moderate or Significant level of stress and also containing a municipal drinking water system moves onto a Tier 2 assessment. In addition, communities with a municipal water supply that have experienced a history of water shortages proceed to the next level.

3.2.3 Tier 2 Water Budget

A Tier 2 water budget is a more detailed review of the water budget for subwatersheds that contain municipal drinking water systems (wells or surface water intakes) and have been identified as having potential hydrologic stress. This level of analysis entails the use of complex numeric models to allow a better understanding of the water budget components and confirmation of stress conditions. At this level of work, consideration is given to potential changes in climate for drought conditions to evaluate the water budget under the worst case scenario. The level of potential hydrologic stress is determined by comparing water use with the volume available after accounting for a reserve quantity. The level of stress is assigned as either Significant, Moderate or Low in accordance with predetermined thresholds as provided by the Province. Areas proceeding to the next level would be those determined as exhibiting a Significant or Moderate level of stress or communities where there has been a history of water shortages.

3.2.4 Tier 3 Water Budget

A Tier 3 water budget is referred to as a local area water budget focusing on the zones contributing water to municipal wells or intakes. This analysis involves a risk assessment to evaluate the reliability of a drinking water supply under various scenarios including drought conditions and evaluation of potential for impact to the water supply from other water takings. This level of work entailed focusing on the contributing area around a municipal water intake referred to as either a water quantity Wellhead Protection Area or surface water Intake Protection Zone.

This analysis reviews how vulnerable the water supply is in these areas and if it is over used under different land development and water supply scenarios (future water use). The needs of other water users in the area must be considered. This assessment determines the level of risk as Low, Moderate or Significant with areas of Significant risk assigned where the municipal drinking water system would be unable to meet current or future water needs of the community.

3.2.5 Quinte Water Budget Activities

In the Quinte Source Protection Region the conceptual and Tier 1 water budgets were completed for the entire watershed region. From this initial screening, a total of eight subwatersheds were assigned a Moderate or Significant level of stress (six surface water and two groundwater). However, only one of the subwatersheds (Ameliasburgh) was identified as containing a municipal surface water intake. In addition one other subwatershed (Tweed) was identified as requiring further work due to water shortage problems at one of the wells servicing the Village of Madoc. (The Tweed subwatershed geographic area includes the Village of Madoc.) Therefore, two subwatersheds, containing municipal drinking water intakes, were identified as requiring further water budget work at the Tier 2 level.

The conceptual and Tier 1 water budgets used existing data and a Geographic Information System water budget model to characterize the hydrologic processes and complete the analysis. This work was completed in-house primarily by Quinte Conservation staff with assistance by Waterloo Hydrogeologic Inc. (now called Schlumberger Water Services) in the development of the Geographical Information System water budget model.

Tier 2 water budgets were prepared for the two subwatersheds. Both subwatersheds were assessed a Low level of stress and no further work was completed.

3.2.6 Peer Review and Provincial Approval

Under provincial direction, the water budget work was peer-reviewed by a team of independent experts. The peer review team was created in 2005 and shared by the Quinte Source Protection Region, the Mississippi-Rideau Source Protection Region, and the Cataraqui Source Protection Area. Members of the team include professors from the University of Ottawa and Queens University and consultants.

The Ministry of Natural Resources provided key directions and draft acceptance of the Conceptual Water Budget and Tier 1 Water Budget and Stress Assessment studies. The Ministry of the Environment (MOE) will issue a final approval of these studies as part of the Assessment Report.

3.3 Conceptual Water Budget

A conceptual water budget considers the amount of water in, and its movement through, the watershed. This includes an overview of natural processes and the various elements of the hydrologic cycle, illustrated by Figure 3-1. Through this work an understanding was developed of the physical features of the watershed, how they affect the water budget, and estimates of the quantity of water entering, leaving and being used in the region. For the Quinte Source Protection Region the conceptual water budget was completed on an annual time scale. The basic steps of this process included:

Step 1 Water Budget Components/Process

Step 2 Characterize the Physical System

Step 3 Collect and Analyze Data

Step 4 Determine Annual Water Budget for the Watershed

3.3.1 Water Budget Components/Process

Evaluation of the water budget requires an understanding of the flux of the various water budget elements in and out of the watershed and how the physical features of the watershed affect them. The main elements that were considered in developing the conceptual understanding are as follows:

- Climate
- Land Cover
- Topography
- Geology/Physiography
- Groundwater
- Surface Water
- Water Use.

The following water budget equation provides the basic parameters that are considered:

Precipitation = Runoff + Evapotranspiration + Groundwater Recharge

Where;
Precipitation = Amount of snow and rain received by the watershed,
Evapotranspiration = Amount of precipitation consumed by this process,
Runoff = Amount of precipitation that runs over the ground surface,
Recharge = Amount of precipitation that infiltrates the ground surface for recharge to the water table.

This equation provides a very simplified approach which does not consider the storage of water in reservoirs such as lakes and wetlands. In terms of quantifying these elements, precipitation and surface runoff can be determined using data from rain gauges and stream flow gauging stations. Evapotranspiration is calculated using known relationships and climate station data such as temperature and precipitation. However, groundwater recharge is the element that has the greatest uncertainty and is the most difficult to quantify.

Various methods exist for estimating groundwater recharge. One method was implemented into the water budget process across the Quinte Region to estimate recharge rates spatially through the use of a Geographic Information System Water Budget Model.

3.3.2 Methodology

The Geographic Information System water budget model was developed to evaluate the components of the water budget equation listed above. This model calculates both recharge and surface runoff from precipitation data after accounting for evapotranspiration according to the Thornthwaite Method (Appendix C1). The model uses mapping of temperature, precipitation and soil water holding capacities to determine the distribution of available water across the watershed. This available water, referred to as surplus water, was then divided between either surface water runoff or groundwater recharge by calculation of a recharge factor. The factor was determined by considering the physical characteristics of the watershed which influence groundwater recharge and how water moves over the ground surface. The main factors are land slope, soil permeability, and land cover. Table 3-1 shows the categories and coefficients that were applied to each parameter. The sum for the three categories was used to determine the recharge factor. This recharge was then determined by multiplying the surplus water by this factor.

Table 3-1: Recharge Factors

Physical Feature	Value of Factor
Land Slope	
Flat - (0-1.5 %)	0.175
Rolling Land (1.5-3%)	0.125
Hilly Land (>3%)	0.075
Soil Type	
Low (Clay)	0.1
Medium (Loam)	0.2
High (Sand)	0.4
Land Cover	
Low (Open Space)	0.1
High (Forested)	0.2

The recharge factors were adopted from Ministry of the Environment (Appendix C1) methodology that was developed based on hydrologic analysis designed for assessing peak runoff for storm water management purposes. However, the slope factors provided by the MOE method were not considered representative of the topography found in the Quinte watershed. To assign factors for the slope ranges commonly found in the Quinte watershed the slope classes and corresponding infiltration factor were graphed as illustrated by Figure 3-3. The relationship, as illustrated by this graph, was used to determine slope factors for the Quinte watershed (listed in Table 3-1) and was calculated from the midpoint of the topographic ranges. In addition to calculating the natural budget, the Geographic Information System model was used to calculate water use and map where this use is occurring. The basic steps of this process are listed below:

1. Using climate data from 1971-2000 assess the distribution of precipitation and evapotranspiration across the watershed;
2. Determine the amount of precipitation available for groundwater recharge or surface runoff by subtracting the volume of evapotranspiration from the precipitation. The difference is referred to as the available surplus water;
3. The percentage of available water recharging the groundwater was determined through calculation of a recharge coefficient. This coefficient was calculated based on three parameters: slope, soil permeability, and land cover. The different classes of the physical landscape and factors for each parameter are listed above in Table 3-1. The sum of the factors for the various combinations is then determined and multiplied by the available water to determine the amount of recharge;
4. The recharge was then calculated in accordance with the following formula:

   Recharge = (Precipitation – Evapotranspiration) * Recharge Factor; and
5. Surface runoff was calculated as the difference between recharge and available water or as follows:

   Surface Runoff = Precipitation – Evapotranspiration – Recharge.

Figure 3-3: Infiltration Factor Derivation from Slope Class

3.3.3 Sources of Data

Following the identification of where the water is located, the next step in the conceptual water budget process was to collect data about the various water budget elements and process this information to quantify each of the elements. Numerous data sources, listed in Table 3-2 were considered. To process the large volumes of data a Geographic Information System water budget model was developed to calculate evapotranspiration, recharge and surface runoff. Estimates of water use were also completed to allow comparison of water use with the volume of available water.

3.3.4 Characterize the Physical System

In addition to use of the Geographic Information System model to calculate volumes of water available in the watershed it was necessary to gain an understanding of how the water moves through the watershed and the processes which affect this. The volume of water in a watershed is the direct result of the climate and precipitation that has fallen on the area. The amount of precipitation that is available for runoff into our rivers or infiltration into the ground is dependent on a number of factors including the climate and physical features of the watershed.

Table 3-2: Data Sources

Data Set	Source	Use in this Study
Precipitation	Environment Canada	Precipitation
Climate Station Data	Environment Canada	Evapotranspiration
Temperature	Environment Canada	Evapotranspiration
Topography	Ministry of Natural Resources	Runoff/Recharge
Digital Elevation Model	Ministry of Natural Resources	(slope calculation)
Land Cover	Ministry of Natural Resources	Runoff/Recharge
Stream Flow Data	Water Survey of Canada	Runoff
Permit to Take Water	Ministry of the Environment	Water Use
Soils	Ministry of Agriculture & Food	Water Holding Capacity
Agricultural Water Use	Ministry of Natural Resources	Water use
Geology	Ontario Geological Survey	Runoff/Recharge
Population Data	Census Canada	Water Use
Ontario Water Well Records	Ministry of the Environment	Water Use

To understand the physical features of the watershed a description of the various components are considered including slope of the land, amount of land cover, and permeability of the soil. These features control the amount of water that either runs off the ground surface or infiltrates into the ground for recharge to the groundwater. For example areas of steep slope and low soil permeability would cause more precipitation to run over the surface of the land than into the ground. Conversely areas of flat topography, high tree cover and permeable soil cause more water to infiltrate into the ground as recharge.

3.3.4.1 Climate

Climate is an indication of the meteorological elements of a region such as temperature and precipitation over a long period of time. This is in contrast to weather which is a measure of the climate elements over a short period of time. The climate of the Quinte Source Protection Region can be described as temperate with warm summers, mild winters and generally consistent precipitation in the form of snow in the winter and rain in the other months (Appendix C1). For the purpose of this water budget work the period of 1971-2000 was used as reference for average climate conditions.

Detailed information about the climate of the region was provided through review of Environment Canada data for climate stations located within and around the watershed. This data was analyzed as part of a much larger project of Natural Resources Canada – Canadian Forestry Service (Appendix C1). This group completed mapping of climate conditions across Canada and the Quinte Region showing the spatial distribution of climate variables.

Details of mean annual temperature and precipitation for the period of 1971 - 2000 are provided by Maps 3.1 and 3.2 respectively. The maps show the northern portions of the watershed are colder with a mean annual temperature of 4.6 degrees Celsius and warmer at the south by almost 4 degrees due to the moderating effect of Lake Ontario. The mean annual precipitation across the watershed varies slightly from 1020 millimetres received by the southeast to approximately 857 millimetres in the north. This range also affects the distribution of evapotranspiration with the highest occurring at the south and lowest in the north where there is lower temperature and precipitation. A summary of the average climate variables for the Quinte Region is provided by Table 3-3.

The relationship between monthly precipitation and evapotranspiration is provided in Figure 3-4 which shows relatively uniform precipitation over the course of the year and increased evapotranspiration in the summer months. A water deficit occurs when the yellow line (actual evapotranspiration) falls below the pink line (potential evapotranspiration). During this period there is not enough precipitation or soil moisture to meet the rate of evapotranspiration. This is often the period when the grass on residential lawns turns brown due to a need for water.

Table 3-3: Quinte Region Average Climate Conditions (1971-2000)

Month	Average Temperature (°C)	Average Precipitation (mm)	Average PE * (mm)	Average AE ** (mm)
January	-8.2	77	0	0
February	-7.2	60	0	0
March	-1.6	73	0	0
April	5.6	74	29	29
May	12.6	76	78	78
June	17.6	77	113	110
July	20.2	65	132	114
August	19.2	79	115	100
September	14.5	89	74	74
October	8.2	77	37	37
November	2	87	7	7
December	-4.9	83	0	0
Annual	**6.5**	**919**	**585**	**550**

* PE = Potential Evapotranspiration, ** AE= Actual Evapotranspiration

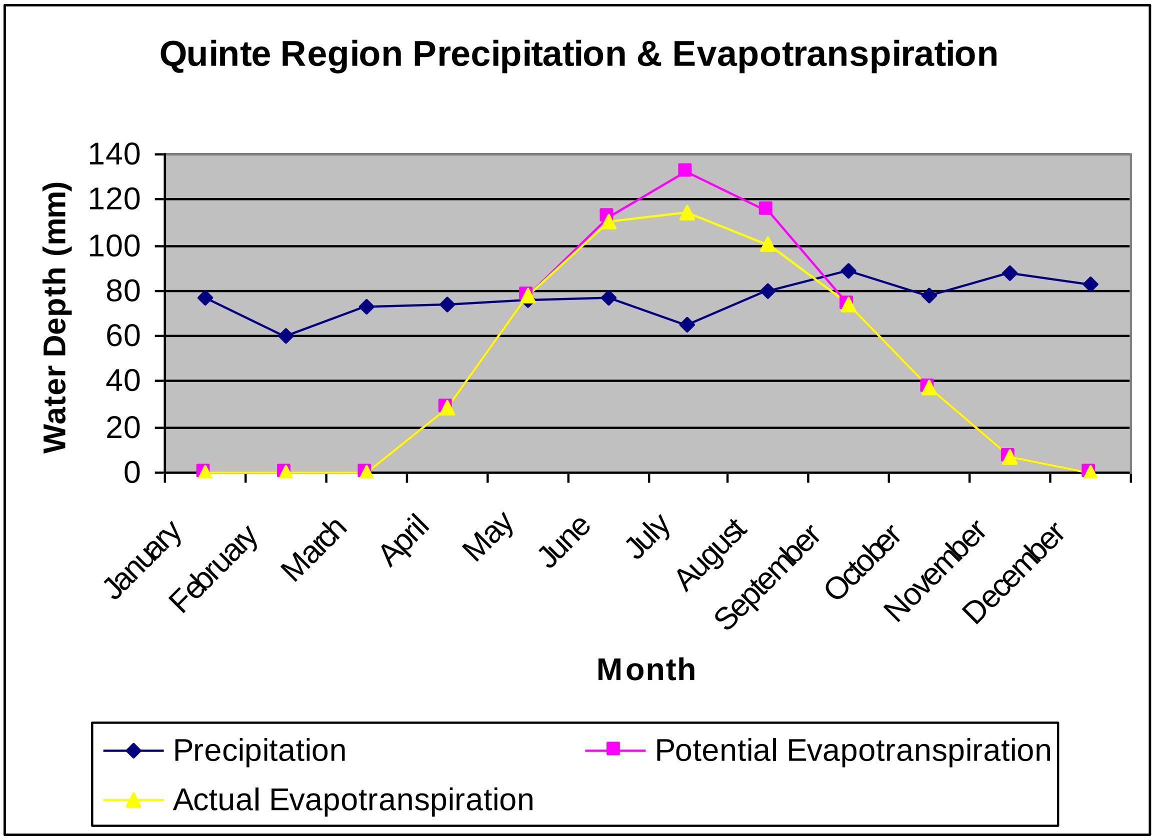


Figure 3-4: Quinte Region Water Deficit Time Sequence

3.3.4.2 Physiographic Regions

The physiography of a region can affect the water budget due to variability in things such as soil type, land cover and topography which in turn may influence the distribution of surface runoff and groundwater recharge. The Quinte Region is made up of a diverse physical landscape and features that may be grouped into distinct physiographic regions. The northern areas are rugged and form part of the Precambrian shield which covers approximately 50 percent of the watershed. To the south of the Precambrian Shield, the area is underlain by Paleozoic limestone bedrock with large areas of thin soil cover as well as some areas of significant soil depth. In the Prince Edward Region the landscape is dominated by thin soil over limestone bedrock. In total there are six different physiographic regions found in the Quinte Region (Appendix C1) illustrated by Map 2.4 and described below.

Algonquin Highlands: Covers the northern Precambrian Shield with rugged topography, shallow soil, numerous lakes and large forested regions.

Georgian Bay Fringe: Borders the Algonquin Highlands with similar characteristics but with rolling to moderately rugged topography.**Dummer**

Moraines: A belt along the border of the Georgian Bay Fringe and southern limestone plain exhibiting hummocky topography with undulating knolls of till soil.

Peterborough Drumlin Field: Extends through the areas north of Belleville, includes deep soil deposits in rolling till plains, many drumlins, eskers, as well as a kame moraine.

Napanee Plain: Covers the southern portion of the Napanee watershed and is comprised of flat to undulating topography with thin soil over limestone bedrock.

Prince Edward Peninsula: Similar to the Napanee plain with flat topography and shallow soil over limestone bedrock. The area exhibits an irregular shoreline with areas of steep bedrock escarpments and bay mouth sand bars.

3.3.4.3 Land Cover

The land cover of the Region can influence the distribution of surface runoff, evapotranspiration and groundwater recharge. Rain falling on forested areas will experience more interception and transpiration and result in reduced surface runoff in contrast to cultivated fields and cropland. Thus, areas with high forest cover will tend to have less runoff than areas without vegetative growth. Mapping of land cover in the Quinte Region has been completed. Map 3.3 illustrates land cover showing the area approximately equally divided between high and low cover. High cover is mapped on the northern region due to forests, while much of the lowlands to the south are agricultural and mapped as low cover.

3.3.4.4 Topography

The topography of the Quinte Region is variable ranging from the rocky highlands of the Precambrian Shield at the north to the more subdued relief of the limestone plains at the south along the shores of the Bay of Quinte and Lake Ontario. In the north the predominant topographic gradient is to the south – southwest with elevations ranging from a high of 400 metres above sea level (masl) in the north to approximately 80 masl at the south along the Bay of Quinte. In Prince Edward County the topography is even more subdued with maximum elevations of 150 masl at inland plateaus which slope outwards towards the Bay of Quinte and Lake Ontario. For purposes of the water budget the watershed was divided into the classes as listed in Table 3-1, with the majority of lands mapped as either flat or hilly.

Slope Class	% Coverage of Watershed
Flat land – 0 -1.5 %	39.1%

Rolling land – 1.5 – 3%	24.4%
Hilly land > 3%	36.6%

3.3.4.5 Geology

The geology of the Quinte Region is predominantly controlled by shallow soil over bedrock. This bedrock may be divided into two main types – Precambrian and Paleozoic. This is illustrated by Map 2.7, where Precambrian rock is found in the north and the Paleozoic in the south. The shallow soils throughout are a direct result of glacial activity which resulted in the scraping and removal of soil. However in other areas significant soils were deposited by the glaciers in the form of till in drumlins as well as eskers, and a moraine. Mapping of the different soil types and depth is illustrated by Map 2.9 and Map 2.5 respectively.

Surficial soils have developed in relation to the underlying bedrock material. Given the two distinct bedrock regions there are numerous soil types found in the watershed which range from poorly developed stony granular soil on the Precambrian shield to sandy loam and clay loam soils on the limestone terrane. Due to the variability of soil types, drainage characteristics range from well drained to poorly drained with permeability classifications as summarized below in respect of the different classes listed in Table 3-1. This grouping indicates the majority of the watershed as being underlain by soils of low to moderate permeability.

Category	Percent of Watershed Area
Low permeability -	36.9%
Medium permeability -	53.9%
High permeability -	9.2%

In addition to permeability classes the different soil types were also assigned water holding capacities for use in the Geographic Information System model in the calculation of evapotranspiration. The maximum water holding capacities are as listed below, however, because of the thin nature of the Quinte soils there tends to be a deficit of available water for plants by the end of the growing season.

Soil Type	Water Holding Capacity
Shallow Soil over Rock	25 millimetres
Sand, Sandy Loam	100 millimetres
Clay Loam	200 millimetres

Clay	250 millimetres

3.3.4.6 Surface Water

The Quinte Region is known for its many significant surface water features which include the Napanee, Salmon, and Moira Rivers draining the northern Precambrian shield into the Bay of Quinte (connecting to Lake Ontario at the south). Conversely the Prince Edward Region is not drained by one main surface water course but by a number of small drainage courses leading outwards from inland plateaus towards either Lake Ontario or the Bay of Quinte. The largest of these Prince Edward water courses is Consecon Creek covering an area of approximately 184 square kilometres. Surface water is an important drinking water resource and provides supply to approximately 50 percent of the residents. The majority of these residents are located in the larger urban centres of the watershed such as Belleville, Napanee, Picton, Wellington and Deseronto.

Watersheds draining into the Bay of Quinte from the north include the three largest rivers, Moira, Salmon, and Napanee and several smaller creeks. The Moira River is the largest river draining over 2700 square kilometres of land and has two major tributaries; the Black and Skootamatta Rivers representing about 40 percent of the system. These drain the Canadian Shield which is dominated by forest cover with several large lakes and a large number of wetlands. Smaller tributaries to the Moira include the Clare River and Parks Creek which drain about 20 percent of the system. There are six operating stream gauges on the Moira River or its tributaries.

The Salmon River has just over 900 square kilometres of drainage area. The northern headwaters are also in the Canadian Shield while the southern half drains the limestone plains. Several large lakes are found in the headwaters including the Kennebec, Big Clear, and Hungry Lakes. In the southern portion there are fewer and smaller lakes with the exception of two large lakes, Beaver and White Lakes. Drainage through the plains is more defined and the river is not slowed by any further online lakes and drains directly into the Bay of Quinte. Two stream flow gauges are present on the Salmon River; one is located in the Village of Tamworth downstream of Beaver Lake and the other is near the river mouth in Shannonville.

Similar to the Salmon River, the Napanee River originates in the Canadian Shield. There are many large lakes and wetlands in the upper portion and only two large lakes (Varty Lake and Camden Lake) in the lower reaches. These lakes are shallow offline lakes with little drainage area. The Napanee River has two major tributaries, Hardwood Creek and Depot Creek that meet in the

Cameron Swamp. Depot Creek is gauged at Bellrock and the only other stream gauge is located on the Napanee River near Camden East.

Table 3-4 contains a listing of all active or abandoned stream gauge locations in the Quinte region. The larger river or creek systems are presented below in Table 3-5 listed in order from west to east along with their respective topographic highs and drainage areas.

Table 3-4: Stream Gauge Locations

Station Name	Catchment Area* (km^{2**})	Water Survey of Canada ID	Period of Record
MOIRA RIVER NEAR DELORO	*296*	02HL005	1965 - 2008
BLACK RIVER NEAR ACTINOLITE	*430*	02HL003	1955 - 2008
SKOOTAMATTA RIVER NEAR ACTINOLITE	*678*	02HL004	1955 - 2008
MOIRA RIVER NEAR TWEED	*1762*	02HL007	2002 - 2008
MOIRA RIVER NEAR TWEED	*1762*	02HL101	1968 - 1977
MOIRA RIVER NEAR THOMASBURG	2210	02HL104	1969 - 1970
CLARE RIVER NEAR BOGART	160	02HL102	1968 - 1977
CLARE RIVER NEAR BOGART	*179*	02HL008	2005 - 2008
PARKS CREEK NEAR LATTA	*199*	02HL006	1984 - 1992
PARKS CREEK NEAR LATTA	*199*	02HL103	1968 - 1977
MOIRA RIVER NEAR FOXBORO	*2593*	02HL001	1915 - 2008
SALMON RIVER NEAR SHANNONVILLE	*909*	02HM003	1958 - 2008
NAPANEE RIVER AT CAMDEN EAST	*697*	02HM007	1974 - 2008
NAPANEE RIVER AT NAPANEE	777	02HM001	1915 - 1974
DEPOT CREEK AT BELLROCK	*181*	02HM002	1957 - 2008
BLOOMFIELD CREEK AT BLOOMFIELD	13.9	02HE001	1970 - 1992
CONSECON CREEK AT ALLISONVILLE	*117*	02HE002	1970 - 2008
DEMORESTVILLE CREEK AT DEMORESTVILLE	29	02HE003	1970 - 1977
BLACK RIVER IN MILFORD	*29*	02HE004	2006 - 2008

* Catchment areas in italics determined by GIS using Digital Elevation Model. Otherwise catchment areas are those reported by Water Survey of Canada.
** square kilometres

Table 3-5: Watersheds

Watershed	Highest Point	Area
	Metres above Sea Level	Square Kilometres
Potter Creek	178	31
Moira River	458	2735
Bell Creek	125	23
Blessington Creek	167	66
Salmon River	342	915
Marysville Creek	152	52
Selby Creek	157	130
Napanee River	247	818

Most of the streams in the Quinte Region are characterized as warm water systems with the exception of a few small tributaries including Waring's Creek in Prince Edward County, Number 10 Creek and portions of Parks Creek in the Moira River system. Water temperature is an indicator of the source of the water; warm is usually associated with surface water runoff while cold water is typically from a groundwater source. The warm water systems of the Quinte region suggest the water source is predominantly from surface runoff. Consequently, during periods of low precipitation the streams can experience very low flow.

Stream gauges record the outflow of a stream and the records can be viewed by plotting the flow over time. This is called a hydrograph. Shorter duration hydrographs show the response to individual runoff events. Longer duration hydrographs show seasonal variation of flow or trends. Two short duration hydrographs have been reproduced below to show the response of each of the major watersheds to a rainfall event in September 2004. The location of stream gauges in the Quinte watershed is illustrated by Map 3.4. The rainfall was a little over 17 hours in duration beginning about 8:00 PM on the 8th of September and ending about 1:00 PM on the 9th. The first graph, Figure 3-5, shows the hydrographs from each of five active gauges in the Moira watershed. Each vertical line represents one day and the horizontal lines are increments of ten cubic metres of flow per second. The blue line is the most downstream gauge in Foxboro. What is notable is the early response in Foxboro and the delayed peak. The early response is the effect of the higher amounts of precipitation experienced on the lower reaches. The delayed, but much higher peak, is the cumulative effect of the precipitation experienced in the upper portion of the watershed. The Skootamatta, Black and Deloro (Moira River at Deloro) gauges reveal much earlier peaks, by approximately two days, than the downstream gauge.

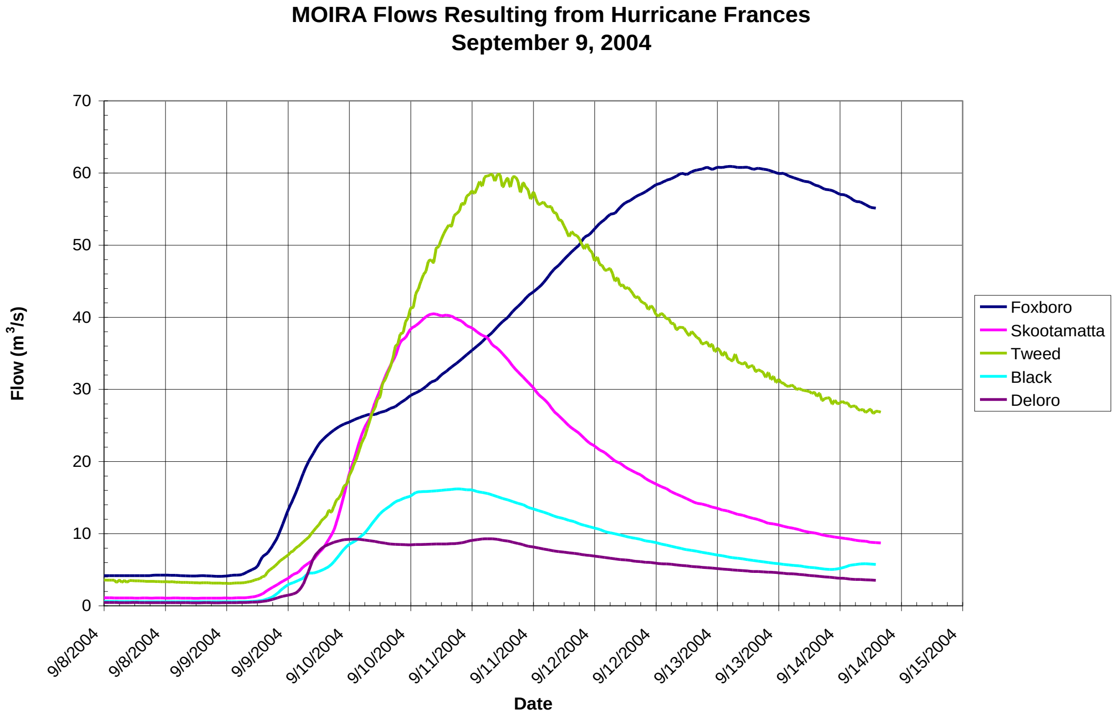


Figure 3-5: Moira River hydrographs

The same hydrographs have been prepared for the gauges in the Napanee and Salmon River watersheds. The Depot Creek gauge at that time was not accessible. Response of the Salmon and Napanee River systems to rain events differs from those of the Moira and can be seen by inspection of the hydrographs in Figure 3-6 where the hydrographs for the same event are reproduced. The Tamworth station is located on the Salmon River system just downstream from the outlet of Beaver Lake and the Shannonville gauge is near the river mouth. The Camden East gauge records the Napanee River flows upstream of the town of Napanee several kilometres north of the river mouth. By simple inspection one can note the almost simultaneous responses of all three stations to the rain input and the delayed but apparent second peak for all three stations. The second peak for the Camden East gauge occurred about six days later on the 16th while the Salmon River stations show a second peak almost ten days after the initial peaks. This second peak is attributed to the lake storage upstream of all the gauges.

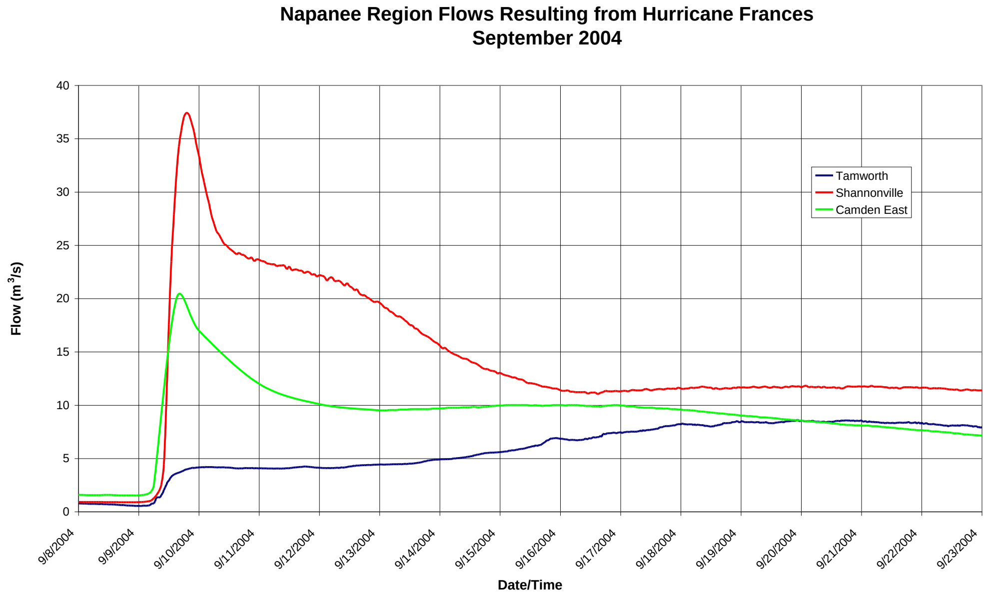


Figure 3-6: Napanee Region Hydrographs

The hydrologic response of the systems can be understood by reviewing drainage area, percent coverage of forests, water bodies, and level of development.

Watershed shape is also important in determining how a stream system will respond to a precipitation or runoff event. Quinte Region watersheds have low impervious cover and this would not be a major contributor to understanding watershed response. Table 3-6 has been adapted from the Watershed Characterization Report (Appendix B1) which shows relative cover of each watershed. The remainder would be agricultural lands.

Table 3-6: Land Cover Type by Watershed

Watershed	**Moira River watershed**		**Salmon River Watershed**		**Napanee River Watershed**		**Prince Edward Region Watershed**		**Total**	
	hectares	**%**	**hectares**	**%**	**hectares**	**%**	**hectares**	**%**	**hectares**	**%**
Total Area (ha)	284,800		91,800		104,200		108,100		588,900	
Woodlands	189,600	67	60,200	66	50,500	49	35,200	33	335,500	57
Waterbodies	15,300	5	5,100	6	6,300	6	3,000	3	29,800	5
Permanent Wetlands	24,600	9	10,000	11	9,300	9	7,000	6	50,900	9
TOTAL	**229,500**	**81**	**75,300**	**82**	**66,100**	**64**	**45,200**	**42**	**416,200**	**71**

Hydrologic response is also affected by the slope of the watershed including the overland component and the stream gradient. Rivers with long narrow watersheds, such as the Salmon and Napanee, will respond to precipitation inputs more rapidly than very dendritic systems like the Moira. Table 3-7 shows major river gradients in various reaches beginning from headwater and leading to the river mouth.

Table 3-7: Major River Gradients

River	Location	Distance (km)	Gradient (m/1000m)
Moira	Headwaters to Moira Lake	76.6	2.4
	Moira L. to Stoco L.	21.6	0.7
	Stoco L. to Plainfield	26.4	1.3
	Plainfield to Corbyville	15.3	0.05
	Corbyville to mouth	7.6	3
Salmon	Headwaters to Kennebec Lake	34.4	2.2
	Kennebec L. to Beaver L.	40.3	0.8
	Beaver L. to Upstream of Forest Mills	24.5	1.5
	Forest Mills to Lonsdale	13.8	3.3
	Lonsdale to mouth	14.2	0.6
Napanee	Depot Creek	22.3	1.9
	Depot Cr. to Downstream of Newburgh	25.6	1.7
	Newburgh to Springside Dam	9.76	0.8
	Springside Dam to mouth	9.6	0.1
Consecon	Headwaters to Big Swamp	6.4	3.3
	Through Big Swamp at Allisonville	15.2	0.5
	Allisonville to Melville	4.8	1.27

Control Structures

Flow in stream systems can be affected by the presence of control structures such as dams or weirs. Dams are often placed near locations where the river gradient is high in order to harness water power. Other dams are placed at outlets of lake systems to control water levels on the lake primarily for recreational use. In addition some were constructed to enhance or create transportation routes for logging; while others were constructed to create reservoirs for water storage. Dams that are located on river systems that do not have large impoundments would not appreciably affect hydrologic response. Table 3-8 contains a listing of dams that impound lakes or reservoirs that have the potential to affect the river flow.

Storage benefits a watershed by holding runoff and releasing it later, supplying water to streams long after a precipitation event is over. At the Conceptual Water Budget stage the temporary effect of storage in the system was not considered because the timeframe is on an annual basis.

Table 3-8: List of Controlled Water Bodies

Dam Name	Water Body Controlled	Active Storage (ha-m)
Moira		
Lingham Lake Dam	Lingham Lake	1730
Skootamatta Lake Dam	Skootamatta Lake	1025
Deerock Lake Dam	Deerock Lake	775
Catons Weir	Stoco Lake	330
Chapmans Weir	Stoco Lake	Incl. above
Downeys Weir	Moira Lake	390
Napanee		
3rd Depot Lake Dam	3rd Depot Lake	890
2nd Depot Lake Dam	2nd Depot Lake	1160
13 Island lake Dam	13 Island Lake	104
Laraby Rapids Dam	Beaver Lake	729
Varty Lake Dam	Varty Lake	185
Prince Edward		
Roblin Lake Dam	Roblin Lake	67
Consecon Lake Dam	Consecon Lake	200

Annual runoff from the major streams is calculated using the stream gauge station statistic called Mean Annual Flow. The values are published on the Water Survey of Canada Website. The annual runoff is determined by multiplying the mean annual flow (reported in cubic metres per second) by the number of seconds in a year (31,536,000) and dividing by the drainage area to the gauge and is then converted to millimetres/year by dividing by another 1000. The results for all the gauged stations are reported in Table 3-9.

The study team used a statistical average of climatic conditions for precipitation and temperature for a specified period of time on which to base the water budget calculations. This is called a climate normal period. For the climate normal period 1971-2000 the annual runoff expressed in millimetres/year for the Moira River at Foxboro is 370 millimetres. When comparing the annual runoff between gauges the mean annual flow of the stations is reported for the entire periods of record. Some are much shorter and do not cover the climate normal period used in the study (Table 3-4 provided earlier shows the periods of record).

Table 3-9: Annual Runoff

Station Name	Catchment Area (km²*)	Mean Annual Flow(m³/s**)	Runoff Expressed as mm/yr***
MOIRA RIVER NEAR DELORO	296	3.77	402
BLACK RIVER NEAR ACTINOLITE	430	5.15	378
SKOOTAMATTA RIVER NEAR ACTINOLITE	678	8.42	392
MOIRA RIVER NEAR TWEED	1762	21.4	383
MOIRA RIVER NEAR TWEED	1762	26.9	481
MOIRA RIVER NEAR THOMASBURG	2210	*25.2*	*360*
CLARE RIVER NEAR BOGART	179	2.79	492
PARKS CREEK NEAR LATTA	199	2.28	362
PARKS CREEK NEAR LATTA	199	3.13	497
MOIRA RIVER NEAR FOXBORO	2593	30.4	370
SALMON RIVER NEAR SHANNONVILLE	909	10.7	371
NAPANEE RIVER AT CAMDEN EAST	697	8.69	393
NAPANEE RIVER AT NAPANEE	777	9.13	371
DEPOT CREEK AT BELLROCK	181	1.98	345
BLOOMFIELD CREEK AT BLOOMFIELD	13.9	0.168	381
CONSECON CREEK AT ALLISONVILLE	117	1.48	399
DEMORESTVILLE CREEK AT DEMORESTVILLE	29	0.404	435

*square kilometre

**cubic metres per second

***millimetres per year

The surface water systems provide sources of water for several drinking water systems in the Quinte region. Table 3-10 lists the systems, the name of the source and the approximate population served.

Table 3-10: Surface Water Intakes

Intake Location	Source	Population Served
Belleville	Bay of Quinte	38300
Point Anne (Belleville)	Bay of Quinte	Included above
Greater Napanee (backup)	Napanee River	7760
Deseronto	Bay of Quinte	1800
Picton	Bay of Quinte	8020
Wellington	Lake Ontario	1700
Ameliasburgh	Roblin Lake	180
7	**Total**	**57760**

Aquatic Habitat

The Quinte Region watersheds have experienced patterns of high and low flow periods that have been continuously recorded from as early as 1915. Local aquatic habitat must adjust to these changes in flow.

Coastal wetlands are important habitat for many species and help to cleanse runoff waters entering the lake and bay. Wetlands adjacent to the Bay of Quinte have experienced changing hydrologic regimes related to the control of Lake Ontario at the Moses-Saunders Dam and have lost species diversity. Lake Ontario is governed by international treaty with the United States and lake levels are controlled by the 1958D Management Plan by order of the International Joint Commission (IJC 2006). This control has reduced the normal fluctuation that maintained species diversity in the coastal wetlands. Coastal wetlands in the Quinte Region are now dominated by cattails.

Since 2000, officials have been preparing a new operating plan for the lake and have consulted with the public and lake users regarding a plan that would take more uses into consideration. A plan that favours aquatic habitat would allow for more lake level variation to improve species diversity.

Lakeshore development and misunderstanding of the importance of wetlands has also led to significant loss of coastal wetlands. Remaining wetlands are shown on Map 2.11.

3.3.4.7 Groundwater

Groundwater is defined as the water below the ground surface in soil pore spaces or in the cracks and fractures of bedrock formations which are referred to as aquifers. Groundwater is an important resource in the Quinte Region providing supply to approximately 50 percent of the residents and base flow to the many streams, lakes and rivers. Of the residents using groundwater the majority obtain supply from private wells, with approximately 3 percent of the watershed population using municipal groundwater systems at the four different locations listed in Table 3-11.

Table 3-11: Municipal Wells

Location	Number of Wells	Population Served	Aquifer
Village of Madoc	2	1250	Precambrian
Village of Tweed	2	1800	Precambrian
Village of Deloro	1	160	Precambrian
Peats Point	1	150	Limestone

For private wells there are records for approximately 22,000 wells at the locations illustrated by Map 3.5. These records were used to provide much of the information about the local groundwater resource which is discussed below.

Aquifers

The aquifers of the Quinte Region are a direct reflection of the geology of the area which is predominantly bedrock with thin soil cover. Given these conditions the majority of wells (95 percent) obtain supply from fractured bedrock aquifers. The remaining 5 percent obtain supply from overburden aquifers comprised of sand and gravel where the soil is of sufficient thickness. The major aquifers and/or hydrogeologic units can be simplified as follows:

Precambrian Aquifer(s) – 21 percent of wells
Limestone Aquifer(s) – 74 percent of wells
Overburden Aquifer(s) – 5 percent of wells

The location of the fractured bedrock aquifers corresponds with the boundaries of the various bedrock formations as mapped by Map 2.7. As the region is entirely underlain by fractured rock these aquifers are found throughout with limestone bedrock aquifers prevalent at the south and Precambrian bedrock aquifers common in the north. For the most part these fractured bedrock aquifers are considered to be unconfined, meaning that there are no layers of soil or rock that prevent the movement of water from the ground surface into the aquifer. Precipitation (rain or melted snow) can move easily from the ground surface into the aquifer. However, in the deep zones of the bedrock the number and density of fractures decreases and are not as well connected to the surface. Since these fractures are the flow path through which water moves, precipitation does not move as easily into these zones. Under these conditions the aquifer is considered to be semi confined or confined meaning that it is more protected from activities at ground surface.

Overburden aquifers (groundwater which is found in the soil as opposed to fractured rock) are not extensive throughout the region but are present where there is sufficient depth of sand and gravel (see Map 2.5). Such conditions exist in the south western portion of the Moira watershed, in the vicinity of a kame moraine formation, and at the Picton Esker near West Lake in Prince Edward County. These aquifers are relatively isolated but are interpreted as being connected with the underlying bedrock aquifers, and serve as storage reservoirs providing significant volumes of recharge.

Yield from the Quinte Region aquifers is typically low to moderate and considered adequate for meeting most domestic and agricultural needs. The exceptions are some areas of Prince Edward County and the Precambrian Shield where the fractures in the bedrock are not well developed and it is difficult to find adequate quantities of water. The opposite is also true of other areas where, because of significant fracture openings, large quantities of water can be found as evidenced by the wells providing municipal supply to the Villages of Deloro, Madoc and Tweed as well as the Peats Point subdivision.

The quality of supply from the aquifers is normally good with fresh water reported on well records. However the water is often hard and in some areas natural water quality problems may be experienced due to mineralization, gas and sulphur. These natural water quality problems are typically encountered when wells are drilled too deep (i.e. depths of greater than 30 metres in limestone bedrock) or in areas of groundwater discharge.

Groundwater Flow

The movement of groundwater in the Quinte Region is typically a reflection of surface topography with groundwater flowing from areas of high ground to low. The direction of groundwater flow is illustrated by Map 3.6 which is a contour map of the water table surface. Under these conditions the regional direction of groundwater flow is similar to surface drainage and is predominantly in a south to southwest direction. In Prince Edward County the water table also mimics topography with flow outwards from high inland plateaus towards the shorelines of the Bay of Quinte and Lake Ontario.

Recharge to the unconfined aquifers is interpreted to be approximately 10 percent of annual precipitation. This recharge occurs primarily in the spring and fall and is a reflection of the annual water budget when surplus water is available during these periods. A hydrograph for a monitor well located in the Quinte watershed is illustrated by Figure 3-7 showing an increase in water levels during spring when recharge is occurring and a decrease in the summer months when more water is leaving the aquifer than entering. The depth to the water table in the Quinte Region is often at shallow depth below ground surface. From mapping of the water table elevation (Map 3.6), it can be seen that greatest depth to the water table is found in topographically high areas and shallow depths are evident in low lands adjacent to water bodies and surface water courses. In the absence of confining layers it is evident that recharge occurs throughout the watershed. However the contrast in the water table elevation mapping indicates that areas of recharge can be interpreted as occurring in the upland areas with discharge in the low lands. Further discussion about mapping of significant groundwater recharge areas is provided in Chapter 5.

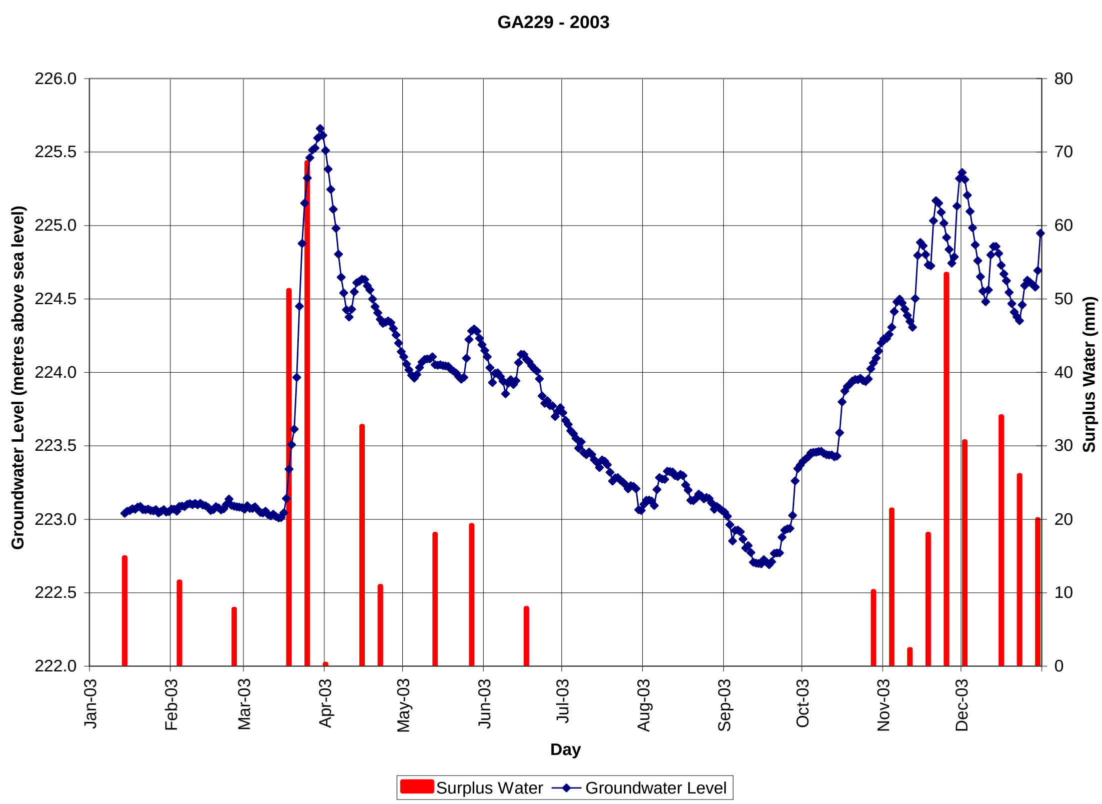


Figure 3-7: Groundwater Hydrograph Monitoring Well 229

Groundwater/Surface Water Interactions

In the Quinte watershed there is significant interaction between surface water and groundwater. Mapping has illustrated that groundwater flows toward, and discharges to surface water features (Map 3.6). Through analysis of groundwater and surface water hydrographs it was also found that the groundwater and surface water features respond in similar fashion to rainfall events with increases in levels observed in each due to precipitation events. This interaction is illustrated in Figure 3-8 which is a graph showing surface water discharge and groundwater levels at a monitor well in the Moira watershed. The quick response of the groundwater to precipitation recharge is an indication of the unconfined nature and vulnerability of the Quinte aquifers.

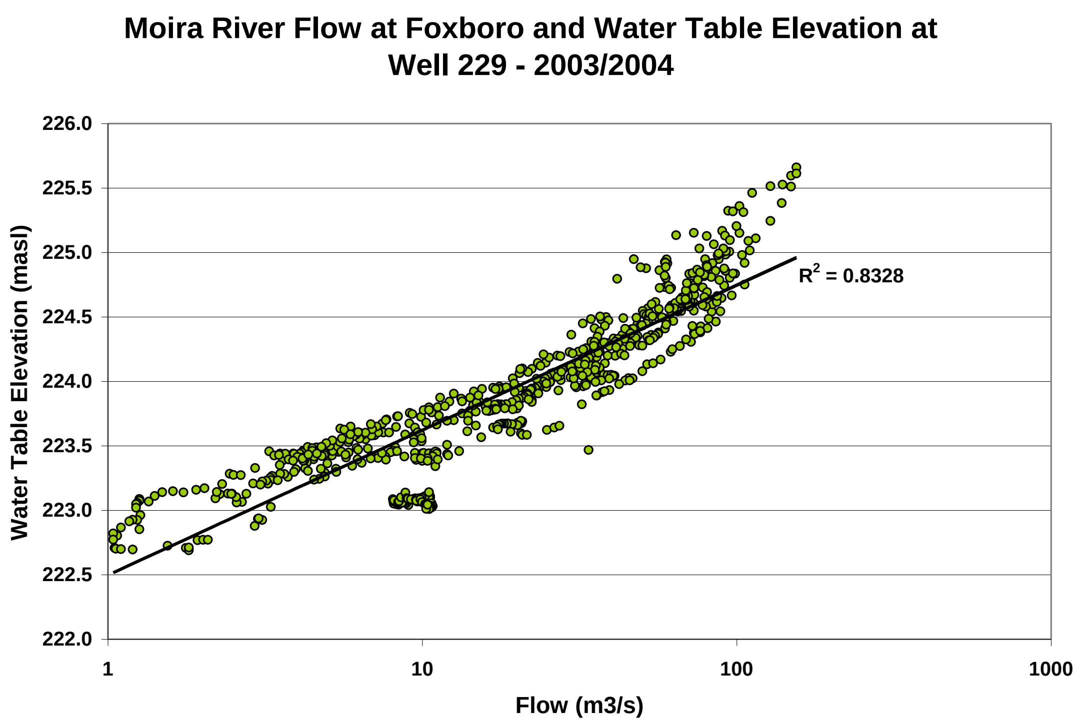


Figure 3-8: Surface Water Discharge and Groundwater levels

3.3.4.8 Water Use

Water is used in the Quinte Conservation watershed for potable supply to municipalities and private homes as well as for irrigation (golf courses), agriculture, industry, hydro electric generation and manufacturing. A review of water use data and population numbers (Appendix C1) indicates that approximately 50 percent of the population utilizes surface water for supply and the balance use groundwater. To determine the volume of both ground and surface water use a review was completed of a variety of data sources which included:

- Permits to Take Water –The MOE maintains a database of permits to take water for large water users (>50,000 Litres/day). Temporary (e.g. short term construction) and permits expired for more than five years were not included in the calculations;
- Municipal Systems – The actual water taking data from each municipal surface water and groundwater system was obtained;
- Agricultural – Water taking data was obtained from the Census of Agriculture (MNR Rob DeLoe Study);
- Private – The number of private wells in each municipality was determined using the MOE Water Well Information System. Based on population distribution data the use was converted to three persons per well at 175 Litres /person/day (525 Litres per day); and
- Public Use – This includes usage for campground and private developments where total daily demand exceeds 50,000 Litres/day.

Summaries of the water use for the various categories of surface and groundwater are provided in Table 3-12 for surface water and Table 3-13 for groundwater. The total use of groundwater in the watershed region was estimated at 16.4 million cubic metres per year and surface water at 13.3 million cubic metres per year. Of these totals all of the surface water use is covered by permits to take water and for groundwater 66 percent or 10.9 million cubic metres per year are covered by permits. Note that the values reported for permitted use are based on the maximum values which are considered to be higher than the actual use.

Table 3-12: Surface Water Demand

Category	Water Use (m^3/year**)	% of Total
Municipal	4320000	33
Irrigation	1450000	11
Industrial	7500000	56
Total	**13300000**	**100**

* The surface water demand does not include usage from the Bay of Quinte and Lake Ontario.
** cubic metres per year

Table 3-13: Groundwater Demand

Category	Water Use (m^3/year*)	% of Total
Private Wells	3630000	22
Municipal	1810000	11
Irrigation	241000	1
Industrial	8300000	51
Bottled Water	175000	1
Agricultural	1860000	11
Public	341000	2
Total	**16400000**	**100**

*cubic metres per year

3.3.5 Conceptual Water Budget Results

From the conceptual work it was found that the Quinte Region has an abundance of both surface and groundwater resources. Surface water is found in many streams lakes and rivers throughout the region. Groundwater is typically found in unconfined fractured bedrock aquifers throughout the area as well as in some isolated overburden aquifers. The surface and groundwater resources are interconnected as there is a strong interaction between them with groundwater actively discharging to the many surface water features. Precipitation is the main way that water enters the watershed providing direct recharge to the ground and surface water supplies. Evapotranspiration is the primary means that water is removed from the watershed; however, both ground and surface water are continually leaving the watershed by draining out through the many streams and rivers into the Bay of Quinte and Lake Ontario.

3.3.5.1 Annual Water Budget

From the conceptual work annual water budgets were established for the main watersheds and overall region listed in Table 3-14. These results are direct output from the Geographic Information System water budget model. The results for the Consecon watershed are reported as this is the largest of the many small watersheds that make up this region. The distribution of precipitation in the natural water budget process is illustrated by Figure 3-9 with approximately 60 percent consumed by evapotranspiration and the remaining divided almost equally between surface runoff and groundwater recharge. This natural water balance was confirmed through review of precipitation and stream gauge data for the Quinte Watershed which indicated actual watershed measurements are in close proximity to that predicted by the Geographic Information System water budget model.

Table 3-14: Annual Water Budget – Watershed and Regional Scale

Watershed	Precipitation	Evapotranspiration	Recharge	Surface Runoff
Moira	905	517	173	215
Salmon	929	551	175	203
Napanee	934	561	176	197
Consecon	925	604	147	174
Overall Region	919	550	168	201

Note: All units are in millimetres

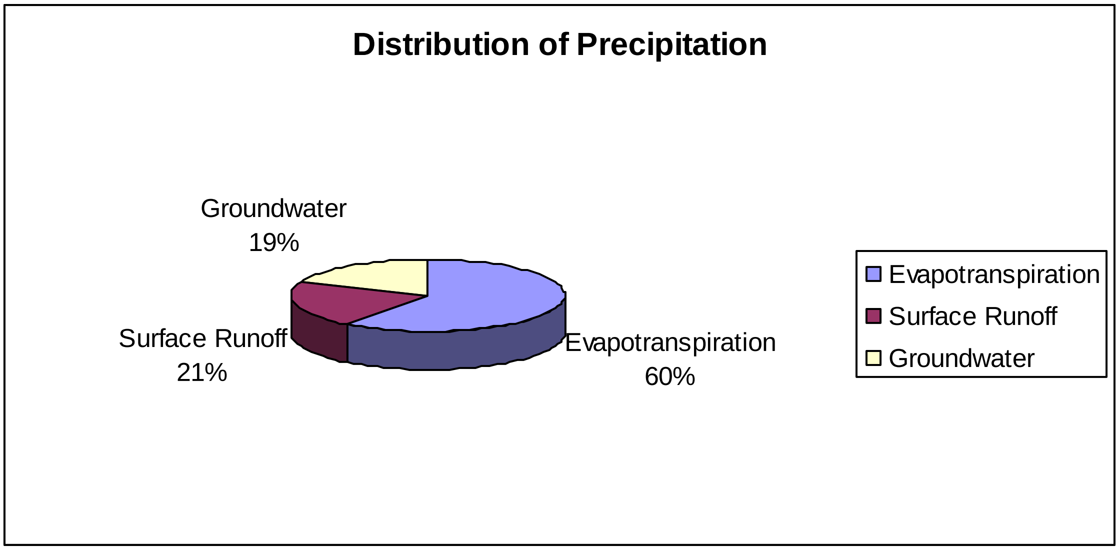


Figure 3-9: Distribution of Precipitation

3.3.5.2 Potential Stress Conditions

To provide an indication of potential stress a comparison of water supply with the water use in the watershed was completed. From review of water use it was determined the largest use of groundwater is Industry (quarry dewatering). The second is private wells, with agriculture and municipal use having the third highest demand. The total use of groundwater in the Quinte region compared to the volume available was determined to represent only 2 percent of the available supply. For surface water the highest water users were first; industrial (quarry dewatering), second, municipal and third, irrigation. The total use of surface water was also determined to be low at approximately 1 percent of the available supply.

Although the overall water use may be considered low in comparison to the available supply, this may not be an accurate indication of potential stress. The conceptual water budget considers the entire watershed on an annual basis which may not accurately reflect small areas where there is high water use or seasonal fluctuations in supply such as during the dry summer months. The effects of water takings may be more significant on a shorter time scale (e.g. monthly) or on a smaller area (e.g. subwatershed) which are to be considered at the Tier 1 level.

3.4 Tier 1 Water Budget & Stress Assessment

A Tier 1 Water Budget refines the work completed at the conceptual stage by focusing on the water budget elements within a smaller area and time scale. For this work the spatial scale is at the subwatershed level and the time scale is monthly. This enables assessment of areas where there may be higher water use and gives consideration to seasonal fluctuations of water supply.

The Tier 1 work was also completed using the Geographic Information System water budget model developed at the conceptual level as well as using field measurements of stream flow. This work enabled the assessment of the natural water budget for each subwatershed. The ratio of water supply to water use was calculated for each subwatershed to allow calculation of the percent water demand. Based on the percent water demand a level of potential hydrologic stress is assigned as Significant, Moderate or Low in accordance with predetermined thresholds. Subwatersheds with a Significant or Moderate level of stress, and containing a municipal drinking water intake, are required to have further water budget work completed. The basic steps of the Tier 1 work may be summarized as follows:

Step 1 Define the Water Budget Components and Process;

Step 2 Refine the Area and Time Scales;

Step 3 Refine Estimates of Water Supply;

Step 4 Refine Estimates of Water Demand; and

Step 5 Calculate percent water demand for each subwatershed.

3.4.1 Tier 1 Water Budget Components/Process

The Tier 1 water budget work was completed in accordance with the Ministry of the Environment Water Budget and Water Quantity Risk Assessment Guidelines (March 30, 2007). The basic water budget equation, as used at the Conceptual Water Budget stage was expanded to consider other variables on a monthly basis. At this level of work it is necessary to consider other inputs of water into the watershed such as groundwater flowing in from other areas and the change in the amount of water stored in the various reservoirs. As such the Tier 1 water budget equation now becomes:

$$P + GW_{in} = ET + Q + \Delta S + U$$

Where:

P = Precipitation
GW_{in} = Horizontal groundwater flow in
ET = Evapotranspiration
Q = Stream flow out (groundwater discharge + surface runoff)
ΔS = Change in storage
U = Net water use including withdrawals and returns

To complete this work, the data sources are the same as those used in the Conceptual Water Budget (Table 3-2). These data were refined to the subwatershed and monthly scale for incorporation into the Geographic Information System water budget model, including a refined estimate of water use.

3.4.2 Calculate Subwatershed Stress Level

The Technical Rules require a stress level to be assigned to each subwatershed for both surface water and groundwater quantity. Subwatersheds that contain municipal drinking water systems and have Moderate or Significant water quantity stresses for surface water or groundwater must move on to Tier 2 analysis.

There are seven municipal drinking water systems in the Quinte Region that draw from surface water. Of these systems, five draw from the either the Bay of Quinte or Lake Ontario. The Technical Rules mandate that water systems that obtain water from the Great Lakes must not be considered in the Tier 1 study. This leaves only two systems; one at the Hamlet of Ameliasburgh drawing water from Roblin Lake, and the other is the backup intake for the Town of Napanee which is located on the Napanee River (Map 2.3).

There are four municipal groundwater systems (Map 2.3). The Villages of Madoc, Tweed, and Deloro draw groundwater from a fractured Precambrian aquifer that is unconfined. The remaining system is at the Peats Point Subdivision which is serviced by one well obtaining supply from a fractured limestone aquifer.

3.4.2.1 Percent Water Demand

The stress level for each subwatershed was determined for both ground and surface water by calculating the percent water demand. The percent water demand is calculated by dividing water usage by the available supply after allowing for a reserve. Subject to this demand three levels of stress are assigned as Significant, Moderate or Low. Subwatersheds with a Significant or Moderate stress level and containing a municipal intake will be studied further.

Surface Water

For surface water all subwatersheds were assessed a ‘stress’ level following the formula below developed to calculate the percent water demand for each month under current and future demand scenarios. Based on this calculation the stress level was assigned in reference to Table 3-15.

$$\% \text{ Water Demand (Stress)} = \frac{Q_{Demand}}{Q_{Supply} - Q_{\mathrm{Re}serve}} \text{ X } 100$$

Where:

Q_{Demand} = Monthly surface water demand calculated as consumptive takings from streams, ponds, and lakes in the watershed. This demand is determined for current and for 25 year projections.

Q_{Supply} = Monthly surface water supply calculated as monthly median flow within the watershed using the flow measured at a stream gauge or prorated from nearby gauge.

$Q_{\mathrm{Re}serve}$ = Surface water reserve is estimated, at a minimum, as the 10th percentile of monthly median flow.

Groundwater

Stress for groundwater was calculated for each subwatershed on an annual and monthly basis as shown below for current and future demand scenarios. Based on this calculation the stress level was assigned in reference to Table 3-15.

$$\% \text{ Water Demand (Stress)} = \frac{Q_{Demand}}{Q_{Supply} - Q_{\mathrm{Re}serve}} \text{ X } 100$$

Where:

Q_{Demand} = Monthly and annual demand calculated as consumptive takings for both current and 25 year projections.

Q_{Supply} = Groundwater supply calculated as the average annual recharge rate divided by 12 for monthly volumes.

$Q_{\mathrm{Re}serve}$ = Groundwater reserve is estimated as 10percent of the recharge.

Table 3-15: Subwatershed Stress Levels

Water Quantity Stress Level	SURFACE WATER	GROUNDWATER	
	Monthly % Demand	Monthly % Demand	Annual % Demand
Significant	>50%	>50%	>25%
Moderate	20% - 50%	>25%	>10%
Low	<20%	0 – 25%	0 – 10%

3.4.2.2 Area and Time Scales

The Tier 1 study required that the water budget and stress assessment calculations be completed for subwatersheds for which the Quinte Source Protection Region was divided into 25 areas (see Map 2.2). These areas were based on the location of surface water flow gauges, where available, and subwatershed boundaries when flow gauges did not exist. Please note these latter subwatersheds were as defined by the Ministry of Natural Resources. As per the Technical Rules, water budgets for groundwater were also carried out using the same 25 subwatershed areas.

The time period for the Tier 1 calculations was also refined from annual to monthly. Calculations were completed monthly for surface water, while calculations for groundwater were completed annually and monthly.

3.4.3 Water Supply

The volume of water supply for the percent demand calculations was determined for both ground and surface water as described below.

3.4.3.1 Surface Water Supply

For the volume of surface water, the actual stream gauge measurements were applied for gauged subwatersheds for which there are records for 17 stations (see Map 3.4) within the Quinte Region. For those subwatersheds where gauges do not exist the flow was prorated from the gauged subwatersheds having similar hydrologic features. The supply of water for each subwatershed was determined based on the median flow as listed in Table 3-16. For the stress calculations a portion of this flow was subtracted as a reserve for the ecological requirements of the stream. This reserve was defined in the Water Budget Guidelines as being the tenth percentile of stream flow, or the rate of discharge that is exceeded 90 percent of the time.

Table 3-16: Subwatershed Median Flows in m^3/s

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Moira River												
Deloro	2.75	2.36	6.94	14	4.83	1.55	0.33	0.13	0.12	0.57	2.65	3.47
Black	4.14	3.72	8.28	16.1	6.13	2.38	1.15	1.05	1.15	1.15	3.29	5.02
Skootamatta	7.78	6.45	13.6	27.7	11	3.45	1.19	0.7	0.72	1.61	4.6	8.39
Tweed	28.6	15.4	45.9	79.1	32.15	10.3	3.48	2.35	2.31	2.89	6.74	20.4
Clare	2.06	1.89	5.75	10.41	3.63	0.63	0.28	0.15	0.14	0.22	0.95	1.84
Parks	3.15	3.09	7.51	9.42	3.97	1.76	0.59	0.22	0.19	0.39	0.97	2.43
Foxboro	23.8	19.95	54.4	106	44.75	16.5	6.16	2.9	2.72	4.07	12.7	23.5
Lower Moira	25.92	21.73	59.25	115.5	48.74	17.97	6.7	3.15	2.96	4.43	13.83	25.6
Salmon River												
Tamworth	14.3	4	6.63	18.2	8.74	5.07	2.19	0.7	0.16	0.93	4.45	13.25
Shannonville	9.39	10	19.8	32.9	14.6	5.51	1.47	0.46	0.34	0.93	6.5	12.65
Lower Salmon	9.49	10.11	20.01	33.25	14.75	5.57	1.49	0.46	0.34	0.94	6.56	12.78
Napanee River												
Depot	1.95	1.97	3.01	4.67	1.93	1.1	0.94	0.93	0.89	0.93	1.13	1.98
Camden	9.1	8.48	16.45	26.3	10.2	4.22	1.64	1.39	1.59	2.46	4.57	9.49
Upper Napanee	5.53	5.59	18.55	34.35	11.4	3.78	1.58	1.09	1.09	1.21	2.97	5.63
Lower Napanee	6.99	7.07	23.46	43.45	14.42	4.78	2	1.38	1.38	1.53	3.75	7.12
Prince Edward County												
Ameliasburgh	1.33	1.16	5.58	4.02	1.34	0.31	0.03	0.01	0.01	0.03	1.11	1.44
Sophiasburgh	1.17	1.01	4.89	3.53	1.17	0.27	0.03	0	0	0.02	0.97	1.26
Consecon	2.05	1.78	8.58	6.19	2.06	0.48	0.05	0.01	0.01	0.04	1.71	2.22
Hiller	1.09	0.95	4.58	3.3	1.1	0.25	0.03	0	0	0.02	0.91	1.18
West Lake	1.22	1.06	5.13	3.7	1.23	0.29	0.03	0.01	0.01	0.03	1.02	1.32
Picton	0.67	0.58	2.81	2.03	0.67	0.16	0.02	0	0	0.01	0.56	0.73
East Lake	1.15	1	4.81	3.47	1.15	0.27	0.03	0	0	0.02	0.96	1.24
Milford	0.91	0.79	3.83	2.76	0.92	0.21	0.02	0	0	0.02	0.76	0.99
North Marysburgh	0.55	0.48	2.32	1.67	0.56	0.13	0.01	0	0	0.01	0.46	0.6
South Marysburgh	0.99	0.86	4.13	2.98	0.99	0.23	0.02	0	0	0.02	0.82	1.07

3.4.3.2 Groundwater Supply

Groundwater supply for the 25 subwatersheds was evaluated as the amount of water recharging the aquifers annually and monthly. The Geographic Information System water budget model was used to calculate this volume. However refinement of this estimate was completed through the use of a network of 31 monitor wells (Map 3.7) located throughout the watershed. Through analysis of water level data for the wells, as illustrated by the graph from the data for one of the wells (Figure 3-7), the recharge to the aquifer was calculated. This was completed by using the measured increase in water levels to determine the volume of water that is causing this increase in groundwater levels at each well. Based on the calculated recharge the Geographic Information System model was calibrated to reflect the field measurements recorded throughout the watershed.

The calculated recharge for the individual subwatersheds as listed in Table 3-17, ranged from 52 to 95 millimetres per year. The monthly rate, was calculated as the annual recharge divided equally over 12 months; ranging from 4.3 to 7.9 millimetres. A groundwater reserve was subtracted from the supply to meet other demand requirements (i.e. ecological), as 10 percent of the rate of recharge.

Table 3-17: Annual and Monthly Groundwater Supply (Recharge) by Subwatershed

Catchment Name	Annual Precipitation (mm)	Annual Evapotranspiration (mm)	Annual Recharge (mm)	Average Monthly Recharge (mm)
Ameliasburgh	930	605	75	6.2
Black	899	503	53	4.4
Milford	972	608	88	7.3
Camden	936	564	70	5.8
Clare	918	539	71	5.9
Consecon	928	607	76	6.3
Deloro	888	511	52	4.3
Depot	930	547	60	5
East Lake	950	545	74	6.1
Foxboro	905	529	63	5.2
Hillier	943	631	72	6
Moira Remainder	926	591	95	7.9
Lower Napanee	954	595	78	5.9
Upper Napanee	943	588	87	6.5
North Marysburgh	1010	632	81	6.7
Parks	921	586	91	7.6
Picton	966	615	88	7.3
Salmon	977	632	70	5.8
Shannonville	931	582	83	6.9
Skootamatta	913	503	55	4.6
Sophiasburgh	955	612	82	6.8
South Marysburgh	1003	638	87	7.2
Tamworth	928	526	59	4.9
Tweed	929	546	59	4.9
West Lake	952	611	83	6.9

3.4.4 Water Demand

The water use estimates of the Conceptual Water Budget were refined using actual water use numbers and/or by assigning consumptive water use factors to permitted values. Consumptive factors, listed in Table 3-18, were applied to individual takings in order that consideration is given to only the portion of water that is not returned directly to the reservoir or source from where it was taken. For example, for a municipality that obtains supply from a water well where the wastewater is treated and then discharged to a surface water body, the water use would be considered as 100 percent consumptive. However, in other cases where the water is used and then discharged to the ground via a septic system the consumptive use would be considered as 20 percent with the remaining 80 percent returned to the source.

In addition to assigning consumptive water use factors, determination of water demand required the analysis of water taking permits to categorize them into various sectors. Some permits were not considered to represent a true taking and were omitted from the totals. This was the case for permits issued for dams and wetlands which were deemed to artificially inflate levels of hydrologic stress of some subwatersheds.

Table 3-18: Consumptive Water Use Factors

Category	Specific Purpose	Consumptive Factor
Groundwater		
Agricultural	Fruit Orchards	0.8
Agricultural	Other - Agricultural	0.8
Commercial	Bottled Water	1
Commercial	Golf Course Irrigation	0.7
Dewatering	Pits and Quarries	0.25
Industrial	Aggregate Washing	0.25
Industrial	Other - Industrial	0.25
Remediation	Groundwater	0.5
Water Supply	Campgrounds	0.2
Water Supply	Communal	0.2
Water Supply	Municipal	0.2
Surface Water		
Agricultural	Other - Agricultural	0.8
Commercial	Golf Course Irrigation	0.7
Dewatering	Pits and Quarries	0.25
Industrial	Aggregate Washing	0.25
Industrial	Manufacturing	0.25
Water Supply	Municipal	0.2
Water Supply	Other - Water Supply	0.2

A total of 223 Permits to Take Water were reviewed. After filtering out temporary permits and those whose source was Lake Ontario, wetlands or dams, only 36 surface, 38 ground and 15 mixed source permits remained.

The monthly ground and surface water demand for the Quinte Region is summarized by Table 3-19 and Table 3-20 (Monthly ground and surface water use) respectively at 8,570,000 cubic metres per year for surface water with the remaining attributed to groundwater at 8,310,000 cubic metres per year. Of interest is that total annual use has decreased by 50 percent for groundwater and 64 percent for surface water in comparison to the totals determined at the conceptual level. A summary of monthly ground and surface water use (excluding wetlands and dams) is provided in Figure 3-10. The top three consumptive users of water in the region are irrigation, pits and quarries, and then municipal takings. Seasonal variations in use were also noted with an increase in use over the summer months owing to irrigation.

Table 3-19: Monthly Consumptive Groundwater Use

Month	Industrial (1000 m^{3*})	Pits & Quarries (1000 m^{3*})	Municipal (1000 m^{3*})	Irrigation (1000 m^{3*})	Public (1000 m^{3*})	Agricultural (1000 m^{3*})	Domestic (1000 m^{3*})
Jan	48.0	172	36.9	254	6.26	57.8	9.8
Feb	50.6	204	32.3	254	6.26	57.8	9.8
Mar	84.1	201	39.4	254	6.26	57.8	9.8
Apr	84.1	207	34.4	254	6.26	57.8	9.8
May	50.1	303	36.0	264	6.33	57.8	9.8
Jun	84.1	177	36.1	276	6.41	193.5	9.8
Jul	12.4	175	36.7	298	6.41	193.5	9.8
Aug	98.9	172	36.2	301	6.33	193.5	9.8
Sep	84.1	172	34.9	277	6.26	193.5	9.8
Oct	98.4	177	30.8	254	6.26	57.8	9.8
Nov	51.3	226	30.9	254	6.26	57.8	9.8
Dec	48.0	181	33.4	254	5.72	57.8	9.8
Annual	794.1	2370	418	3190	75	1240	118

*cubic metres

Table 3-20: Monthly Consumptive Surface Water Use

Month	Industrial (1000 m^{3*})	Pits & Quarries (1000 m^{3*})	Municipal (1000 m^{3*})	Irrigation (1000 m^{3*})
Jan	61.3	80.9	154	266
Feb	61.3	80.9	154	266
Mar	61.3	85.8	154	268
Apr	102	80.9	154	268
May	106	81.9	154	330
Jun	106	81.9	154	515
Jul	106	84.3	154	600
Aug	106	84.3	154	707
Sep	106	83.3	154	564
Oct	106	80.9	154	337
Nov	102	80.9	154	266
Dec	61.3	80.9	154	266
Annual	1090	987	1840	4650

*cubic metres

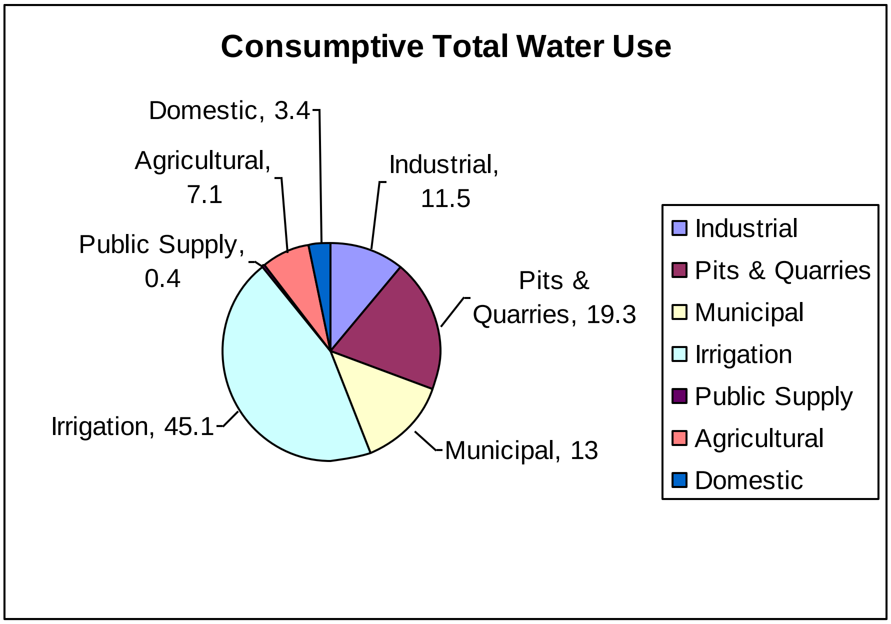


Figure 3-10: Distribution of Overall Consumptive Water Use (%)

3.4.5 Tier 1 Results

Percent water demand calculations were performed on both groundwater supply and usage results as well as surface water supply and usage reported earlier following the calculation in Section 3.4.2.1. The results of the percent water demand calculations and Tier 1 assessment are discussed below.

3.4.5.1 Surface Water

Completion of the stress assessment and percent water demand calculations as listed in Table 3-21 resulted in several Prince Edward County subwatersheds showing Moderate or Significant stress and one subwatershed in the Moira region having a Moderate stress level. Subwatersheds showing Moderate or Significant stress have been bolded. Much of this potential stress occurs in the summer months of July, August, and September. A map of subwatershed stress for August is illustrated by Map 3.8. Some subwatersheds were noted to have stress exceeding 100 percent. Possible explanations are that the source may be other than that reported on the Permit to Take Water or, as is often the case, the actual use is much less than the permitted taking. Only one of the subwatersheds, the Ameliasburgh catchment in Prince Edward County has a municipal intake that is located in Roblin Lake to provide supply to the Hamlet of Ameliasburgh. This subwatershed was recommended for further study at the Tier 2 level. The calculations were repeated for future water use. Only those subwatersheds having municipal systems have increased water use and percent water demand (Table 3-22).

3.4.5.2 Groundwater

Assessment of percent water demand (current and future) for groundwater was completed both annually and monthly as reported in Table 3-23 with annual stress levels illustrated by Map 3.9. In Table 3-23 the future percent demand is only reported for the subwatersheds containing municipal wells because the other areas did not change. The majority of the subwatersheds were assessed at less than 1 percent annual demand which is considered to be low stress conditions. However, the Picton and Camden subwatersheds were assigned a moderate level of annual stress. Similar to the annual results most subwatersheds showed low monthly water demand and low stress conditions, that is, at below 1 – 2 percent of available supply with the exception of Tweed (10 percent in May), Madoc (7 percent in May), Picton catchment (25 percent in April) and Camden catchment (11 percent in summer months). A review of water taking data for the Picton and Camden catchments indicated the majority of water use was attributed to single permits in each subwatershed. It is speculated that the data may be not truly reflective of the actual use of groundwater.

From this assessment all subwatersheds were assigned a low level of monthly stress and Moderate level of stress for annual use for two subwatersheds. Neither of these areas contains a municipal groundwater intake, therefore further water budget work was not completed.

Table 3-21: Percent Water Demand Surface Water (Current Use)

Catchment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Moira River												
Deloro	0	0	0	0	0	0	0	0	0	0	0	0
Black	0	0	0	0	0	0	0	0	0	0	0	0
Skootamatta	0	0	0	0	0	0	0	0	0	0	0	0
Tweed	0	0	0	0	0	1	2	3	2	2	1	0
Clare	0	0	0	0	0	0	0	0	0	0	0	0
Parks	0	0	0	0	0	1	5	**22**	7	0	0	0
Foxboro	0	0	0	0	0	0	1	3	2	0	0	0
Lower Moira	0	0	0	0	0	0	0	1	1	1	0	0
Salmon River												
Tamworth	0	0	0	0	0	0	0	5	1	0	0	0
Shannonville	0	0	0	0	0	1	2	6	8	2	0	0
Salmon Remainder	0	0	0	0	0	0	0	0	0	0	0	0
Napanee River												
Depot	0	0	0	0	0	0	0	0	0	0	0	0
Camden	2	2	2	1	2	4	16	16	11	7	3	1
Upper Napanee	1	1	0	0	1	1	5	5	4	4	1	1
Lower Napanee	1	1	0	0	1	2	7	9	8	6	2	1
Prince Edward County												
Ameliasburgh	0	0	0	0	0	1	5	**32**	**36**	8	0	0
Sophiasburgh	0	0	0	0	0	0	0	0	0	0	0	0
Consecon	0	0	0	0	0	1	10	**58**	**65**	0	0	0
Hillier	0	0	0	0	0	11	**95**	**626**	**608**	0	0	0
West Lake	1	1	0	0	1	7	**67**	**487**	**384**	**40**	1	1
Picton	0	0	0	0	0	0	0	0	0	0	0	0
East Lake	0	0	0	0	0	0	0	**259**	0	0	0	0
Milford	0	0	0	0	0	0	0	0	0	0	0	0
North Marysburgh	0	0	0	0	0	0	0	0	0	0	0	0
South Marysburgh	0	0	0	0	0	0	6	0	0	0	0	0

Note: Subwatersheds showing Moderate or Significant stress have been bolded.
Stress Ranges are: Low (0<20), Moderate (20-50), Significant (>50)

Table 3-22: Percent Water Demand Surface Water (Future Use)

Catchment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Moira River												
Deloro	0	0	0	0	0	0	0	0	0	0	0	0
Black	0	0	0	0	0	0	0	0	0	0	0	0
Skootamatta	0	0	0	0	0	0	0	0	0	0	0	0
Tweed	0	0	0	0	0	1	2	3	2	2	1	0
Clare	0	0	0	0	0	0	0	0	0	0	0	0
Parks	0	0	0	0	0	1	5	**22**	7	0	0	0
Foxboro	0	0	0	0	0	0	1	3	2	0	0	0
Lower Moira	0	0	0	0	0	0	0	1	1	1	0	0
Salmon River												
Tamworth	0	0	0	0	0	0	0	5	1	0	0	0
Shannonville	0	0	0	0	0	1	2	6	8	2	0	0
Salmon Remainder	0	0	0	0	0	0	0	0	0	0	0	0
Napanee River												
Depot	0	0	0	0	0	0	0	0	0	0	0	0
Camden	2	2	2	1	2	4	16	16	11	7	3	1
Upper Napanee	1	1	0	0	1	1	5	5	5	4	1	1
Lower Napanee	1	2	1	0	1	2	8	10	9	7	3	1
Prince Edward County												
Ameliasburgh	0	0	0	0	0	1	6	**32**	**36**	8	0	0
Sophiasburgh	0	0	0	0	0	0	0	0	0	0	0	0
Consecon	0	0	0	0	0	1	10	**58**	**65**	0	0	0
Hillier	0	0	0	0	0	11	**95**	**636**	**608**	0	0	0
West Lake	1	1	0	0	1	7	**67**	**487**	**984**	**40**	1	1
Picton	0	0	0	0	0	0	0	0	0	0	0	0
East Lake	0	0	0	0	0	0	0	**259**	0	0	0	0
Milford	0	0	0	0	0	0	0	0	0	0	0	0
North Marysburgh	0	0	0	0	0	0	0	0	0	0	0	0
South Marysburgh	0	0	0	0	0	0	6	0	0	0	0	0

Note: Subwatersheds showing Moderate or Significant stress have been bolded.
Stress Ranges are: Low (0<20), Moderate (20-50), Significant (>50)

Table 3-23: Percent Groundwater Demand Current and Future Use

Subwatershed	Current Demand												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Deloro	3	3	3	3	3	3	3	3	3	3	3	3	3
Black	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Skootamatta	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Tweed	3	2	3	3	8	3	3	3	3	2	2	2	3
Clare	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Parks	<1	<1	<1	<1	<1	1	1	1	1	<1	<1	<1	<1
Foxboro	1	1	1	1	2	1	1	1	1	1	1	1	1
Lower Moira	5	6	7	7	7	8	10	8	8	7	6	6	7
Tamworth	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Shannonville	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Lower Salmon	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Depot	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Camden	10	10	10	10	10	10	10	10	10	10	10	10	**10**
Upper Napanee	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Lower Napanee	<1	<1	<1	<1	<1	1	1	1	1	<1	<1	<1	<1
Ameliasburgh	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Sophiasburgh	<1	<1	<1	<1	<1	2	2	2	2	<1	<1	<1	1
Consecon	<1	<1	<1	<1	<1	2	2	2	2	<1	<1	<1	1
Hillier	<1	<1	<1	<1	2	4	4	4	4	2	<1	<1	2
West Lake	<1	<1	<1	<1	<1	2	2	2	2	1	<1	<1	1
Picton	14	24	23	25	18	17	15	13	15	16	16	17	**18**
East Lake	1	1	1	1	1	3	3	3	3	1	1	1	2
Milford	<1	<1	<1	<1	<1	2	2	2	2	<1	<1	<1	<1
North Marysburgh	<1	<1	<1	<1	<1	1	1	1	1	<1	<1	<1	1
South Marysburgh	<1	<1	<1	<1	<1	2	2	2	2	<1	<1	<1	1
Subwatershed	**Future Demand**												
Deloro	4	4	4	4	4	4	4	4	4	4	4	4	4
Ameliasburgh	<1	<1	<1	<1	<1	1	1	1	1	<1	<1	<1	<1
Tweed	5	4	5	5	10	5	5	5	5	4	4	4	5

Note: Subwatersheds showing Moderate or Significant stress have been bolded.
Stress Categories are: Monthly: Low (0 – 25), Moderate (> 25 – <50), Significant (>=50)
Annual: Low (0 – 10), Moderate (>10 - < 25), Significant (>=25)

3.4.5.3 Historical Performance of Municipal Systems

In addition to consideration of percent water demand, the Technical Rules required that a surface water intake or groundwater well that has reported any of the following criteria since January 1, 1990, must be assigned, as a minimum, a Moderate stress level:

Surface Water Intakes:

- any part of a surface water intake was not below the water's surface during normal operation of the intake; or
- the operation of a surface water intake pump was terminated because of an insufficient quantity of water being supplied to the intake.

Groundwater Wells:

- the groundwater level in the vicinity of the well was not at a level sufficient for the normal operation of the well; or
- the operation of a well pump was terminated because of an insufficient quantity of water being supplied to the well.

Only the Madoc groundwater system in the Tweed subwatershed was promoted to further study for Tier 2 when these criteria were applied. This assignment was not a result of stress calculations, but because a lack of supply that was recorded in 2007 when one of the municipal wells was pumped dry on several occasions.

3.4.6 Uncertainty

All water budget calculations contain a level of uncertainty due to the quality and availability of data and the limitations of the methods used in estimating the water budget components.

Models are tools developed using scientific knowledge to represent a natural system. However, they cannot entirely represent the complexity of that system. Through the preparation of the Geographic Information System water budget model all efforts were taken to use the best quality data and to validate the model with real field measurements taken in the watershed. Through comparison of the output of the model with stream flow measurements it was found that there was very good correlation between the two. The difference in measurements and predicted output was typically less than 10 percent. Likewise error associated with field measurements exists and are typically in the order of 5 to 10 percent. Such uncertainty is considered acceptable for this level of work on a regional and subwatershed scale.

3.5 Ameliasburgh Tier 2 Water Budget

From the Tier 1 study, the Ameliasburgh subcatchment was identified to have a Moderate stress potential. In this subcatchment, the municipal surface water intake is located in the Village of Ameliasburgh in Roblin Lake.

No surface water gauge is present in the Ameliasburgh subcatchment.

The study area was determined in the Tier 1 exercise as shown in Map 2.2. For this level of study the area under consideration was refined to the Sawguin Creek subwatershed. The area of Sawguin Creek is less than half of the Tier 1 study area. For the drought scenarios the Roblin Lake subcatchment area must be used as the exposure of the intake is in question. Table 3-24 shows the drainage areas with locations illustrated by Map 3.10.

Table 3-24: Drainage Area Summary

Location	Drainage Area
Ameliasburgh Subcatchment	132 km^2
Sawguin Creek Subcatchment	53.3 km^2
Roblin Lake Subcatchment	3.6 km^2

3.5.1 Methodology

The study team was assembled based on the proposed work plan and modelling needs. The work included the following tasks:

1. Review Water Use
2. Develop Hydrologic Model
3. Review and Refine Inputs
4. Undertake Groundwater Investigation
5. Complete Stress Calculations
6. Estimate Calculation Uncertainty

Three scenarios are reviewed to highlight the potential for stress in the watershed. The first scenario uses average meteorological conditions and follows the calculation of water use divided by available flow that was presented earlier in the Tier 1 Section 3.4.2. Again, a Low, Moderate, or High stress may be determined for average meteorological conditions. Two other scenarios look at watershed conditions during drought; a 2-year drought and a 10-year drought.

2-Yr Drought
The continuous two year period for which precipitation records exist with the lowest mean annual precipitation.

10-Yr Drought
The continuous ten year period for which precipitation records exist with the lowest mean annual precipitation.

Only a Moderate stress can be assigned in drought conditions. Stress is revealed if the intake would be exposed or if pumps would need to be shut down.

The process is repeated for water demand that would be expected in the future. Future water demand is to be determined using expected municipal growth projections.

3.5.2 Water Use

Permits to take water were reviewed and all permit holders were contacted to determine usage. There were eight active permits. These are listed below in Table 3-25.

Table 3-25: Summary of All Permits to Take Water – Ameliasburgh Subcatchment

Permit No.	Location	Purpose
00-P-4042	Tributary to Mellville Creek	Wildlife Conservation
04-P-4024	Roblin Lake	Municipal
81-P-4026	Sawguin Creek	Municipal
92-P-4021	Source area to Sawguin Creek	Wildlife Conservation
97-P-4039	Tributary of Sawguin Creek	Wildlife Conservation
97-P-4049	Tributary to Sawguin Creek	Wildlife Conservation
5560-6F7NU9 *	Sawguin Creek	Irrigation
03-P-4067 *	Sawguin Creek	Irrigation

* The latter two permits were not in the earlier PTTW database and water budget assessments but were obtained during Tier 2 study

The eight valid permits to take water in the Ameliasburgh subcatchment were reviewed in more detail to develop a reliable estimate of consumptive water use. Four of these permits are for wetlands (wetlands that have been constructed or modified for wildlife habitat enhancement), two are for municipal water use and two are for agriculture (irrigation).

Wildlife Conservation permits were excluded from the stress calculation as our experience in Prince Edward County has shown that inclusion of the consumptive water takings for wetlands based on their permitted amounts introduces extraordinary stress values for all subwatersheds. Constructed wetlands are usually located in headwater areas and often where soils are near saturation. They capture runoff in large melt or rain events and slowly release water back to the system. Their effect is to reduce peak discharges from rapid runoff and increase the volume that shows up later as baseflow.

The remaining four permits are discussed individually.

Permit 81-P-4026 was issued for a communal drinking water system for Fenwood Gardens and has no expiry date. Due to supply and quality issues, municipal water was piped to Fenwood Gardens from the Belleville water treatment plant in the early 2000s by extension of the Rossmore water main.

The water taking in this permit has ceased and is not expected to be used in the foreseeable future. This permit was disregarded.

Permit 04-P-4024 is for the municipal system in the Village of Ameliasburgh. It is an active permit and Quinte Conservation obtained the records of usage for the past three years (2006 to 2008). Average total water withdrawal was determined to be only approximately 20 percent of the permitted values. Per Table 3-18, actual consumptive use is 20 percent of the total withdrawal. Table 3-26 includes the annual water demand for 2006 to 2008 and Figure 3-11 shows the monthly consumptive water use calculated for Ameliasburgh municipal intake.

Table 3-26: Ameliasburgh Annual Water Demand

Year	Volume (m^{3*})
2006	27,421.0
2007	21,752.7
2008	21,019.6
Ave	**23,397.8**

***cubic metres**

Permit 5560-6F7NU9 is for irrigation. The pond receives overland flow during the spring freshet or large runoff events. The permit considers the taking as the filling of the pond. Maximum pond volume is 13,230 cubic metres. This permit provides the user 307 litres per minute to a maximum of 441,632 litres per day for 150 days in the spring freshet. It represents a potential taking of 10,600 cubic metres per month from January to May inclusive. Effectively, water is withdrawn in the spring and used later for spreading on the fields during dry periods in the summer. The impact of this type of taking is not expected to be significant and may be a benefit during low flow periods if the 20 percent that is not consumed (refer to Table 3-18) recharges groundwater or creek system. The permit holder was contacted and provided usage information in the form of annual totals. Since issuance of this permit in late 2005 only one year of taking was recorded in 2006. This is reported as 720,000 US gal or 2,725 cubic metres.

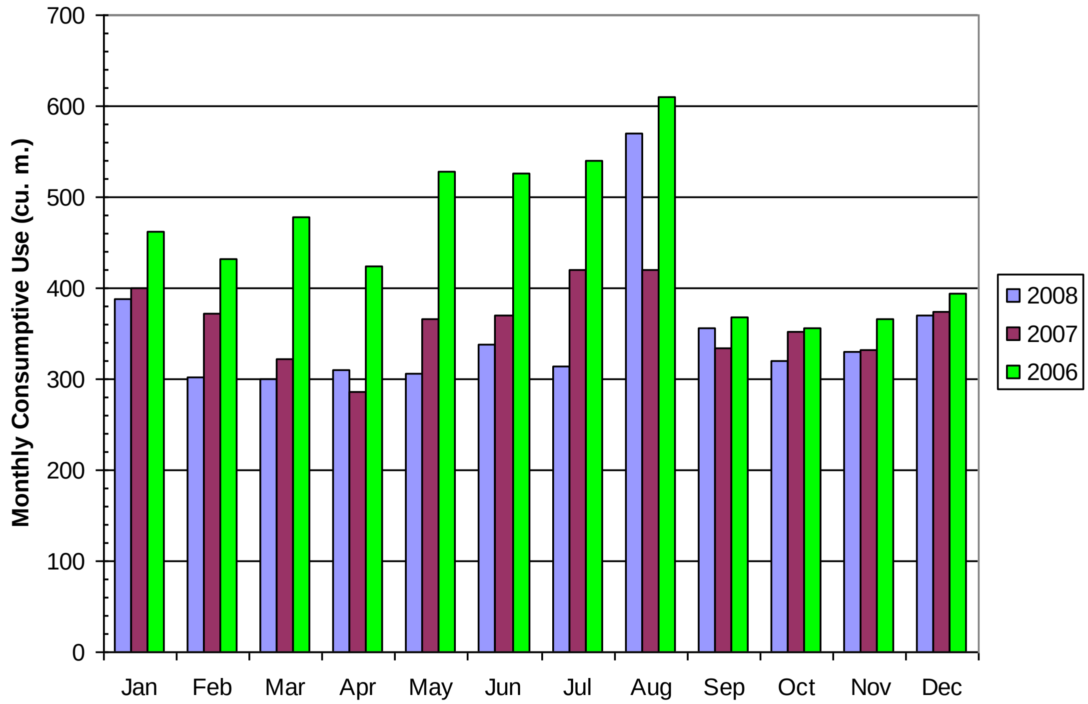


Figure 3-11: Ameliasburgh Consumptive Water Use – 2006-2008

Permit 03-P-4067 is also issued for irrigation. This permit allows water withdrawal of 1136 litres per minute or 946,250 litres per day from June 15 to September 15 for a total of 93 days per year. This represents a potential consumptive taking of approximately 23,500 cubic metres per month. Summer lowest median flow is in September with 3,800 cubic metres per day (from Table 3-33) or 114,000 cubic metres per month. A taking of the entire permitted amount during September would represent 21 percent of the median flow. The permit holder was contacted and provided annual usage totals from 2003 to current. Two years (2004 and 2009) showed no usage. Highest year was 1,827,000 US gal or 19,000 cubic metres. Average annual use was calculated as 2,700 cubic metres and highest annual usage was 6,915 cubic metres in 2005.

Recorded water usage for both irrigation permits has been reproduced below in Table 3-27. Usage was converted into cubic metres and summed.

Table 3-27: Records of Water Use for Irrigation Permits

Year	Permit 03-P-4067		Permit 5560-6F7NU9		Total
	Usage (U.S. Gal)	m³*	Usage (U.S. Gal)	m³*	m³*
2003	1071000	4050			4050
2004	0	0			0
2005	1827000	6920			6920
2006	14400	60	720000	2730	2790
2007	1359000	5140	0	0	5140
2008	747000	2830	0	0	2830
2009	0		0	0	0
Total	5018400	18900	720000	2730	21600
Average		**2710**		**680**	

*cubic metres

In conclusion of the review of water usage, there are three active permits in Sawguin Creek; one municipal taking that has good actual monthly use records from Roblin Lake and two irrigation takings from Sawguin Creek for which only annual usage was provided. Monthly usage was estimated based on permitted periods. Consumptive use was calculated per criteria on Table 3-18.

The summary of water use for Sawguin Creek is presented in Table 3-28 for current and Table 3-29 for future use conditions.

Table 3-28: Sawguin Creek Monthly Water Use (m^3) – Current

PTTW	J	F	M	A	M	J	J	A	S	O	N	D
Municipal Water	417	369	366	340	400	411	425	533	353	343	343	379
Irrigation	0	0	0	0	0	362	723	723	362	0	0	0
Irrigation	0	0	272	272	0	0	0	0	0	0	0	0
Total	**417**	**369**	**638**	**612**	**400**	**773**	**1149**	**1257**	**715**	**343**	**343**	**379**

Note: All units are in cubic metres

Table 3-29: Sawguin Creek Monthly Water Use (m^3) – Future

PTTW	J	F	M	A	M	J	J	A	S	O	N	D
Municipal Water	479	424	421	391	460	473	489	613	406	395	394	436
Irrigation	0	0	0	0	0	362	723	723	362	0	0	0
Irrigation	0	0	272	272	0	0	0	0	0	0	0	0
Total	**479**	**424**	**693**	**663**	**460**	**835**	**1212**	**1337**	**768**	**395**	**394**	**436**

Note: All units are in cubic metres

3.5.3 Model Development

Quinte Conservation operates a surface water model based on the GAWSER (Guelph All Weather Sequential Event Runoff) platform for the Moira, Salmon, and Napanee watersheds but did not have a working model for the Prince Edward Region that included the Sawguin Creek drainage area. Schroeter and Associates was retained by Quinte Conservation to complete a hydrologic model for the Sawguin Creek drainage area.

Water Survey of Canada operates a stream flow gauge on nearby Consecon Creek at Allisonville (02HE002). See also Map 3.4 provided earlier. This gauge is used in model development as a calibration gauge. For this reason, the hydrologic model was also developed for Consecon Creek. The comparison of model output and stream gauge record is provided later in Section 3.5.5.

Quinte Conservation's Geographic Information Systems department supported this work by providing input data to the model. Using the digital elevation model subcatchments were defined for creek systems in Prince Edward County. Map 3.11 shows the drainage areas and provides catchment numbers developed for the model. The Sawguin Creek subwatershed is represented by areas 504, 505, and 506.

Meteorological data were extracted from Meteorological Services of Canada (MSC) stations shown in Map 3.12 and processed to develop continuous data sets for model application. This is discussed further in Section 3.5.4.

To account for the wide variation in runoff generation response attributed to the different land cover features and soil types (e.g. source areas), the subcatchment elements were further subdivided into nine 'hydrologic response units' (HRUs); one impervious and eight pervious. These HRUs are developed within the Geographic Information Systems framework by overlaying the soil-type and land cover information. Within the Quinte Region watersheds, the nine most common land cover/soil type groupings determined the HRUs applied in the model. The nine groupings represent the watershed conditions shown below in Table 3-30.

Table 3-30: Hydrologic Response Unit Description

Hydrologic Response Unit	Surface Feature
1	Impervious Cover
2	Open Water (Large lakes that provide storage)
3	Other Water (Small water bodies, rivers and streams)
4	Wetlands
5	Low Vegetative Cover with Poorly Drained Soils
6	Low Vegetative Cover with Moderately Drained Soils
7	Low Vegetative Cover with Well Drained Soils
8	High Vegetative Cover with Poorly Drained Soils
9	High Vegetative Cover with Well Drained Soils

The Geographic Information System was also used to assist in finding the length and slope of channel routing reaches, length of the longest tributary within each subcatchment element, drainage areas, and the surface areas for major modelled lakes. Map 3.14 shows the coverage for the HRUs. Urban areas were assumed to have 35 percent impervious cover, and the remaining pervious areas were assigned to response units with low vegetative cover. The percent coverage of the HRUs is provided in Table 3-31.

Table 3-31: Hydrologic Response Units for Prince Edward County Model

Catchment	HRU1	HRU2	HRU3	HRU4	HRU5	HRU6	HRU7	HRU8	HRU9	Total
	%	%	%	%	%	%	%	%	%	%
501	1.7	0.0	0.0	5.6	2.7	69.6	0.0	20.4	0.0	100.1
502	1.0	0.0	0.2	1.6	0.0	82.3	0.0	14.9	0.0	100.0
503	2.0	0.0	0.1	2.7	1.3	31.7	18.5	28.5	15.2	100.0
504	1.4	0.0	0.0	18.9	2.0	44.7	0.6	31.3	1.0	100.0
505	2.4	24.5	0.0	2.3	0.9	58.1	0.0	12.4	0.4	101.0
506	1.2	0.1	0.1	13.2	2.2	64.5	0.1	17.9	0.7	100.0
507	2.4	0.0	0.1	3.9	1.4	50.9	0.0	41.4	0.0	100.0
508	1.7	5.0	0.0	15.9	0.7	45.3	0.0	31.1	0.2	100.0
510	10.0	0.0	0.1	0.0	3.9	57.9	0.0	28.3	0.0	100.0
515	1.7	0.0	0.0	3.1	0.0	54.1	0.5	40.0	0.6	100.0
518	1.1	0.0	0.0	26.7	1.5	55.8	0.0	14.8	0.0	100.0
520	1.0	0.0	0.1	28.8	1.7	48.2	0.0	20.2	0.0	100.0
522	1.5	0.0	0.1	18.1	1.3	57.8	0.0	21.2	0.0	100.0
523	1.9	0.0	0.1	14.8	0.4	58.9	0.0	23.9	0.0	100.0
525	1.9	11.4	0.2	4.9	2.6	57.7	0.8	20.3	0.3	100.0

Catchment	HRU1	HRU2	HRU3	HRU4	HRU5	HRU6	HRU7	HRU8	HRU9	Total
531	1.7	0.0	4.8	6.0	3.3	55.0	0.5	28.6	0.2	99.9
532	1.4	0.0	0.1	16.4	5.7	57.4	0.0	18.9	0.0	100.0
533	2.4	0.0	0.1	15.3	3.9	72.2	0.0	6.2	0.0	100.0
534	2.1	0.0	0.1	8.3	4.4	62.1	1.6	21.4	0.1	100.0
535	2.1	0.0	0.1	4.2	0.0	77.6	1.6	14.1	0.3	100.0
536	2.2	0.0	0.1	0.2	1.6	81.9	2.9	11.0	0.1	100.0
540	2.0	0.0	0.3	2.1	0.5	85.3	0.0	9.9	0.0	100.0
542	2.3	0.2	0.1	3.5	2.9	52.2	24.9	9.1	5.0	100.0
544	7.1	0.0	0.2	8.2	4.0	24.9	50.0	1.6	3.9	99.9
545	3.1	0.0	0.3	4.6	5.9	11.1	56.2	8.2	10.7	100.0
547	1.5	0.0	0.0	10.2	0.6	51.3	6.4	19.0	10.8	99.9
550	0.9	0.0	0.0	4.4	1.5	48.3	26.7	11.4	6.6	100.0
552	0.2	0.0	0.7	7.6	2.2	41.7	21.3	20.3	6.0	100.0
554	1.0	0.0	0.0	10.0	0.0	32.8	0.6	55.3	0.3	100.0
560	2.3	0.4	0.0	3.4	2.6	41.7	2.4	47.1	0.1	100.0
562	1.3	0.0	0.0	3.9	2.1	49.4	3.6	39.6	0.2	100.0
565	0.7	0.0	0.0	9.6	2.9	44.9	1.1	40.4	0.3	100.0
570	2.7	0.0	0.2	0.0	0.4	11.3	0.0	85.0	0.0	99.8
572	14.6	0.0	0.3	0.0	13.6	10.5	14.9	38.5	7.3	99.6
574	9.1	0.0	0.0	0.0	0.0	14.2	72.2	0.2	4.2	100.0
576	4.5	0.0	0.0	3.2	2.2	40.0	30.7	9.2	10.2	99.9
578	3.2	0.0	0.0	24.7	0.1	55.2	0.0	16.7	0.0	100.0

Note: HRU is Hydrologic Response Unit
Catchment number locations are referenced on Map 3-11

Once the model was constructed several events were simulated and compared with nearby gauging stations to confirm that outflows were reasonable. Water budget summaries were also reviewed to provide assurance that evapotranspiration results were well modelled. Adjustments were made to model inputs through parameter adjustment factors to provide good agreement between measured and modelled flows comparison for all gauges with the model running in both continuous and event modes.

3.5.4 Meteorological Inputs

Meteorological data were obtained from Meteorological Services of Canada for the period of 1950 to 2005 for the following stations:

- Bancroft Auto (6161001)
- Madoc (6154779)
- Cloyne Ontario Hydro (6161662)
- Frankford MOE (6152555)

- Belleville (6150689)
- Mountainview (615EMR7)

The data were reviewed and mean annual and 2-year and 10-year drought periods were determined by calculating running averages of annual precipitation values and selecting the period that produced the lowest average. This calculation for drought periods is shown graphically using the example of the Bancroft Station in the Figure 3-12.

The summary of the calculated values is provided below in Table 3-32.

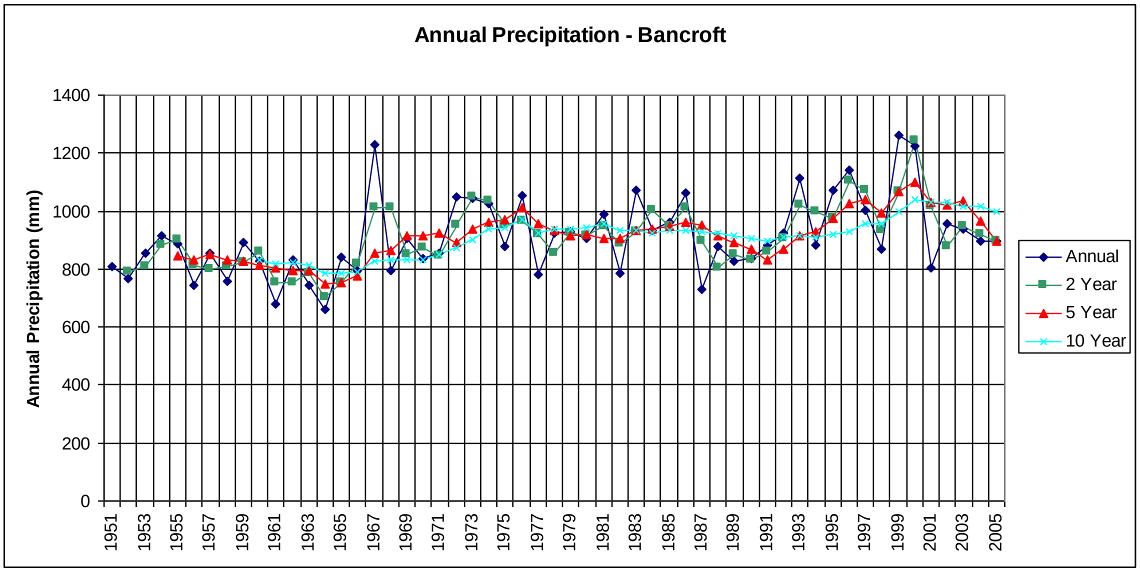


Figure 3-12: Annual Precipitation for Bancroft with Moving Average

The drought periods were selected based on the six station averages. These were 1963 to 1964 for the 2-year drought and 1957 to 1966 for the 10-year drought. The hydrologic model uses 'water year' which recognizes the winter storage of precipitation in snowfall. Therefore, the period of record is adjusted by two months earlier from November 1, 1962 to October 31, 1963 for the 2-year and November 1, 1956 to October 31, 1966.

The periods of study were also compared to Trenton Airport and the same drought periods were found as the six station average.

Table 3-32: Summary of Climate Station Records in Millimetres

Climate Station	1950-2005 Mean Annual	1950-2005 Minimum	1950-2005 Maximum	Minimum 2 Years	Minimum 10 years
Bancroft	910	660 (1964)	1260 (1999)	700 (1963-1964)	780 (1956-1965)
Cloyne Ontario Hydro	860	620 (1961)	1170 (1996)	620 (1963-1964)	690 (1955-1964)
Madoc	920	740 (1982)	1140 (1955)	770 (1982-1983)	870 (1957-1966)
Frankford MOE	870	580 (1963)	1180 (1986)	670 (1962-1963)	760 (1957-1966)
Belleville	880	680 (1989)	1120 (1955)	700 (1988-1989)	780 (1961-1970)
Mountainview	880	600 (1963)	1100 (1976)	640 (1963-1964)	750 (1961-1970)
6 Station Average	890	680 (1963)	1070 (1996)	700 (1963-1964)	780 (1957-1966)

Note: The model used Water Years for the calculation. This would be from November 1 to October 31. For example, the 1963 water year is from November 1, 1962 to October 31, 1963.

3.5.5 Results of Stress Assessment

Model Output for Node 2506 – Sawguin Creek

Table 3-33 contains the flow summary for the model output of Sawguin Creek at Highway 62 (see Map 3.10). Median flows are understood as the 50 percent duration flows. Reserve flows used in the water budget equation are understood as the 90 percent duration flows from this table.

Table 3-33: Sawguin Creek Modelled Flows – Average Hydrologic Conditions in cubic metres/second

Month	Mean	Highest	Lowest	50%Dur	90%Dur
JAN	0.61	15.1	0.02	0.24	0.15
FEB	0.75	19.9	0.01	0.20	0.13
MAR	2.18	23.0	0.01	0.83	0.19
APR	1.92	25.4	0.05	0.62	0.27
MAY	0.40	18.3	0.01	0.19	0.04
JUN	0.06	7.6	0.00	0.02	0.00
JUL	0.08	13.6	0.00	0.00	0.00
AUG	0.06	7.2	0.00	0.01	0.00
SEP	0.09	10.5	0.00	0.01	0.00
OCT	0.12	20.8	0.00	0.03	0.01
NOV	0.50	16.4	0.00	0.17	0.01
DEC	0.83	22.5	0.01	0.27	0.12
Annual	0.63	25.4	0.00	0.15	0.00

The hydrologic model also has the capability to produce a water budget summary for the subcatchment and this has been included as Table 3-34 below.

Table 3-34: Water Budget Summary for Sawguin Creek 1950 to 2005 (in mm)

Month	Rainfall	Snowfall	Precip	ActualET	TotalFlow	Runoff	Baseflow	NetStor
JAN	28	51	79	8	31	21	10	40
FEB	32	30	61	7	34	26	8	21
MAR	51	21	72	8	109	99	11	-45
APR	75	7	82	45	94	83	12	-57
MAY	71	0	71	98	20	13	7	-48
JUN	57	0	57	99	3	2	1	-45
JUL	66	0	66	69	4	3	1	-7
AUG	71	0	71	64	3	3	0	3
SEP	77	0	77	53	4	3	1	20
OCT	63	1	64	39	7	4	2	18
NOV	83	18	100	19	25	19	6	57
DEC	55	37	92	7	42	32	10	43
Total	727	165	892	517	375	307	68	0

Note: Actual ET is the actual evapotranspiration
Total Flow is sum of Runoff (surface flow) and Baseflow (groundwater portion)
NetStor is the Net Storage in the system (i.e. precipitation is gained during winter months and lost in the summer)

3.5.5.1 Percent Water Demand Calculation – Average Hydrologic Conditions

From Section 3.4.2, the percent water demand on the Sawguin Creek drainage area is calculated and summarized in Table 3-35 below. Stress during average hydrologic conditions varies from a low of 0 percent in winter and spring months to a high of 12 percent in July with current municipal usage. In future usage conditions the percent water demand rises slightly in the same month to 13 percent. A Low stress is indicated during average hydrologic conditions.

Table 3-35: Percent Water Demand for Sawguin Creek – Average Hydrologic Conditions

Month	Flow (m^3/s*)		Usage (L/s**)		Stress (%)	
	Q_{Supply}	$Q_{Reserve}$	Current	Future	Current	Future
Jan	0.23	0.15	0.2	0.2	0	0
Feb	0.19	0.12	0.2	0.2	0	0
Mar	0.83	0.18	0.2	0.3	0	0
Apr	0.60	0.24	0.2	0.3	0	0
May	0.18	0.04	0.1	0.2	0	0
Jun	0.02	0.00	0.3	0.3	2	2
Jul	0.00	0.00	0.4	0.5	12	13
Aug	0.01	0.00	0.5	0.5	5	6
Sep	0.01	0.00	0.3	0.3	3	3
Oct	0.03	0.01	0.1	0.2	1	1
Nov	0.16	0.01	0.1	0.2	0	0
Dec	0.25	0.12	0.1	0.2	0	0

Note: for definitions of Q_{Supply} and $Q_{Reserve}$ see section 3.4.2.
*cubic metres per second
**litres per second

3.5.5.2 Stress Assessment for 2-Year and 10-Year Droughts

Water availability is decreased during drought periods. Precipitation depth for the two drought periods are summarized in Table 3-32 earlier. The 2-year drought calculation (Nov 1962 – Oct 1964 water years) shows a decrease in water availability to 700 millimetres on average across the Quinte Region. Water availability during the 10-year drought (Nov 1956 – Oct 1966) rises to 780 millimetres across the region.

To determine stress on the subwatershed during drought periods the impact of the drought on the lake levels must be forecast and compared to the known elevations of the intake structure. Only a Moderate or Low stress can be assigned. A Moderate stress would be indicated if the intake is exposed or pumping must be suspended during the drought.

The exact elevation of the intake could not be confirmed by the municipality. However, they were able to provide the length and size of the intake pipe and by comparing to the bathymetry data, the elevation of the invert is estimated to be 3.0 metres below top of water (at time of survey water level was 110.54 metres above sea level (masl)) and obvert would be 1.93 masl below top of water. The critical water elevation is then 110.54 – 1.93 = 108.6 masl. If the water level approaches this elevation the municipality would experience difficulty with supply.

Roblin Lake was modelled within the hydrologic model for the two drought conditions as well as for the average conditions. An estimate of lake level was provided based on the dam settings for winter and summer conditions. The following figures (Figure 3-13, Figure 3-14, and Figure 3-15) show the estimated lake levels for Average, 2-year and 10-year drought conditions respectively. Lowest mean water elevation is experienced during the months of September or October reaching as low as 109.9 masl in October during the 2-year drought. This is about 1.3 metres higher than the estimated top of the intake structure.

Water usage from the lake must also be considered in determining if the intake would be exposed. A conservative approach would be to look at raw water withdrawals from the lake. The monthly totals were provided in Table 3-36. The total depth of water withdrawal is determined by dividing raw water withdrawal by the lake area of 1 square kilometre. Amounts would be in the 2-3 millimetres range for the highest monthly water taking in August. Again, a conservative approach would be to consider the annual withdrawal and subtract this amount from the total depth of water over the intake found above. Annual withdrawal totals 23,400 cubic metres. This is in the order of 25 millimetres depth over the lake. With the annual water usage considered during existing and future conditions the cover over the intake would be above 1.28 metres.

The mean values represent mean monthly water level. Upper and lower lines on the charts show the maximum and minimum lake level determined from the hourly simulations. These are provided to ensure fluctuations of high and low days within the mean would not expose the intake. Recalling the critical elevation is 108.6, one can see from Figure 3-14 and Figure 3-15 that the intake is not exposed, nor would the pumping need to cease at the treatment plant during either of the two drought scenarios.

A Low stress for drought conditions is indicated.

Table 3-36: Monthly Average Raw Water Withdrawals at Ameliasburgh Intake (2006 – 2008)

04-P-4024	J	F	M	A	M	J	J	A	S	O	N	D
Permitted Taking	10800	10800	10800	10800	10800	10800	10800	10800	10800	10800	10800	10800
Actual Current Taking	2084	1843	1832	1698	1999	2057	2125	2667	1766	1715	1714	1896
Actual Current Consumptive	417	369	366	340	400	411	425	533	353	343	343	379
Future Consumptive	479	424	421	391	460	473	489	613	406	395	394	436

Note: All units are in cubic metres

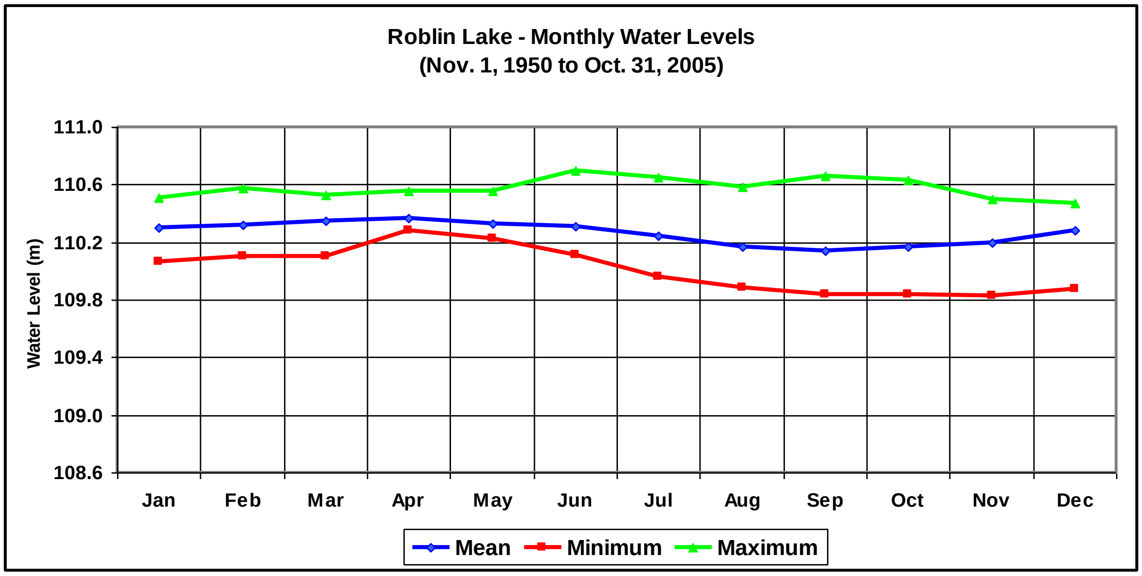


Figure 3-13: Roblin Lake Level – Average Hydrologic Conditions

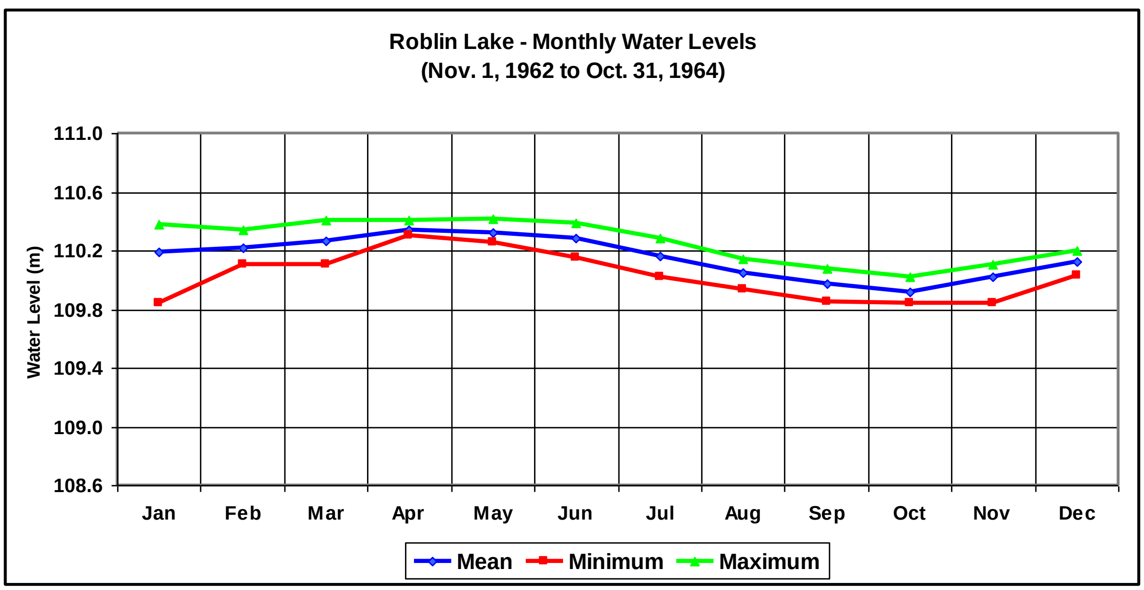


Figure 3-14: Roblin Lake Level – 2-Year Drought

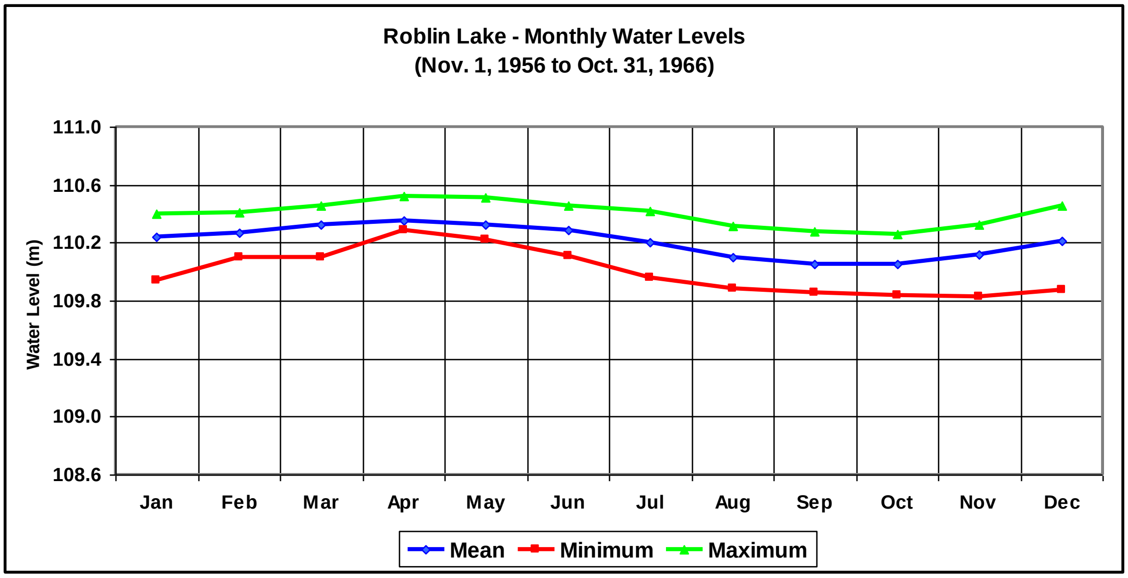


Figure 3-15: Roblin Lake Level – 10-Year Drought

3.5.6 Uncertainty

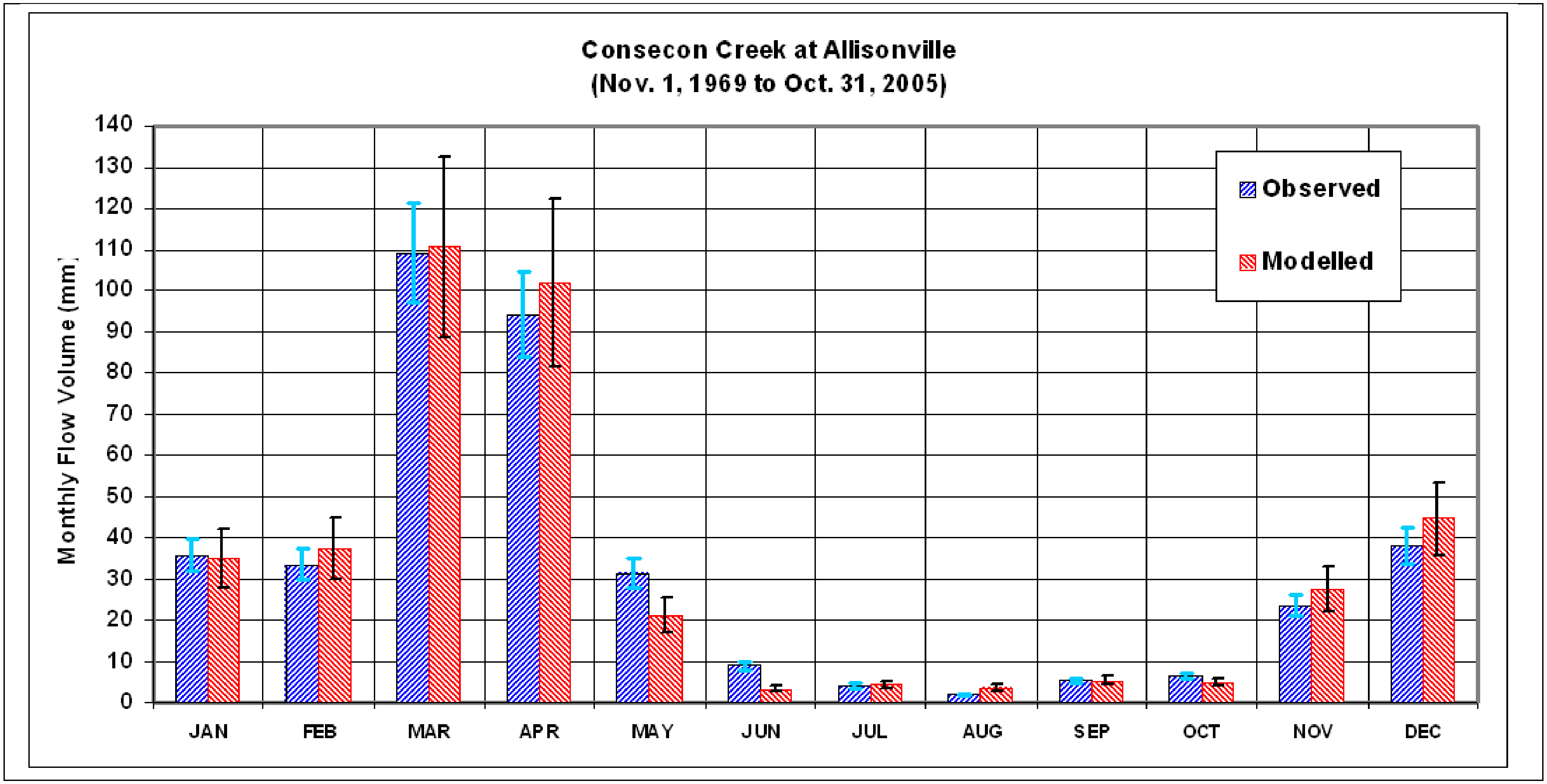
Uncertainty of the results is a product of the data input and the model's capabilities to accurately reproduce the subwatershed response. The uncertainty was reviewed by two means. The first was by statistical computations within the model and some hand calculations. Flows generated from the model are reported to have an error of ± 23 percent. The results are presented graphically in

Figure 3-16 including the calculated error represented by the 'whiskers'.

The second method was by comparison to other gauges in Prince Edward County. The modelled outflows for Sawguin Creek were derived in part from Consecon Creek flows as the calibration gauge. There was close agreement with the outflows. The median and reserve flows generated by the model for Sawguin Creek are small values and stress calculations are quite sensitive to small variations in such low flow values. This method is derived from Hydrology of Floods in Canada (Appendix C3) and is intended for inter-basin transfer between sites within 0.5 to 2.0 times the gauged area, but is used here between basins for information purposes only.

Basin Transfer: $Q_2 = Q_1 * (A_1/A_2)^n$

Where:
Q_1 is flow at gauged station
Q_2 is flow at area of interest
A_1 is flow at gauged station
A_2 is flow at area of interest
$n = 0.9$



Note: Results are based on the Refined Mountainview Climate Data and Additional Parameter Adjustments.

Figure 3-16: Measured and Modelled Monthly Flow Volumes for the Consecon Creek at Allisonville Gauge

Table 3-37 contains the summary of the comparisons between gauged stations and the station of interest at Sawguin Creek.

Table 3-37: Calculated Median Flows (cubic metres/second) for Sawguin Creek (Basin Transfer Method)

Gauge Station	Consecon		Bloomfield		Demorestville		Method 2: Sawguin Projected Flow Using Basin Transfer				
Area (km^2)	116.9		13.9		29.3					Average	
	Flow	Flow/ km^2	Flow	Flow/ km2	Flow	Flow/ km2	Con	Bloom	Dem	All	Excl Bloom
January	1.21	0.010	0.16	0.012	0.23	0.008	0.646	0.478	0.366	0.496	**0.506**
February	1.05	0.009	0.17	0.013	0.36	0.012	0.560	0.510	0.580	0.550	**0.570**
March	5.07	0.043	0.46	0.033	1.56	0.053	2.705	1.350	2.518	2.191	**2.611**
April	3.66	0.031	0.37	0.027	1.06	0.036	1.950	1.095	1.704	1.583	**1.827**
May	1.22	0.010	0.14	0.010	0.29	0.010	0.648	0.396	0.462	0.502	**0.555**
June	0.28	0.002	0.06	0.004	0.04	0.001	0.150	0.167	0.070	0.129	**0.110**
July	0.03	0.000	0.03	0.002	0.01	0.000	0.016	0.079	0.016	0.037	**0.016**
August	0.01	0.000	0.02	0.001	0.00	0.000	0.003	0.056	0.002	0.020	**0.002**
September	0.01	0.000	0.02	0.001	0.00	0.000	0.003	0.048	0.002	0.018	**0.002**
October	0.03	0.000	0.04	0.003	0.00	0.000	0.013	0.107	0.006	0.042	**0.010**
November	1.01	0.009	0.10	0.007	0.05	0.002	0.539	0.296	0.086	0.307	**0.312**
December	1.31	0.011	0.14	0.010	0.23	0.008	0.699	0.419	0.365	0.494	**0.532**
						A1/A2	0.456	**3.8**	1.819		

Consecon Creek and Demorestville Creek produced results that more closely agreed to the modelled flows. Bloomfield Creek produced comparatively high flows. This gauge was known to experience backwater conditions at the low flow weir that were influenced by weed and debris accumulation and values are not believed to be reliable[1]. Bloomfield Creek has dissimilar geology with 84 percent of the watershed having medium to highly drained soils, whereas Demorestville, Consecon and Sawguin have values of 45 percent, 54 percent, and 59 percent medium to highly drained soils respectively (refer to Table 3 cited in Ameliasburgh Tier 2 Water Budget Report in Appendix C3). Results were averaged for all three stations and also for just the Consecon and Demorestville stations. Bloomfield results were ignored.

By these methods August flows for Sawguin Creek would be less than those derived by the model. Stress calculated based on the basin transfer method would be in the order of 22 percent for average current water use and 25 percent

[1] personal communication with Mr. Jim Millman, Water Survey of Canada

for future water use which is in the Moderate stress category (refer to Table 3-15).

The results of the uncertainty calculations would not change the Low stress assignment for the Sawguin Creek subwatershed. According to the Technical Rules, all of the three following conditions must be satisfied for a Moderate stress to be assigned:

1. Stress for average hydrologic conditions must be between 18 percent and 20 percent;
2. Uncertainty must be High; and
3. A sensitivity analysis must suggest the stress level could be Moderate.

The first condition fails since the stress calculation reveals 12 percent and 13 percent stress under current and future water use conditions respectively.

Based on the foregoing and despite a calculated uncertainty of 23 percent, there is sufficient variation in the potential flow results to assign a High uncertainty to the results of the stress assessment.

3.5.7 Ameliasburgh Tier 2 Water Budget Conclusions

A detailed continuous model was developed based on the Guelph All Weather Sequential Event Runoff platform to assist the investigation by providing an estimate of monthly water availability for each area of study. The model also provided water budget summaries for average, 2-year drought and 10-year drought hydrologic conditions.

Model runs were enhanced by using continuous meteorological data derived from Meteorological Services of Canada station at Mountainview for the period between 1950 and 2008. Drought years were selected by averaging the records across the Quinte Region to determine the periods with the two lowest back to back precipitation years (1963-1964) and ten lowest back to back precipitation years (1957-1966).

Results are reported for the Sawguin Creek drainage area where Low Stress is indicated for average, 2-year drought and 10-year drought conditions. Future water demand was also investigated. It was determined that water demand for Prince Edward County is expected to increase 15 percent by 2021. The stress on the water supply was found to also be Low during future water demand. Map 3.15 shows Tier 2 water budget surface water stress results for the watershed is Low.

3.6 Village of Madoc Tier 2 Water Budget

A Tier 2 water budget was completed for the Tweed subwatershed containing the Village of Madoc wells. This entailed the development of a computer based three dimensional groundwater flow model to assess groundwater flows and levels in the subwatershed. To assist in this work and development of a groundwater flow model, Quinte Conservation engaged the services of Schlumberger Water Services (SWS) formerly Waterloo Hydrogeologic Inc. The objective of this work may be described as follows:

- Evaluate the percent water demand (monthly and annual) for the subwatershed and ability of the municipal wells to meet demand under drought conditions; and
- Based on the results of assessment assign the subwatershed a groundwater stress level of Significant, Moderate or Low.

To meet the above objectives the following activities were completed in respect of the Ministry of the Environment Technical Rules:

- Determine the appropriate area of study for development of a groundwater flow model;
- Determine average and drought climate conditions for the study area
- Review water use in the subwatershed and project future rates of water use at the municipal wells;
- Apply the model to assess the percent water demand (current and future) in the subwatershed and ability of the municipal wells to meet demand under drought conditions (2 and 10-year scenarios) ;
- Assign the subwatershed a stress level of significant, moderate or low in accordance with the Ministry of the Environment Technical Rules; and
- Assess the degree of uncertainty associated with the model used to assess the water budget.

3.6.1 Study Area

The study area is based on the original subwatershed (Tweed) as used at the Tier 1 level but has been refined to be more representative of the aquifer system containing the Village of Madoc wells. The study area as illustrated by Map 3.14 covers approximately 278 square kilometres.

3.6.2 Climate Conditions

For the Tier 2 exercise consideration of the following climate conditions was required:

- Average Climate - assessed for the period of 1971-2000;
- 2-Year Drought - a simulated period with no groundwater recharge; and
- 10-Year Drought - continuous ten year period for which precipitation record exists with the lowest mean annual precipitation.

Climate data as collected and processed for the Conceptual and Tier 1 water budgets was used for determination of climate conditions in the study area. From this data the Geographic Information System water budget model was used to assess the distribution of precipitation and evapotranspiration across the watershed under average climate conditions for the 1971-2000 period as well as for the 10-year drought.

For the 2-year drought period no climate data was required since the rules require the assumption of no recharge (no precipitation). For the 10-year drought period, climate station data was reviewed for a total of 36 climate stations. From this review the 10-year drought was determined as the period from 1956-1965 with a mean annual precipitation of 718 millimetres. This period was also confirmed through review of stream flow records available for the Foxboro stream gauge.

3.6.3 Recharge

Completion of this level of work required development of a groundwater model which would reflect monthly variations in recharge therefore it was necessary to assess the monthly distribution of groundwater recharge as predicted at the Tier 1 level. This was completed through use of data for Provincial Groundwater Monitoring Wells located in the vicinity of the Tweed subwatershed. Through a review of the water level data from 2003/07 the monthly distribution of groundwater recharge was determined as illustrated by Figure 3-17 and summarized in Table 3-38.

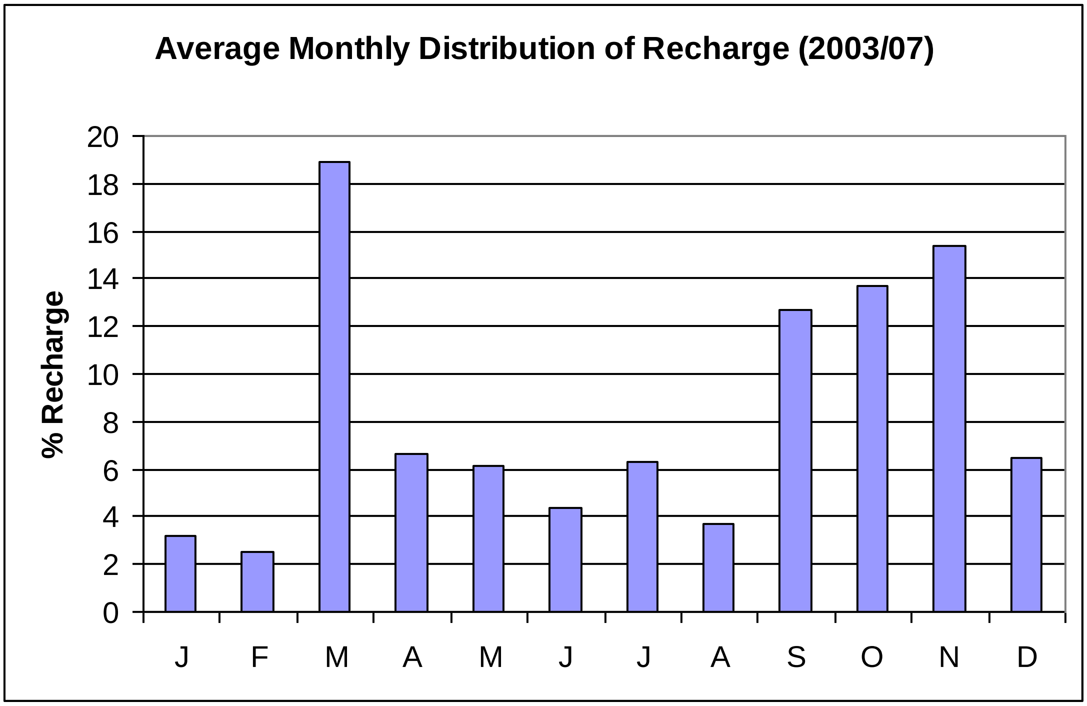


Figure 3-17: Average Monthly Distribution of Recharge for Tweed Subwatershed (2003/07)

Table 3-38: Average Distribution of Recharge in Percent Tweed Subwatershed (2003/07)

Month											
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
3	2	19	7	6	4	6	4	13	14	15	6

3.6.4 Municipal Wells

The Village of Madoc obtains supply from two wells referred to as the Whytock and Rollins wells. The supply wells are located on the west side of the Village, one at the north (Whytock Well) and the other (Rollins Well) at 600 metres to the south, as illustrated by Map 2.3. Deer Creek is located approximately 150 metres to the east of both wells, flowing from the north through the middle of the Village into Moira Lake. Given the close proximity of the wells to the Creek, they are classified as GUDI (Groundwater Under the Direct Influence of Surface Water).

Water supply to the wells is obtained from a Precambrian aquifer with the Rollins well drilled to a depth of 49 metres and the Whytock well to 90 metres. The Rollins well is used to provide the majority of the supply and the Whytock well is secondary, with water use as summarized in Table 3-39. Water quantity problems were reported in 2007. This was a result of a decline in water levels at the Rollins well as illustrated by Figure 3-18 which is a hydrograph of the water levels in this well. However, the water use is also graphed showing a marked increase for this well during 2007. This rate of use was approximately double the current and future rates but less than the permitted.

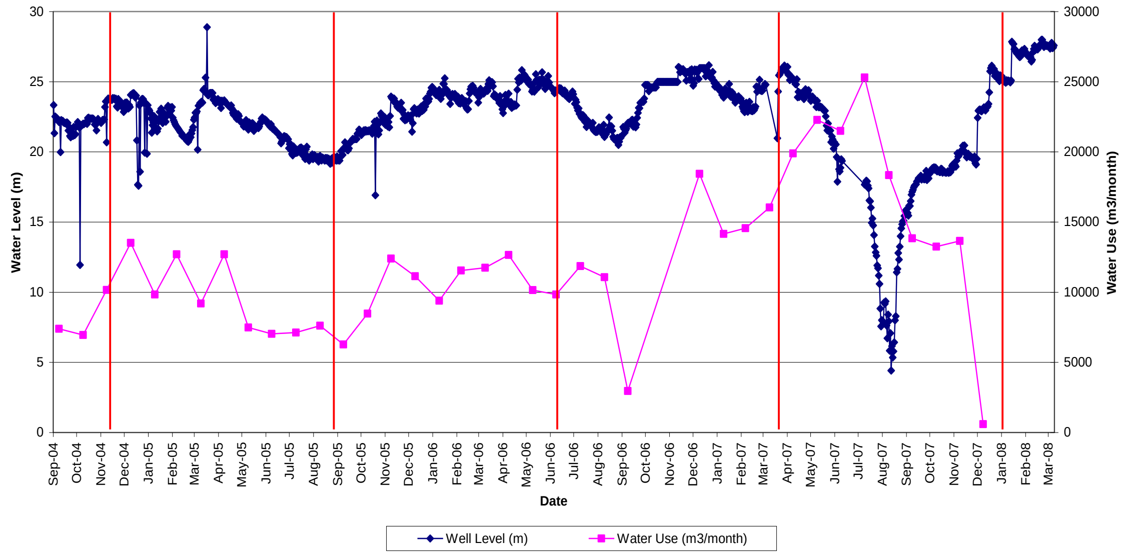


Figure 3-18: Hydrograph and Water Use of Rollins Well (data provided by the Ontario Clean Water Agency)

Table 3-39: Village of Madoc Water Use

Demand	Whytock	Rollins	Total
Actual	257	325	582
Future	303	384	687
Permitted	818	1469	2287

Note: All units are in m3/day

3.6.5 Water Demand

The water demand for the subwatershed was determined based on information taken from the Tier 1 water budget report as previously described. A summary of the water use in the subwatershed is provided by Table 3-40 and Figure 3-19. For future pumping only the rates for the municipal wells were increased in view of growth projections of the official plan for Hastings County.

Table 3-40: Tweed Subwatershed Water Use with Consumptive Factors

Water Use Category	# of Wells	Consumptive Factor	Total (m^3/day*)
Domestic Wells	701	0.2	73.6
Agricultural Wells	68	0.8	103.6
Municipal Wells	2	1	582
Permit to Take Water	9	0.25-1	1606

*cubic metres per day

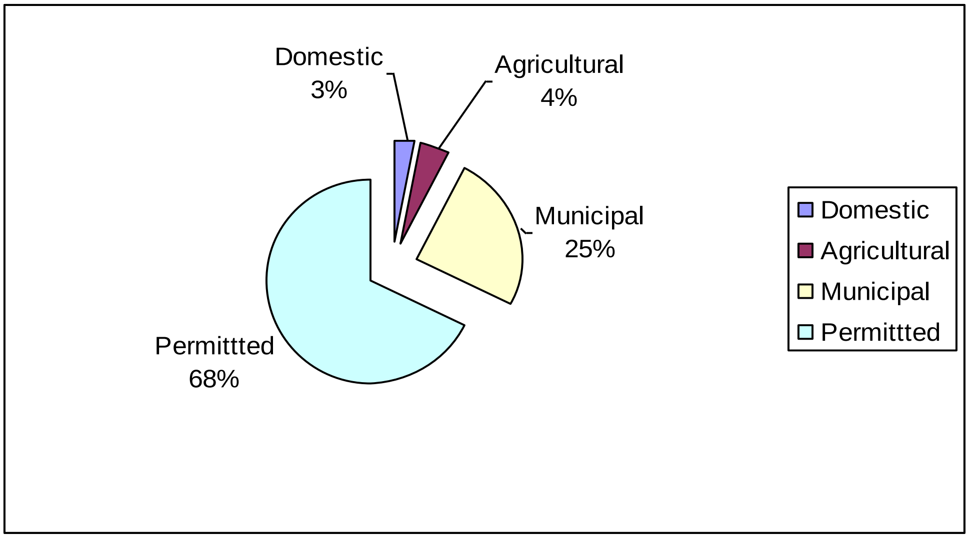


Figure 3-19: Distribution of Water Use in Tweed Subcatchment

3.6.6 Groundwater Model Results

A three dimensional numeric groundwater flow model was developed and calibrated using the available information about hydrogeologic conditions of the area. Much of the information was taken from previous hydrogeologic modeling completed for the assessment of the Wellhead Protection Area as discussed in Chapter 5. A summary of the model parameters are listed in the Madoc Tier 2 Water Budget Draft Report (Appendix C4).

For the Tier 2 water budget exercise the Technical Rules prescribe a number of scenarios which require completion prior to assigning a hydrologic stress of Significant, Moderate or Low to the subwatershed. These scenarios are summarized as follows:

- Scenario A: Current water demand under average climate conditions;
- Scenario B: Future water demand under average climate conditions;
- Scenario D: Current water demand under 2-year drought climate conditions;

- Scenario E: Future water demand under 2-year drought climate conditions;
- Scenario G: Current water demand under 10-year drought climate conditions; and
- Scenario H: Future water demand under 10-year drought climate conditions.

In accordance with the Technical Rules, completion of the above scenarios requires percent water demand calculations for the subwatershed under scenarios A and B and comparison of the ratios with the thresholds listed in Table 3-41. The percent water demand is calculated using the same equation as listed for groundwater under the Tier 1 water budget. Completion of scenarios D, E, G, and H require assessment of the ability of the municipal wells to meet water demand. Should the wells not be able to meet demand then the subwatershed is assigned a Moderate level of stress.

In all cases if the subwatershed is assigned a Moderate or Significant level of stress then further work at the Tier 3 level is required. The other requirement for proceeding to Tier 3 is if there is historic evidence that a municipal well was pumped dry and was not able to meet demand as previously described.

Table 3-41: Tier 2 Groundwater Stress Thresholds (Percent water demand)

Ground water Quantity Stress Assignment	Average Annual	Monthly Maximum
Significant	> 50%	>25%
Moderate	>25-50%	>10-25%
Low	0-25%	0-10%

3.6.7 Results

The result of the percent water demand calculations for scenario A or B are listed in Tables 3-41 and 3-42. From this assessment the maximum monthly percent water demand was determined to be 4.6 percent and the annual was 4.2 percent. In accordance with the threshold values this level of demand correlates to a Low level of subwatershed stress as illustrated by Map 3.16. As regards to scenarios D, E, G and H, (2 and 10-year droughts) scenarios E and H were completed and indicated the wells were able to meet demand, thus signifying a Low level of stress. However, scenarios D and E (2-year drought) were not completed as per reference to the Ministries of the Environment and Natural Resources, Technical Bulletin Water Budget and Water Quantity Risk Assessment Tier 2 Subwatershed Stress Assessment Groundwater Drought Scenarios (July, 2009). This bulletin indicates that if the ten year drought scenario is completed first and the stress level is assigned as low then the 2-year drought scenario does not need to be completed. Of potential concern from evaluation of the drought scenarios was that the model indicated increased influence from the creek to maintain pumping conditions. Further work would be required to quantify this volume and determine if there is potential impact on water levels in Deer Creek.

Table 3-42: Current Percent Groundwater Demand, Tweed Subwatershed Average Climate

Month	Recharge (m^3/day*)	Pumping (m^3/day*)	Baseflow (m^3/day*)	Water Demand (%)
January	56933	1993	62286	3.9
February	56933	1935	62286	3.8
March	56933	2099	62286	4.1
April	56933	1983	62286	3.9
May	56933	2021	62286	4.0
June	56933	1918	62286	3.8
July	56933	2141	62286	4.2
August	56933	2210	62286	4.4
September	56933	2219	62286	4.4
October	56933	1733	62286	3.4
November	56933	1911	62286	3.8
December	56933	1876	62286	3.7
Average	56933	2003	62286	4.0

*cubic metres per day

Table 3-43: Future Percent Groundwater Demand, Tweed Subwatershed Average Climate

Month	Recharge (m^3/day*)	Pumping (m^3/day*)	Baseflow (m^3/day*)	Water Demand (%)
January	56933	2116	62181	4.2
February	56933	2048	62181	4.0
March	56933	2240	62181	4.4
April	56933	2093	62181	4.1
May	56933	2138	62181	4.2
June	56933	2017	62181	4.0
July	56933	2229	62181	4.4
August	56933	2311	62181	4.6
September	56933	2322	62181	4.6
October	56933	1798	62181	3.5
November	56933	2009	62181	4.0
December	56933	1978	62181	3.9
Average	56933	2108	62181	4.2

*cubic metres per day

While the assignment of a Low level of stress to the subwatershed under scenarios A, B, G and H, the fact remains that one of the municipal wells was pumped dry in 2007. This circumstance triggers a Moderate level of stress. However, further assessment of the circumstance has indicated that it was due to an operational issue and not an issue with the source water supply. This was attributed to increased demand on the Rollins Wells as a result of taking the other well (Whytock well) offline due to a water quality problem, and a problem with the water treatment system (at the Rollins Well) which allowed significant volumes of water to be pumped to waste. An illustration of the increased water use and decrease in water levels at the Rollins Well is provided by Figure 3-18. Discussion with the municipality about this situation has indicated that the problems have been rectified and they have not experienced any water shortages since then. The rate of taking from this well was in excess of the committed demand which is required to meet future needs but also less than as allowed by the permit to take water.

3.6.8 Uncertainty

A numerical groundwater flow model is a representation of hydrogeological and physical conditions based on a set of assumptions and available data. Therefore, a model must be recognized as having limitations and uncertainty. According to Technical Rule 36, uncertainty of the modeling results must be classified as high or low. Uncertainty in a numerical flow model is generally reflective of the quality of the data used to develop the model, the amount of data available, the complexity of the physical system and the complexity of the numerical model. There is a great deal of regional data available for the subwatershed; however, it is not of the highest quality. The data available for the immediate vicinity of Madoc is of much higher quality; therefore, in this region of the numerical model there is greater certainty about the simulation results.

The model indicates that the projected pumping rates at Rollins and Whytock would be sustainable. However, for the 10-year drought conditions, the certainty of the model results is lower. Under these conditions, it is likely that not only would the amount of recharge be affected but the levels in the many creeks, ponds and lakes close to Madoc would also be reduced. At this time, the model does not include this information, due to lack of availability of the data. Therefore, it would be prudent to recognize that although the simulations indicate that pumping at current and future demand would be sustainable, there is the possibility that one or both of the wells might run dry under lengthy drought conditions. Based on the quality of the data the model was assigned a high uncertainty. In spite of this assignment the actual uncertainty is considered low given that under realistic conditions the wells have been shown to meet the water demands of the community and previous assessment of the percent water demand at the Tier 1 level also provided a low stress assessment.

3.7 Future Work

A water budget has been completed for the Quinte Source Protection Region to provide an understanding of the volumes of water and how it moves through the watershed. Conceptual and Tier 1 water budgets were completed for the entire Quinte Region. Using the prescribed methodology a total of six subwatersheds, the majority in Prince Edward County, were assigned either Moderate or Significant surface water stress. Two subwatersheds were also assigned a Moderate groundwater stress level on an annual time basis. From this assessment it was speculated that much of the potential stress was attributed to inaccuracies in data taken from Permits to Take Water such as the source of water and volume of taking. In addition, this assessment did not reveal high levels of groundwater stress for Prince Edward County levels where it is known that many wells routinely run dry during the dry summer months and sometimes in winter under prolonged frozen ground conditions. Improvements to the Permit to Take Water process and water budget assessment are required to provide a better understanding and management of the water resources.

From the initial Tier 1 work the Ameliasburgh subwatershed in Prince Edward County was recommended for Tier 2 surface water study. The Tweed subwatershed, containing the Village of Madoc wells, was also recommended for Tier 2 work due to water shortage problems experienced in the summer of 2007. Development of complex numeric flow models indicated that both areas did not need to proceed to the Tier 3 level. At Ameliasburgh, refinement of the volumes of water taking (Permits to Take Water) in the subwatershed reduced the percent water demand to a Low stress level. For Madoc, the Low subwatershed stress identified at the Tier 1 level was confirmed and the wells were indicated as being able to meet demand under theoretical drought conditions. However, this work indicated potential for increased contribution from nearby surface water to maintain pumping at the wells. Further work would be required to assess potential impact on Deer Creek under drought conditions. This work also revealed that the water shortage problems at Madoc in the summer of 2007 were a result of increased water use at one of the wells due to operational problems as opposed to the source of supply.

3.8 Prescribed Drinking Water Threats – Water Quantity

There are two Prescribed Drinking Water Threats related to water quantity (see Table 3-44) which can only exist if work proceeds to a Tier 3 Water Budget Level.

No municipal drinking water systems proceeded to a Tier 3 level of investigation and therefore no threats were identified for water quantity.

Table 3-44: Prescribed Drinking Water Threats – Water Quantity

Prescribed Drinking Water Threat		Land Use Activities
1	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.	Irrigation, Water Bottling, Manufacturing etc.
2	An activity that reduces the recharge of an aquifer.	Land use changes such as parking lots, highways, and buildings

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4 Methodology for Vulnerable Areas and Water Quality Risk Assessment

4.1 Introduction

This chapter provides a description of the methodologies that have been followed to delineate the location of vulnerable areas, and assess risks to water quality in the Quinte region. To streamline the process the location of vulnerable areas and threats were identified in areas where the source water is deemed most sensitive to pollution and/or overuse. For the purpose of the *Clean Water Act, 2006*, these vulnerable areas are either related to groundwater resources on a broad scale, or to groundwater and surface water around municipal drinking water sources (i.e. wells and surface water intakes).

There are four main types of vulnerable areas:

- **Highly Vulnerable Aquifers** are those water bearing formations that are highly susceptible to contamination. This vulnerability is dependent on a number of factors such as how deep the groundwater is located underground, the type of soil or rock above it, and how easy it is for water to move from the ground surface to the aquifer. Identification of such areas in the Quinte watershed was completed by use of the Intrinsic Susceptibility Index which considers the above factors and measures the susceptibility of the groundwater to being polluted by surface water moving from the surface into the underlying aquifer. Typically these areas within the Quinte region have underlying fractured bedrock.
- **Significant Groundwater Recharge Areas** are areas of the watershed where higher volumes of precipitation can infiltrate the ground than the surrounding lands. In the Quinte watershed recharge typically occurs throughout, however significant groundwater recharge areas have been identified as those parts of the watershed where higher volumes of groundwater are able to infiltrate and recharge the local aquifers. These areas are not as vast as the highly vulnerable aquifers and are typically associated with significant deposits of sand and gravel.
- **Wellhead Protection Areas** are delineated zones around municipal wells where groundwater moves toward the well within a specified period of time. The closer to the well the higher the vulnerability. There are four municipal groundwater systems in the Quinte region with Wellhead Protection Areas as discussed in Chapter 5.
- **Surface Water Intake Protection Zones** are areas of land and water delineated around the end of the municipal intake pipes. These zones are

typically determined by the amount of time it would take for a spilled material to reach the water intake. There are seven municipal surface water systems which are discussed in detail in Chapter 6.

After determining the location of these vulnerable areas each is given a score to show how vulnerable the area is to contamination. These scores range between 2 and 10 with the higher the score meaning the more vulnerable the area is to contamination. Vulnerability scores are typically determined by how fast a contaminant may reach a municipal well or intake. This information is then considered in the water quality risk assessment through the assessment of threats to water quality and whether a specific threat is considered to be of Significant, Moderate or Low priority. An outline of the methodology on how the vulnerable areas were delineated, scored for vulnerability and assessed for water quality threats is provided below.

4.2 Groundwater Vulnerability

In the Quinte Source Protection Region there are three main types of vulnerable groundwater areas. These include:

- Highly Vulnerable Aquifers
- Significant Groundwater Recharge Areas
- Wellhead Protection Areas

A description of how these areas were delineated and scored for vulnerability is provided in Sections 4.3 to 4.5.

4.3 Highly Vulnerable Aquifers

Highly vulnerable aquifers are those sources of groundwater that may be easily contaminated. An illustration of such an aquifer is provided in Figure 4.1. There are several factors used to determine the vulnerability of an aquifer such as the depth of the aquifer, what sort of soil or rock is covering it, and the characteristics of the surrounding soil or rock. Deep aquifers that are covered by thick deposits of clay have a relatively low vulnerability whereas shallow aquifers in fractured bedrock with thin to absent soil cover would be indicative of a more vulnerable aquifer. Therefore, the faster and easier it is for a contaminant to move from the ground surface into an aquifer, the higher the vulnerability.

Groundwater in the Quinte Source Protection Region is commonly found in fractured bedrock aquifers which include Precambrian and Limestone bedrock. This bedrock is typically heavily fractured in the upper 10 to 30 metres and overlain by a thin layer of soil. Under these conditions, the aquifers can be considered highly susceptible to contamination. In some cases wells in the Quinte region reach depths in excess of 30 metres. Under such conditions the aquifer may not be as susceptible to contamination due to a decrease in permeability of the bedrock with depth. However, in the absence of discrete confining layers and information to support the presence of these layers this cannot be certain.

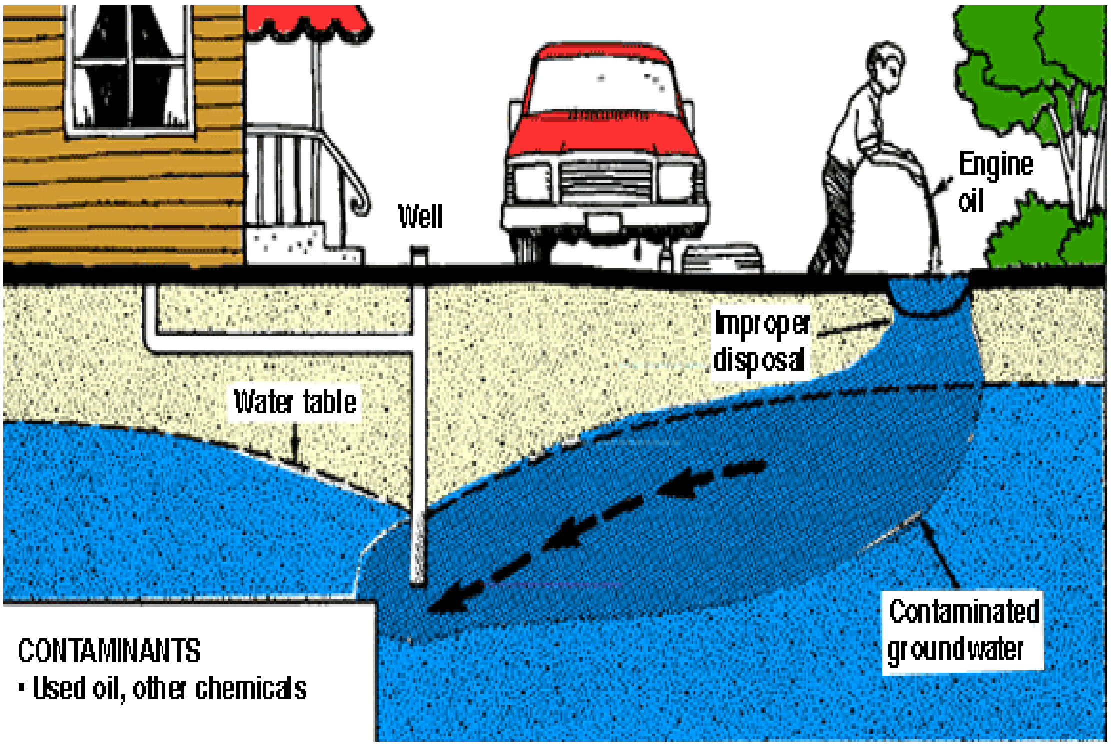

Figure 4-1: Groundwater Contamination of Vulnerable Aquifer

4.3.1 Delineation of Highly Vulnerable Aquifers

There are various methods available to evaluate aquifer vulnerability and delineate highly vulnerable aquifers as described in the Technical Rules (Appendix A-2). The identification and delineation of highly vulnerable aquifers was previously completed through the Quinte Regional Groundwater Study (October, 2004) following methodology outlined in the Ministry of the Environment Terms of Reference (2002). The methodology used is the Intrinsic Susceptibility Index (ISI) which makes use of information taken from the Ontario Water Records to determine aquifer vulnerability at each water well location as follows:

1. Determination of the depth of the water table;
2. Determination of the type of aquifer (unconfined or confined);

3. Determination of the type of geologic material located between the water table and ground surface such that a permeability factor (K Factor) may be applied to each layer;
4. The depth of the geologic material is multiplied by the permeability factor and summed together for all layers above the water table;
5. The final total for each well is the score which is used to determine aquifer vulnerability as follows:

High Vulnerability	- Score < 30
Medium Vulnerability	- Score > 30 and < 80
Low Vulnerability	- Score > 80

6. The above methodology incorporated the assumption that all bedrock aquifers with less than 1.5 metres of overburden, or with overburden that is relatively highly permeable, are unconfined aquifers; and
7. Based on the unconfined nature of the shallow bedrock aquifers and the ISI index all areas with less than 1.5 metres of overburden were mapped as highly vulnerable aquifers.

Following calculation of the index at each location a map of aquifer vulnerability is generated using the Geographic Information System by interpolating between the well record locations and the score at each well. The results of this assessment are presented by showing the entire region as being highly vulnerable to contamination as discussed in Chapter 5. This result is expected given that the shallow soil conditions do not provide significant protection to the underlying fractured bedrock aquifers. A few points were calculated as having moderate vulnerability where the wells intercepted isolated deposits of clay, silt or till. However, the distribution of these low permeability soils is not continuous enough to provide significant protection to the underlying aquifer. A potential limitation to the methodology as described above is that some bedrock wells, encountering water at depth, may be confined or semi confined owing to the permeability of the bedrock itself (i.e. zones of unfractured bedrock). The data taken from the Ontario Water Well Records does not allow determination of zones of unfractured bedrock. The typical method of construction of water wells in the Quinte region as open hole (no casing to isolate different zones in the bedrock) also does not permit the use of hydraulic data for assessment of vertical hydraulic gradients to assist in isolating zones as being confined or unconfined.

4.4 Significant Groundwater Recharge Areas

Recharge to an aquifer is the process that occurs when rain or melted snow infiltrates the ground surface and continues to migrate to the water table and underlying aquifers. The land area where the rain or snow seeps into the ground and enters an aquifer is called a recharge area, illustrated in Figure 4.2. In the Quinte Source Protection Region, given the absence of significant low permeability soil layers, this recharge process occurs throughout. However, areas where higher volumes of recharge can infiltrate and recharge the local aquifers are referred to as Significant Groundwater Recharge Areas. Such areas are typically comprised of loose or permeable deposits of sand and gravel which allow the water to easily seep into the ground.

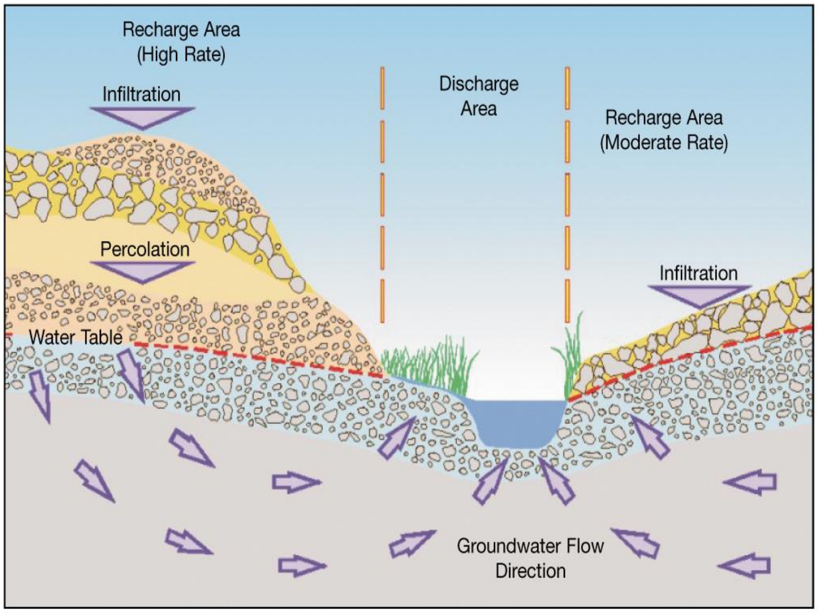

Figure 4-2: Groundwater Recharge

4.4.1 Delineation of Significant Groundwater Recharge Areas

Since recharge occurs throughout the Quinte Source Protection Region, areas of significant recharge are considered to be those locations where higher volumes of water are supplied to an aquifer used for drinking water than is contributed by the land around it. To delineate these areas, consideration is given to three main physical features of the region: topography, land cover, and soil permeability. Topography is a factor in determining amount of runoff. Areas of steep topography promote water to run off quickly, decreasing the chance for significant infiltration. Land cover affects the interception of precipitation and slows down the rate of runoff, allowing the water a chance to infiltrate. Soil permeability is the last significant factor to affect recharge as the more permeable the soil, the higher the infiltration.

To assist in identifying areas of the watershed where significant groundwater recharge could occur, a GIS model was developed (as described under the Conceptual Water Budget Section 3) to determine the water budget and calculate infiltration coefficients in respect of land slope, land cover and soil permeability.

Based on the use of this model, areas of significant groundwater recharge were delineated in accordance with Technical Rules *44, 45, and 46* as follows:

1. Areas of the watershed where recharge was more than 55 percent of the volume of precipitation available for infiltration after accounting for evapotranspiration;
2. Screening of areas less than one square kilometer that are not considered to be large enough to be significant;
3. Overlay of mapping with water table elevation contours to exclude areas in obvious groundwater discharge zones;
4. Overlay of mapping with glaciofluvial deposits of sand and gravel such as eskers, as well as other notable formations such as a kame moraine, to exclude modern alluvial deposits of sand and gravel as well as other minor deposits; and
5. Overlay of mapping with cold water streams and wells to determine hydrological connection to a surface water body or aquifer that is a source of drinking water for a drinking water system using water from these areas.

4.5 Wellhead Protection Areas

A Wellhead Protection Area is the zone around the well that includes the land above and below ground where land use activities have the potential to affect the quality of water flowing towards the well. In the Quinte region these areas have been delineated around municipal drinking-water wells. There are four such areas in the Quinte Source Protection Region where municipal groundwater supply systems exist. These systems (shown on Map 2.3) are listed as follows:

- Village of Madoc – 2 wells
- Village of Tweed – 2 wells
- Village of Deloro – 1 well
- Peats Point Subdivision – 1 well

All of these systems obtain water from aquifers located in fractured bedrock that are recharged by rain and melted snow. Since the people of these communities rely on this groundwater for their source of drinking water it is essential to determine areas around the well that need to be protected. An outline of how the Wellhead Protection Areas were delineated is provided below.

4.5.1 Delineation of a Wellhead Protection Area

There are various methods for delineating a Wellhead Protection Area with a range of complexity involved dependent on the amount and quality of available information/data. The basic information which determines the location and size of a Wellhead Protection Area includes the following:

1. The direction in which groundwater moves;
2. The speed or rate at which the groundwater moves; and
3. The volume of water that is pumped from the wells.

Determination of Wellhead Protection Areas requires analysis of hydrogeologic information. This starts with geologic maps to determine the formation the aquifer is located in, as well as tests on the well to determine aquifer parameters such as porosity and hydraulic conductivity. The configuration of the water table and gradient are determined using data from borehole records as well as testing that has been completed on wells located in the aquifer. In addition, local climate data is analyzed to determine the volumes of precipitation available for recharge to the groundwater. From this analysis, flow lines and groundwater velocity around the municipal well can be determined to allow the delineation of various capture zones. Quite often numeric computer models are used to assist in processing the complex data sets and numeric calculations to assimilate the groundwater system being analyzed. The outcome of the model is the identification of flow paths and capture zones around a wellhead based on the length of time it takes water to flow towards the well. These zones, illustrated by Figure 4-3, include WHPA A which is a simple 100 metre radius.

The various zones represent the time it takes for groundwater to move towards the well. The farther away from the well the longer it takes for water to reach the well. These zones are important to wellhead protection planning as activities occurring in close proximity to the wellhead could potentially contaminate the water more quickly than activities occurring farther away.

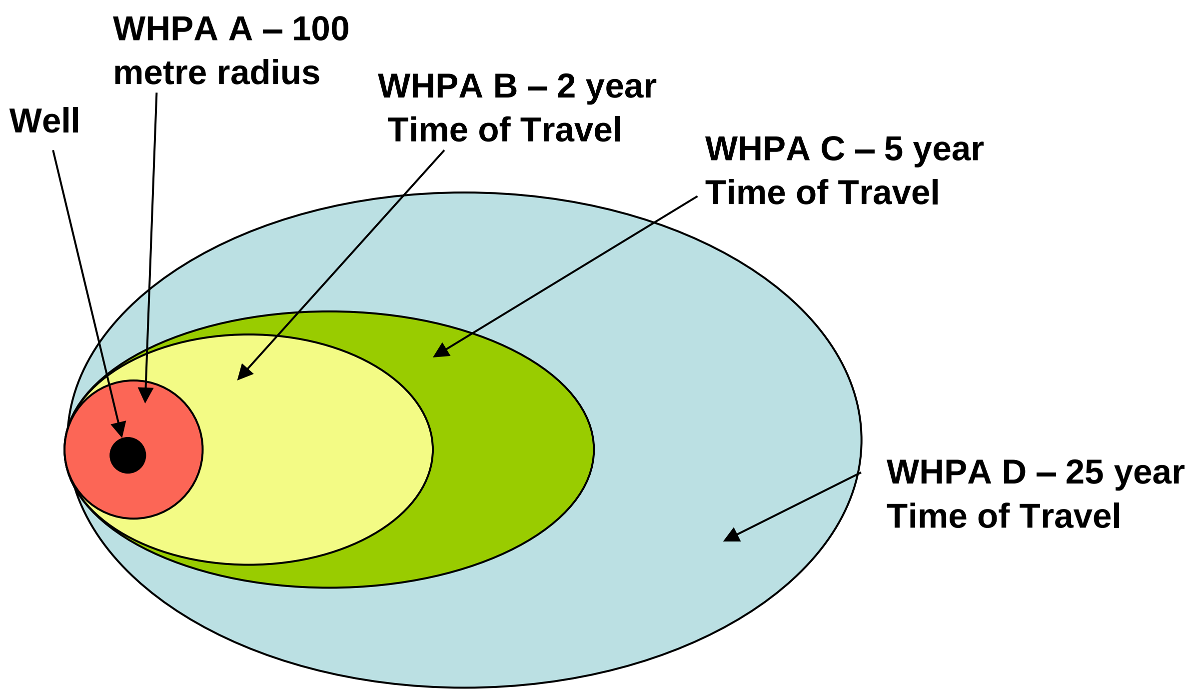

Figure 4-3: Wellhead Protection Area

4.5.2 Wells Influenced by Surface Water

In addition to the delineation of Wellhead Protection Areas described above, some wells and aquifers experience interaction with nearby surface water bodies. In such situations a pumping well that is located in close proximity to a surface water body may cause water from the surface source to be drawn into the aquifer or well. In these situations it is necessary to also delineate zones in the surface water where there is potential for activities to occur that may affect the water quality in the wells. These zones are located up gradient of the point of interaction between ground and surface water illustrated by Figure 4-4 and described below:

- WHPA E – 2 hour or less time of travel in the surface water body from the point of interaction between the surface water body and the groundwater that is the source of supply to well (corresponding with an IPZ 2 for surface water intakes). Where the point of interaction is not known it is chosen as the point in the surface water body that is in closest proximity to the supply well. This zone does not extend more than 120 metres inland from the water body unless a transport pathway exists.

- WHPA F – The area of the watershed contributing water to the point of interaction between the surface water body and the groundwater that is the source of supply to well (corresponding with an IPZ 3 for surface water intakes).

A description of how these zones are determined is provided in Section 4.6 with the Wellhead Protection Area Zone E corresponding to IPZ 2 and Wellhead Protection Area Zone F to IPZ 3 (Sections 4.6.2 and 4.6.3 respectively).

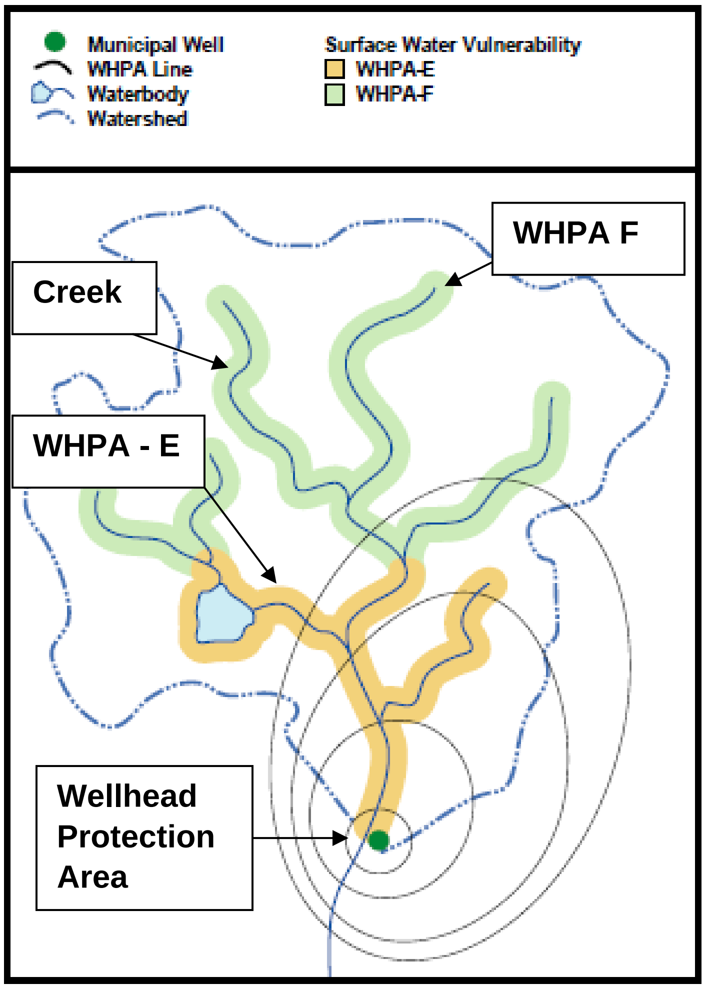

Figure 4-4: Surface Water Protection Zones for Wells Diagram

In the Quinte Source Protection Region there is a strong interaction between ground and surface water. More information about this interaction is provided in Chapter 3 under section 3.3.4.7. Two of the municipal groundwater systems are located in settings where the wells are classified as Groundwater Under the Direct Influence of Surface Water (GUDI). These are the Madoc and Peats Point water well systems where the Madoc wells are located in close proximity to Deer Creek and the Peats Point well is in close proximity to the Bay of Quinte. In these situations it is necessary to determine the zones in the surface water that may be contributing to the groundwater supply through delineation of the 2 hour time of travel in the water body referred to as the Wellhead Protection Area zone E and in some cases where issues exist the total contributing watershed, referred to as the Wellhead Protection Area zone F. These zones are determined in the same fashion around a municipal surface water intake as described in Section 4.6.

4.5.3 Wellhead Protection Vulnerability

The second stage in assessing Wellhead Protection Areas is to determine the vulnerability of these zones or how easily the groundwater may be contaminated. This susceptibility depends on the geology of the area as it relates to how deep the groundwater is found and what type of soil is located above it. For example, a deep sand and gravel aquifer that is covered by a thick deposit of clay is well protected from surface activities. Conversely a shallow aquifer in fractured bedrock with shallow soil is highly vulnerable to contamination.

The vulnerability of the groundwater in the Wellhead Protection Area zones is determined through calculation of the Intrinsic Susceptibility Index (ISI) as previously described under the Highly Vulnerable Aquifer section. Mapping of the ISI is used to determine what the aquifer vulnerability is in each of the Wellhead Protection Area zones with potential scoring listed in Table 4-1. These scores are assigned based on the vulnerability of the aquifer and how close the zone is to the well (i.e. the closer to the well the higher the score). The results of this exercise will be used later in assigning the potential risk for various water quality threats and land use activities that may be located in the Wellhead Protection Area. Note that in the Quinte area the entire region has been assessed as having high aquifer vulnerability, therefore the scores in the first line of Table 4-1 apply to the Wellhead Protection Areas as medium and low vulnerability aquifers do not exist in the Region.

Table 4-1: Wellhead Protection Area Vulnerability Scores

Aquifer Vulnerability	Wellhead Protection Area Zone			
	WHPA A (100 metre)	WHPA B (2 year)	WHPA C (5 year)	WHPA D (25 year)
HIGH	10	10	8	6
MEDIUM	10	8	6	4
LOW	10	6	4	2

Assessment of vulnerability and a score is also required for the Wellhead Protection Zones E and F zone. The methodology for this is as outlined in Section 4.6.

4.5.4 Wellhead Protection Area Constructed Transport Pathways

The vulnerability score within each zone may be increased if there is a substantial concentration of transport pathways within a particular zone. Transport pathways are pathways or shortcuts that may allow contaminants to be transported to the source of drinking water faster than they would otherwise travel. Transport pathways may allow contaminants to bypass the natural protection provided by the geological layers that are above the aquifer of interest, and therefore may enhance the vulnerability of an area. Improperly constructed wells, gravel pits and storm sewers are examples of transport pathways. In this study, the scores were not adjusted based on transport pathways, as there was no area where there was an unusually high concentration of pathways and the vulnerability scores are at the highest level permitted.

A summary of transport pathways and the data sources used to identify them within the Quinte Source Protection Region are listed in Table 4-2.

Table 4-2: Transport Pathway Classes

Category	Primary Data Source
Existing Wells	MOE Water Well Information System Air Photo Review
Abandoned Wells	MOE Water Well Information System Historical Map Review Air Photo Review Municipal/Provincial Records
Pits and Quarries	Air Photo Review MNR Databases
Mines	MNR Databases
Construction Activities	Air Photo Review Windshield Survey
Storm Water Infiltration	Air Photo Review
Septic System	Air Photo Review Municipal Information
Septic Systems	Air Photo Review
Sanitary Sewer Infrastructure	Municipal Mapping

4.6 Delineation of Intake Protection Zones

An Intake Protection Zone is an area of concern or interest around a municipal drinking water intake. It shows the zone around the surface water source that is sensitive to contamination. This area includes the surrounding water and, in most cases, the land that surrounds the water. The zone is determined by a variety of factors such as the time it would take for any materials spilled in or near the water to flow to the water intake. The Intake Protection Zone is delineated according to an established set of rules, determined by minimum distances from the intake or by scientific method.

Up to three zones may be established around an intake. The nearest to the intake is Zone 1 and extending out sequentially are Zones 2 and 3. Each zone provides opportunity for the source protection committee or municipality to apply different levels of protective measures on activities planned or existing within the zone.

Land use activities or open water activities may pose a risk to sources of drinking water; some have the potential to release large volumes of toxic chemicals or pathogens into our drinking water supplies. The Intake Protection Zones are delineated following a methodology able to be replicated across the province to highlight areas of greatest vulnerability to contaminants. Zone 1, closest to the intake, is considered the primary area of protection around the intake. Zones are established based on increasing levels of concern from IPZ 3 to IPZ 2 to IPZ 1.

The establishment of the zones must take into account the hydrologic setting of the intake. Four different intake classifications are used; these are called Types A, B, C, and D intakes and they affect the way Intake Protection Zones are determined. The four classifications have been provincially determined and may not all be present within a source protection region. These are:

- Type A intake has a Great Lake as a source;
- Type B is within a defined connecting channel such as the St. Lawrence or Niagara rivers;
- Type C intake is located in inland rivers; and
- Type D intakes include those in inland lakes or any not classified by Types A, B, or C.

4.6.1 Intake Protection Zone 1

According to the Technical Rules 61 and 62, the following definition for IPZ 1 delineation for includes:

61) An area known as IPZ 1 shall be delineated in respect of each surface water intake associated with a drinking water system described in rules 58 and 59 and shall be composed of the following areas:

1. a circle that has a radius of 1000 metres from the centre point of every intake that serves as the source or entry point of raw water supply for the system, if the intake is a:

a) type A intake;

b) type D intake; or

c) a type C intake to which rule 63 relates;

62) If the area delineated in accordance with rule 61 includes any land, the IPZ 1 shall only include a setback on the land that is the greater of,

1. The area of land, measured from the high water mark[1] of the surface water body where overland flow drains into the surface water body and this area shall not exceed 120 metres; and
2. If a Conservation Authority Regulation Limit is in effect in the IPZ 1, the area of land that is within the Conservation Authority Regulation Limit.

The IPZ 1 is the area immediately adjacent to the intake, and is the primary protection area around the intake. The technique for delineating IPZ 1 for Type D intakes has been defined in principle by the MOE as the area within a circle that has a radius of 1,000 metre centred on the crib of the intake. Where an IPZ 1 extends more than 120 metres onto land from the high water mark of a surface water body, the area of the IPZ 1 on the land is reduced to include only a setback of 120 metres or the regulation limit.

Due to its close proximity to the intake, this zone is considered the most vulnerable, since any contaminant of concern entering this area would have little to no dilution prior to reaching the intake.

4.6.2 Intake Protection Zone 2

Zone 2 is determined with consideration for the time required for the operator of the water treatment plant to respond to an adverse condition in the water, such as a chemical spill. While a minimum of 2 hours is stipulated, longer response times may be recommended by the operating authority. In that period of time, winds, waves, currents, and flow may move the contaminant plume to the intake. The theoretical distance of this movement within two hours is used to establish boundaries of Zone 2. A spill or release of contaminants outside of Zone 2 (within Zone 3) would not be expected to enter the treatment system within the time frame for Zone 2 and would therefore represent the least risk.

It is acknowledged that land use near the shoreline is of most interest and therefore in the establishment of the zones, lands further than 120 metres from the shoreline are excluded. In addition areas further than 120 metres from a waterway such as tile drains, and ditches, known as transport pathways and

[1] There was insufficient data to delineate the high water mark so the Ministry of Natural Resource's shoreline dataset was used as the high water mark.

storm sewer systems that can contribute runoff to the intake within the response time are also included.

Zone 2 is delineated as:

1. The area within each surface water body that may contribute water to the intake where the time of travel to the intake is equal to or less than 2 hours. The 2 hour time of travel may be increased to the time that is sufficient to allow the operator of the system to respond to a spill or other event that may impair the quality of the water at the intake;
2. Where the area abuts land, a setback that is the greater of;
   a) the area of land that drains into the surface water body measured from the high water mark and the area must not exceed 120 metres,
   b) if a Conservation Authority Regulation Limit is in effect in the IPZ 2, the area of land that is within the Conservation Authority Regulation Limit;
3. In respect of every stormwater management works that may contribute water to the intake, the area within the storm sewershed that contributes water to the works where the time of travel to the intake is equal to or less than the time that is sufficient to allow the operator of the system to respond to a spill or other event that may impair the quality of the water at the intake (same time as 1 above);
4. Transport Pathways, either natural or anthropogenic in source, may be included and must consider:
   a) the hydrological and hydrogeological conditions of the area where the transport pathway is located; and
   b) the time of travel for water to enter into and pass through the transport pathway.

4.6.3 Intake Protection Zone 3

Zone 3 is the larger contributing area to the intake. Again, the zone does not extend more than 120 metres inland from a water body unless a transport pathway exists. Activities in this area would generally present less risk to the municipal drinking water, but the zone is established considering some degree of influence on activities may be warranted.

IPZ 3 Delineation for Types C and D intakes in the Quinte region:

1. The area within each surface water body that may contribute water to the intake;

2. A setback on the land that abuts the portion of the surface water body that contributes water to the intake that is the greater of;
    a) the area of land that drains into the surface water body measured from the high water mark and the area must not exceed 120 metres, and
    b) if a Conservation Authority Regulation Limit is in effect in the IPZ 3, the area of land that is within the Conservation Authority Regulation Limit.

Transport Pathways, either natural or anthropogenic in source, may be included and must considerthe hydrological and hydrogeological conditions of the area where the transport pathway is located.

For a Type A intake the surface water contribution is defined differently as the area within each surface water body through which contaminants released during an extreme event may be transported to the intake.

4.6.4 Intake Protection Zone Vulnerability

Once the zones have been determined following principles of science and minimum distance stipulations, the objective is to establish the vulnerability of the intake to contamination. Vulnerability is enumerated in each zone following a scoring system that takes into account the geometry of the intake (distance from shore, depth below surface) as well as intake type. This produces a vulnerability score that is used later to determine the risk of certain activities within each of the zones helping the Source Protection Committee to make decisions on the suitability of those activities.

The zones are delineated irrespective of the depth of the intake below water surface. An intake that is in very deep water would be less vulnerable to contaminants than one very near to the surface. Similarly, an intake closer to shore would be more vulnerable to contamination than one that is far from shore.

The Intake Protection Zones and corresponding vulnerability are repeated for each municipal intake in the source protection region/area. Complete detailed analyses are available in Appendix F of the DVD found in the back of the Assessment Report.

The methodology used to calculate vulnerability scores varies by intake type but is consistent for each in that the score is composed of the product of vulnerability factors for the area surrounding the intake and the geometry of the intake itself.

4.6.5 Intake Protection Zone Area Vulnerability Factors

Area vulnerability factors are assigned individually to each Intake Protection Zone based on professional judgment considering:

- The percentage of the area that is composed of land;
- The land cover, soil type, permeability and slope;
- Hydrological and hydrogeological conditions that contribute water to the area through transport pathways; and
- The proximity of the area of the IPZ 3 to the intake.

The statistics and methodology are not intended to be used as a formulaic decision framework, but are considerations for the reviewer with which to make qualitative judgments on the vulnerabilities of the IPZs 2 and 3. This is called professional judgment. Zones with higher percentage of land area, higher slope of land area, greater percentage of developed area, rapid runoff soils etc. will have a comparatively higher area vulnerability factor assigned. For each intake a table showing all the considerations has been prepared and a short explanation as to selection of the factor is given. This has also been applied for the WHPA E delineations for Peats Point and Madoc.

Factors for the area vulnerability are prescribed in the Technical Rules per rules 88 to 93. In summary, the scores available to the reviewer are reproduced below in Table 4-3.

Table 4-3: Intake Protection Zone Area Vulnerability Factors per Zone

Intake Protection Zone	Area Vulnerability Factor
IPZ 1	10
IPZ 2	7 to 9
IPZ 3	1 to 9*

* IPZ 3 score must not exceed the score assigned for IPZ 2

4.6.6 Intake Protection Zone Source Vulnerability Factors

Source vulnerability factors are assigned to each intake based again on professional judgment and must consider:

- Depth of the intake from the top of the water surface;
- Distance of the intake from land;
- History of water quality concerns at the surface water intake.

Source vulnerability factors are provided in the Technical Rules per rules 94 to 96. These are reproduced in Table 4-4 and represent ranges available to the reviewer to assign to the specific intake. They can be expressed to one decimal place. One source vulnerability factor is determined for each intake. For the WHPA E delineations for Peats Point and Madoc wells the same approach has been followed.

Table 4-4: Intake Protection Zone Source Vulnerability Factors per Intake Type

Intake Type	Source Vulnerability Factor
type A intake	0.5 to 0.7
type B intake	0.7 to 0.9
type C intake	0.9 or 1
type D intake	0.8 to 1

4.7 Water Quality Risk Assessment

There are numerous types of risks to drinking-water sources. Some risks are chronic in that the quality of water is being continuously degraded by surface runoff or by the underground leaching of chemicals or pathogens over time. Conversely, spills can occur in a short period of time and impact the quality of a supply, potentially providing long term problems if the spill is not easily and readily cleaned up. Potential drinking water threats are illustrated by Figure 4-5, and include such things as landfills, land application of manure, pesticides and other human activities.

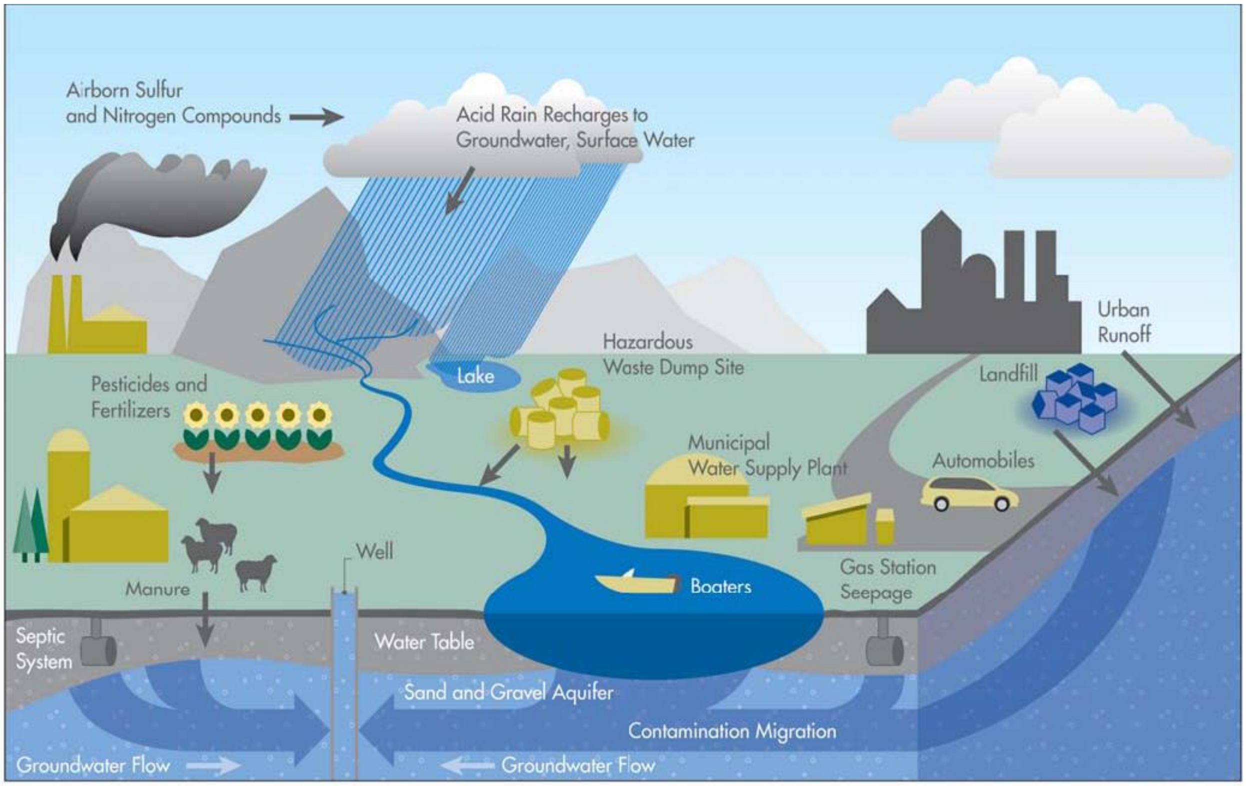

Figure 4-5: Potential Drinking Water Threats Diagram

Through the source protection process an inventory of drinking water issues, risk and threats in vulnerable areas is completed to assign the level of risk associated with past, present, and future land use activities. By evaluating the issues and threats associated with the water quality of a drinking-water system, local communities can make informed decisions about how best to protect their sources. This process prescribed by the Ontario Government is outlined below with the results of assessment for the vulnerable areas outlined in Chapters 5 and 6 for groundwater and surface water respectively.

4.7.1 Drinking Water Threats Assessment

The following is an overview of the process used to evaluate and identify threats within the vulnerable areas. A drinking water threat is defined as an activity or condition that adversely affects or has the potential to adversely affect the drinking water quality or quantity. An activity may be defined as use of the land that either exists or could in the future. The activity may pose a risk to a drinking-water supply. Drinking water threats that result from past or present land use activities that have impacted the land or water are referred to as conditions (i.e. contamination in the ground from an old gas station).

A drinking water threat may be identified in the following three different ways:

1. Through an activity prescribed by the *Clean Water Act, 2006*;
2. Through an activity identified by the Source Protection Committee; and
3. Through a condition or activity associated with a drinking water issue.

The threats and activities must be determined for the four types of vulnerable areas as listed below:

- Highly Vulnerable Aquifers
- Significant Groundwater Recharge Areas
- Wellhead Protection Areas
- Intake Protection Zones

In reference to the Technical Rules and the Technical Bulletin: Threats Assessment and Issues Evaluation (Ministry of the Environment, 2010), there are four specific requirements for completion of the Threats Assessment for each of the vulnerable areas as follows:

1. Identify activities or conditions that are or would be drinking water threats;
2. Identify circumstances under which activities would be considered Significant, Moderate, or Low drinking water threats;
3. Identify areas where an activity or condition would be a Significant, Moderate, or Low drinking water threat;
4. Determine the number of locations in each vulnerable area where an activity or condition is a Significant drinking water threat.

In accordance with the *Clean Water Act, 2006*, the groups of activities in Table 4-5 may be considered as drinking water threats. In this table are also typical land use activities that may be associated with the prescribed drinking water threat.

Table 4-5: Prescribed Drinking Water Threats – Water Quality

Prescribed Drinking Water Threat		Land Use Activities
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.	Landfills-Active Landfills-Closed Hazardous Waste Disposal Liquid Industrial Waste
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	Sewage Infrastructures Septic Systems etc.
3	The application of agricultural source material to land.	spreading of manure, whey etc.
4	The storage of agricultural source material.	storage of manure, whey etc.
5	The management of agricultural source material.	aquaculture
6	The application of non-agricultural source material to land.	Organic Soil Conditioning Biosolids
7	The handling and storage of non-agricultural source material.	Organic Soil Conditioning Biosolids
8	The application of commercial fertilizer to land.	Fertilizing land
9	The handling and storage of commercial fertilizer.	General Fertilizer Storage
10	The application of pesticide to land.	Use of Pesticides
11	The handling and storage of pesticide.	General Pesticide Storage
12	The application of road salt.	Road Salt Application
13	The handling and storage of road salt.	Road Salt Storage
14	The storage of snow.	Snow Dumps
15	The handling and storage of fuel.	Petroleum Hydrocarbons
16	The handling and storage of a dense non-aqueous phase liquid.	Use of dangerous chemicals
17	The handling and storage of an organic solvent.	Use of dangerous chemicals
18	The management of runoff that contains chemicals used in the de-icing of aircraft.	Airplane De-icing
19	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. *Ontario Regulation 385/08, s.3.*	Agricultural operations

Nineteen threats listed above may be both chemical and pathogenic in nature and are further broken down into various scenarios called circumstances for different land use activities. These circumstances are listed in the Provincial Table of Circumstances (MOE, 2010); chemical threats; and pathogen threats (Appendix D-1). To determine if a land use activity is a Significant, Moderate or Low drinking water threat the Tables of Circumstances are used to review the activity, the circumstances associated with it, and the vulnerability of the zone in which it occurs. For example, a circumstance may be a Significant threat in an area with a high vulnerability score of 10, and a Moderate threat in an area with a lower vulnerability score of 8.

To determine whether or not these threats exist, and if so how many, an inventory was completed in each of the vulnerable areas. This inventory provides necessary information for the source protection planning process to rank the threats posed by the individual activities and address how the risk may be managed and/or minimized. In some cases a threat may not actually be causing an impact to the drinking water but has the potential to do so when improperly managed or adequate safe guards are not in place.

4.7.2 Threats Approach

An overview of the threats approach used to inventory and assess threats within each of the vulnerable areas is summarized as follows.

1) Listing Drinking Water Threats

Activities Prescribed by the Clean Water Act

The activities prescribed by the *Clean Water Act, 2006* that may be considered drinking water threats are those as listed in Table 4-5. These are activities that are or would be drinking water threats in a vulnerable area under specific circumstances. The listing of these activities is a means of identifying what could be considered a threat in a given vulnerable area.

Activities Identified by the Source Protection Committee

A drinking water threat can also be identified by the Source Protection Committee if the activity is not included in the provincial list of 19 prescribed drinking water quality threats (Table 4-5). This can only occur if a hazard assessment confirms that the activity is a threat, and this assessment is approved by the Ministry of the Environment.

Conditions Resulting From Past Activities

Threats can also be identified if conditions relating to a past activity (i.e. a contaminated site) have resulted in:

- the presence of non-aqueous phase liquid in groundwater (i.e. gasoline) in a highly vulnerable aquifer, significant groundwater recharge area or Wellhead Protection Area;
- the presence of a single mass of 100 liters of one or more Dense Non-Aqueous Phase Liquids in surface water in a surface water Intake Protection Zone;
- the presence of a contaminant in groundwater in a highly vulnerable aquifer, significant groundwater recharge area or a Wellhead Protection Area, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards and is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table;

- the presence of a contaminant in surface soil in a surface water Intake Protection Zone, if the contaminant is listed in Table 4 of the Soil, Ground Water and Sediment Standards is present at a concentration that exceeds the surface soil standard for industrial/commercial/community property use set out for the contaminant in that Table; and
- the presence of a contaminant in sediment, if the contaminant is listed in Table 1 of the Soil, Ground Water and Sediment Standards and is present at a concentration that exceeds the sediment standard set out for the contaminant in that Table.

For a drinking water threat to be associated with a condition documented proof of one of the above situations is required. To identify properties within vulnerable zones where past land use activities may be considered a potential condition an assessment of the environmental condition of the site is required. The process that was followed to identify potential conditions and assess the level of drinking water threat is:

1. Review of available information pertaining to the location of potentially contaminated sites;
2. Confirm the location of the site within a vulnerable area,
3. Apply local knowledge about the location of potentially contaminated sites (current or past activity);
4. Review available records to determine if sufficient information was available to provide evidence of contamination;
5. Compare the evidence of contamination to the Technical Rule 126 (2009) to determine if the site can be classified as a condition; and
6. Calculate the risk score to determine if the site represents a Significant drinking water threat in reference to the MOE Technical Rules (2009).

Where data was available and it was confirmed that a drinking water threat associated with conditions exists, it is noted under the relevant section of this report discussing the respective vulnerable area. An overall summary with more detailed information of the review of conditions is also provided in Appendix I.

This review was the first identification of contaminated sites that should be considered as conditions and drinking water threats in the source protection planning process. The focus of the initial work was only on the vulnerable areas located around municipal drinking water intakes and wells, not including all of the highly vulnerable aquifer or significant groundwater recharge areas. It is recognized that other drinking water threats associated with conditions and potentially contaminated sites may exist in these zones. However, there needs to be extensive data to identify such conditions. As data becomes available it is recommended that the condition process be applied to address potential drinking water threats.

2) Listing Circumstances for Activities and Conditions

To determine circumstances under which an activity listed in Table 4-7 may be considered a threat reference was made to the Provincial Tables of Circumstances (MOE, March, 2010) as well as a database referred to as the Upper Thames Region Conservation Authority Threats Analysis Tool. These tables and tools provide lists of the various threats and circumstances for a given vulnerable area in consideration of the type of activity, the vulnerability score, and vulnerability zone. Through this approach a list can be developed of possible scenarios for a given chemical or pathogen threat to be considered as Significant, Moderate or Low.

The circumstances for a condition to be considered a drinking water threat are listed above under the heading Conditions Resulting From Past Activities.

3) Identify Areas where an Activity or Condition would be a Threat

Areas where an activity or condition would be considered a Significant, Moderate or Low drinking water threat were determined in reference to the Tables of various threats, and the corresponding vulnerable area and vulnerability score. For example, the lists referred to above may be cross referenced with maps showing the location of each zone and the associated vulnerability score to identify the location of threats.

For drinking water threats associated with conditions the risk score was calculated to assess if the condition could be considered a Significant, Moderate or Low threat. The risk score was calculated in accordance with the Technical Rules as follows:

Risk Score = A X B

Where:

A = the hazard rating of the condition,
B = the vulnerability score of the vulnerable area (as outlined in the relevant section of the Assessment Report),

The hazard rating is determined as outlined in the Technical Rules based on either a score of 10 or 6. A score of 10 is assigned where there is evidence of off site contamination or the condition is associated with the property of a drinking water system, or a score of 6 if neither applies. The threat level is then assigned as Significant, Moderate, or Low in accordance with Table 4-6.

Table 4-6: Risk Score and Drinking Water Threat Category

Drinking Water Threat Level	Risk Score
Significant	Equal to or greater than 80
Moderate	Equal to or greater than 60 and less than 80
Low	Greater than 40 and less than 60

4) Determine Number of Drinking Water Threats

To determine the location and number of Significant drinking water threats a review was completed of a range of data sources including: public records, land use mapping, Certificates of Approval, business information, and contaminant inventories among others. Site specific information was collected through roadside observations. Aerial photography and existing mapping of potential contaminants were referenced extensively and local knowledge was also relied upon.

To determine the number and location of Significant drinking water threats reference was made to the lists of various threats that were developed for each vulnerable area. Using the threats tables described above, lists were developed for all possible land use activities that pose a Significant, Moderate or Low threat for each drinking water system. This process is a summary of possible threats; it does not reflect what activities are actually taking place in the vulnerable areas. All Significant, Moderate, and Low threats were pulled from the threats tables for all of the vulnerable areas.

The second step was to remove any of the land use activities that do not occur within each drinking water system. To do this, the list of threats and the land uses were reviewed. Where a threat was linked to a land use that did not exist, it was removed from the list. A list of Moderate and Low threats was compiled for each system. This was the final step for Moderate and Low threats.

Next, an inventory of existing Significant threats was compiled. Using aerial photography, municipal mapping, engineering studies, various databases, and roadside observations an inventory of locations in each Wellhead Protection Area and Intake Protection Zone that may have significant threats was recorded. These records were enumerated based on each zone and whether they are chemical or pathogen.

The final step in identifying threats was to confirm the Significant threat inventory where deemed necessary. This was completed by contacting select property owners through mail surveys, telephone interviews, and/or site visits. Such information included details about specific practices and potential contaminants in use on the property. The accuracy of such information is subject to cooperation and/or participation by the property owner.

4.7.3 Listing of Drinking Water Threat Results

The results of the water quality risk assessment are provided in Chapter 5 for vulnerable groundwater zones and Chapter 6 for vulnerable surface water areas. This includes the enumeration of the number of properties with Significant threats as well as a list of Moderate and Low threats that could occur. To complete the identification of threats, calculations were completed for various land use activities to allow identification of circumstances under which a threat could occur in accordance with the Tables of Drinking Water Threats. This entailed:

1. Calculation of the percent managed lands in the vulnerable areas to assist in the assessment of threats from fertilizers and agricultural source materials;
2. Calculation of livestock density for each of the vulnerable areas to allow evaluation of the potential impact from generation, application, and storage of agricultural source material; and
3. Calculation of the percentage of impervious surfaces in a vulnerable area for assessing the potential for impact from the application of road salt.

A summary of the methodology used for each of these calculations is provided below.

4.7.4 Managed Lands

The managed lands in each of the vulnerable areas were calculated in reference to the Technical Bulletin entitled Proposed Methodology for Calculating Percentage of Managed Lands and Livestock Density for Land Application of

Agricultural Source of Material, Non Agricultural Source of Material and Commercial Fertilizers (Ministry of the Environment 2009). Managed lands are those lands to which agricultural source material, commercial fertilizer or non agricultural source material is applied. In the Quinte region there are two categories of managed lands which include agricultural lands and non agricultural lands.

The agricultural lands are cropland, fallow and improved pasture lands where agricultural nutrients are applied. The location and percentage of these lands were determined based on land use mapping and mapping completed for the Quinte Regional Groundwater Study, (Dillon 2004). This entailed a review of agricultural lands throughout the region by comparison of land use mapping, agricultural census data, and Landsat satellite imagery. This information was used to calculate the percentage of managed lands in each vulnerable zone.

Non-agricultural managed lands include golf courses, sports fields, lawns and other built up areas that may receive nutrients. The location of these lands was determined through review of aerial photography and the Geographic Information System to delineate areas such as golf courses and sports fields. For residential, commercial, and institutional lands that could receive nutrients, a review was completed of municipal zoning to determine the location of such areas. Based on the zoning bylaws an estimate of the percentage of these lands which could receive nutrients was determined in reference to minimum landscaped area specifications.

The above methodology was applied to individual vulnerable areas for Wellhead Protection Areas (WHPA) A, B, C, D, E and F, Intake Protection Zones (IPZ) 1, 2, and 3 and Significant Groundwater Recharge Areas. However, for the Highly Vulnerable Aquifers a variation from the Technical Rule 16(9) was required and approved by the Director in correspondence dated February 9, 2010 (Appendix D-2). This variation was required in respect of the large area of the Highly Vulnerable Aquifer over the entire Quinte Watershed. The methodology to determine the percentage of managed lands within the entire vulnerable area would not provide meaningful numbers with respect to the diverse landscape and large area of the Precambrian Shield where there are minimal managed lands. Therefore the percent of managed lands were calculated for the individual physiographic regions (i.e. Precambrian, Limestone Terrane, and Prince Edward Peninsula as illustrated by Map 2.1) to allow better representation of the distribution of managed lands in the different regions.

4.7.5 Livestock Density

The livestock density was calculated though determination of the nutrient units per acre as a surrogate measure for the potential for the application of nutrients such as Agricultural Source Material, Non-agricultural Source Material, and commercial fertilizers. The methodology applied entailed:

1. Calculate the number of different types of livestock using Canada Census Data (2006) for the census subdivision in which the vulnerable area is located (Statistics Canada 2006);
2. Convert the number of livestock in nutrient units for the census subdivision in reference to the *Nutrient Management Act, 2002*;
3. Determine the number of acres within the census subdivision that are used for the application of nutrients;
4. Calculate the livestock density for the census subdivision by dividing the nutrient units by the number of hectares of land used for application of nutrients;
5. The resulting density was then applied to the smaller vulnerable area located within the respective census subdivision to determine threat activities; and
6. For the larger highly vulnerable aquifer area which covers many census subdivisions a weighted mean was calculated for the three different physiographic regions (Precambrian, Limestone Terrane, and Prince Edward Peninsula).

Calculation of livestock density required permission from the Director to vary from the Technical Rules 16(10) as summarized in correspondence from the Director dated February 9, 2010 (Appendix D-2). Rationale for the alternate method was in reference to the lack of site specific information about the numbers of livestock using a given parcel of property or the presence of a barn for the housing of livestock. Given the lack of information, Canada Census Data which provides the numbers of livestock for individual census subdivisions, was used. This was considered an appropriate approach given that it provides an indication of the typical agricultural practice in the Quinte region. Given changing land use practices it is difficult to predict livestock numbers as this may change subject to market conditions. In the Quinte watershed it was also found that some of the agricultural land located in the vulnerable areas was not being actively farmed and/or there were no buildings present to house livestock. This made it difficult to assess livestock numbers for such areas. Therefore, the census data was a suitable substitute to assess what the potential use of some of these areas may be. Limitations of this approach are discussed further in Chapter 8 Data Gaps and Future Research.

4.7.6 Impervious Surfaces

To assess whether the application of road salt may present a threat to water quality the percent of impervious area where road salt could be applied was calculated. This was completed using a Geographic Information System, aerial photography and mapping to digitize/delineate the impervious areas within the watershed. By this method the percent of impervious area was determined by using a 1 square kilometres grid over the vulnerable area with a node of the grid centered on the centroid of the vulnerable area. This method of using the centroid of the vulnerable area as opposed to the Source Protection Area was considered to provide representative results. However, permission from the Director was required to vary from Technical Rule 17 outlined in correspondence dated February 9, 2010 (Appendix D-2).

4.8 Drinking Water Issues

If a contaminant in the municipal source water derived from human activity exceeds acceptable limits it can become a drinking water issue. The Technical Rules (rule 114) lists the requirements to identify a particular contaminant as an issue. These requirements are simplified below.

- Issues can only be identified at an intake, well, or monitoring well;
- For drinking water systems included in the Terms of Reference, issues can be identified for parameters in Schedules 1, 2 or 3 of the Ontario Drinking Water Quality Standard or in Table 4 of the Technical Support Document;
- For any other drinking water systems defined under the Safe Drinking Water Act, only chemical drinking water issues may be included (Schedules 2 and 3 of the Ontario Drinking Water Quality Standards or Table 4 of the Technical Support Document). The definition of a drinking water system under the Safe Drinking Water Act means any system that takes water for drinking water purposes. This includes any private well or intake; and
- Issues must result in or be trending towards the deterioration in quality of drinking water.

4.8.1 Drinking Water Issues Approach

The issues approach complemented the work of the threats-based approach. While the threats-based approach looked at vulnerability scores to determine which land use activities were potential Significant threats, the issues approach looked at the raw water quality at the intake or well to identify Significant drinking water threats.

Water quality data from various sources was collected. The Quinte Source Protection Authority adapted and applied four screening steps to identify drinking water quality issues as defined in the 2017 Technical Rules for the Assessment Report*.* The screening steps are:

1. Compare results of each water quality parameter at a surface water intake or in a well (including a monitoring location) to a Maximum Acceptable Concentration (a water quality benchmark) by checking whether:
    a. The parameter is present at a concentration that may result in the deterioration of the quality of the water for use as a source of drinking water, or
    b. There is a trend of increasing concentrations of the parameter at the surface water intake, well or monitoring location, and a continuation of that trend would result in the deterioration of the quality of the water for use as a source of drinking water.

    The benchmarks used for the evaluation of parameters are those standards, objectives, and guidelines listed in Schedule 1, 2, and 3 of the Ontario Regulation 169/03 for the *Ontario Safe Drinking Water Act, 2002* and Table 4 of the Ministry of the Environment's *Technical Support Document for Ontario Drinking Water Standards, Objectives, and Guidelines (Ministry of the Environment 2006)*. There are some exceptions for surface water systems, listed in Table 4-7 which were considered more appropriate benchmarks for the evaluation of untreated surface water.
2. Evaluate which water quality issues are naturally occurring conditions and therefore not able to be managed.
3. Using parameters that met or exceeded screening process 1b, conduct a trend analysis, checking whether the trend line exceeds half the Maximum Acceptable Concentration benchmark within 50 years.
4. Qualitative Factors:
    a) Evaluate which parameters are treatable at the associated drinking water system during normal conditions as well as during extreme conditions, and whether treatability is cost effective over the long run;
    b) Interview municipal drinking water operators for their input;
    c) Determine whether the threat(s) associated with the issue would be captured through the Threats Approach described in Section 4.4 and therefore are reported for each drinking water system in Chapters 5 and 6 as threats already;

d) Determine whether the threat(s) associated with the issue could be minimized or eliminated through measures in a Source Protection Plan; and

e) Professional Judgment.

Ultimately, after reviewing the outcome of the screening process for each drinking water system it is up to the discretion of the Source Protection Committee to elevate a parameter to a water quality issue.

After an issue was identified, the source(s) of contamination that may be contributing to the issue was determined and all prescribed drinking water threats that could contribute to the issue were listed. Next, an Issue Contributing Area was delineated upstream of the wells. The Issue Contributing Area is the "area within a vulnerable area (WHPA or IPZ)" where an activity or condition can contribute to an issue.

Once the Issue Contributing Area was delineated, those parcels that exhibit land use activities or conditions that are possible sources of the contaminate contributing to the issue were identified as threats. Threats identified through the Issues Approach are automatically classified as significant for those drinking water systems that are defined in the Terms of Reference or as moderate threats for other drinking water systems.

More detail on data used for issues evaluation is described in Chapters 5 and 6 for the Highly Vulnerable Aquifers, the Significant Groundwater Recharge Areas and for each individual municipal drinking water system.

Table 4-7: Modified water quality benchmarks for surface water intakes

Parameter Type	Parameter	Proposed Benchmark	Rationale and Source
Microbiological	*E. coli* *	10 cts/100mL (Lakes) 50 cts/100mL (Rivers)	USEPA "Surface Water Guidance Manual for Public Water Systems
	Total Coliforms	1000 cts/100mL	General restriction for direct filtration (Procedure for Disinfection of Drinking Water in Ontario)
Operational/ Aesthetic	Turbidity	20 NTU	General restriction for direct filtration (Procedure for Disinfection of Drinking Water in Ontario).
	Colour	40 TCU	General restriction for direct filtration (Procedure for Disinfection of Drinking Water in Ontario).
	Hardness	500 mg/L	Note: Table 4 of the Technical Support Documentation for the ODWQS, Objectives and Guidelines OG is 80 – 100 mg/L for waters at the point of consumption. Hardness in excess of 200 mg/L is considered poor but tolerable. In excess of 500 mg/L is unacceptable.

Notes: * The Belleville, Point Anne, Deseronto, Picton, Ameliasburgh, and Wellington Intakes are considered lake settings and use 10 counts/100ml as a benchmark for *E.coli*. Napanee Backup intake is considered a river setting and 50 counts/100ml as a benchmark for *E.coli*.

This table was modified from the Appendix D in Dillon Consulting 2009 Intake Protection Zone Study reports, see Dillon 2009b in Appendix F-1.

4.9 Uncertainty Evaluation of the Vulnerable Areas

Depending upon the quality of the information that was available to the reviewer as well as the methodology used in the determination of the vulnerable areas and scores, some uncertainty may exist in each. Uncertainty is assigned as High or Low to the delineation of and the vulnerability score for each vulnerable area listed in Section 4.1 per rules 13 to 15. The uncertainty evaluation must consider:

1. The distribution, variability, quality and relevance of data used in the preparation of the Assessment Report.;
2. The ability of the methods and models used to accurately reflect the flow processes in the hydrological system;
3. The quality assurance and quality control procedures applied;
4. The extent and level of calibration and validation achieved for models used or calculations or general assessments completed;

5. For the purpose of subrule 13(1), the accuracy to which the groundwater vulnerability categories effectively assess the relative vulnerability of the underlying hydrogeological features; and
6. For the purpose of subrule 13(4), the accuracy to which the area vulnerability factor and the source vulnerability factor effectively assesses the relative vulnerability of the hydrological features.

The methodology for the assignment of uncertainty evolved since many of the original technical reports were authored. Since the finalization of the technical rules, assignment of uncertainty has become more standardized. Therefore the uncertainty levels may have changed in the most recent reports. All technical reports can be found in the Appendix E for well systems and Appendix F for intake systems.

Zone delineation and vulnerability assignment is explained earlier in this chapter. The best available data was used but where data gaps existed or where the reviewers were not confident in the quality of the data, a higher uncertainty level was used.

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5 Groundwater Resources

A key component of the source protection planning process is protecting the groundwater resource within the Quinte Source Protection Region. The level of protection required is directly related to how vulnerable the groundwater is to contamination as areas with a high vulnerability to contamination require more protection than areas of lower vulnerability. In order to develop groundwater protection plans it is necessary to understand how vulnerable or sensitive the groundwater is to contamination and where these vulnerable areas are located. The three main types of vulnerable areas for groundwater that exist in the Quinte Source Protection Region are:

- Highly Vulnerable Aquifers
- Significant Groundwater Recharge Areas
- Wellhead Protection Areas

A summary of the location and vulnerability of each of these zones is provided below followed by an assessment of what may be considered a threat to water quality and any issues associated with the water quality.

5.1 Highly Vulnerable Aquifers

Highly Vulnerable Aquifers are those sources of groundwater that may be easily contaminated. Groundwater in the Quinte Source Protection Region is commonly found in fractured bedrock aquifers which include Precambrian and Limestone bedrock. This bedrock is typically heavily fractured in the upper 10 to 30 metres and overlain by a thin layer of soil. Under these conditions, the aquifers can be considered very susceptible to contamination. An outline of how this vulnerability was determined is provided in Chapter 4 and a discussion of the results is below.

5.1.1 Highly Vulnerable Aquifer Delineation

Delineation of the Highly Vulnerable Aquifer in the Quinte region resulted in identification of most of the watershed as highly vulnerable. This is illustrated in Map 5.1 and was completed by the ISI or Intrinsic Susceptibility Index method as part of the Quinte Regional Groundwater Study (October, 2004) in reference to protocol developed by the Ministry of the Environment (MOE, 2002). An overview of the methodology is outlined in Section 4.3.1 of Chapter 4, Assessment of the region by this method through the review of 15,356 well records resulted in the majority of wells (97.5 percent) having an index showing high vulnerability. This high vulnerability was due to shallow depth of the water table and in many areas lack of significant depth of soil. Throughout much of the

Quinte area the water table is at shallow depth with a mean depth of 4.3 metres below grade. More detailed information about water table depth was obtained from review of water level data for 31 monitor wells in the Quinte watershed installed as part of the Provincial Groundwater Monitoring Network (see Map 2.16). These wells confirm shallow water table depth at typically less than 6 metres below ground. In addition to shallow water table much of the Quinte watershed is underlain by shallow soil at depths of less than 1.5 metres above bedrock as illustrated by Map 2.5. Some areas, particularly in the southern portion of the Moira watershed have greater soil depth with soils extending up to depths of 50 metres. However, the thickness and relative high permeability of these soils do not provide significant protection. A few of the well records (2.4 percent of total) scored a moderate level of vulnerability in isolated areas where low permeability soils were encountered. However, the location and occurrence of these wells was sporadic and not continuous enough to allow delineation of areas of moderate vulnerability. In view of these results the entire Quinte region was mapped as highly vulnerable (see Map 5.1).

Support of High Aquifer Vulnerability using Hydrogeologic Data

Following the assessment of aquifer vulnerability by the ISI methodology additional review was completed of hydrogeologic information to verify the findings. The following information was evaluated in support of the designation of the local aquifers as highly vulnerable:

1. Review of annual hydrographs for monitor wells that are part of the Provincial Groundwater Monitoring Network.
2. Review of a storm event based hydrograph of a monitor well and stream flow.
3. Comparison of surface water levels with water levels in a monitor well.
4. Review of water quality data for monitor wells and various surveys of private water supply wells.

1. Monitor Well Hydrographs

A review of water level data for PGMN wells installed in both Paleozoic and Precambrian bedrock aquifers have demonstrated that after rainfall events a sudden and rapid increase in water levels is observed. Figure 5-1 illustrates daily precipitation and the water level for a deep well (Number GA130) installed in Precambrian bedrock to a depth of 65 metres with the water table near ground surface. This well is located near a sand and gravel esker formation (close proximity to the Village of Tweed municipal wells) where soils can reach depths of up to 10 metres. A review of water levels shows significant correlation of increase in water levels with precipitation events. Note the sharp increase in water table elevation near days 211 and 251 when high precipitation was recorded.

A similar pattern is evident at monitor well GA267 (illustrated by Figure 5-2) with significant groundwater fluctuations in response to precipitation events. This well extends to a depth of 12 metres into limestone bedrock and is overlain by 8 metres of a mixed sand and clay till soil of moderate permeability. Such information confirms the highly vulnerable aquifer designation as the overburden is not continuous and does not provide significant protection to the underlying aquifer. Similar groundwater response and patterns are evident in other PGMN wells located throughout the Quinte region. This rapid response of groundwater levels to precipitation events is evidence of high aquifer vulnerability as it is an indication of how quickly a contaminant could move from the ground surface to the water table, if present.

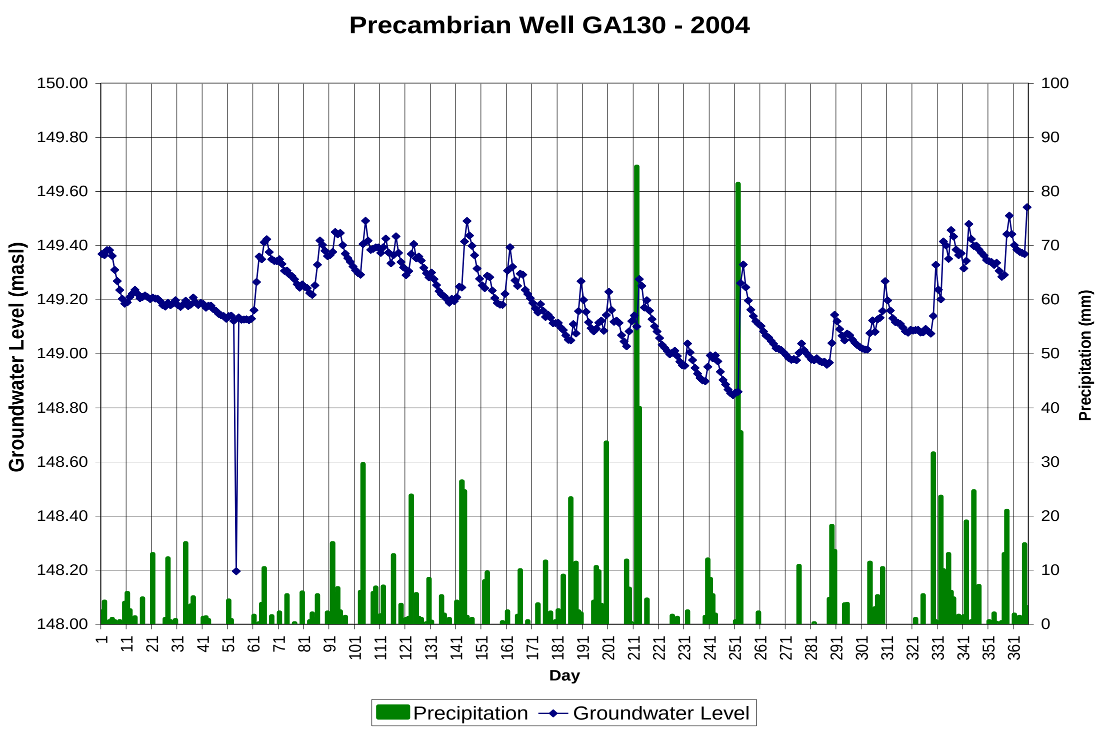

Figure 5-1: Groundwater Hydrograph Precambrian Aquifer

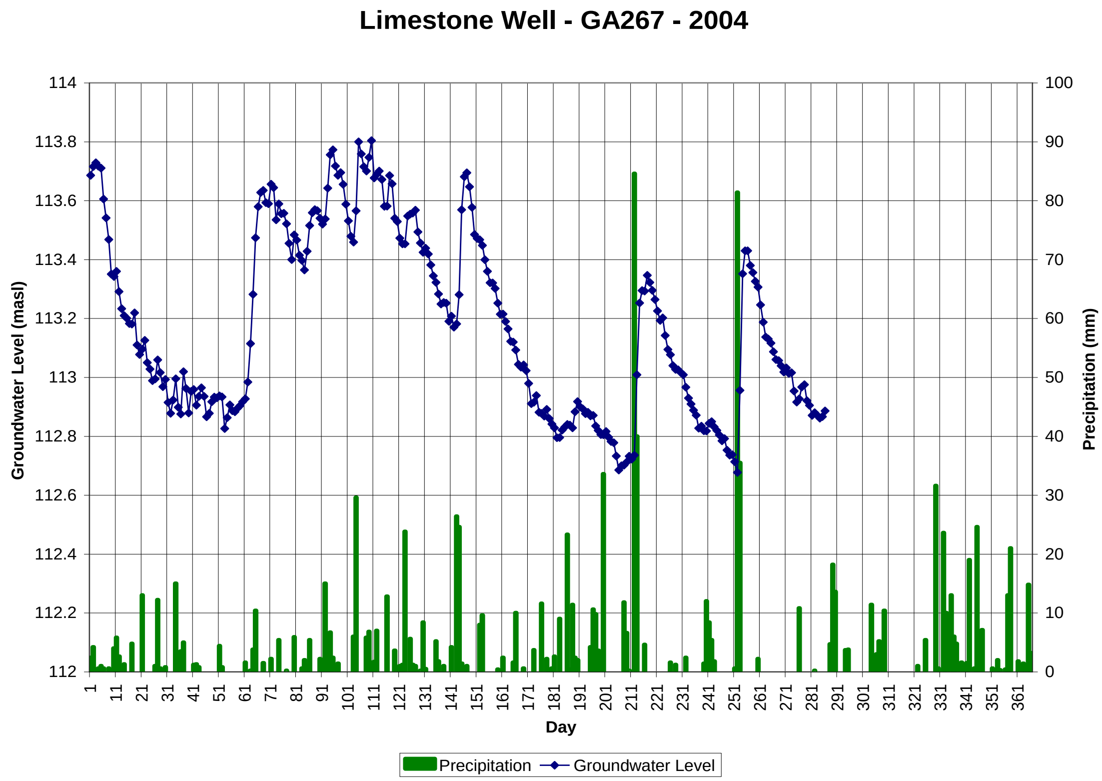

Figure 5-2: Groundwater Hydrograph Paleozoic Aquifer

2. Precipitation Storm Event-based Hydrograph

In addition to the annual hydrographs a detailed review was completed of a precipitation storm event that occurred in the Quinte region in November of 2006. For this event radar coverage was obtained to assist in interpreting the depth and intensity of rainfall over the Region. To analyse this event both ground and surface water hydrographs from PGMN wells and stream gauges were analysed to interpret volumes of water running off as surface flow or into the groundwater as recharge. The observed changes in water levels for a 70 metre deep well (well number GA 266) installed into a Precambrian aquifer and nearby stream gauge (02HL-005) on the Moira River near Deloro is illustrated in Figure 5-3. The observed trend and shape of the hydrograph shows groundwater levels responding in a similar fashion as surface water. This response is very rapid in consideration of the well depth and bedrock geology of the Canadian Shield and is further evidence of the Highly Vulnerable Aquifer designation as determined by the ISI methodology.

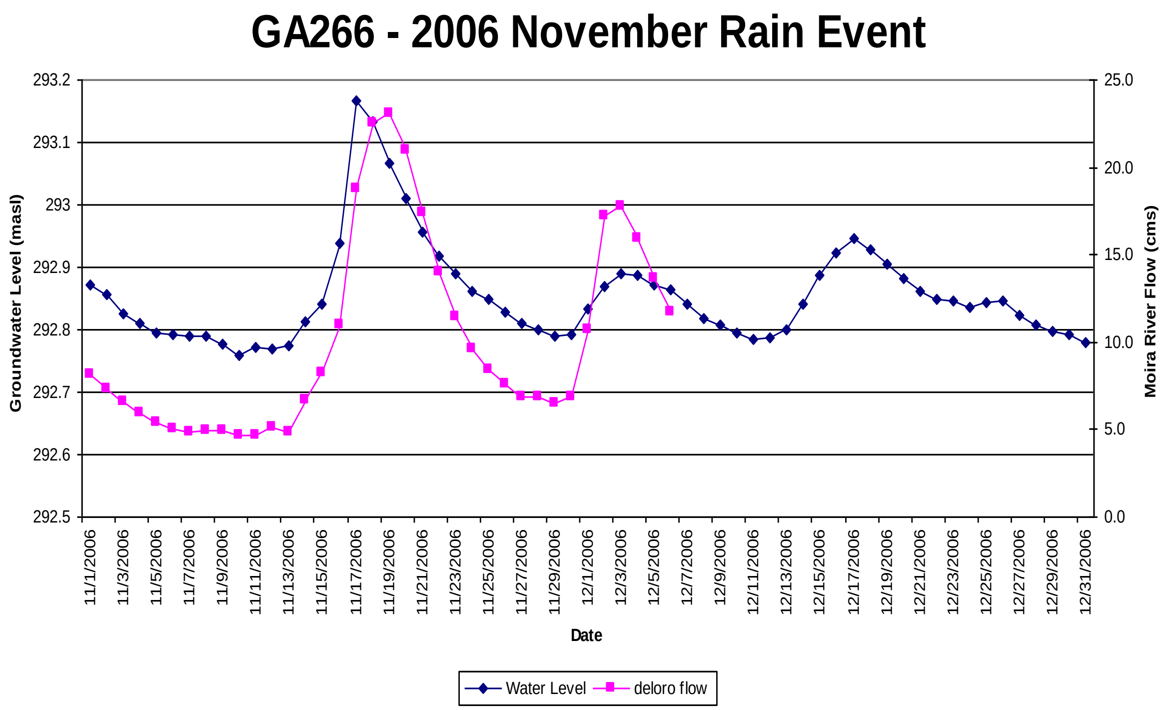

Figure 5-3: Ground and Surface Water Hydrographs November 2006

3. Comparison of Ground and Surface Water Levels – Scatter Plot

To further illustrate the correlation of groundwater levels with surface water a scatter plot is provided in Figure 5-4. This plot is of groundwater levels observed at a monitor well (well number GA 229) and stream flow observed at a gauge in the Moira River at Foxboro (02HL-001). The groundwater levels are for a well advanced 31 metres deep into a limestone aquifer located in the Moira River watershed. The plot (Figure 5-4) shows there is a positive correlation between stream flow and groundwater levels which has also been concluded from the information discussed above. This comparison is further support of the highly vulnerable aquifer designation with groundwater levels being positively correlated with surface water flow over a relatively rapid time period.

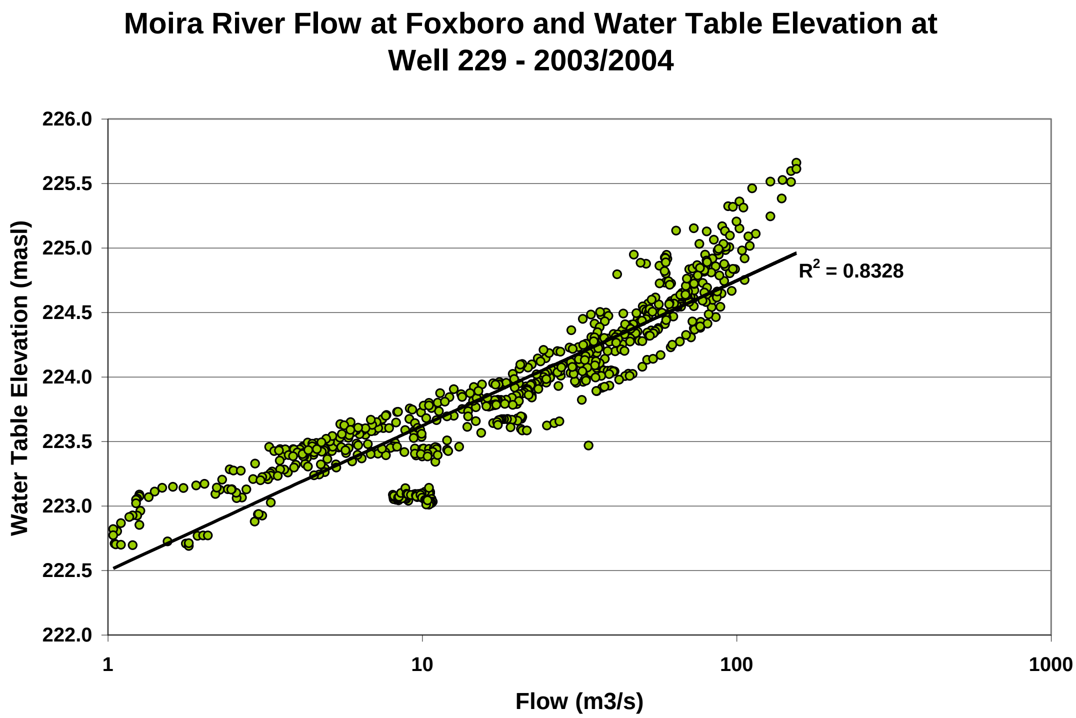

Figure 5-4: River Flow versus Water Table Elevation – Moira Watershed

From the information provided above it is evident that the water levels of both deep and shallow wells respond quickly to precipitation events, which is indicative of unconfined conditions. In the majority of cases wells in the Quinte region, listed in Table 5-1, are installed in fractured bedrock aquifers to depths of less than 35 metres with average depths ranging from 16 to 30 metres. In some cases, although not as prevalent, some wells reach depths in excess of 30 metres. Under such conditions the aquifer may not be as susceptible to contamination due to a decrease in permeability of the bedrock with depth. However, in the absence of discrete confining layers and information to support the presence of these layers this cannot be certain.

Table 5-1: Water Well Depths

Municipality	Well Depth	Average Well Depth
Prince Edward	65% < 20 metres	20 metres
Stone Mills	80% <35 metres	25 metres
Tyendinaga	80% < 30 metres	24 metres
City of Belleville	80 % < 20 metres	16 metres
Tweed	80% < 40 metres	28 metres
Madoc	80% < 45 metres	30 metres

Data Source: Quinte Regional Groundwater Study (Oct, 2004)

4. Water Well Quality

Additional information supporting the high vulnerability of the Quinte region aquifers is the water quality data that was reviewed from various sources such as the monitor wells of the Provincial Groundwater Monitoring Network, regional and local hydrogeologic studies, and other water quality surveys discussed below in Section 5.1.6. The information summarized in this section indicates that there are natural water quality problems of wells drilled to depth into salt water. However, the reports do indicate that the local aquifers are susceptible to contamination from sources such as road salting activities, septic systems, and nutrient application. This was evident due to the detection of elevated levels of total coliform, *E.coli*, nitrate, and chloride. In some cases detection of poor water quality was associated with improper well construction from inadequate casing length, too close to roads etc. Some of the water quality surveys that were reviewed were for areas of variable but moderate soil depth. These areas include the Hamlets of Moira, Roslin, rural Tweed, and the Tyendinaga Mohawk Territory. In these areas soils can extend up to depths of 30 metres and range in composition from sand and gravel to a fine and coarse grained till. Many of these studies reported the aquifer to be susceptible to contamination in view of variable and discontinuous soil conditions. Regardless, in spite of some areas of significant soil depth the detection of unacceptable water quality parameters confirms that contaminants from surface activities can readily move into the shallow aquifers. This conclusion is further support that the Quinte region aquifers are highly vulnerable to contamination.

5.1.2 Highly Vulnerable Aquifer Score

For the evaluation of threats within the Highly Vulnerable Aquifer it is necessary to assign a vulnerability score. This score will assist in the threats evaluation in determining the potential significance of various activities for contamination of the groundwater. Therefore in accordance with the Technical Rule 79 the vulnerability score for all of the Highly Vulnerable Aquifers is 6.

5.1.3 Highly Vulnerable Aquifer Identification of Transport Pathways

Transport pathways that can allow contaminants to enter a drinking water source are listed in Table 4-2 of Chapter 4. These pathways exist throughout the Highly Vulnerable Aquifer region, however due to size of this area an inventory has not been completed. Given the area has been classified as highly vulnerable; the presence of such pathways cannot increase the classification but are still a concern.

5.1.4 Highly Vulnerable Aquifer Managed Lands and Livestock Density

The percent managed lands and livestock density was calculated for the Highly Vulnerable Aquifer area by methodology provided in Chapter 4 and reported in Table 5-2. As expected the managed land percentage, illustrated by Map 2.20 is Low on the Precambrian Shield and Moderate in the southern regions of the Limestone Terrane and Prince Edward Peninsula. Livestock density is Moderate to High in all areas, however the calculation for the Precambrian Shield is thought to be a high estimate based on the methodology used. This methodology used livestock data for census subdivisions illustrated by Map 2.21. Some of these census areas cover large areas spanning both the Limestone Terrane and Precambrian Shield therefore the estimate may be skewed to be like the areas where there is more agricultural activity.

Table 5-2: Highly Vulnerable Aquifer Managed Lands and Livestock Density

Zone	Managed Lands (%)	Livestock Density (NU/acre)*
Precambrian	6.9	2.2
Limestone	41	2.7
Prince Edward	53.2	2.7

* Note: NU/acre = Nutrient Units/acre

5.1.5 Highly Vulnerable Aquifer Percentage of Impervious Surfaces

The percent impervious area for the Highly Vulnerable Aquifers is shown by Map 2.22 and calculated based on a 1 square kilometre grid using methodology as described in section 4.7.6 of Chapter 4. This mapping indicated approximately 62 percent of the watershed at less than 1 percent impervious area and 38 percent in the range of 1-8 percent with minor amounts in the higher classes. This mapping of low impervious coverage is reflective of the rural nature of the watershed and large undeveloped areas of the Precambrian Shield. Higher impervious surface areas are found in the urban centres.

5.1.6 Highly Vulnerable Aquifer Water Quality Issues

Water quality in the Highly Vulnerable Aquifer area is an important consideration for the various users of the water for agriculture, business, industry and residential use. Approximately 50 percent of the watershed residents rely on private wells in this region. To provide information about the quality of the regional groundwater and to allow the identification of issues, a review was completed of available water quality data. Issues may be associated with water quality parameters that exceed the drinking water standards when the incidence is unexplained by problems associated with poor natural water quality or when there is a link to a direct threat that has caused a problem.

In accordance with the Technical Rules (see Appendix A-2) a water quality issue in the Highly Vulnerable Aquifer area may be identified if there is evidence of widespread presence of a parameter listed in the Ontario Drinking Water Quality Standards (excluding microbiological) and the parameter may result in the deterioration of the water for use as a source of drinking water, or there is evidence of a trend in increasing concentration of the parameter that would result in the deterioration of the quality of the water as a source of drinking water.

5.1.7 Highly Vulnerable Aquifer Issues Evaluation

An outline of the methodology used for identifying water quality issues in the Quinte Source Protection Region is provided in Chapter 4. Variation was made to this basic methodology due to the limited quantity and availability of data. The basic steps that were followed are:

1. Compare the water quality data with drinking water standards, as set out in the Ontario Drinking Water Quality Standards listed in Schedules 2 and 3 of the Ontario Regulation 169/03 and Table 4 of the Technical Support Document (Ministry of the Environment 2006), to identify exceedances,
2. Determine which parameters with exceedances are attributed to natural sources,
3. Provide a summary of parameters that may be considered as issues.

5.1.7.1 Highly Vulnerable Aquifer Data Sources

For the Highly Vulnerable Aquifer area the main sources of data that were reviewed are:

1. Water Quality data for the Provincial groundwater monitoring network,
2. Regional and local reports summarizing groundwater conditions and water quality surveys conducted for various purposes.

A summary of the results from these sources is provided below.

5.1.7.2 Highly Vulnerable Aquifer Provincial Groundwater Monitoring Network

The Provincial Groundwater Monitoring Network is a network of monitoring wells that is operated and maintained by Quinte Conservation in partnership with the Ministry of the Environment. There are 31 monitoring wells within the watershed at the locations illustrated in Map 3.7. The location of these wells has been selected to represent the various hydrogeologic regions with 25 wells located in the Highly Vulnerable Aquifer region and the balance of six located in Significant Groundwater Recharge Areas (SGRA) to be discussed later. The distribution of the 25 wells in the Highly Vulnerable Aquifer region is:

- 21 wells in the limestone aquifer
- 3 wells in the Precambrian aquifer and
- 1 well in the overburden aquifer

The depth of these wells ranges from 5.9 to 70 metres with the majority at relatively shallow depths of less than 30 metres. These wells are used to monitor both groundwater quality and groundwater levels with data available since 2002. Water levels are measured hourly and water quality samples are collected on an annual basis for laboratory analysis for general chemistry and the presence of metals. Other parameters which are monitored less frequently include pesticides and volatile organics.

Provincial Groundwater Monitoring Network Water Quality Exceedances

Review of water quality data collected between 2002 to 2008 indicated the following parameters exceed the drinking water objectives in three or more samples:

Limestone Aquifer: Hardness, Iron, Sodium, Chloride, Dissolved Organic Carbon, Manganese and Fluoride.

Precambrian Aquifer: Hardness and Sodium

Overburden Aquifer: Hardness and Iron

The majority of these parameters may be associated with natural sources related to the geology of the aquifers and the influence of these aquifers by nearby sources of surface water. However, sodium and chloride are parameters that may be attributed to human sources of contamination such as the use of salt for road deicing and effluent from septic systems. The detection of these parameters in wells can also be attributed to poorly constructed wells that are in close proximity to sources of these contaminants. However, elevated levels of chloride and sodium can also be associated with natural sources in wells that are drilled into deep aquifers. In this region the deep groundwater has had a long residence time, allowing for the water to dissolve the minerals in the rock. Such water is sometimes referred to as mineral water and elevated parameters may include sodium, chloride and other minerals.

5.1.7.3 Highly Vulnerable Aquifer Regional Reports

Further information about groundwater quality in the Quinte region was provided through review of reports summarizing hydrogeologic conditions from completion of various studies. The reports reviewed included:

- Quinte Regional Groundwater Study Final Report by Dillon Consulting Limited – October, 2004.
- Hydrogeology of Southern Ontario, Second Edition by Singer et al, Ministry of the Environment, April 2003.
- Groundwater in Ontario: Hydrogeology, Quality Concerns and Management by MacRitchie et al. November, 1994.
- Water Resources of the Moira River Drainage Basin by Sibul et al. Ministry of the Environment, 1974.
- Preliminary Hydrogeological Investigation of Prince Edward County – Final Report Water and Earth Science and Associates – March 1985.

Groundwater was reported to be of reasonably good quality in these reports. However, natural water quality problems were reported for wells that are drilled to depth in the limestone aquifers and sometimes in the groundwater discharge zones of these aquifers. The following parameters were reported as elevated and associated with natural sources:

- Hardness
- Sulphate
- Sulphur
- Sodium
- Chloride
- Minerals
- Methane gas

Aside from the natural water quality problems these reports also indicate that in some areas water quality problems can be experienced due to human sources of contaminations detected by elevated levels of the following parameters:

- Total Coliform
- *E.coli*
- Fecal coliform
- Nitrate
- Chloride

Detection of elevated levels of these parameters was attributed to areas of dense development serviced by private wells and septic tanks. High levels of sodium and chloride were also attributed to wells being located too close to roads where salt is used for deicing.

5.1.7.4 Highly Vulnerable Aquifer Water Quality Surveys

More site specific information was provided through review of reports prepared for water quality surveys conducted by other agencies as well as Quinte Conservation. These surveys primarily focused on specific hamlets where servicing is by private wells and septic systems, however some surveys covered outlying rural areas also serviced by private wells. The surveys that were reviewed are listed:

- Municipality of Centre Hastings – Hamlets of Crookston, Fuller, Ivanhoe, Moira, and Roslin Groundwater Management Study Final Report by TSH. March, 2001;
- Well Water Quality Survey – Camden East Township, Lennox and Addington County prepared by the Ministry of the Environment Southeastern Region, 1985;
- Private Systems Studies in the Villages of Colebrook and Yarker - Hydrogeological Study prepared for the Township of Camden East and Ontario Clean Water Agency by Marshall, Macklin, and Monaghan. June 1996;
- Quinte Conservation Correspondence to the Municipality of Stone Mills dated Aug 14, 2007 and July 25, 2008 summarizing the results of 2 groundwater quality surveys for the Village of Newburgh;
- Baseline Survey of Environmental Conditions, Kinlin Road Hog farm, Municipality of Tweed. Prepared by Quinte Conservation for the Municipality of Tweed. November, 2004; and
- Hydrogeological Study of the Tyendinaga Mohawk Territory by XCG Consulting, February 2006.

Similar to the information provided by the Provincial Groundwater Monitoring Network and Regional Reports, many of the surveys confirmed natural water quality problems are associated with parameters listed in Table 5-3. Much of the natural water quality problems are associated with wells drilled into the deep groundwater discussed above.

Aside from the natural water quality problems other parameters that were noted as not complying with the Drinking Water Standards and potentially being attributed to human sources include:

- Total Coliform
- Fecal Coliform
- *E.coli*
- Nitrate
- Chloride

Table 5-3: Natural Water Quality Problems – Quinte Watershed

Location	Colebrook	Yarker	Roslin	Newburgh	TMT*	Tweed**
Year of Survey	**1985/96**	**1985/96**	**2000**	**2007/08**	**2004**	**2004**
Parameter						
Hardness	√	√	√	√	√	-
Sulphide	√	√	√	-	-	√
Chloride	√	√	√	√	√	-
Sodium	√	√	√	√	√	√
Uranium					-	√
Iron	√	√	-	-	√	√
Fluoride	-	-	-	√	√	-
Manganese					√	√
Total Dissolved Solids					√	-

*TMT = Tyendinaga Mohawk Territory a rural area ** Small rural area in the Municipality of Tweed. Colebrook, Yarker, Roslin and Newburgh are Hamlets

The location of surveys where these parameters were noted to exceed the guidelines is provided in Table 5-4. From these surveys it is evident that bacteriological water quality problems are widespread throughout the area with approximately 30 to 50 percent of the samples showing unacceptable quality. Some of the reports did not differentiate between the type of bacteria (i.e. Total Coliform, *E.coli*, or Fecal Coliform) that was elevated above the drinking water objective. However, from the surveys where the results were available, it was evident that Total Coliform was most prevalent and *E.coli* and Fecal Coliform were detected less frequently.

For Nitrate and Chloride, the surveys did not detect these parameters to be widespread over the areas reviewed. A much lower percentage of samples with unacceptable levels were reported. Unacceptable levels of Nitrate were detected in four of the sampling areas in a relatively low number of samples (0.5 to 7 percent of the total) and not at all in the other sampling areas. Unacceptable levels of Chloride were detected in all but two of the sampling areas at a relatively low frequency of typically less than 15 percent of the samples. Some of the samples with elevated chloride were reported to be attributed to wells located in close proximity to sources of contamination such as septic systems or roads. However others may be due to natural conditions as it is difficult to differentiate in the absence of necessary detail or further assessment.

Table 5-4: Non Natural Water Quality Parameters

Location	Year	# of wells sampled	Unacceptable Bacteria	Unacceptable Nitrate	Unacceptable Chloride
Colebrook	1985	29	10	2	4
Yarker	1985	59	31	3	2
Moira	2000	14	7	1	1
Roslin	2000	15	4	0	0
TMT *	2000	631	263	n/a	n/a
TMT *	2004	171	154	1	26
Newburgh	2007	20	9	0	3
Newburgh	2008	24	10	0	2
Tweed **	2004	16	3	0	0

***** TMT = Tyendinaga Mohawk Territory, ** A small rural area in the municipality of Tweed.

5.1.8 Highly Vulnerable Aquifer Issues

A review of available information indicated that the majority of Quinte region aquifers yield fresh water with few water quality issues. There are several parameters which were detected at elevated levels that are attributed to natural sources. However the majority of these parameters are aesthetics related and easily treated to improve the aesthetic quality of the water. Two naturally occurring parameters related to health that were detected and are not easily treated are sodium and uranium. Sodium is an important concern to persons on sodium restricted diets. Uranium can also adversely affect health because of radioactivity.

Parameters that were detected and reported attributed to human activities are Total Coliform, *E.coli*, Fecal Coliform, Nitrate and Chloride. From the available information, it would appear that detection of these parameters is associated with areas of high density development (hamlets), age and location of septic systems and improper well construction. Other rural areas of lower density development were also found to have unacceptable levels of these parameters which may be associated with improper well construction, or wells that are located too close to sources of contamination. In the surveys completed by Quinte Conservation (Hamlet of Newburgh and rural area of the Municipality of Tweed) observations were recorded of well construction indicating that 60 to 70 percent of the wells in the Hamlet were improperly constructed and 33 percent of the wells in the rural area did not comply. The most frequent problems were wells constructed in well pits, buried below grade and/or with improper caps. In addition, at some locations, it was noted that some residents did not know where their well was located. Overall this information indicates a lack of awareness about groundwater, a need for maintenance of wells, a need for increased public education and protection of drinking water quality.

5.1.9 Highly Vulnerable Aquifer Threats Assessment

The identification and assessment of potential and known contaminant sources is an essential element for the protection and management of the groundwater resource. To assist in the source protection planning process a list of potential threats is provided as well as a summary of the existing threats in the Highly Vulnerable Aquifer area.

A drinking water threat may be described as a land use activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is, or may be used as a source of drinking water. In accordance with the *Clean Water Act, 2006* the activities listed in Table 4-3 of Chapter 4 may be considered a drinking water threat in the Highly Vulnerable Aquifer area.

Listing of Drinking Water Threats

In reference to the vulnerability score of 6 and the Technical Rules Look Up Tables (Appendix D-1) there can be no Significant or pathogen threats within the Highly Vulnerable Aquifer area. However, prescribed drinking water threats that are considered Moderate and Low chemical threats for this area are listed in Table 5-6. Moderate level threats include the operation or maintenance of a waste disposal site such as a landfill and the operation or maintenance of systems to collect, store, transmit and treat sewage such as a sewage treatment plant. Activities that may be considered a low chemical drinking water threat include all 19 categories listed in Table 5-6. The circumstances under which these activities may be considered threats are listed in the Provincial Table of Circumstances (MOE, March, 2010) with relevant Tables listed in Table 5-5. The location where these activities may be considered moderate or low drinking water threats is the entire Quinte Source Protection Region.

Table 5-5: **Highly Vulnerable Aquifers Provincial Circumstance Tables**

HIGHLY VULNERABLE AQUIFER -CHEMICAL THREATS			
VULNERABILITY SCORE	SIGNIFICANT	MODERATE	LOW
6	No Threats	TABLE 17-CSGRAHVA6M	TABLE 18-CSGRAHVA6L

Further information about the location of contaminant sources in the Quinte region was provided through review of The Quinte Regional Groundwater Study (Dillon Consulting 2004). This study included an assessment of potential contaminant sources in the Quinte region through a review of data sources listed in Table 5-7. Coordinates were assigned to each potential source with mapping as provided in The Quinte Regional Groundwater Study (Dillon Consulting

2004). From this inventory a preliminary indication of the number of activities which can be considered Moderate threats were determined by listing the number of landfill sites and sewage treatment plants below.

In addition, the number of contaminated sites which may be considered potential conditions were listed as the number of known contaminated sites and federal contaminated sites. Further work is required to confirm whether each activity meets the requirements to be considered a condition as not all of these sources have resulted in contamination of the groundwater. The number of each of these features found in the Highly Vulnerable Aquifers is:

- Landfills – 16
- Sewage Treatment Plants – 8
- Known Contaminated Sites – 10
- Federal Contaminated Sites – 6

There have been no other activities identified by the Source Protection Committee as a drinking water threat in the Highly Vulnerable Aquifer area.

Table 5-6: Moderate and Low Chemical Threats in Highly Vulnerable Aquifers

	Vulnerability Score = 6	**Moderate**	**Low**
	Prescribed Drinking Water Threats (*Clean Water Act. 2006* - Ontario Regulation 287/07)		
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.	✓	✓
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓
3	The application of agricultural source material to land.		✓
4	The storage of agricultural source material.		✓
5	The management of agricultural source material.		✓
6	The application of non-agricultural source material to land.		✓
7	The handling and storage of non-agricultural source material.		✓
8	The application of commercial fertilizer to land.		✓
9	The handling and storage of commercial fertilizer.		✓
10	The application of pesticide to land.		✓
11	The handling and storage of pesticide.		✓
12	The application of road salt.		✓
13	The handling and storage of road salt.		✓
14	The storage of snow.		✓
15	The handling and storage of fuel.		✓
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).		✓
17	The handling and storage of an organic solvent.		✓
18	The management of runoff that contains chemicals used in the de-icing of aircraft.		✓
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.		✓

Table 5-7: Contaminant Site Inventory Data Sources

Study Categorization	Database (Author/supplier)
Gas Stations	Retail Fuel Storage Tanks (MOE/TSSA/ERIS) Municipal Survey
Fuel/Chemical Storage	Retail Fuel Storage Tanks (MOE/TSSA/ERIS) Private Fuel Storage Tanks (TSSA/ERIS)
Landfills – Active Landfills - Closed	Waste Disposal Site Inventory, (MOE/ERIS) Anderson's Waste Disposal Sites (ERIS) Municipal Survey
Sewage Treatment Plants	Wastewater Discharger Database (MOE)
Waste Generators	*Ontario Regulation* 347 Waste Generators (MOE/ERIS)
Waste Receivers	*Ontario Regulation* 347 Waste Receivers (MOE/ERIS)
Manufacturing/Industrial	Scott's Manufacturing Directory (Scott's) Municipal Survey
Coal Gasification	Inventory of Coal Gasification Plants (MOE/ERIS)
PCB Storage	Ontario Inventory of PCB Storage Sites (MOE/ERIS)
Pesticide Storage	Pesticide Register (MOE/ERIS)
Salt Storage	Municipal Survey
Auto Scrap Yard	Automobile Wrecking and Supplies (ERIS) Municipal Survey
Spills	MOE Spills Database (MOE)
Known Contaminated Sites	Federal Contaminated Sites (Canada) Ontario MOE Interviews Municipal Survey

MOE: Ministry of the Environment, ERIS: Ecolog Environmental Risk Information Services, Scott's: Scott Business Directories,
TSSA: Technical Standards and Safety Authority

5.2 Significant Groundwater Recharge Areas

Significant Groundwater Recharge Areas were delineated in the Tier 1 Water Budget Report (Appendix C-2) using the methodology described in Chapter 4. Further detailed water budget work completed at the Tier 2 level did not provide any changes to the delineation that was completed in the Tier 1 report. These areas are considered important in providing higher volumes of recharge to the underlying aquifers and because of this significance are designated as vulnerable areas.

To determine the location of these areas the Geographic Information System Water Budget Model was used. The results of this exercise are illustrated by Map 5.2 indicating that approximately 3.1 percent of the watershed region is comprised of Significant Groundwater Recharge Areas. These areas are found throughout the Region and are associated with formations containing significant deposits of permeable sand and gravel. The significant formations that correspond with these areas are:

- The Tweed esker connected with the Tweed municipal groundwater supply,
- The Picton esker connected with the Waring's Creek cold water stream, and
- The Oak Hills (Kame Moraine) connected with several cold water streams such as Chrysal Creek, Palliser Creek, Number 10 Creek, and Parks Creek.

5.2.1 Significant Groundwater Recharge Area - Vulnerability Score

The vulnerability of these areas was assessed by the Intrinsic Susceptibility Index as described above in Chapter 4. This method indicated these areas to be highly vulnerable. In accordance with Technical Rules the vulnerability score for the Significant Groundwater Recharge Areas with a high vulnerability is 6.

5.2.2 Significant Groundwater Recharge Area - Identification of Transport Pathways

Transport pathways that can allow contaminants to enter a drinking water source are listed in Table 4-2 of Chapter 4. These pathways exist throughout the Significant Groundwater Recharge Area; however an inventory has yet to be completed. Given the area has been classified as highly vulnerable, the presence of such pathways cannot increase the classification but are still a concern.

5.2.3 Significant Groundwater Recharge Area - Managed Lands and Livestock Density

The percent managed lands and livestock density were calculated for the Significant Groundwater Recharge Area by methodology provided in Chapter 4 and reported in Table 5-8. The average percent managed lands for these areas is moderate at 48.3 percent and livestock density is moderate to high at 2.7 Nutrient Units per acre. These results are expected given the significant groundwater recharge areas are located in areas where there is more substantial deposits of soil to support agricultural activities.

Table 5-8: Managed Lands & Livestock Density Significant Groundwater Recharge Areas

Zone	Managed Lands (%)	Livestock Density (NU/acre)*
SGRA	48.3	2.7

* Note: NU/acre=Nutrient Units/acre

5.2.4 Significant Groundwater Recharge Area - Percentage of Impervious Surfaces

The average percent impervious area of the Significant Groundwater Recharge Areas (see Map 2.22) using a 1 square kilometer grid and methodology described in section 4.7.6 of Chapter 4. This impervious area coverage is low with 41 percent at less than 1 percent impervious, 58 percent in the range of 1 to 8 percent impervious, and the balance at 8 to 80 percent.

5.2.5 Significant Groundwater Recharge Area – Water Quality Issues

Water quality in the Significant Groundwater Recharge Areas is an important consideration for the various users of the water in these areas for agriculture, business, industry and residential use. In addition it is noted that many of these recharge areas are closely associated with sensitive cold water streams that could be impacted by the discharge of poor quality groundwater. To provide information about the quality of the groundwater in these areas a review was completed similar to that described under the Highly Vulnerable Aquifer Area Section 5.1.6.

In accordance with the Technical Rules, a water quality issue in the Significant Groundwater Recharge Area may be identified if there is evidence of widespread presence of a parameter listed in the Ontario Drinking Water Quality Standards (excluding microbiological) and the parameter may result in the deterioration of the water for use as a source of drinking water, or there is evidence of a trend in increasing concentration of the parameter that would result in the deterioration of the quality of the water as a source of drinking water.

5.2.6 Significant Groundwater Recharge Area – Issues Evaluation

An outline of the methodology used for identifying water quality issues in the Quinte region is provided in Chapter 4 and as specified in Section 5.1.7 for the Highly Vulnerable Aquifers.

5.2.6.1 Significant Groundwater Recharge Area – Data Sources and Results

For this assessment the main source of data was water quality data from the Provincial Groundwater Monitoring Network. The regional studies and surveys that were reviewed under the Highly Vulnerable Aquifer section were not specific enough to allow specification of water quality issues within the smaller Significant Groundwater Recharge Areas.

There are six Provincial Groundwater Monitoring Network wells located in areas mapped as Significant Groundwater Recharge. These wells, range from depths of 16.8 to 62.8 metres with the majority at depths of less than 30 metres (see Map 3.7). The distribution of these wells in the Quinte Aquifer Regions is:

- 3 wells in the Overburden aquifers
- 2 wells in Precambrian aquifers and
- 1 well in the Limestone aquifer

Review of water quality data, collected between 2002 to 2008, indicated the following parameters exceeded the Ontario Drinking Water Quality Standards (Schedules 2 and 3 of the *Safe Drinking Water Act, 2002* – Ontario Regulation 169/03 and Table 4 in Ministry of the Environment 2006) in three or more samples:

- Hardness
- Iron

Both of these parameters are attributed to natural sources and from the data reviewed there do not appear to be elevated parameters associated with water quality issues in the Significant Groundwater Recharge Areas. Note that this conclusion has been made on a limited amount of data and additional data would be required to confirm there are no issues in these areas.

5.2.7 Significant Groundwater Recharge Area – Threats Assessment

The identification and assessment of potential and known contaminant sources is an essential element for the protection and management of the groundwater resource. To assist in the source protection planning process a list of potential threats is provided as well as a summary of the existing threats in the Significant Groundwater Recharge Area.

This assessment was completed in a similar fashion for the Highly Vulnerable Aquifer Area. In accordance with the *Clean Water Act, 2006* the activities listed in Table 4-3 of Chapter 4 may be considered drinking water threats in this area. In view of the vulnerability score there can be no Significant or pathogen threats. A list of the categories of prescribed drinking water threats that may be considered Moderate and Low chemical threats (see Table 5-10). The moderate threats include the operation or maintenance of a waste disposal site such as a landfill and the operation or maintenance of systems to collect, store, transmit and treat sewage such as a sewage treatment plant. The number of these activities in the Significant Groundwater Recharge Areas was determined through review of the contaminant source inventory of the Quinte Regional Groundwater Study (October 2004). In total there were two landfills and no sewage treatment plant facilities. Activities that may be considered a low chemical drinking water threat include all 19 categories as listed in Table 5-10. The location of these threats may be anywhere in a Significant Groundwater Recharge Area and the circumstances under which they may be considered threats are as listed in the Provincial Circumstance Tables (March, 2010) with relevant tables as listed in Table 5-9.

Table 5-9: Significant Groundwater Recharge Area Provincial Circumstance Tables

SIGNIFICANT GROUNDWATER RECHARGE AREA - CHEMICAL THREATS			
VULNERABILITY SCORE	**SIGNIFICANT**	**MODERATE**	**LOW**
6	No Threats	TABLE 17-CSGRAHVA6M	TABLE 18-CSGRAHVA6L

In addition, the number of contaminated sites which may be considered potential conditions were reviewed in the Quinte Regional contaminant inventory. This review did not reveal any contaminated sites to be located in the Significant Groundwater Recharge Area.

There have been no other activities identified by the Source Protection Committee as a drinking water threat in the Significant Groundwater Recharge Area. Conditions have also not been identified with reference to the circumstances provided in the Technical Rules.

Table 5-10: Moderate and Low Chemical Threats in Significant Groundwater Recharge Areas

	Vulnerability Score = 6	**Moderate**	**Low**
	Prescribed Drinking Water Threats (*Clean Water Act*, 2006 - Ontario Regulation 287/07)		
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.	✓	✓
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓
3	The application of agricultural source material to land.		✓
4	The storage of agricultural source material.		✓
5	The management of agricultural source material.		✓
6	The application of non-agricultural source material to land.		✓
7	The handling and storage of non-agricultural source material.		✓
8	The application of commercial fertilizer to land.		✓
9	The handling and storage of commercial fertilizer.		✓
10	The application of pesticide to land.		✓
11	The handling and storage of pesticide.		✓
12	The application of road salt.		✓
13	The handling and storage of road salt.		✓
14	The storage of snow.		✓
15	The handling and storage of fuel.		✓
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).		✓
17	The handling and storage of an organic solvent.		✓
18	The management of runoff that contains chemicals used in the de-icing of aircraft.		✓
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.		✓

5.3 Wellhead Protection Areas

The final type of vulnerable groundwater area in the Quinte Source Protection Region that was studied is the Wellhead Protection Areas. These areas are the zones around a municipal well which include the land above and below ground where land use activities have the potential to affect the quality of water flowing towards the well. There are four locations within the Quinte Source Protection Region where municipal groundwater supply systems exist. These systems (see Map 2.3) are:

- Peats Point Subdivision – 1 well
- Village of Deloro – 1 well
- Village of Tweed – 2 wells
- Village of Madoc – 2 wells

For each of these systems a Wellhead Protection Area was delineated by methodology described in Chapter 4. The four main zones include a 100 metre radius and three zones representing time in which it takes groundwater to move towards the well. These zones are:

- WHPA A: 100 metre radius
- WHPA B: 2 year Time of Travel
- WHPA C: 5 year Time of Travel
- WHPA D: 25 year Time of Travel

All of these systems obtain water from aquifers located in fractured bedrock that are recharged by rain and melted snow. However at some systems the wells are located near surface water features where surface water can contribute and influence the quality of water in the well. In these situations it is also necessary to delineate zones in the surface water that require protection. These zones are:

- WHPA E – 2 hour time of travel in the surface water body
- WHPA F – Total contributing watershed area

Following the delineation of the vulnerable zones further work was completed to assess the vulnerability of each zone, review water quality data for each system to determine if there are issues, review of land use activities to assess the location of potential drinking water threats as well as determine what could be a drinking water threat. The methodology used is described in Chapter 4 and a summary of the results for each of the drinking water systems is provided below.

5.4 Peats Point Groundwater Supply, Municipality of Prince Edward County

The Peats Point water system is within a small residential development servicing 19 residences located in the northern part of Prince Edward County. The community is located on a point of land extending into the Bay of Quinte that is approximately 800 metres long by 300 metres wide. Water supply to the community is provided by a single well located on the south side of the point at approximately 40 metres from the Bay. Land use in the area includes residential, open space, and agricultural land to the south. Not all of the residents are serviced by this well.

The well was installed in May, 2004 to replace a previous well that was of substandard construction. The new well was drilled to a depth of 36.9 metres into a fractured limestone aquifer and constructed with 7.6 metres of steel casing. Water was encountered at a similar depth to the old well at approximately 32.8 metres. Given the proximity of this well to the Bay of Quinte it is classified as a Groundwater Under the Direct Influence of Surface Water (GUDI) necessitating the delineation of a WHPA-E in the Bay of Quinte.

The water use, as summarized in Table 5-11, is low with permitted use far exceeding the actual use. Although growth in this subdivision is not anticipated, future use was estimated based on Minister of Finance growth projections at a rate of 1 percent per year over 25 years.

Table 5-11: Peats Point Water Use

	Daily	Monthly	Annual
Actual	13.3	404	5086
Future	22	660	8030
Permitted	260	8060	94900

Note: All Units are in m^3

5.4.1 Peats Point Wellhead Protection Area

The Wellhead Protection Area was originally determined through completion of the Quinte Regional Groundwater Study (Dillon, 2004) and is summarized in the Peats Point Subdivision-Wellhead Protection Area Delineation Update Report (Dillon Consulting 2008 in Appendix E-1). This required the development of a numerical 3-dimensional groundwater flow model to represent the groundwater flow system and delineate the capture zones (WHPA) based on future pumping rates listed in Table 5-11. This includes WHPA A, B, C, and D extending in a southerly direction for a distance of approximately 1700 metres over a maximum width of 450 metres(see Map 5.3). For the low volume of water being used this distance is considered relatively large but is attributed to high flow velocities of groundwater in the fractured limestone bedrock.

5.4.2 Peats Point Surface Water Protection Zone

In addition to the groundwater capture zones a WHPA E (equivalent to an IPZ 2) was delineated in the adjacent Bay of Quinte. This is considered to be the zone where water in the Bay may influence water quality in the well. Given the location of the well on a point of a land extending into the Bay of Quinte, determination of this zone was completed by projecting the potential groundwater and surface water interaction to three locations encompassing the point. From each location the 2 hour time of travel was delineated to include a 120 metre setback along the shoreline. This provided delineation of the WHPA E (see Map 5.3). Included in this Zone is an intermittent drainage course at the west end of an inlet of the Bay, draining agricultural lands located at the south.

This methodology is a variation from the technical rules and approval from the Director of Source Protection Programs Branch of Ministry of Environment has been received. (see Appendix D-2)

5.4.3 Peats Point Vulnerability Scoring

The aquifer vulnerability in this area was evaluated by the Intrinsic Susceptibility Index by methodology described in Section 4.3.1. Due to the shallow nature of the limestone aquifer and the absence of significant thickness of overlying low permeability materials the aquifer vulnerability was evaluated as high. A review of the ISI scores for wells located in and around the wellhead protection area indicated scores ranging from a low of 3.6 to 27. This is in spite of a relatively deep 'water found' depth as lack of low permeability formations above the aquifer does not afford significant protection. In the municipal well the static level is near ground surface and as such there is short time of travel for contaminants to move from ground surface to the water table. From this point contaminants could move deeper into the aquifer via fractures potentially connected with the deeper water bearing zones. In addition to the ISI, the water quality data for this well is indicative of vulnerable conditions. This data is discussed below in Section 5.4.7 which indicates that total coliform and *E.coli* have been detected in the raw water at this well. Potential nearby sources of contamination include septic systems and agricultural source material. Detection of cyano bacteria in the raw water of this well also confirms vulnerability of the aquifer to potential contamination from the nearby Bay of Quinte. Based on the high aquifer vulnerability the vulnerability scores for WHPA A through D were assigned in reference to Table 4.1 and are listed in Table 5-12 and illustrated in Map 5.4.

Table 5-12: Peats Point Vulnerability

Aquifer Vulnerability	WHPA			
	WHPA A (100 m)	WHPA B (2 year)	WHPA C (5 year)	WHPA D (25 year)
HIGH	10	10	8	6

A vulnerability score was assigned to the WHPA-E zone in accordance with Part VIII, Rule 87 of the Technical Rules. The score is a product of the area vulnerability factor and the source vulnerability factor. Details on the calculation of the score are presented in the following subsections.

WHPA E Area Vulnerability Factor

Area vulnerability factors were assigned to the WHPA-E zone as per Part VIII.2, Rules 88 to 93. For the WHPA-E zone, Rule 89 specifies a value that is not less than 7 and not more than 9. This value was derived based on the following criteria as required in Rule 92:

1. The percentage of the area that is composed of land;
2. The land cover, soil type, permeability and slope; and
3. Hydrological and hydrogeological conditions that contribute water to the area through transport pathways.

Some criteria for defining Area Vulnerability Factors are shown on Table 5-13. Soils in the WHPA zones are predominantly gravelly loam and sand with moderate slopes. The soils around the well consist of silty sand/sandy silt with moderate natural drainage characteristics. Significant percentage of the WHPA area is composed of water.

The overburden geology has been mapped (Leyland 1982) as shallow drift over limestone bedrock. Generally, the overburden material in the vicinity of Peats Point Subdivision is less than 1 metre thick, such that the above-mentioned soils do not provide significant protection to the aquifer form surface contaminants. The bedrock geology consists of limestone and shale of the Verulum Formation. The upper portion of the limestone aquifer can be considered an unconfined fractured bedrock aquifer. Both vertical and horizontal fractures are common in the top 30 to 50 metres of the bedrock. The presence of vertical fractures results in the aquifer being susceptible to surface contamination. The lack of a protective low permeability overburden layer results in the aquifer most likely being recharged quickly after precipitation events and being vulnerable to contamination from the surface (Dillon 2008).

Therefore, out of three possible numbers, the highest Area Vulnerability Factor of 9 was assigned to the Peats Point WHPA-E zone. The decision was mainly based on hydrogeology.

Table 5-13: Criteria for defining Area Vulnerability Factors for Well Head Protection Areas

	Soil Type	Average Slope	Land Use
WHPA-E	A mixed of gravelly loam, gravelly sandy and sandy	3.0 %	Water - 61%, Urban - 0%, Crop - 15% , Swamp/Marsh - 3%, Forest - 4% , Bog/Fen - 0% Pasture -15%, Other - 2%

WHPA E Source Vulnerability Factor

A source vulnerability factor was assigned to the WHPA-E zone prescribed in Part VIII, Rules 94 through 96 of the Technical Rules. The source vulnerability factor for a Type D intake (see Section 6.0 for discussion on intake types for Bay of Quinte) can be 0.8, 0.9, or 1.0 based on the following criteria as required in Rule 95:

- Depth of the intake from the top of the water surface;
- Distance of the intake from land; and
- Number of recorded drinking water issues related to the intake (if any).

The well depth is 36.9 metres and it intercepts a moderate-yield fracture at a depth of 32.8 m. The Peats Point Subdivision well is located about 40 metres from the Bay of Quinte. Since the well was opened in 2005, there have been no drinking water issues related to the intake. However, it should be noted, that disposal of sewage within the Peats Point subdivision and adjacent properties is through on-site septic systems which may recharge the groundwater.

The Peats Point Subdivision well has been identified as being GUDI, and therefore may receive some water from the Bay of Quinte. Overall, the major source of water to the well is attributed to groundwater, however, a small, and unknown portion of water may potentially originate from a surface water source. Raw water in the well may be prone to contamination from bacteria from the septic tanks.

Considering the potential impacts of the well from surface water, a value of 0.9 was assigned to WHPA-E. The score, which is at the middle portion of the recommended range for a Type D intake, reflects the condition that the well does not pump directly from surface water, however in close proximity of potential bacterial contamination. The overall vulnerability score is 8.1 as illustrated by Map 5.4.

5.4.4 Peats Point Identification of Transport Pathways

Transport pathways that may allow contaminants to enter a drinking water source are listed in Table 4-2 of Chapter 4. A review of land use indicated the following features serving as transport pathways within the Wellhead Protection Area:

- existing wells
- abandoned wells (none confirmed but potential exists)
- septic systems

Given the area has been classified as highly vulnerable, the presence of such pathways cannot increase this classification but are still a concern.

5.4.5 Peats Point Managed Lands and Livestock Density

The percent managed lands and livestock density were calculated for individual zones listed in Table 5-14. The overall percentage is moderate to high as there are agricultural lands under cultivation to the immediate south of the subdivision. Livestock density is also reported as moderate to high as livestock farming is active in this region. However the housing, pasturing and grazing of livestock was not observed in this area where the application of agricultural source material was reported as occurring.

Table 5-14: Peats Point Managed Lands and Livestock Density

WHPA	Managed Lands (%)	Livestock Density (NU/acre)*
A	30	0
B	18	0
C	10.2	2.7
D	59.3	2.7
E	19.8	2.7

* Note: NU/acre=Nutrient Units/acre

5.4.6 Peats Point Percentage of Impervious Surfaces

The percentage of impervious surface for each zone is reported in Table 5-15 and illustrated by Map 5.6 which was calculated using a 1 square kilometer grid and methodology described in section 4.7.6 of Chapter 4. The impervious area is low in view of low density development including open water and farms.

Table 5-15: Peats Point Impervious Areas

WHPA	Impervious Area (%)
A	1-8
B	1-8
C	<1 &1-8
D	<1
E	<1 &1-8

5.4.7 Peats Point Water Quality Issues

The raw water quality data at the Peats Point Subdivision well supply was screened using the approach described in Section 4.8 to identify issues in the source water which may contribute to degraded water quality. The Peats Point well supply is groundwater under the direct influence of surface water due to its location next to the Bay of Quinte. Data sources used in the review are presented later in this section.

The 4-step screening process was applied to the Peats Point Subdivision well supply raw water data and results are summarized below. A more complete analysis is contained in Appendix E-2.

Screening Step 1

The following six parameters passed screening step 1.

- *E. coli*
- Total Coliforms
- Alkalinity
- Colour
- Hardness
- Sodium

E.coli and Total Coliform individual results were compared to their Maximum Acceptable Concentration of zero counts/100 ml. *E.coli*, Total Coliform, and Sodium had an average greater than their Maximum Acceptable Concentrations. The other three parameters had individual results that exceeded their Half Maximum Acceptable Concentration, the half benchmark. These three were analyzed for trending in Step 3.

Screening Steps 2 and 3

E.coli and Total Coliform passed screening Steps 2 and 3 for having a suspected anthropogenic source and upward trend lines that if continued the average could exceed the benchmark within 50 years. Trend analysis was not necessary for *E.coli* and Total Coliform as their averages are already above the benchmarks of zero counts/100ml. The *E.coli* parameter represents the generic *E.coli* bacteria commonly found in the lower intestine of warm-blooded organisms and naturally found in the gut. Most *E.coli* strands are harmless but some can cause serious health risk in humans. Total Coliform is a parameter representing generic coliforms including *E.coli* and fecal coliforms which are abundant in the feces of warm-blooded animals, but can also be found in the aquatic environment, in soil and on vegetation. The presence of Total Coliform is an indicator of potential bacteria, viruses, and protozoa.

Alkalinity, Hardness, Colour, and Sodium are considered natural background parameters for groundwater. Sodium had a range of concentrations that is considered normal for groundwater which can be slightly elevated compared to surface water. Sodium in treated water had an average concentration higher than the benchmark of 20 mg/L, a benchmark set out to alert people on sodium restriction diets, but observations were never above the aesthetic objective of 200 mg/L. Sodium is only tested in the treated water at Peats Point.

Screening Step 4

No issues were identified at Peats Point Well Supply because the Source Protection Committee determined the Threats Approach (Section 5.4.5) captures all associated Significant threats linked to *E.coli* and Total Coliforms in the Wellhead Protection WHPA A, B, and E (no Significant pathogenic threats were found in WHPA C). The Director of Water and Waste Water at the Corporation of the County of Prince Edward was contacted in November 2009 and was in agreement with this assessment.

Early Action Stewardship funding in 2008 and 2009 allowed for some wells to be decommissioned and upgraded, and some septic systems to be upgraded in WHPA A. This work reduced the risk of future contamination of the aquifer.

Data Sources

Raw water quality data was obtained from several sources. They are summarized below and were provided by the Ontario Ministry of the Environment and Prince Edward County on behalf of the Plant Operators:

- Ontario Ministry of Environment (MOE) Drinking Water Information Systems data, Quinte Systems (2005-2009)
- Water Treatment Plant Lab Results Data (2005-2008) provided by the municipality
- MOE Drinking Water Compliance Inspection Report (Ministry of the Environment 2009a)

5.4.8 Peats Point Threats Assessment

Completion of a threats assessment has resulted in the development of a list of what may be considered a threat in this area, where these threats may occur, the circumstances under which they would be considered Significant, Moderate or Low, and an inventory of existing Significant threats in reference to land use activities.

Listing of Drinking Water Threats

Potential drinking water threats within the Peats Point Wellhead Protection Area are prescribed by the *Clean Water Act* and listed in Table 4-3 of Chapter 4. The circumstances under which these threats may be considered as Significant Moderate or Low are referenced in the Provincial Table of Circumstances (MOE, March, 2010). A summary of the list of Provincial Tables relative to each vulnerable zone is provided by Table 5-16. The location of the vulnerable zones where threats listed in these tables may occur (see Map 5-4).

Condition Based and Source Protection Committee Designated Activity Threats

There are no conditions based threats that have been identified nor have there been any activities, beyond the Prescribed Drinking Water Threats, that the Source Protection Committee identified as a potential threat.

Enumeration of Significant Threats

A threats inventory resulted in the identification of 34 individual parcels, five threat types with 49 Significant threats enumerated within the WHPA A, B, and E (see Table 5-17).

There are 49 threats because each parcel may have more than one threat activity. In consideration of the land use, residential septic systems were determined to present Significant chemical and pathogen threats in the WHPAs A and B. There is little uncertainty about the septic systems as each house is known to be serviced by these systems; however some uncertainty is associated with lots located in the WHPA B as the exact location of the septic system is not known and may possibly be outside of the zone. Other Significant chemical threats are the use of home heating oil tanks, of which five were inventoried. There is high uncertainty associated with the use of these tanks. More information was gathered to confirm this inventory through the threats verification exercise.

Table 5-16: Peats Point List of Provincial Circumstance Tables

WELLHEAD PROTECTION AREA - CHEMICAL THREATS				
WHPA	**VULNERABILITY SCORE**	**SIGNIFICANT**	**MODERATE**	**LOW**
A & B	10	TABLE 1-CW10S	TABLE 2-CW10M	TABLE 6-CW10L
C	8	TABLE 2-CW8S	TABLE 4-CW8M	TABLE 7-CW8L
D	6	No Threats	TABLE 5-CW6M	TABLE 8 -CW6L
E	8.1	TABLE 21-CIPZWE8.1S	TABLE 25-CIPZWE8.1M	TABLE33-CIPZWE8.1L
WELLHEAD PROTECTION AREA - PATHOGEN THREATS				
A & B	10	TABLE 12-PW10S	TABLE 13-PW10M	No Threats
C & D	Any Score	No Threats	No Threats	No Threats
E	8.1	TABLE 47-PIPZWE8.1S	TABLE 51-PIPZWE8.1M	No Threats
WELLHEAD PROTECTION AREA - DNAPL THREATS				
A, B & C	Any Score	TABLE 9-DWAS	TABLE 9-DWAS	TABLE 9-DWAS
D	6	No Threats	TABLE 10-DW6M	TABLE11-DW6L

Table 5-17: Peats Point Significant Threat Enumeration

Zone	Threat*	Number of Affected Parcels**	Circumstance Example
WHPA A	Residential Septic System	5	Septic System
	Fuel Tanks	1	Fuel tanks below grade and partially below grade >250-2500 litres
WHPA B	Residential Septic System	22	Septic System
WHPA E	Pesticides	7	Area > 10 ha
	Agricultural Source Material	7	Any quantity of manure spreading
	Livestock Grazing	7	Pasture or grazing of 1 or more animals
Totals	5 Threat Types	***49 threats on 34 parcels****	

Note: * Prescribed Drinking Water Threats, *Clean Water Act* (2006) – O. Reg. 287/07, 1.1(1)
** “Affected parcels” represents the number of parcels on which a specific activity is being engaged in. Some parcels may have more than one threat activity on-site.

In the WHPA E the main Significant threats relate to agricultural land use along the intermittent drainage course to the south. These lands are actively farmed, however there is some uncertainty associated with the threats as the exact farming practice used at these locations may change. No Significant threats were identified in the WHPA-C and D.

Peats Point Moderate and Low Threats

Moderate and Low threats were identified for both chemical and pathogen threats. Table 5-18 and Table 5-19 list all of the potentially Moderate and Low chemical and pathogen threats for the Peats Point Wellhead Protection Area. These threats were established in reference to land use and the list of prescribed drinking water quality threats.

5.4.9 Peats Point Concerns and Data Gaps

The enumeration approach used was conservative and may overestimate the number of threats compared to actual conditions. For example, all farms were considered to apply Agricultural Source Material (ASM). There was also a general lack of information on the presence/absence of contamination associated with historical land uses. As a result, no condition-related drinking water threats (if present) were identified. In addition, the type and quantity of chemicals stored at residences within the Wellhead Protection Area is unknown.

Table 5-18: Peats Point Moderate and Low Chemical Threats

		WHPA									
Prescribed Drinking Water Threats (Clean Water Act, 2006 - Ontario Regulation 287/07)		A Mod	A Low	B Mod	B Low	C Mod	C Low	D Mod	D Low	E Mod	E Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.									✓	
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.			✓		✓			✓		✓
3	The application of agricultural source material to land.					✓			✓	✓	
4	The storage of agricultural source material.					✓			✓	✓	✓
5	The management of agricultural source material.										
6	The application of non-agricultural source material to land.					✓			✓	✓	
7	The handling and storage of non-agricultural source material.					✓	✓		✓	✓	✓
8	The application of commercial fertilizer to land.					✓			✓	✓	
9	The handling and storage of commercial fertilizer.								✓	✓	✓
10	The application of pesticide to land.	✓	✓	✓	✓	✓	✓		✓	✓	✓
11	The handling and storage of pesticide.						✓		✓	✓	✓
12	The application of road salt.	✓		✓							✓
13	The handling and storage of road salt.								✓		
14	The storage of snow.										
15	The handling and storage of fuel.	✓	✓	✓	✓	✓	✓		✓	✓	✓
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).										
17	The handling and storage of an organic solvent.	✓	✓	✓	✓	✓	✓		✓	✓	✓
18	The management of runoff that contains chemicals used in the de-icing of aircraft.										
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.					✓	✓		✓	✓	

Table 5-19: Peats Point Moderate and Low Pathogen Threats

		WHPA			
Prescribed Drinking Water Threats (Ontario Regulation 287/07)		A Mod	B Mod	E Mod	E Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.				
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.			✓	
3	The application of agricultural source material to land.				
4	The storage of agricultural source material.			✓	
5	The management of agricultural source material.				
6	The application of non-agricultural source material to land.				✓
7	The handling and storage of non-agricultural source material.			✓	
8	The application of commercial fertilizer to land.				
9	The handling and storage of commercial fertilizer.				
10	The application of pesticide to land.				
11	The handling and storage of pesticide.				
12	The application of road salt.				
13	The handling and storage of road salt.				
14	The storage of snow.				
15	The handling and storage of fuel.				
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).				
17	The handling and storage of an organic solvent.				
18	The management of runoff that contains chemicals used in the de-icing of aircraft.				
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.				

5.5 Village of Deloro Groundwater Supply, Municipality of Marmora and Lake

The Village of Deloro is a small community located north of Highway 7 on the fringe of the Precambrian Shield. The community, comprised of approximately 180 people, grew around the adjacent Deloro mine site (presently under remediation) where gold mines were originally developed and later used for the processing of various ores. The community has been serviced by water and sewer for some time with current water supply obtained from a single well which is owned and operated by the Municipality of Marmora and Lake. This well is located at the southwestern end of the Village adjacent to surrounding land use being residential and marginal agricultural lands. There is a small amount of commercial activity in the Village and the former Deloro mine site is to the east.

The current well was drilled in 1976 to a depth of 29.9 metres intercepting water at depths of 14 and 21 metres in fractured Precambrian bedrock. The well was reported as being constructed with 9.6 metres of steel casing and a recommended pumping rate of 75 gallons per minute.

This water supply is classified as a Groundwater Under the Direct Influence of Surface Water (GUDI). This classification is due to the shallow unconfined nature of the aquifer as opposed to the presence of nearby surface water features. Therefore the delineation of a WHPA E was not required. The water from the well is treated by membrane filtration (to provide the equivalent to chemically assisted filtration) followed by ultraviolet and chlorine disinfection prior to distribution. After water use, the wastewater is discharged to a municipally owned subsurface septic system located immediately east of the well. The water use at this well is relatively low within permitted capacity and summarized in Table 5-20.

Table 5-20: Village of Deloro Water Use

	Daily	Monthly	Annual
Actual	68	2040	24820
Future	90	2700	32850
Permitted	327	9810	119355

Note: All units are in m^3

5.5.1 Village Of Deloro Wellhead Protection Area

A Wellhead Protection Area was developed using a numeric three dimensional groundwater flow model to delineate the various zones (Golder Associates 2007 in Appendix E-3). First a conceptual model was developed to assist in an understanding of the local hydrogeologic setting. The area was generally characterized as exhibiting moderate topography with minimal overburden above fractured Precambrian and Paleozoic bedrock.

Groundwater was reported to flow through the fractures in the bedrock with recharge from precipitation. Following calibration of the groundwater flow model the various capture zones were delineated based on future pumping rates. The Wellhead Protection Area was determined as extending up gradient from the well to the northwest for a distance of approximately 1350 metres and a maximum width of 350 metres (see Map 5.5). This relatively short distance is due to the shallow nature of the aquifer and a groundwater divide where groundwater flows to the north.

5.5.2 Village of Deloro Vulnerability Scoring

The vulnerability of the supply aquifer within the WHPA was assessed using the ISI approach in reference to MOE guidance documents (Draft Groundwater Module 3 (October, 2006). The ISI was calculated according to methodology for unconfined aquifers using the ground surface elevation, the water table elevation and geological mapping. The geologic materials above the water table consist of weathered Paleozoic limestone and fractured Precambrian bedrock. The K-Factor for this material was assigned as 1 and the depth to the water table ranged from 4 to 22 metres. Therefore the K factor was calculated to range between 4 and 22. As these scores were less than 30 the aquifer vulnerability was assigned as high. This high vulnerability is a direct result of the shallow water table and thin overburden which does not provide significant protection of the aquifer from surface activities. The relatively deep water found depth of the municipal well suggests there may be some protection from the overlying bedrock, however, the shallow depth of the water table and variable nature of fractured bedrock does not provide assurance that any deep fractures are not connected with surface. An illustration of a hydrograph of water levels for this well is provide by Figure 5-5 showing direct fluctuations due to recharging precipitation and seasonal fluctuations of water levels in the order of approximately 5 metres.

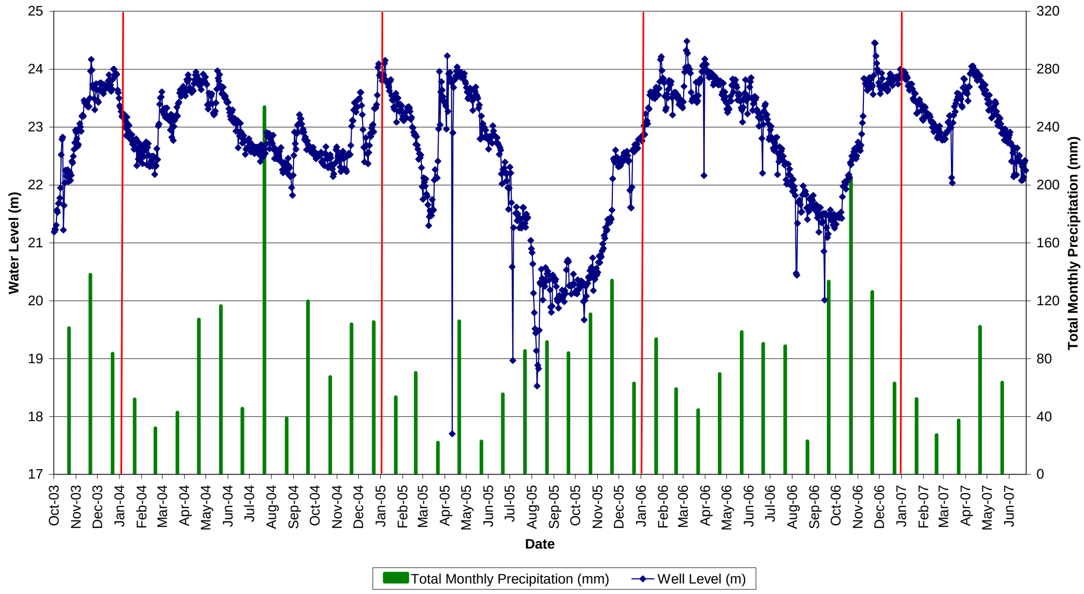

Figure 5-5: Deloro Municipal Well Hydrograph with Monthly Precipitation

Water quality data from this well is also supportive of the highly vulnerable conditions as counts of total coliform and *E.coli* have been detected in the raw water as discussed below in Section 5.5.6. Bacteriological parameters are not normally found in the groundwater and may be associated with nearby sources of contamination which could include stormwater runoff and septic systems. Classification of the well as Groundwater Under the Direct Influence of Surface Water (GUDI) due to the shallow nature of the water supply is another factor which points to vulnerability of the well and need for precaution in protection of the water quality. Through use of the Intrinsic Susceptibility Index the vulnerability was assigned as high with scores for each WHPA listed in Table 5-21 and illustrated by Map 5.6.

Table 5-21: Village of Deloro Vulnerability

Aquifer Vulnerability	WHPA			
	WHPA A (100 m)	WHPA B (2 year)	WHPA C (5 year)	WHPA D (25 year)
HIGH	10	10	8	6

5.5.3 Village of Deloro Identification of Transport Pathways

Transport pathways that may allow contaminants to enter a drinking water source are listed in Table 4.2 of Chapter 4. A review of land use indicated the following features serving as transport pathways within the Wellhead Protection Area:

- one private domestic supply well;
- one private septic systems;
- one communal septic system;
- one former municipal water supply well (no decommissioning record);
- one municipal sanitary sewer; and
- potential exists for other unknown abandoned wells and mine shafts.

Please note that although these pathways exist the vulnerable areas were scored as highly vulnerable and their presence does not increase the vulnerability.

5.5.4 Village of Deloro Managed Lands and Livestock Density

The percent managed lands and livestock density were calculated for individual WHPAs listed in Table 5-22. The overall percentage is low to moderate as there are agricultural lands to the north. Livestock density is also reported as moderate to high; however this is based on the census subdivision data as the agricultural lands in the Wellhead Protection Area are not being actively cultivated or used.

Table 5-22: Village of Deloro Managed Lands and Livestock Density

WHPA	Managed Lands (%)	Livestock Density (NU/acre)*
A	0	0
B	62.8	3
C	28	3
D	0	3

*NU/acre = Nutrient Units/acre

5.5.5 Village of Deloro Percentage of Impervious Surfaces

The percentage of impervious surface for each WHPA is reported in Table 5-23 and Map 5.9 which was calculated using a 1 square kilometer grid and methodology as described in Section 4.7.6 of Chapter 4.

Table 5-23: Village of Deloro Impervious Areas

WHPA	Impervious Area (%)
A	1-8
B	<1, & 1-8
C	<1
D	<1

5.5.6 Village of Deloro Water Quality Issues

The raw water quality data at the Village of Deloro well supply was screened using the approach described in Section 4.8 to identify issues in the source water which may contribute to degraded water quality. The well supply is groundwater under the direct influence of surface water because it is a shallow well with a potential connection to the surface. Data sources used in the review are presented later in this section.

The 4-step screening process was applied to the Deloro well raw water data and results are summarized below with more complete analysis in Appendix E-4.

Screening Step 1

The following eight parameters passed screening step 1.

- *E.coli*
- Total Coliforms
- Chromium
- Alkalinity
- Hardness
- Sodium
- Terbufos
- Iron

E.coli and Total Coliform individual results were compared to their Maximum Acceptable Concentration of zero counts/100 millilitres. With the exception of *E.coli* and Total Coliform the other six parameters had individual results that exceeded their Half Maximum Acceptable Concentration, the half benchmark. They were analyzed for trending in Step 3. *E.coli* and Total Coliform had averages greater than the Maximum Acceptable Concentration.

Screening Steps 2 and 3

Three parameters listed below pass screening Step 2 as they are most likely a result of human activities.

- *E.coli*
- Total Coliform
- Terbufos

Chromium, Alkalinity, Hardness, Sodium and Iron are considered naturally occurring parameters. Iron, Chromium, and Sodium had trend lines in a downward direction and if they continue they will not exceed their benchmarks in 50 years time.

Terbufos

Terbufos is an insecticide typically used on corn, sugar beets, and grain sorghum crops applied at planting time. Terbufos in treated water was analyzed in this case because there were not enough data to do trend analysis on raw water samples. Terbufos in treated water did not pass screening Step 3 because the trend line is in a downward direction showing no indication that water quality is deteriorating for this parameter in treated water. Although Terbufos passed screening Steps 1 and 2 it did not pass Step 3, but should continue to be monitored at the Deloro well supply.

E.coli and Total Coliform

The *E.coli* parameter represents the generic *E.coli* bacteria commonly found in the lower intestine of warm-blooded organisms and naturally found in the gut. Most *E.coli* strands are harmless but some can cause serious health problems in humans. Total Coliform is a parameter representing generic coliforms including *E.coli* and fecal coliforms which are abundant in the feces of warm-blooded animals, but can also be found in the aquatic environment, in soil and on vegetation. The presence of Total Coliform is an indicator of potential bacteria, viruses, and protozoa. Trend analysis of screening Step 3 was not necessary for *E.coli* and Total Coliform as their averages were already above the benchmarks of zero counts/100ml.

Chromium

Based on professional judgement Chromium concentrations in raw water at the Deloro well are unlikely to be attributed to human activities. Most concentrations for Chromium are below the half benchmark and comparable to groundwater concentrations at local wells on the Canadian Shield of the Provincial Groundwater Monitoring Network.

Screening Step 4

No issues were identified at the Deloro well supply because the Source Protection Committee determined that the Threats Approach (Section 5.5.7) captures all associated Significant threats linked to *E.coli* and Total Coliforms given the extent of the WHPA A and B (no Significant pathogenic threats were found in WHPA C). The Manager of Water and Waste Water at Marmora and Lake Township was contacted in December 2009 and was in agreement with this assessment.

Early Action Stewardship funding in 2008 and 2009 allowed for one well and one septic system to be decommissioned, and the relocation of a municipal storm water discharge outfall that were both located in WHPA A. These projects could reduce future *E.coli* and Total Coliforms entering into the aquifer.

Data Sources

The municipality took over from the Ontario Clean Water Agency in operating the drinking water system in January 2008. Raw water quality data was obtained from several sources. They are summarized below and were provided by the Ontario Ministry of the Environment, the Ontario Clean Water Agency, and Municipality of Marmora and Lake on behalf of the plant operators:

- Ontario Ministry of Environment (MOE) Drinking Water Information System Data, Quinte Systems (2003-2009)
- MOE Drinking Water Surveillance Program, Deloro System (1999-2003)
- Ontario Ministry of Environment Drinking Water Systems Regulation O. Reg. 170/03 (2002-2007) annual summaries of results provided by Ontario Clean Water Agency
- Water Treatment Plant Lab Results Data (2008-2009) provided by the municipality
- MOE Drinking Water Compliance Inspection Report (Ministry of the Environment 2009b)

5.5.7 Village of Deloro Threats Assessment

Completion of a threats assessment has resulted in development of a list of what may be considered a threat in this area, where these threats may occur, the circumstances under which they would be considered Significant, Moderate or Low, and an inventory of existing Significant threats in reference to land use activities.

Listing of Drinking Water Threats

Potential drinking water threats within the Deloro Wellhead Protection Area are as prescribed by the *Clean Water Act, 2006* and listed in Table 4.3 of Chapter 4. The circumstances under which these threats may be considered Significant Moderate or Low are referenced in the Provincial Table of Circumstances (MOE, March, 2010). A summary of the list of Provincial Tables relative to each vulnerable zone is provided by Table 5-24. The location of the vulnerable zones where threats listed in these tables may occur (see Map 5-6).

Enumeration of Significant Threats

A preliminary list of Significant threats in the Deloro Wellhead Protection Area is presented in Table 5-25. A total of 11 parcels were enumerated with 16 Significant drinking water threats. These threats relate mainly to the location and use of the sanitary sewage collection and disposal system for the Village. Significant agricultural threats were noted in the WHPA B, these lands are zoned as marginal agriculture and were observed to be fallow or dormant. In spite of this observation the lands were enumerated due to the potential for agricultural use. No Significant threats were identified in the WHPAs C and D.

Table 5-24: Village of Deloro List of Provincial Circumstance Tables

WELLHEAD PROTECTION AREA - CHEMICAL THREATS				
WHPA	**VULNERABILITY SCORE**	**SIGNIFICANT**	**MODERATE**	**LOW**
A & B	10	TABLE 1-CW10S	TABLE 2-CW10M	TABLE 6-CW10L
C	8	TABLE 2-CW8S	TABLE 4-CW8M	TABLE 7-CW8L
D	6	No Threats	TABLE 5-CW6M	TABLE 8 -CW6L
WELLHEAD PROTECTION AREA - PATHOGEN THREATS				
A & B	10	TABLE 12-PW10S	TABLE 13-PW10M	No Threats
C & D	Any Score	No Threats	No Threats	No Threats
WELLHEAD PROTECTION AREA - DNAPL THREATS				
A, B & C	Any Score	TABLE 9-DWAS	TABLE 9-DWAS	TABLE 9-DWAS
D	6	No Threats	TABLE 10-DW6M	TABLE11-DW6L

Table 5-25: Village of Deloro Significant Threat Enumeration

Zone	Threat*	Number of Affected Parcels**	Circumstance Example
WHPA A	Municipal Septic System	1	Large Septic System
	Fuel Tanks	1	Fuel tanks below grade and partially below grade >250-2500 litres
WHPA B	Livestock Grazing	5	Livestock density >1 nu/acre
	Application of Agricultural Source Material	5	Any Quantity of manure spreading
	Fuel Tanks	4	Fuel tanks below grade and partially below grade >250-2500 litres
Totals	5 Threat Types	16 threats on 11 parcels	

Note: * Prescribed Drinking Water Threats, *Clean Water Act* (2006) – O. Reg. 287/07, 1.1(1)
** “Affected parcels” represents the number of parcels on which a specific activity is being engaged in. Some parcels may have more than one threat activity on-site.

Condition and Source Protection Committee Designated Activity Threats

No condition based threats were identified in the absence of available data. There are also no additional activities, beyond the Prescribed Drinking Water Threats, that the Source Protection Committee has identified as a potential threat.

Moderate and Low Threats

Moderate and Low threats were identified for both chemical and pathogen threats. It is not required that these threats be enumerated as the Significant threats were but instead be listed by Wellhead Protection Area. Table 5-26 and Table 5-27 list the Moderate and Low chemical and pathogen threats for the Deloro Wellhead Protection Area in reference to existing and future land use. The circumstances for these threats to be considered Moderate or Low are provided in the Provincial Table of Circumstances (MOE, March, 2010).

5.5.8 Village of Deloro Concerns and Data Gaps

The nearby contaminated Deloro mine site presents a host of contaminants that have potential to impact the groundwater in the area. However, the contaminated site is located down gradient and not in the vulnerable zone of the municipal well. Regardless, it is recommended that remediation work especially the transport of contaminated soil on the road adjacent to the well be monitored.

The enumeration approach used for this assessment was conservative and may overestimate the number of threats compared to actual conditions. This is in light of the assumption that all farms were considered to apply agricultural source material. There was a general lack of information on the presence/absence of contamination associated with historical land uses. As a result, no condition-related drinking water threats (if present) were identified. In addition, the type and amounts of chemicals stored at residences within the Wellhead Protection Areas is unknown. Effort was made to verify this information through mail out survey to residents located within the vulnerable zones.

Table 5-26: Village of Deloro Moderate and Low Chemical Threats

		WHPA							
Prescribed Drinking Water Threats (*Clean Water Act, 2006* - Ontario Regulation 287/07)		A Mod	A Low	B Mod	B Low	C Mod	C Low	D Mod	D Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.			✓					
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓	✓	✓	✓			
3	The application of agricultural source material to land.					✓			✓
4	The storage of agricultural source material.	✓				✓			
5	The management of agricultural source material.								
6	The application of non-agricultural source material to land.					✓			✓
7	The handling and storage of non-agricultural source material.	✓		✓		✓	✓		✓
8	The application of commercial fertilizer to land.					✓			✓
9	The handling and storage of commercial fertilizer.				✓				
10	The application of pesticide to land.	✓	✓	✓	✓	✓	✓		✓
11	The handling and storage of pesticide.								
12	The application of road salt.	✓	✓	✓					
13	The handling and storage of road salt.								
14	The storage of snow.	✓		✓					
15	The handling and storage of fuel.	✓	✓	✓	✓	✓	✓		✓
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).								
17	The handling and storage of an organic solvent.	✓	✓	✓	✓	✓	✓		✓
18	The management of runoff that contains chemicals used in the de-icing of aircraft.								
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.	✓				✓			✓

Table 5-27: Village of Deloro Moderate and Low Pathogen Threats

		WHPA	
Prescribed Drinking Water Threats (*Clean Water Act, 2006* - Ontario Regulation 287/07)		A Mod	B Mod
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.		
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.		
3	The application of agricultural source material to land.		
4	The storage of agricultural source material.		
5	The management of agricultural source material.		
6	The application of non-agricultural source material to land.		✓
7	The handling and storage of non-agricultural source material.		✓
8	The application of commercial fertilizer to land.		
9	The handling and storage of commercial fertilizer.		
10	The application of pesticide to land.		
11	The handling and storage of pesticide.		
12	The application of road salt.		
13	The handling and storage of road salt.		
14	The storage of snow.		
15	The handling and storage of fuel.		
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).		
17	The handling and storage of an organic solvent.		
18	The management of runoff that contains chemicals used in the de-icing of aircraft.		
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.		

5.6 Village of Tweed Groundwater Supply

The Village of Tweed is a community of approximately 1500 people located on the southern fringe of the Precambrian shield along the western shore of Stoco Lake. The Village of Tweed is located in the Municipality of Tweed. The land use around the Village is a mixture of residential, commercial and open space with some areas of industrial land. Outside of the Village, particularly to the west, the land use is primarily agricultural and undeveloped rural land. Water supply to the Village is provided by two wells and sewage is collected and treated in a municipal sewage treatment facility.

The two wells are located on the western edge of the community and are referred to as Well # 1 and Well # 3. There is no Well # 2 because this well was decommissioned. Well # 1 is located at the north along the Hungerford Rd, and was installed in 1954 to a depth of 132.6 metres. The well was drilled through 12.5 metres of sand and gravel into the underlying Precambrian bedrock, intercepting water at a depth of 130.5 metres. The yield is in the order of 755 L/min, however the water quality is reported to contain elevated levels of uranium and as a result the well is used for backup purposes only. Prior to use the water is treated to reduce uranium levels.

Well # 3 is located approximately 700 metres to the south of Well # 1 along the Crookston Rd. This well was installed in 1995 to a depth of 122.2 metres through 10.1 metres of sand and gravel into Precambrian Bedrock, intercepting water bearing zones at depths of 15.5 and 47.2 metres. The well is classified as Groundwater Under the Direct Influence of Surface Water (GUDI). This classification is related to the shallow depth of the aquifer as opposed to the presence of nearby surface water features. The total water use of both wells is reported by Table 5-28 including actual, future and permitted.

Table 5-28: **Village of Tweed Water Use**

	Daily	Monthly	Annual
Actual	579	17370	211335
Future	741	22230	270465
Permitted	2583	77490	942795

Note: All units are in m^3

5.6.1 Village of Tweed Wellhead Protection Area

The Wellhead Protection Area for this system was developed through completion of the Quinte Regional Groundwater Study outlined in the report Tweed Village Municipality of Tweed Wellhead Protection Area Delineation (Dillon Consulting 2004 in Appendix E-5). This study required the development of a three dimensional groundwater flow model to represent the groundwater flow system. Using this model the capture zones were delineated as illustrated by Map 5.7 using future pumping rates. The capture zones are oriented in a westerly direction away from the village in the up gradient direction of groundwater flow. This area is approximately 2.3 kilometres in length and 1.7 kilometres in width, encompassing mainly agricultural land as well as wetland areas. This capture zone was determined assuming that each well was being used to supply 100 percent of the water to the municipality and then combining the two zones. This is the most appropriate way to represent the actual use of the wells as only one well is used at a given time. Well # 1 is only used for emergency backup purposes.

5.6.2 Village of Tweed Vulnerability Scoring

The vulnerability of the groundwater in the Wellhead Protection Area was evaluated by the Intrinsic Susceptibility Index (ISI) method described in Section 4.3.1 assuming unconfined conditions. This approach takes into consideration the ability of a contaminant at surface to migrate vertically downwards into the aquifer. The ISI index was calculated the same way as the other Wellhead Protection Areas even though there is a greater depth of soil at this location. The coarse nature of the overlying sand and gravel soils do not provide significant protection to the underlying aquifer. The ISI index for wells within and around the wellhead protection area commonly ranged from 2 to 25 indicating a high vulnerability. This high vulnerability is not unexpected given the shallow nature of the bedrock aquifer and the absence of significant thickness of overlying low permeability materials. A sand and gravel esker is present in this area providing significant soil cover but the coarse nature of the formation does not provide significant protection. Exceptions to the ISI were three wells which provided a higher index suggesting moderate aquifer vulnerability. However, contouring/interpolation of the scores of all wells did not result in identifying a continuous area with moderate vulnerability as the majority of wells scored in the high vulnerability category.

Further information confirming the high aquifer vulnerability is water quality data for the municipal wells discussed below in Section 5.6.6. From a review of water quality data elevated levels of total coliform, nitrate, nitrite, ammonia, and turbidity were detected. These parameters are indicators of potential contamination from nearby sources such as private septic systems, livestock housing/pasturing and agricultural source material. In addition to detecting elevated parameters the levels of nitrate were noted as fluctuating in the main municipal well over the course of the year. Detection of elevated ammonia is also an indicator of contamination. This is potentially related to the application of nutrients and agricultural source material within the Wellhead Protection Area.

Further to the assessment of aquifer vulnerability by the ISI method, was the completion of a SWAT (Surface to Well Advection Times) analysis. A summary of this assessment is provided in the Dillon Consulting report dated July 27, 2005 contained in Appendix E-5. Through completion of this analysis the time of travel of water from ground surface to the water table was found to be rapid confirming the high aquifer vulnerability.

The vulnerability scores were assigned at the highest rating illustrated by Map 5.8 and listed in Table 5-29. This high vulnerability is supported by the classification of one of the wells as Groundwater Under the Direct Influence of Surface Water (GUDI) due to the shallow nature at which water enters the well.

Table 5-29: Village of Tweed Vulnerability

Aquifer Vulnerability	WHPA			
	WHPA A (100 m)	WHPA B (2 year)	WHPA C (5 year)	WHPA D (25 year)
HIGH	10	10	8	6

5.6.3 Village of Tweed Identification of Transport Pathways

Transport pathways that may allow contaminants to enter a drinking water source are listed in Table 4.2 of Chapter 4. A review of land use indicated the features listed in Table 5-30 are transport pathways within the Wellhead Protection Area. Please note that given the aquifer is already at the highest vulnerability level; the scores cannot be increased by the presence of these transport pathways.

Table 5-30: Village of Tweed Transport Pathways Wellhead Protection Area

MOE Pathway Class	Description
Existing Potable Water Wells	The majority of the land parcels that front Crookston Road and Quin-Mo-Lac Road, west of College Street are serviced by private individual wells. East of College Street, and within the WHPA, no private wells are known.
Monitoring Wells	Monitoring wells were inventoried /observed around well # 3.
Abandoned Wells	A high potential for abandoned wells exists at farmsteads, municipal well field and areas that were developed prior to the construction of the municipal system.
Septic Systems	Homes/buildings west of College Street are expected to have current or historic septic systems.
Water Mains and Sewers	Water mains and sewers are located along College Street, and along Crookston Road and Quin-Mo-Lac Road, east of College Street.

5.6.4 Village of Tweed Managed Lands and Livestock Density

The percent managed lands and livestock densities are reported in Table 5-31. These numbers are relatively high and are a reflection of active agricultural operations in the wellhead protection zones which include the housing and pasturing of livestock.

Table 5-31: Village of Tweed Managed Lands and Livestock Density

WHPA	Managed Lands (%)	Livestock Density (NU/acre)*
A	51.8	3.2
B	62.7	3.2
C	81.9	3.2
D	82.5	3.2

*NU/acre = Nutrient Units/acre

5.6.5 Village of Tweed Percentage of Impervious Surfaces

The percent impervious areas for the zones around each of the Tweed wells are reported in Table 5-32 and Map 5.12 which were calculated using a 1 square kilometer grid and methodology as described in section 4.7.6 of Chapter 4.

Table 5-32: Village of Tweed Impervious Area

Well #	WHPA	Impervious Area (%)
Well 1	A	1-8
	B	1-8, & 8-80
	C	<1, & 1-8
	D	<1, & 1-8
Well 3	A	1-8
	B	1-8, & 8-80
	C	<1, & 1-8
	D	<1, & 1-8

5.6.6 Village of Tweed Water Quality Issues

The raw water quality data collected at the Tweed Well supply were screened using the approach described in Section 4.8 to identify issues in the source water of the aquifer which may contribute to degraded water quality. The well supply is Groundwater Under the Direct Influence of Surface Water (GUDI) because it is a shallow well with a potential connection to the surface. Data sources used in the review are presented later in this section.

The 4-step screening process was applied to the Tweed Well supply raw water data and the results are summarized below. A more complete analysis by Dillon Consulting (2009) and an addendum added by the Source Protection Authority in 2021 is contained in Appendix E-6.

Screening Step 1

The following seven parameters listed below passed modified screening Step 1.

- Total Coliform
- Fluoride
- Uranium
- Nitrates and Nitrates+Nitrites
- Sodium
- Manganese
- Turbidity

This screening approach deviated slightly from the summary in Section 4.8. This is a more conservative approach elevating more parameters for initial review since a single exceedance of the Half Maximum Acceptable Concentration would trigger the parameter to be analyzed. Since groundwater is the source water, microbial parameters, e.g. Total Coliform, had their individual results compared to the Maximum Acceptable Concentration of zero counts/100 millilitres. The other parameters had individual results compared to their Half Maximum Acceptable Concentration.

Screening Steps 2 and 3

In the original assessment, only Total Coliform passes screening Steps 2 and 3. However, in 2021, the Municipality of Tweed notified the Quinte Region Source Protection Authority and Committee that nitrate levels in the raw water at the municipal drinking water wells were increasing. As a result of the upward trend in nitrate levels, an issue evaluation was required using updated data sets.

Total Coliform is a parameter representing generic coliforms including *E.coli* and fecal coliform which are abundant in the feces of warm-blooded animals, but can also be found in the aquatic environment, in soil and on vegetation. The presence of Total Coliform is an indicator of potential bacteria, viruses, and protozoa. Total Coliform counts ranged from 0 to 280 counts/100 millilitres in Well # 1 and were detected during each reporting year between 2001 to 2003 and 2006 to 2008. Well # 1 was not in service for the years 2006 to 2008 as it is now a back-up well supply only used in an emergency. Total Coliform in Well # 3 raw water was reviewed between 2001 to 2008 with no results over the benchmark (0 counts/100ml) since 2004. Trend Analysis is not necessary for

Total Coliform for Well # 1 and Well # 3 since the averages are already greater than the benchmark of zero counts/100 millilitres.

Since 2001 no samples were reported over the Half Maximum Acceptable Concentration for Sodium (20 mg/L) or for Manganese (0.05 mg/L). There has been no reported concentrations greater than the Half Maximum Acceptable Concentration for Turbidity (5 NTU) since 2005 (Dillon Consulting 2009 Tweed). There is not enough data available to perform trend analysis on Sodium, Manganese, and Turbidity.

The Ontario Clean Water Agency, the operating authority for the Tweed well supply, was contacted in September 2009. They were aware of the slightly elevated Fluoride levels that they deemed to be naturally occurring. They continue to monitor Fluoride levels closely.

The system operator has noted that only the raw water from Well # 1 is directed through the uranium removal system. The operating authority maintains the uranium levels within criteria without an overtaxing demand on the uranium removal system. Overall, uranium is not considered an issue as treatment effectively mitigates the natural exceedance of this parameter; however, it is identified as a concern for further monitoring.

Uranium and Fluoride in raw water are considered background parameters and are naturally high as the result of high levels in the Precambrian rock aquifer and are believed not to be from any human activities. Trend analysis of Fluoride and Uranium does not appear to be trending upwards or downwards in concentration (steady state, no change overtime).

Nitrate and Nitrates+Nitrites (2001 to 2007 data) only had two reported samples greater than the Half Maximum Acceptable Concentration in Well # 3 since 2002 and never above the Half Maximum Acceptable Concentration in Well # 1. Nitrate and Nitrates+Nitrites appeared to show a slight downward trend but since the concentration range was quite broad the downward trend is debatable.

Nitrate levels have changed since the time of the original assessment. Concentrations of nitrate-nitrogen in both municipal drinking water wells have been increasing. The levels are acceptable in respect of the Ontario drinking water standard of 10 milligrams/litre (Ontario Regulation 169/03), however the increasing trend is of significant concern and the concentrations in samples from Well 3 are exceeding half of the maximum acceptable concentration (i.e. 5mg/l) (Ontario Regulation 169/03) in the late spring to early fall months (See Figure 5-6). The concentrations of nitrite-nitrogen also appear to be increasing in Well 1 but are somewhat stable in well 3. All concentrations are within the Ontario drinking water standards and have not reached the critical half maximum acceptable concentration level.

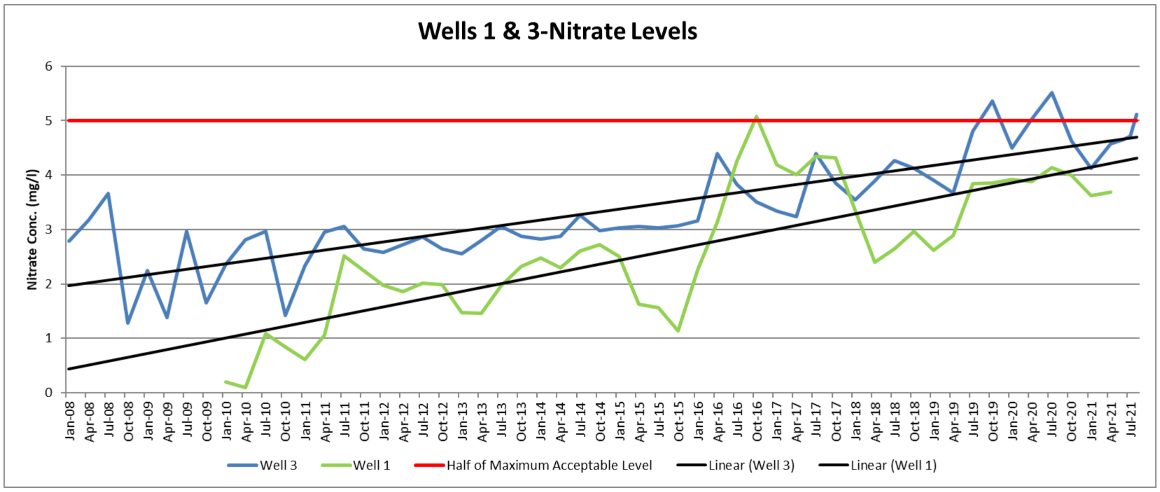

Figure 5-6: Nitrate Levels in Tweed Municipal Drinking Water Wells

In addition to monitoring of raw water quality at the municipal wells, monitoring is conducted at a nearby monitoring well. The samples from this well are collected on a quarterly basis by municipal staff and submitted to a qualified laboratory for analysis. The samples are analysed for nitrate, nitrite, ammonia, uranium, e. Coli and total coliform as part of the Municipality’s bi-annual Permit to Take Water Monitoring Report. These levels, as illustrated by Figure 5-7, have been observed to increase above the Ontario drinking water standard of 10 mg/l. This increase began in 2018 and although the nitrate levels have fluctuated, the results of the most recent sample indicate the level remains above the drinking water standard.

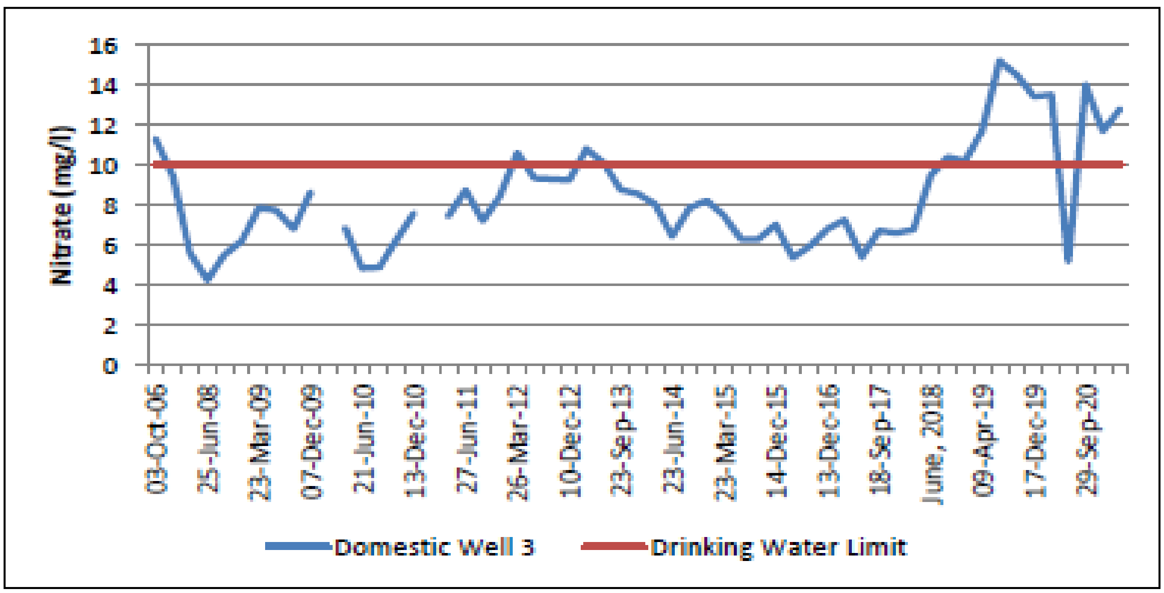

Figure 5-7: Nitrate Levels in Domestic Well #3

Using the 2017 Technical Rules, the Source Protection Authority reviewed the water quality data from the municipal and monitoring wells against Rules 114 and 115. Under Rule 114, one of the following three rules must be met before deeming Nitrates an Issue in the Tweed Wellhead Protection Area:

1) The parameter in the groundwater is listed in Schedule 1, 2, or 3 of the Ontario Drinking Water Quality Standards or Table 4 of the Technical Support Document and,
    a. The concentration of the parameter may result in the deterioration of the source of drinking water, or
    b. There is a trend of increasing concentrations of the parameter at the municipal well or monitoring well.
2) The presence of a pathogen in the water at a municipal or monitoring well and,
    a. The concentration of the parameter may result in the deterioration of the source of drinking water, or
    b. There is a trend of increasing concentrations of the parameter at the municipal well or monitoring well.
3) In respect of drinking water systems in the vulnerable area that are not mentioned in clause 15(2)(e) of the Act, there is evidence of the widespread presence of a parameter listed in Schedule 2 or 3 of the Ontario Drinking Water Quality Standards or Table 4 of the Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines at surface water intakes or in wells, including monitoring locations, related to those systems, and
    a. The concentration of the parameter may result in the deterioration of the source of drinking water, or
    b. There is a trend of increasing concentrations of the parameter at the municipal well or monitoring well.

Rule 114(1)(b) is met using the raw water results from the municipal drinking water well (see Figure 5-6) and Rule 114(3)(a)&(b) are met using the results from Domestic Well #3 (see Figure 5-7). Because one or more conditions of Rule 114 were met, and the parameter passed the screening steps previously discussed, it was necessary to proceed to screening step four, and identify Nitrates as an issue for the Tweed well supply.

Further, because the nitrate levels fluctuate throughout each year, with results showing nitrate levels drop in the late fall -winter months and then rise again in late spring – early summer, it is evident nitrate impacts are attributed to anthropogenic causes, such as agriculture activities in the area. These impacts are linked to agricultural activities, as nitrate levels are elevated during the typical agricultural operation season then decrease in the winter months when nutrient spreading does not occur.

Screening Step 4

The operating authority, the Clean Water Agency was contacted in the fall of 2009 and again in 2021 regarding their knowledge of any raw water quality issues associated with the system. In 2021 they identified nitrates as issues for the Tweed well supply as mentioned in screening Step 3. Discussion with the operators reported these parameters to be issues due to the level of nitrates had exceeded half Maximum Allowable Concentrate (i.e., 5 mg/l) in the raw water of the municipal drinking water wells.

As this parameter passed the four screening steps it was necessary to identify nitrates as an issue for the Tweed well supply. Therefore, it was necessary to identify an Issues Contributing Area and associated land use activities that may contribute to these water quality parameters. Total Coliform is not an issue at the Tweed well supply because the well supply is Groundwater Under the Direct Influence of Surface Water (GUDI) which has a treatment system with primary and secondary disinfection capable of treatment. In addition, the Threats Approach reviewed in the following section captures all associated Significant threats linked to Total Coliform given the extent of the WHPA A and B (no Significant pathogenic threats were found in WHPA C).

Data Sources

Raw water quality data was obtained from several sources. They are summarized below and were provided by the Ontario Ministry of the Environment, the Ontario Clean Water Agency, and the Municipality of Tweed on behalf of the Plant Operators:

- 2001-2007 Ontario Clean Water Agency annual summary data
- 2006-2020 Ontario Ministry of Environment Drinking-Water Systems Regulation O. Reg. 170/03 Annual Reports provided by the Ontario Clean Water Agency
- 2008-2021 Raw water samples from Municipal Well#1 and Well#3
- 2006-2021 Raw water samples at Domestic Well 3

- MECP Drinking Water Inspection Reports for the Tweed Well Supply (DWS 220001557).

Under Rule 115 of the 2017 Technical Rules, any drinking water issue identified under Rule 114 that is a result of anthropogenic causes, must include the following information:

1) The parameter concerned.
2) The well or monitoring location at which the presence of the parameter occurred.
3) The area within the vulnerable areas where activities may contribute to the parameter of concern. This area is identified as the Issues Contributing Area; and
4) The identification of the drinking water threats that may contribute to the parameter of concern.

Description

Once Nitrate was identified as an Issue for the Tweed municipal well#3 and monitoring well Domestic Well#3, it was necessary to determine potential drinking water threat activities that may impact the nitrate levels in the drinking water and the extent of the issues contributing area as per Rule 115(3).

Activities Assessment

Once nitrates were determined to be an issue to the Tweed groundwater supply, a list of possible prescribed drinking water threat activities was created. Ontario Regulation 287/07, pursuant to the *Act,* provides a list of Prescribed Drinking Water Threats (PDWTs) that could constitute a threat to drinking water sources Any threat activity that could contribute Nitrates to the source water of the well supply was added to the list. These activities include sewage threats, application of agricultural source material, application, handling and storage of commercial fertilizer to land, handling and storage of agricultural source material, application and storage of non-agricultural source material or biosolids to land, the storage of snow, storage, treatment and discharge of tailings from mines, the application of hauled sewage to land, waste disposal sites, and livestock grazing/pasturing.

Issue Contributing Area Delineation

When an issue is identified, an Issues Contributing Area can be delineated to address the concern. When required, an Issues Contributing Area is delineated and a threat assessment is completed to determine which land use activities affect could be contributing to the elevated concertation of the substance in the well.

According to Technical Rule 115 (3) and (4), an Issue Contributing Area and an inventory of threats contributing to the issues are required. The Issue Contributing Area is defined as *the area within a vulnerable area where activities, conditions that result from past activities, and naturally occurring conditions may contribute to the parameter or pathogen and this area shall be identified as the "issue contributing area"* and can be shown within a Wellhead Protection Area, Intake Protection Zone, or Highly Vulnerable Aquifer. Several threat activities that could impact nitrate levels have already been removed or managed in the WHPA A and B by policies in the source protection plan. An air photo review showed similar activities operating at a larger scale in the WHPA C and D.

The issues contributing area approach was based on local knowledge of the watershed, negotiation with the affected municipality, various Ministries' staff, the 2017 Technical Rules under the *Clean Water Act, 2006,* a review of other related regulations, water quality analysis and field work to determine threats that could contribute to the issues.

After numerous discussions with Source Protection Authority staff, and OMAFRA staff, it was determined that the existing operations within the Wellhead Protection Area could not be solely responsible for the elevated nitrate levels in the raw water. Risk Management Officials met with the municipality to discuss nearby agricultural operations that may be impacting nitrate levels and found several larger agricultural operations exist in the Wellhead Protection Areas C and D. Source Protection Authority staff met OMAFRA staff again in the fall of 2021 to discuss the extent of the wellhead protection area. Based on the high levels of nitrates, the windshield survey by Risk Management Officials, and the numerous discussions with Source Protection Authority staff, MECP staff, municipal staff, and OMAFRA staff, the Source Protection Committee approved by consensus an Issue Contributing Area equal to the extent of the Wellhead Protection Area D, the 25 year time of travel (see Map 5-13).

Enumeration of Issue-based Significant Threats

Inventorying land use activities that may be associated with the nitrate issue was based on a review of multiple data sources including public records, data provided through questionnaires completed by municipal officials, previous contaminant/historical land use information, and data collected during windshield surveys.

It is important to note, that although a number of activities fall within the Wellhead Protection Areas A and B, the majority of these threats have been either removed or managed through implementation of policies in the Quinte Region Source Protection Plan. As such, the enumeration looked at the addition of threats in the Wellhead Protection Areas C and D. No site-specific information was collected; therefore, all prescribed drinking water threats are considered potential rather than confirmed. Because threat activities have not been verified through ground-truthing, additional threats may be identified for the Tweed drinking water system, specifically in the Wellhead Protection C and D. The threats inventory resulted in 15 septic system threats, and 126 potential agricultural threats.

5.6.7 Village of Tweed Threats Assessment

Completion of a threats assessment has resulted in development of a list of what may be considered a threat in this area, where these threats may occur, the circumstances under which they would be considered Significant, Moderate or Low, and an inventory of existing Significant threats in reference to land use activities.

Listing of Drinking Water Threats

Potential drinking water threats within the Tweed Wellhead Protection Area are as prescribed by the *Clean Water Act, 2006* and listed in Table 4.3 of Chapter 4. The circumstances under which these threats may be considered Significant, Moderate or Low are referenced in the Provincial Table of Circumstances (MOE, March, 2017). A summary of the list of Provincial Tables relative to each vulnerable zone is provided by **Error! Reference source not found.**. The location where these threats may occur is within the various vulnerable zones as illustrated by Map 5.10.

Enumeration of Significant Threats

The number and type of Significant prescribed drinking water threats are presented in Table 5-. Based on an inventory of the land uses within the Wellhead Protection Area, and a review of available government and commercial databases on past and present land uses as well as other data, 220 potential Significant provincial drinking water threats (PDWTs) on 39 parcels were identified (see Table 5-). These threats relate mainly to home heating fuel tanks. Other Significant threats pertain to agricultural land use to the west as well as commercial activities near the wellheads.

Condition and Source Protection Committee Designated Activity Threats

A potential condition related drinking water threat was identified as a closed landfill site within the Village of Tweed Wellhead Protection Area D. The Certificate of Approval for this site, included in Appendix I, indicated the site was used for the disposal of wood waste from a planing and saw mill located in the Village of Tweed. The records also indicated that this activity occurred during the 1970s and entailed the filling of a wetland area with sawdust, slab wood and scrap wood. Such activity can result in the contamination of groundwater by such things as Phenols, Tannins and Lignins, biological oxygen demand, Total Kjeldahl Nitrogen, Organic Nitrogen, Nitrates and Total Phosphorus. From this review insufficient information was available to identify this property as a condition. It is recommended that groundwater quality testing be undertaken at this site to establish the impact the former landfill may be having on the aquifer and municipal drinking water supply. There are no additional activities, beyond the Prescribed Drinking Water Threats, that the Source Protection Committee identified as a potential threat.

Moderate and Low Threats

Moderate and Low threats were identified for both chemical and pathogen threats. It is not required that these threats be enumerated, however they must be listed by Wellhead Protection Area. Table 5- and Table 5-35

Table 5- list the Moderate and Low chemical and pathogen threats for the Tweed Wellhead Protection Area in reference to existing and future land use. The circumstances under which these threats may be considered Moderate or Low are provided in the Provincial Table of Circumstances (MOE, March, 2017).

5.6.8 Village of Tweed Concerns and Data Gaps

Concerns that were identified for this system are as follows:

- Well # 3 is defined as Groundwater Under the Direct influence of Surface Water (GUDI), with adequate in-situ filtration. A microbial contaminant control plan is in place. There is a concern that the wells may be susceptible to nearby agricultural activities to the west (up-gradient). Agricultural activities can be a source of pathogens and nutrient impacts.

Data gaps that were encountered during the identification of Significant drinking water threats were a lack of site-specific information on the use of septic systems and application of agricultural source material. There was a general lack of information on the presence/absence of contamination associated with historical land uses. As a result, no condition-related drinking water threats (if present) were identified. In addition, the type and amounts of chemicals stored at commercial operations within the Wellhead Protection Areas is unknown. Effort was made to verify this information through a mail out survey to residents located within the vulnerable zones as well as telephone survey of a select number of property owners.

Table 5-33: Village of Tweed Significant Threat Enumeration

Zone Description	Prescribed Drinking Water Threat (PDWT)*	Number of Affected Parcels**	Circumstance Example
WHPA-A	The handling and storage of fuel.	2	Private residential fuel oil tanks at least partially below grade.
	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. O. Reg. 385/08, s. 3.	1	livestock grazing
	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	2	Septic systems for residences, and sanitary sewer near Main well.
	The application of agricultural source material to land	1***	Manure spreading on agricultural fields
WHPA-B	The handling and storage of fuel.	36	Private residential fuel oil tanks at least partially below grade.
	The storage of agricultural source material.	2	Agricultural manure storage
	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. O. Reg. 385/08, s. 3.	4***	Livestock grazing***
	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	9	septic systems and holding tanks , sanitary sewer
	The handling and storage of organic solvent	1	
	The handling and storage of non-agricultural source material	2	
	The application of commercial fertilizer to land	7	Fertilizer applied to agricultural fields
	The application of pesticide to Land	5	Pesticide applied to agricultural fields
	The application of agricultural source material to land	7	Manure spreading on agricultural fields***
WHPA C+	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	**6**	septic systems and holding tanks ,

Zone Description	Prescribed Drinking Water Threat (PDWT)*	Number of Affected Parcels**	Circumstance Example
	The application of agricultural source material to land.	10	Spreading manure on agricultural fields
	The storage of agricultural source material.	10	Manure storage
	Management Or Handling Of Agricultural Source Material - Agricultural Source Material (ASM) Generation (Grazing and pasturing)	10	grazing livestock
	The application of non-agricultural source material to land.	10	Application of Biosolids to land
	The handling and storage of non-agricultural source material.	10	Biosolid storage
	The application of commercial fertilizer to land.	10	Agriculture Fertilizer
	The handling and storage of commercial fertilizer.	10	General Fertilizer Storage
WHPA D+	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	9	septic systems and holding tanks ,
	The application of agricultural source material to land.	8	Spreading manure on agricultural fields
	The storage of agricultural source material.	8	Manure storage
	Management Or Handling Of Agricultural Source Material - Agricultural Source Material (ASM) Generation (Grazing and pasturing)	8	grazing livestock
	The application of non-agricultural source material to land.	8	Application of Biosolids to land
	The handling and storage of non-agricultural source material.	8	Biosolid storage
	The application of commercial fertilizer to land.	8	Agriculture Fertilizer

Zone Description	Prescribed Drinking Water Threat (PDWT)*	Number of Affected Parcels**	Circumstance Example
	The handling and storage of commercial fertilizer.	8	General Fertilizer Storage
Totals	**12 Threat Types**	**220 potential threats on 39 parcels**	

Note: * Prescribed Drinking Water Threats, *Clean Water Act* (2006) – O. Reg. 287/07, 1.1(1)
** "Affected parcels" represents the number of parcels on which a specific activity is being engaged in. Some parcels may have more than one activity on-site.
***Threats on one parcel were counted in both zones WHPA-A and WHPA-B to assist in development of the Source Protection Plan.
+ Additional threats may be identified for the Tweed drinking water system, specifically in WHPA C and D, resulting from the delineation of the Nitrate Issues Contributing Area.

Table 5-34: Village of Tweed Moderate and Low Chemical Threats

		WHPA							
	Prescribed Drinking Water Threats (*Clean Water Act, 2006* - Ontario Regulation 287/07)	A Mod	A Low	B Mod	B Low	C Mod	C Low	D Mod	D Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.	✓	✓	✓	✓	✓	✓	✓	✓
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓	✓	✓	✓	✓	✓	✓
3	The application of agricultural source material to land.	✓		✓		✓	✓		✓
4	The storage of agricultural source material.	✓		✓		✓	✓		✓
5	The management of agricultural source material.								
6	The application of non-agricultural source material to land.			✓		✓	✓		✓
7	The handling and storage of non-agricultural source material.	✓		✓		✓	✓		✓
8	The application of commercial fertilizer to land.	✓		✓		✓	✓		✓
9	The handling and storage of commercial fertilizer.	✓	✓	✓	✓	✓	✓		✓
10	The application of pesticide to land.	✓	✓	✓	✓	✓	✓		✓
11	The handling and storage of pesticide.	✓	✓	✓	✓	✓	✓		✓
12	The application of road salt.	✓		✓	✓	✓	✓		✓
13	The handling and storage of road salt.	✓	✓	✓	✓	✓	✓		✓
14	The storage of snow.	✓		✓		✓	✓		✓
15	The handling and storage of fuel.	✓	✓	✓	✓	✓	✓		✓

16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).							✓	✓
17	The handling and storage of an organic solvent.	✓	✓	✓	✓	✓	✓		✓
18	The management of runoff that contains chemicals used in the de-icing of aircraft.	✓	✓	✓	✓	✓	✓		✓
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.	✓		✓		✓	✓		✓
22	The establishment and operation of a liquid hydrocarbon pipeline	✓	✓	✓	✓	✓	✓		✓

Table 5-35: Village of Tweed Moderate and Low Pathogen Threats

Prescribed Drinking Water Threats (*Clean Water Act, 2006* - Ontario Regulation 287/07)		WHPA A Mod	WHPA A Low	WHPA B Mod	WHPA B Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.	✓		✓	
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓		✓	
3	The application of agricultural source material to land.				
4	The storage of agricultural source material.				
5	The management of agricultural source material.				
6	The application of non-agricultural source material to land.	✓		✓	
7	The handling and storage of non-agricultural source material.	✓		✓	
8	The application of commercial fertilizer to land.				
9	The handling and storage of commercial fertilizer.				
10	The application of pesticide to land.				
11	The handling and storage of pesticide.				
12	The application of road salt.				
13	The handling and storage of road salt.				
14	The storage of snow.				
15	The handling and storage of fuel.				
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).				
17	The handling and storage of an organic solvent.				
18	The management of runoff that contains chemicals used in the de-icing of aircraft.				
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.				
22	The establishment and operation of a liquid hydrocarbon pipeline				

5.7 Village of Madoc Groundwater Supply, Municipality of Centre Hastings

The Village of Madoc, a community of approximately 1500 people, is located in the northern portion of the Municipality of Centre Hastings along the southern fringe of the Canadian Shield. Land use is a mixture of commercial, residential, open space and industrial. Beyond the Village limits land use is primarily agricultural and undeveloped land mixed with commercial, residential, and industrial with active mining operations. Water supply to the Village is provided by two wells with sewage disposal by municipally owned sewage lagoons at the south end of the community.

Water supply for the Village is obtained from two wells drilled into a fractured Precambrian bedrock aquifer. There were three wells numbered 2, 3, and 4 located within the Village as illustrated by Map 5.14. Well numbers 2 (commonly referred to as the Whytock well) and 3 (commonly referred to as the Rollins Well) were used for supply to the Village at the time the Assessment Report was prepared. Well number 4 was recently installed as a replacement to well number 2. The Municipality had been experiencing problems with well number 2 due to insufficient yield and natural water quality problems. Before well number 4 was brought online, in the Fall of 2019, well number 2 was decommissioned.

All of the wells are located on the west side of the Village with well number 2 at the north, well number 3 to the south and well number 4 between both and to the west. All of these wells are in close proximity to Deer Creek flowing from the north through the middle of the Village and draining into Moira Lake. Given the close proximity of the wells to the Creek (less than 500 metres) and the geology of the aquifer, they are all classified as Groundwater Under the Direct Influence (GUDI) of surface water with necessary water treatment including physical filtration, ultraviolet and chlorine disinfection.

Well number 2 was drilled in 1978 to a depth of 90 metres in an unconfined Precambrian bedrock aquifer. The well was reported as intercepting a main water bearing fracture at a depth of 64 metres and was constructed with 7 metres of water tight casing. For several years this well was on stand-by and only used as a backup to well number 3, if needed. This was due to low yield and poor natural water quality of well number 2 which is attributed to the depth.

Well number 3 was drilled in 2006 to replace a well that was located inside the pump house building (well number 1). The replacement well was drilled approximately 6 metres to the east of the pump house building and constructed with a 10 metres of casing to assist in sealing of shallow fractures that potentially could intercept shallow water from the nearby creek. The well was advanced to a depth of 49 metres intercepting water in a fractured Precambrian bedrock aquifer at depths of 11, 15, and 27 metres.

Well number 4 was drilled in 2016 into a Precambrian bedrock aquifer to a depth of 81.6 metres. Significant water bearing fractures were intercepted between depths of 12 to 48 metres, however due to natural water quality problems that were discovered during the assessment of this well the lower fractures were decommissioned (sealed off) in 2017. The final depth of the well is 45 metres and the natural water quality problems were reduced. The assessment indicated the flow rate to be in the order of 1000 litres per minute and the well was proven as adequate for use as supply to the Village.

The average water use of the Municipality, as of 2018, is reported in Table 5-36. This usage is much less than the permitted capacity and reduced from the previous review of water use (as summarized in the previous Quinte Region Assessment Report dated July, 2014). This reduction was attributed to the implementation of water conservation measures as well as improvements to the water distribution piping to eliminate loss of water through leakage. The anticipated future demand was estimated by allowing for a 1 percent increase in use over the next 20 years.

Table 5-36: Village of Madoc Water use

Madoc Water Use			
	Daily	Monthly	Annual
Actual	507	15210	185055
Future	619	18570	225935
Permitted	1968	59040	718320

Note: All Units are in cubic metres

5.7.1 Village of Madoc Wellhead Protection Area

The Wellhead Protection Area that is currently implemented by the Municipality was previously delineated as summarized in the Quinte Region Assessment Report (July 2014). This work was completed through the use of a numeric 3-dimensional groundwater flow model as described in the report Madoc Village Municipality of Centre Hastings Wellhead Protection Area Delineation Update (Dillon Consulting 2007 in Appendix E-7). The model was reviewed and rerun (to include the addition of well number 4 and elimination of well number 2) to delineate a new wellhead protection area as summarized in the Technical Memorandum dated August 22, 2018 from Dillon Consulting to Quinte Conservation (Dillon Consulting, 2018 in Appendix E-7). Based on future pumping rates the model was used to determine the well head protection area capture zones including the 2 year, 5 year and 25 year horizontal times of travel (named WHPA B, C, and D). These capture zones were oriented to the northwest in the up gradient direction of groundwater flow extending into the adjacent Municipality of Madoc Township. This new wellhead protection area is illustrated by Map 5.14.

5.7.2 Village of Madoc Surface Water Protection Zone

Since the wells supplying the Village of Madoc are classified as Groundwater Under the Direct Influence (GUDI) it was also necessary to delineate the zones in the adjacent Deer Creek where land use activities could impact on the drinking water supply. This zone is referred to as the WHPA E which represents the 2 hour time of travel in the adjacent creek upstream of the point of interaction between ground and surface water. This WHPA E includes a 120 metre buffer from the high water mark of the Creek as well as any transport pathways such as storm water drainage and ditches along roads. As a result the WHPA E was determined to extend approximately 5 kilometres up both Deer and Madoc Creeks.

In addition to the WHPA E it was necessary to delineate a WHPA F because water quality issues exist. These issues are discussed below in section 5.7.7 of this report. The WHPA F is the area beyond the 2 hour time of travel (WHPA E) that is considered the total contributing watershed. There could be sources of contamination in both the WHPA E and F that could impact on the drinking water supply. These zones are considered to be the areas within the Deer and Madoc Creek watersheds that may contribute water to the well. The WHPA F is limited to a 120 meter setback from both Creeks. The results of this delineation are illustrated by Map 5.14 with a discussion provided below.

5.7.3 Village of Madoc Vulnerability Scoring

The vulnerability of the aquifer in the Madoc WHPA was evaluated using the ISI method as outlined in Section 4.3.1 using Ministry of the Environment methodology (MOE, 2002), under the assumption of unconfined conditions. This method considers the depth to the water table, thickness of materials overlying the aquifer, and the permeability of these materials. The water table throughout the Madoc area is shallow and soils are thin with some areas of bedrock outcropping. The ISI score for wells within and around the WHPA was in the order of 2 to 3. Under these conditions the aquifer was assessed as highly vulnerable. This assignment of high vulnerability is in spite of relatively deep water found depths for these wells. However, in this hydrogeologic setting the fractures providing water supply may be oriented on an angle or connected with other fractures that extend to ground surface.

The water quality information for the municipal wells, discussed below in Section 5.7.7, is also indicative of highly vulnerable conditions. Detection of elevated levels of *E.coli*, Total Coliform, Nitrate, Nitrites, Ammonia and Turbidity are indicators of contamination of the relatively deep aquifer from near surface activities. These parameters may be linked to activities at the ground surface such as septic systems, livestock grazing, sanitary sewers, application of nutrients etc. Ammonia is not detected persistently and therefore the detection of Ammonia is indicative that the contamination is recent from a source that has moved into the aquifer quickly.

The water system operator noted that turbidity levels in the raw water increase after rainfall events. It was also reported that the water treatment system is equipped with cartridge type filters which sometimes require changing due to fouling after these rainfall events. This water quality information together with evaluation of aquifer vulnerability by the ISI methodology confirms the high vulnerability of the groundwater in this area.

The vulnerability scores for the WHPA A through E are illustrated by Map 5.15. The scores for the WHPA A through D, listed in Table 5-37, were determined as the highest possible due to high aquifer vulnerability determined by the ISI. This high score has been assigned, even in spite of the relatively deep nature of the water found depths of the two wells due to factors as discussed above.

Table 5-37: Village of Madoc Vulnerability

Aquifer Vulnerability	WHPA			
	WHPA A (100 m)	WHPA B (2 year)	WHPA C (5 year)	WHPA D (25 year)
HIGH	10	10	8	6

A vulnerability score was also assigned to the WHPA-E zone in accordance with Part VIII, Rule 87 of the Technical Rules. The score is a product of the area vulnerability factor and the source vulnerability factor. Details on the calculation of the score are presented in the following subsections.

WHPA E Area Vulnerability Factor

An area vulnerability factor was assigned to the WHPA-E zone as per Part VIII.2, Rules 88 to 93. For the WHPA-E zone, Rule 89 specifies a value that is not less than 7 and not more than 9. This value was derived based on the following criteria as required in Rule 92:

- The percentage of the area that is composed of land.

- The land cover, soil type, permeability and slope.
- Hydrological and hydrogeological conditions that contribute water to the area through transport pathways.

The WHPA-E zone is predominantly covered with land, with no major lakes in the area. Lakes and wetlands occupy around 0.15 percent and 6 percent correspondingly of the total WHPA-E. Urbanized land use (Madoc village urban area) covers about 18 percent, medium permeability soils and moderate slopes (5.3 percent). Soils are predominantly gravelly loam with some areas of sandy loam. Storm water ditches along the roads and two major highways 7 and 62 in the village are considered transport pathways for potential contamination. Hydrogeology around the well is represented by fractured rock, which can be considered the transport pathway for potential contamination. Through analysis of the Area Vulnerability Factor criteria, it was decided to assign the significant weight to the land cover and improved transport pathways. Therefore, out of three possible numbers, the highest area vulnerability factor of 9 was assigned to the Madoc WHPA-E zone. Table 5-38 contains a summary of the factors considered in applying the area vulnerability factor.

Table 5-38: Criteria for defining Area Vulnerability Factors for Wellhead Protection Areas

	Soil Type	Average Slope	Land Use	% Lakes	% Wetlands
WHPA-E	Predominantly gravelly loam and loam with some areas of sandy loam	5.3%	Urban: 18% Crop: 17% Swamp/Marsh: 5% Forest: 45% Bog/Fen: 1% Pasture: 13% Other: 1%	0.15 %	6.0 %

WHPA E Source Vulnerability Factor

A source vulnerability factor was assigned to the WHPA-E zone as prescribed in Part VIII, Rules 94 through 96 of the Technical Rules. The source vulnerability factor for a Type C intake can be 0.9 or 1.0 based on the following criteria as required in Rule 95:

- Depth of the intake from the top of the water surface.
- Distance of the intake from land.
- Number of recorded drinking water issues related to the intake (if any).

Well number 3 is located approximately 150 metres west of Deer Creek with well number 4 at an approximate distance of 450 metres from the Creek. A small drainage gully that leads to Deer Creek, and potentially receives runoff during storm events, is located approximately 30 metres east of well number 3. The closest point of measurement from Deer Creek to these wells has not changed; therefore the WHPA E did not change from the original mapping. Both wells have been identified as GUDI, and therefore they may receive some water from Deer Creek. Overall, the major source of water to the wells is attributed to groundwater, however, a small, and unknown portion of water may potentially originate from a surface water source. Earlier source protection work (Dillon 2008) has identified elevated Ammonia concentrations in well number 2, and periods of increased Turbidity in the raw water at well number3, following storm events. Raw water at well number 2was identified as prone to contamination from bacteria. Considering the potential impacts of the wells from surface water, a value of 0.9 was assigned to each WHPA. The score, which is at the lower portion of the recommended range for a Type C intake, reflects the condition that the well does not pump directly from surface water, and therefore, would be less vulnerable than a comparable surface water intake at the same location.

WHPA E Vulnerability Score

The product of the WHPA-E zone vulnerability factor and source vulnerability factor is a vulnerability score of 8.1 suggesting a high vulnerability. The WHPA-E score is comparable with the IPZ 2 score for surface water intakes in similar settings in Ontario.
The WHPA F does not receive a vulnerability score as it is only used for identification of potential threats related to water quality issues.

5.7.4 Village of Madoc Transport Pathways

Transport pathways that may allow contaminants to enter a drinking water source are listed in Table 4-2 of Chapter 4. A review of land use indicated the features listed in Table 5-39 as transport pathways within the Madoc Wellhead Protection Area. Please note that in spite of the presence of such pathways the vulnerability score cannot be increased as it is at the highest possible level.

Table 5-39: Village of Madoc Transport Pathways

MOE Pathway Class	Description
Existing Potable Water Wells	The majority of the land parcels south of Highway 7 are serviced; however, lots developed prior to municipal services may still be on private well water. The land parcels north of Highway 7, with the exception of a few parcels just north of the Highway 7/Highway 62 intersection, are serviced by private wells.
Monitoring Wells	One monitoring well located to the north of well number 2.
Exploration Wells	Numerous exploration testing programs have occurred. Hard copy mapping of these wells is available, and the information will be included in the future transport pathways database.

MOE Pathway Class	Description
Abandoned Wells	Abandoned wells are potentially present considering that the general area was settled in the 1800's prior to municipal servicing. A high potential for abandoned wells exists at farmsteads, municipal well fields and areas that were developed prior to the construction of the municipal system.
Pits and Quarries	Several pits and quarries were identified in the MNR database, and have been mapped.
Mines	Several mines were identified in the MNR database, and have been mapped.
Septic Systems	Buildings north of Highway 7 and to the west of the Village of Madoc limits (Madoc Township) are serviced by individual private septic systems. Known septic systems are also located south of Highway 7.
Water Mains and Sewers	Water mains and sewers are located near Well 3 in the WHPA A as wells as in the WHPA B at both well number 3 & 4.

5.7.5 Village of Madoc Managed Lands and Livestock Density

The percent managed lands and livestock densities for each wellhead protection area are reported in Table 5-40. These numbers are moderate to high and are a reflection of agricultural lands to the north and west of the Village.

Table 5-40: Village of Madoc Managed Lands and Livestock Density

WHPA	Managed Lands (%)	Livestock Density (NU/acre)*
A	0	0
B	13.2	2.9
C	19.2	2.9
D	19.7	2.9
E	29.6	2.9

***** NU/acre = Nutrient Units/acre

5.7.6 Village of Madoc Percentage of Impervious Surfaces

The percent impervious area in the Madoc Wellhead Protection Area is listed in Table 5-41 and Map 5.16 which was calculated using a 1 square kilometer grid and methodology described in section 4.7.6 of Chapter 4.

Table 5-41: Village of Madoc Impervious Area

WHPA	Impervious Area (%)
A	1-8
B	1-8
C	<1, 1-8
D	<1, & 1-8,
E	<1, & 1-8, & 8-80
F	<1, & 1-8

5.7.7 Village of Madoc Water Quality Issues and Issues Threats Assessment

The raw water quality data for the Village of Madoc water supply was screened using the approach described in Section 4.8 to identify issues in the source water which may contribute to degraded water quality. The wells supplying the Village are classified as Groundwater Under the Direct Influence of Surface Water (GUDI) due to its close proximity to the Deer Creek.

The 4-step screening process was applied to the Madoc well supply raw water data and results are summarized below. A more complete analysis of the 2002 – 2007 data by Dillon Consulting is contained in Appendix E-8 (Dillon 2010). Given that well number 4 has recently been established and is scheduled to come online soon there is insufficient data to establish any tends in water quality. As a result this review will be based on raw water quality data from wells 2 and 3, which will be considered as representative of the aquifer conditions.

This screening process was completed for the initial Assessment Report (2011) through a review of water quality data between the years 2002 to 2007. However, since preparation of the initial report, more recent data has become available. Therefore a review of this data from 2007 to 2012 (See Appendix E-8) was completed in house by Quinte Conservation to confirm no changes occurred and the water quality issues previously identified still exist.

Screening Step 1

The seven parameters listed below passed the modified screening Step 1.

- *E.coli*
- Total Coliform
- Antimony
- Nitrates and Nitrates+Nitrites
- Sodium (20 mg/L Medical Officer of Health notification level)

- Organic Nitrogen
- Manganese

This screening approach deviated slightly from the summary in Section 4.8. This is a more conservative approach elevating more parameters for initial review since a single exceedance of the Half Maximum Acceptable Concentration would trigger the parameter to be analyzed. As groundwater is the source water, microbial parameters of *E.coli* and Total Coliform had their individual results compared to the Maximum Acceptable Concentration (the benchmark) of zero counts/100 ml. The other parameters had individual results compared to their Half Maximum Acceptable Concentration. It is noted that Ammonia is not listed in Schedule 1, 2, 3, or Table 4 of the *Ontario Drinking Water Standards, Objectives, and Guidelines* but it is flagged as a concern by the Ontario Clean Water Agency, the operating authority for the Madoc water supply system. Ammonia cannot be an issue since there is no benchmark value, therefore the parameter does not pass Step 1.

Special Consideration

Ammonia:

There have been multiple reported instances of ammonia in the raw water for well numbers 2 & 3. The highest reported concentrations between 2007 and 2008 are 0.50mg/L and 0.08 mg/L for each well respectively. There is no ammonia criteria listed in the *Ontario Drinking Water Standards, Objectives, and Guidelines*. The operator is aware of the high levels of ammonia in the raw water at Madoc. Levels of ammonia in the raw water can interfere with chlorine based disinfection. An ammonia analyzer has been added to the water stream to dynamically adjust the dosed level of sodium hypochlorite (chlorine) for secondary disinfection. Additional treatment system alterations were completed to address levels of ammonia in the raw water.

The presence of ammonia in the water is a possible indicator of a direct connection of the groundwater with surface water impacted by farm runoff, adjacent Deer Creek or from leaking sanitary sewers. Ammonia levels are flagged as a concern due to their possible indicators of potential contamination by other sources. The system operator has also noted that sources of ammonia in the system include old septic tanks, nearby Deer Creek and a farm that is within 100m of the well. The operator did note that they had not detected any trends or patterns in the ammonia test data.

Screening Steps 2 and 3

Four parameters listed below passed screening Step 2.

- *E.coli*
- Total Coliform
- Organic Nitrogen
- Nitrates and Nitrates+Nitrite

It is uncertain whether the presence of *E.Coli* and Total Coliform is attributed to human activities or from natural sources such as wildlife. Organic Nitrogen and Nitrates potentially have both natural factors and human activities as sources. Sodium, Antimony, and Manganese are naturally occurring and do not pass Step 2.

For the initial 2002 to 2007 data review period Step 3 was completed without performing trend analysis since data was only available over a limited period. After acquisition of data for 2007 to 2012, further analysis for the entire period of record was completed. This entailed graphing the results of E. coli, Total Coliform and Organic Nitrogen followed by plotting a trend line to identify any positive or negative trends (see Appendix E-8). No trends were identified for E. coli and Total Coliform; however, elevated counts above the drinking water standard occurred randomly. Elevated counts of both E. coli and Total Coliform occur more frequently and at higher levels in well number 3 than in well number 2. The quality of the water in both of these wells is considered to be influenced by the nearby creek therefore it is not unexpected that these parameters have been detected in samples of the raw water. A potential reason for the difference in results between the two wells is that well number 3 is used as the main supply and thus is pumped at a higher rate than well number 2, resulting in a higher degree of connection with the creek. The treatment system at each well is reported to be capable of addressing this water quality problem.

The trend line for Organic Nitrogen in samples of raw water in both wells show the concentrations appear to be declining. However, some samples still exceed the drinking water guideline and occur randomly. For the period of 2002 to 2006 the level of Organic Nitrogen exceeded the limit in 45 percent of the samples for well number 3 and 65 percent of the samples taken from well number 2. In comparison, for the 2007 to 2012 period exceedances were detected in only 35 percent of the samples from both wells. Review of water quality results for nearby Madoc and Deer Creeks (sampling completed by Quinte Conservation in 2009 and 2010) has shown the creeks to be potential sources of Organic Nitrogen. Given the wells are influenced by Deer Creek the detection of elevated levels of this parameter is not unexpected.

E.coli 2002 to 2007:

The *E.coli* parameter represents the generic *E.coli* bacteria commonly found in the lower intestine of warm-blooded organisms. Most *E.coli* strains are harmless but some can cause serious toxic effects in humans. *E.coli* was found to be present in the raw water in both Madoc wells. This may be because both wells are considered to be GUDI. The benchmark value for drinking water quality in groundwater supplies is zero counts/100ml. *E.coli* was present in samples taken from both wells during 2007 and 2008. This system incorporates disinfection with ultraviolet light for primary disinfection and sodium hypochlorite (chlorine) for secondary disinfection, and therefore treated water met drinking water standards. Data analysis shows that since the average has already surpassed the benchmark, this parameter passed Step 3.

E.coli 2007 to 2012:

E.coli was found to be present in samples collected from both well number 2 and 3 at levels above zero counts per 100 ml (the Ontario Drinking Water Standard). Over the 72 month period, *E.coli* was detected in 10 percent of the raw water samples for well number 2 and 55 percent for well number 3. *E.coli* levels were generally low at 1 to 2 counts/100 ml with the highest count of 5 counts/100 ml detected in a sample from the well number 2 in September of 2012 and 115 counts/100 ml in a sample collected in July of 2010 from well number 3.

Total Coliform 2002 to 2007:

Total Coliform is a parameter representing generic coliforms including *E.coli* and fecal coliforms which are abundant in the feces of warm-blooded animals, but can also be found in the aquatic environment, in soil and on vegetation. The presence of Total Coliform is an indicator of potential bacteria, viruses, and protozoa. Positive test results for Total Coliform occurred at all the wells for the reported years. The benchmark value for drinking water quality in groundwater supplies is 0 counts/100ml. The presence of Total Coliform in GUDI wells requires additional disinfection at the water treatment plant. There is not enough data for the Madoc wells to perform any trend analysis. However, since the average had already surpassed the benchmark, this parameter passes Step 3. Careful monitoring of the treated water should continue to confirm that treated water does not contain *E.coli* or any Total Coliforms Even though *E.coli* and Total Coliform exceedances in the raw water are mitigated through effective treatment, the presence of these parameters was identified as an issue (both natural and anthropogenic source) because of their constant reoccurring presence in the source water.

Total Coliform 2007-2012:

Total coliform was detected in samples collected from both wells above the acceptable limit on many occasions over the 72 month period. For well number 2, unacceptable counts were detected in raw water samples 42 percent of the time and again more frequently at well number 3 with analysis of samples detecting unacceptable counts 96 percent of the time. The maximum observed count at well number 3 was 1000 counts/100ml in April of 2011. The highest count detected in well number 2 was 69 counts/100 ml in October of 2011.

Organic Nitrogen 2002 to 2007:

Organic Nitrogen is an operational objective and is a calculated parameter of the difference between Total Kjeldahl Nitrogen and Ammonia. There are multiple reported samples in excess of the *Ontario Drinking Water Operational Guideline*, the benchmark. Samples have been reported in excess since 2002 for the Whytock Well. The benchmark for Organic Nitrogen is 0.15 mg/L. Values have been reported on seven different occasions to be over 0.15 mg/L for well number 2 The reported concentrations have been over the Half Maximum Acceptable Concentration six different occasions for well number 2.

The data does not identify any specific trend to the data. Elevated concentrations appear to occur randomly. This indicates that these wells are susceptible to this type of contamination. The source of the elevated Organic Nitrogen is unknown. Possible sources include use of organic fertilizers or decaying plant matter. Organic Nitrogen passes Step 3. The operator is aware of issues with organic nitrogen and has noted that they have greater concerns with levels of ammonia.

Organic Nitrogen 2007-2012

Organic Nitrogen was detected in samples from both well number 2 and 3 at levels above the operational guideline of 0.15 mg/l. This occurrence was not detected on a regular basis and appears to be random. Of the months that samples were collected elevated levels were detected in approximately 30 to 35 percent of the samples. The highest concentrations were reported as 1.28 and 1.45 mg/l in well number 2 and 3 respectively.

Nitrates and Nitrates+Nitrites:

Levels of Nitrates and Nitrates+Nitrites were observed above the Half Maximum Acceptable Concentration in 2002. There have been no reported instances of Nitrates or Nitrate+Nitrites above the Half Maximum Acceptable Concentration since then. Based on the reviewed data, there are no discernable trends in the information.

Since levels reported in 2002 were just over the Half Maximum Acceptable Concentration criterion and haven't been reported above this criterion since, Nitrates and Nitrates+Nitrites do not pass Step 3. There are no observed trends in the reported nitrate data. The system operators have not noted any trends in the field with respect to Nitrates and Nitrates+Nitrites, nor do they have any concerns with Nitrates and Nitrates+Nitrites.

Screening Step 4

The operating authority, the Clean Water Agency was contacted in the fall of 2009 and again in the spring of 2013 regarding their knowledge of any raw water quality issues associated with the system. They identified *E. coli*, Total Coliform, and Organic Nitrogen as issues for the Madoc well supply as mentioned in screening Step 3. Discussion with the operators reported these parameters to be issues due to potential problems of increased chlorine demand, organic fouling and taste issues in the distribution system.

As these parameters passed the four screening steps it was necessary to identify E*. coli*, Total Coliform, and Organic Nitrogen as issues for the Madoc well supply. Therefore it was necessary to identify an Issues Contributing Area and associated land use activities that may contribute to these water quality parameters.

Additional Analysis

It was important to determine whether or not sources of *E.coli*, Total Coliform, and Organic Nitrogen were captured as Significant threats in Wellhead Protection Areas A, B, and E. Sources of the parameters in the WHPA C and D were not considered as *E.coli* and Total Coliform would not persist in the groundwater over these large time of travel zones. Organic Nitrogen transforms to a different form of Nitrogen as it moves through the groundwater therefore, sources of Organic Nitrogen in the WHPA C and D do not contribute to the issue.

As the Madoc municipal well supply is GUDI and are influenced by Madoc and Deer Creeks, it was necessary to understand the water quality conditions of these features. If elevated levels of *E.coli*, Total Coliform, and Organic Nitrogen were observed in these creeks then sources could be tracked upstream. If sources were found to be from WHPA F then they would need to be identified as threats through the Issues Approach.

Funding for a stream assessment survey was secured from the Ontario Drinking Water Source Protection Fund through the Ontario Ministry of Natural Resources in 2008 for the 2009 field season. This was a stream assessment survey for the Deer Creek (includes Madoc Creek) watershed which involved taking water samples for water chemistry analysis as well as sampling aquatic macroinvertebrate and fish communities to assess the state of these natural resources. The Ministry of Natural Resources' *Ontario Stream Assessment Protocol* was followed for study design and field data collection. Two water chemistry monitoring stations were sampled once a month in July, August, September and October 2009: one in Deer Creek off of Highway 7 and one in Madoc Creek on Highway 7 both in WHPA E.

In addition, 13 water chemistry monitoring stations were sampled in November and December of 2009 for *E.coli*, Total Coliform, and Organic Nitrogen in WHPA F as part of an ongoing study to determine potential sources of contamination.

The monitoring surveys identified randomly occurring elevated levels of *E.coli*, Total Coliform, and Organic Nitrogen in WHPA F. There are sources of these parameters that could not be identified as Significant drinking water threats through the Activities-Based Threats Approach. This justified the need to expand the initial drinking water threat enumeration. These three parameters come from natural sources and human activities; however, it is only possible to manage the threats created from human activities.

Quinte Conservation had an opportunity to participate in a pilot project with Environment Canada to sample for *E. coli* and determine whether the DNA from a strain of bacteria unique to the human gut, could be detected in water samples.

The results of the project showed that no human DNA marker was detected at the surface water sites in Deer Creek and Madoc Creek even though *E. coli* was high at the Deer Creek site located at Highway 7. However, it was recognized that this does not mean fecal contamination from septic systems and other human sources would not be present in the study area at other times during the year outside the sampling period (Edge and Hill 2011 in Appendix J) and therefore no concrete conclusions could be drawn to rule out human sources of the parameters.

Data Sources

Raw water quality data was obtained from several sources. They are summarized below and were provided by the Ontario Ministry of the Environment, the Ontario Clean Water Agency, and Municipality of Marmora and Lake on behalf of the plant operators:

- 2002-2007 Ontario Clean Water Agency annual summary data
- 2007-2008 Ontario Ministry of Environment Drinking-Water Systems Regulation *O. Reg.* 170/03 Annual Reports provided by the Ontario Clean Water Agency
- 2008 Ontario Ministry of Environment Annual Compliance Inspection Report (Ministry of the Environment 2008)
- Quinte Conservation Deer and Madoc Creek stream assessment survey water chemistry results, 2009

Activities Assessment

Once *E.coli*, Total Coliform, and Organic Nitrogen were determined to be issues to the Madoc groundwater supply, a list of possible prescribed drinking water threat activities was created. These threats are referenced in the Provincial Table of Circumstances (MOE, March, 2010). Any threat activity that could contribute *E.coli*, Total Coliform, and Organic Nitrogen to the source water of the well supply was added to the list. These activities include sewage threats, application of agricultural source material, handling and storage of agricultural source material, and livestock grazing/pasturing.

Issue Contributing Area Delineation

E. coli, Total Coliform, and Organic Nitrogen are issues in raw water at the Village of Madoc wells as explained above. According to Technical Rule 115 (3) and (4) an Issue Contributing Area and an inventory of threats contributing to the issues are required. The Issue Contributing Area is defined as “the area within a vulnerable area” and can be shown within a Wellhead Protection Area, Intake Protection Zone, Highly Vulnerable Aquifer, or Significant Groundwater Recharge Area. As previously discussed, the Source Protection Committee determined the activities were being managed by the threats-based approach in the WHPA A and B but evidence showed the three parameters to be issues in the WHPA E and F. The WHPA E had been delineated for the threats-based approach but the upstream WHPA F still needed to be defined. According to Technical Rule 47(6), the WHPA F is delineated in accordance with the rules in Part VI that apply to the delineation of an IPZ 3, the area of land that drains into the surface water body measured from the high water mark and the area must not exceed 120 meters. There is no floodplain mapping or high water mark extent currently available, therefore the WHPA F was delineated as the total contributing watershed, upstream of the WHPA E and not extending more than 120 meters inland from a water body or wetland (delineated through a GIS exercise).

Once the vulnerable zones were delineated, the Issue Contributing Area could be delineated. An approach to delineate the Issues Contributing Area was developed by the Source Protection Authority.

The approach was based on local knowledge of the watershed, negotiation with the affected municipalities, Technical Rules under the *Clean Water Act, 2006* a review of other related regulations, water quality analysis and field work to determine threats that could contribute to the issues.

Deer and Madoc Creeks would be best described as having a dendritic drainage pattern in the Precambrian zone of the Quinte region. The area is predominantly forest and wetland with approximately 25 percent marginal agricultural land that is used as pasture and for crops. Some agricultural locations allow cattle access into the creek. There are also 14 septic systems within 30 metres of the creeks. The area is characterized by shallow soil over fractured bedrock with some pockets comprised mostly of loam and gravelly loam with some sandy loam.

The Source Protection Authority staff met with the clerks of the two affected municipalities on April 30th, 2013 to discuss the delineation of the Issues Contributing Area. The WHPA E had previously been delineated, assigned a vulnerability score and Significant threats were enumerated within the zone. WHPA F had also been delineated but no vulnerability score had been assigned. The clerks and staff discussed that no septic systems were identified as Significant drinking water threats in the WHPA E because the vulnerability score was too low and no Significant threats were identified in the WHPA F. The option of using the entire WHPA E and F for the Issues Contributing Area was discussed but based on the local knowledge of the clerks and staff it was agreed that this would be excessive. The Director's Technical Rule 115(3) defines an Issues Contributing Area as an area within a vulnerable area. A suggestion to use a 30 metre zone was tabled in the meeting based on the following:

- The Madoc Township Zoning Bylaw (2002) Environmental Protection section establishes a 30 metre development setback from watercourses;
- Quinte Conservation's internal policy related to Section 28 Regulation (O. Reg. 319/09) uses a 30 metre setback where floodplain mapping is not available;
- Ontario Building Code setback for a septic system to a water body is 15 metre and up to 30 metres for a drinking water source; and
- Consultation with staff from Ontario Ministry of Agriculture and Rural Affairs confirmed that under the *Nutrient Management Act*, 2002, 30 metres would be a maximum setback for application of nutrients.

The above are all based on scientific research and accepted standards and practices. For these reasons the 30 metre zone buffering the creeks was approved by the Source Protection Committee as the Issues Contributing Area. Map 5.17 shows the WHPA F and Issue Contributing Area for Madoc.

Enumeration of Significant Threats

A threats inventory was completed in the 30 metre Issue Contributing Area. Initially a GIS desktop exercise was done to identify parcels that contained farm operations or showed a septic system within the Issue Contributing Area. The number of threats initially identified was reduced considerably as a result of a landowner questionnaire and subsequent field verification, completed in the spring of 2013. The threats inventory resulted in 14 septic system threats and 44 parcels with agricultural threats. As this is a large area, there is some uncertainty in terms of the exact septic system locations on properties and whether the location is within the 30 metre zone. There is also some uncertainty as to the exact farming practice used on the agricultural properties however most would fall under the category of simple farm operation.

5.7.8 Village of Madoc Threats Assessment

Completion of a threats assessment has resulted in the development of a list of what may be considered a threat in this area, where these threats may occur, the circumstances under which they would be considered a Significant, Moderate or Low, and an inventory of existing Significant threats in reference to land use activities.

Listing of Drinking Water Threats

Potential drinking water threats within the Madoc Wellhead Protection Area are as prescribed by the *Clean Water Act, 2006* and listed in Table 4.3 of Chapter 4. The circumstances under which these threats may be considered Significant, Moderate or Low are as referenced in the Provincial Table of Circumstances (MOE, March, 2018). The location where these threats may occur is within the various vulnerable zones illustrated by Map 5.17 which shows each zone with the corresponding vulnerability score.

Enumeration of Significant Threats

The results of the Water Quality Risk Assessment are presented in Table 5-43. This table presents the Significant prescribed drinking water threats for both groundwater-based vulnerability areas (WHPA-A through D) and surface water-based vulnerability areas (WHPA-E).

Based on an inventory of the land uses within the Wellhead Protection Area, and a review of available government and commercial databases on past and present land uses as well as other data, 61 potential Significant threats were identified on 35 parcels of land. Of this, a total of 26 parcels had Significant threats associated with groundwater vulnerability based threats, and 9 parcels with surface water vulnerability based threats. The threats relate mainly to home heating fuel tanks. Other threats pertain to use of septic systems and sanitary sewers as well as potential use of chemicals at garages. Agricultural threats have been enumerated for lands to the north. Some of these farms are not actively farmed; however, they have been enumerated due to the potential for agricultural use.

Condition and Source Protection Committee Designated Activity Threats

A review of condition based threats was previously completed as summarized in Appendix I. From this review two properties, one containing a former gas station and the other commercial activity (garage and vehicle maintenance) were identified as potential conditions. However, in consideration of the new well head protection area only one of these sites (Site 2 as referenced in the Appendix I conditions report) is within the new zones and considered as a potential condition based threat. However, there is no new information about this property and as such insufficient information was available to identify if contamination exists on the property. An internet search of the Provincial registry of the Record of Site Conditions on January 22, 2019 did not yield the identification of any records for the Madoc area. Likewise discussion with the local representative of the Ministry of the Environment, Conservation and Parks, on the same date, did not result in the identification of any properties that would be of concern. In addition source protection staff were not aware of any other potentially contaminated sites within the new zones that could be considered as a potentially contaminated site. In the absence of site specific information there are no condition based threats that have been identified in the Wellhead Protection Area. There are also no additional activities, beyond the Prescribed Drinking Water Threats, that the Source Protection Committee has identified as being a potential threat. In the future, the Committee may consider Highway 7 and Highway 62 as designated transportation corridor based threats, since these roads are major transportation routes in the area, and bisect WHPA E that has a high vulnerability score (8.1). Spills of chemicals along these routes within the WHPAs may impact the well field. However, it is understood that such a designation may not be practical considering that any threats would need to correspond with specific substances that are transported on these roads. Such a designation also has implications for the development of the source protection plan, in that all identified Significant threats must be mitigated so that they are no longer significant. At a minimum, it is recommended that the municipality have in place policies for quick response to chemical spills that may occur along these corridors and other roads that cross the well head protection area. To assist with promoting awareness signs could also be placed along the highway to identify the location of the Wellhead Protection Area.

Moderate and Low Threats

Moderate and Low threats were identified for both chemical and pathogen threats. It is not required that these threats be enumerated as the Significant threats were but instead be listed by Wellhead Protection Area.

Table 5-44 and Table 5-45 list the Moderate and Low chemical and pathogen threats for the Madoc Wellhead Protection Area with the circumstances for these threats listed in the Technical Rules Look Up Tables (Appendix D-1).

5.7.9 Village of Madoc Concerns and Data Gaps

An additional concern was the presence of Ammonia in the raw water supply. The Ammonia is likely associated with the *E.coli* and/or organic nitrogen impacts in the water. Therefore, future source tracking of these compounds, as mentioned above, will likely also provide information on the source of the Ammonia. Minimal information is available for water quality trends of well number 4. This is due to the recent installation of this well. As the well is brought online and water quality data is collected there will be more information to assist in the assessment of water quality issues. In the interim the data generated at well number 2 will be used as an indication of water quality issues in the aquifer.

There was a general lack of information on the presence/absence of contamination associated with historical land uses. As a result, no condition-related drinking water threats (if present) were identified.

In addition, the type and amounts of chemicals stored at the commercial operations within the Wellhead Protection Areas is unknown. More detail will be provided through site visits and interviews with the property owners.

Table 5-42: Village of Madoc Significant Threat Enumeration

Zone	Prescribed Drinking Water Threat (PDWT)*	Number of Affected Parcels**	Circumstance Example
WHPA-A	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	1	Sanitary sewer along roads
WHPA-B	The handling and storage of fuel.	31	Private fuel oil tanks; potential for bulk storage at farms and commercial properties
	The storage of commercial fertilizer	1	Retail, farm supply, garden centre
	The application of commercial fertilizer to land.	1	Application of fertilizer of farm fields
	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	5	Septic leaching beds and sanitary sewer
	The storage of organic solvents	1	Retail
	The storage of pesticide	1	Retail, farm supply, garden centre
WHPA C	The storage and handling of DNAPL.	1	Car dealership, garages, construction yards, car part supplier
WHPA-E	The storage of agricultural source material.	3	manure storage
	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. O. Reg. 385/08, s. 3.	6	livestock grazing
	The application of pesticide to land	3	application of pesticide on farm fields
	The application of agricultural source material to land	7	application of manure on farm fields
Totals	9 Threat Types	61 threats on 35 parcels	

Note: * Prescribed Drinking Water Threats, *Clean Water Act* (2006) – O. Reg. 287/07, 1.1(1)
** “Affected parcels” represents the number of parcels on which a specific activity is being engaged in. Some parcels may have more than one activity on-site. NA – Not Applicable

Table 5-43: Village of Madoc Moderate and Low Chemical Threats

		WHPA									
Prescribed Drinking Water Threats (*Clean Water Act, 2006* - Ontario Regulation 287/07)		A Mod	A Low	B Mod	B Low	C Mod	C Low	D Mod	D Low	E Mod	E Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.					✓	✓		✓	✓	✓
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓	✓	✓	✓	✓		✓	✓	✓
3	The application of agricultural source material to land.					✓			✓	✓	✓
4	The storage of agricultural source material.					✓			✓	✓	✓
5	The management of agricultural source material.										
6	The application of non-agricultural source material to land.					✓			✓	✓	✓
7	The handling and storage of non-agricultural source material.			✓		✓	✓		✓	✓	✓
8	The application of commercial fertilizer to land.					✓			✓	✓	✓
9	The handling and storage of commercial fertilizer.		✓	✓		✓	✓		✓	✓	✓
10	The application of pesticide to land.	✓	✓	✓	✓	✓	✓		✓	✓	✓
11	The handling and storage of pesticide.		✓	✓	✓	✓	✓		✓	✓	✓
12	The application of road salt.	✓	✓	✓		✓			✓	✓	✓
13	The handling and storage of road salt.								✓	✓	✓
14	The storage of snow.	✓		✓		✓	✓		✓	✓	✓
15	The handling and storage of fuel.	✓	✓	✓	✓	✓	✓		✓	✓	✓
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).										
17	The handling and storage of an organic solvent.	✓	✓	✓	✓	✓	✓		✓	✓	✓
18	The management of runoff that contains chemicals used in the de-icing of aircraft.										
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.	✓				✓			✓	✓	

Table 5-44: Village of Madoc Moderate and Low Pathogen Threats

Prescribed Drinking Water Threats (*Clean Water Act, 2006* - Ontario Regulation 287/07)		WHPA A Mod	WHPA B Mod	WHPA E Mod	WHPA E Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.				✓
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.			✓	✓
3	The application of agricultural source material to land.				
4	The storage of agricultural source material.			✓	
5	The management of agricultural source material.				
6	The application of non-agricultural source material to land.		✓		✓
7	The handling and storage of non-agricultural source material.			✓	✓
8	The application of commercial fertilizer to land.				
9	The handling and storage of commercial fertilizer.				
10	The application of pesticide to land.				
11	The handling and storage of pesticide.				
12	The application of road salt.				
13	The handling and storage of road salt.				
14	The storage of snow.				
15	The handling and storage of fuel.				
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).				
17	The handling and storage of an organic solvent.				
18	The management of runoff that contains chemicals used in the de-icing of aircraft.				
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.				

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6 Surface Water Municipal Intakes

This chapter contains abridged information on each of the surface water intakes in the Quinte region including:

1. The classification and description of the intake;
2. How the vulnerability zones were delineated;
3. How the vulnerability scores were determined;
4. Lists of threats to drinking water quality that exist in the zones; and
5. Issues that exist at each of the intakes.

Complete reports for each system have been included in Appendix F. The reader is cautioned that this background work was compiled over a period of four years. During this time the legislation for preparing the assessment report changed. Earliest reports may contain information, conclusions or drawings that refer to outdated guidelines or legislation. Nevertheless, the science and data are current and not compromised by the legislation changes.

Methodologies applied to the work contained in this section have been compiled within the Methodology chapter 4. For more information on the delineation of Intake Protection Zones see Section 4.6.

Divisions have been placed in this chapter to allow the reader the option of viewing information pertaining only to a particular intake. For this reason the chapter divisions (subsections) contain information that is repeated for each. Where necessary, the reader is referred to other sections of this chapter or other chapters of the assessment report when additional detail is needed.

Two important discussions are presented below that explain the special circumstances in the Bay of Quinte that affect how the intakes are classified and how the zones were established.

Bay of Quinte Intakes

There are four Bay of Quinte municipal intakes in the Quinte Source Protection Region that were studied as part of the Source Protection program. These included: Belleville, Point Anne, Deseronto, and Picton intakes. A fifth intake for Bayside, within the Trent Conservation Coalition Source Protection Region, is also located in the Bay of Quinte.

The intakes were classed as Type D intakes as opposed to Type A (Great Lake) intakes. This explains the reasons for classifying all Bay of Quinte intakes as Type D (those not fitting the classifications of Types A, B, or C).

The Bay of Quinte is a long, narrow, Z-shaped embayment off Lake Ontario. Four major river systems flow into the Bay; these are the Trent, Moira, Salmon, and Napanee Rivers. The bay drains eventually into Lake Ontario. Water in the Bay of Quinte originates from the four major river systems and from several smaller tributaries that drain into the bay; water in the bay does not originate from Lake Ontario.

The character and nature of the Bay of Quinte is distinct from the Great Lakes – specifically, Lake Ontario. This was concluded by reviewing the hydrodynamics and the water quality of the Bay of Quinte and comparing with Lake Ontario.

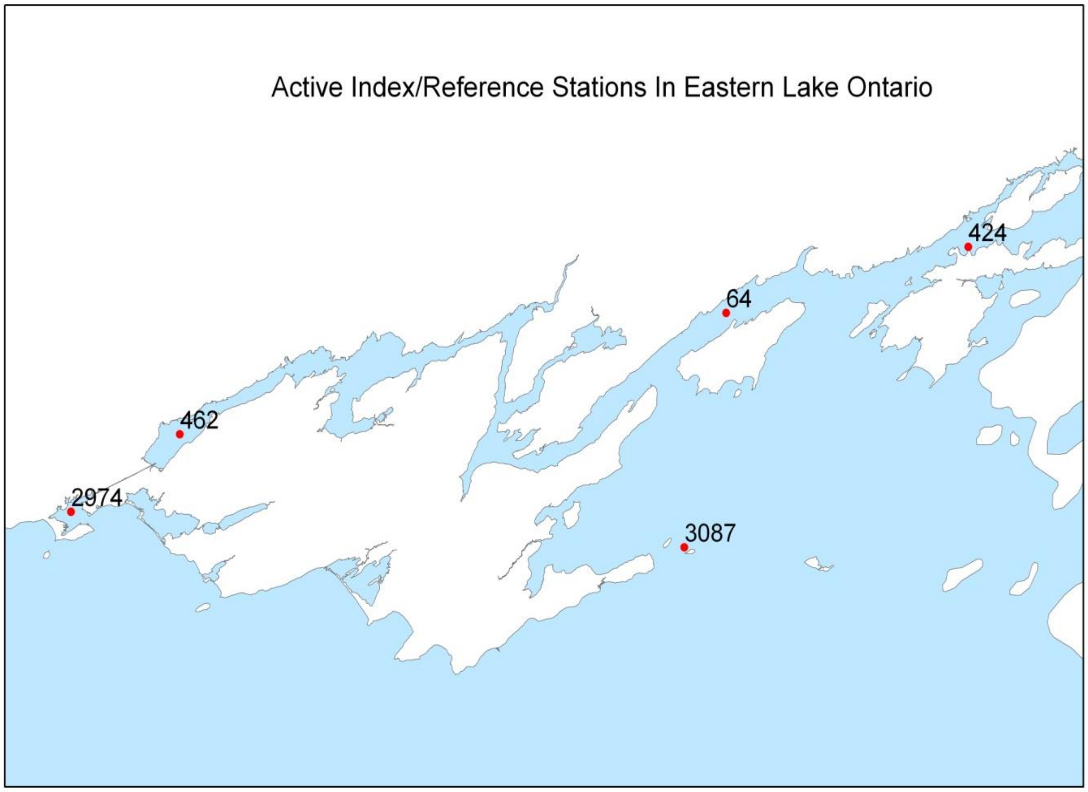
Hydrodynamics.

Flow in the Bay of Quinte is predominantly governed by outflows from the major river systems listed above. Of these, the Trent River system is the largest watershed followed by Moira, Salmon and Napanee Rivers. The Bay is very shallow (typically less than 7 metres deep) and experiences peak spring flows coincident with the peak outflow from the Trent system in April. Lake Ontario is a much deeper body of water receiving flow from the other four Great Lakes and a much larger contributing land area. Peak flows occur late May or early June.

Back water effects of Lake Ontario influence the surface water elevations in the bay and cross-sectional flow area as well as velocity. In this way, they are connected. However, Lake Ontario water does not flow into the Bay of Quinte. This means that the source of water in the Bay of Quinte is not the same as the source of the Lake Ontario water.

Water Quality

Secondly, the quality of water in the Bay is statistically different from Lake Ontario. Statistical tests (Z-test for means) were performed on several water quality parameters for two stations (Figure 6-1) using data supplied by Ministry of the Environment and analysed by Quinte Conservation (Munro 2010). Stations 462 (Trenton in the Bay of Quinte) and 3087 (Prince Edward Point on Lake Ontario, south-east of Prince Edward County) were reviewed using data for sampling events from 1997, 2000, and 2003. A total of 25 sampling events from Trenton station and 36 from Prince Edward Point station were analyzed to test for statistical difference of sample means of seven parameters (secchi, alkalinity, conductivity, total phosphorus, suspended solids, hardness, and dissolved organic carbon). All results show the sample means were not from the same set. This means that the water chemistry and physical properties of the two bodies of water are distinct.



(Figure courtesy of Ministry of the Environment)

Figure 6-1: Water Quality Sampling Stations in Lake Ontario, Near Bay of Quinte

General Discussion Regarding Intake Delineation in the Bay of Quinte

Although a Type D assignment for the Bay of Quinte intakes is preferred as discussed above, the linear flow of the bay passing all five intakes presents a challenge in determining the boundaries between upstream and downstream IPZs. Map 2.3 shows the Quinte systems while Bayside is seen in Map 6.3 in relation to Belleville. Zones 1 and 2 are comparatively small while zone 3 is much larger taking in the upstream contributing area. Theoretically, the upstream intake could have as many as five IPZ 3s.

There would be no need to apply more than one zone on each intake in the Bay of Quinte systems since a contamination problem in Bayside IPZ 3 would become an issue for the Bayside water treatment plant and trigger source protection actions long before any actions would be necessary in Picton.

With this thinking in mind, the study team ended the IPZ 3 from a downstream drinking water system at the IPZ 1 or 2 of an upstream drinking water system. In this way, all contributing areas fall within an IPZ 3 boundary for a single drinking water system. This methodology varies from the Technical Rules, but was considered more appropriate in this setting. Permission for this variance from the

Technical Rules was received from the Director of Source Protection Program Branch of the Ministry of the Environment and is contained in Appendix D2.

6.1 Belleville Intake Protection Zone (IPZ)

The City of Belleville has a population approaching 50,000 residents, of which 40,000 are connected to municipal water. The Gerry O'Connor water treatment plant, located at the end of Sidney Street, takes water from the Bay of Quinte by one of two intake pipes. The first, a 750 millimetres diameter intake pipe extends approximately 430 metres into the bay and the second a 900 millimetres diameter pipe, extends approximately 490 metres. Each of these intake pipes is 5.5 metres below the water surface. Both pipes have a 50 millimetres diameter chlorine solution line inside the pipe and a Potassium Permanganate diffuser in the intake structure for taste and odour, and zebra mussel control.

In addition to serving the City of Belleville, there are 400 residential customers in Prince Edward County (Rossmore and Fenwood Gardens) that receive their drinking water from the Gerry O'Connor plant. See Map 2.3 for area serviced by this water treatment plant.

The plant was most recently upgraded in 2001 and can treat up to 72.7 Megalitres per day. It has reserve capacity for anticipated growth of 20 years.

6.1.1 Intake Classification

The Belleville intake has been classified as a Type D (inland lake) intake. The classification is discussed under Bay of Quinte Intakes in Section 6.0 on page 6-1.

6.1.2 Source Water Description

The Bay of Quinte is a Z-shaped embayment off Lake Ontario. Water in the Bay of Quinte flows from west to east and the major water source is the Trent River system.

Map 6-1 shows the boundary of the catchment area of the bay with its major tributaries. The Bay of Quinte is an international area of concern and has an established Remedial Action Plan (RAP) that has concentrated much effort over the past 16 years to improving the water quality. Algal blooms related to high phosphorus concentrations have been persistent problems in past years, but are less frequent as a result of efforts to reduce inputs of phosphorus.

Water supply has not been a concern at this intake since the water level in the bay is controlled by regulation of Lake Ontario at Cornwall. Usual annual water level variation is 0.5 metres ranging from an average high of 75.04 metres above sea level in June to an average low of 74.53 metres above sea level in December.

6.1.3 IPZ 1 Delineation

An area known as Intake Protection Zone 1 (IPZ 1) was delineated using the methodology in Section 4.6. There are two intakes and a circle of 1 kilometre radius was applied to both intakes. Map 6-2 shows the location of the two intakes and the circles around each intake.

Map 6-2 presents the final shape of IPZ 1 for the Belleville intake. The edge of surface water body has been used to represent the limits of high water. Where the IPZ 1 boundary intersects the shore it has been extended inland by the greater of 120 metres or the conservation authority regulated area. The 120 metres setback is greater than the conservation authority regulated area for most of the shore lands with the exception of the area in the vicinity of Sidney Street where the regulated area governed.

6.1.4 IPZ 2 Delineation

The contributing area to IPZ 2 was determined by considering contributions from flows, wind, transport pathways and urban sewer systems. The methodology is discussed in Section 4.6. There are two intakes but they are close enough together that only one IPZ 2 was delineated by combining the extents of each.

Belleville water treatment plant operators confirmed they can respond to an adverse condition at the drinking water plant within 2 hours. Areas contributing to the intake within a 2-hour travel time were determined by assessing flow in the bay, wind effects on the bay, transport pathways and sewersheds.

Following the methodology, IPZ 2 is extended such that its limits envelop the IPZ 1. This occurred on the east side of the Belleville intakes. The details of the development of the IPZ 2 limits based on the local hydrodynamic influences are discussed further below. This considers the flow, wind, transport pathways and storm sewer contributions.

Flow in the Bay

A HEC-GeoRAS hydraulic model (Dillon 2007 in Appendix F-1) with 47 cross-sections was used to simulate velocities around the Belleville and Point Anne intakes based on flow rates obtained from Environment Canada. The 2-year flow in the Bay of Quinte downstream of Trenton was estimated at 508 cubic metres per second, while the flow in the Big Bay was 669 cubic metres per second. The combined flow of the Moira River, Blessington Creek, Sawguin Creek, and smaller tributaries between these locations was estimated to be 161 cubic metres per second. The Bay of Quinte water level fluctuates throughout the year and an elevation of 74.2 metres above sea level was selected for the model. This level corresponds to a low water level datum ensuring higher flow velocities will be used in the model and, as a result, more conservative travel distances over the 2-hour travel time.

Flows in the Bay of Quinte provided by Environment Canada and a detailed description of the 1-D HEC-GeoRAS river model development is provided in Appendix F-1 (Dillon 2007). The Belleville IPZ 2 reflects the variation in flow velocity across the Bay with longer distances appearing in the deeper areas. As the southernmost intake lies within a deeper, faster moving part of the Bay, that intake is associated with a longer more conservative 2-hour travel distance used to define the in stream limits of the IPZ 2.

Wind Effects

Wind-driven surface effects have been determined based on historical wind records obtained for the Trenton meteorological station. Typically these transport velocities representing contaminant movement are estimated as 3 percent to 5 percent of the wind velocity measured 10 metres above ground. One-hour time series of wind speed and direction obtained from Meteorological Service of Canada were processed to create a 2-hour time series that formed the basis of this analysis.

Upper quartile wind speeds were used to determine the maximum distance that contaminants near the surface can be moved by the wind. For conservatism it was assumed that wind speeds transfer 5 percent of their velocity to the surface water. It was also assumed that there was no flow condition while winds from the east were applied. Winds from the west were added to results from 2-yr flow distances.

Results indicate that 2-hour travel distances range from 164 metres from the southeast to 1167 metres from the south-west. Details of the wind analysis are provided in Appendix F-1 (Dillon 2007). These values have been used as one component in defining the overall 2-hour travel distances.

Transport Pathways

Ditches and small creeks were included into IPZ 2. Generally, ditches and small creeks are found further west of the intake and close to the shore of Bay of Quinte. Detailed information on their times of travel were not available to the study team and these were included in the IPZ 2 as travel times are expected to be very short and they outlet into IPZ 2.

Storm Sewer Contributions

Travel velocities within urbanized areas with sewersheds can be relatively high given surface grading and storm sewer conveyance. The Ministry of the

Environment's minimum design velocity in a typical storm sewer is 0.6 metres/second (0.9 metres/second for pipes 1200 millimetres diameter and greater) to prevent sedimentation (Ministry of the Environment 2008). Therefore the 2-hour storm sewer travel distance is just over 4 kilometres. To identify the area of storm sewer contribution in the town, sewer and sewershed mapping was obtained for the City of Belleville. A review of this data indicates that within the city the longest sewershed is approximately 1.5 kilometres. This suggests that the travel time from the upper urban catchments limits to the river is generally less than 0.7 hours. Based on the conducted analysis all sewersheds draining to the Bay of Quinte upstream of the intake were included into IPZ 2, consistent with the Technical Rules. The upstream limit of the IPZ 2 was then extended up to the Grosvenor Drive and Kensington Crescent area to include those entire development areas and all areas that drain directly to the IPZ 2. The IPZ 2 also includes two local subwatersheds that discharge east of Kalnay Lane. Storm sewersheds and the refined IPZ 2 for the Belleville intake are shown on Map 6.2. Storm sewer outfalls are also indicated. It is noted that several storm sewers discharge directly to the IPZ 1 area. These discharges are considered in setting vulnerability scores for the intakes as described in Section 6.1.3.

Intake Protection Zone (IPZ) 2 Amendment

The intake protection zone 2 was delineated using the approach described in Section 4.6.2 in 2009 for the initial Assessment Report (2011). However, since the Approved Quinte Region Assessment Report (2014), new areas of land have been developed within the City of Belleville and this development has brought with it new storm sewersheds and drainage patterns. The first phase of the development (south of Aldersgate Drive) was included in the original IPZ 2 as the storm sewershed had been finalized. City of Belleville and the Source Protection Authority staff were aware that this proposed development would affect the IPZ 2 but as plans were not finalized or approved, the rest of the development was not included.

Development has largely occurred to the west of Aldersgate Drive, north of Old Highway 2/Dundas Street West, and east of Avonlough Road. This area was originally agricultural with naturally occurring drainage on the land. When updated storm and sewershed mapping was obtained from the City of Belleville, Source Protection Authority staff noted that these development areas outlet into the IPZ 2 and therefore the IPZ 2 would require an amendment. As discussed above, within the city, the longest storm sewershed is approximately 1.5 kilometres meaning the travel time from the upper limits to the river is generally less than 0.7 hours and therefore all sewersheds draining to the Bay of Quinte upstream of the intake were included into IPZ 2, consistent with the Technical

Rules. A conservative measurement of 800 metres was applied to the amended storm sewershed to account for the areas not yet developed, and to calculate the additional time of travel. Using the minimum design velocity above of 0.6 metres/second, the amended area was calculated to increase travel time by approximately 20 minutes. Thus, the newly developed area extends portions of the storm sewershed but does not increase the time of travel over the prescribed two hours. For these reasons the Source Protection Authority proposed an amended intake protection zone 2.

Map 6-2 presents the shape of IPZ 2 for the Belleville intake with the proposed amendments to include the newly urbanized and developed areas.

6.1.5 IPZ 3 Delineation

The IPZ 3, for the City of Belleville intake was delineated following the methodology in Section 4.6. Map 6-3 shows the extent of the IPZ 3.

Ongoing consultation between Quinte Conservation and Trent Conservation Coalition has been established to ensure consistency in setting the IPZ boundaries between Belleville and Bayside IPZs. The IPZs described here abut the most recent Bayside IPZs made available. Management of any issues-based threats at the Belleville and downstream intakes may ultimately extend upstream through IPZs of the Bayside and other intakes.

6.1.6 Vulnerability Scoring

For more information on vulnerability scoring see Section 4.6.

Each IPZ is ‘scored’ to identify its vulnerability to contamination and allows a determination of risk to contamination.

The vulnerability scores for IPZs are determined by multiplying the ‘area vulnerability factor’ times the ‘source vulnerability factor’.

6.1.6.1 Area Vulnerability Factor

For a Type D intake the area vulnerability factors are:

- IPZ 1 10
- IPZ 2 7 – 9
- IPZ 3 1 – 9, but not greater than the score assigned in IPZ 2

IPZ 1 is assigned a vulnerability factor of 10.

Table 6-1 below contains the summary statistics that were reviewed following the methodology provided in Section 4.6 to determine the area vulnerability factors for IPZs 2 and 3.

Table 6-1: Area Vulnerability Considerations at Belleville Intake

Land/Water	Landcover, Slope, Soil Type	Transport Pathways / Storm Sewers	Combined Vulnerability
72% land	high percentage of urban land use, variable permeability and moderate slopes	many storm sewers	**HIGH**
MODERATE	**HIGH**	**HIGH**	

IPZ 2 is composed of 72 percent land and 28 percent water. It has a high percentage of urban land use, low permeability and moderate slopes. The City of Belleville storm sewers provide opportunities for increased urban runoff to reach the intake more quickly. Therefore, an area vulnerability factor of 9 (maximum value) was assigned to the Belleville IPZ 2 primarily on the basis of the relative abundance of storm sewer systems. Because the area vulnerability considerations did not change with the amended area, the area vulnerability was not changed.

A single IPZ 3 vulnerability was considered for Belleville and an area vulnerability factor of 8 was assigned. The lower area vulnerability factor for IPZ 3 reflects the lower influence of transport pathways in the IPZ 3 as compared to IPZ 2.

6.1.6.2 Source Vulnerability Factor

Source vulnerability factors for a Type D intake must be in the range of 0.8 to 1.0 and are assigned by the reviewer (in this case Dillon Consulting) by considering the following:

- Depth of the intake from the top of the water surface;
- Distance of the intake from the land; and
- Number of recorded drinking water issues related to the intake.

The depth of the intakes are estimated to be 4.6 metres and the offshore distance is about 430 and 490 metres. The history of the water quality concerns was a primary decision factor for assigning the source vulnerability factor. The Belleville intake has some historical concerns with water quality (e.g., total phosphorous, taste and odour) therefore; a moderate value of 0.9 was assigned to each IPZ.

Table 6-2 below shows the results of the score assignments. Map 6-4 illustrates the vulnerability scores and various zones.

Table 6-2: Belleville Vulnerability Scoring

Intake Protection Zone		Area Vulnerability Factor	Source Vulnerability Factor	Vulnerability Score, V
Belleville	IPZ 1	10	0.9	9.0
	IPZ 2	9	0.9	8.1
	IPZ 3	8	0.9	7.2

Belleville Vulnerability Score

- **IPZ 1 = 9**
- **IPZ 2 = 8.1**
- **IPZ 3 = 7.2**

Note: These scores are used in conjunction with the Prescribed Threats Look Up Tables to determine Significant, Moderate and Low threats.

6.1.6.3 Belleville Managed Lands, Livestock Density and Impervious Surfaces

The percentage of managed lands, livestock density (Nutrient Units per Acre) and impervious surfaces were calculated for the Belleville Intake Protection Zones to assist with the determination of Significant threats as per Technical Rule 16 (9),(10) and (11). Map 6.5 shows the percentages. The impervious surfaces were calculated based on the use of a one square kilometre grid as described in methodology section 4.7.6 of Chapter 4. The impervious surface area saw slight changes in the calculations with the inclusion of the amended intake protection zone 2 with a slight increase in impervious surface percentage in the amended area as a result of the inclusion of new roads. See map 6.5 for impervious surface area percentages.

Managed lands were recalculated to include the amended areas. With the help of up-to-date air photos and land use information, the percentage of managed lands was determined to still be less than 40 percent. Livestock density followed the methodology in Chapter 4 and therefore did not change with the amended area.

6.1.7 Threats to Drinking Water Quality

This section reviews risks to drinking water through two approaches. The first is identifying threats through an issues based approach where contaminants have been chronically detected in the raw water supply and linked to land use activities. The second approach is threats based and considers current and former land use activities in the contributing areas to the intake. Threats are assessed to determine level of risk between Significant, Moderate, or Low.

6.1.7.1 Issues Approach

The raw water quality data at the City of Belleville's Gerry O'Connor (Belleville) Water Treatment Plant intake were screened using the approach described in Section 4.8 to identify issues in the source water which may contribute to degraded water quality. The intake is located in the West Zwick's Island embayment of the Bay of Quinte. Data sources used in the review are presented later in this section.

The 4-step screening process was applied to the Belleville intake raw water data outlined in Section 4.8.1. The results are summarized below. A more complete analysis of issues (up to screening Step 3) is contained in Appendix F-1 (Dillon 2010).

Screening Step 1

Twelve parameters listed below passed screening Step 1. All of these parameters had concentrations greater than the Half Maximum Acceptable Concentration. Three parameters: Total Coliform, Organic Nitrogen, and Dissolved Organic Carbon had average concentrations greater than their Maximum Acceptable Concentrations. Trend analysis was done in Step 3 on the remaining nine parameters.

- *E.coli*
- Total Coliform
- Lead,
- Organic Nitrogen,
- Nitrate + Nitrite,
- Microcystin LR (an indicator of total phosphorus loads),
- Turbidity
- Aluminum,
- Dissolved Organic Carbon
- Iron,
- Manganese,
- Field Temperature

Screening Steps 2 and 3

Three parameters listed below passed screening Steps 2 and 3 for having potential anthropogenic sources and upward trend lines that if continued the average could exceed the benchmark within 50 years. Microcystin-LR did not pass screening Step 3 because there was insufficient data to perform a trend analysis. Staff from the municipality was interviewed by Dillon Consulting Limited and their feedback on parameters listed in Step 1 was incorporated in the evaluation during screening Steps 2 and 3.

- Total Coliform
- Manganese
- Organic Nitrogen

Microcystin-LR

The algae toxin Microcystin-LR is only a concern, not an issue, for the Belleville intake at this time because there is very limited number of Microcystin-LR results for raw water (seven observations in 2004). More monitoring is required in raw water at the Belleville intake. The Bay of Quinte that has been identified as an Area of Concern by the International Joint Commission due to elevated phosphorous levels. Phosphorus is thought to be a contributing factor to growth of harmful algae blooms. Research and monitoring specifically on Harmful Algae Blooms and Microcystic toxins in the Bay of Quinte is ongoing by Environment Canada through the efforts of the Bay of Quinte Remedial Action Plan (Annex 1 of the Canada-Ontario Agreement). Refer to Section 2.5 of this report for more on the Great Lakes Agreements. There is much less known about the algae toxins compared to the algae blooms themselves (Watson 2008). Refer to Chapter 8 on future research on this topic. If Microcystin-LR was addressed as an issue in source protection planning it would involve upstream identification of all non point sources contributing to nutrient enrichment. This would be premature at this time based on the lack of data and understanding of Microcystin-LR in the source water of the Bay of Quinte.

Screening Step 4

No parameters pass screening Step 4 because the three remaining parameters: Total Coliform, Organic Nitrogen, and Manganese are considered to be captured in the Threats Approach or through other legislative mechanisms. Therefore no issues were identified for the Belleville intake.

Contents of the Threats Approach reviewed in the following section captures Significant threats of the application, management/handling and storage of agricultural source material, and management/storage of non agricultural source material given the shape of the IPZs 1 and 2. Managing these Significant threats in source protection planning can help minimize the concerns with bacteria (*E.coli* and Total Coliform) and nutrients (Organic Nitrogen, Nitrates + Nitrites, and phosphorous linked to Microcystin-LR) at the municipal drinking water systems.

Manganese is not an issue at the Belleville intake because there are already monitoring programs in place for the close Zwick’s Island landfill that fulfill any monitoring requirements of source protection planning. Based on available documentation the closed Zwick’s Island landfill is suspected to be a source of

Manganese at the Belleville intake. However, the closed landfill is already managed by the City of Belleville following requirements under the Record of Site Condition O. Reg. 153 that relate to details of site assessment and clean up, Part XV.1 of the *Ontario Environmental Protection Act*. The closed Zwick's Island landfill site was evaluated as a condition-based-threat through the Threats Approach. Note that Manganese in surface water for intakes does not fall into the criteria for evaluating condition-based-threats according to Assessment Report Technical Rule 126.

Parameters that pass screening Step 1 will remain as concerns for source water and should be monitored. The Gerry O'Connor (Belleville) Water Treatment Plant is a conventional treatment facility with equipment and processes capable of treating raw water at the current conditions and in accordance with the Ministry of Environment legislation. However there is a lack of data on raw water parameters at this system. In addition to the regulatory monitoring for the Drinking Water Information Systems Program, it is important that this drinking water system participate in the Ontario Drinking Water Surveillance Program. Although this program is a voluntary water quality monitoring program for municipalities the data are valuable because the program collects data on additional parameters that are not regularly monitored in raw water at the intake, e.g. Microcystins. The drinking water system discontinued participating in the Drinking Water Surveillance Program after 2004. The Gerry O'Connor Water Treatment Plant should participate once again in the Ontario Drinking Water Surveillance Program.

Data Sources

Raw water quality data was obtained from several sources. These are summarized below and were provided by the Ministry of the Environment, Environment Canada, and the City of Belleville on behalf of the Plant Operator:

- Ontario Ministry of Environment Drinking-Water Systems Regulation O. Reg. 170/03 Annual Reports (2003-2008) provided by the City of Belleville
- Ontario Ministry of the Environment (MOE) Drinking Water Information System Data: Quinte Systems (2002-2006)
- MOE Water Treatment Plant Drinking Water Surveillance Program Annual Reports (1988 – 1990 data)
- MOE Drinking Water Surveillance Program: Routine data (1990-1996)
- MOE Drinking Water Surveillance Program: Special data (1998-2004)
- MOE Drinking Water Surveillance Program: Water Treatment Plant Data (1988-1990)

- Environment Canada, Department of Fisheries and Oceans Data (2002-2005) provided by the Bay of Quinte Remedial Action Plan Committee through Project Quinte

6.1.7.2 Threats Approach

Threats to drinking water intakes may be determined from the vulnerability scores for each zone and the circumstances under which an activity would be a drinking water threat. The circumstances under which these threats may be considered as Significant, Moderate or Low are referenced in the Provincial Table of Circumstances (MOE, March, 2018). The interested reader is directed Map 6-4 to determine the location of the particular vulnerability zone.

Significant Threats

Significant drinking water threats can be determined based on current land uses (activities) and past land uses (conditions).

Activity Based Threats

Table **6-3** enumerates Significant prescribed drinking water threats through activities inventoried in the Belleville Intake Protection Zones (1 and 2) using the multi-step Water Quality Risk Assessment approach. One parcel was identified as having such Significant threats. The Property owner was contacted by telephone to discuss suspected activities that could be drinking water threats. Results from the phone survey were used to help enumerate the potential threats. A desktop threats enumeration exercise was conducted to determine if the amended areas would contribute new existing significant threats. It was determined that as the area is residential and the vulnerability score did not change, that no new threats exist in the amended area.

Condition Based Threats

An assessment of potential conditions within the Belleville IPZ is summarised in Appendix I. This review resulted in the identification of two properties that were assessed. The first was a property located in the IPZ 2 which was used by an industrial, manufacturing facility for the electroplating of circuit boards. Contamination of the soil with heavy metals was identified prior to redevelopment of the property for commercial purposes. The concentrations of some of the contaminants were determined as meeting Technical Rule 126, thereby defining the site as a condition. However, information was provided by the municipality indicating that areas of contamination were excavated and removed from the site. Based on this information, further assessment of the site as a condition was not completed.

The second site was a closed landfill referred to as Zwicks Island located in the IPZ 1. This landfill site was established in the 1950's through the construction of earthen dykes into the Bay of Quinte followed by the filling with waste behind. Since closure of the site in 1971, extensive monitoring of both ground and surface water has been completed. A review of a recent report (Golder & Associates,2009) indicated the presence of landfill leachate in the groundwater and some areas of point discharge into the Bay of Quinte. However, monitoring of surface water quality has not resulted in the detection of extensive surface water contamination but rather suggested a continuous loading of a low level of contaminants. The groundwater data from two monitoring wells located within the limits of the IPZ 1 was reviewed in respect of Technical Rule 126. This monitoring was completed in 2008 and a total of 21 parameters (PAH's, heavy metals, volatile organic compounds, and pesticides) were found to exceed the potable groundwater standards of Table 2 in the Ministry of the Environment Soil, Ground Water and Sediment Standards (July 27, 2009). As a result of these exceedances the site is classified as a condition.

The risk score for this condition was calculated as below indicating the site is to be considered as a Significant drinking water threat in the Source Protection Planning Process.

Risk Score = 10 X 9.0 = 90

Where:

- The hazard rating was assigned as 10 given the property is in the IPZ 1 associated with the City of Belleville Intake and there is offsite impact; and
- The vulnerability score of the IPZ 1 was assigned as 9.0 as outlined in section 6.1.6.2.

Identification of Moderate and Low Threats

Moderate and Low risks may also exist in the Intake Protection Zones for Belleville. Table 6-4 and Table 6-5 below have been developed by comparing land uses and the potential for chemical or pathogen hazards to exist on those lands with the vulnerability scores for the zones. The tables are to be interpreted as indications of potential for Moderate or Low threats. The risk is calculated as vulnerability x hazard rating. A score above 60 and below 80 is a Moderate risk. A score between 40 and 60 is a Low risk.

Table 6-3: Belleville Significant Threat Enumeration

Zone	Threat *	Number of Affected Parcels**	Circumstance Example
Belleville IPZ 1	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	1	Bypass pumping station
Belleville IPZ 2	No drinking water threats in IPZ 2	0	
Condition Based Drinking Water Threat			
Belleville IPZ 1	Closed Zwicks Island Landfill Site	2	
Totals	2 Threat types	3 threats on 3 parcels	

Note: * Prescribed Drinking Water Threats, Clean Water Act (2006) – O. Reg. 287/07, 1.1(1)
** "Affected parcels" represents the number of parcels on which a specific activity is being engaged in. Some parcels may have more than one activity on-site.

6.1.8 Uncertainty

The delineation of the Intake Protection Zones and assignment of vulnerability scoring have some degree of associated uncertainty. For example, if scores were assigned with substantial data lacking about the intake or bathymetry of the bay then because of the lack of knowledge, a high uncertainty would be applied. Also, if methods used to delineate IPZ s are coarse or modelling was not calibrated then there would be higher uncertainty about the results.

Dillon Consulting used a calibrated HEC-geoRAS hydraulic model to aid in the determination of vulnerability zones. Additionally, long periods of wind and flow records were used to create the model. Zones were established with conservative conditions, using either a combination of effects or the worst case condition, to establish the outer bounds of the zones. By a complex qualitative method of assigning scores to all variables influencing vulnerability of the intake, scores were tallied using a repeatable approach. This method was used on several intakes and results were compared for their reasonableness.

Table 6-4: Belleville Moderate and Low Chemical Threats

		Intake Protection Zone (IPZ)									
	Prescribed Drinking Water Threats (Ontario Regulation 287/07)	1 Mod	1 Low	2 Mod	2 Low	3 Mod	3 Low	3a Mod	3a Low	3b Mod	3b Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.			✓		✓	✓				
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓	✓	✓	✓	✓				
3	The application of agricultural source material to land.			✓		✓					
4	The storage of agricultural source material.			✓	✓	✓	✓				
5	The management of agricultural source material.										
6	The application of non-agricultural source material to land.			✓		✓	✓				
7	The handling and storage of non-agricultural source material.		✓	✓	✓	✓	✓				
8	The application of commercial fertilizer to land.			✓		✓					
9	The handling and storage of commercial fertilizer.	✓		✓	✓	✓	✓				
10	The application of pesticide to land.	✓		✓	✓	✓	✓				
11	The handling and storage of pesticide.		✓	✓	✓	✓	✓				
12	The application of road salt.	✓		✓			✓				
13	The handling and storage of road salt.			✓	✓						
14	The storage of snow.	✓		✓	✓	✓	✓				
15	The handling and storage of fuel.	✓	✓	✓	✓	✓	✓				
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).										
17	The handling and storage of an organic solvent.	✓	✓	✓	✓	✓	✓				
18	The management of runoff that contains chemicals used in the de-icing of aircraft.										
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.*										
20	An activity that reduces the recharge of an aquifer.*										
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.			✓		✓	✓				

*Water quantity threats will be evaluated as a part of the Water Budget studies

Table 6-5: Belleville Moderate and Low Pathogen Threats

		Intake Protection Zone (IPZ)					
	Prescribed Drinking Water Threats (Ontario Regulation 287/07)	1 Mod	1 Low	2 Mod	2 Low	3 Mod	3 Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.						
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.			✓	✓		
3	The application of agricultural source material to land.						
4	The storage of agricultural source material.			✓			
5	The management of agricultural source material.						
6	The application of non-agricultural source material to land.						
7	The handling and storage of non-agricultural source material.						
8	The application of commercial fertilizer to land.						
9	The handling and storage of commercial fertilizer.						
10	The application of pesticide to land.						
11	The handling and storage of pesticide.						
12	The application of road salt.						
13	The handling and storage of road salt.						
14	The storage of snow.						
15	The handling and storage of fuel.						
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).						
17	The handling and storage of an organic solvent.						
18	The management of runoff that contains chemicals used in the de-icing of aircraft.						
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.*						
20	An activity that reduces the recharge of an aquifer.*						
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.						

*Water quantity threats will be evaluated as a part of the Water Budget studies

Given the precautionary approach taken in the analysis and the good knowledge of the bay’s hydrology and hydraulics, the uncertainty of the zones and the vulnerability scores is Low. This is summarized along with the vulnerability scores on Table 6-6 below.

Table 6-6: Belleville Vulnerability Scores and Uncertainty Summary

Zone	Vfz (Area Vulnerability Factor)	Vfs (Source Vulnerability Factor)	V (Vulnerability Score)	Uncertainty	
				Zone Delineation	Vulnerability Score
1	10	0.9	9.0	Low	Low
2	9	0.9	8.1	Low	Low
3	8	0.9	7.2	Low	Low

6.1.9 Data Gaps

No significant data gaps were encountered during the identification of Significant drinking water threats, considering that the enumeration approach used was conservative (approach is considered to overestimate number of threats compared to actual conditions). Interviews with property owners were conducted to confirm the actual number and type of Prescribed Drinking Water Threats.

6.2 Point Anne Intake Protection Zone

Point Anne is a small hamlet east of the serviced area of the City of Belleville in the former Township of Thurlow on the north shore of the Bay of Quinte. A small municipally operated drinking water system services 22 residences for a total population of about 55. The intake has its source in the Bay of Quinte, drawing water through a small diameter pipe 105 metres in length projecting 80 metres into the Bay of Quinte. At this location the bay is shallow and depth of cover is about 2.5 metres.

The community is a former company town (Point Anne Cement Company) with residences connected to a communal water supply system. Sewage is not treated in a municipal sewage treatment plant, but is disposed of in private systems that may or may not be shared between some residences. Little is known about the sewage disposal. Land use immediately adjacent to this community is predominantly industrial with a large aggregate quarry to the north and a marine construction company located to the east. Lands to the west are primarily residential and commercial. See Map 2.3 for area serviced by this water treatment plant.

Water is taken to an inland well by gravity where it mixes with groundwater that infiltrates the well. This wet well was constructed with concrete well tile which has openings in the side which are reported as allowing significant volumes of shallow groundwater to enter the well. This allows the mixing of both ground and surface water together such that the system has been classified as a combined surface water/groundwater system. Given the potential for local sources of groundwater contamination it is necessary to evaluate the location of groundwater capture zones around this well in addition to an Intake Protection Zone.

Two treatment systems are used either in series or alone depending on the water quality and predominant source (surface or ground). The chemical assisted filtration system consists of a flocculator, plate settlers, and a mixed media (anthracite/sand) filter. The alternate system utilized a cartridge filtration process that if used in series provides pre-treatment. Sodium Hypochlorite is applied to filtered water in a chlorine contact tank which is then discharged to a finished water storage clearwell.

The system was built in about 1974, and inherited by the City of Belleville in 1998 and was last updated in 2005.

Intake Classification

The Point Anne intake is classified as a Type D (inland lake) intake. This is discussed under Bay of Quinte Intakes in Section 6 on page 6-1.

6.2.1 Source Water Description

The Bay of Quinte is a Z-shaped embayment off Lake Ontario. Water in the Bay of Quinte flows from west to east and the major water source is the Trent River system.

Map 6-1 shows the boundary of the catchment area of the bay with its major tributaries. The Bay of Quinte is an international area of concern and has an established Remedial Action Plan (RAP) that has concentrated much effort over the past 16 years toward improving the water quality. Algal blooms related to high phosphorus concentrations have presented persistent problems in past years, but are less frequent as a result of reduced inputs of phosphorus.

Water supply has not been a concern at this intake since the water level in the bay is controlled by regulation of Lake Ontario at Cornwall. Usual annual water level variation is 0.5 metres ranging from an average high of 75.04 metres above sea level in June to an average low of 74.53 metres above sea level in December.

6.2.2 IPZ 1 Delineation

An area known as Intake Protection Zone 1 (IPZ 1) was delineated following the method provided in Section 4.6.

A 1 kilometre radius circle was placed around the intake and trimmed along the shoreline with a 120 metre setback. The setback exceeded the conservation authority regulation limit and was therefore governed by the 120 metre setback with one exception. On the east side the 1 kilometre radius bisected a shoreline wetland that is regulated by the conservation authority. The setback was extended to include the portion of the wetland that would fall within the 1 kilometre radius and the setback on the land draining to this area was applied.

The IPZ 1 may be modified to reflect the local hydrodynamic conditions. However, due to high probability of reverse flows in the Bay of Quinte near Point Anne the conservative approach with a 1,000 metres circle was adopted.

Map 6-6 presents the final shape of IPZ 1 for the Point Anne intake. The edge of surface water body has been used to represent the limits of high water.

6.2.3 IPZ 2 Delineation

The IPZ 2 was developed following the methodology presented in Section 4.6.

The contributing area to IPZ 2 was determined by considering contributions from flows, wind and transport pathways.

Flow Effects

A HEC-GeoRAS hydraulic model with 47 cross-sections was used to simulate velocities around the Point Anne intakes based on flow rates obtained from Environment Canada. The 2-year flow in the Bay of Quinte downstream of Trenton was estimated at 508 cubic metres per second, while the flow in the Big Bay was 669 cubic metres per second. The combined flow of the Moira River, Blessington River and Sawguin River between these locations was estimated to be 161 cubic metres per second. The selected downstream water level was 74.2 metres based on a low water level datum. This low level ensures higher flow velocities and, as a result, more conservative travel distances over the 2-hour travel time.

Flows in the Bay of Quinte are provided by Environment Canada and a detailed description of the 1-D HEC-GeoRAS river model development is provided in Appendix F-1 (Dillon 2007). The flow velocities in the Bay of Quinte around Point Anne are minimal (about 0.04 m/s at this location). The 2 hour flow influence extends only about 200 metres from the intake. When wind effects are added the in-bay extent is determined.

Wind Effects

Wind-driven surface transport velocities have been determined based on historical wind records obtained from the Trenton meteorological station. Typically these transport velocities representing contaminant movement are estimated as 3 percent to 5 percent of the wind velocity measured 10 metres above ground. One-hour time series of wind speed and direction obtained from Meteorological Service of Canada were processed to create a 2-hour time series that formed the basis of this analysis. Results indicate that 2-hour travel distances range from 164 metres from the southeast to 1167 metres from the southwest. Details of the wind analysis are provided in Appendix F-1 (Dillon 2007). These values have been used as one component in defining the overall 2-hour travel distances.

Transport Pathways

Travel velocities within developed areas with improved surface grading and drainage can be high. The Point Anne area has a number of ditches which channel overland flow to the Bay of Quinte in vicinity of the intake. The longest drainage pathway in Point Anne is approximately 400 metres. This suggests very short travel time to the intake during runoff events. Based on runoff travel time considerations all Point Anne area catchments draining to the Bay of Quinte were included in IPZ 2 as transport pathways, consistent with the Technical Rules.

Storm Sewers

No storm sewers are present in Point Anne.

6.2.4 IPZ 3 Delineation

The IPZ 3 is the contributing area upstream of the intake. However, the IPZ 3 for the Point Anne intake was terminated at the IPZ 2 boundary for the Belleville intake. For further discussion on how the IPZ 3 boundaries for the Bay of Quinte intakes were terminated refer to the discussion in Section 6.0.

IPZ 3 includes tributaries along the Bay of Quinte such as Blessington and Bell Creeks, some portions of Prince Edward County and the entirety of the Moira River watershed.

IPZ 3 was divided into two subzones, 3a and 3b, due to the different area conditions and vulnerability considerations. IPZ 3a includes the drainage area immediately upstream of IPZ 2 to the approximate limit of the higher density agricultural land use area within the watershed. Within IPZ 3a, land use is predominantly agricultural while within IPZ 3b it is mainly wooded and less developed. Using this distinction it was determined that the IPZ 3a should have a higher vulnerability score than the IPZ 3b. The divide between IPZ 3a and 3b also corresponds to the approximate limit of the Canadian Shield geology. Each of IPZ 3a and 3b extend from water features to 120 metres inland or the regulation limit, whichever is greater. Map 6-6 shows the IPZs 3a and 3b for Point Anne.

6.2.5 Vulnerability Scoring

For more information on vulnerability scoring see Section 4.6.

Each IPZ is ‘scored’ to identify its vulnerability to contamination and allows a determination of risk to contamination.

The vulnerability scores for IPZs are determined by multiplying the ‘area vulnerability factor’ times the ‘source vulnerability factor’.

6.2.5.1 Area Vulnerability Factor

For a Type D intake the area vulnerability factors are:

- IPZ 1 10
- IPZ 2 7 – 9
- IPZ 3 1 – 9, but not greater than the score assigned in IPZ 2

IPZ 1 is assigned a vulnerability factor of 10.

Table 6-7 below contains the summary statistics for the Point Anne intake that were reviewed following the methodology provided in Section 4.6 to determine the area vulnerability factors for IPZs 2 and 3.

Table 6-7: Area Vulnerability Considerations at Point Anne Intake

Land/Water	Landcover, Slope, Soil Type	Transport Pathways / Storm Sewers	Combined Vulnerability
60% land	moderate percentage of urban land use. Soils are loams with variable drainage. Slopes are mild.	only a couple of ditches	MODERATE
MODERATE	MODERATE	MODERATE	

IPZ 2 is composed of 40 percent land and 60 percent water. It has a high percentage of urban land use. Soils are mostly Farmington loam with variable drainage. Slopes are mild, runoff potential is low. Vegetation cover is high. The transport pathways are represented only by a couple of ditches in Point Anne. Therefore, an area vulnerability factor of 8 (medium value) was assigned to the Point Anne IPZ 2.

IPZ 3 was divided into two subzones, 3a and 3b, due to the different area conditions and vulnerability considerations (see Map 6.7). IPZ 3a includes the drainage area immediately upstream of IPZ 2 and the lower part of the Moira River. It also extends to the approximate limit of the higher density agricultural land use area within the watershed. Within IPZ 3a, land use is predominantly agricultural while within IPZ 3b, it is mainly wooded. The divide between IPZs 3a and 3b also corresponds to the approximate limit of the shield geology.

An area vulnerability factor of 7 was assigned to IPZ 3a in recognition of the proximity to the intake and the reduced land cover. The second sub-zone, IPZ 3b is composed primarily of wooded areas and was assigned an area vulnerability factor of 3 based on the land cover and remoteness from the intake.

6.2.5.2 Source Vulnerability Factor

Source vulnerability factors for a Type D intake must be in the range of 0.8 to 1.0 and are assigned by the reviewer (in this case Dillon Consulting) by considering the following:

- Depth of the intake from the top of the water surface;
- Distance of the intake from the land; and
- Number of recorded drinking water issues related to the intake.

The depth of the intake is relatively shallow and estimated to be 2.5 metres. The offshore distance is about 80 metres. The history of the water quality concerns was a primary decision factor for assigning the source vulnerability factor. The Point Anne intake has historical concerns with water quality (*E.coli* and Total Coliforms) therefore; a high value of 1.0 was assigned to each IPZ.

Table 6-8 shows the results of the score assignments.

Table 6-8: Point Anne Vulnerability Scores

Intake Protection Zone		Area Vulnerability Factor	Source Vulnerability Factor	Vulnerability Score, V
Point Anne	IPZ 1	10	1.0	10.0
	IPZ 2	8	1.0	8.0
	IPZ 3a	7	1.0	7.0
	IPZ 3b	3	1.0	3.0

Point Anne Vulnerability Score

- **IPZ 1 = 10**
- **IPZ 2 = 8**
- **IPZ 3a = 7**
- **IPZ 3b = 3**

Note: These scores are used in conjunction with the Prescribed Threats Look Up Tables to determine Significant, Moderate and Low threats.

6.2.5.3 Point Anne Managed Lands, Livestock Density and Impervious Surfaces

The percentage of managed lands, livestock density (Nutrient Units per Acre) and impervious surfaces were calculated for the Point Anne Intake Protection Zones to assist with the determination of Significant threats as per Technical Rule 16 (9),(10) and (11). Maps 6.11, 6.12, 6.13 and 6.14 show the percentages.

The impervious surfaces were calculated based on the use of a one square kilometre grid as described in methodology section 4.7.6 of Chapter 4.

6.2.6 Threats to Drinking Water Quality

This section reviews risks to drinking water through two approaches. The first is finding threats through an issues based approach where contaminants are chronically be detected in the raw water supply and linked to land use activities. The second approach is threats based and looks at current and former land use activities in the contributing areas to the intake. Threats are assessed to determine level of risk between Significant, Moderate, or Low.

6.2.6.1 Issues Approach

The raw water quality data at the Point Anne Hamlet intake were screened using the approach described in Section 4.8 to identify issues in the source water of the Bay of Quinte which may contribute to degraded water quality. The water supply combines both surface water and groundwater. Data sources used in the issues evaluation are presented later in this section.

The 4-step screening process was applied to the Point Anne intake raw data outlined in Section 4.8. The results are summarized below. A more complete analysis (up to screening Step 3) is contained in Appendix F-2 (Dillon 2010).

Screening Step 1

Two parameters listed below pass Step 1. The *E.coli* parameter represents the generic *E.coli* bacteria commonly found in the lower intestine of warm-blooded organisms and naturally found in the gut. Most *E.coli* strands are harmless but some can cause serious health risk in humans. Total Coliform is a parameter representing generic coliforms including *E.coli* and fecal coliforms which are abundant in the feces of warm-blooded animals, but can also be found in the aquatic environment, in soil and on vegetation. The presence of Total Coliform is an indicator of potential bacteria, viruses, and protozoa. Both parameters had individual results exceeding the Half Maximum Acceptable Concentration, the half benchmark. *E.coli* had an average greater than the Maximum Acceptable Concentration, therefore only Total Coliform was analyzed for trending in Step 3.

- *E.coli*
- Total Coliform

Screening Steps 2 and 3

Two parameters listed below passed screening Steps 2 and 3. They potentially have sources stemming from human activities, e.g. septic and sewage systems, and they have average counts exceeding the benchmark or in the case for Total Coliform a trend line in an upward direction that if continued will reach the benchmark within 50 years. Staff from the municipality were interviewed by Dillon Consulting Limited and their feedback on parameters listed in Step 1 was incorporated in the evaluation during screening Steps 2 and 3.

- *E.coli*
- Total Coliform

Screening Step 4

No parameters pass screening Step 4 therefore no water quality issues for the Point Anne Hamlet intake exist. There will always be bacteria found in surface waters because of natural sources, e.g. birds and wildlife. *E.coli* and Total Coliform were not considered issues because the water treatment facility is capable of treating microbial parameters at these levels and it is highly unlikely that the water quality standards (benchmarks of 10 counts/100ml and 1000 counts/100ml respectively) would be consistently attained in raw surface water. In addition, relative to other intakes in the Bay of Quinte (e.g. Belleville Intake) these raw water values for bacteria observed at Point Anne Hamlet intake are reasonable.

The Threats Approach reviewed in the following section did not capture Significant threats associated with *E.coli and* Total Coliform in the IPZ 1 and 2 or Wellhead Protection Area (WHPA) A. However, the Threats Approach did capture Significant threats in WHPA B associated with bacteria. The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage was identified as a Significant threat in WHPA B. This refers to the septic systems of the residences in Point Anne Hamlet. Therefore Significant threats associated with *E.coli* and Total Coliform were captured in the Threats Approach which will be managed through source protection planning mechanisms.

Raw water data for the Point Anne Hamlet intake is limited to *E.coli* and Total Coliform. For instance there are no raw water observations for Microcystin-LR, an algae toxin. Algae toxins such as Microcystin-LR is a concern for the Bay of Quinte based on historic events of Harmful Algae Blooms that may pose a risk to public health. However, research is being conducted because there are still many unknowns about the factors driving algae toxins. This is discussed further in Chapter 8. Any changes on the status on Microcystin-LR or any other parameter as an issue for the Point Anne Hamlet intake will be included in the next version of the Assessment Report. The City of Belleville should enrol the Point Anne Hamlet drinking water system in the Ontario Drinking Water Surveillance Program. Although it is not mandatory under current provincial regulations it is free of cost to all municipalities and would be valuable in that the program is designed to collect data on additional parameters that are not regularly monitored for raw water, e.g. Microcystins.

Data Sources

Raw water quality data was obtained from several sources. They were provided by the Ontario Ministry of the Environment, Environment Canada, and the City of Belleville on behalf of the Plant Operator and are summarized below:

- Belleville Utilities Commission Quarterly Reports (Point Anne Water System) for 2001
- Ontario Ministry of Environment Drinking-Water Systems Regulation O. Reg. 170/03 Annual Reports (2000-2008) provided by the City of Belleville
- Annual Point Anne Bacteriological Sampling Data (2003-2007) provided by the City of Belleville
- Drinking Water Information System Data, Quinte Systems (2002-2006) provided by the Ontario Ministry of the Environment
- Quinte Conservation Bell Creek stream assessment survey water chemistry results, 2009

6.2.6.2 Threats Approach

Threats to drinking water intakes may be determined from the vulnerability scores for each zone and the circumstances under which an activity would be a drinking water threat. The circumstances under which these threats may be considered as Significant, Moderate or Low are referenced in the Provincial Table of Circumstances (MOE, March, 2018). The interested reader is directed Map 6-9 to determine the location of the particular vulnerability zone within IPZs 1 and 2 and Map 6-10 for IPZ 3.

Significant Threats

Significant drinking water threats can be determined based on current land uses (activities) and past land uses (conditions).

Activity Based Threats

Table 6-9 enumerates Significant prescribed drinking water threats through activities inventoried in the Point Anne Intake Protection Zones (1 and 2) using the multi-step Water Quality Risk Assessment approach. One parcel was identified in IPZ 1 to have such threats. Note, that no Significant threats were identified in IPZ 2.

Condition Based Threats

There is no evidence of the presence of any condition based threats.

Identification of Moderate and Low Threats

Moderate and Low risks may also exist in the Intake Protection Zones for Point Anne. Table 6-10 and Table 6-11 below have been developed by comparing land uses and the potential for chemical or pathogen hazards to exist on those lands with the vulnerability scores for the zones. The tables are to be interpreted as indications of potential for Moderate or Low threats. The risk is calculated as vulnerability x hazard rating. A score above 60 and below 80 is a Moderate risk. A score between 40 and 60 is a Low risk.

Table 6-9: Point Anne Significant Threat Enumeration – Intake Protection Zone

Zone	Threat *	Number of Affected Parcels**	Circumstance Example
Point Anne IPZ 1	The establishment, operation, or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	1	Septic System
Totals	**1 Threat type**	**1 threat on 1 parcel**	

Note: * Prescribed Drinking Water Threats, Clean Water Act (2006) – O. Reg. 287/07, 1.1(1)
** “Affected parcels” represents the number of parcels on which a specific activity is being engaged in. Some parcels may have more than one activity on-site.

Table 6-10: Point Anne Moderate and Low Chemical Threats

		Intake Protection Zone (IPZ)									
	Prescribed Drinking Water Threats (Ontario Regulation 287/07)	1 Mod	1 Low	2 Mod	2 Low	3 Mod	3 Low	3a Mod	3a Low	3b Mod	3b Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.							✓	✓		
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓		✓			✓	✓		
3	The application of agricultural source material to land.							✓			
4	The storage of agricultural source material.							✓	✓		
5	The management of agricultural source material.										
6	The application of non-agricultural source material to land.							✓			
7	The handling and storage of non-agricultural source material.							✓	✓		
8	The application of commercial fertilizer to land.							✓			
9	The handling and storage of commercial fertilizer.								✓		
10	The application of pesticide to land.	✓		✓	✓			✓	✓		
11	The handling and storage of pesticide.							✓	✓		
12	The application of road salt.			✓					✓		
13	The handling and storage of road salt.							✓	✓		
14	The storage of snow.			✓	✓			✓	✓		
15	The handling and storage of fuel.	✓	✓	✓	✓			✓	✓		
16	The handling and storage of a dense non-aqueous phase liquid DNAPLs).										
17	The handling and storage of an organic solvent.	✓	✓	✓	✓			✓	✓		
18	The management of runoff that contains chemicals used in the de-icing of aircraft.							✓	✓		
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.*										
20	An activity that reduces the recharge of an aquifer.*										
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.							✓	✓		

*Water quantity threats will be evaluated as a part of the Water Budget studies

Table 6-11: Point Anne Moderate and Low Pathogen Threats

		Intake Protection Zone (IPZ)					
Prescribed Drinking Water Threats (Ontario Regulation 287/07)		1 Mod	1 Low	2 Mod	2 Low	3 Mod	3 Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.						
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.			✓			
3	The application of agricultural source material to land.						
4	The storage of agricultural source material.						
5	The management of agricultural source material.						
6	The application of non-agricultural source material to land.						
7	The handling and storage of non-agricultural source material.						
8	The application of commercial fertilizer to land.						
9	The handling and storage of commercial fertilizer.						
10	The application of pesticide to land.						
11	The handling and storage of pesticide.						
12	The application of road salt.						
13	The handling and storage of road salt.						
14	The storage of snow.						
15	The handling and storage of fuel.						
16	The handling and storage of a dense non-aqueous phase liquid DNAPLs).						
17	The handling and storage of an organic solvent.						
18	The management of runoff that contains chemicals used in the de-icing of aircraft.						
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.*						
20	An activity that reduces the recharge of an aquifer.*						
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.						

**Water quantity threats will be evaluated as a part of the Water Budget studies

6.2.7 Uncertainty

The delineation of the Intake Protection Zones and assignment of vulnerability scoring have some degree of associated uncertainty. For example, if scores were assigned with substantial data lacking about the intake or bathymetry of the bay then because of the lack of knowledge a high uncertainty would be applied. Also, if methods used to delineate zones are coarse or modelling was not calibrated then there would be higher uncertainty about the results.

Dillon Consulting used a calibrated HEC-geoRAS hydraulic model to aid in the determination of vulnerability zones. Additionally, they employed long periods of wind and flow records to create the model. Zones were established with conservative conditions using either a combination of effects or the worst case condition to establish the outer bounds of the zones. By a complex qualitative method of assigning scores to all variables influencing vulnerability of the intake, scores were tallied using a repeatable approach. This method was used on several intakes and results were compared for their reasonableness.

Given the precautionary approach taken in the analysis and the good knowledge of the bay's hydrology and hydraulics, the uncertainty of the IPZs and the vulnerability scores is Low. This is summarized along with the vulnerability scores on

Table **6-12** below.

Table 6-12: Point Anne Vulnerability Scores and Uncertainty Summary

Zone	Vfz (Area Vulnerability Factor)	Vfs (Source Vulnerability Factor)	V (Vulnerability Score)	Uncertainty	
				Zone Delineation	Vulnerability Score
1	10	1.0	10.0	Low	Low
2	9	1.0	9.0	Low	Low
3a	7	1.0	7.0	Low	Low
3b	3	1.0	3.0	Low	Low

6.2.8 Data Gaps

No significant data gaps were encountered during the identification of Significant drinking water threats, considering that the enumeration approach used was conservative (approach is considered to overestimate number of threats compared to actual conditions). Interviews with property owners were conducted to confirm the actual number and type of Prescribed Drinking Water Threats. There was a general lack of information on the presence/absence of contamination associated with conditions. As a result, no conditions-related drinking water threats were identified.

6.2.9 Groundwater Investigation.

Of particular consideration to the Point Anne analysis is that the system is operated as a surface water intake but also has groundwater influences. Based on concerns regarding potential upgradient bacteriological threats (i.e., private septic beds), it was decided that vulnerability zones and water quality risks should be analyzed according to well intake methods. Issues screening has been completed as part of the surface water analysis for Point Anne and revealed *E.coli*. and Total Coliform levels above benchmark values for surface water sources.

6.2.9.1 Delineation of Groundwater Protection Areas

Groundwater contributions enter the system at the intake well (pre-cast manhole construction) via an opening at shallow depth in the well wall. Due to the shallow groundwater influence on the well, bacteria levels are reportedly higher in Point Anne's raw water than in the Bay of Quinte itself. Operators have also observed that when the groundwater table is high the bacterial concentrations drop. However, following major rainfall events, these concentrations increase reflecting the influence of shallow surface/groundwater inputs. It is based on this understanding of groundwater influences and a concern that upgradient development may pose bacteriologic risks that the groundwater based assessment of vulnerability zones, activities and threats was initiated for this system.

Design drawings describing the Point Anne intake works have been provided by the City of Belleville through Quinte Conservation. Relevant drawings for the Point Anne Water System intake include the following:

1. Intake Pipe Elevation
2. Intake Well and Intake Structure

Elevations in these drawings suggest that groundwater influences on the wet well may be via the adjacent surface water (i.e., Bay of Quinte) or shallow groundwater. These drawings are found in Appendix F-1 (Dillon 2008).

6.2.9.2 Approach to Determine Wellhead Protection Areas

In general, there is very little hydrogeological data and groundwater use data for the Point Anne system. No information is available on water levels in the aquifer near the well or how much groundwater is taken. Therefore, it is recommended that a simple approach be used to identify the potential capture and vulnerability zones. Existing data includes intake well pumping capacity, topography, MOE water well locations, surface water elevations and total system maximum pumping rates (from groundwater and surface water). Groundwater is more likely to enter the system during the months of December to April; however surface water is also expected to enter during this time, but the relative groundwater/surface water proportion is unknown.

Using this data, the following information can be calculated:

Natural Gradient

Using information on the Bay of Quinte water elevation and data from the MOE water well records, a natural gradient is calculated. The December 2004 Bay level was reported to be 73.61 metres above sea level (Appendix F-1, Dillon 2007). The water level elevation in water wells located approximately 300 metres inland from the Bay was 78.15 metres above sea level, giving a hydraulic gradient of 0.015 metres/metre.

Aquifer Parameters

The hydrogeological parameters for the limestone aquifer were based on modeling that was conducted at the Peats Point well field. While not used in this analysis, it is assumed that the aquifer thickness is equal to the depth of the water table around the intake well. Drawing S3 (Appendix F1 Dillon 2007a) provided by the City of Belleville, indicates that the depth of the water level in the intake structure was 1.44 metres. It is also assumed that there is no upward vertical gradient produced during pumping of the intake well.

Natural Groundwater Velocity

The estimated natural groundwater velocity was calculated using the estimated natural gradient (0.015), and the estimated hydraulic conductivity ($2.3E^{-6}$ m/s). Multiplying these numbers together, and dividing by the porosity (0.01), produces an estimated velocity of 110 metres/year.

Capture Zones

Using the natural groundwater velocity, vulnerability zones were calculated based on time of travel. These zones, as shown on Map 6.8, include Zone A (a circle of 100 metres radius), the 2 year TOT (Zone B), and the 5 year TOT (Zone C). This Wellhead Protection Area represents the area that is directly upgradient of the intake well based on the digital elevation model and groundwater elevation contours. The 25 year time of travel zone (Zone D) was not delineated because of the influence of a large rock quarry.

Vulnerability Scores

All areas are assumed to have a high vulnerability according to the Quinte Regional Groundwater Study. Therefore Zone A and B will receive a score of 10, and Zone C will receive a score of 8. Maps of vulnerability scores for these zones can be found in Maps 6.9 and 6.10. The table of vulnerability scores is in Section 6.2.9.5.

6.2.9.3 Discussion

The approach assumes that most of the water entering the intake is from surface water and that there is no significant drawdown cone developed in the aquifer during its operation. This assumption appears reasonable, as most of the year the intake well receives surface water. A temporal drawdown cone may develop between December and April, when groundwater enters the intake well; however, between May and November, the water levels in the groundwater will likely recover as the proportion of groundwater entering the intake decreases. Therefore, it is possible that a long-term drawdown cone never develops. In addition, the method of mapping the upgradient area is fairly conservative, in that the width of the upgradient area (shown in green dashed lines) is fairly wide. Therefore, any short-term capture zone that is developed during the winter months would likely be incorporated into this area.

The methodology to delineate the Wellhead Protection Area varied from the Technical Rules and permission was obtained for this variance from the Director of the Source Protection Programs Branch of the Ministry of the Environment.

6.2.9.4 Threats in Wellhead Protection Areas

Similar to the Intake Protection Zones, threats to the drinking water at the wellhead may be determined from the vulnerability scores for each zone and the circumstances under which an activity would be a drinking water threat. The circumstances under which these threats may be considered as Significant, Moderate or Low are referenced in the Provincial Table of Circumstances (MOE, March, 2018). The interested reader is directed Map 6.9 to determine the location of the particular vulnerability zone.

Activity Based Threats

Table 6-13 enumerates Significant prescribed drinking water threats through activities inventoried in the Point Anne Wellhead Protection Areas (A, B and C) using the multi-step Water Quality Risk Assessment approach discussed in Section 5.1. No Significant threats were found in WHPA A and 15 parcels were identified to have Significant threats in WHPA B.

Condition Based Threats

There is no evidence of the presence of any condition based threats in the groundwater capture zones.

Identification of Moderate and Low Threats

Moderate and Low risks may also exist in the Wellhead Protection Zones for Point Anne. The tables below have been developed by comparing land uses and the potential for chemical or pathogen hazards to exist on those lands with the vulnerability scores for the zones. The tables are to be interpreted as indications of potential for Moderate or Low threats. The risk is calculated as vulnerability multiplied by the hazard rating. A score above 60 and below 80 is a Moderate risk. A score between 40 and 60 is a Low risk.

Table 6-13: Point Anne Significant Threat Enumeration – Wellhead Protection Area

Zone	Threat*	Number of Affected Parcels**	Circumstance Example
Point Anne WHPA-B	Septic Systems	15	Residential Septic System
	The handling and storage of fuel.	8	Fuel tanks below grade and partially below grade >250-2500 litres
Totals	**2 Threat types**	**23 threats on 15 Parcels**	

Note: * Prescribed Drinking Water Threats, Clean Water Act (2006) – O. Reg. 287/07, 1.1(1)
** “Affected parcels” represents the number of parcels on which a specific activity is being engaged in. Some parcels may have more than one activity on-site.

Table 6-14: Point Anne Moderate and Low Chemical Threats

		Wellhead Protection Area (WHPA)													
	Prescribed Drinking Water Threats (Ontario Regulation 287/07)	A Mod	A Low	B Mod	B Low	C Mod	C Low	D Mod	D Low	E Mod	E Low	F Mod	F Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.												
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓	✓	✓	✓	✓						
3	The application of agricultural source material to land.												
4	The storage of agricultural source material.												
5	The management of agricultural source material.												
6	The application of non-agricultural source material to land.												
7	The handling and storage of non-agricultural source material.												
8	The application of commercial fertilizer to land.												
9	The handling and storage of commercial fertilizer.												
10	The application of pesticide to land.			✓	✓	✓	✓						
11	The handling and storage of pesticide.			✓		✓	✓						
12	The application of road salt.				✓		✓						
13	The handling and storage of road salt.												
14	The storage of snow.			✓		✓	✓						
15	The handling and storage of fuel.	✓	✓	✓	✓	✓	✓						
16	The handling and storage of a dense non-aqueous phase liquid DNAPLs).												
17	The handling and storage of an organic solvent.			✓	✓	✓	✓						
18	The management of runoff that contains chemicals used in the de-icing of aircraft.												
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.*												
20	An activity that reduces the recharge of an aquifer.*												
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.												

**Water quantity threats will be evaluated as a part of the Water Budget studies

Table 6-15: Point Anne Moderate and Low Pathogen Threats

		Wellhead Protection Area (WHPA)					
	Prescribed Drinking Water Threats (Ontario Regulation 287/07)	A Mod	B Mod	E Mod	E Low	F Mod	F Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.						
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓				
3	The application of agricultural source material to land.						
4	The storage of agricultural source material.						
5	The management of agricultural source material.						
6	The application of non-agricultural source material to land.	✓	✓				
7	The handling and storage of non-agricultural source material.		✓				
8	The application of commercial fertilizer to land.						
9	The handling and storage of commercial fertilizer.						
10	The application of pesticide to land.						
11	The handling and storage of pesticide.						
12	The application of road salt.						
13	The handling and storage of road salt.						
14	The storage of snow.						
15	The handling and storage of fuel.						
16	The handling and storage of a dense non-aqueous phase liquid DNAPLs).						
17	The handling and storage of an organic solvent.						
18	The management of runoff that contains chemicals used in the de-icing of aircraft.						
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.*						
20	An activity that reduces the recharge of an aquifer.*						
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.						

*Water quantity threats will be evaluated as a part of the Water Budget studies

6.2.9.5 Data Gaps and Uncertainty

The Wellhead Protection Areas were determined on a simplified basis using the best available information. Groundwater data covering the entire area was not complete. Thus, there is a high uncertainty regarding the delineation of the Wellhead Protection Areas. Table 6-16 is provided to summarize the uncertainties along with the scoring of the Wellhead Protection Areas.

Table 6-16: Point Anne Vulnerability Scores and Uncertainty Summary

Well-head Protect-ion Area	Vfz (Area Vulnerability Factor)	Vfs (Source Vulnerability Factor)	V (Vulnerability Score)	Uncertainty	
				Zone Delineation	Vulnerability Score
A	10	1.0	10.0	High	Low
B	10	1.0	10.0	High	Low
C	8	1.0	8.0	High	Low

6.3 Picton Intake Protection Zone

The Town of Picton is situated on the east side of Prince Edward County on the Bay of Quinte. The drinking water system services 5,905 people in Picton and 643 people in the Village of Bloomfield. The location of the drinking water system is shown in Map 2.3. Water is drawn from the Bay of Quinte in Picton Bay by one of two intake pipes. The north intake that is not currently used consists of approx. 305 metres of 400 millimetres diameter screened pipe. The south intake is approximately 91 metres of 400 millimetres diameter screened pipe. Both intakes include an intake crib at approximately 3.3 metres from the surface. There is a 38 millimetres diameter chlorine solution line and a 25 millimetres stainless steel raw water sample line in the south intake pipe for zebra mussel control and for sampling respectively.

The water treatment plant consists of low lift pumping, a chemically assisted filtration treatment process, chlorine disinfection, clearwell, and high lift pumping. Process residues (filter backwash and settled solids) are discharged into the Bay of Quinte without treatment. Construction began on an upgrade to remedy this situation in January 2010. The plant was also upgraded in 2005.

Picton upgraded the municipal sewage treatment plan in 2011 to allow growth of the town as well as to improve effluent quality. This system has tertiary treatment and meets more stringent effluent water quality targets. The sewage treatment plant discharges into Marsh Creek immediately upstream of Picton Bay, the source for the drinking water system.

Land use around the intake is a mixture of predominantly residential and agricultural with some commercial, industrial and institutional. See Map 2.3 for area within Picton serviced by this water treatment plant.

Intake Classification

The Picton intake is classified as a Type D (inland lake) intake. This is discussed under Bay of Quinte Intakes in Section 6 on page 6-1.

6.3.1 Source Water Description

The Bay of Quinte is a Z-shaped embayment off Lake Ontario. Water in the Bay of Quinte flows from west to east and the major water source is the Trent River system.

Map 6.1 shows the boundary of the catchment area of the bay with its major tributaries. The Bay of Quinte is an international area of concern and has an established Remedial Action Plan (RAP) that has concentrated much effort over the past 16 years to improving the water quality. Algal blooms related to high phosphorus concentrations have been persistent problems in past years, but are less frequent with ongoing efforts to reduce inputs of phosphorus.

Water quantity supply has not been a concern at this intake since the water level in the bay is controlled by regulation of Lake Ontario at Cornwall. Usual annual water level variation is 0.5 metres ranging from an average high of 75.04 metres above sea level in June to an average low of 74.53 metres above sea level in December.

The plant has experienced clogging of the intake from time to time caused by build-up of aquatic plants also known as macrophytes. When this happens, plant operators employ divers to manually clear the intake. Operators will also switch to the more northern intake when clogging occurs.

6.3.2 IPZ 1 Delineation

An area known as Intake Protection Zone 1 (IPZ 1) was delineated using the methodology in Section 4.6.

The intakes have been plotted on a map using coordinates supplied by the operators of the Picton plant. A one kilometre radius circle was drawn around each of the two intakes and this established the most extreme boundary. Where the circle intersects the shore the protection zone was extended 120 metres inland measured perpendicular from the shore and trimmed at the 120 metres inland limit or the regulation limit whichever was the greatest.

Intake Protection Zone 1 extends from just south of Chuckery Hill Road at its most northerly point in Picton Bay to the south tip of the bay. This includes the marina and outlets from several drainage systems.

Map 6.15 presents the final shape of IPZ 1 for the Picton intakes. The edge of surface water body has been used to represent the limits of high water.

6.3.3 IPZ 2 Delineation

The IPZ 2 was delineated following the methodology presented in Section 4.6. There are two intakes but they are close enough together that only one IPZ 2 was delineated.

The contributing area to IPZ 2 was determined by considering contributions from flows, wind, sewersheds and transport pathways.

Typically, an Intake Protection Zone 2 is delineated by mapping the 2 hour time of travel for surface water to reach the intake. For the Picton intakes, early indications were that the IPZ 2 would not extend outside the IPZ 1 if the 2 hour criterion was used. The shape of Picton Bay and the location of the intakes result in most of the water from the drainage area in and around the town flowing into the Bay close to the intakes. A conservative approach of increasing the time of travel for the IPZ 2 to a 4 hour time of travel ensures the IPZ 2 adequately reflects what is happening on the landscape and provides the water system operators adequate time to respond in an emergency. This situation was discussed with input from the Prince Edward County staff and it was determined that the limits for Intake Protection Zone 2 should be established with a 4-hour time of response. Winds and flow affect water movement in Picton Bay near the intake. XCG Consulting reviewed the conditions at the intake to gain an understanding of water movement and exposure to wind and wind direction.

Drogues (neutrally buoyant devices placed in the water below the surface) were deployed in the bay and tracked with hand-held GPS for periods of time ranging between 1.2 to 2.6 hours in winds from 4 to 15 kilometres per hour coming generally from the northeast. The largest fetch is from the northeast and winds from this direction have the opportunity to generate most significant surface currents in the bay.

Results from the drogue study were used to help develop and field truth a hydrodynamic model of Picton Bay. The model was based on a US EPA Environment Fluid Dynamics Code platform that allows users to ‘track’ particle movement in a water body under influences of wind and flow. Inputs to the model include bathymetry, flow, water level, and wind velocities. Hydrologic and meteorologic conditions at the time of the drogue study were simulated in the model and the results were compared to those obtained in the field. They were found to compare satisfactorily. Variations that were noted may have been due to weed growth that hung up the drogues or variations in wind speed during gusts that occurred but which were modelled only as average.

Once the model produced satisfactory results, XCG Consulting used Trenton Airport meteorological station historic data[1] to determine 2-year wind speeds that fell within each of eight directions. Influences on the time of travel by northerly winds were found to be 100 percent wind dominated while the southerly direction was influenced by both wind and flow. Flow in Picton Bay is predominantly driven by discharges from Marsh Creek and to some extent by smaller creeks such as Hospital (or Mosquito) Creek.

[1] Hourly wind data for a ten year period were analyzed.

Flow values for the 2-year frequency (or bank full flow) were derived from previous work as 5 cubic metres per second (Paine 1995). Finally, a water level boundary condition of 74.2 metres above sea level (International Great Lakes Datum for Lake Ontario) was supplied.

The model result yielded a flow distance of 1400 metres from the north during the 4-hour travel time. From the south the IPZ 2 extends 800 metres up Marsh Creek and all the way up the smaller tributaries.

Within the IPZ 2 some upland areas (transport pathways and storm sewer systems) may also contribute runoff within the 4-hour travel time. Several storm sewer systems discharge into IPZ 2 and have been included into the zone. Municipal storm sewer mapping and sewershed information was provided by XCG (XCG 2005) from which the upstream limits of storm sewer contribution were determined. Minimum sewer velocities of 0.6 m/s (MOE 2008) were applied as a conservative estimate to determine if all the sewershed would contribute. The longest sewershed was about 1 kilometre. It was found that times of flow by this method were about 30 minutes. The entire sewersheds were included within the IPZ 2.

Intake Protection Zone (IPZ) 2 Amendment

The intake protection zone 2 was delineated using the approach described in Section 4.6.2 in 2009 for the initial Assessment Report (2011). However, since the Approval of the Quinte Region Assessment Report in 2014, new areas of land have been developed within the Town of Picton and this development has introduced new storm sewersheds and drainage patterns. These developments can be split into three general areas; an industrial area in the McFarland, McDonald and MacSteven Drive vicinity, residential development to the north east of Talbot Street, and an additional residential development on the eastern side of the IPZ 2 on County Road 8.

When originally delineated, the IPZ 2 was limited to the 120 meter buffer of Hospital Creek which included MacSteven Drive. This area had seen very little development and McDonald Drive did not exist. McDonald Drive has since been created from Johnson Street to McFarland drive and has developed into an industrial area. Stormwater ditches and ponds have been created to drain into Hospital Creek. Source Protection Authority staff received updated stormwater drawings from the Corporation of the County of Prince Edward confirming all properties on McFarland, McDonald, and MacSteven Drives are now conducting stormwater into Hospital Creek and therefore need to be amended to IPZ 2.

The second development area is the southwestern portion of the IPZ 2 located to the east of Hospital Creek, north of Talbot Street and west of Barker Street. The storm sewershed for existing development in the Barker Street area is part of the IPZ 2. However, development on Downes Avenue and Jasper Avenue has changed the existing land drainage. A small portion of Hospital Creek has been diverted to the west and stormwater in these development areas is now draining into the creek. Source Protection Authority staff met with planners from the municipality to discuss the subdivision plans in this area and whether or not they would affect the delineation of the IPZ 2. Planners explained which developments have been approved and verified the direction of flow of the stormwater in this area. Those subdivision and development plans still in the draft stages were brought to the attention of Source Protection Authority staff but were not included in the amended area.

The final amendment area is located on the western edge of the IPZ 2, along County Road 8. This is an existing storm sewershed that has been extended to include a newly approved subdivision area.

As mentioned in the previous section, times of travel for the existing storm sewersheds were well below the approved four hour time of travel. To remain conservative, the amended areas' storm-sewer lengths were added onto the longest sewershed (approximately 1 kilometre) and minimum sewer velocities of 0.6 m/s (MOE 2008) were applied to determine if all the sewersheds and transport pathways would contribute. It was determined the amended areas would increase the length of the sewershed by 367 meters at most. It was found that times of flow by this method were about 38 minutes, still well below the four hour time of travel for the intake protection zone 2. Therefore the subdivisions' stormwater systems were included into the intake protection zone 2 amended areas.

Map 6.15 presents the final shape of IPZ 2 for the Picton intakes located in Picton Bay with the proposed amendments to include the newly developed areas.

6.3.4 IPZ 3 Delineation

Tributary to the Town of Picton intakes is almost the entirety of the Bay of Quinte drainage system. The total contributing area has the potential to influence the Picton Bay. Upstream of the Picton intakes are Deseronto, Point Anne, Belleville, and Bayside intakes. An IPZ 3 is a further zone of protection for the intakes that takes in account the upstream contributing area. Intake Protection

Zones have also been established for these upstream intakes and it is not necessary to extend the Picton IPZ 3 into those areas.

It is recognized that IPZ 3 represents an area of reduced risk relative to the IPZ 1 or 2. This is then the remainder of the contributing watershed that is not within the IPZ 1 or 2 including the rest of the Marsh Creek drainage system and a portion of the Bay of Quinte, Hay Bay and tributaries within the Cataraqui Region Source Protection Area.

Since the IPZ 3 is very extensive area, it was necessary to split this into IPZ 3a and 3b as illustrated by Map 6.16. The former encompasses the remainder of the Marsh Creek tributaries outside IPZ 2, while the latter includes the upper watershed tributaries. Another distinction is that water from IPZ 3a definitely flows by the Intake while water from the IPZ 3b could reach the intake. IPZ 3a represent a higher risk than IPZ 3b. Each of IPZ 3a and 3b extend from water features to 120 metres inland or the regulation limit, whichever is greater.

6.3.4 Vulnerability Scoring

For more information on vulnerability scoring see Section 4.6.

Each IPZ is ‘scored’ to identify its vulnerability to contamination and allows a determination of risk to contamination.

The vulnerability scores for IPZs are determined by multiplying the ‘area vulnerability factor’ times the ‘source vulnerability factor’.

6.3.4.1 Area Vulnerability Factor

For a Type D intake the area vulnerability factors are:

- IPZ 1 10
- IPZ 2 7 – 9
- IPZ 3 1 – 9, but not greater than the score assigned in IPZ 2

IPZ 1 is assigned a vulnerability factor of 10.

Table 6-17 below contains the summary statistics for the Picton intake that were reviewed following the methodology provided in Section 4.6 to determine the area vulnerability factors for IPZs 2 and 3.

Table 6-17: Area Vulnerability Considerations at Picton Intake IPZ 2

Land/Water	Landcover, Slope, Soil Type	Transport Pathways / Storm Sewers	Combined Vulnerability
74% land	High percentage of	Several storm sewers	HIGH

	urban land use. Soils are loams and sands with high drainage. Slopes are steep.	and open drainage systems	
MODERATE	HIGH	HIGH	

Intake Protection Zone 2 has a high percentage of urban land use, low permeability and moderate slopes. The Town of Picton storm sewers represent transport pathways. Therefore, an area vulnerability factor of 9 (maximum value) was assigned to the Picton IPZ 2 primarily on the basis of storm sewer contributions. Because the area vulnerability considerations did not change with the amended areas, the area vulnerability was not changed.

Two IPZ 3 vulnerability scores were considered for Picton and area vulnerability factors of 8 and 6 were assigned respectively to IPZs 3a and 3b. The area vulnerability factor for IPZ 3a was selected to reflect the close proximity of the zone to the intake, high slopes and recognizes the existence of several storm sewer systems. IPZ 3b reflects the reduced influence of transport pathways and sewersheds in the zones as compared to IPZ 2 and 3a.

6.3.4.2 Source Vulnerability Factor

Source vulnerability factors for a Type D intake must be in the range of 0.8 to 1.0 and are assigned by the reviewer (in this case XCG Consulting) by considering the following:

- Depth of the intake from the top of the water surface;
- Distance of the intake from the land; and
- Number of recorded drinking water issues related to the intake.

The depth of the intakes are estimated to be 3.3 metres below water surface. Each intake projects to the centre of the bay approximately 90 to100 metres from shore. Due to the presence of several transport pathways and owing to the fairly nearshore location and shallow depth of the intakes, a high source vulnerability factor of 1.0 is assigned to the intakes.

Table 6-18 below shows the results of the score assignments with vulnerability mapping provided by Maps 6.17 and 6.18.

Table 6-18: Picton Vulnerability Scores

Intake Protection Zone	Area Vulnerability	Source Vulnerability	Vulnerability Score, V

		Factor	Factor	
Picton	IPZ 1	10	1.0	10.0
	IPZ 2	9	1.0	9.0
	IPZ 3a	8	1.0	8.0
	IPZ 3b	6	1.0	6.0

Picton Vulnerability Score

- **IPZ 1 = 10**
- **IPZ 2 = 9**
- **IPZ 3a = 8**
- **IPZ 3b = 6**

Note: These scores are used in conjunction with the Prescribed Threats Look Up Tables to determine Significant, Moderate and Low threats.

6.3.4.3 Picton Managed Lands, Livestock Density and Impervious Surfaces

The percentage of managed lands, livestock density (Nutrient Units per Acre) and impervious surfaces were calculated for the Picton Intake Protection Zones to assist with the determination of Significant threats as per Technical Rule 16 (9),(10) and (11). Maps 6.19, 6.20, 6.21 and 6.22 show the percentages. Managed lands were recalculated to include the amended areas. With the help of up-to-date air photos and land use information, the percentage of managed lands within the amended intake protection zone equalled 21 percent. Livestock density followed the methodology in Chapter 4 and therefore did not change with the amended area. The impervious surfaces were calculated based on the use of a one square kilometre grid as described in methodology section 4.7.6 of Chapter 4. The impervious surface area saw slight changes in the calculations with the inclusion of the amended intake protection zone 2 but generally total impervious surface area percentages decreased. See map 6.19 for impervious surface area percentages.

6.3.5 Threats to Drinking Water Quality

This section reviews risks to drinking water through two approaches. The first is identifying threats through an issues based approach where contaminants have been chronically detected in the raw water supply and linked to land use activities. The second approach is threats based and looks at current and former land use activities in the contributing areas to the intake. Threats are assessed to determine level of risk between Significant, Moderate, or Low.

6.3.5.1 Issues Approach

The raw water quality data collected at the Picton intakes were screened using the approach described in Section 4.8 to identify issues in the source water of Picton Bay which may contribute to degraded water quality. Data sources used in the review are presented later in this section.

The 4-step screening process was applied to the Picton intakes raw water data outlined in Section 4.8.1. The results are summarized below. A more complete analysis is contained in a report produced by XCG Consulting Limited found in the Appendix F-3 (XCG 2009b).

Screening Step 1

The following 15 parameters listed below had individual results that exceeded the Half Maximum Acceptable Concentration, the half benchmark. They were analyzed for trending in Step 3. Three parameters: *E.coli*, Total Coliform, and Aluminum had an average greater than Maximum Acceptable Concentration, the benchmark.

- *E.coli*
- Total Coliforms
- Field Temperature
- pH
- Colour
- Hardness
- Dissolved Organic Carbon (DOC)
- Field Turbidity
- Sodium
- Chromium
- Manganese
- Selenium
- Aluminum
- Aldicarb
- Microcystin LR (an indicator of total phosphorus loads)

Screening Steps 2 and 3

A trend analysis was completed on the above parameters and a determination of origin (anthropogenic or natural) was made. Temperature, pH, Colour and Hardness are unlikely to have sources stemming from human activities and are considered naturally occurring. *E.coli*, Field Turbidity and Sodium had trend lines that if continued could reach their benchmark within 50 years. Three parameters passed screening Steps 2 and 3 with the addition of Aluminum based on the recommendation by the drinking water system operator.

- *E.coli*
- Sodium
- Field Turbidity; and
- Aluminum

Microcystin-LR

Microcystin-LR did not pass screening Step 3 as the trend line had a downward direction and is not an issue for this intake. However algae toxins such as Microcystin-LR are a concern for the Bay of Quinte based on historic events of Harmful Algae Blooms that may pose a risk to public health. Research is being conducted because there are many unknowns about algae toxins compared algae blooms themselves. This is discussed further in Chapter 8. Any changes to the status on Microcystin-LR or any other parameter considered an issue for the Picton intakes will be included in a future version of the Assessment Report. In the meantime the Corporation of the County of Prince Edward is encouraged to keep the Picton system enrolled in the Ontario Drinking Water Surveillance Program. Although it is not mandatory under current provincial regulations the program is free of cost to all municipalities and it is valuable in that it collects data on additional parameters that are not regularly monitored for raw water, e.g. Microcystins.

Turbidity

Turbidity is not considered to be an issue as it is a parameter which only exceeds the aesthetic objectives. The spikes in turbidity that occur may be attributed to storm events, freshet conditions and high winds from the east, northeast and south directions. With regards to storm events and freshet conditions there are several storm sewer outlets and creeks (Hospital / Mosquito Creek in particular) which act as transport pathways and in some cases can result in high turbidity loads. Management of these outfalls and watershed planning on Hospital / Mosquito Creek may provide benefit in terms of turbidity reduction. High winds from certain directions likely re-suspend sediments from the bottom of the bay causing the turbidity spikes which cannot be controlled.

pH

For the pH dataset, there are rare (< 2percent) exceedances of the guideline (pH > 8.5). The bulk of the exceedances occur in the summer months; this may indicate that increases in pH are caused by excessive weed growth and/or algae blooms. It is the opinion of XCG Consulting that this parameter is the result of background conditions and is therefore not an issue. If excessive weed and algae is the cause of an elevated pH then a reduction of phosphorus loads may be beneficial. As mentioned earlier, the Bay of Quinte Remedial Action Plan addresses phosphorus concerns in the Bay of Quinte.

Screening Step 4

No parameters pass screening Step 4 and therefore no issues are identified at the Picton intakes. Some discussion follows that explains the decisions not to identify Sodium, *E.coli*, Total Coliform, and Aluminum as issues.

E.coli as well as Total Coliform are treatable in the Picton water treatment process and level are considered normal for surface waters. They do not pass this screening step and are not issues.

Sodium

Sodium in raw water had a trend line showing that in 50 years the average could exceed the Sodium benchmark (20 mg/L) in the source water. However, a review of the time series shows that a probable data jump exists (meaning that the average value from time period 1 to time period 2 switches at a single point) around 1999 (Figure 6-2). Reasons for a jump of this sort could result from a change in monitoring location or a change in the method of testing. Sodium was deemed not to be an issue due to the existence of a possible jump and a marginal exceedance based on a long duration trend line (Appendix F-3, XCG 2009b).

Aluminum

Aluminum is likely a background parameter. However discussions with the operating authority revealed that the higher levels of Aluminum may in part be caused by the treatment residues that are laden with aluminum, which are discharged during filter backwash, in the vicinity of the intakes without being treated. This problem has been addressed through an upgrade.

Data Sources

Raw water quality data was obtained from several sources listed in Table 6-19.

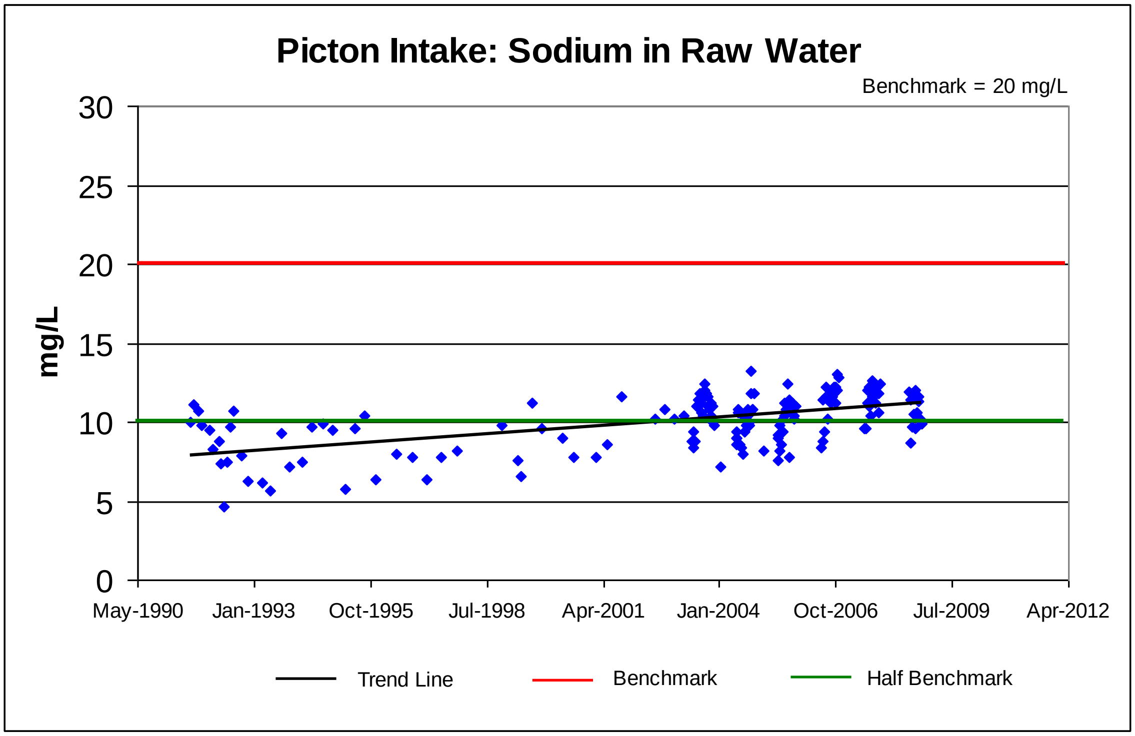


Figure 6-2: Sodium Time Series

6.3.5.2 Threats Approach

A threats approach may also be used to identify potential drinking water threats. These are determined from the vulnerability scores for each zone and the circumstances under which an activity would be a drinking water threat. The circumstances under which these threats may be considered as Significant, Moderate or Low are referenced in the Provincial Table of Circumstances (MOE, March, 2018). See Maps 6.17 and 6.18 to determine the location of the particular vulnerability zone.

Significant Threats

Significant drinking water threats can be determined based on current land uses (activities) and past land uses (conditions).

Activity Based Threats

Table 6-20 enumerates Significant prescribed drinking water threats through activities inventoried in the Picton Intake Protection Zones 1,2, and 3. Forty-seven parcels were identified in IPZ 1 and 20 parcels in IPZ 2 to have such threats. The score for IPZ 3a was also high enough for 1 parcel to have Significant threats.

Table 6-19: Reviewed Water Quality Data Sources

Source	Parameters in Dataset	Period of Record	Raw / Treated Water
Annual Reports	Schedule 1 Schedule 2 Table 4	2006-2008	Treated Water
WTP Water Quality	Schedule 1 Table 4	2002-2007	Raw Water Treated Water
Drinking Water Information System (DWIS)	Schedule 1 Schedule 2 Table 4	2003-2009	Raw Water Treated Water
Drinking Water Surveillance Program (DWSP)	Schedule 1 Schedule 2 Table 4	1991-2005	Raw Water
DWSP - Special	Schedule 2 Table 4	2003-2008	Raw Water Treated Water
DWSP - Routine	Schedule 1 Schedule 2 Table 4	1991-2007	Raw Water Treated Water
Microcystin Data	Schedule 2	2003-2006	Treated Water

Note: Other data sources were also reviewed but were not included due to proximity and potentially being non-representative of the source water quality at the Picton water treatment plant (i.e. The Ministry of the Environment’s Great Lakes Index Station Network and the Department of Fisheries and Oceans data located further out in Bay of Quinte and the Provincial Water Quality Monitoring Network data for Marsh Creek, Picton Creek, and Hospital Creek).

Condition Based Threats

A review of records indicated two properties within the Intake Protection Zone for the Town of Picton as presenting potential conditions. A summary of the review of these conditions is provided in Appendix I. One of the sites is located in the IPZ 3a and is presently used as a waste transfer station. A Certificate of Approval for this site indicated that it was licensed for the disposal of wood waste. However, recent inspections indicated that there is no evidence of land filling as it was common practice to burn the wood waste. This activity no longer occurs at this site and it was reported by the Municipality that there has been no testing or assessment for the presence of contamination. As a result insufficient information was available to assess if the site could be considered a condition. However, the absence of such data does not necessarily mean that contamination does not exist.

Table 6-20: Picton Significant Threat Enumeration

Zone	Threat*	Number of Affected Parcels**	Circumstance Example
IPZ 1	Road Salt Application	2	Road salt spread on impervious area > 8 but <80%
	Septic Systems	44	Septic systems regulated under Building Code
	Fuel Storage	1	Fuel tanks below grade and partially below grade >250-2500 litres
IPZ 2	Pesticides	9	Agricultural source material is applied to land in any quantity
	Livestock Grazing	1	Pasturing/ Grazing of Livestock
	Commercial Fertilizer	4	Application of Commercial Fertilizer to land
	Municipal Sewage System	2	Municipal Sewage Treatment Plant Effluent & Bypass Discharges
	Municipal Stormwater Pond	1	On-Site Sewage System
	The Storage of Agricultural Source Material	1	Manure storage facility
	Fuel Storage	1	Fuel tanks above grade >2500 litres
	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act	7	Waste Oil
IPZ 3	Municipal Sewage System	1	Municipal Sewage Treatment Plant Bypass Discharges
Totals	9 Threat Types	74 threats on 68 parcels	
Condition Based Drinking Water Threat			
IPZ 2	Closed Landfill Site	Condition	n/a

Note: * Prescribed Drinking Water Threats, *Clean Water Act* (2006) – O. Reg. 287/07, 1.1(1)
** "Affected parcels" represents the number of parcels on which a specific activity is being engaged in. Some parcels may have more than one threat activity on-site.

The second site, located in the IPZ 2, is a closed landfill referred to as the Picton Dump. This site was formerly a marsh located adjacent to Marsh Creek draining into Picton Bay. Filling was reported to have started in the early 1900's until the site was closed in 1979. Subsequent hydrogeological study of the site was completed in 1988 (Water & Earth Science & Associates, 1989) which indicated the presence of landfill leachate in the groundwater and discharge to Marsh Creek. A review of groundwater data from monitor wells located within the Intake Protection Zone indicated 6 parameters exceeding the potable groundwater standards of Table 2 in the Ministry of the Environment Soil, Ground Water and Sediment Standards (July 27, 2009). Based on these exceedances the site is considered a condition.

Calculation of the risk score as listed below indicated the site is to be considered a Significant drinking water threat. Regardless, given the date of the data that was used for this assessment it is also recommended that more updated data be obtained to confirm the findings.

Risk Score = 10 X 9.0 = 90

Where:

- The hazard rating was assigned as 10, given the property is in the IPZ 2 associated for the Town of Picton Intake and past evidence suggests there is offsite impact; and
- The vulnerability score of the IPZ 2 was assigned as 9.0 as outlined in above in section 6.3.5.

Identification of Moderate and Low Threats

Moderate and Low risks may also exist in the Intake Protection Zones for Picton. Table 6-21 and Table 6-22 have been developed by comparing land uses and the potential for chemical or pathogen hazards to exist on those lands with the vulnerability scores for the IPZs. The tables are to be interpreted as indications of potential for Moderate or Low threats. The risk is calculated as vulnerability score multiplied by the hazard rating. A score above 60 and below 80 is a Moderate risk. A score between 40 and 60 is a Low risk.

6.3.6 Uncertainty

The delineation of the Intake Protection Zones and assignment of vulnerability scoring have some degree of associated uncertainty. For example, if scores were assigned with substantial data lacking then a high uncertainty would be applied. Also, if methods used to delineate zones are coarse or modelling was not calibrated or used inadequate data sets then there would be high uncertainty about the results.

Table 6-21: Picton Moderate and Low Chemical Threats

		Intake Protection Zone (IPZ)									
	Prescribed Drinking Water Threats (Ontario Regulation 287/07)	1 Mod	1 Low	2 Mod	2 Low	3 Mod	3 Low	3a Mod	3a Low	3b Mod	3b Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.			✓				✓			✓
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓	✓	✓			✓	✓	✓	✓
3	The application of agricultural source material to land.			✓				✓			✓
4	The storage of agricultural source material.			✓				✓	✓		✓
5	The management of agricultural source material.										
6	The application of non-agricultural source material to land.			✓				✓			✓
7	The handling and storage of non-agricultural source material.	✓	✓	✓	✓			✓	✓		✓
8	The application of commercial fertilizer to land.			✓				✓			✓
9	The handling and storage of commercial fertilizer.	✓	✓	✓	✓			✓	✓		✓
10	The application of pesticide to land.	✓		✓				✓	✓		✓
11	The handling and storage of pesticide.	✓	✓	✓	✓			✓	✓		✓
12	The application of road salt.	✓									
13	The handling and storage of road salt.			✓	✓			✓	✓		✓
14	The storage of snow.	✓	✓	✓	✓			✓	✓		✓
15	The handling and storage of fuel.	✓	✓	✓	✓			✓	✓		✓
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).										
17	The handling and storage of an organic solvent.	✓	✓	✓	✓			✓	✓		✓
18	The management of runoff that contains chemicals used in the de-icing of aircraft.										
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.*										
20	An activity that reduces the recharge of an aquifer.*										
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.							✓			✓

**Water quantity threats will be evaluated as a part of the Water Budget studies

Table 6-22: Picton Moderate and Low Pathogen Threats

		Intake Protection Zone (IPZ)					
Prescribed Drinking Water Threats (Ontario Regulation 287/07)		1 Mod	1 Low	2 Mod	2 Low	3 Mod	3 Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.						
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.			✓			
3	The application of agricultural source material to land.						
4	The storage of agricultural source material.			✓			
5	The management of agricultural source material.						
6	The application of non-agricultural source material to land.						
7	The handling and storage of non-agricultural source material.						
8	The application of commercial fertilizer to land.						
9	The handling and storage of commercial fertilizer.						
10	The application of pesticide to land.						
11	The handling and storage of pesticide.						
12	The application of road salt.						
13	The handling and storage of road salt.						
14	The storage of snow.						
15	The handling and storage of fuel.						
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).						
17	The handling and storage of an organic solvent.						
18	The management of runoff that contains chemicals used in the de-icing of aircraft.						
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.*						
20	An activity that reduces the recharge of an aquifer.*						
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.						

**Water quantity threats will be evaluated as a part of the Water Budget studies

IPZ 1 was established according to the Technical Rules and therefore there is a high degree of confidence in the delineation. Thus, uncertainty in IPZ 1 is Low.

The IPZ 2 for Picton was delineated using two separate approaches. XCG Consulting used a calibrated hydrodynamic model to aid in the delineation of the IPZ 2 in Picton Bay. They assigned an uncertainty of High because the model was field verified with only one event evaluated and commented that refinements could be made to the model and other field observations and/or events made to improve model calibration. The Committee looked at the consultant's uncertainty assignment but decided that uncertainty should be re-evaluated. This review is based on the following factors. The first factor is that modelling of the upstream creeks and storm sewersheds used HEC-2 and Mannings Models respectively to determine the 4 hour time of travel zones provided reliable results. Secondly, the Committee is confident in the creek and storm sewershed mapping and hydrology used. These factors were not addressed in XCG's uncertainty assessment. When the Committee looked at all factors they were confident that the actual uncertainty for IPZ 2 delineation should be Low.

Uncertainty assigned to zone 3 was set to Low as the best available stream information was used.

Uncertainty associated with scoring has been reduced by the precautionary approach used by XCG Consulting. The source vulnerability score is the highest possible. Source factors were selected taking into consideration the factors outlined in the director's rules and the uncertainty is also Low.
23 below shows the summary of uncertainties.

Table 6-23: Picton Vulnerability Scores and Uncertainty Summary

Zone	Vfz (Area Vulnerability Factor)	Vfs (Source Vulnerability Factor)	V (Vulnerability Score)	Uncertainty	
				Zone Delineation	Vulnerability Score
1	10	1.0	10.0	Low	Low
2	9	1.0	9.0	Low	Low
3a	8	1.0	8.0	Low	Low
3b	6	1.0	6.0	Low	Low

6.3.7 Data Gaps

No significant data gaps were encountered during the identification of Significant drinking water threats, considering that the enumeration approach used was conservative (approach is considered to overestimate number of threats compared to actual conditions). Interviews with property owners were conducted to confirm the actual number and type of Prescribed Drinking Water Threats. Further threats verification, including site visits, was conducted in 2013.

6.4 Deseronto Intake Protection Zone

The Deseronto Water Plant is a conventional treatment plant. Water is drawn from the Bay of Quinte and low-lift pumps transfer the water from the bay to the treatment plant. The treatment process consists of coarse screening, pre-chlorination (zebra mussel control), coagulation, flocculation, clarification (upflow clarifier), filtration, pH control, disinfection and distribution. Granular activated carbon (GAC) contactors are used for taste and odour control. This plant has a rated capacity plant capacity of 2,946 cubic metres/day (34.1 Litres/second) and serves a population of approximately 2,100 (Annual Drinking Water Compliance Report for 2005, 2006).

The plant was constructed in 1972 and was last upgraded in the late 1970s. It has a 400 millimetres diameter and 488 metre long intake pipe extending 480 metres off-shore into the Bay of Quinte. The intake is located approximately 6 metres below the mean lake surface level. It is equipped to deliver chlorine solution to the intake crib for zebra mussel control.

Deseronto is also serviced with municipal sewage treatment that discharges into the Bay of Quinte less than 1 kilometre east of the drinking water intake.

Land use around the intake is a mixture of predominantly residential and agricultural with some commercial, industrial and institutional. See Map 2.3 for area serviced by this water treatment plant.

Intake Classification

The Deseronto intake is classified as a Type D (inland lake) intake. This is discussed under Bay of Quinte Intakes in Section 6 on page 6-1.

6.4.1 Source Water Description

The Bay of Quinte is a Z-shaped embayment off Lake Ontario. Water in the Bay of Quinte flows from west to east and the major water source is the Trent River system.

Map 6.1 shows the boundary of the catchment area of the bay with its major tributaries. The Bay of Quinte is an international area of concern and has an established Remedial Action Plan (RAP) that has concentrated much effort over the past 16 years to improving the water quality. Algal blooms related to high phosphorus concentrations have been persistent problems in past years, but are less frequent because of efforts to reduce inputs of phosphorus.

Water quantity supply has not been a concern at this intake since the water level in the bay is controlled by regulation of Lake Ontario at Cornwall. Usual annual water level variation is 0.5 metres ranging from an average high of 75.04 metres above sea level in June to an average low of 74.53 metres above sea level in December. The intake has not been and is not likely to be susceptible to low water conditions. Boundaries for the Intake Protection Zones were prepared with the assistance of Dillon Consulting.

6.4.2 IPZ 1 Delineation

An area known as IPZ 1 was delineated following the method outlined in Section 4.6.

The IPZ 1 may be modified to reflect the local hydrodynamic conditions. However, due to high probability of reverse flows in the Bay of Quinte near Deseronto the conservative approach with a 1,000 metres circle was adopted (see Map 6.23). It was trimmed along the shoreline with the appropriate setback applied (Section 4.6).

6.4.3 IPZ 2 Delineation

In consultation with the drinking water plant operators, it was determined that since plant operators are able to respond to a water quality issue at the plant in less than 2 hours, the limits for IPZ 2 should be established with a 2-hour time of response.

The contributing area to IPZ 2 was determined by considering contributions from flows, wind and transport pathways.

Flow Driven Effects

There are three reaches in the Bay of Quinte that will influence flows and times of flow in the vicinity of the Deseronto intake. From the west, the upper and middle bay reaches receive flows from the Trent, Moira, and Salmon River systems as well as other smaller tributaries. From the east the tributaries to Mohawk Bay including the Napanee River flow in the direction of the intake. And from the south, flows in the Bay would only reach the intake under a reverse flow condition.

Design flow rates for the Upper Bay and Adolphus reaches were determined based on the analysis of daily flow time series created by Environment Canada as part of their temperature modeling analysis of the Bay of Quinte. With the assistance of a HEC-geoRAS model a hydraulic model of the Bay of Quinte was prepared to calculate times of flow for each reach (see Dillon 2007 in Appendix F-4).

In brief, the elevation model used to represent the Bay and to derive cross sections was created based on digital point data from navigational charts obtained from Nautical Data International. Cross sections were 'cut' using this elevation model and derived bathymetric contours. The starting water level was set equal to the chart datum (74.2 metres above sea level), a low water level that results in smaller cross-sectional flow areas. As a result higher flow velocities are calculated leading to a larger contributing area to IPZ 2. This conservative approach to setting velocities and resulting travel distances is in keeping with the precautionary approach promoted for source protection planning. Table 6-24 below shows the 2-hour travel distances calculated in each reach.

Table 6-24: Flow Rate and Travel Distance Summary

Study Reach	2-Year Flow Conditions			Reverse Flow Conditions		
	Flow Rate (cms*)	Average Flow Velocity (m/s**)	2-Hour Travel Distance (metres)	Flow Rate (cms*)	Average Flow Velocity (m/s**)	2-Hour Travel Distance (metres)
Upper Bay Reach	721.9	0.192	1385 m	N/A	N/A	N/A
Napanee River / Mohawk Bay Reach	49.4	0.007	50.4 m	N/A	N/A	N/A
Adolphus Reach	N/A	N/A	N/A	- 189.4	- 0.0286	205.7

*cubic metres per second
**metres per second

Wind Driven Effects

Wind-driven surface transport velocities have been determined based on historical wind records obtained for the Trenton meteorological station. Typically these transport velocities representing contaminant movement are estimated as 3 percent to 5 percent of the wind velocity measured 10 metres above ground. One-hour time series of wind speed and direction obtained from Meteorological Survey of Canada were processed to create a 2-hour time series that formed the basis of this analysis. Results indicate that 2-hour travel distances range from 181 metres from the east to 1,121 metres from the south-west.

Transport Pathways

Source protection staff reviewed background reports that have been prepared for Deseronto to determine the extent and type of municipal drainage. A Bay of Quinte Remedial Action Plan report (XCG 2005) determined preliminary drainage boundaries for Deseronto. No storm sewer systems were identified in this report. No storm outfalls are evident along the shoreline. It appears that all drainage reaches the Bay of Quinte via open ditch. There are some catchbasins in the downtown section that are not directly connected by storm sewer to the bay front. The urban drainage systems are less than 1 kilometre in extent. Storm flow would be in the order of 0.5 hours and would contribute to the IPZ 2 close to the intake location. All municipal drainage that outlets into the Bay of Quinte within IPZ 1 were included into IPZ 2 as transport pathways.

A small drainage course that outlets into the IPZ 1 was included within IPZ 2 as a regulated area. It is approximately 2 kilometres in length and would flow roughly 0.5 metres/second during a 2-year event. The time of travel would be approximately 1 hour. The point of discharge is well within the IPZ 2.

The IPZ 2 was synthesized from all these effects to produce an area where a contaminant may reach the intake within a 2-hour time period given the most conservative combination of effects. See Map 6.23 showing the limit of this IPZ.

6.4.4 IPZ 3 Delineation

The IPZ 3 for the Town of Deseronto Intake includes: the Bay of Quinte up to the Point Anne intake, the Salmon River and the Napanee River up to the Napanee Back-up Supply. These areas form IPZ 3. Also IPZ 3 includes contributing tributaries and mapped drainage features, on-line and contiguous lakes and wetland features upstream of the intake, and a setback of 120 metres or the regulation limit, whichever is greater. Tile drainage areas that may contribute water and are interconnected to the surface water system are also included. Map 6.24 shows the extent of IPZ 3.

IPZ 3 was divided into two subzones, 3a and 3b, due to the different area conditions and vulnerability considerations. IPZ 3a includes the drainage area immediately upstream of IPZ 2 to the approximate limit of the higher density agricultural land use area within the watershed. Within IPZ 3a, land use is predominantly agricultural while within IPZ 3b it is mainly wooded and less developed. Using this distinction it was determined that the IPZ 3a should have a higher vulnerability score than the IPZ 3b. The divide between IPZ 3a and 3b also corresponds to the approximate limit of the Canadian Shield geology.

6.4.5 Vulnerability Scoring

For more information on vulnerability scoring see Section 4.6.

Each zone is ‘scored’ to identify its vulnerability to contamination and allow a determination of risk to contamination.

6.4.5.1 Area Vulnerability Factors

For a Type D intake the area vulnerability factors are:

- IPZ 1 10
- IPZ 2 7 – 9

- IPZ 3 1 – 9, but not greater than the score assigned in IPZ 2

IPZ 1 is assigned a vulnerability factor of 10.

Table 6-25 below contains the summary statistics for Deseronto that were reviewed following the methodology provided in Section 4.6 to determine the area vulnerability factors for IPZs 2 and 3.

Table 6-25: Area Vulnerability Considerations at Deseronto Intake IPZ 2

Land/Water	Landcover, Slope, Soil Type	Transport Pathways / Storm Sewers	Combined Vulnerability
60% land	High percentage of urban land use, moderately permeable soils, steep slopes at shore, and low vegetation cover	a number of storm ditches	HIGH
MODERATE	HIGH	HIGH	

IPZ 2 is composed of 40 percent land and 60 percent water. It has a high percentage of urban land use, moderately permeable soils, steep slopes at the shore, and low vegetation cover. The Deseronto urban drainage represents transport pathways. Therefore, an area vulnerability factor of 9 (maximum value) was assigned to the Deseronto IPZ 2 primarily on the basis of transport pathways.

A vulnerability factor of 8 was assigned to IPZ 3a considering the close proximity to the intake, but also in recognition of the low vegetative cover and agricultural land use. The second sub-zone, IPZ 3b is composed primarily of wooded areas and was assigned an area vulnerability factor of 3 based on the land cover and remoteness from the intake. The catchments defining these zones with vulnerability scores are shown on Maps 6.25 and 6.26.

6.4.5.2 Source Vulnerability Factor

Source vulnerability factors for a Type D intake must be in the range of 0.8 to 1.0 and are assigned by the reviewer (in this case Dillon Consulting) by considering the following:

- Depth of the intake from the top of the water surface;
- Distance of the intake from the land; and
- Number of recorded drinking water issues related to the intake.

The intake is in deeper water compared to other Bay of Quinte intakes and is relatively far from shore. The history of the water quality concerns was a primary decision factor for assigning the source vulnerability factor. The Deseronto intake has some historical concerns with water quality based on raw water issues evaluations presented in Section 6.4.6. Some examples are: total phosphorous and related parameters (Microcystin-LR), *E.coli*, Total Coliforms, and Taste and Odour (Geosmin). Therefore, a moderate value of 0.9 was assigned to the source vulnerability factor. Table 6-26 below shows the results of the score assignments.

Table 6-26: Deseronto Vulnerability Scoring

Intake Protection Zone		Area Vulnerability Factor	Source Vulnerability Factor	Vulnerability Score, V
Deseronto	IPZ 1	10	0.9	9.0
	IPZ 2	9	0.9	8.1
	IPZ 3a	8	0.9	7.2
	IPZ 3b	3	0.9	2.7

Town of Deseronto Intake Vulnerability Scoring

- **IPZ 1 = 9**
- **IPZ 2 = 8.1**
- **IPZ 3a = 7.2**
- **IPZ 3b = 2.7**

Note: These scores are used in conjunction with the Prescribed Threats Look Up Tables to determine Significant, Moderate and Low threats.

6.4.5.3 Deseronto Managed Lands, Livestock Density and Impervious Surfaces

The percentage of managed lands, livestock density (Nutrient Units per Acre) and impervious surfaces were calculated for the Deseronto Intake Protection Zones to assist with the determination of Significant threats as per Technical Rule 16 (9),(10) and (11). Maps 6.27, 6.28, 6.29 and 6.30 show the percentages. The impervious surfaces were calculated based on the use of a one square kilometre grid as described in methodology section 4.7.6 of Chapter 4.

6.4.6 Threats to Drinking Water Quality

This section reviews risks to drinking water through two approaches. The first is identifying threats through an issues based approach where contaminants have been chronically detected in the raw water supply and linked to land use activities. The second approach is threats based that considers current and former land use activities in the contributing areas to the intake. Threats are assessed to determine level of risk between Significant, Moderate, or Low.

6.4.6.1 Issues Approach

The raw water quality data at the Deseronto intake was screened using the approach described in Section 4.8 to identify issues in the source water of the Bay of Quinte which may contribute to degraded water quality. Data sources used in the review are presented later in this section.

The 4-step screening process was applied to Deseronto intake raw water data and results are summarized below. A more complete analysis up to screening Step 3 is contained in Appendix F-4 (Dillon 2009b).

Screening Step 1

Eleven parameters listed below passed screening Step 1. All of these parameters had concentrations greater than the Half Maximum Acceptable Concentration. Dissolved Organic Carbon had an average concentration greater than their Maximum Acceptable Concentrations. Trend analysis was done in Step 3 on the remaining nine parameters.

- *E.coli*
- Total Coliform
- Lead
- Aluminum
- Microcystin-LR (an indicator of total phosphorus)
- Dissolved Organic Carbon
- Colour
- Field Temperature
- Iron
- Manganese
- Turbidity

Screening Steps 2 and 3

None of the parameters listed above pass screening Steps 2 and 3. Dissolved Organic Nitrogen, Colour, Field Temperature, Iron, Manganese, and Turbidity are unlikely to have sources stemming from human activities and none of these had a rising trend line. The remaining parameters have potential sources involving human activities but do not pass screening Step 3 because each of their trend lines are in a downward direction that if continued would not exceed the benchmark within 50 years. Staff from the municipality were interviewed by Dillon Consulting Limited and their feedback on parameters listed in Step 1 was incorporated in the evaluation during screening Steps 2 and 3.

Lead and Aluminum

Two parameters, Lead and Aluminum, were screened out following the Step 3 trend analysis which revealed outliers in the data. Once these anomalous values were removed, Lead no longer passed screening Step 1. It is important that valid high concentration values are not discarded as a result of the outlier review process as this could result in sporadic, emerging trends in impairment being missed. In the case of Deseronto Lead samples, this is not a concern as the single Lead reading was removed on the basis of statistical tests that revealed it was not from the same distribution as the other 89 readings (i.e., it had a probability of less than 0.00001 percent of representing the sample data). Hence the outlier data removed was not representative and is considered to be the result of a sampling or other error. Records of all the original data are included in issues documentation for reference in case other high values are observed indicating a potential valid trend in impairment.

A single Aluminum data outlier was removed based on similar considerations as noted above. The anomalously high value removed had a probability of less than 0.00000001 percent of representing the sample data and is likely the result of a sampling or other error. When the outlier was removed, the average concentration was less than half the benchmark value and would not pass screening Step 1. Few individual samples are above the benchmark and the trend is downward.

Microcystin-LR

Microcystin-LR did not pass screening Step 3 as the trend line had a downward direction. However algae toxins such as Microcystin-LR is a concern for the Bay of Quinte based on historic events of Harmful Algae Blooms that may pose a risk to public health. Research is being conducted because there are many unknowns regarding algae toxins compared to algae blooms themselves. This is discussed further in Chapter 8. Any changes to the status on Microcystin-LR or any other parameter as an issue for the Deseronto intake will be included in the next version of the Assessment Report. In the mean time the Town of Greater Napanee (system operator) is encouraged to have the Deseronto system continue participating in the Ontario Drinking Water Surveillance Program. Although it is not mandatory under current provincial regulation it is free of cost to all municipalities and it is valuable in that it collects data on additional parameters that are not regularly monitored for raw water, e.g. Microcystins.

Screening Step 4

No parameters were evaluated for screening Step 4 because none had passed the previous screening step. No water quality issues were identified for the Deseronto intake.

Data Sources

Raw water quality data was obtained from several sources. They are summarized below and were provided by the Ontario Ministry of the Environment and the Town of Deseronto on behalf of the Plant Operators.

1. Ontario Ministry of the Environment (MOE) Drinking Water Information System Data: Quinte Systems (2002-2006)
2. Water Treatment Plant lab results data (2004 to 2006) provided by the municipality data
3. Ontario Ministry of Environment Drinking Water Systems Regulation O. Reg. 170/03 Annual Reports (2004-2008) provided by the Town of Deseronto
4. MOE Drinking Water Surveillance Program: Routine data (1990-1996)
5. MOE Drinking Water Surveillance Program: Special data (1998-2004)
6. MOE Drinking Water Surveillance Program: Water Treatment Plant Data (1988-1992)

6.4.6.2 Threats Approach

Threats to drinking water intakes may be determined from the vulnerability scores for each zone and the circumstances under which an activity would be a drinking water threat. The circumstances under which these threats may be considered as Significant, Moderate or Low are referenced in the Provincial Table of Circumstances (MOE, March, 2018). The interested reader is directed Maps 6.25 and 6.26 to determine the location of the particular vulnerability zone.

Significant Threats

Significant drinking water threats can also be determined based on current land uses (activities) and past land uses (conditions).

Activity Based Threats

Table 6-27 enumerates Significant prescribed drinking water threats through activities inventoried in the Deseronto Intake Protection Zones (1 and 2) using the multi-step Water Quality Risk Assessment approach. A total of four parcels were identified as having such threats.

Condition Based Threats

A closed landfill was identified as being located within the IPZ 3a for the Deseronto drinking water system. Assessment of this site as a condition is outlined in Appendix I and discussed below. The landfill is located along the Napanee River in the Town of Greater Napanee and was operated from the 1950’s to the early 1980’s. A recent assessment of contaminants in the soil and groundwater has been completed as summarised in reports provided by the Municipality (Malroz, 2010, Genivar, 2010). From this information it was indicated that landfill leachate exists in the groundwater and seasonal seeps occur adjacent to the River. A review of the soil and groundwater data indicated 16 parameters exceeding relevant standards for Tables 2 and 4 of the Ministry of the Environment Soil, Ground Water and Sediment Standards (MOE, July 27, 2009). Based on these exceedances the site is considered as a condition.

The risk score for the site was calculated at 72, as listed below, which classifies this site as a Moderate drinking water threat.

Risk Score = 10 X 7.2 = 72

Where:

- The hazard rating was assigned as 10, given the property is in the IPZ 3a associated for the Town of Deseronto Intake; and
- The vulnerability score of the IPZ 3a was assigned as 7.2 as outlined in section 6.4.5.

Identification of Moderate and Low Threats

Moderate and Low risks may also exist in the Intake Protection Zones for Deseronto. Table 6-28 and Table 6-29 have been developed by comparing land uses and the potential for chemical or pathogen hazards to exist on those lands with the vulnerability scores for the IPZs. The tables are to be interpreted as indications of potential for Moderate or Low threats. The risk is calculated as vulnerability x hazard rating. A score above 60 and below 80 is a Moderate risk. A score below 60 is a Low risk.

Table 6-27: Deseronto Significant Threat Enumeration

Zone	Prescribed Drinking Water Threat (PDWT)*	Affected Parcels**	Circumstance Example
Deseronto IPZ 1	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	1	Sewage Treatment Plant storage of sludge/sewage
	The handling and storage of non-agricultural source material	1	Sewage Treatment Plant storage of sludge/sewage
Deseronto IPZ 2	The application of agricultural source material to land.	2	manure spreading on farm fields
	The application of non-agricultural source material to land.	2	biosolid spreading on farm fields
	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. O. Reg. 385/08, s. 3.	1	Livestock grazing
Totals	5 threat types	7 threats on 4 parcels	

Note: * Prescribed Drinking Water Threats, Clean Water Act (2006) – O. Reg. 287/07, 1.1(1)
** "Affected parcels" represents the number of parcels on which a specific activity is being engaged in. Some parcels may have more than one activity on-site.

6.4.7 Uncertainty

The delineation of the Intake Protection Zones and assignment of vulnerability scoring have some degree of associated uncertainty. For example, if scores were assigned with substantial data lacking then a high uncertainty would be applied. Also, if methods used to delineate zones are coarse or modelling was not calibrated or used inadequate data sets then there would be high uncertainty about the results.

Dillon Consulting used a calibrated HEC-geoRAS hydraulic model to aid in the determination of vulnerability zones. Additionally, long periods of wind and flow records were used to create the model. IPZs were established with conservative conditions using either a combination of effects or the worst case condition to establish the outer limits of the IPZs. By a complex qualitative method of assigning scores to all variables influencing vulnerability of the intake, scores were tallied using a repeatable approach. This method was used on several intakes and results were compared for their reasonableness.

Given the precautionary approach taken in the analysis and the good knowledge of the bay’s hydrology and hydraulics, the uncertainty of the IPZs and the vulnerability scores is Low. This is summarized along with the vulnerability scores on Table 6-30 below.

Table 6-28: Deseronto Moderate and Low Chemical Threats

		Intake Protection Zone (IPZ)									
	Prescribed Drinking Water Threats (Ontario Regulation 287/07)	1 Mod	1 Low	2 Mod	2 Low	3 Mod	3 Low	3a Mod	3a Low	3b Mod	3b Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.							✓	✓		
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓		✓			✓	✓		
3	The application of agricultural source material to land.							✓			
4	The storage of agricultural source material.	✓						✓	✓		
5	The management of agricultural source material.										
6	The application of non-agricultural source material to land.										
7	The handling and storage of non-agricultural source material.	✓			✓			✓	✓		
8	The application of commercial fertilizer to land.										
9	The handling and storage of commercial fertilizer.				✓			✓	✓		
10	The application of pesticide to land.	✓		✓				✓	✓		
11	The handling and storage of pesticide.	✓			✓			✓	✓		
12	The application of road salt.	✓		✓				✓	✓		
13	The handling and storage of road salt.							✓	✓		
14	The storage of snow.	✓		✓	✓			✓	✓		
15	The handling and storage of fuel.	✓	✓	✓	✓			✓	✓		
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).										
17	The handling and storage of an organic solvent.	✓	✓	✓	✓			✓	✓		
18	The management of runoff that contains chemicals used in the de-icing of aircraft.							✓	✓		
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.*										
20	An activity that reduces the recharge of an aquifer.*										
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.							✓			

**Water quantity threats will be evaluated as a part of the Water Budget studies

Table 6-29: Deseronto Moderate and Low Pathogen Threats

		Intake Protection Zone (IPZ)					
Prescribed Drinking Water Threats (Ontario Regulation 287/07)		1 Mod	1 Low	2 Mod	2 Low	3 Mod	3 Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.						
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓		✓			
3	The application of agricultural source material to land.						
4	The storage of agricultural source material.						
5	The management of agricultural source material.						
6	The application of non-agricultural source material to land.						
7	The handling and storage of non-agricultural source material.						
8	The application of commercial fertilizer to land.						
9	The handling and storage of commercial fertilizer.						
10	The application of pesticide to land.						
11	The handling and storage of pesticide.						
12	The application of road salt.						
13	The handling and storage of road salt.						
14	The storage of snow.						
15	The handling and storage of fuel.						
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).						
17	The handling and storage of an organic solvent.						
18	The management of runoff that contains chemicals used in the de-icing of aircraft.						
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.*						
20	An activity that reduces the recharge of an aquifer.*						
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.						

**Water quantity threats will be evaluated as a part of the Water Budget studies

Table 6-30: Deseronto Vulnerability Scores and Uncertainty Summary

Zone	Vfz (Area Vulnerability Factor)	Vfs (Source Vulnerability Factor)	V (Vulnerability Score)	Uncertainty	
				Zone Delineation	Vulnerability Score
1	10	0.9	9	Low	Low
2	9	0.9	8.1	Low	Low
3a	8	0.9	7.2	Low	Low
3b	3	0.9	2.7	Low	Low

6.4.8 Data Gaps

The original Deseronto drinking water intake water quality risk assessment identified data gaps. These were addressed through the threats verification work in 2013.

Interviews with property owners and site visits were conducted to confirm the actual number and type of Prescribed Drinking Water Threats.

There was a general lack of information on the presence/absence of contamination associated with conditions. As a result, no conditions-related drinking water threats were identified.

6.5 Napanee Backup Intake Protection Zone

The Town of Greater Napanee Backup Supply municipal water intake is located in the Napanee River, off Dundas Street East, south of the railway bridge. The intake draws water from the head pond of the Springside Dam immediately upstream of Napanee Falls, approximately 35 metres long. The intake is located approximately at the shore on the west bank of the river (Map 2.3). Water is drawn by gravity through an operational gate, from a channel that brings water westward towards the treatment plant.

The A.L. Dafoe Water Purification Plant, located in the Town of Greater Napanee was built in the late 1880s and was recently upgraded in 2004. It is a conventional design, chemically assisted filtration plant that uses a multi-barrier approach to prevent water borne contamination and resulting illness. Under normal operation, raw water is drawn from Lake Ontario, approximately 18 kilometres away from an intake crib located 50 metres offshore. The permitted plant capacity is 2,946 cubic metres per day. If an emergency situation arises where transmission from Lake Ontario is interrupted for an extended period of time (such as a long duration power black-out), the plant can draft water from the Napanee River through this backup intake.

The Napanee River was the water source for the Town of Napanee until 1982. Since that time it has seldom been used and it has not been used in the past decade. Prior to that, from the early 1980s to the mid 1990s, the river was used regularly, at least once per year (personal communication, Meaghan Lewis, Greater Napanee Utilities).

The Town of Napanee is serviced with municipal sewage treatment that discharges downstream of the intake.

Land use around the intake is a mixture of predominantly urban and agricultural. See Map 2.3 for area serviced by this water treatment plant.

6.5.1 Intake Classification

Two options are available for classifying the Napanee backup intake. These are Types C and D. The intake has been classified as a Type C intake by the Quinte Source Protection Authority. Type C intakes are located in a river where the direction of flow and the velocity are not affected by impoundment. Although the Springside Dam acts as an impoundment, the velocity and flow direction are not appreciably affected by the dam. A Type D intake is a ‘catch-all’ designation that assumes water can reach the intake from any direction.

The dam is a 1.8 metre high concrete structure located at the top of a 9 metre water fall. The HEC-2 (United States Army Corps of Engineering, Hydraulic Engineering Centre) hydraulic model of the river developed for the floodplain mapping of the river in the late 1970s was updated by Quinte Conservation staff to run on the HEC-RAS (Hydraulic Engineering Centre River Analysis System) model platform.

Velocity changes at the dam are negligible as can be seen from the results of the HEC-RAS model 5-year flow run below in Table 6-31. Flow is unidirectional at this reach where the river is long, narrow and subcritical.

Table 6-31: Napanee River HEC-RAS model output at Springside Dam

Cross Section (running distance in metres from river mouth)	Channel Velocity (m/s*)	Water Surface Elevation (metres)	Channel Invert (metres above sea level)
4474 (401 bridge)	0.53	86.26	83.20
4175	0.59	86.22	83.20
2050	0.85	85.92	83.60
1224 (hwy 2 bridge)	0.78	85.63	83.84
1185	0.86	85.57	83.84
1099 (Springside dam)	0.60	85.56	83.84

*metres per second

If the intake were classed as Type D, one would draw a circle of 1000 metre radius around the intake for the IPZ 1 that would be trimmed inland 120 metres from shore or to the extent of the regulated area (whichever is greater). Type D presumes water from downstream of the intake can reach the dam. It also allows for a broad upstream impoundment that could provide water to the intake laterally. The Type C intake has a 200 metre radius upstream of the intake and allows a 10 metre extension downstream for the limits of the IPZ 1. Upland limits from the shoreline are identical to the Type D. The Type C presumes water could not reach the intake from downstream, as is the case at the dam. Also, due to the narrow river section, a 200 metre radius provides equal shoreline projection of the IPZ 1. In a setting where the river was wide, a 200 metre radius may not be suitable to capture land uses on both sides. Table 6-32 below summarizes the intake classification justification.

Table 6-32: Classification of Napanee Backup Intake

Classification Consideration – Type Needed to Explain Hydraulic Setting	Type C	Type D	Comment
Velocity Change	Yes	No	Velocity change is minor. If Velocity change were significant it would suggest a Type D
Flow Direction Change	Yes	No	Flow direction does not change in the river.
Best Explains Downstream Contribution	Yes	No	Intake is a gate on the dam. There is no downstream contribution (consistent with Type C setting).
Upstream Extent satisfactory for IPZ 1 extent	Yes	No	The river is narrow and the 200 metre radius circle for IPZ 1 limits would be satisfactory for inclusion of land use on both sides of river to same upstream extent.

6.5.2 Source Water Description

The Napanee River basin drains a mixture of shield-type, forested and agricultural lands with several large water bodies (open lakes and wetlands) in the north and agricultural limestone plain dominated lands in the south. More information is provided on the nature of the Napanee River basin in the Watershed Characterization report (Appendix B-1). The Napanee River drains into the Bay of Quinte in the area of Mohawk Bay.

River flows on average are 8.7 cubic metres per second (cubic metres per second) reaching an average high of 26.2 cubic metres per second in April and an average low of 1.6 cubic metres per second in August[2]. Summer low flows prior to the completion of the reservoirs were about 1.3 cubic metres per second in both August and September.

The river intake formerly provided the Town of Napanee with all their drinking water. Water quality was not satisfactory during periods of low river flow in the summer months when aesthetic issues would arise (Colour, Taste and Odour). In the 1950s and 1960s the Napanee Region Conservation Authority, in cooperation with the province and the municipality, undertook to construct a very large reservoir system in the Depot Lakes to augment flows in the summer in an effort to improve water quality.

[2] Water Survey of Canada website, http://www.wsc.ec.gc.ca/products/main_e.cfm?cname=products_e.cfm

Eventually the town sought and established another supply in Lake Ontario where water conditions were better. Since that time the Napanee River Intake has been maintained as a backup source because of the concern regarding the vulnerability of the un-looped 18 kilometre raw water pipeline running from Lake Ontario.

6.5.3 IPZ 1 Delineation

An area known as IPZ 1 was delineated following the methodology provided in Section 4.6:

IPZ 1 was modified to reflect local hydrodynamic conditions. For example, the part of the river downstream of the dam was excluded from the zone. Also, the portion of the setback that drains downstream of the intake was excluded.

Map 6.31 presents the final shape of IPZ 1 for the Napanee backup intake. The edge of the surface water body has been used to represent the limits of high water.

6.5.4 IPZ 2 Delineation

In consultation with the drinking water plant operators, it was determined that since plant operators are able to respond to a water quality issue at the plant in less than 2 hours, the limits for IPZ 2 should be established with a 2-hour time of response.

The IPZ 2 is delineated following the methodology in Section 4.6.

The 2-hour travel area has been divided into two components based on available data and analysis methods: the instream portion representing the Napanee River, and the up-tributary portions representing small watercourses and drainage features that discharge into the river. Transport pathways and sewersheds also contribute to the IPZ 2 delineation.

Instream Delineation

A U.S. Army Corps of Engineers HEC-RAS hydraulic model was used to establish the Napanee River instream 2-hour travel distance under the two year flow event. A HEC-2 hydraulic model was originally prepared for Quinte Conservation by Crysler and Lathem Ltd., Consulting Engineers and Resource Planners for the Napanee River for flood hazard mapping and water resource management purposes in 1978. It was then converted by conservation staff to the updated HEC-RAS modeling platform in 2006 and provided to Dillon Consulting in electronic format. Dillon Consulting staff converted the model to metric units for use in this study. Model documentation is included in Appendix F-5 (Dillon 2007).

At the upper reaches of the Napanee River, the two year flow rate is approximately 50 cubic metres per second. At its downstream end and within the two hour travel distance zone, the two year flow rate is 68.1 cubic metres per second. The average two year flow rate in the Napanee River upstream of the intake is 59 cubic metres per second. The total distance of this reach is 33 kilometres, with an average instream travel velocity of 0.9 metres per second.

Using descriptive text in the hydraulic model as well as hard copy floodplain mapping provided by Quinte Conservation, cross-section locations were mapped using GIS. The 2-hour instream travel distance is approximately 5 kilometres, extending upstream of Highway 401. The flow velocities throughout this area of interest range from 0.4 to 1.3 metres per second with an average value of 0.8 metres per second.

Up-tributary delineation

Velocity calculations in the Napanee River tributaries were based on the Manning Equation. The channel slope was estimated based on a digital elevation model that describes topographic relief, and the roughness value was estimated based on creek conditions observed during a tributary survey. The hydraulic radius is also estimated based on the tributary survey findings and considers the larger drainage features that were investigated. As these larger features typically have larger hydraulic radius values and correspondingly larger velocities, the instream calculation for smaller features in the subwatershed is considered to be conservative. Based on conducted analysis the average velocity based on 2-year flows for the studied tributaries was estimated as 0.5 metres per second.

Storm sewer Contributions to IPZ 2

Travel velocities within urbanized areas with sewersheds can be relatively high given surface grading and storm sewer conveyance. The Ministry of the Environment minimum design velocity in a typical storm sewer is 0.6 m/s to prevent sedimentation. Therefore the 2-hour storm sewer travel distance is just over 4 kilometres. To identify the area of storm sewer contributions in the town, sewer and sewershed mapping was obtained from TSH Consulting Engineers on behalf of the Town of Napanee and converted to a GIS format. A review of this data indicates that within the town the longest sewershed is approximately 1 kilometre. This suggests that the travel time from the upper urban catchments limits to the river is generally less than 0.5 hours. Based on the conducted analysis all sewersheds draining to the Napanee River upstream of the intake were included into IPZ 2, consistent with the Technical Rules.

Transport Pathway Contributions to IPZ 2

The IPZ 2 was extended to include tile drainages and ditches along Highway 401 up to the watershed divide. Ditched portions of the city within the urban area were also included as their contributions are anticipated to be within the 2-hour time period assuming an average flow velocity of 0.5 metres per second during a 2-year event.

Map 6.32 presents the final shape of IPZ 2 for the Napanee backup intake.

6.5.5 IPZ 3 Delineation

The IPZ 3 for the Town of Napanee Backup System was delineated following the methodology contained in Section 4.6.

The IPZ 3 area includes the Napanee River, contributing tributaries and mapped drainage features, on-line and contiguous lakes and wetland features upstream of the intake, and the greater of a 120 metres setback or the regulated area. Generally, the 120 metre setback governed, but IPZ 3 was extended to include several wetland areas. Tile drainage areas that may contribute water and are interconnected to the surface water system are also included.

The IPZ 3 upstream limits extend to the upper limits of the Napanee River Watershed and exclude lands that flow overland or via tributaries to the Napanee River downstream of the back-up intake.

The IPZ 3 was divided into IPZ 3a and IPZ 3b due to the different potential impacts of these zones on water quality at the intake (Map 6.33). IPZ 3a includes the drainage area immediately upstream of IPZ 2 to the approximate limit of the higher density agricultural land use area within the watershed. Within IPZ 3a, land use is predominantly agricultural while within IPZ 3b, it is mainly wooded. The divide between IPZ 3a and IPZ 3b also corresponds to the approximate limit of the Canadian Shield geology.

The delineation of the sub-watersheds within IPZ 3 is based on the 2007 Provincial Land Cover and information collected during the Quinte Regional Groundwater Study. Specifically, livestock units per area and Precambrian geology mapping were studied.

6.5.6 Vulnerability Scoring

For more information on vulnerability scoring see Section 4.6.
Each zone is ‘scored’ to identify its vulnerability to contamination and allow a determination of risk to contamination.

The vulnerability scores for IPZs are determined by multiplying the 'area vulnerability factor' times the 'source vulnerability factor'.

6.5.6.1 Area Vulnerability Factors

For a Type C intake the area vulnerability factors are:

- IPZ 1 10
- IPZ 2 7 – 9
- IPZ 3 1 – 9, but not greater than the score assigned in IPZ 2

IPZ 1 is assigned a vulnerability factor of 10.

Table 6-33 below contains the summary statistics that were reviewed following the methodology provided in Section 4.6 to determine the area vulnerability factors for IPZs 2 and 3.

Table 6-33: Area Vulnerability Considerations at Napanee Intake

Land/Water	Landcover, Slope, Soil Type	Transport Pathways / Storm Sewers	Combined Vulnerability
97% land	high percentage of urban land use, low permeability and moderate slopes	many storm sewers	HIGH
HIGH	HIGH	HIGH	

IPZ 2 area is composed of 97 percent land and only 3 percent water. It has a high percentage of urban land use, low permeability and moderate slopes. Many storm sewers representing transport pathways are present within IPZ 2. Therefore, an area vulnerability factor of 9 (maximum possible value) was assigned to the Napanee IPZ 2 primarily on the basis of transport pathways.

A vulnerability factor of 8 was assigned to IPZ 3a in considering the close proximity to the intake and moderate runoff potential given the land uses with improved drainage and moderate soil permeability. The second sub-zone, 3b is composed primarily of wooded areas and was assigned an area vulnerability factor of 3 reflecting lower runoff potential given the land uses and soil permeability and remoteness from the intake. The catchments defining these zones with vulnerability scores are shown on Maps 6.34 and 6.35.

6.5.6.2 Source Vulnerability Factor

Source vulnerability factors for a Type C intake must be either 0.9 or 1.0 and is assigned by the reviewer (in this case Dillon Consulting) by considering the following:

- Depth of the intake from the top of the water surface;

- Distance of the intake from the land; and
- Number of recorded drinking water issues related to the intake.

The depth of the intake is estimated to be 2 to 4 metres (river location). The offshore distance is minimal since the intake is located at the shore on the west bank of the river. A low weight was assigned to the intake depth and the offshore distance since the river is well mixed considering its width in comparison with the extent of IPZ 2. The history of the water quality concerns was the primary factor for assigning the source vulnerability factor. The Napanee backup supply intake has only minor historical concerns with water quality (Taste and Odour, Total Phosphorous and Organic Nitrogen) therefore; a value of 0.9 was assigned to each zone. Table 6-34 below shows the results of the score assignments.

Table 6-34: Napanee Vulnerability Scoring

Intake Protection Zone		Area Vulnerability Factor	Source Vulnerability Factor	Vulnerability Score, V
Napanee	IPZ 1	10	0.9	9.0
	IPZ 2	9	0.9	8.1
	IPZ 3a	8	0.9	7.2
	IPZ 3b	3	0.9	2.7

Napanee Intake Vulnerability Score

- **IPZ 1 = 9**
- **IPZ 2 = 8.1**
- **IPZ 3a = 7.2**
- **IPZ 3b = 2.7**

Note: These scores are used in conjunction with the Prescribed Threats Look Up Tables to determine Significant, Moderate and Low threats.

6.5.6.3 Napanee Managed Lands, Livestock Density and Impervious Surfaces

The percentage of managed lands, livestock density (Nutrient Units per Acre) and impervious surfaces were calculated for the Napanee Intake Protection Zones to assist with the determination of Significant threats as per Technical Rule 16 (9),(10) and (11). Maps 6.37, 6.38, 6.39 and 6.40 show the percentages. The impervious surfaces were calculated based on the use of a one square kilometre grid as described in methodology section 4.7.6 of Chapter 4.

6.5.7 Threats to Drinking Water Quality

This section reviews risks to drinking water through two approaches. The first is identifying threats through an issues based approach where contaminants have been chronically detected in the raw water supply and linked to land use activities. The second approach is threats based and looks at current and former land use activities in the contributing areas to the intake. Threats are assessed to determine level of risk as Significant, Moderate, or Low.

6.5.7.1 Issues Approach

The raw water quality data that represent conditions at the Napanee Backup intake was screened using the approach described in Section 4.8 to identify issues in the source water of the Napanee River which may contribute to degraded water quality. No water quality data is available for the Napanee Backup Intake because it is the emergency backup intake for the A. L. Dafoe Water Purification Plant in an event that the main intake located at Adolphus Reach in Lake Ontario fails. However, raw water quality data used to evaluate issues at the Napanee Backup system were collected at two Provincial Water Quality Monitoring Network stations in the Napanee River: one located upstream to the intake near the community of Newburgh and a second station downstream of the Town of Napanee (Map 6.36). The intake is located approximately half way between the two network stations. Data sources used in the review are listed later in this section. The Cataraqui Region Conservation Authority is evaluating the main intake in Lake Ontario as it is located in their Drinking Water Source Protection Area.

The 4-step screening process was applied to Napanee intake raw water data outlined in Section 4.8.1. The results are summarized below. A more complete analysis (up to screening Step 3) is contained in a report prepared by Dillon Consulting Limited found in the Appendix F-5 (Dillon 2009c).

Screening Step 1

Seven parameters listed below pass screening Step 1. *E.coli,* Total Coliform, Dissolved Organic Nitrogen, and Aluminum have average concentrations greater than the benchmark value at one of the two monitoring stations. The average *E.coli* count was above the benchmark value only at the upstream monitoring station (Newburgh) and not at the Napanee monitoring station. Average Aluminum concentration was greater than the benchmark value only at the downstream monitoring station in Napanee. The remaining five parameters did not have average concentrations above their benchmark values however they did have observations above their Half Maximum Acceptable Concentrations (half benchmark) thus passing screening Step 1.

- *E.coli*
- Aluminum

- Total Coliform
- Cadmium
- Lead
- Dissolved Organic Carbon
- Field Temperature

Screening Steps 2 and 3

A trend analysis was completed on the above parameters and a determination of origin (anthropogenic or natural) was made. Only three parameters pass screening Steps 2 and 3:

- *E.coli*
- Total Coliforms
- Aluminum

Aluminum

While Aluminum passes each screening step because of a few high readings, concentrations have been trending downward since the early 1970’s. Since the mid-1990’s the average concentration upstream of Napanee (Newburgh station) has been below half the benchmark value and trending downward, but occasionally concentrations above the benchmark were recorded (see Figure 6-3). Downstream of Napanee, average concentrations are above the benchmark and trending lower but with more frequent exceedances of the benchmark. While recent conditions do not represent a health risk given treatment reductions in concentrations since Aluminum is an operational parameter, the increase through Napanee could indicate the need to identify local sources through further study.

Screening Step 4

Even though three parameters pass screening Step 3, no parameters pass screening Step 4 based on professional judgement and the Threats Approach results.

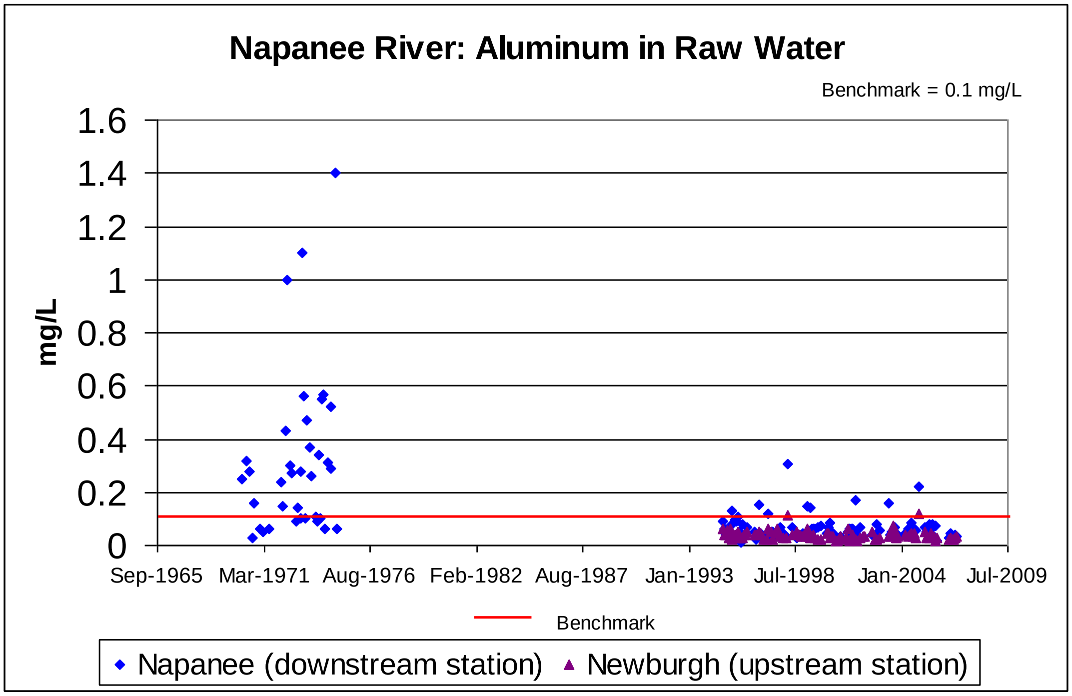


Figure 6-3: Concentrations of Aluminum in Raw Water Samples

The Threats Approach reviewed in the following section captures Significant threats associated with *E.coli and* Total Coliform. The application, management or handling of Agricultural Source Material (ASM) as a Significant threat in IPZ 2 associated with *E.coli* and Total Coliform will be managed through source protection planning mechanisms.

The Town of Greater Napanee confirmed that no issues in raw water exist. Raw water from the Napanee Backup in the Napanee River is not currently used for the Town of Greater Napanee. However, based on treated water results and the opinion of the operator the water treatment plant is capable of treating raw water parameters *E.coli,* Total Coliform and Aluminum should the backup intake supply be put into operation.

Data Sources

In the mid 1980's the Town of Napanee moved their drinking water supply from the intake on the Napanee River to Lake Ontario. The Napanee River intake now operates under emergency scenarios only and recent water quality data is not available from the plant. Therefore, raw water quality data used to characterize the river was taken from two Provincial Water Quality Monitoring Network (PWQMN) stations. Monitoring data spanned 1969 to 2006, and the stations are:

- County Rd 1, downstream of Newburgh (Station ID# 17003500202), located upstream of the river intake
- River Rd at County Rd 9, downstream of Napanee (Station ID# 17003500102), located downstream of the river intake

6.5.7.2 Threats Approach

Threats to drinking water intakes may be determined from the vulnerability scores for each zone and the circumstances under which an activity would be a drinking water threat. The circumstances under which these threats may be considered as Significant, Moderate or Low are referenced in the Provincial Table of Circumstances (MOE, March, 2018). The interested reader is directed Maps 6-34 and 6-35 to determine the location of the particular vulnerability zone.

Significant Threats

Significant drinking water threats can also be determined based on current land uses (activities) and past land uses (conditions).

Activity Based Threats

Table 6-35 enumerates Significant prescribed drinking water threats through activities inventoried in the Napanee Back-up Intake Protection Zones (1 and 2) using the multi-step Water Quality Risk Assessment approach. No significant threats were identified in IPZ 1 and 14 parcels were found to have threats in IPZ 2.

Table 6-35: Napanee Significant Threat Enumeration

Zone	Threat *	Number of Affected Parcels**	Circumstance Example
Napanee IPZ 1	No Threats	0	
Napanee IPZ 2	Application Of Agricultural Source Material (ASM) To Land	4	Manure spreading
	Application Of Non-Agricultural Source Material (NASM) To Land (Including Treated Septage)	2	Biosolid spreading
	The application of pesticide to land.	5	Application of pesticide on crops
	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. O. Reg. 385/08, s. 3.	6	Livestock grazing
Totals	4 Threat Types	17 threats on 14 parcels	

Note: * Prescribed Drinking Water Threats, Clean Water Act (2006) – O. Reg. 287/07, 1.1(1)
** "Affected parcels" represents the number of parcels on which a specific activity is being engaged in. Some parcels may have more than one activity on-site.

Property owners were contacted by telephone to discuss suspected activities that could be drinking water threats. Results from the phone survey were used to help enumerate the potential threats.

Condition Based Threats

There is no evidence of the presence of any condition based threats.

Identification of Moderate and Low Threats

Moderate and Low risks may also exist in the Intake Protection Zones for Napanee. Table 6-36 and Table 6-37 have been developed by comparing land uses and the potential for chemical or pathogen hazards to exist on those lands with the vulnerability scores for the zones. The tables are to be interpreted as indications of potential for Moderate or Low threats. The risk is calculated as vulnerability x hazard rating. A score above 60 and below 80 is a Moderate risk. A score between 40 and 60 is a Low risk.

6.5.8 Uncertainty

The delineation of the Intake Protection Zones and assignment of vulnerability scoring have some degree of associated uncertainty. For example, if scores were assigned with substantial data lacking then a high uncertainty would be applied. Also, if methods used to delineate zones are coarse or modelling was not calibrated or used inadequate data sets, then there would be high uncertainty about the results.

Table 6-36: Napanee Moderate and Low Chemical Threats

		Intake Protection Zone (IPZ)									
Prescribed Drinking Water Threats (Ontario Regulation 287/07)		1 Mod	1 Low	2 Mod	2 Low	3 Mod	3 Low	3a Mod	3a Low	3b Mod	3b Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.			✓				✓	✓		
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓	✓	✓			✓	✓		
3	The application of agricultural source material to land.			✓				✓	✓		
4	The storage of agricultural source material.			✓	✓			✓			
5	The management of agricultural source material.										
6	The application of non-agricultural source material to land.			✓				✓			
7	The handling and storage of non-agricultural source material.		✓	✓	✓			✓	✓		
8	The application of commercial fertilizer to land.			✓				✓			
9	The handling and storage of commercial fertilizer.			✓	✓			✓	✓		
10	The application of pesticide to land.	✓		✓	✓			✓	✓		
11	The handling and storage of pesticide.	✓	✓	✓	✓			✓	✓		
12	The application of road salt.	✓							✓		
13	The handling and storage of road salt.							✓	✓		
14	The storage of snow.	✓	✓	✓	✓			✓	✓		
15	The handling and storage of fuel.	✓	✓	✓	✓			✓	✓		
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).										
17	The handling and storage of an organic solvent.	✓	✓	✓	✓			✓	✓		
18	The management of runoff that contains chemicals used in the de-icing of aircraft.										
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.							✓			

Table 6-37: Napanee Moderate and Low Pathogen Threats

		Intake Protection Zone (IPZ)					
Prescribed Drinking Water Threats (Ontario Regulation 287/07)		1 Mod	1 Low	2 Mod	2 Low	3 Mod	3 Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.						
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓		✓	✓		
3	The application of agricultural source material to land.						
4	The storage of agricultural source material.			✓			
5	The management of agricultural source material.						
6	The application of non-agricultural source material to land.				✓		
7	The handling and storage of non-agricultural source material.				✓		
8	The application of commercial fertilizer to land.						
9	The handling and storage of commercial fertilizer.						
10	The application of pesticide to land.						
11	The handling and storage of pesticide.						
12	The application of road salt.						
13	The handling and storage of road salt.						
14	The storage of snow.						
15	The handling and storage of fuel.						
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs).						
17	The handling and storage of an organic solvent.						
18	The management of runoff that contains chemicals used in the de-icing of aircraft.						
19	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.						

Dillon Consulting used a calibrated HEC-RAS hydraulic model to aid in the determination of vulnerability IPZs. Intake Protection Zones were established with conservative conditions using either a combination of effects or the worst case condition to establish the outer bounds of the IPZs. By a complex qualitative method of assigning scores to all variables influencing vulnerability of the intake, scores were tallied using a repeatable approach. This method was used on several intakes and results were compared for their reasonableness.

Given the precautionary approach taken in the analysis and the detailed data of the Napanee River's hydrology and hydraulics, the uncertainty of the IPZ s and the vulnerability scores is Low**.** This is summarized along with the vulnerability scores on Table 6-38 below.

Table 6-38: Napanee Vulnerability Scores and Uncertainty Summary

Zone	Vfz (Area Vulnerability Factor)	Vfs (Source Vulnerability Factor)	V (Vulnerability Score)	Uncertainty	
				Zone Delineation	Vulnerability Score
1	10	0.9	9	Low	Low
2	9	0.9	8.1	Low	Low
3a	8	0.9	7.2	Low	Low
3b	3	0.9	2.7	Low	Low

6.5.9 Data Gaps

No significant data gaps were encountered during the identification of Significant drinking water threats, considering that the enumeration approach used was conservative (approach is considered to overestimate number of threats compared to actual conditions). For example, all farms were considered to apply Agricultural Source Material and Non Agricultural Source Material. Interviews with property owners were conducted to confirm the actual number and type of Prescribed Drinking Water Threats.

There was a general lack of information on the presence/absence of contamination associated with conditions. As a result, no conditions-related drinking water threats were identified.

6.6 Ameliasburgh Intake Protection Zone

The Hamlet of Ameliasburgh is located on the north shore of Roblin Lake in the Ameliasburgh Ward of the County of Prince Edward. Within this small community is the Ameliasburgh Hamlet Water Treatment Plant. The plant is situated on the northwest shore of Roblin Lake and services 75 residences. The plant's intake is 115 meters long, 200 millimetres in diameter, and connects to a 1070 millimetre diameter prefabricated intake structure in Roblin Lake. The exact depth of the intake is unknown to municipal staff. Using the length of pipe and bathymetry information for Roblin Lake that was collected during the Tier 2 Water Budget exercise we were able to infer a depth of approximately 3 metres for the intake. Within the plant there are two treatment trains that operate in parallel, each having two filters in series. A coagulant feed system supplies alum ahead of the filters and chlorination is supplied to the treatment process.

Although the treatment plant services 75 residences in Ameliasburgh, this is only half of the Roblin Lake community. There are 82 additional parcels around the lake that are unserviced, obtaining their water supply from either a private well or pumping water directly from the lake.

Ameliasburgh has no sewage treatment facility and all residences are serviced by private sewage systems of uncertain effectiveness.

Land use near the intake is mostly agricultural and residential with some institutional. See Map 2.3 for area serviced by this water treatment plant.

The plant was last updated in 2005 and has the capacity to treat 360 cubic meters per day.

The Ameliasburgh intake is classified as a Type D (inland lake) intake.

6.6.1 Source Water Description

Roblin Lake is an inland lake that has a surface area of one square kilometre. The total contributing area of the lake is approximately only four square kilometres. A variety of land uses is supported on its shores including permanent and seasonal residences, a municipal park and beach, a former Salvation Army camp, and agricultural land.

The outflow of Roblin Lake is controlled by a small dam, which is operated by Quinte Conservation, located on the north side near the former Salvation Army Church camp. Water drains over ground through a swale and then disappears underground to flow under County Road 19 and into the Sawguin Creek system.

Bathymetry mapping (Appendix C-3) was completed for the lake as part of source protection water budget work. From this mapping it is known that the lake is very shallow (less than 4 metres) at its east end and becomes deeper (12 – 15 metres) near the west end. There is a sharp underwater rock ledge very near the western shore where water depth increases from about 4 metres to over 12 metres. It is presumed the intake is located in the vicinity of the rock ledge in deeper water.

6.6.2 IPZ 1 Delineation

An area known as Intake Protection Zone 1 was delineated following the method discussed in Section 4.6.

The IPZ 1 may be modified to reflect the local hydrodynamic conditions. For example, the IPZ 1 circle extends past the natural drainage divide for the Lake and areas not draining to the lake were trimmed out. See Map 6.41.

6.6.3 IPZ 2 Delineation

The County of Prince Edward staff estimate they could respond to a spill (or other event that may degrade the quality of water) within a minimum of two hours. Therefore the limits for IPZ 2 have been established with a 2-hour time of response.

The IPZ 2 was delineated following the methodology in Section 4.6. The contributing area to IPZ 2 was determined by considering contributions from flows, wind and transport pathways. There are no sewersheds or tile drains in Ameliasburgh.

Since the lake storage is quite small and shallow (on the east half), a simplified approach was used to establish boundaries of IPZ 2. This considered the small storage and dilution potential as well as the shallow depths. It also considered the limits of the IPZ 1 which extends over 75 percent of the lake surface. Therefore the IPZ 2 boundaries were drawn to include the whole lake. Where the boundary abutted land, a 120 metre setback from the shoreline was created.

The boundary was extended inland in two instances; the first, at the south-eastern shoreline to include the area within the Conservation Authority Regulation Limit and the second, at Coleman Street to include transport pathways (improved drainage and ditches). The completed IPZ 2 boundary is also presented on Map 6.41.

6.6.4 IPZ 3 Delineation

IPZ 3 would include the tributaries for the entire contributing area to the lake. Since the lake is situated in an upland area with no tributaries draining into the lake and since the IPZ 2 boundaries extend to the entire lake and include the only transport pathway, no IPZ 3 can be delineated past the IPZ 2 boundary. Therefore, no IPZ 3 exists for the Ameliasburgh intake.

6.6.5 Vulnerability Scoring

As discussed in the introduction, each IPZ is 'scored' to identify its vulnerability to contamination and allow a determination of risk to contamination. The vulnerability score is a product of the area and source vulnerability factors (refer to the methodology Section 4.6 for general discussion on how vulnerability scores are determined).

6.6.5.1 Area Vulnerability Factor

For a Type D intake the area vulnerability factors are:

- IPZ 1 10
- IPZ 2 7 – 9
- IPZ 3 1 – 9, but not greater than the score assigned in IPZ 2

IPZ 1 has an area vulnerability factor of 10.

IPZ 2 is composed of 46 percent land. It has moderate slopes and moderate soil permeability. There are no storm sewers that outlet into the area of the intake and all flow is by overland drainage. Table 6-39 contains the area statistics that were developed to assist in the selection of the area vulnerability factor for IPZ 2. A factor of 8 was selected primarily on the basis of the moderate amount of land area within the IPZ 2. The moderate soil type and land slope support this selection.

Table 6-39: Ameliasburgh Intake IPZ 2 Statistics for Area Vulnerability Factor

Intake	% Land	Land Cover	Permeability	Soil Type	Slope of Setback (%)
IPZ 2	46	54%water, 0.1% settlement, 11.3 % forest, 3.9%wetland, 5.7% built up pervious, 25% transportation	0.2 (medium)	Farmington loam	2.5

6.6.5.2 Source Vulnerability Factor

Source vulnerability factors for a Type D intake must be in the range of 0.8 to 1.0 and are assigned by considering the following:

- Depth of the intake from the top of the water surface;
- Distance of the intake from the land; and
- Number of recorded drinking water issues related to the intake.

The depth of the intake is uncertain, the intake is only 50 metres from shore, and some issues were reported at the water treatment plant. Because of these factors the highest source vulnerability was assigned to the intake. Therefore a source vulnerability score of 1.0 is assigned.

Table 6-40 below shows the results of the score assignments with the locations illustrated by Map 6.42.

Table 6-40: Ameliasburgh Vulnerability Scores

Intake Protection Zone		Area Vulnerability Factor	Source Vulnerability Factor	Vulnerability Score, V
Ameliasburgh	IPZ 1	10	1.0	10.0
	IPZ 2	8	1.0	8.0

Ameliasburgh Intake Vulnerability Scoring

- **IPZ 1 = 10**
- **IPZ 2 = 8**

6.6.5.3 Ameliasburgh Managed Lands, Livestock Density and Impervious Surfaces

The percentage of managed lands, livestock density (Nutrient Units per Acre) and impervious surfaces were calculated for the Ameliasburgh Intake Protection Zones to assist with the determination of Significant threats as per Technical Rule 16 (9),(10) and (11). Map 6.43 shows the percentages. The impervious surfaces were calculated based on the use of a one square kilometre grid as described in methodology section 4.7.6 of Chapter 4.

6.6.6 Threats to Drinking Water Quality

This section reviews risks to drinking water through two approaches. The first is identifying threats through an issues based approach where contaminants have been chronically detected in the raw water supply and linked to land use activities. The second approach is threats based and looks at current and former land use activities in the contributing areas to the intake. Threats are assessed to determine level of risk as Significant, Moderate, or Low.

6.6.6.1 Issues Approach

The raw water quality data at the Ameliasburgh intake was screened using the approach described in Section 4.8 to identify issues in the source water of Roblin Lake which may contribute to degraded water quality. Data sources used in the review are presented later in this section.

The 4-step screening process was applied to the Ameliasburgh intake raw water data outlined in Section 4.8.1. The results are summarized below. A more complete analysis is contained in an issues summary table in Appendix F-6.

Screening Step 1

The following parameters had individual results that exceeded the Half Maximum Acceptable Concentration. They were analyzed for trending in Step 3. None of the parameters had an average greater than the Maximum Acceptable Concentration, the benchmark.

- *E.coli*
- pH
- Field Temperature
- Turbidity
- Colour
- Aluminum
- Benzo(a)pyrene
- Aldicarb
- Terbufos
- Sodium
- Alkalinity
- Dissolved Organic Carbon
- Hardness

Screening Steps 2 and 3

E.coli is the only parameter that passed screening Steps 2 (human induced) and 3 (trend analysis) that can potentially come from human activities, such as septic and sewage systems.

The *E.coli* parameter represents the generic *E.coli* bacteria commonly found in the lower intestine of warm-blooded organisms and naturally found in the gut and always detected in surface waters. Most *E.coli* strands are harmless but some can cause serious poisoning in humans. Average *E.coli* samples taken from 2002 to 2009 were 3 counts/100 millilitres with 40 samples out 318 (13 percent) greater than the Half Maximum Acceptable Concentration (half benchmark) and 6 percent greater than the benchmark. It has a trend line with an upward direction that if continued the average could exceed the benchmark within 50 years (Figure 6-4).

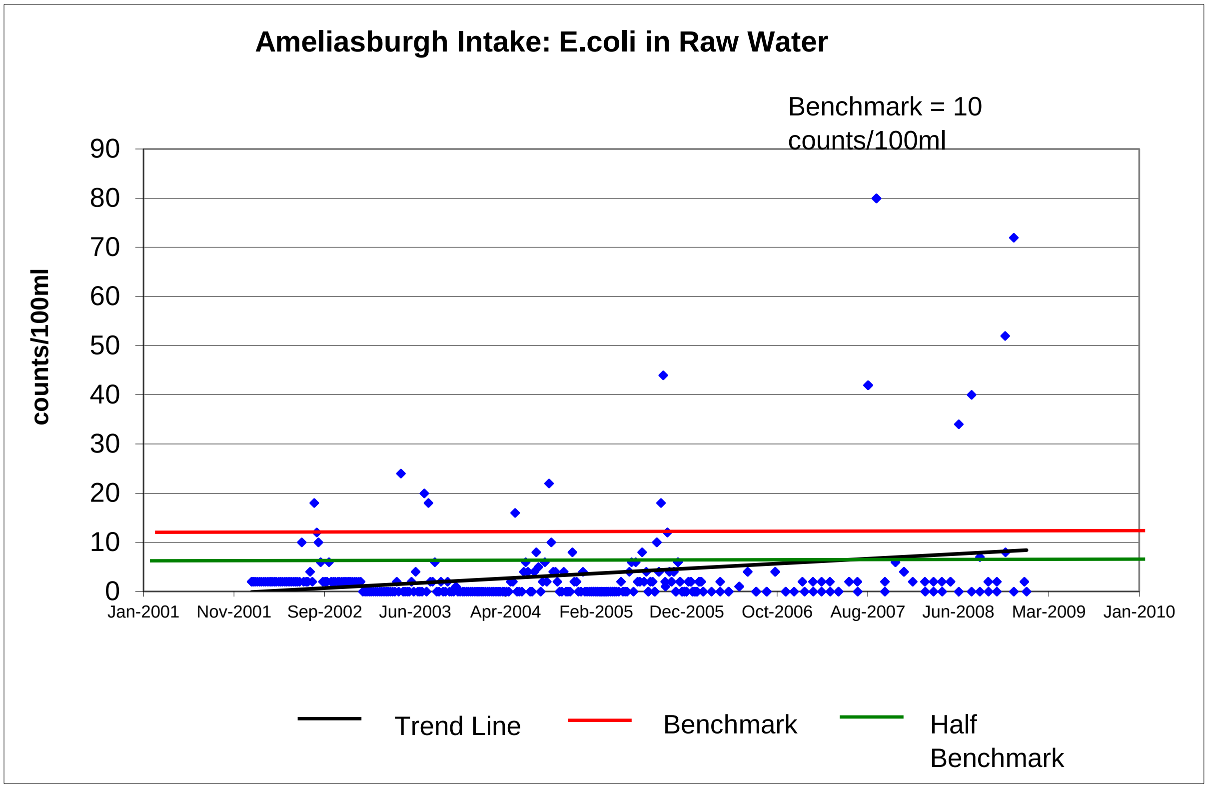


Figure 6-4: Time series plot for *E.coli* in raw water at Ameliasburgh Intake.

Field Temperature, Turbidity, pH, Alkalinity, Aluminum, Colour, and Hardness results were compared to the Ontario Drinking Water Objectives for aesthetics for the proper operation of treatment plants and are considered natural levels for Roblin Lake. Generally Dissolved Organic Carbon is naturally occurring in all lake environments but there was not enough data on raw water from the intake to perform trend analysis.

There are no data available for Aldicarb and Terbufos concentrations in treated raw water. Concentrations of these two parameters in treated water never exceeded their Ontario Drinking Water Standards and had declining trend lines, therefore no reason to believe that they pose a problem.

Sodium and Benzo(a)pyrene only had treated water samples available for analysis but there were not have enough samples to perform a trend analysis. Most concentrations were below the half benchmark and neither parameter had concentrations greater than the Maximum Acceptable Concentration, the benchmark of the Ontario Drinking Water Standards.

Screening Step 4

All of the parameters that pass Steps 2 and 3 are treatable at the treatment plant. No parameter would be considered an issue. Most *E.coli* sample counts are relatively low and the plant is fully capable of treating for bacterial parameters. In addition, land uses surrounding the lake area, consistent with a threat of *E.coli* release, fall within the protection zones in the threats approach (discussed later).

Data Sources

Raw water quality data was obtained from several sources. They are summarized below and were gathered by Quinte Conservation from the Ontario Ministry of the Environment and the Water and Waste Water Services at the Corporation of the County of Prince Edward:

- Ontario Ministry of Environment (MOE) Drinking Water Information Systems data, Quinte Systems (2003-2009)
- Water Treatment Plant lab results data provided by the municipality (2002-2008)
- MOE Drinking Water Annual Compliance Inspection Reports (2004-2008)

6.6.6.2 Threats Approach

Threats to drinking water intakes may be determined from the vulnerability scores for each zone and the circumstances under which an activity would be a drinking water threat. The circumstances under which these threats may be considered as Significant, Moderate or Low are referenced in the Provincial Table of Circumstances (MOE, March, 20108). Map 6-42 shows the location of the Ameliasburgh vulnerability zones.

Significant Threats

Significant drinking water threats can also be determined based on current land uses (activities) and past land uses (conditions).

Activity Based Threats

Table 6-41 enumerates Significant prescribed drinking water threats through activities inventoried in the Ameliasburgh IPZ s (1 and 2) using the multi-step Water Quality Risk Assessment approach. There are 56 parcels containing 64 Significant threats.

Table 6-41: Ameliasburgh Significant Threat Enumeration

Zone	Threat*	Number of Affected Parcels**	Circumstance Example
IPZ 1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act	1	Waste Oil
	Application of Agricultural Source Material	1	Manure spreading
	Application of Commercial Fertilizer	1	application of commercial fertilizer on farm fields
	Septic Systems	55	Septic systems regulated under Building Code
	Pesticides	1	Application of pesticides on farm fields
	Livestock Grazing	1	Pasturing/grazing of Livestock
IPZ 2	Application of Agricultural Source Material	1	Manure spreading
	Livestock Grazing	1	Pasturing/ Grazing of Livestock
Totals	5 Threat Types	64 threats on 56 parcels	

Note: * Prescribed Drinking Water Threats, *Clean Water Act* (2006) – O. Reg. 287/07, 1.1(1)
** “Affected parcels” represents the number of parcels on which a specific activity is being engaged in. Some parcels may have more than one threat activity on-site.

Condition Based Threats

There is no evidence of the presence of any condition based threats.

Identification of Moderate and Low Threats

Moderate and Low risks may also exist in the Intake Protection Zones for Roblin Lake. Table 6-42 and Table 6-43 below have been developed by comparing land uses and the potential for chemical or pathogen hazards to exist on those lands with the vulnerability scores for the IPZ s. The tables are to be interpreted as indications of the potential for Moderate or Low threats. The risk is calculated as

Table 6-42: Ameliasburgh Moderate and Low Chemical Threats

		Intake Protection Zone (IPZ)									
	Prescribed Drinking Water Threats (Ontario Regulation 287/07)	1 Mod	1 Low	2 Mod	2 Low	3 Mod	3 Low	3a Mod	3a Low	3b Mod	3b Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.										
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	✓	✓		✓						
3	The application of agricultural source material to land.			✓							
4	The storage of agricultural source material.	✓		✓	✓						
5	The management of agricultural source material.										
6	The application of non-agricultural source material to land.			✓							
7	The handling and storage of non-agricultural source material.	✓	✓	✓	✓						
8	The application of commercial fertilizer to land.			✓							
9	The handling and storage of commercial fertilizer.	✓	✓	✓	✓						
10	The application of pesticide to land.	✓		✓	✓						
11	The handling and storage of pesticide.	✓	✓								
12	The application of road salt.	✓		✓							
13	The handling and storage of road salt.	✓									
14	The storage of snow.	✓	✓								
15	The handling and storage of fuel.	✓	✓	✓	✓						
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs)*.										
17	The handling and storage of an organic solvent.	✓	✓	✓	✓						
18	The management of runoff that contains chemicals used in the de-icing of aircraft.										
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.**										
20	An activity that reduces the recharge of an aquifer.**										
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.			✓							

**Water quantity threats will be evaluated as a part of the Water Budget studies

Table 6-43: Ameliasburgh Moderate and Low Pathogen Threats

		Intake Protection Zone (IPZ)					
	Prescribed Drinking Water Threats (Ontario Regulation 287/07)	1 Mod	1 Low	2 Mod	2 Low	3 Mod	3 Low
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the *Environmental Protection Act*.						
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.						
3	The application of agricultural source material to land.						
4	The storage of agricultural source material.		✓				
5	The management of agricultural source material.						
6	The application of non-agricultural source material to land.	✓					
7	The handling and storage of non-agricultural source material.		✓				
8	The application of commercial fertilizer to land.						
9	The handling and storage of commercial fertilizer.						
10	The application of pesticide to land.						
11	The handling and storage of pesticide.						
12	The application of road salt.						
13	The handling and storage of road salt.						
14	The storage of snow.						
15	The handling and storage of fuel.						
16	The handling and storage of a dense non-aqueous phase liquid (DNAPLs)*.						
17	The handling and storage of an organic solvent.						
18	The management of runoff that contains chemicals used in the de-icing of aircraft.						
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.**						
20	An activity that reduces the recharge of an aquifer.**						
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard.						

**Water quantity threats will be evaluated as a part of the Water Budget studies

vulnerability x hazard rating. A score above 60 and below 80 is a Moderate risk. A score between 40 and 60 is a Low risk.

6.6.7 Uncertainty

The delineation of the Intake Protection Zones and assignment of vulnerability scoring have some degree of associated uncertainty. For example, if scores were assigned with substantial data lacking then a high uncertainty would be applied. Also, if methods used to delineate zones are coarse or modelling was not calibrated or used inadequate data sets then there would be high uncertainty about the results.

Quinte Conservation staff performed the delineations on the intake without the use of modelling. While reference was made to the bathymetry of Roblin Lake and field surveys were performed to gain an understanding of the dynamics of the lake, a High uncertainty exists in IPZ 2 delineation.

The Committee determined that based on the small size of the lake and absence of drainage features into the lake the Area Vulnerability Factor and Source Vulnerability Factor would not change regardless of the size of the IPZ 2. Therefore the values assigned to the vulnerability scores are more conservative and a Low uncertainty exists.

This is summarized along with the vulnerability scores on Table 6-44 below.

Table 6-44: Ameliasburgh Vulnerability Scores and Uncertainty Summary

Zone	Vfz (Area Vulnerability Factor)	Vfs (Source Vulnerability Factor)	V (Vulnerability Score)	Uncertainty	
				Zone Delineation	Vulnerability Score
1	10	1	10	Low	Low
2	8	1	8	High	Low

6.6.8 Data Gaps

Interviews with property owners and site visits were conducted to confirm the actual number and type of Prescribed Drinking Water Threats.

There was a general lack of information on the presence/absence of contamination associated with conditions. As a result, no conditions-related drinking water threats were identified.

6.7 Wellington Intake Protection Zone

The Village of Wellington is located in Prince Edward County along the north shore of Lake Ontario and is considered a Type A intake (drawing supply from a Great Lake). The intake was included as part of the Lake Ontario Collaborative study (see Stantec 2008 in Appendix F-7).

The water treatment plant is a conventional facility with chemically assisted filtration that uses a multi-barrier approach to preventing water borne illness. Under normal operation, raw water is drawn from Lake Ontario from an intake crib located about 1,500 metres offshore in 8.5 metres depth of water. The permitted plant capacity is 2,488 cubic metres per day servicing 1,700 people in the Village of Wellington. Disinfection of the treated water is performed by addition of sodium hypochloride.

The plant is operated by Prince Edward County municipal staff and was recently upgraded in 2005.

The Village is also serviced with municipal sewage which is discharged near the intake.

Land use around the intake is a mixture of predominantly agricultural, residential and some commercial. See Map 2.3 for area serviced by this water treatment plant.

6.7.1 Source Water Description

Lake Ontario is a good source of drinking water having well regulated supply and generally good quality. The water surface elevation fluctuates from an average high of 75.04 masl (metres above sea level) in June to a low of 74.53 masl in December. The lake bottom is gently sloping along the shore in the vicinity of the intake dropping 10 metres vertical over 1,000 metres horizontal. East of the intake is a barrier beach separating Lake Ontario from West Lake.

6.7.2 IPZ 1 Delineation

An area known as IPZ 1, as illustrated by Map 6.44, was delineated following the methodology contained in Section 4.6. The intake is located more than 1 kilometre offshore and therefore the IPZ 1 is a complete circle of radius 1 kilometre.

6.7.3 IPZ 2 Delineation

In consultation with the drinking water plant operators, it was determined that since plant operators are able to respond to a water quality issue at the plant in less than 2 hours, the limits for IPZ 2 should be established with a 2-hour time of response.

The IPZ 2 was delineated following the methodology discussed in Section 4.6.

The contributing area to IPZ 2 was determined by considering contributions from flows, wind and transport pathways. Some assumptions were made in developing the IPZ 2 for Wellington. These assumptions are discussed more fully in Appendix F-7 (Stantec 2008) and in the data gaps Section 8.

Flow and Wind driven transport

A 2 dimensional model was created for Lake Ontario in the vicinity of the intake based on 2D-ADCIRC modelling software (Stantec 2008, Appendix F-7) to provide a conservative in-water time of travel for development of the IPZ 2. The model used 100-yr 2-hour wind speeds to develop 100-yr currents for the delineations.

The approximate extents of the 2-hour 100 year return period zones are:

- Southwest 8000 m
- Southeast 5000 m
- Offshore 4000 m

Stream contributions were considered simply using an estimation of velocity during a 2-yr runoff event so that the 2-hour times of travel could be calculated to the extent of the creek contribution. Two creeks are included in IPZ 2.

Storm sewer Contributions

Sewersheds within Wellington discharge in the IPZ 2. Times of travel within sewers are rapid. Since these are small by contrast to the extent of the IPZ 2 and since they discharge very near the centre of the zone, the sewersheds were included within the IPZ 2.

Transport Pathways

Other pathways can include tile drainage and ditches. The urban drainage has some ditched systems leading to areas with storm sewers. The ditched portions are included as transport pathways. No tile drains were identified in this study.

Map 6.44 presents the final shape of IPZ 2 for the Wellington intake.

6.7.4 IPZ 3 Delineation

The IPZ 3 was delineated by modelling of the entire Lake Ontario as part of the collaborative study. For a type A intake, an IPZ 3 can only be developed by modelling.

Two potential events were considered. The first was a Tritium spill from Pickering and Darlington nuclear generating stations modelled after an actual spill which occurred in 1992. Tritium is present in cooling water that contains two additional neutrons in each hydrogen atom. The second spill event was a sewage spill from the Wellington sewage treatment plant. A more complete accounting of the model construction and event simulations is provided in the Appendix F-7 but a brief summary is provided below.

Tritium Spill

The 1992 spill event – 2,900 kg at 7.9 x 10^{11} Bq/l (a measure of radioactivity) in 6 hours - was released during a period of easterly currents, in this case on May 17 at 1200 hrs. The temperature was set to 35 °C as it was released into the cooling water channel of the plant, assumed to be running at high power generation rates due to summer demand. The lake was still cold, between 4 and 8 °C. Traces of the spill were detected in Hamilton Harbour several days later. A MIKE 3 mixing model was developed to replicate this event and extended to determine the potential impacts further east at Wellington. The result was that the peak would take about 43 days to reach Wellington and a negligible impact can be expected. Therefore it was determined that no Significant threat exists.

Sewage Spill

A continuous spill was modelled at a rate of 1,500 cubic metres per day with an *E.coli* concentration of 5,000,000 counts/100 millilitres (raw sewage) and ammonia of 15 milligrams/Litre (raw sewage). The sewage temperature was set at 20°C. Both parameters were modelled as conservative substances - no decay. The peak *E.coli* level at the intake is about 1,000 counts/100 millilitres while the ammonia peak is at 0.003 milligrams/Litre - both parameters have 5000:1 dilution. The peak events coincide with currents in the 80°N direction.

A spill of sewage has the potential to develop a concentration of 0.003 milligrams/Litre of ammonia at the intake. This is not a concern. It would also have a peak *E.coli* level of 1,000 counts/ 100 millilitres. Treatment at the plant exists to remove *E.coli*. The question of establishing a significant risk to a sewage release of this concentration is not clearly answered. Operationally, the water treatment plant has a guideline of 200 counts of *E.coli* / 100 millilitres. This would exceed that guideline. The Director of Water and Waste Water Services was asked if the treatment system is capable of treating the 1,000 counts. The

Director reported that a spill from the sewage treatment plant would be immediately known to the water treatment plant operators as they are both operated by the same personnel and the plants are located side by side. The water treatment system is quite robust and if additional disinfection were needed there are several points where pre-chlorination can be added to respond to higher expected counts of *E.coli*. Furthermore, post-chlorination can also be increased to provide added residual chlorine levels even as late in the system as the tower.

As a result of evaluating the spill scenarios, no significant threats to water quality are anticipated and therefore an IPZ 3 was not established for Wellington.

6.7.5 Vulnerability Scoring

Each IPZ is 'scored' to identify its vulnerability to contamination and allow a determination of risk to contamination. The vulnerability scores for IPZs are determined by multiplying the 'area vulnerability factor' times the 'source vulnerability factor'.

For more information on how vulnerability scoring is determined see Section 4.6.

6.7.5.1 Area Vulnerability Factors

For a Type A intake the area vulnerability factors are:

- IPZ 1 10
- IPZ 2 7 – 9

The IPZ 1 at Wellington is given an area vulnerability factor of 10.

Table 6-45 below contains the summary statistics for the Wellington intake that were reviewed following the methodology provided in Section 4.6 to determine the area vulnerability factors for IPZ 2.

Table 6-45: Area Vulnerability Considerations at Wellington Intake IPZ 2

Land/Water	Landcover, Slope, Soil Type	Transport Pathways / Storm Sewers	Combined Vulnerability
87% Water	Gentle slopes, moderate urban development, low permeability clay loam soils	Few known	**LOW**
LOW	**MODERATE**	**LOW**	

An area vulnerability factor of 7 was selected for the IPZ 2 in recognition of the gentle slopes of the shoreline, high percentage of water area and few transport pathways.

An IPZ 3 was not determined for the Wellington intake therefore no factor was determined.

6.7.5.2 Source Vulnerability Factor

Source vulnerability factors for a Type A intake must be between 0.5 to 0.7 and is assigned by the reviewer by considering the following:

- Depth of the intake from the top of the water surface;
- Distance of the intake from the land, and
- Number of recorded drinking water issues related to the intake.

The depth of the intake is estimated to be 8.5 metres. The offshore distance is 1.5 kilometres. Plant operators were interviewed and have indicated that the source water is good and of predictable quality. Considering that the IPZ 1 area is entirely water and the IPZ 2 is mostly water with a small portion of overland contribution including shoreline and small transport pathways, the source vulnerability factor was set at the lowest end of the range at 0.5.

Table 6-46 below shows the results of the score assignments.

Table 6-46: Wellington Vulnerability Scoring

Intake Protection Zone	Area Vulnerability Factor	Source Vulnerability Factor	Vulnerability Score, V
IPZ 1	10	0.5	5.0
IPZ 2	7	0.5	3.5

Wellington Intake Vulnerability Score

- **IPZ 1 = 5**
- **IPZ 2 = 3.5**

Map 6.45 shows the vulnerability scores for the Wellington intake.

Note: These scores are used in conjunction with the Prescribed Threats Look Up Tables to determine Moderate and Low threats.

6.7.6 Threats to Drinking Water Quality

This section reviews risks to drinking water using two approaches. The first is identifying threats through an issues based approach where contaminants have been chronically detected in the raw water supply and linked to land use activities. The second approach is threats based and looks at current and former land use activities in the contributing areas to the intake. Threats are assessed to determine level of risk as Significant, Moderate, or Low.

6.7.6.1 Issues Approach

The raw water quality data at the Wellington intake was screened using the approach described in Section 4.8 to identify issues in the source water of Lake Ontario which may contribute to degraded water quality. Data sources used in the review are presented later in this section.

The 4-step screening process was applied to Wellington intake raw water data outlined in Section 4.8.1. The results are summarized below. In some cases treated water results were analyzed for parameters when raw water results were not available and when these parameters were not considered as being treatment by-products, e.g. Aldicarb, Benzo(a)pyrene, Nitrite, Terbufos, and Sodium.

Screening Step 1

The following parameters had individual results that exceeded the Half Maximum Acceptable Concentration (see issues summary table in Appendix F-7). Those parameters with potential human activities as sources were analyzed for trending in Step 3. Colour was the only parameter with an average greater than the Maximum Acceptable Concentration, the benchmark.

- *E.coli*
- Aldicarb
- Benzo(a)pyrene
- Nitrite
- Terbufos
- Colour
- pH
- Field Temperature
- Turbidity
- Sodium

Screening Steps 2 and 3

The following parameters passed screening Steps 2 and potentially come from human activities. Field Temperature, Colour and pH are considered natural.

- Aldicarb
- Benzo(a)pyrene
- Nitrite
- *E.coli.*
- Terbufos
- Turbidity
- Sodium

None pass screening Step 3. *E.coli*, Aldicarb, Nitrite, Terbufos, and Turbidity did not have a trend line with an upward direction therefore if the trend continues their averages will not reach their benchmark within 50 years. Benzo(a)pyrene and Sodium had less than 10 observations and therefore not enough data to perform a trend analysis.

Screening Step 4

No parameters are considered an issue because none pass screening Step 3. Screening Step 4 looks for treatability of the parameter and other factors (see Section 4.8.1). All of the parameters analyzed in this screening process are treatable at the treatment plant and municipal drinking water operators do not identify any issues. The treatment plant is fully capable of treating for bacterial parameters as well as organic and inorganic compounds.

Data Sources

Raw water quality data was obtained from several sources. They are summarized below and were gathered by Quinte Conservation from the Ontario Ministry of the Environment and the Water and Waste Water Services at the Corporation of the County of Prince Edward:

- Ontario Ministry of Environment (MOE) Drinking Water Information Systems data, Quinte Systems (2003-2009)
- Water Treatment Plant lab results data provided by the municipality (2002-2008)
- MOE Drinking Water Annual Compliance Inspection Report (2008)

6.7.6.2 Threats Approach

Threats to drinking water intakes may be determined from the vulnerability scores for each zone and the circumstances under which an activity would be a drinking water threat. The circumstances under which these threats may be considered as Significant, Moderate or Low are referenced in the Provincial Table of Circumstances (MOE, March, 2018). The interested reader is directed Map 6.45 to determine the location of the particular vulnerability zone.

Significant Threats

Significant drinking water threats can also be determined based on current land uses (activities) and past land uses (conditions).

Activity Based Threats

No Significant threats were identified in IPZ 1 or IPZ 2.

Condition Based Threats

A closed landfill site was identified in the IPZ 2 as discussed in a report provided in Appendix I. Little information was available about the history of this site, however a recent environmental assessment was completed as outlined in a report prepared by Trow Consulting (September, 2010). From this study landfill leachate was identified in the groundwater. A review of the groundwater chemistry data indicated 10 parameters as exceeding the relevant standards in Table 2 of the Soil, Groundwater Water and Sediment Standards for Use Under Part XV.1 of the Environmental Protection Act Ministry of the Environment July 27, 2009. In consideration of these exceedances the site is considered to be a condition. However calculation of a low risk score at 35, as listed below, means that this site is not considered as a drinking water threat to the Village of Wellington system.

Risk Score = 10 X 3.5 = 35

Where:

- The hazard rating was assigned as 10 given the property is in the IPZ 2 associated for the Village of Wellington; and
- The vulnerability score of the IPZ 2 was assigned as 3.5 as outlined in Section 6.7.5.

Identification of Moderate and Low Threats

Moderate and Low risks were reviewed in the Intake Protection Zones for Wellington. A score above 60 and below 80 is a Moderate risk. A score between 40 and 60 is a Low risk.

Since the IPZ 1 does not include any land areas, no threats are present in this zone. In IPZ 2, the maximum score potential is 35. Since a minimum score of 41 is required to indicate a Low risk potential to a land use activity in IPZ 2, no Low or Moderate risks were identified at Wellington.

6.7.7 Uncertainty

The delineation of the Intake Protection Zones and assignment of vulnerability scoring have some degree of associated uncertainty. For example, if scores were assigned with substantial data lacking then a high uncertainty would be applied. Also, if methods used to delineate zones are coarse or modelling was not calibrated or used inadequate data sets then there would be high uncertainty about the results.

An uncalibrated MIKE 3 hydrodynamic mixing model was developed to aid in the determination of vulnerability zones. IPZs were established with conservative conditions using either a combination of effects or the worst case condition to establish the outer bounds of the IPZs. Some estimates were made to supply data that were not available at the time of the study and therefore a High uncertainty is placed on the delineation of the vulnerability zones.

However, the source vulnerability factor scores have been compared to many others throughout the province and have a Low uncertainty.

Table 6-47 summarizes the vulnerability scores for each IPZ and the uncertainties applied to each.

Table 6-47: Wellington Vulnerability Scores and Uncertainty Summary

Zone	Vfz (Area Vulnerability Factor)	Vfs (Source Vulnerability Factor)	V (Vulnerability Score)	Uncertainty	
				Zone Delineation	Vulnerability Score
1	10	0.5	5.0	Low	Low
2	7	0.5	3.5	High	High

6.7.8 Data Gaps

Further detail would be needed on the small creeks and on the municipal storm sewer system to confirm the 2 hour time of travel and extent of the IPZ 2. Given that any land use activity in the IPZ 2 would not be identified as a Low, Moderate or Significant threat, the additional effort to confirm the IPZ 2 is not warranted.

6.8 Bayside Intake Protection Zone

The Bayside intake is located within the Trent Conservation Coalition source protection region. It is situated in the Bay of Quinte between Belleville and Trenton and supplies drinking water to the Hamlet of Bayside in Quinte West.

While the intake is outside of the Quinte source protection region, this intake affects the determination of the IPZ 3 for Belleville (discussed in Section 6) and protection zones for the intake affect the Quinte region (see Map 6.3 and Map 6.46).

The reader is referred to the Assessment Report for the Trent Conservation Coalition for the development of the protection zones, information on how the scores were assigned and threats and issues. The zone scores have been provided on Map 6.46 and are listed below:

Bayside Vulnerability Scores

- **IPZ 1 = 8**
- **IPZ 2 = 6.4**
- **IPZ 3 = 6.4, 5.6 and 3.2**

Map 6.47 shows the locations of the vulnerability scores for the various protection zones for the Bayside intake.

Within the IPZ 1 there is one Significant threat located within the Quinte region on one parcel.

Table 6-48: Bayside Intake Significant Threats Enumeration

Prescribed Drinking Water Threat (PDWT)*	**Score to Trigger a Significant Threat**	
	Vulnerability Score **= 8**	
	Affected Parcels	**No. of PDWT**
21. The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. O. Reg. 385/08, s. 3.	1	1
Total Number of Affected Parcels	**1**	**1**

Table courtesy of Trent Conservation Coalition

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7 Climate Change

As part of the Assessment Report, there is an acknowledgement that considerations of climate change are important. Some of the eastern Ontario Source Protection Regions/Areas have prepared climate change reports for their specific jurisdictions, Cataraqui (Watt 2009), Mississippi-Rideau (Oblak 2009) and Trent Conservation (TCC 2009). The reports summarize a number of other climate change reports and studies and describe some potential water quantity and water quality impacts as well as some mitigation and adaptation considerations.

This chapter of the Assessment Report provides a further summary of that work.

It must be noted that there is large uncertainty associated with climate change across the globe. It is very clear that our climate is changing, but which aspects of our climate, and how much they may change in the future, is very unclear. All the potential impacts presented here are by no means definitive.

7.1 Research to Date for South-eastern Ontario

Climate change impacts are probably best understood by looking at the regional scale (eastern Ontario) rather than by property, city or town. Much of the research and the published reports done to date are structured this way. These look at areas as large as eastern Ontario, or eastern Canada and the northeastern United States. In fact, there is minimal research specific to southeastern Ontario with regards to climate change. However, most of the studies do come to the same general conclusions about potential climate change in our area.

The Intergovernmental Panel on Climate Change (IPCC) (2007a, 2007b) reports summarize potential climate change across the globe, looking at both global variability as well as smaller areas such as eastern North America. The reports synthesize results from 21 global climate change models. For our area, the reports predict:

- increase in temperature, higher winter minimum temperatures; and summer maximum temperatures;
- more winter precipitation;
- changes in summer precipitation are less certain;
- small increase in runoff (may not be statistically significant); and
- more frequent heavy precipitation.

It has also been observed, since the IPCC report was published, that the predictions it contains are actually occurring faster than expected (Richardson et al. 2009).

Also in 2007, the Ontario Ministry of Natural Resources produced a report (Colombo et al 2007) and mapping considering climate change in Ontario. The authors used Canadian data provided by Natural Resources Canada. Specifically, this study looked at the relative change in temperature and precipitation for three 30 year periods (2011-2040, 2041-2070, 2071-2100), compared to the 1971-2000 period. It must be noted that the 1971-2000 period happens to be one of the wettest periods in recent history (Hogg 2007) based on the analyses of climate data conducted by Mekis and Hogg (1999). The MNR study predicts:

- precipitation decreases from zero to ten per cent in most areas of the region, though some areas show an increase of zero to ten percent (this does not represent a statistically significant change), and
- temperature increase of a few degrees, more in the winter months than summer months.

In addition to the IPCC and MNR studies, numerous other studies and reports have been completed that provide much the same predictions and conclusions. Some of these other reports include predictions such as:

- decrease in the number of cold events;
- increase in the number of warm events;
- increase in night-time temperatures;
- decrease in snow depth in many areas, but an increase in eastern Ontario;
- increase in the number of days of precipitation, specifically rain,
- decrease in length of dry spells;
- less ice cover on the Great Lakes (thinner, and shorter ice-in season); and
- drop in Great Lake levels (predicted one metre for Lake Ontario if not mitigated by change in dam operation at Cornwall).

Some of the predictions presented are contradictory, which contributes to the large degree of uncertainties associated with climate change models. This must be taken into account when considering potential climate change; there is not enough information to predict the results with certainty.

7.2 Quinte Modelling for Climate Change

Quinte Conservation undertook a review of potential effects of climate change on the region with Dr. Harold Schroeter from Schroeter and Associates and the assistance of a Quinte Region GAWSER model. The model was prepared to simulate average conditions, 2-year and 10-year drought conditions for each of three scenarios: The average conditions are defined by the meteorological period 1950 to 2005. The 2-year and 10-year-droughts are defined in the Technical Rules as:

- *2-Year Drought*
  The continuous two year period for which precipitation records exist with the lowest mean annual precipitation.

- *10-Year Drought*
  The continuous ten year period for which precipitation records exist with the lowest mean annual precipitation.

Three modelled scenarios include:

1. Current meteorological conditions
2. Conditions in 2050
3. Conditions in 2090

This work made use of a Canadian Centre for Climate modelling and analysis (CCCma) gridded model output for southern Ontario (Environment Canada 2009). The model provided gridded modifiers for meteorological inputs such as temperature, precipitation, cloud cover, solar radiation and wind speed.

The Quinte region fell within vertical grid points 76 and 77 and horizontal grid points 36 and 37. Specific modifiers for the Quinte Region were developed by averaging each of the horizontal and vertical factors (note that the temperature change factors are provided in degrees C). The resulting modifiers are assembled in Table 7-1. This table shows that precipitation will increase in the winter and spring months and decrease slightly during summer and fall. Temperature will likewise increase in winter and spring and less so in the summer and fall. The Quinte Region GAWSER model used the precipitation and temperature multipliers to develop the models to determine the potential effects on the Quinte Region.

The following table contains a summary of the modifiers used in the Quinte Region GAWSER (Guelph All Weather Sequential Event Runoff) model. The model was capable of simulating evapotranspiration using the Linacre method that is discussed in detail in Chapter 3. It is also capable of redistributing snowfall, providing estimates of snow melt, and separating runoff from infiltration through nine soil types and two soil layers. The Quinte model was constructed for the water budget exercise and its development is further discussed in Chapter 3.

The initial modelling work was centred upon development of a model to simulate current meteorological conditions. This was assisted by placing nodes at stream gauge locations so that the predicted model output can be verified by actual stream flow measurements. The model was verified using meteorological data from 1950 to 2005. Once the model verification or calibration was completed two future scenarios were programmed into the model by making use of the climate change factors in Table 7-1.

Model results were provided as an ASCII (American Standard Code for Information Interchange) file and these were imported into Excel spreadsheets for comparison. The results generally show peak stream flows are experienced earlier in the spring and summer flows are drier. Figures 7-1 to 7-4 show flows from three scenarios discussed above for several Moira flow gauge stations. The current conditions show a large peak runoff in April. This peak is reduced in 2050 and 2090 and is also earlier. Also, the summer low flow conditions appear to become more reduced.

Table 7-1: CCCma Climate Change Estimate Factors

CCCMA Climate Change Estimates for Quinte Conservation Source Protection Region													
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Mean**
Cloud Fraction													
C2030	1.04	1.04	0.99	1.03	1.02	1.03	0.97	0.94	0.97	0.99	0.99	0.98	**1.00**
C2050	1.05	1.07	1.06	1.04	1.02	0.99	0.96	0.95	0.96	1.00	1.01	0.99	**1.01**
C2090	1.06	1.13	1.09	1.08	1.02	1.05	1.04	0.95	0.98	0.99	0.99	0.96	**1.03**
Evaporation													
E2030	1.25	1.41	1.15	1.21	1.11	1.01	1.02	1.04	1.04	1.05	0.96	0.81	**1.09**
E2050	1.20	1.70	1.17	1.39	1.13	1.03	1.03	1.06	1.06	1.07	0.95	0.74	**1.13**
E2090	1.02	1.79	1.52	1.86	1.19	1.04	1.03	1.07	1.08	1.10	0.96	0.63	**1.19**
Precipitation													
P2030	1.05	0.99	1.01	1.06	1.01	1.11	1.02	0.92	1.02	1.01	0.97	0.99	**1.01**
P2050	1.04	1.07	1.07	1.15	1.03	1.02	0.94	0.88	0.97	0.98	0.97	0.95	**1.01**
P2090	1.06	1.21	1.28	1.19	1.07	1.11	0.99	0.90	1.03	1.13	0.98	0.99	**1.08**
Incident Solar Radiation													
S2030	0.96	0.97	0.98	0.97	1.00	0.98	0.99	1.02	1.00	1.00	1.00	1.01	**0.99**
S2050	0.97	0.94	0.96	0.97	0.99	0.98	1.00	1.01	1.00	0.99	0.99	1.00	**0.98**
S2090	0.96	0.92	0.93	0.96	0.97	0.94	0.93	0.97	0.97	0.97	0.98	1.00	**0.96**
Mean Screen Temperature													
T2030	3.97	4.36	2.55	2.07	1.71	1.47	1.56	1.49	1.73	1.29	1.18	0.85	**2.02**
T2050	4.87	6.29	3.83	3.33	2.69	2.22	2.19	2.14	2.16	2.10	1.96	1.05	**2.90**
T2090	6.11	8.97	6.68	7.40	5.91	5.07	4.28	4.13	4.20	4.34	4.07	2.49	**5.31**
10-m wind													
W2030	1.04	1.06	0.99	1.06	1.02	0.97	0.98	0.98	0.98	0.99	0.94	0.92	**0.99**
W2050	1.00	1.06	1.00	1.07	1.01	0.94	0.93	0.95	0.96	0.96	0.93	0.86	**0.97**
W2090	0.93	1.07	1.01	1.13	0.95	0.90	0.90	0.92	0.90	0.94	0.90	0.80	**0.95**

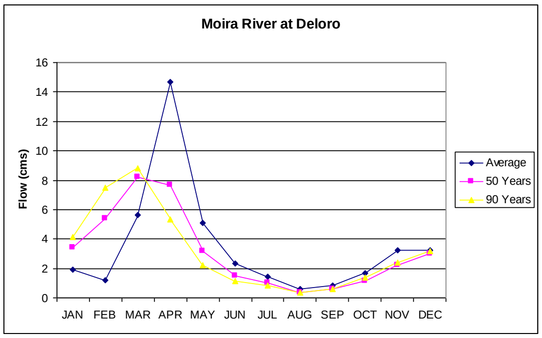

Figure 7-1: Moira River at Deloro Flows (m^3/s)

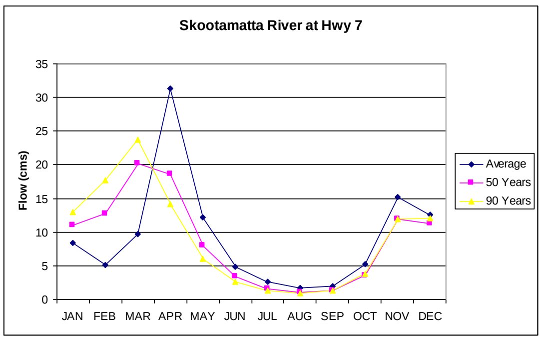

Figure 7-2: Skootamatta River at Hwy 7 Flows (m^3/s)

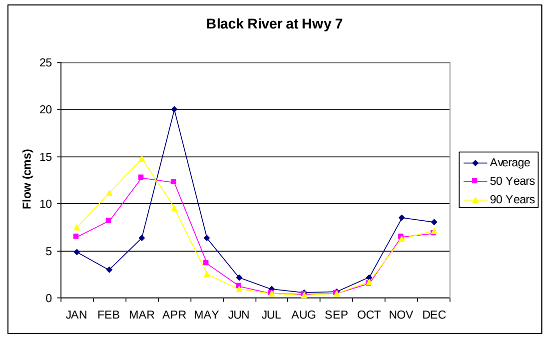

Figure 7-3: Black River at Hwy 7 Flows (m^3/s)

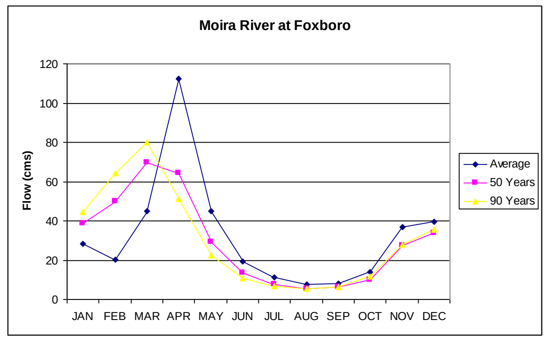

Figure 7-4: Moira River at Foxboro Flows (m^3/s)

Water balance values were provided by the model output showing the potential changes to precipitation, snowfall, evapotranspiration, total runoff and baseflow. These values are provided in Tables 7–2 to 7–6 respectively. These are annual totals and will not reveal the seasonal variations discussed above. The model output provided monthly water balances for each station and scenario, but these are too cumbersome to reproduce here. The Figures 7–1 to 7–4 are included to illustrate the monthly trends for total flow.

The effect of increased precipitation and temperature on water quantity of the Moira River system is interpreted by reviewing the Average Conditions columns in Tables –2 to 7–6. The portion of precipitation that is expected to fall as snow is not expected to increase (Table 7-3).

Evapotranspiration, on the other hand, is expected to increase significantly in both 2050 and more so by 2090 by well over 100 mm (Table 7-4). Total runoff in Table 7-5 is projected to remain relatively unchanged in the 2050 and 2090 scenarios.

Table 7-2: Precipitation

	Average Conditions			2 Yr Drought			10 Yr Drought		
Station	**Current**	**2050**	**2090**	**1963-1964**	**2050**	**2090**	**1957-1966**	**2050**	**2090**
Deloro	931	943	1014	718	729	777	804	817	948
Black	950	970	1047	876	892	959	895	922	1130
Skootamatta	987	1008	1089	905	922	994	927	955	1173
Foxboro	944	958	1033	812	824	887	859	875	1057

Note: All units are in mm depth

Table 7-3: Snowfall

	Average Conditions			2 Yr Drought			10 Yr Drought		
Station	**Current**	**2050**	**2090**	**1963-1964**	**2050**	**2090**	**1957-1966**	**2050**	**2090**
Deloro	208	220	208	156	155	142	183	182	205
Black	200	199	205	238	240	240	221	233	248
Skootamatta	194	194	200	231	234	234	215	226	241
Foxboro	180	192	186	198	191	195	200	194	204

Note: All units are in mm depth

Table 7-4: Evapotranspiration

	Average Conditions			2 Yr Drought			10 Yr Drought		
Station	**Current**	**2050**	**2090**	**1963-1964**	**2050**	**2090**	**1957-1966**	**2050**	**2090**
Deloro	557	613	682	557	586	646	542	578	672
Black	556	599	663	547	572	628	543	570	663
Skootamatta	555	605	672	551	577	637	545	577	668
Foxboro	543	594	659	523	550	608	526	559	646

Note: All units are in mm depth

Table 7-5: Total Runoff

	Average Conditions			2 Yr Drought			10 Yr Drought		
Station	**Current**	**2050**	**2090**	**1963-1964**	**2050**	**2090**	**1957-1966**	**2050**	**2090**
Deloro	371	331	332	218	188	182	258	235	327
Black	389	369	382	362	350	360	349	349	497
Skootamatta	430	404	418	394	375	387	382	376	545
Foxboro	400	366	376	328	305	311	331	316	453

Note: All units are in mm depth

Table 7-6: Baseflow

	Average Conditions			2 Yr Drought			10 Yr Drought		
Station	**Current**	**2050**	**2090**	**1963-1964**	**2050**	**2090**	**1957-1966**	**2050**	**2090**
Deloro	180	179	178	130	124	117	138	136	185
Black	189	187	189	177	177	175	147	153	252
Skootamatta	216	209	210	196	193	208	170	177	277
Foxboro	201	191	190	167	166	167	154	156	239

Note: All units are in mm depth

What happens to seasonal low flow values in these scenarios is summarized in Table 7-7 following based on the example of the Moira River at Foxboro station. It can be seen from this table that lowest monthly base flows in the river are projected to diminish over time although it is apparent from Table 7-6 above that annual base flows will remain fairly steady. Again, the effects of climate change are expected to be more pronounced seasonally.

Table 7-7: Projected Lowest Monthly Baseflow in Moira River at Foxboro

	Average		2 yr Drought		10 yr Drought	
Period	**Flow (m^3/s)**	**Lowest Month**	**Flow (m^3/s)**	**Lowest Month**	**Flow (m^3/s)**	**Lowest Month**
Current	4.1	Sept	2.3	Sept	2.2	Sept
2050	2.7	Sept	1.7	Sept	1.6	Sept
2090	2.5	Aug/Sept	1.5	Sept/Oct	2.2	Sept

Drought scenarios provide less reliable predictions since they are based on short periods of record. The application of the precipitation modifier on the drought scenario may not be scientifically appropriate. It implies that precipitation totals would increase during a drought period. Naturally, if precipitation increases at the same rate as Average conditions the evapotranspiration and total runoff would increase over time. Perhaps more telling is the projected seasonal low base flow value for the 2-year drought. The historical 2-year drought had a base flow of 2.3 metres per secondduring September. This value decreases in the model results to 1.5 metres per second by 2090 and is projected to occur during both September and October (Table 7-7).

7.3 Potential Impacts on Water Quantity

The climate projections vary and impacts are dependent upon those projections. The Quinte Region impact modelling was based on the Canadian Centre for Climate Modelling and Analysis climate model that projects increased precipitation. Evapotranspiration increases significantly and annual runoff remains generally the same. Annual base flows also remain generally unchanged, but seasonally summer base flows are anticipated to diminish.

Some models suggest a decrease in precipitation could occur. In either event, storage of runoff will become more important to provide water supply during low base flow periods.

If climate change produces a decrease in precipitation and an increase in temperature, then we can expect that evapotranspiration will also increase if sufficient soil moisture exists.

The projected temperature increase and earlier spring runoff despite the disagreement in precipitation projections would have common impacts on water quantity listed below:

- less water available for surface storage (lakes and wetlands), flow augmentation, etc., and consequently less supply for drinking water;
- further, the demand is expected to increase, given the longer warm and dry periods;
- lower lake levels in summer, wetlands dry up, recreational problems (boating, swimming, etc.);
- less water recharging into the ground, lower groundwater levels, dry wells, dry groundwater fed streams/lakes; and
- more rain vs. snow, earlier freshet, less water to ground during snow melt, but more during traditional winter periods.

7.4 Potential Impacts on Water Quality

The impacts to water quality due to climate change will also vary depending on what actually changes.

If higher temperatures occur, expectations would include:

- warmer winters, possibly allowing the overwintering of pests/invasive species;
- warmer winters/waters may also allow new pests to emigrate, causing fouling of intakes similar to current zebra mussel problems;
- warmer winter temperatures could mean less snow and ice accumulation leading to reduction in sand and salt application. However, more freezing rain may develop, meaning more salt and sand needed;
- less snow may mean less "toxic flush" into surface water as snow melts;
- reduced stream flows, means an increase in contaminant concentration potentially leading to effects not normally experienced; and
- warmer surface water, which will foster more (and earlier) algal growth leading to more frequent fouling of intakes and require increased treatment at the drinking water plants.

If higher precipitation occurs, or more intense precipitation, more contaminants may be washed off the surface and into the water. There was a link found between heavy precipitation and water borne disease outbreaks (CCSP, 2008). More erosion would be expected due to heavy precipitation, which could also increase the loading of contaminants bound to sediment into streams and groundwater.

During the period when the former Village of Napanee took its municipal water from the Napanee River, low flows were noted to negatively impact water quality. To reduce the impacts of low summer flows on water quality, two large dams and reservoirs were constructed at the Depot Lakes to provide low flow augmentation. The Second Depot Lake Dam was constructed in 1958. Third Depot Lake Dam was completed in 1975.

Further evidence of impact on low flows to river quality is again with reference to the Napanee River. Quinte Conservation staff regularly installs seasonal weirs on several rivers for summer recreation. The Newburgh Weir on the Napanee River is no longer installed due to very poor water quality conditions that would routinely develop over the summer.

7.5 Potential Impacts to Vulnerable Area Delineations

Climate change may also mean changes to the various vulnerable area delineations.

Wellhead Protection Areas

- reduced recharge may mean larger capture zones (WHPAs) in supply wells in order to meet demand;
- reduced recharge may also lead to lower groundwater levels and reduced discharge to surface water (i.e. reduced base flow); and
- earlier runoff timing will also affect the timing and duration of groundwater recharge affecting supply.

Intake Protection Zones

- higher temperature may mean lower water levels due to increased evapotranspiration, which could expose some intakes to the surface, or surface impacts; and
- warmer temperatures resulting in a shorter ice cover period may make additional land use activities subject to consideration (e.g. shipping), and given that winds are generally stronger in the winter, this would require an increase in the size of wind-derived IPZs.

Significant Groundwater Recharge Areas

- SGRAs are based on the composition of the soil and rock, so the identification of the areas will probably not change.

7.6 Mitigation/Adaptation to Climate Change

Awareness of Climate Change is important in order that efforts can be made to mitigate the effects and prepare to adapt. Some of the mitigation/adaptation measures for consideration should include:

- adopting water conservation measures to ensure that reduction in storage can be accommodated in reduced use;
- promoting water conservation and reuse methods such as rainwater harvesting, grey water systems, etc.;
- monitoring of groundwater levels, groundwater recharge and discharge, groundwater movement, stream flow (particularly low flows), precipitation, evaporation, and radiation, to name a few. This monitoring data will help to identify what parameters are changing, and how they are changing. Modelling results are much more useful by actual data for calibration and validation (Silberstein 2006). As he states, "we cannot manage what we do not measure";
- continuing analysis of existing data, by multiple independent experts to improve our confidence in detecting past changes (as recommended by the Climate Change Science Program (CCSP) 2008);
- developing new storage opportunities or increasing existing storage capacities; and
- providing municipal water to those areas that experience water shortages in private well supplies if possible.

7.7 Considerations for Monitoring Climate Change

Climate change is a global phenomenon with local variation. This indicates that monitoring the changing climate should be coordinated by higher levels of government. Results of climate change are however, locally measurable and this would capture local variations in climate change impacts.

Most studies agree that the current monitoring of climate is not well suited to capturing the right data to identify what parameters might change, and how they might change. More monitoring is needed, as identified by a number of sources. Specific recommendations on monitoring are not necessarily appropriate for this document. Monitoring should be done through a partnership among all levels of government (federal, provincial, municipal), as well as scientific/research organizations such as conservation authorities and universities. Some of the parameters that should be monitored include: precipitation (rain, snow, rate), evapotranspiration, radiation, water and air temperature, and water use, to name but a few.

7.8 Future Work for Understanding Climate Change Effects in Quinte

This is a rapidly developing field of study that has only recently received any local study. Climate change understanding is developing in Canada and regional models provide some insight on the effects on Quinte. Global climate models are being refined and suggest the projections used in the current study may be high.

As such, the current climate change work should be reviewed with updated modelling as it becomes available to provide improved projections on potential impacts.

In the Quinte region modelling completed for the climate change effects, several subwatersheds lack groundwater or surface water monitoring that would add confidence as calibration events. Future work should incorporate new monitoring information in the Quinte model to improve interpretation of the local effects.

Within the model are capabilities that were not engaged that could better evaluate the changes in evapotranspiration. Potential evapotranspiration routines require improved local data to support climate change effects using projected changes in cloud cover, solar radiation and wind speed.

Chapter 8 Table of Contents

8 Data Gaps and Future Work

In some cases various knowledge or data sets were either missing or not available during the collection, assembly and interpretation of hydrologic, water quality and physical data for the production of this report. These gaps in data have been noted in the applicable sections of the report.

Some gaps are very minor and were filled with conservative assumptions such as velocity in creeks used to delineate the Intake Protection Zone (IPZ) 2 boundaries. Other gaps in data or information were more significant and will lead to further study and collection of more data. Some of the data sets were too short in duration or non-existent and were not able to provide reliable conclusions or direction. An example of this deficiency is water quality data where an insufficient amount of data existed for some parameters to perform trend analyses to confirm if the concentrations of water contaminants were increasing or decreasing.

Data gaps of lesser significance have been noted in the various sections of the assessment report. Those which may lead to uncertainties with conclusions or identification of risks are reproduced below and listed with the corresponding assessment report chapter or section where the gaps were identified.

8.1 Chapter 2 Data Gaps

Aquatic Habitats: Macroinvertebrates

The Ontario Benthos Biomonitoring Network requires the establishment of reference sites which are relatively unimpaired from human activities in order to characterize the water course following the method preferred by the Ontario Ministry of the Environment. Reference sites have not yet been established and therefore an alternative method of characterization called the Hilsenhoff Biotic Index was employed. A provincial grading system has not been established to provide a basis of comparison.

Riparian Vegetated Areas

Geographic Information System (GIS) layers are not detailed enough to isolate forest patches. Attempts to produce this map using existing layers were unsuccessful. Therefore, riparian vegetated areas layer is a gap.

Federal Lands

Federal lands GIS layers were provided that include national parks and land ownership. No national parks are identified in the Quinte Source Protection Region. Federal lands include the Mohawk Territory and a small sliver of land which may be an error. There are other federal lands under the control of the Department of National Defence that were not identified in the layer. Available information on Federal lands was grouped with Protected Lands and shown on Map 2.19. Federal lands remain a data gap.

Serviced Areas

Serviced areas (water and waste water) within settlements have been produced with some approximation. Further information is required to confirm the accuracy of the boundaries. This remains a data gap.

8.2 Chapter 3 Data Gaps

Work on the development of water budgets spanned four years. More recent efforts required more detailed analysis which also identified some data gaps. Some of these gaps were filled, for example, by contacting water taking permit holders and requesting this information from them.

Gaps that remain after all the water budget investigations are listed below:

Tier 1 Water Budget

There is a need for:

- better Permit To Take Water data related to source of taking (for example, wetlands, dams and permits for quarries where there is often taking labeled as groundwater but it is rain water that accumulates in the Quarries);
- better information on actual water use;
- more stream gauges (many subwatersheds have no stream gauge data and water availability had to be estimated); and
- better understanding on consumptive use of wetland and dam permits (using consumptive ratios some wetland uses suggested extremely high stress conditions exist. Local observations would not support such conclusions.)

Tier 2 – Madoc

There is a need for:

- better Permit To Take Water data to reflect actual use instead of permitted
- better water well record data (i.e. static levels and well locations) to allow better calibration of groundwater flow model;
- accurate water level data for Village of Madoc wells; and
- stage level data for Moira Lake and Deer/Madoc Creeks.

Tier 2 – Ameliasburgh

There is a need for:

- flow information on the Sawguin Creek system as well as outflow data from Roblin Lake to confirm model estimates of outflow. The stress assignment for the Ameliasburgh municipal intake relies upon the estimate of flow. The model was calibrated to a nearby system, but low flow periods data were not as reliable as that for high flow periods; and
- reliable flow data at stream gauging stations for very low flow periods. Improved accuracy of low flow measurement is suggested for increased confidence in the stress assignments.

8.3 Chapters 5 and 6 Data Gaps

8.3.1 Drinking Water Threats

Generally, very good databases were compiled for land uses, while activities on the properties were not fully confirmed initially. Since there were large numbers of potential Significant threats identified for some systems, as well as Moderate and Low threats, it was logistically difficult to confirm that the threats were present. Field work in 2013 verified the number of Significant threats, reducing many previously reported data gaps.

The Wellington intake, located in Prince Edward County, was studied as part of the Lake Ontario Collaborative. The study was managed by external agencies and undertaken by several consulting firms. A draft spill model report was used to base the decision by the source protection committee not to establish an IPZ 3 around the Wellington intake. The final report is complete and no further information was provided from the collaborative effort on Lake Ontario. The Source Protection Committee will continue to monitor the municipal intake in Wellington and may determine the need for an IPZ 3 to be delineated in the future.

Other Threats Assessment Data Gaps

- Livestock density was estimated on the basis of census data. The specific locations of higher or lower densities are not available due to the groupings into census units. Improved information is needed on densities on a parcel basis to confirm threats. This can be achieved either through site visits to individual properties or in future updates to the Assessment Report provided that improved information is available.
- Data to allow the assessment of condition based threats in all vulnerable areas was lacking.

8.3.2 Intake Protection Zone (IPZ) Delineations

Good information existed to produce IPZs. Some exceptions were transport pathways where times of travel were not available for most storm sewers. These were estimated using engineering principles and IPZ 2 delineations are identified with low uncertainty for all intakes. The process of delineation is documented in the reports included in the appendices.

8.3.3 Wellhead Protection Area Delineations

Wellhead Protection Areas around municipal wells were determined with the assistance of computer modeling. Models assume groundwater flow through porous media. Aquifers in the Quinte Source Protection Region are predominantly found in fractured bedrock and models have been adapted to bedrock conditions by assigning values of equivalent porous media to the bedrock layers. Characterization of fractured bedrock environments is often difficult owing to the complex nature of the bedrock, variable distribution and frequency of fractures, and limited budgets available to characterize these environments. In the past, extensive research and methodology has been conducted into understanding how water moves through porous media. Given relative familiarity with these processes and methodologies, application of these models to fractured bedrock environments is common. However, this is not always the correct practice given that the same theories of water movement do not transfer directly to fractured bedrock. Although there has been development of technology and methods for characterizing fractured bedrock environments, the transfer of this information to the general practicing community is not occurring. In addition, further development on techniques to better characterize fractured bedrock sites need to be developed.

8.3.4 Water Quality Gaps

While there is an abundance of water quality information about treated water at the drinking water systems, there is a lack of detailed information about source water. There is a lack of data about raw water quality parameters listed under Ontario Drinking Water Quality Standards Schedules 1, 2, and 3 of Ontario Regulation 169/09 and Table 4 of the Technical Support Document for Ontario Drinking Water Standards, Objectives, and Guidelines (Ministry of the Environment 2006). Where there was a lack of raw water quality data, treated water data was used, however these data do not accurately represent source water.

Water quality data is limited for Significant Groundwater Recharge Areas. For more information on other items identified for future study see Section 8.5

8.3.5 Conditions

Past activities were reviewed in the previous update with a view toward determining those that have conditions that would be Significant threats. Locations of past activities are known, but there is little documented evidence that contamination is occurring at these sites. Exceptions are the former landfill sites at Zwick's Park in Belleville and Delhi Park in Picton.

Information is difficult to obtain regarding past activities, but as reports become available further suspected contaminated sites in areas which may score Moderate and Low risk threats will be reviewed in later updates.

8.3.6 Groundwater Vulnerability

Information was not available for abandoned wells to determine constructed transport pathways.

8.3.7 Groundwater Issues

Water quality data is limited for Significant Groundwater Recharge Areas.

There was very little information for the Point Anne Intake on groundwater such as hydraulic parameters, quality and the volume of groundwater use at this source. This is a unique system where the intake is connected to a groundwater source.

8.4 Chapter 7 Data Gaps

Climate change projections are based on extrapolations of observed trends in climate data. From these projections, potential impacts are postulated with the support of hydrologic modeling. Not enough is known about climate trends and potential anthropogenic influences to place confidence on the projections. The local modeling undertaken for climate change impacts used data from climate models that is already dated. Further climate change work is required using the most up to date climate model data in order to better forecast local impacts from the observed trends. Further, if projections continue to reveal the potential for earlier spring runoff, the hydrologic models used locally for prediction of flood peaks and flow statistics will require modifications to infiltration coefficients as frozen ground conditions are less likely to be present during spring runoff events in late March and early April. Understanding of potential climate change impacts on the watershed is a data gap.

8.5 Items Identified for Future Study

Pharmaceuticals and Personal Care Products

Pharmaceuticals and Personal Care Products are substances found in pharmaceuticals, natural health products, and personal care products such as cosmetics, fragrances, toiletries. Pharmaceuticals and Personal Care Products in the soils and water may be deposited through various pathways. Sources include the spreading of liquid municipal biosolids on agricultural fields; hazardous waste from industrial and domestic sources; landfills and Sewage Treatment Plants. The long-term risks to public health and the environment associated with Pharmaceuticals and Personal Care Products are still unclear.

Few solutions currently exist in Canada to minimize the potential contamination of the environment from Pharmaceuticals and Personal Care Products. The risks associated with their presence in the environment, effects, and means of control have been studied over the past 10 years but the information available is still not sufficient to develop risk assessments or risk management strategies at this time. Management strategies that do exist include emission controls by pharmaceutical return programs, education of the medical professionals to reduce prescription rates to patients, incentives for green drug manufacturing, improving treatment technologies at drinking water and sewage plants. More research is required on effects and risk mitigation of these measures (Marsalek 2008).

The various ministries of the Ontario government review the latest science around the potential impacts to soil, surface water, groundwater and agricultural practices and are conducting a number of studies. Currently, under the 2007 Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem, the Ministry of the Environment has ongoing studies in partnership with the federal government and research institutions reviewing best management practices. For example the Ministry of the Environment is working in collaboration with Agriculture and Agri-Food Canada to further evaluate the persistence and fate of a selected group of organic compounds including pharmaceuticals, antimicrobial agents and personal care products in fields where biosolids are applied. As of 2009 a select few Ontario municipal drinking water systems will be participating in monitoring of some Pharmaceuticals and Personal Care Product substances through the Ontario Drinking Water Surveillance Program.

Algae Toxins

The Bay of Quinte has a long history of harmful algal bloom occurrences, particularly in late summer and early fall. They have the potential to occur every year with the right conditions. Recently, there has been an increase in the proportion of potentially toxic cyanobacterial (blue-green) species dominating harmful algae blooms in the Bay; and the risk to municipal drinking water systems, to date, is largely unknown. Cyanobacteria toxins (notably Microcystin) can be hazardous to human health and to fish and wildlife. They were first reported in the Great Lakes in the mid 1990s and have been detected each summer/fall during surveys and at select Bay of Quinte monitoring sites since the early 2000s (particularly the Deseronto-Hay Bay area). Microcystin levels in the Bay of Quinte can reach those seen at other Areas of Concern and at highly impacted inshore sites in the Lower Great Lakes. To date, the occurrence, severity and toxicity of harmful algae blooms in the Bay of Quinte remain unpredictable and often unrecorded, and the threat to our drinking water and recreational waters remain uncharacterized (Watson 2008).

The four drinking water systems which draw water from the Bay of Quinte and participate in the Ministry of the Environment's Drinking Water Surveillance Program (Belleville, Deseronto, Picton in the Quinte Source Protection Region and Bayside in Trent Conservation Coalition Source Protection Region) intermittently detected raw water Microcystin-LR levels that exceed the Ontario Drinking Water Standard of 1.5µg/L. Since 2004 the City of Belleville had no longer participated in the Drinking Water Surveillance Program but Bayside, Deseronto, and Picton drinking water systems continue to sample both raw (unchlorinated) and treated water for Microcystin-LR three to five times a month (weekly). Some open water monitoring sites in the Bay of Quinte have recorded Microcystin levels many times greater than this water quality standard and at times, approach or exceed the provisional Health Canada Guideline for recreational waters (i.e. >20µg/L) (Watson et al. 2009 and unpublished data).

A large harmful algae bloom was recorded in early October 2009 that extended for many kilometres from Bayside to Point Anne in the Bay of Quinte. Residences along the shoreline were notified of the presence of algae toxins (microsystins) in the water, particularly those who are on private drinking water systems with shore wells drawing water from the Bay. No detections of microsystins occurred in any of the treated water samples.

Long term water quality surveillance (e.g. through the Great Lakes Action Plan-funded Project Quinte) has provided a general understanding of the factors promoting harmful algae blooms in the Bay of Quinte. These blooms appear to respond to elevated nutrient concentrations, water transparency, temperatures, and calm conditions. However, the factors that control bloom toxicity and the production, release, distribution and degradation of toxins in the Bay of Quinte are poorly understood, highlighting the critical need for increased monitoring. During bloom development there is typically more toxin in the particulate fraction (i.e. cells) than in the dissolved phase, but with cell damage and/or breakdown, the amount of dissolved toxin - which is more difficult to remove - increases. This increase in dissolved toxin often occurs in late summer when biological activity is high and removal by water treatment can be further challenged by high levels of other dissolved material competing for filter adsorption sites. Furthermore, there is considerable spatial and temporal / inter-annual variation in the risks associated with harmful algae blooms in the Bay of Quinte (and other waterbodies). Toxin concentrations vary with depth and proximity to shore and there are yearly differences in species dominance and their toxicity, as seen with the Taste and Odour compounds that are also produced by certain cyanobacteria (Watson et al. 2009 and unpublished data).

A proposed pilot project was submitted to the Ontario Ministry of the Environment in September 2009 and funding was approved through the Ontario Drinking Water Stewardship Program to support work prior to source protection planning phase. The project is called the Bay of Quinte Algae Watch program. In 2010 and 2011, specific locations in the Bay of Quinte were monitored for algal toxins and data was collected to help better understand the risk these toxins pose to our municipal drinking water systems and to recreational areas. Partners include the Ontario Ministry of the Environment, Environment Canada, Hastings and Prince Edward Counties Health Unit, Quinte Conservation Lower Trent Conservation and municipalities (City of Belleville – Gerry O'Conner and Point Anne Hamlet systems, Town of Greater Napanee – Deseronto system, Prince Edward County – Picton system, and City of Quinte West – Bayside system). Results of the project are as yet unpublished.

Chapter 9 Table of Contents

9 Key Outcomes – Quinte Source Protection Region

Chapter 9 summarizes the key findings of the Assessment Report and provides a high level of understanding gained in the study.

9.1 Key Outcomes

9.1.1 Drinking Water Sources

In the Quinte Source Protection Region approximately half the population receives their drinking water from municipal drinking water systems, while the remainder has either private wells or intakes. The municipal systems can be classified as surface water intakes, groundwater wells, groundwater wells that are under the direct influence of surface water and in one case, a surface water intake that is influenced by groundwater. The municipal systems have a varying degree of treatment facilities ranging from simple systems serving fewer than 20 residences to state of the art facilities, serving from 30,000 to 40,000 people. All of the municipal residential systems in the Region treat water and monitor the quality in accordance with the rigorous standards imposed under the *Safe Drinking Water Act, 2002*.

9.1.2 Water Quality

The scientific research and data collection carried out by the Quinte Source Protection Authority has shown that while there are some water quality concerns throughout the region, generally the water quality is reasonably good. However drinking water still requires treatment to safeguard the people relying on these sources.

A number of programs and initiatives have helped improve water quality in recent years including the Bay of Quinte Remedial Action Plan, the former Clean Up Rural Beaches Program, the Canada-Ontario Farm Stewardship Program and the Ontario Drinking Water Stewardship Program. Levels of phosphorous, for example, have declined significantly in the Bay of Quinte since the 1980's. Similarly, the amount of sediment loading has been decreased because of better land stewardship practices. Many of these initiatives encourage good land stewardship through incentives and education programs.

9.1.3 Water Quantity

The various stages of water budget analysis undertaken as part of the source protection exercise have garnered a much better understanding of the availability of water within the region. A particularly interesting discovery was that about two thirds of the water coming into the collective watersheds of the Quinte Region is lost through evaporation and transpiration. On average the equivalent of about one metre of precipitation falls in the area but only a third of that is available to recharge aquifers, to replenish lakes and rivers and to supply water for a range of uses throughout the region.

Another interesting finding was that stress on water quantity (for aquifers in particular) tends to be seasonal. In the typically dry months of summer and early fall the aquifers can become stressed but usually rebound almost immediately once precipitation or snow melt occurs. This finding was not reflected in the prescribed Tier 1 water budget methodology which generally indicated consistent low monthly stress throughout the year. Anecdotal evidence for the Prince Edward County Region suggests that many wells run dry during the dry summer months. Bulk water sales from water treatment plants in the region indicate that this occurs throughout the region. Future work will look at improving study methodology to identify areas that may be impacted more severely by seasonal changes.

Five of the Quinte Region's seven intakes draw their water either from the Bay of Quinte or Lake Ontario. These two bodies of water are interconnected and represent an enormous volume of water. Lake Ontario and the Bay of Quinte water levels have been regulated since 1960, primarily through the Moses-Saunders power dam near Cornwall and Massena. Barring a catastrophic failure of the control structure it is hard to imagine that stress on the water quantity would become an issue in the foreseeable future. One other potential concern might be the effect of climate change on the Great Lakes system in terms of water quantity. Should climate change result in consistently drier years, the overall impact could mean less water available from the Great Lakes.

Two municipal drinking systems showed enough potential stress after completion of the Tier 1 Water Budget exercise to warrant conducting a Tier 2 Water Budget (see Water Budget Methodology Chapter 3). The first system was the groundwater system for the Village of Madoc. One of the Village's wells ran dry in 2007 which would normally require the completion of a Tier 3 Water Budget. However after completing the Tier 2 Water Budget, it was determined that the well ran dry as a result of an operational error. Research and models undertaken showed that under normal operating conditions the well would not run dry. Through this work it was also indicated that under drought conditions the nearby creek assists in maintaining the pumping levels in the municipal wells. Future work should evaluate this occurrence and the potential for impact on the creek.

The second system reviewed in detail was the surface water intake at Roblin Lake in Prince Edward County. At the Tier 1 level it appeared that high water usage in the watershed could cause stress to the system. However through the

Tier 2 exercise it was realized that actual water usage was much less than the permitted amounts. Modeling of both surface water and groundwater input helped to determine that the lake itself had enough storage and inflow to reduce any chances of water shortage for this system.

9.1.4 Threats

Since the completion of the vulnerability mapping and scoring and the enumeration of Significant threats, it has become apparent that there are Significant threats that have been identified for each municipal system with the exception of Wellington. Twenty-one prescribed threats have been developed as part of the Technical Rules. A table of circumstances has been compiled that indicates when an activity in a particular vulnerable area becomes a Significant threat.

Chapters 5 and 6 enumerate the Significant threats for all the municipal drinking water systems in the Quinte Region. The original Assessment Report looked only at current landuse activities in the enumeration of Significant threats. The Assessment Report contains an analysis of several past activities and determined two sites (the closed Zwicks landfill and the closed Picton landfill) should be considered Significant threats. All Significant threats will be addressed in the Source Protection Plan.

9.1.5 Issues

Issues evaluation is an important component of the water quality analysis because it provides an extra measure of scrutiny to help determine any unexplained water quality concerns that show up in the sources of drinking water. The Source Protection Committee used its judgment regarding the information collected through this exercise because not all water quality concerns warrant the same level of response. For example, bacteria are commonly found in surface water sources but should not be prevalent in groundwater aquifers. As well, it is important to understand whether or not the water quality issue is a result of a natural cause or not is important.

The Source Protection Committee had to consider a number of other factors to determine if an issue exists, including treatability of the parameter and whether it can be explained by known existing threats.

After careful consideration and screening the following issues were identified by the Source Protection Committee:

- *E.coli*, Total Coliform, and Organic Nitrogen were identified as issues in raw water at the Madoc well supply

- Nitrate as an issue in the raw water at the Tweed supply.

The Source Protection Committee reviewed the regional water quality information for the highly vulnerable aquifers which indicated occurrence of bacteriological parameters, nitrates and chlorides in some private wells. These occurrences were primarily detected in areas of high density development (hamlets) and these problems may be attributed to substandard wells and septic systems.

Staff at Quinte Conservation identified sources of contamination and delineated the Issue Contributing Area.. Once a source is identified it automatically becomes a Significant threat when it is captured through the Issues Approach. The updated Source Protection Plan will address the Significant threats in the Issues Contributing Area..

9.2 Consideration for the Source Protection Plan

This Assessment Report forms the foundation of the Quinte Region Source Protection Plan which was submitted in August 2012. The Quinte Region Source Protection Committee l considered the scientific work collected for the Assessment Report, as well as the input and comments from stakeholder groups. The Committee also examined the financial implications and effectiveness of policies proposed in the Plan.

Although the Source Protection Plan focuses on the municipal residential drinking water systems, there will be secondary benefits derived from this process that will help to promote the protection of all sources of water in the Quinte Region.

9.3 Matters Requiring Additional Consultation with Other Source Protection Committees

The Quinte Source Protection Region is bordered by two other Source Protection Regions and one Source Protection Area. The Trent Conservation Coalition Source Protection Region lies to the west. The Mississippi Rideau Source Protection Region is situated to the north east. The Cataraqui Source Protection Area is adjacent to Quinte Source Protection Region's eastern boundary. During the Terms of Reference exercise 12 matters were identified as requiring additional consultation with neighbouring jurisdictions.

9.3.1 Matters Requiring Additional Consultation with all Three Neighbours:

1. Common Information Management Protocols

2. Coordinated approaches to communication, technical work and source protection planning
3. Approach to common groundwater resources
4. Common approach to conducting financial implications related to proposed Source Protection Policies

9.3.2 Matters Requiring Additional Consultation with the Trent Conservation Coalition Source Protection Region

1. Common approach to the Bay of Quinte technical studies
2. Addressing the portion of the Bayside Intake Protection zone that extends into Prince Edward County
3. Addressing issues related to the Trenton Water Treatment Plant which supplies water to several communities in Prince Edward County
4. Addressing any Lake Ontario or Bay of Quinte targets

9.3.3 Matters Requiring Additional Consultation with the Cataraqui Source Protection Area

5. Addressing any Lake Ontario or Bay of Quinte targets
6. Coordinating approach to the Town of Greater Napanee's water supplies because there are two intakes (one in each jurisdiction)
7. Working together to address any Bay of Quinte Remedial Action Plan targets related to Source Protection
8. Considering agreements, policies and emergency response plans when contemplating acute contamination results from a spill in one jurisdiction that affects another.

More details on these matters are available in the Quinte Region Terms of Reference February 2009 which can be found in Appendix A-1 of this report.

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