Long Point Region Source Protection Area

DRAFT UPDATED ASSESSMENT REPORT

Prepared on behalf of:
Lake Erie Region Source Protection Committee

Under the Clean Water Act, 2006
(Ontario Regulation 287/07)

October 5, 2017

400 Clyde Road, Cambridge, ON N1R 5W6 • www.sourcewater.ca

DOCUMENT AMENDMENTS

Amendments to this document, made under Ontario Regulation 287/07, Section 51 following approval on October 30, 2015, are summarized below:

DATE AMENDMENT POSTED	DESCRIPTION OF AMENDMENT
February 21, 2017	Identification of threats tables and associated text updated to reflect implementation of new provincial threats tool (www.swpip.ca)

EXECUTIVE SUMMARY

In July 2010 the Lake Erie Region Source Protection Committee released the Draft Long Point Region Source Protection Area Assessment Report for a 35-day public comment period, during which members of the public, municipalities and others had the opportunity to view the draft, attend public meetings and submit comments to the Committee. Comments received during the consultation period were taken into consideration by the Committee, and revisions to the document were made, where necessary. These revisions were reflected in the Proposed Long Point Region Source Protection Area Assessment Report.

The Proposed Assessment Report was posted for a second 30-day public comment period beginning October 8, 2010. All comments received during this second comment period were forwarded to the Ontario Ministry of the Environment with the submission of the Proposed Long Point Region Source Protection Area Assessment Report on November 25, 2010. The Long Point Region Source Protection Area Assessment Report received approval from the Ministry of the Environment on April 29, 2011.

When new information became available, revisions were made to the Updated Long Point Region Source Protection Area Assessment Report. This report was posted for a public comment period beginning on April 15, 2011. All comments received during this comment period were considered by the Lake Erie Region Source Protection Committee. The Ministry of the Environment approved the Updated Long Point Region Assessment Report on February 27, 2012.

Following the 2012 approval of the Updated Assessment Report further updates and new information has been added to the Long Point Region Assessment Report; these updates include new information regarding a nitrate Issue Contributing Area in Oxford County and a new drinking water system located in the Municipality of Bayham. A 30-day public consultation period took place from February 9 to March 10, 2015 and a separate, focused consultation was held from March 16 to April 10, 2015 for the new Elgin County – Municipality of Bayham section of the Assessment Report. The Long Point Region Source Protection Authority submitted the Updated Long Point Region Assessment Report to the Ministry of Environment and Climate Change for approval on June 3, 2015.

Following the June 2015 submission, additional comments were addressed and the Assessment Report was re-submitted for approval October 27, 2015. The Ministry of the Environment and Climate Change approved the Updated Long Point Region Assessment Report November 4, 2015.

New information has since been added to the Approved Updated Long Point Region Assessement Report; these updates include a Tier 3 Water Budget and Local Area Risk Assessment and Wellhead Protection Area (WHPA) updates in the communities of Delhi, Simcoe, Waterford and the Village of Richmond.

Comments received during all previous public consultation periods are summarized in **Appendix A**.

The Draft Updated Assessment Report is now posted for a 38-day public consultation period. All comments received during this comment period will be forwarded to the Ontario Ministry of the Environment and Climate Change with the submission of the Long Point Region Assessment Report. Comments on the Draft Updated Assessment Report can be sent to Martin Keller, Program Manager, until November 15, 2017:

comments@sourcewater.ca

Martin Keller, M.Sc.
Source Protection Program Manager
Lake Erie Source Protection Region
c/o Grand River Conservation Authority
400 Clyde Road, Box 729, Cambridge N1R 5W6
519-620-7595

The Assessment Report summarizes the technical studies undertaken in the Long Point Region Source Protection Area (watershed) to delineate areas around municipal drinking water sources that are most vulnerable to contamination and overuse. Within these vulnerable areas, historical, existing and possible future land use activities were identified that could pose a threat to municipal water sources. Technical studies include a characterization of the human and physical geography of the watershed, a water budget and water quantity stress and risk assessment, an assessment of groundwater and surface water vulnerability, a land use activity inventory, and an evaluation of existing water quality contamination Issues.

The Assessment Report provides an introduction to the Source Protection Planning process, and the roles and responsibilities of the Lake Erie Region Source Protection Committee, municipalities and conservation authorities. Section 2 of the Assessment Report provides a summary of the human and physical geography of the Long Point Region watershed area, while Section 3 summarizes the water quality risk assessment process and ~~budget and stress assessment findings. Section 4~~ summarizes groundwater vulnerability, including Highly Vulnerable Aquifer areas~~ and Significant Groundwater Recharge Areas~~. Sections 4, 5, 6 and 7 summarize the studies undertaken for the municipal residential drinking water systems in the Counties of Oxford, Norfolk, Haldimand and Elgin, respectively, including delineation of vulnerable areas (groundwater Wellhead Protection Areas and surface water Intake Protection Zones) and summaries of the threats assessment and Issues evaluation in each vulnerable area.

Sections 8, 9 and 10 summarize the results of water quantity studies undertaken, specifically the Tier 2 Water Budget and Local Area Stress Assessment and the Tier 3 Water Budget and Local Area Risk Assessment. Section 11 provides information on how climate change in the area may affect the results of the Assessment Report and how Great Lakes agreements were considered as part of the work undertaken. Sections 12 through 15 include the consideration of Great Lakes Agreements, conclusions, references and maps and citations, respectiviely.~~1 summarizes the findings in the Assessment Report and provides an outline of the next steps in developing a source protection plan for the Long Point Region Source Protection Area.~~

The Long Point Region watershed area contains ten municipal drinking water systems, sourced within the Region. Three systems are located in Oxford County in the communities of Dereham Centre, Oxford South (communities of Norwich, Otterville and Springford) and the Town of Tillsonburg, all of which are groundwater systems. Combined, the systems serve over 22,000~~19,000~~ people, the majority of which are in the Town of Tillsonburg.

Norfolk County has five municipal-residential drinking water systems in the communities of Delhi, Port Dover, Port Rowan, Simcoe and Waterford. The Delhi system draws water from both surface and groundwater sources. Port Dover and Port Rowan draw water from intakes in Lake Erie. The communities of Simcoe and Waterford rely solely on groundwater sources. In total, approximately 34,600~~2,200~~ people rely on municipal water supplies in Norfolk County, which represents almost half of the total population.

One municipal-residential drinking water system is located in the portion of Haldimand County that falls in the Long Point Region watershed area. The Nanticoke water system, operated by Haldimand County, draws water from Lake Erie. The system serves the communities of Hagersville, Jarvis, Townsend, and the New Credit Reserve, as well as the Lake Erie Industrial Park.

Elgin County has one municipal residential drinking water system, located in the Municipality of Bayham that serves the village of Richmond. The system is a groundwater system and serves approximately 140~~50~~ people ~~homes~~ in the village of Richmond.

The findings of the Tier 2 Water Budget and Stress Assessment studies indicated that three municipal water systems required additional Tier 3 Water Quantity Stress Assessments (Tier 3 Assessments): Delhi-Courtland, Simcoe, and Waterford in Norfolk County. The subwatersheds within which these water supplies fall were assessed as having either the potential for moderate or significant stress under current or future conditions. The Tier 3 Water Quantity Risk~~Stress~~ Assessment for these three systems was completed in April 2015. The Tier 3 Assessment identified a “significant” water quantity risk for the Simcoe water supply. To follow up on the significant risk classification a technical study, ~~also called~~ referred to as a Risk Management Measures Evaluation Process (RMMEP), was ~~undertaken and~~ completed in November 2016. This process ~~is used to~~ identified and ranked ~~the~~ water quantity threats to the Simcoe municipal supplies ~~-~~and ~~select and~~ evaluated which Water Quantity Risk Management Measures (RMM)~~, using the water budget model developed in the Tier 3 Assessment, to determine what measures can~~ could be used to effectively manage ~~the~~ water quantity risks to ~~drinking water~~the Simcoe supply. ~~Information from the Tier 3 Water Quantity Stress Assessments will be added to a future Updated Assessment Report.~~

~~An additional study was undertaken in 2010 to gather more detailed information on the Simcoe Nitrate Issue Contributing Area. As well, revisions have occurred to the delineations of the Nanticoke and Lehman Intake Protection Zone-2s and to the vulnerability scoring within the County of Oxford. In 2014 a study was undertaken to delineate a Nitrate Issue Contributing Area for wells located to the north of the Town of Tillsonburg.~~ Four additional water quality technical studies have been undertaken since approval of the Long Point Region Assessment Report in November 2015:

- 2017 – The 2016 nitrate monitoring report assessing nitrate concentrations related to municipal wells in the Village of Richmond (Municipality of Bayham);
- 2017 – Wellhead Protection Area (WHPA) delineations, vulnerability and threats assessment for two new wells in the Delhi Drinking Water System;
- 2017 – WHPA updates to wells in the Simcoe (Norfolk County) Drinking Water System;
- 2017 – WHPA updates to wells in the Waterford (Norfolk County) Drinking Water System.

The results of the technical studies and information contained in the Assessment Report have been used to develop and revise policies to protect sources of municipal drinking water. These policies have been developed under the leadership of the Lake Erie Source Protection Committee by municipality and conservation authority staff, in consulation with property and business owners, farmers, industry, health officials, community groups and others working together to develop a fair, practical and implementable Source Protection Plan. Public input and consultation has played a significant role throughout the process.~~–~~The Updated Long Point Region Assessment Report was submitted for approval October 27, 2015. The Ministry of the

Environment and Climate Change approved the Updated Long Point Region Assessment Report November 4, 2015.~~The Proposed Source Protection Plan was submitted to the Minister of the Environment in December 2012. The Ministry of the Environment provided comments on the proposed plan in July 2014. The Amended Proposed Long Point Region Source Protection Plan was re-submitted to the Minister of the Environment and Climate Change for approval on June 3, 2015~~.

Note: In June 2014, the Ministry of the Environment changed its name to the Ministry of the Environment and Climate Change and the Ministry of Natural Resources changed its name to the Ministry of Natural Resources and Forestry. The new and former names of both Ministries are used within this document.

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1.0 INTRODUCTION

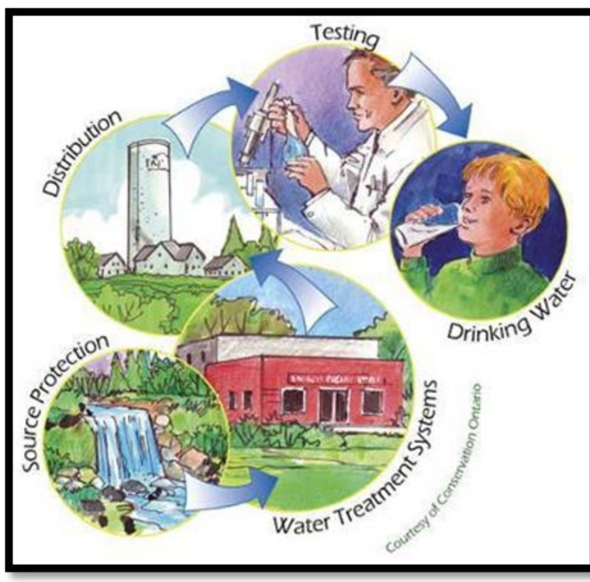
Following the public inquiry into the Walkerton drinking water crisis in May 2000, Justice Dennis O'Connor released a report in 2002 containing 121 recommendations for the protection of drinking water in Ontario. Since the release of the recommendations, the Government of Ontario has introduced legislation to safeguard drinking water from the source to the tap, including the *Clean Water Act* in 2006. The Act provides a framework for the development and implementation of local, watershed-based source protection plans, and is intended to implement the drinking water source protection recommendations made by Justice Dennis O'Connor in Part II of the Walkerton Inquiry Report. The Act came into effect in July 2007, along with the first five associated regulations.

The intent of the *Clean Water Act, 2006* is to ensure that communities are able to protect their municipal drinking water supplies now and in the future from overuse and contamination. It sets out a risk-based process on a watershed basis to identify vulnerable areas and associated drinking water threats and Issues. It requires the development of policies and programs to reduce or eliminate the risk posed by significant threats to sources of municipal drinking water through science-based source protection plans.

Source Protection Committees are working in partnership with municipalities, Conservation Authorities, water users, property owners, the Ontario Ministry~~ies~~ of the Environment and Climate Change (MOECC), ~~and~~ Ministry of Natural Resources and Forestry (MNRF), and other stakeholders to facilitate the development of local, science based source protection plans.

The *Clean Water Act, 2006* and Drinking Water Source Protection are one component of a multi-barrier approach to protecting drinking water supplies in Ontario. The five steps in the multi-barrier approach include:

- **Source water protection**
- Adequate treatment
- Secure distribution system
- Monitoring and warning systems
- Well thought-out responses to adverse conditions



After the Walkerton Inquiry, the Government of Ontario enacted the *Safe Drinking Water Act, 2002*, which provides new requirements and rules for the treatment, distribution and testing of municipal drinking water supplies. Together, the *Clean Water Act, 2006* and *Safe Drinking Water Act, 2002*, along with their associated regulations, provide the legislative and regulatory framework to implement the multi-barrier approach to municipal drinking water protection in Ontario.

The protection of municipal drinking water supplies through the *Clean Water Act, 2006* is one piece of a much broader environmental protection framework in Ontario. Water resources in Ontario are protected directly and indirectly through the federal and provincial governments, municipalities, conservation authorities and public health units. These agencies are responsible for protecting and improving water quality, water quantity and aquatic habitats, providing land use planning and development rules to ensure that water resources are not negatively affected, providing flood management and responses to low water availability, and many others. For more information on how water resources are protected in Ontario, please visit www.ontario.ca/ministry-environment-and-climate-change or call 1-800-565-4923.

1.1 Source Protection Planning Process

The key objectives of this process are the completion of science-based Assessment Reports that identify the risks to municipal drinking water sources, and locally-developed Source Protection Plans that put policies in place to reduce the risks to protect current and future sources of drinking water.

Since 2005, municipalities and conservation authorities have been undertaking studies to delineate areas around municipal drinking water sources that are most vulnerable to contamination and overuse. Within these vulnerable areas, technical studies have identified historical, existing and possible future land use activities that are or could pose a threat to municipal water sources. This Assessment Report is a compilation of the findings of the technical studies undertaken in the Long Point Region Source Protection Area (watershed area).

The Draft Long Point Region Assessment Report was posted for a 35-day public consultation period in July 2010. During this time members of the public, municipalities and other interested bodies had the opportunity to provide comments on the draft report. All comments received during this period were considered by the Lake Erie Region Source Protection Committee and revisions to the document were made. The Proposed Long Point Region Assessment Report was then posted for a second period of public consultation in October 2010. The Proposed Long Point Region Assessment Report was submitted to the Ministry of the Environment on November 25, 2010. The Long Point Region Assessment Report received approval from the Ministry of the Environment on April 29, 2011.

An Updated Assessment Report (*June 16, 2011*) was submitted to the Ministry of the Environment on July 7, 2011. This occurred when new information created the need to update the Long Point Region Source Protection Area Assessment Report. Following minor clarifications requested by the Ministry of the Environment, the Updated Assessment Report (*December 15, 2011*) was re-submitted by the Long Point Region Source Protection Authority in January 2012 and was approved by the Ministry of the Environment on February 27, 2012.

In 2014, further studies were undertaken to better delineate the wellhead protection areas for wells located in the Tillsonburg North wellfield and a new section characterizing a municipal drinking water system serving the Municipality of Bayham was added. The Draft Updated Assessment Report was posted for a 30-day public consultation period from February 9 to March 10, 2015. A separate, focused consultation was held from March 16 to April 10, 2015 for the new Municipality of Bayham section that has been added to the Assessment Report. The comments and feedback received during the comment period were reviewed by the Source

Protection Committee and considered in the finalization of this report. The Long Point Region Source Protection Authority submitted the Proposed Updated Assessment Report to the Minister on June 3, 2015. For details on the public comment periods and public consultation meetings, please see **Section 1.7.**

Following the June 2015 submission, additional comments were addressed and the Assessment Report was re-submitted for approval October 27, 2015. The Ministry of the Environment and Climate Change approved the Updated Long Point Region Assessment Report November 4, 2015.

New information has since been added to the Approved Updated Long Point Region Assessement Report; these updates include a Tier 3 Water Budget and Local Area Risk Assessment and Wellhead Protection Area (WHPA) updates in the communities of Delhi, Simcoe, Waterford and the Village of Richmond.

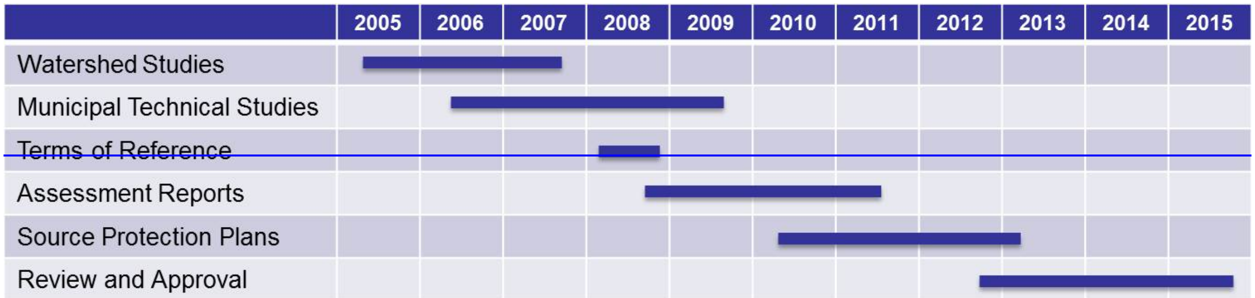
The Source Protection Plan is a document that contains policies to protect sources of drinking water against threats identified in the Assessment Report. The Plan sets out:

- how the risks posed by drinking water threats will be reduced or eliminated;
- policy, threat and Issues monitoring programs;
- who is responsible for taking action;
- timelines for implementing the policies and programs; and
- how progress will be measured.

The task of plan development involved municipalities, conservation authorities, property and business owners, farmers, industry, health officials, community groups and others working together to develop a fair, practical and implementable Source Protection Plan. Public input and consultation played a significant role throughout the process.

~~As illustrated in **Figure 1-1**, technical studies and the development of the Source Protection Plan has taken a number of years. The Source Protection Plan was submitted to the Minister of Environment on December 6, 2012 for review and approval. Revisions to the Source Protection Plan as a result of Ministry review comments received were consulted on together with changes to this Updated Assessment Report.~~

Following ~~After approval of the~~ Source Protection Plan approval, annual progress ~~monitoring~~ reports ~~and progress reports~~ on implementation are~~will be~~ required. Implementation of the Source Protection Plan~~,~~ is ~~once it has been approved by the Minister of the Environment, will be~~ led by municipalities and provincial agencies in most cases. In some cases, conservation authorities, public health units, or other organizations may be involved in implementing policies in the Source Protection Plans. The implementers ~~will be able to~~ use a range of voluntary and regulatory programs and tools, including education and outreach; incentive programs; land use planning (zoning by-laws, and Official Plans); new or amended provincial instruments; Risk Management Plans; and prohibition. Actions to reduce the risk posed by activities found to be significant threats are ~~will be~~ mandatory, since the *Clean Water Act, 2006* requires that all identified significant threats cease to be significant. ~~significant.~~



~~Figure 1-1: Source Protection Timeline~~

1.2 Source Protection Authorities and Regions

The province has organized the Source Protection Program using watershed boundaries, rather than municipal or other jurisdictions. The watershed boundary is the most appropriate scale for water management, since both groundwater and surface water flow across political boundaries. For Source Protection planning purposes, the watershed is referred to as a Source Protection Area under the *Clean Water Act, 2006*. The Long Point Region watershed area is called the Long Point Region Source Protection Area. Similarly, conservation authorities are referred to as Source Protection Authorities under the *Clean Water Act, 2006* and are responsible for facilitating and supporting the development of source protection plans.

For the purposes of source protection, the Long Point Region Source Protection Authority is partnered with the Catfish Creek Source Protection Authority, Kettle Creek Source Protection Authority and Grand River Source Protection Authority to create the Lake Erie Source Protection Region. The Lake Erie Source Protection Region is one of 19 regions established across the province. The Grand River Source Protection Authority acts as the lead Source Protection Authority in the Lake Erie Region.

1.3 Source Protection Committee

In the Long Point Region Source Protection Area, the Source Protection Planning process is being led by a multi-stakeholder steering committee called the Lake Erie Region Source Protection Committee. The Committee was formed in November 2007, and met monthly until the Proposed Grand River Source Protection Plan was submitted to the Ministry of the Environment in December 2012. Since then the Committee has continued to meet on a quarterly basis. The Committee is responsible for directing the development and update of the Assessment Reports and Source Protection Plans and annual reporting for each of the four Source Protection Areas in the Lake Erie Region. The list of current and past members is summarized in **Table 1-1.**

Table 1-1: Current and Past Members of the Lake Erie Region Source Protection Committee

Name	Seat Held	Appointment	Joined	Resigned
Wendy Wright-Cascaden	~~Acting~~ Chair	~~Lake Erie Region Source Protection Committee~~ Minister of the Environment and Climate Change	Nov~~Sep~~, 2016~~5~~	-
Wendy Wright-Cascaden	Acting Chair	Lake Erie Region Source Protection Committee	Sep, 2015	Nov, 2016

Table 1-1: Current and Past Members of the Lake Erie Region Source Protection Committee

Name	Seat Held	Appointment	Joined	Resigned
Craig Ashbaugh	Chair	Minister of the Environment	Nov, 2007	Jul, 2015
Brad Carberry	Agriculture	Agricultural Community	Aug, 2017	-
Peter Busatto	Municipal	City of Guelph	Nov, 2012	Sep, 2013
Marguerite Ceschi-Smith	Public Interest	Grand River Source Protection Authority	Nov, 2007	Sep, 2014
Howard Cornwell	Municipal	Perth, Oxford	Nov, 2007	-
Alan Dale	Public Interest	Grand River Source Protection Authority	Jan, 2012	-
Paul General	First Nations	Six Nations of the Grand River	Nov, 2007	-
Mark Goldberg	Public Interest	Grand River Source Protection Authority	Nov, 2007	Nov, 2011
Roy Haggart	Municipal	Brant, Brantford, Hamilton	Nov, 2007	-
John Harrison	Public Interest	Grand River Source Protection Authority	Nov, 2007	Jun, 2012~~-~~
Andrew Henry	Public Interest	Elgin Area Primary Water Board	Nov, 2007	-
Carl Hill	First Nations	Six Nations of the Grand River	May, 2016	-
Darryl Hill	First Nations	Six Nations of the Grand River	Apr, 2012	Nov, 2015~~-~~
Eric Hodgins	Municipal	Grand River Source Protection Authority	May, 2016	-
Ken Hunsberger	Agriculture	Agricultural Community	Nov, 2007	-
Robert E. Johnson	First Nations	Six Nations of the Grand River	Mar, 2011	Apr, 2011
Casey Jonathan	First Nations	Mississaugas of the New Credit	Feb, 2016	-
Jim Kirchin	Public Interest	Grand River Source Protection Authority	Mar, 2015	-
Ralph Krueger	Business and Industry	Grand River Source Protection Authority	Nov, 2007	-
Clynt King	First Nations	Mississaugas of the New Credit	Mar, 2011	Dec, 2015~~-~~
Bryan LaForme	First Nations	Mississaugas of the New Credit	Nov, 2007	Mar, 2011
Janet Laird	Municipal	City of Guelph	Nov, 2007	Nov, 2012
Ian MacDonald	Business and Industry	Grand River Source Protection Authority	Nov, 2007	-
Christ Martin	First Nations	Six Nations of the Grand River	Nov, 2007	Nov, 2010
George Montour	First Nations	Six Nations of the Grand River	Apr, 2011	Jan, 2012
Dale Murray	Municipal	Grey, Dufferin, Halton, Wellington	Nov, 2007	Jul, 2016~~-~~
Thomas Nevills	Public Interest	Grand River Source Protection Authority	May, 2017	-
Jim Oliver	Municipal	Haldimand, Norfolk	Nov, 2007	-
David Parker	Agriculture	Agricultural Community	Nov, 2007	Mar, 2016~~-~~
Lloyd Perrin	Municipal	Elgin, Middlesex, London	Nov, 2007	-
Phil Wilson	Public Interest	Nanticoke Grand Valley Water Supply	Nov, 2007	-
Geoff Rae	Public Interest	Nanticoke Grand Valley Water Supply	Nov, 2007	Jul, 2010
Peter Rider	Municipal	City of Guelph	Oct, 2013	-
Richard Seibel	Aggregate Industry	Ontario Stone, Sand & Gravel Assoc.	Nov, 2007	Aug, 2011
Thomas Schmidt	Municipal	Waterloo Region	Nov, 2007	Mar, 2016~~-~~
George Schneider	Aggregate	Ontario Stone, Sand & Gravel Assoc.	Oct, 2011	-

Table 1-1: Current and Past Members of the Lake Erie Region Source Protection Committee

Name	Seat Held	Appointment	Joined	Resigned
	Industry			
Bill Strauss	Public Interest	Grand River Source Protection Authority	Jul, 2012	-
Bill Ungar	Business and Industry	Grand River Source Protection Authority	Nov, 2007	-
Mark Wales	Agriculture	Agricultural Community	Nov, 2007	-
Don Woolcott	Public Interest	Grand River Source Protection Authority	Nov, 2007	-
Wendy Wright-Cascaden	Public Interest	Grand River Source Protection Authority	Nov, 2007	Sep, 2015~~-~~

Message from the Committee

The overall objective of the Lake Erie Region Source Protection Committee, in partnership with local communities and the Ontario government, is to direct the development of source protection plans that protect the quality and quantity of present and future sources of municipal drinking water in the Lake Erie Source Protection Region. We will work with others to gather technical and traditional (local and aboriginal) knowledge on which well-informed, consensus-based decisions can be made in an open and consultative manner. In developing the Source Protection Plan, the Lake Erie Region Source Protection Committee intends to propose policies that are environmentally protective, effective, economical, and fair to local communities.

The committee will strive to develop policies that are practical and implementable, and that focus limited resources on areas that net the greatest benefit, while recognizing that the plan must address significant threats so that they cease to be significant. Where possible, the committee will strive to develop policies and programs that also provide a benefit to broader protection of water quality and quantity. The process to assess drinking water threats and Issues will be based on the best available science, and where there is uncertainty, we will strive to follow the precautionary approach.

The Committee's Terms of Reference for the Long Point Region Source Protection Area Assessment Report and Source Protection Plan was submitted to the Minister of the Environment in December 2008. The Terms of Reference sets out the work plan for completing both the Assessment Report and Source Protection Plan, and received Ministerial approval on July 13, 2009. A copy of the Long Point Region Source Protection Area Terms of Reference can be found at: www.sourcewater.ca.

1.4 Financial Assistance

Section 97 of the *Clean Water Act, 2006* establishes the Ontario Drinking Water Stewardship Program. The purpose of the program is to provide financial assistance to those whose activities and properties may be affected by the implementation of the Source Protection Plan. The program also provides for outreach and education programs to raise awareness of the importance and opportunities for individuals to take actions to protect sources of drinking water. Ontario Regulation 287/07 (General) further clarifies the details of the Ontario Drinking Water Stewardship Program.

Under this program, Early Action Programs funded by the Ministry of the Environment have directed grants to landowners within close proximity to municipal wells or surface water intakes to undertake projects to reduce existing potential contamination sources. Communications and outreach efforts have also occurred to persons and businesses in these areas. The program had funding through 2013 to provide grants to undertake Early Response Programs to address significant drinking water threats identified in the Long Point Region Source Protection Area Proposed Assessment Report, in advance of approved source protection plans. ~~The Lake Erie Region Source Protection Committee will continue to request that the province fund the program beyond 2013 in order to provide financial assistance to property owners affected by new policies and risk reduction strategies that may result from approved source protection plans~~.

1.5 Framework of the Assessment Report

The Long Point Region Source Protection Area Assessment Report was completed in compliance with Ontario Regulation 287/07 (General) under the *Clean Water Act, 2006*, which sets out the minimum requirements for Assessment Reports. In addition, the technical work summarized in this Assessment Report was completed in conformance with the Technical Rules: Assessment Report under O.Reg. 287/07. The technical work was undertaken by municipalities and the Grand River Conservation Authority, as the lead source protection authority in the Lake Erie Source Protection Region. Funding to complete the technical studies for the Assessment Report was provided by the Ministry of the Environment and Climate Change~~Province of Ontario~~.

Within the Long Point Region Source Protection Area (SPA), the Counties of Elgin, Haldimand, Norfolk and Oxford supply drinking water through ten municipal drinking water systems, sourced within the Region. Six systems draw water from groundwater sources; one system is supplied from both groundwater and surface water (North Creek in the Big Creek watershed); and three systems are supplied by intakes in Lake Erie.

The *Clean Water Act, 2006* focuses on the protection of municipal drinking water supplies; however, the Act allows for other water systems to be considered, including clusters of private wells, communal systems, and other non-municipal supplies. Only municipalities within which the supplies are located or the Minister of the Environment have the power to add non-municipal systems. To date, no municipalities in the Long Point Region Source Protection Area have designated non-municipal drinking water supplies under the *Clean Water Act, 2006*.

The technical studies summarized in this Assessment Report start with information at the watershed scale, and then move to the municipal drinking water system scale. The document is organized into the following sections: Watershed Characterization; ~~Water Budget and Water Quantity Stress Assessment;~~ Water Quality Risk Assessment (including Groundwater Vulnerability, Wellhead Protection Areas and Intake Protection Zones); Water Quantity Process, Tier 2 Water Budget, Tier 3 Water Budget, State of Climate Change Research; Great Lakes Considerations; and Conclusions.

The descriptions of the technical work provided in the Assessment Report are summaries of more detailed technical reports. In order to find more detail on any of the components of the Assessment Report, the reader is encouraged to view the technical studies and background reports available online in full at www.sourcewater.ca.

1.6 Continuous Improvement

The findings of this ~~Updated~~ Assessment Report are based on the best available information. It is recognized that new information that informs the findings of this Assessment Report will become available in the future. Beyond the completion of this Assessment Report, municipalities and conservation authorities will continue to refine and improve the findings, and attempt to address the data gaps documented in this report. As new or improved information becomes available, the relevant components of the Assessment Report will be amended as required. Opportunities for input and review of updated Assessment Reports will be made available to those affected by the proposed changes.

1.7 Public Consultation

Throughout the development of the Long Point Region Assessment Report there have been multiple periods of public consultation. During each consultation period members of the public, municipalities and other interested bodies were invited to review the Assessment Report documents. These documents were made available via the www.sourcewater.ca website and hard copies were also available at the conservation authority and municipal administrative offices. A series of public meetings were also held during each public consultation period. **Table 1-2** below provides details regarding each of the public consultation periods held regarding the Long Point Region Assessment Report.

Table 1-2: Long Point Region Assessment Report – Public Consultation Periods

Document / Notice	Notification Date	Consultation Period	Public Meetings	
			Date	Location
Draft Assessment Report	Jul 9, 2010	Jul 9, 2010 – Aug 17, 2010	Aug 5, 2010	Long Point Region Conservation Authority, Tillsonburg
			Aug 10, 2010	Talbot Gardens Arena (Simcoe)
Proposed Assessment Report	Mar 5, 2010	Mar 5, 2010 – Apr 9, 2010	N/A *	N/A *
Draft Updated Assessment Report	Apr 15, 2011	Apr 15, 2011 – May 21, 2011	May 9, 2011	Talbot Gardens Arena (Simcoe)
Updated Assessment Report	Feb 9, 2015	Feb 9, 2015 – Mar 10, 2015	Feb 17, 2015	Long Point Region Conservation Authority, Tillsonburg
			Feb 19, 2015	Simcoe Recreation Centre
Updated Assessment Report: Elgin County – Municipality of Bayham Section	Mar 16, 2015	Mar 16, 2015 – Apr 10, 2015	Mar 26, 2015	Richmond United Church

Draft Updated Assessment Report	Oct 9,2017	Oct 9, 2017 – Nov 15, 2017	Nov 1, 2017	Simcoe Recreation Centre Arena
			Nov 2, 2017	To Be Determined

* no public meeting required – comments received were appended to the submission package

During each period of public consultation members of the public, municipalities or other interested bodies were able to submit comments to the Source Protection Committee. Comments could be submitted via regular mail, e-mail, fax, or in person at a public consultation meeting. The Committee in turn, considered these comments following each period of public consultation.

All comments received by the Source Protection Committee during periods of public consultation are included in Appendix A.

The Draft Updated Assessment Report is now posted for a 38-day public consultation period between October 9, 2017 and November 15, 2017. The public is invited to review the Assessment Report on www.sourcewater.ca, during public open houses, or at the Long Point Region Conservation Authority where hard copies will be made available.

The public can submit comments on the Assessment Report at public open houses, by email (comments@sourcewater.ca), or by regular mail to:

Martin Keller, M.Sc.
Source Protection Program Manager
Lake Erie Source Protection Region
c/o Grand River Conservation Authority
400 Clyde Road, Box 729, Cambridge ON N1R 5W6

All comments received during this comment period will be forwarded to the Ontario Ministry of the Environment and Climate Change with the submission of the Long Point Region Assessment Report.

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2.0 WATERSHED CHARACTERIZATION

Understanding the human and physical characteristics of a watershed is important to protecting and managing its water. Interactions between surface water, groundwater, potential sources of contamination, and the overuse of water require an understanding of the physical characteristics of the bedrock and surficial geology, physiographic regions, climate and significant natural features within the watershed. Additionally, how the people of the watershed interact with these physical characteristics plays an ever-increasing role in determining the overall health of the ecosystem. The following sections are intended to provide information on the physical and human characteristics of the Long Point Region watershed area.

2.1 Lake Erie Source Protection Region

In an effort to share knowledge and resources for the purpose of developing source protection plans, a partnership was formed in 2004 between the Grand River, Long Point Region, Catfish Creek and Kettle Creek Conservation Authorities to form the Lake Erie Source Protection Region. The partnership was formalized in 2007 by Ontario Regulation 284/07 (Source Protection Areas and Regions) under the *Clean Water Act, 2006*. The Grand River Conservation Authority, referred to in the regulation as the Grand River Source Protection Authority, acts as the lead source protection authority for the region.

Map 2-1 shows the areal extent of ~~covered by~~ the Lake Erie Source Protection Region, including municipal boundaries and main rivers and tributaries. The four Source Protection Authorities agreed to jointly undertake research, public education, and watershed planning and management for the advancement of drinking water source protection for the respective watersheds. The watersheds have a long history of partnership and cooperation, and also have a natural association by containing the majority of inland rivers and streams flowing from Ontario directly into Lake Erie.

With a population of more than 1 million people (Statistics Canada Census 2006 & 2017; GSP Group, 2010), the Lake Erie Source Protection Region represents a diverse area, ranging from intense agricultural production to large and rapidly expanding urban areas. The region spans an area from the City of St. Thomas in the west, to Halton Hills on the east, and as far north as the community of Dundalk. The area includes, in whole or in part, 49 upper, lower and single tier municipalities, as well as two First Nations communities (LPRCA, 2008). **Table 2-1**~~and~~ ~~**Table 2-2**~~ lists the municipalities~~, population and population projections~~ in the Long Point Region Watershed Area.

2.2 Long Point Region Source Protection Area

The Long Point Region watershed area covers an area of approximately 2,900 km^2 in Southern Ontario. **Map 2-2** shows the several watercourses and watersheds that ~~make up~~form Long Point Region, each with their own unique traits and values. The combined length of all the streams and their tributaries equals over 3,700 km. The Long Point Region watershed area is almost 100 km at its widest point and 60 km running north to south. The Region spans ~~and has~~ 225 km of Lake Erie shoreline, including the internationally renowned Long Point sand spit.

The ground surface elevation ranges from 357 m above sea level in the northwest (west of Norwich), to 169 m above sea level in the southeastern limits of the ~~study area~~Long Point Region along the Lake Erie shoreline. Moderate relief is apparent in the central part of the ~~study area~~Region (north of Tillsonburg, Otterville, Courtland, and Waterford) corresponding to the Tillsonburg, Courtland, St. Thomas and Paris moraines.

Flat plains, which are characteristic of the Long Point Region, attracted early settlers ~~were attracted to the area due to the presence of flat plains, which were more~~because they were easily cleared. Other attractions were the transportation afforded by Lake Erie, the abundance of fish, wildlife, and fur as well as the moderate climate. The ~~subsequent alteration~~clearing of the plains and harvest of the surrounding heavily forested lands has had a significant impact on ~~the~~ modern day surface and groundwater quality and quantity.

Although there are two First Nations communities located in the Lake Erie Region, neither of these communities are in the Long Point Region Watershed. As such, a map representing the First Nations communities is not included in the Long Point Region Source Protection Area Assessment Report.

2.3 Population, Population Density and Future Projections

According to the ~~2006~~ 2016 Statistics Canada Census, the Long Point Region watershed area had a population of approximately ~~112,893~~113,808 people. **Table 2-2** shows a ~~breakdown~~ summary of the population in each municipality for the area that falls within the Long Point Region boundaries. **Table 2-2** ~~also~~ summarizes the 2026 and 2056 population projections by municipality. The 2026 projections are based on municipal population projection estimates from municipal official plans, master servicing plans or other municipal documents from 2006. The same growth rates and assumptions used for the 2026 projections were applied for the period up to 2056 to estimate the 2056 projections. A detailed summary of population and population projections in the Long Point Region watershed area is provided in the report entitled *Grand River, Long Point Region, Catfish Creek and Kettle Creek Watershed Areas: Population Forecasts, January 2010*, available online at www.sourcewater.ca.

Table 2-1: Municipalities in the Long Point Region Watershed Area

Upper/Single Tier Municipality	Lower Tier Municipality
Oxford County	Township of Southwest Oxford
	Town of Tillsonburg
	Township of Norwich
County of Brant	
Norfolk County	
Haldimand County	
Elgin County	Municipality of Bayham
	Township of Malahide

Table 2-2: Population and Population Projections in the Long Point Region Watershed Area

Municipality	~~2006~~ 2016 Population*	2026 Projection*	2056 Projection*
County of Brant	~~1,360~~1,285	1,456	1,616
Haldimand County	~~11,416~~12,182	12,811	14,766
Norfolk County	~~66,643~~64,044	71,996	87,488
Township of Norwich	~~11,001~~9,791	11,020	13,610
Township of Southwest Oxford	~~2,206~~2,517	2,681	3,357
Town of Tillsonburg	~~14,822~~15,872	20,600	27,700
Municipality of Bayham	~~6,689~~7,396	8,713	11,561
Township of Malahide	~~670~~721	909	1,266
Total	~~112,893~~113,808	130,186	161,364

Source: Statistics Canada Census, ~~2006~~2016; GSP Group Inc., 2010.
*~~Total population and projected~~ Projected population within Long Point Region watershed area boundary by municipality based on 2006 projections.

~~**Table 2-3: Population Density in the Long Point Region Watershed Area**~~

~~Municipality/Reserve~~	~~2006 Population Density (people/km^2)*~~	~~2026 Projected Population Density (people /km^2)*~~	~~2056 Projected Population Density (people /km^2)*~~
~~County of Brant~~	~~9.7~~	~~10.4~~	~~11.5~~
~~Haldimand County~~	~~26.3~~	~~29.5~~	~~34.0~~
~~Norfolk County~~	~~42.4~~	~~45.8~~	~~55.6~~
~~Township of Norwich~~	~~27.7~~	~~33.6~~	~~41.5~~
~~Township of Southwest Oxford~~	~~20.3~~	~~24.7~~	~~30.9~~
~~Town of Tillsonburg~~	~~672.6~~	~~934.8~~	~~1257.0~~
~~Municipality of Bayham~~	~~27.5~~	~~35.9~~	~~47.6~~
~~Township of Malahide~~	~~18.7~~	~~25.4~~	~~35.4~~

~~Source: Statistics Canada Census, 2006; GSP Group Inc., 2010.~~
~~*Prorated to the area of the municipality that falls within the Long Point Region Watershed~~

The population of the watershed that receives municipal water supplies is approximately 61,720, which represents over 54 percent of the 2016 watershed population. **Table 2-3** provides a breakdown of the serviced population by municipality for ~~2006~~2016.

Table 2-3: ~~2006~~ 2016 Municipally-Serviced Population in the Long Point Region Watershed Area

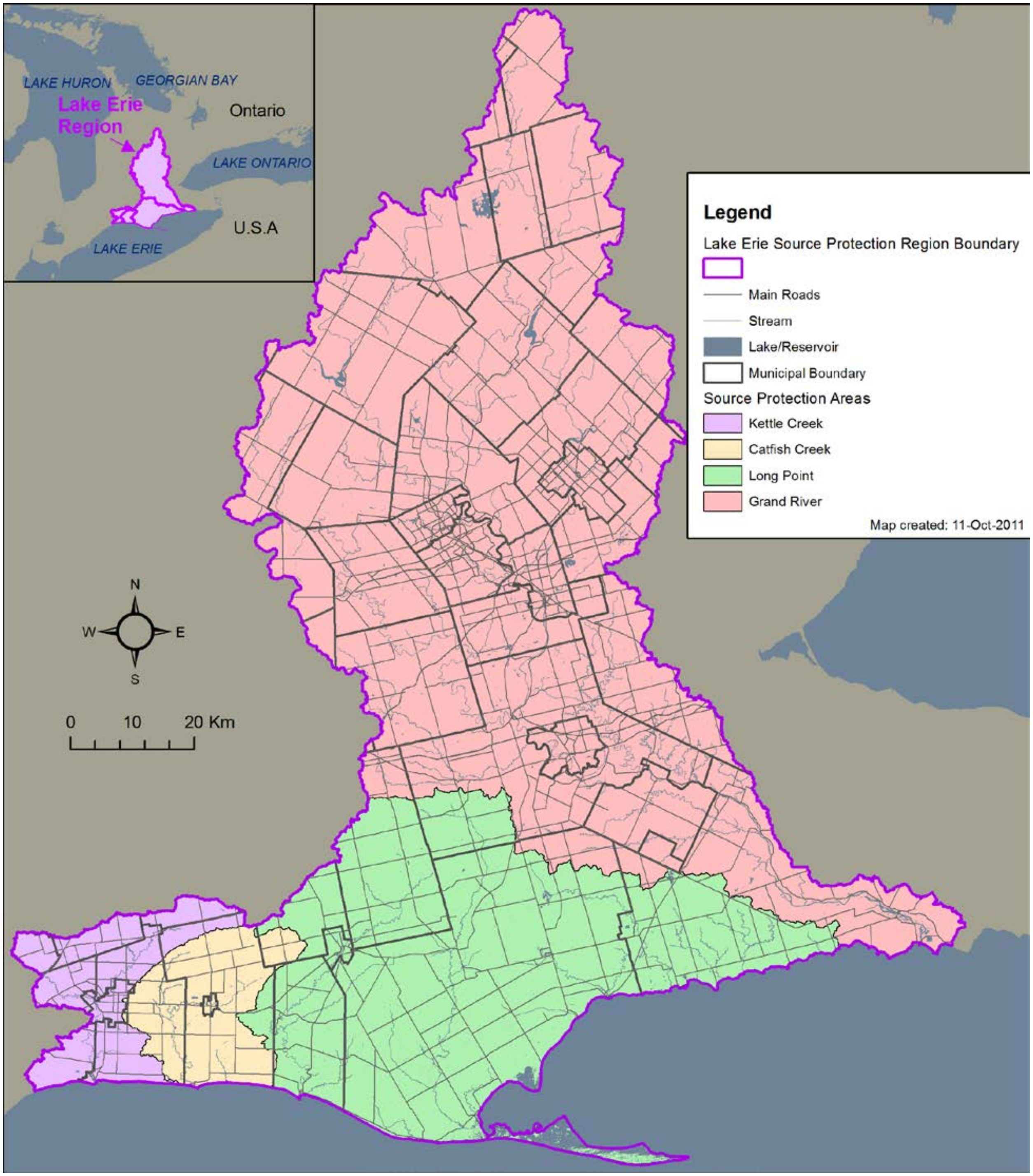
Municipality	2016~~06~~ Population*
County of Brant	0
Haldimand County	~~5,130~~5,092**
Norfolk County	~~32,220~~34,018***
Township of Norwich	~~4,306~~4,943
Township of Southwest Oxford	227~~188~~
Town of Tillsonburg	~~14,822~~16,340
Municipality of Bayham	1,100
Township of Malahide	0

Total	**61,720**

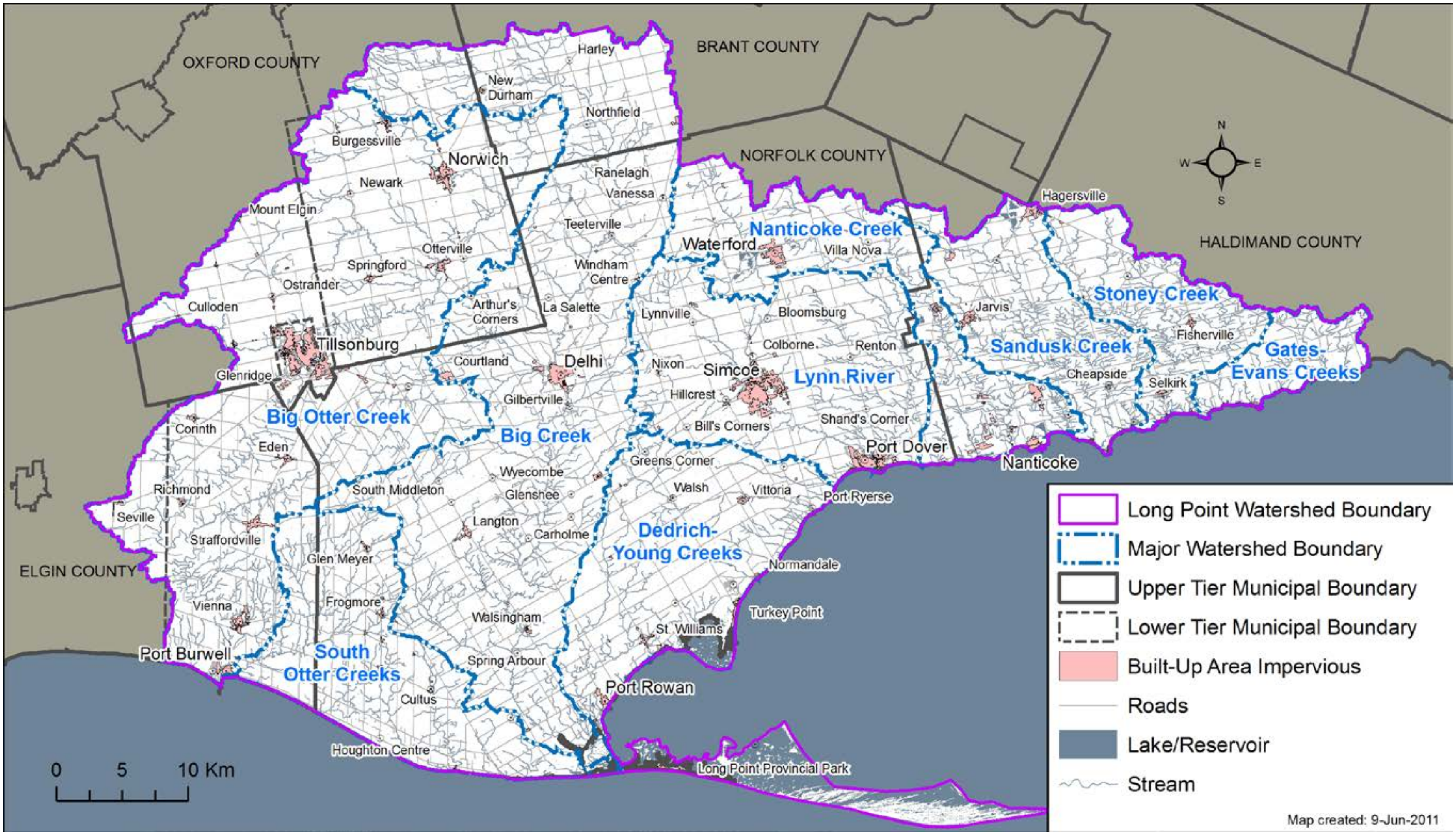
Source: Statistics Canada Census, 2006; GSP Group Inc., 2010.
*Population receiving municipality serviced drinking water within Long Point Region watershed area boundary by municipality
**Haldiman County population based on 2011 data
***Norfolk County population based on 2017 data

There are no residents in Brant County or Township of Malahide that are within the Long Point Region watershed that are serviced by municipal drinking water.

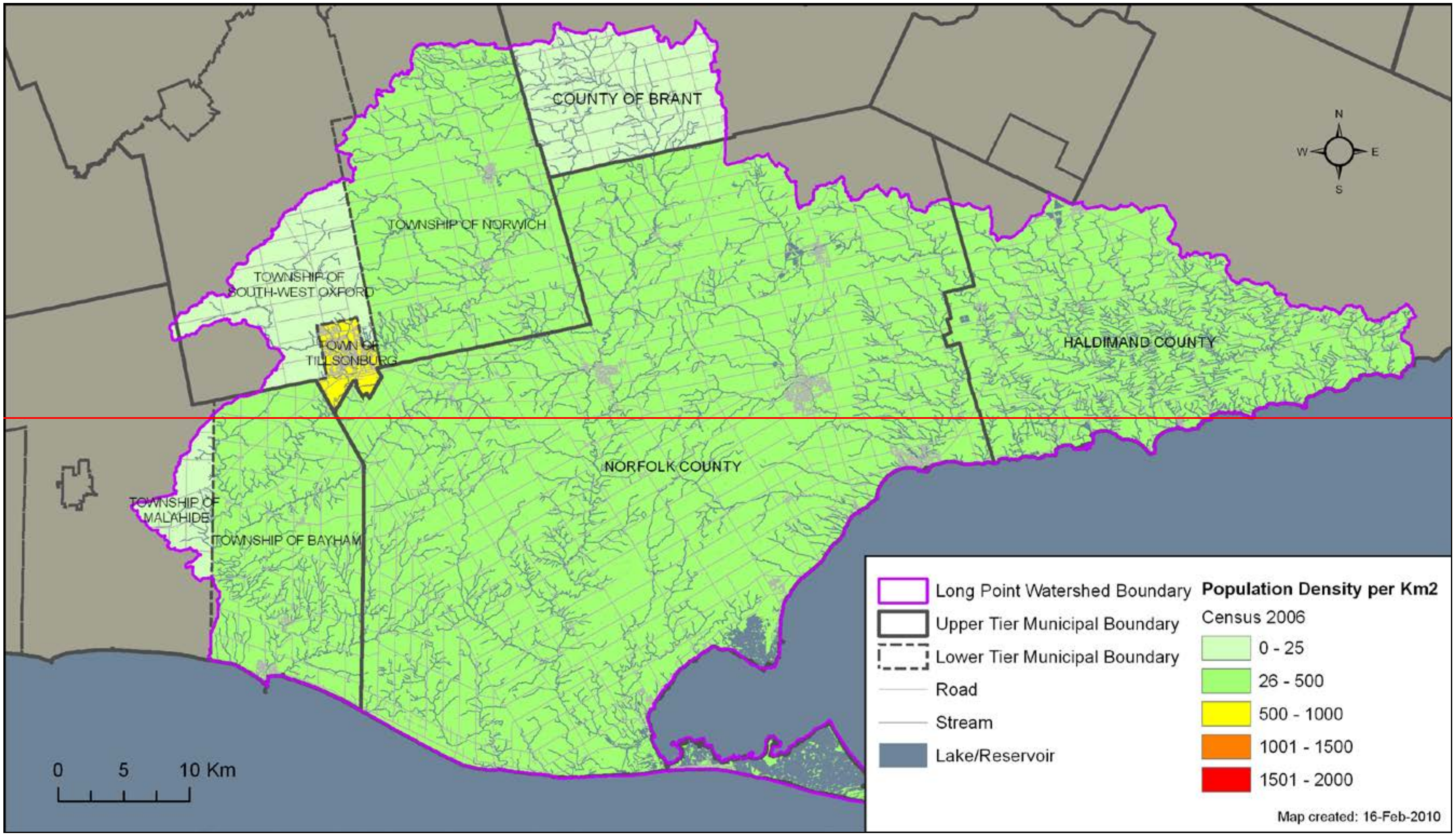
Map 2-1: Lake Erie Source Protection Region



Map 2-2: Long Point Region Watershed Boundary



~~Map 2-3: Population and Population Density in Watershed by Municipality in the Long Point Region Waters~~



2.4 Physiography

The physiographic features (as mapped by Chapman and Putnam, 1984) within the Long Point Region watershed area are presented in **Map 2-3.** These landforms were shaped by glacial processes occurring during the Late Wisconsinan glaciation, and define the three main physiographic regions within the Long Point Region: the Horseshoe Moraines, the Norfolk Sand Plain, and the Haldimand Clay Plain.

There are direct relationships between physiography, groundwater and surface water hydrology. In general, areas with fine-grained clays lying at the surface (e.g. the Haldimand Clay Plain) tend to have more tributaries than those areas where coarse-grained sediments dominate the surficial sediments. This is due to the low infiltration capacity of clay-rich soils. Precipitation falling on the clay plain commonly travels as overland flow to surface water features rather than infiltrating to the groundwater system. In contrast, areas with coarser sands and gravels at the surface (e.g., the Norfolk Sand Plain and moraines) have fewer tributaries as a larger portion of precipitation percolates downward to recharge the groundwater system.

2.4.1 Norfolk Sand Plain

The Towns of Tillsonburg, Delhi, Simcoe, and Waterford are found within the physiographic region known as The Norfolk Sand Plain which borders the Mount Elgin Ridges to the northwest, the Horseshoe Moraines to the northeast, the Haldimand Clay Plain to the east, and the Ekfrid Clay Plain to the west (Chapman and Putnam 1984). This region is characterized by relatively flat to undulating glaciolacustrine deltaic deposits of sands (up to 27 m thick) and silts which are observed to cover or partially cover the moraines in the area (Chapman and Putnam 1984; Barnett 1982). The moraines rise up to 23 m above the surrounding terrain, whereas the Big Otter and Big Creeks have incised into this plain up to 38 m (Chapman and Putnam 1984; Barnett 1982). While some finer-grained sands exist, the local soils are predominantly coarse-grained and both the coarse and fined grained sands have been historically well suited to the tobacco farming industry (Chapman and Putnam 1984). More recently, the type of crop planted is in a state of flux as acreage devoted to tobacco production has declined, with the acreage devoted to fruits, vegetables and ginseng increasing. Anecdotal evidence does suggest that the decline in tobacco acreage has ceased, and may have started to increase again.

~~The Norfolk Sand Plain is characterized as a low-relief, silty sand and gravel sand plain that extends through most of the western and central portions of the Long Point Region. The sand plain is wedge shaped with a broad curved base along the Lake Erie shoreline tapering northward to a point near Brantford on the Grand River. The sand plain is rich in water and is intensively used as an irrigation source for both mixed farming and cash crops. Many private wells have also been completed in the unconfined, shallow sand aquifer. However, since the soils are more permeable, this also allows for surficially applied chemicals to enter the groundwater system and potentially impact well supplies.~~

2.4.2 Haldimand Clay Plain

The area to the east of ~~the communities of~~ Waterford and Simcoe is characterized by a low-relief lacustrine clay plain (Chapman and Putnam, 1984), referred to as the Haldimand Clay Plain. The Clay Plain consists of fine-grained silts and clays deposited at the bottom of a deep glacial lake basin during the Port Huron Stade, about 13,000 years ago. In areas farther to the north where the clay deposits are among moraines and relief increases, the clay thins and is interbedded with till (Chapman and Putnam 1984). Soils of the region are predominantly fine-grained, which often prevents adequate drainage, but coarser grained soils are also locally present (Chapman and Putnam 1984). ~~It is characterized by heavy clay soils which are~~

~~relatively impermeable, resulting in a high level of runoff and little groundwater recharge. Much of the land is poorly drained and is used predominantly as livestock pastures and for soybean, corn and hay production. In this area, groundwater is generally obtained from the bedrock of the Dundee Formation and the Detroit River Group because sufficient quantities of water cannot be obtained from the overburden. Groundwater drawn from the bedrock aquifers in this area is often poor in quality as a result of naturally elevated concentrations of sulphur, salts and minerals in the water.~~

Horseshoe Moraines and ~~/~~Mount Elgin Ridges

The Horseshoe Moraines physiographic region ~~includes~~ represents the southward extent Paris and Galt Moraines that are located just to the east of Delhi and west of Simcoe, respectively.~~in the central portion of the Long Point Region and provide low to moderate relief above the surrounding sand plain~~. The Paris and Galt Moraines, oriented in a north-south direction, are scarcely visible in the Long Point Region as they have been either eroded or buried by overlying glaciolacustrine or glaciofluvial sediments (Barnett, 1982). The moraines in this area are primarily composed of the Wentworth Till, but outwash deposits, glaciolacustrine deposits, and stratified drift also make up the structure of the ridges (Barnett 1978). Well-drained surficial soils, categorized as Huron clay loam, can be found both on and off the moraine (Chapman and Putnam 1984).While not identified as hummocky topography, the general locations of these moraines are shown in **Map 2-4**.

The Mount Elgin Ridges are situated in the northwestern portion of the Long Point Region. They include several end moraines that provide low to moderate relief above the surrounding sand plain and in some areas exhibit slightly hummocky topography. Several of these moraines were deposited at the front of the Lake Erie ice sublobe during the Wisconsin glaciation (Chapman and Putnam, 1984). These moraines, which run east-west roughly paralleling the current Lake Erie shoreline, include (from north to south) the St. Thomas, Norwich, Tillsonburg, Courtland, and Mabee Moraines. These moraines are shown as hummocky topography on **Map 2-4**.

All the end moraines within the Long Point Region are kilometres in length. In general, the surface relief of the moraines decreases southward toward Lake Erie. The moraines located nearest to Lake Erie (including the north-trending Paris and Galt moraines) are ~~smaller~~ more subdued ~~because~~ as they ~~have been more~~were subjected to increased erosion and burial by the encroachment of glacial Lake Erie (Barnett 1982; Chapman and Putnam 1984). The St. Thomas Moraine (the oldest of the moraines in the area) shows the greatest relief (Chapman and Putnam 1984). It is located in the northwest corner of the watershed, and extends beneath the towns of Mount Vernon and Mount Elgin (Barnett, 1982).

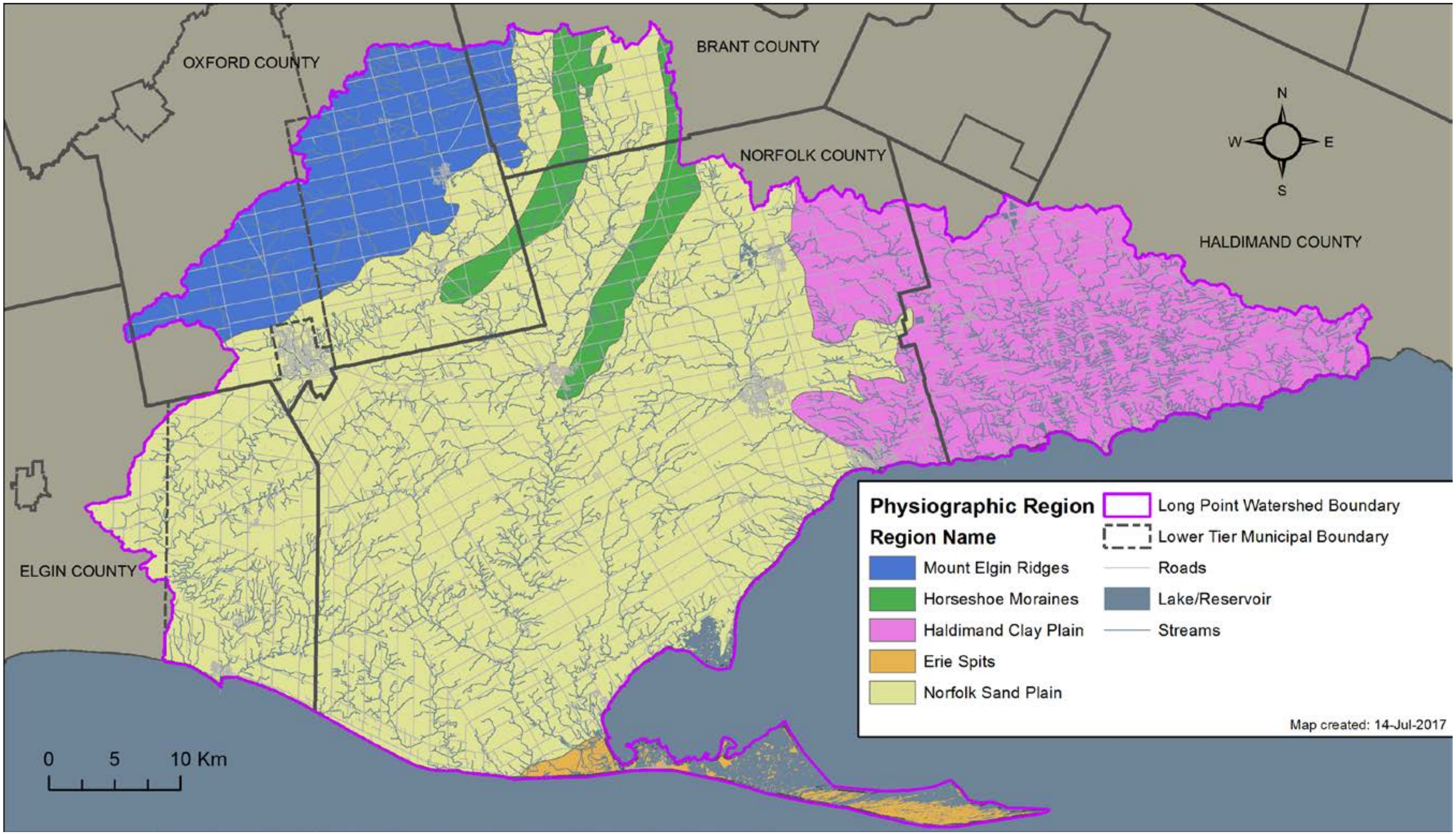
2.5 Ground Surface Topography

The present day ground surface topography evolved from erosional and depositional processes that occurred during glacial and post-glacial times. **Map 2-5** shows the topography of the Long Point Region watershed. The ground surface elevation ranges from 357 masl in the northwest on the St. Thomas Moraine, to 169 masl in the southeastern limits along the Lake Erie shoreline. Areas mapped as hummocky topography are minimal through the Long Point Region, and are illustrated on **Map 2-4**. ~~The Galt and Paris Moraines were not mapped as hummocky topography within Long Point Region.~~

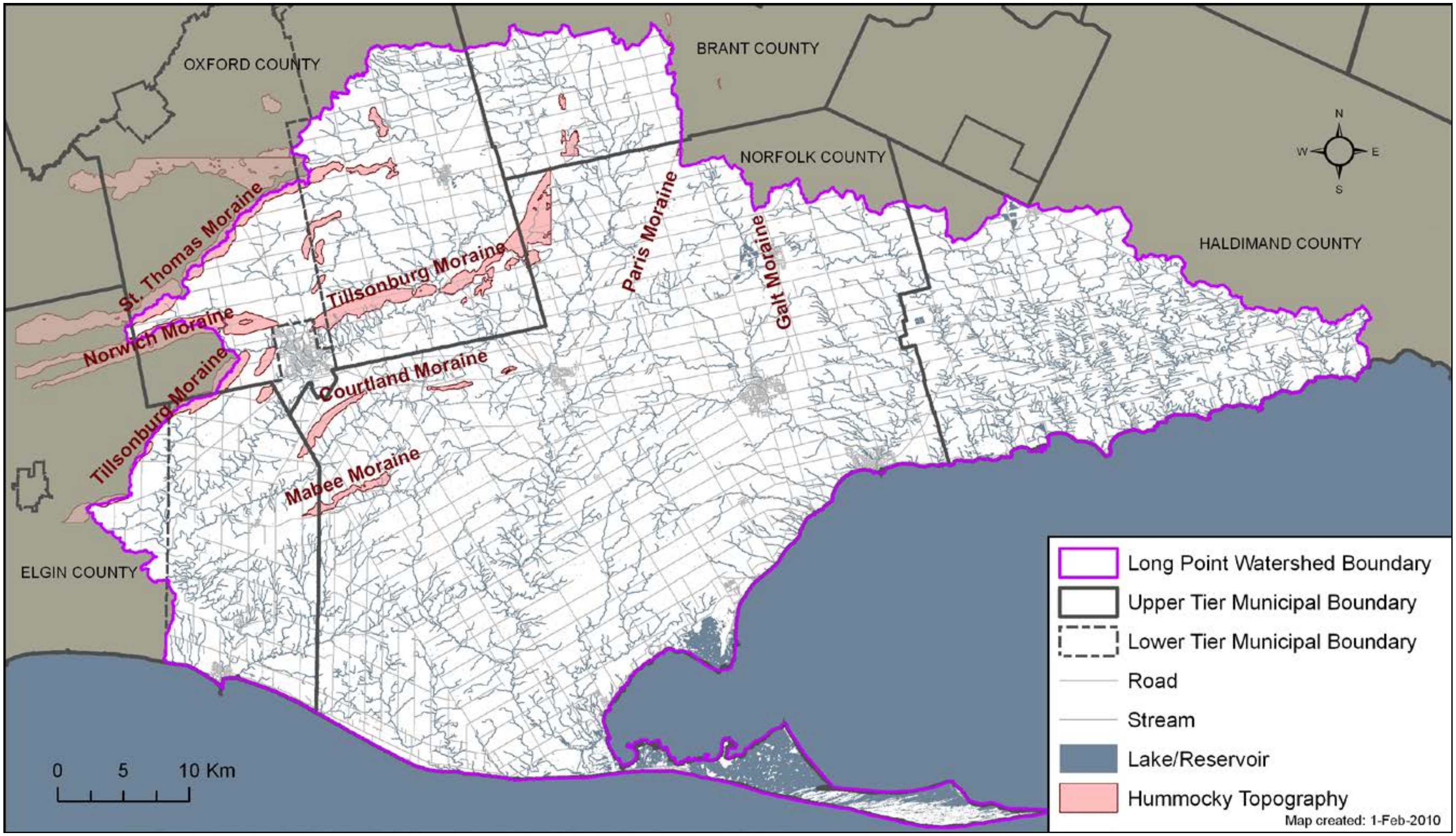
2.5.1 Bedrock Topography

In Ontario, there was an extensive period of time between the final deposition of the Paleozoic sedimentary rocks (approximately 200~~350~~ million years ago) and the earliest record of glacial deposition during the Wisconsinan Glaciation approximately 115,000 years ago. During this period, the exposed bedrock surface was likely subjected to glacial and fluvial erosion and weathering that shaped the underlying bedrock surface. Much of the bedrock surface's irregular topography is attributed to fluvial erosion whereby paleo-drainage was focused along the bedrock for extensive periods of time. This led to the erosion of river valleys in the bedrock, which in some places were subsequently infilled with sediment. Generally, bedrock topography slopes from the north towards the south. **Map 2-6** illustrates bedrock topography across the Long Point Region.

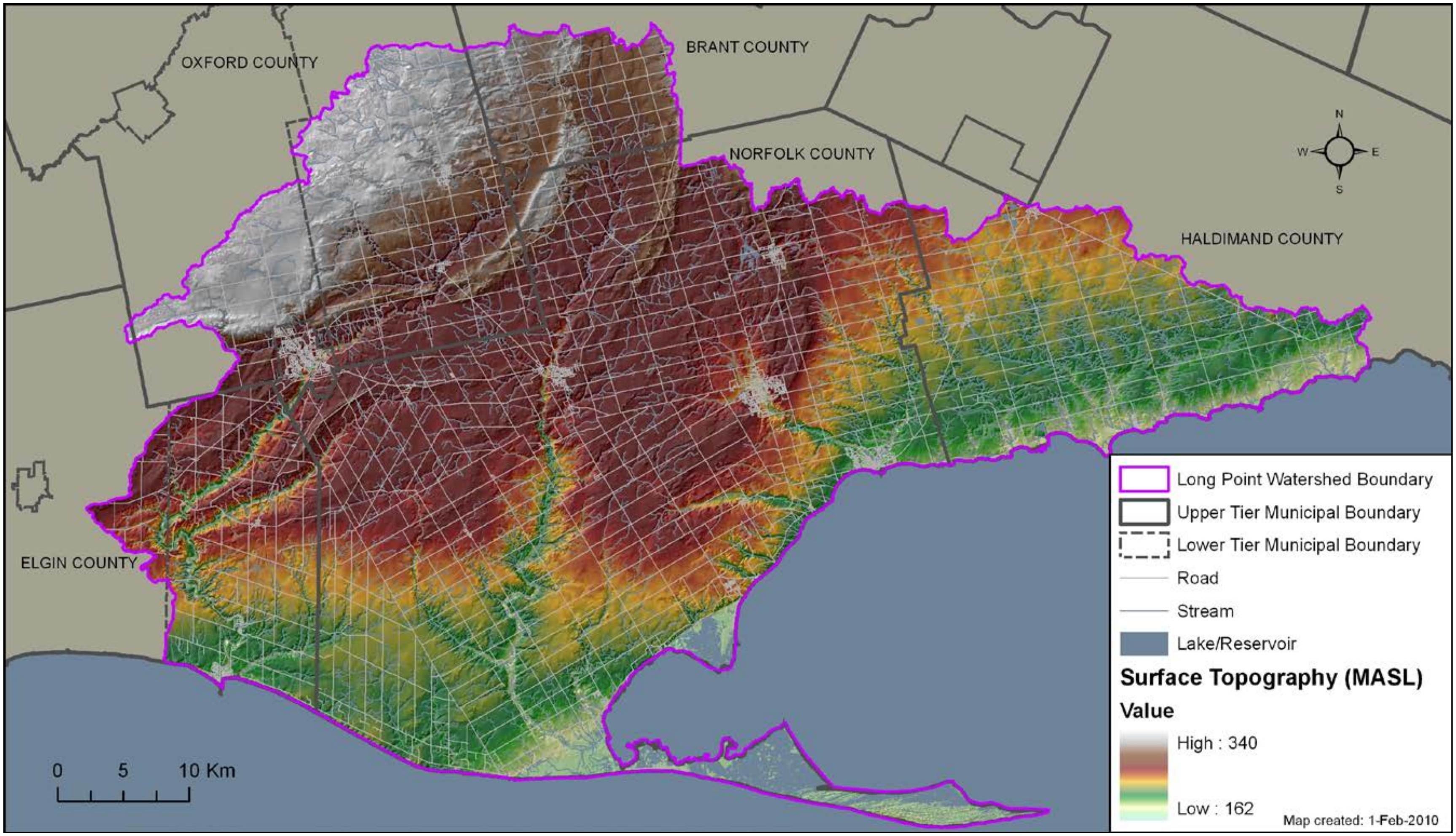
Map 2-3: Physiography of the Long Point Region Watershed Area



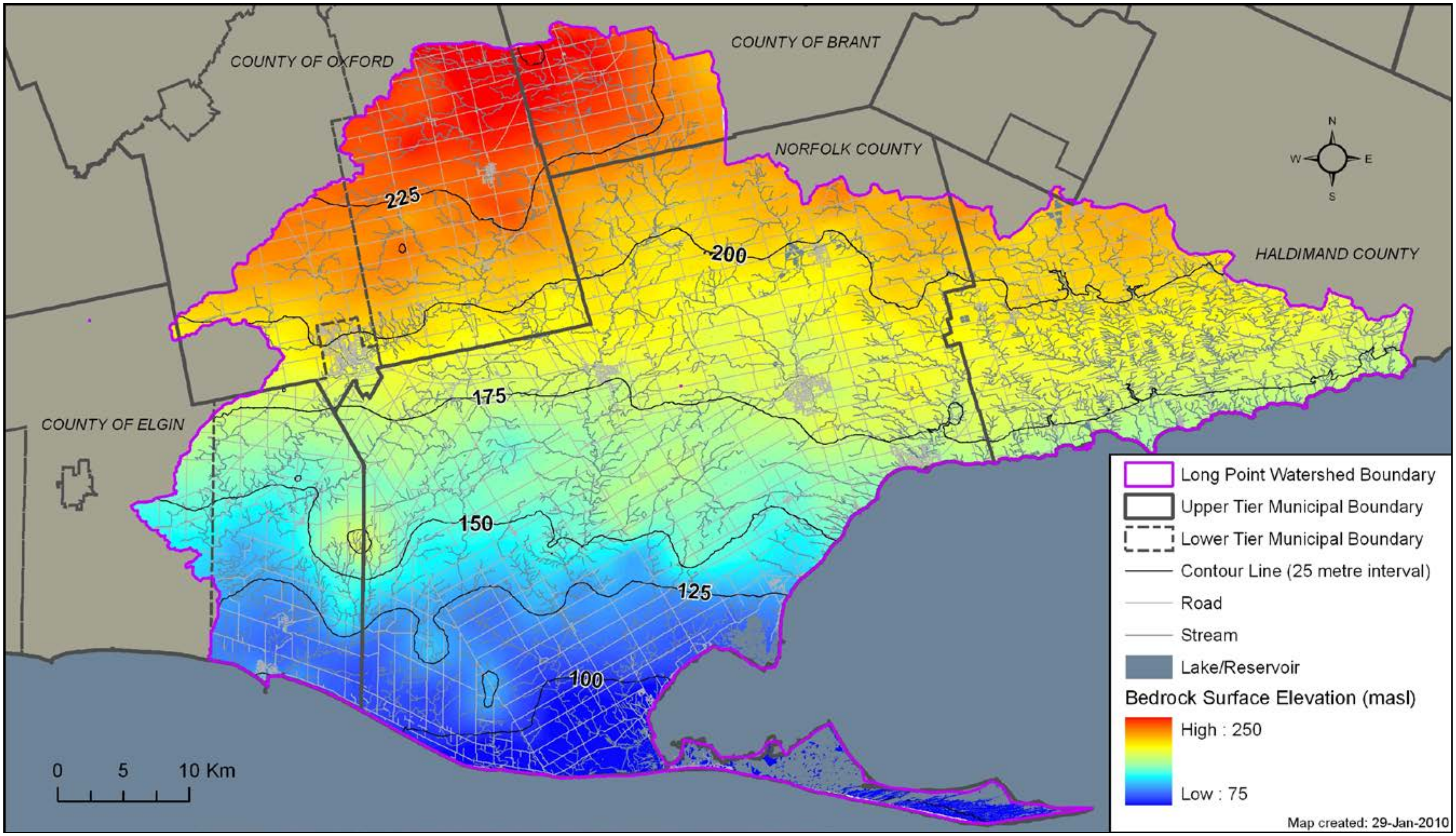
Map 2-4: Hummocky Topography in the Long Point Region Watershed



Map 2-5: Ground Surface Topography in the Long Point Region Watershed



Map 2-6: Bedrock Topography in the Long Point Region Watershed



2.6 Geology

The watershed is underlain by a series of gently dipping Paleozoic sedimentary rocks consisting of deep-water shales interbedded with shallow water carbonates and sandstone. These rocks are overlain by unconsolidated Quaternary-aged sediments of variable thickness that were laid down after the last glaciation. Paleozoic bedrock outcrops in the Long Point Region in only a few areas in the east near Hagersville; in the remainder of the Long Point Region ~~these rocks are~~bedrock buried beneath a thick veneer of sediments.

2.6.1 Bedrock Geology

Glacial sediments in the Long Point Region are underlain by Upper Silurian to Middle Devonian bedrock consisting mainly of limestones, dolostones and shales. This Paleozoic succession is subdivided into 10 formations. In order from oldest to youngest, these are the Salina, Bertie and Bass Island, Oriskany, Bois Blanc, Onondaga, Amherstburg, Lucas, Dundee and Marcellus Formations. The bedrock geology presented in **Map 2-7** was assembled by the Ontario Geological Survey (OGS) in 2007~~1~~.

The oldest subcropping Paleozoic bedrock in Long Point Region ~~subcropping~~ is the Salina ~~Formation~~Group. This formation consists of interbedded shale, mudstone, dolostone, and evaporites (including gypsum and salt; Johnson et al., 1992). Within the Long Point Region, the Salina Group subcrops in the far northern reaches near Hagersville (Johnson et al., 1992), and outside the village of Springvale. Subcropping south of the ~~Salina Formation~~Salina Group is the younger (Late Silurian) Bertie/ Bass Islands Formation. The contact between the ~~Salina Formation~~Salina Group and the overlying Bertie/ Bass Islands Formation is conformable. The Bertie/Bass Island Formations form a narrow, 1-3 km wide band of oolitic and microsucrosic brown dolostone with minor thin beds of shaley dolostone along the northern edges of the Long Point Region (Hewitt, 1972; Barnett, 1982; Johnson et al., 1992).

The Oriskany Formation is a very small and localized (approximately 6 km^2) subcrop of Lower Devonian coarse-grained, calcareous, quartz sandstone with a thin basal conglomerate approximately 10 km east of Hagersville that pinches out laterally between the Bertie and Bois Blanc Formations. It is estimated to have a maximum thickness of less than 6 m (Johnson et al. 1992). The contact between the Oriskany Formation and the underlying Bertie Formation is sharp and disconformable, showing pronounced small-scale karst features (Johnson et al., 1992).

Resting stratigraphically above the Oriskany and Bertie/ Bass Islands Formations, is the Early Devonian Bois Blanc Formation. This formation consists of cherty brownish grey, fossiliferous limestone and is estimated to be roughly 3 to 15 m thick (Johnson et al., 1992). The Bois Blanc Formation and the underlying Bass Islands are separated by a major regional unconformity (Hewitt, 1972; Johnson et al., 1992). This feature may be significant from a hydrogeologic perspective as the upper surface of the Bois Blanc is interpreted to be weathered, highly fractured and therefore, able to transmit greater volumes of water than the more competent rock at depth.

The middle Devonian Detroit River Group (Onondaga, Amherstburg and Lucas Formations) stratigraphically overlies the Bois Blanc Formation and extends from Norwich and Otterville, beneath Waterford eastward to Lake Erie. East of Hagersville, the Bois Blanc Formation is overlain by the Onondaga Formation. The contact between the Bois Blanc and Onondaga formations is poorly understood, but is believed to be disconformable (Johnson et al. 1992). The Middle Devonian rocks of the Onondaga Formation consist of cherty fossiliferous limestone (Johnson et al. 1992; Telford and Tarrant, 1975). West of Hagersville, the crinoidal limestones and dolostones of the Amherstburg Formation overlie the Bois Blanc Formation. The contact between the Bois Blanc and Amherstburg formations is poorly defined and largely interpretative. The lateral contact between the contemporaneous Amherstberg Formation (deposited in the Michigan basin) and the Onondaga Formation (deposited in the Appalachian basin) is gradational (Johnson et al. 1992). The Lucas Formation conformably overlies the Amherstberg Formation and consists of microcrystalline limestone (Johnson et al. 1992). The Lucas Formation is thickest in the western part of the Long Point Region. It gradually thins and pinches out near Port Dover.

The Dundee Formation is a grey to brown fossiliferous limestone that lies stratigraphically above the Detroit River Group. The Dundee Formation is the subcrop strata across much of the central and southern portions of the Long Point Region and is buried beneath Quaternary sediments throughout the majority of the Long Point Region. The formation outcrops along Black Creek, Nanticoke Creek, a small area just north of the town of Nanticoke, as well as the Lake Erie shoreline between Port Dover and Nanticoke. Several karst features have been mapped in association with the Dundee Formation (Barnett, 1978). Karst is a distinctive type of topography or terrain, formed primarily by the dissolution of carbonate rocks, such as limestone or dolostone, by groundwater. In areas near Port Dover, the mildly acidic groundwater reacts with carbon dioxide in the atmosphere and soil, and enlarges the openings in the Dundee Formation limestone, creating a subsurface drainage system. Barnett (1982) mapped several sinkholes within the Long Point Region, ranging up to 15 m in diameter and 8 m deep. From a hydrogeological standpoint, bedrock aquifers in these karstic areas are highly susceptible to groundwater contamination because surface water and contaminants tend to flow directly into the aquifers via sinkhole drains.

The youngest Paleozoic bedrock formation to subcrop beneath the Long Point Region is the Marcellus Formation. This formation is restricted to the southwestern portions of the Long Point Region on the north shores of Lake Erie where it conformably overlies the Dundee Formation. The Marcellus Formation is described as a black, organic-rich shale, with a few minor, thin, impure carbonate interbeds and ranges in thickness between 3 and 15 m (Barnett, 1982, 1993; Johnson et al., 1992). The Marcellus Formation marks a sharp change in the bedrock from older carbonate-dominated bedrock to shale-dominated strata (Johnson et. al., 1992).

2.6.2 Quaternary (Surficial) Geology

Quaternary-aged overburden sediments within the watershed provide a detailed record of glacial and interglacial events that took place throughout the most recent Wisconsinan Glaciation. During the Wisconsinan glacial period (~~115 to 7 ka before present~~beginning 30,000 years before present), ~~a continental-scale glacier termed~~ the Laurentide Ice Sheet, a continental-scale glacier, repeatedly advanced and retreated ~~through~~ across Ontario, extending southward into the states of Ohio and Indiana ~~in the United States~~ (Barnett, 1992). The ice front advanced forward during cold periods (glacial stades) and retreated when the climate temporarily warmed (glacial interstades) leaving behind a complex ~~subsurface~~ sediment~~ological~~ record. As the Laurentide Ice Sheet advanced ~~over~~across southern Ontario, it scoured the Paleozoic bedrock surface and reworked the vast majority of pre-existing ~~glacial and interglacial~~ sediments.

Within the Long Point Region, the advance of ice during the Late Wisconsinan glacial period essentially erased over 250,000,000 years of climatic history (the period of time between the deposition of the Paleozoic rocks (350 million years ago) and the deposition of pre-Wisconsinan overburden sediments (100 ~~ka~~years ago)). The Late Wisconsinan glacial period ~~lasted~~extended from 23,000 years ago ~~(23 ka)~~ to 10,000 years ago (~~10 ka;~~ Dreimanis and Goldthwait, 1973). It was during this period that the Laurentide Ice Sheet reached its most southerly extent, advancing through Ontario and extending southward into the United States.~~. It was also during the Late Wisconsinan that~~During this period, the ~~Laurentide~~ice sheet began to thin and ~~formed~~ a series of sublobes developed, each moving independently of one another at different rates, and in different directions. ~~Both of these~~The sublobes deposited a series of distinct subglacial tills and ~~associated~~ landforms within the Long Point Region. Overburden within the Region was predominately deposited by the Erie sublobe, or at times by the Ontario-Erie sublobe, when the two sublobes temporarily amalgamated. The glacial events of the Late Wisconsinan ~~and their resulting deposits are~~ resulted in the most commonly occurring and extensive deposits in the Long Point Region. **Table 2-4** presents a list of the ~~Quaternary~~ sediments identified in the Long Point Region, their distribution, and the general time period in which the deposits were laid down (OGS, 2007). **Map 2-8**~~**Map 2-8**~~**,** shows the spatial distribution of these units at surface across the Region.

Table 2-4: Quaternary Deposits Located Within the Long Point Region Source Protection Study Area

Age (y.b.p)*	Glacial Stage	Substage	Glacial Stade/ Interstade	Associated Deposits
5000-11,500	Wisconsinan	Late Wisconsinan	Holocene/ Recent	Modern alluvium, organic deposits, Long Point spit, Eolian sand dunes
11,500- 12,000			Twocreekean Interstade	Shoreline Formation Glaciolacustrine Deposition
12,000- 13,200			Port Huron Stade	Wentworth Till, Norfolk Sand Plain, Haldimand Clay Plain
13,200- 14,000			Mackinaw Interstade	Paris/ Galt Moraines
14,000- 15,500			Port Bruce Stade	Port Stanley Till, Glaciolacustrine Deposits
15,500- 18,000			Erie Interstade	Glaciolacustrine Deposits
18,000- 25,000			Nissouri Stade	Catfish Creek Till
25,000- 53,000	Middle Wisconsinan		Undifferentiated tills and deposits	
53,000- 80, 000	Early Wisconsinan			

* y.b.p. represents number of years before present

The most extensive subglacial till sheet in southern Ontario is the Catfish Creek Till (deVries and Dreimanis, 1960; Barnett, 1978; 1992; 1993), which was deposited during the Nissouri Stade, when the Laurentide ice sheet last advanced as one thick cohesive ice sheet. The till is composed of stacked layers of subglacial lodgement till as well as stratified glaciofluvial and glaciolacustrine sediments and supraglacial till layers and lenses (Dreimanis, 1982; Barnett, 1992). The till is described as a highly calcareous, gritty, sandy silt till. It is often described as hardpan in water well drillers' records because of its stoniness and hardness (*Barnett, 1978; 1982; 1992*). The till occurs primarily as a buried till plain across the Long Point Region watersheds, but it outcrops along the Tillsonburg Moraine and on selected drumlins in the northeast near Hagersville (Barnett, 1978; 1982).

The Port Stanley Till is described as a silt to clayey silt till with few clasts (*Barnett, 1982*). Within the watershed, the `till complex' consists of up to 5 layers of subglacial till separated by glaciolacustrine sediments resulting from glacial lake level fluctuations within the Lake Erie basin (Barnett, 1982; 1992). Further inland, the Port Stanley Till consists of only one layer of subglacial till with associated glaciofluvial sediments (Barnett, 1992). The Port Stanley Till is buried beneath younger glaciolacustrine sediments across most of the Long Point Region; however it outcrops north of Tillsonburg (Barnett and Girard, 1982). The Till also makes up the vast majority of the sediments within the east-trending end moraines in the Long Point Region, including (from oldest to youngest) the St. Thomas, Norwich, Tillsonburg, Courtland and Mabee Moraines (Barnett, 1993).

The Wentworth Till is the youngest till within the watershed, and is commonly buried beneath younger glaciolacustrine sediments (Barnett, 1982); however, it outcrops in some areas northeast of Delhi along the Paris Moraine, in areas approximately 3 km north of Port Rowan, and in drumlins north of Hagersville (Barnett, 1978). Within the Long Point Region, Wentworth Till is ~~described as~~ a ~~stony, silt till that coarsens inland~~very poorly sorted massive clayey silt to silty clay containing minor coarse sand, pebbles and boulders, which becomes gradually coarser-grained toward the northwest (Barnett, ~~1992; 1993~~1978). The Paris and Galt Moraines are both composed of Wentworth Till (Barnett, 1978)

Glacial Lake Whittlesey followed by Glacial Lake Warren, each flooded the Long Point Region throughout the Port Huron Stade (Barnett, 1992). It was at the base of these lakes that the Haldimand Clay Plain and extensive Norfolk Sand Plain were deposited (*Barnett, 1982*). The Haldimand Clay Plain was deposited in the eastern part of the Long Point Region as fine-grained silts and clays settled to the bottom of the deep lake basin. The Norfolk Sand Plain lies across the western and central parts of the Region and forms an extensive surficial feature deposited when the sediment laden Grand River (historic alignment) emptied into the deep glacial lake. The Grand River deposited a deltaic sequence of sands and silts throughout the western portion of the Region at the front of the eastward retreating ice front (Chapman and Putnam, 1984). Norfolk Sand Plain sands are described as fine to medium-grained, ranging in thickness from less than 1 m to roughly 27 m (although this estimate may include deeper, and older sands; Barnett, 1982). Within the Long Point Region watershed area, the Norfolk Sand Plain forms an important aquifer across the area which is used for private groundwater supply.

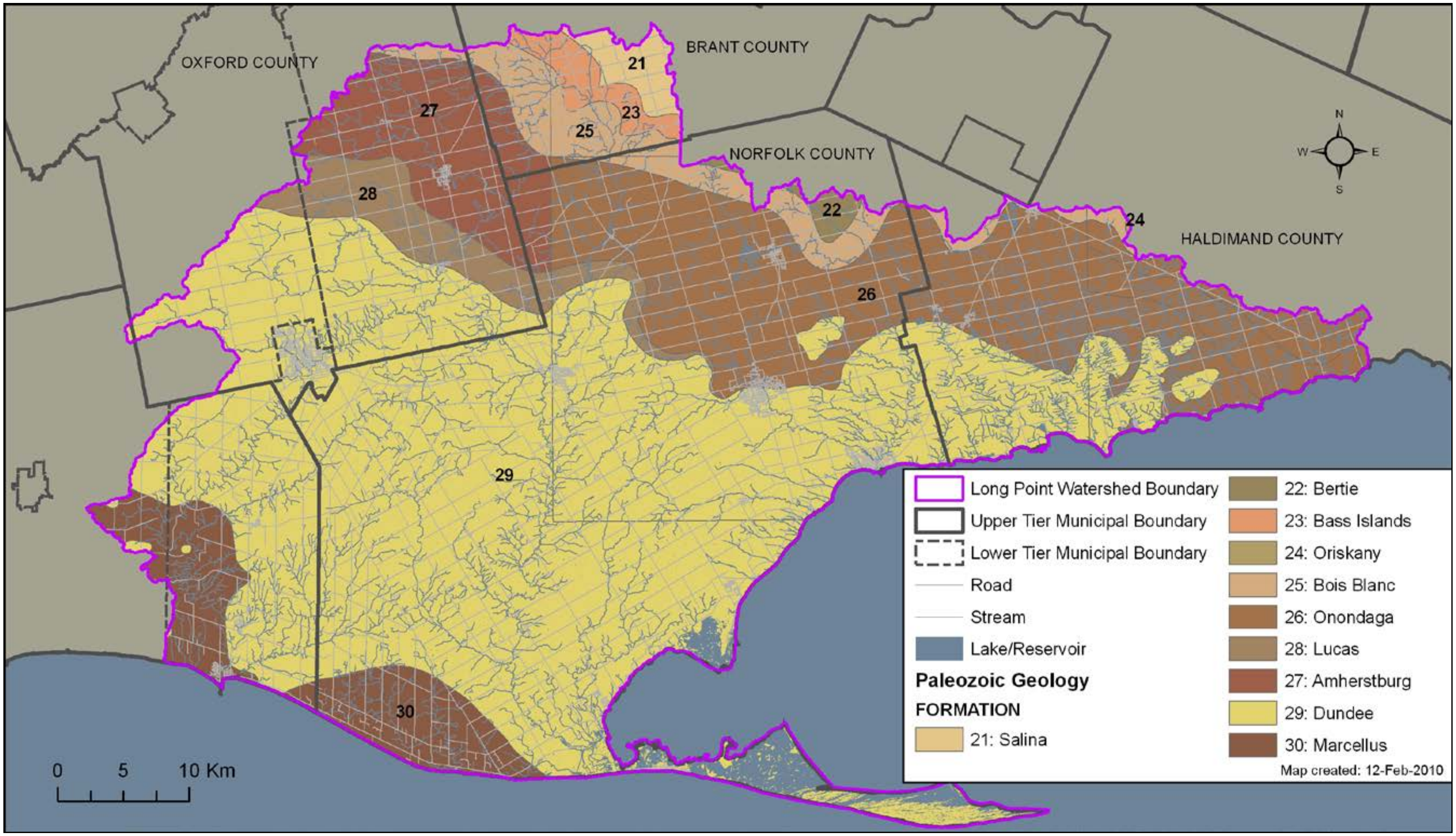
Postglacial and erosional processes during the Holocene continued to shape the landscape within the Long Point Region. The 40 km long Long Point sand spit began to form in Lake Erie roughly 7,600 years ago when coarse grained sediments were carried by long shore currents from the west, and this process has continued ever since (~~Stenson, 1993;~~ Davidson-Arnott and Van Heyningen, 2003). Most sand spits or peninsulas become eroded or separated from the mainland during storms or high water events (Davidson-Arnott, 1988) and the distance between the Long Point sand spit and the mainland will continue to fluctuate with time as deposition and erosion rates fluctuate with the climate. In the Tillsonburg area of the Long Point Region, portions of the Norfolk Sand Plain have been modified to varying extents throughout the Holocene by the wind as it forms large dunes, some reaching 6 m high (Barnett, 1982). In addition, modern alluvial deposits are scattered throughout the Long Point Region and are associated with Big Creek, Big Otter Creek and the Grand River (Barnett, 1993).

2.6.3 Overburden Thickness

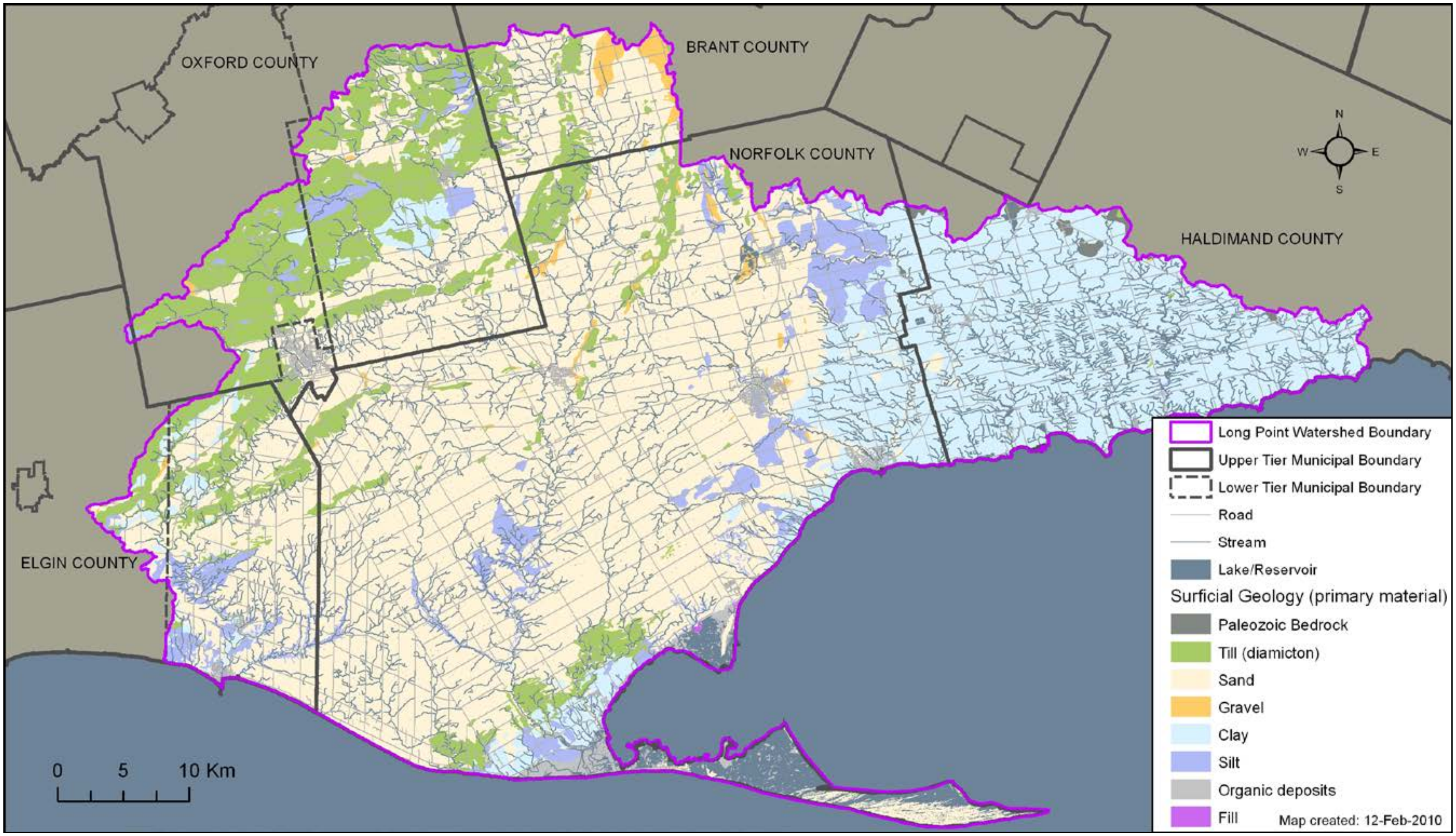
Overburden thickness is an important feature as it provides an indication of the relative protection of buried overburden and bedrock aquifers. Overburden thickness and grain size distribution of those sediments control the infiltration rate of precipitation, as well as the rate of movement of surface contamination into these aquifers.

Overburden thickness was derived by subtracting the bedrock topographic surface (see above) from the ground surface digital elevation model (DEM). **Map 2-9** shows the distribution of overburden throughout the watershed, and illustrates the presence of moraines and incised river valleys. Overburden thickness ranges from zero along some river valleys and on the Haldimand Clay Plain, to over 115 m in areas where the end moraines overlie thick till deposits. The thickest overburden materials are found in the southern regions of the watershed along the Lake Erie shoreline. In addition, the thicknesses of the Norwich, Tillsonburg, Mabee, Courtland, Paris and Galt Moraines are also readily identifiable on this map.

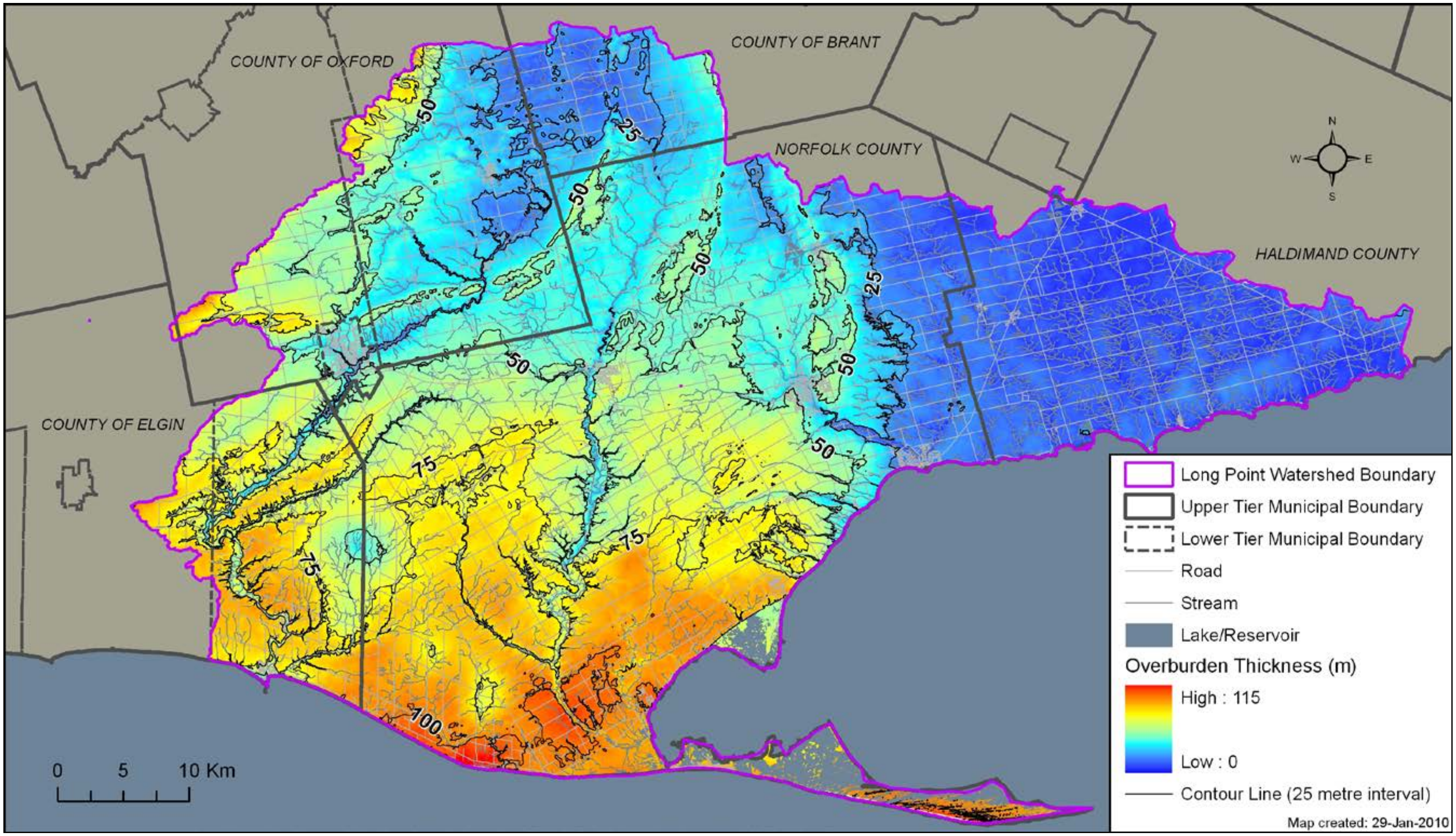
Map 2-7: Bedrock Geology in the Long Point Region Watershed



Map 2-8: Quaternary (Surficial) Geology in the Long Point Region Watershed



Map 2-9: Overburden Thickness in the Long Point Region Watershed



2.7 Groundwater

~~Within the Long Point Region watershed, the location and spatial distribution of aquifers, has largely been based upon geologic and hydrogeologic information held within the Ministry of the Environment's Water Well Information System (WWIS), in combination with the knowledge of the glacial history of the area. Cross-sections through the subsurface have been drawn across much of the watershed for various water supply or groundwater related studies.~~

Groundwater resources within Long Point Region are utilized by much of the population for domestic and municipal water supply, agricultural, and industrial use. Groundwater also supplies baseflow to cold and cool surface water features such as streams, creeks and wetlands, maintaining cool stream temperatures during warm summer months and providing additional flow.

To a large extent, the regional groundwater flow system in Long Point Region is a reflection of the ground surface topography. Groundwater moves from areas of high hydraulic head to areas of low hydraulic head, generally following topographic relief, unless it is impeded by geologic conditions, or local changes in relief such as stream valleys that intersect the water table.

In areas where rivers, streams or wetlands intersect the water table, groundwater discharges into the stream or river and contributes baseflow to the surface water feature. Understanding the movement of groundwater through the subsurface, and through interactions with surface water features requires an understanding of the location and extent of the Region's aquifers (water bearing units) and aquitards (confining units) as well as the location of significant recharge areas.

The most recent characterization and quanitification of groundwater resources in Long Point Region has been through the completion of the Long Point Region Tier 3 Water Budget and Local Area Risk Assessment (Matrix, 2015). A full summary of the Tier 3 Water Budget Summary is located in Section 10 of this report.

2.7.1 Regional Hydrostratigraphy

Hydrostratigraphic units are derived from the bedrock and overburden stratigraphic units based on their general hydrogeologic properties. The interpretation of hydrostratigraphic units is based ~~on geologic descriptions from borehole logs~~primarily on the glacial history of Long Point Region, as summarized in Section 2.5.2, and high quality corehole data collected as a part of the Tier 3 Water Budget Study.

Units composed primarily of coarse-grained overburden materials (e.g., sands and gravels) or higher transmissivity bedrock units are referred to as aquifers and units composed of lower permeability overburden (e.g., clay or fine-grained tills) or poorly transmissive bedrock units are referred to as aquitards.

Within Long Point Region, a total of 11 overburden and 1 bedrock hydrostratigraphic layers have been identified (Matrix Solutions, 2015) as summarized in **Table 2-5**. While some of the units are regional in extent, many are restricted to certain areas due to the spatial variability of the depositional environments.

Table 2-5: Regional Hydrostratigraphy of Long Point Region

Layer Number	Geologic Unit	Glacial Period	Aquifer/Aquitard
1	Haldimand Clay Plain / Surficial Clay	Holocene	Aquitard
2	Norfolk Sand Plain / Interstadial Sediment	Mackinaw Interstade / Port Huron Stade	Aquifer
3	Wentworth Drift		Aquitard
4	Coarse-grained Interstadial Sediment (Sand, Gravel)		Aquifer
5	Wentworth Drift		Aquitard
6	Coarse-grained Interstadial Sediment (Sand, Gravel)		Aquifer
7	Port Stanley Drift	Port Bruce Stade	Aquitard
8	Coarse-grained Interstadial Sediment (Sand, Gravel)		Aquifer
9	Port Stanley Drift		Aquitard
10	Coarse-grained Interstadial Sediment (Sand, Gravel)	Erie Interstade	Aquifer
11	Catfish Creek Drift	Nissouri Stade	Aquitard
12	Paleozoic Bedrock		Aquifer/Aquitard

The Norfolk Sand Plain is a thick and spatially extensive unconfined aquifer ~~and~~ is found in the central portion of Long Point Region. An intermediate aquifer is located below the Norfolk Sand Plain, which is confined by the Wentworth or Port Stanley Drift. Further to the east, the Haldimand Clay Plain is found at surface and is not interpreted to overlie any overburden aquifer units. In this area, the carbonate bedrock aquifers of the Dundee and Onondaga Formations are used for domestic water supply. Bedrock aquifers exist in other parts of the regional area (e.g., Dundee, Lucas, and Amherstburg Formations) however, water quality can be sulphurous (Armstrong and Carter 2010) and these bedrock aquifers may not be used due to the availability of transmissive overburden aquifers at shallower depths.

~~**2.7.2 The conceptual hydrostratigraphic framework presented in Table III was used as the basis for the development of the numerical model layers. As several of the hydrostratigraphic units described in Table III are discontinuous across the regional area, and to reduce the total number of layers represented in the numerical models, the hydrostratigraphic model was subdivided into three geological zones. Each zone represents three distinct, more localized, depositional environments, including Port Stanley**~~

~~Drift Plain (west), Norfolk Sand Plain (centre), and Haldimand Clay Plain (east). As a result, the number of overburden hydrostratigraphic layers in any one zone was reduced from 11 layers to 7 (Table IV). The updated model was constructed with two layers to represent bedrock based on the inclusion of weathered and unweathered bedrock layers used in the Tier Two Model. There was not enough evidence to support the existence of a continuous highly weathered zone of bedrock at a regional-scale in the Tier Three model; therefore, layers eight and nine in the updated model are considered the same hydrostratigraphic unit: Paleozoic Bedrock. 15077-527 Long Point Region R 2015-05-01 final.docx ix Matrix Solutions Inc. TABLE IV. Hydrostratigraphic Framework Layer Geologic Unit Glacial Period Aquifer / Aquitard ZONE 1: Haldimand Clay Plain Zone (zone extends approximately from the Galt Moraine in the west, across the Haldimand Clay Plain to the eastern model boundary) 1 Haldimand Clay Plain / Surficial Clay Holocene Aquitard 2 Norfolk Sand Plain / Interstadial Sediment Mackinaw Interstade / Port Huron Stade Aquifer 3 Wentworth Drift Aquitard 4 Interstadial Sediment (Sand, Gravel) Aquifer 5 Wentworth Drift Aquitard 6 Interstadial Sediment (Sand, Gravel) Aquifer 7 Port Stanley Drift Port Bruce Stade Aquitard 8 Paleozoic Bedrock Paleozoic Aquifer / Aquitard 9 ZONE 2: Norfolk Sand Plain Zone (zone extends approximately from the Tillsonburg Moraine in the west, to the Galt Moraine in the east) 1 Surficial Clay Holocene Aquitard 2 Norfolk Sand Plain / Interstadial Sediment Mackinaw Interstade / Port Huron Stade Aquifer 3 Wentworth Drift Aquitard 4 Interstadial Sediment (Sand, Gravel) Aquifer 5 Port Stanley Drift Port Bruce Stade Aquitard 6 Interstadial Sediment (Sand, Gravel) Aquifer 7 Port Stanley Drift Aquitard 8 Paleozoic Bedrock Paleozoic Aquifer / Aquitard 9 ZONE 3: Port Stanley Drift Plain (extending from the Study Area boundary in the west, approximately to the Tillsonburg Moraine in the east) 1 Surficial Clay Holocene Aquitard 2 Surficial Interstadial Sediment (Sand, Gravel) Mackinaw Interstade Aquifer 3 Port Stanley Drift Port Bruce Stade Aquitard 4 Interstadial Sediment (Sand, Gravel) Aquifer 5 Port Stanley Drift Aquitard 6 Interstadial Sediment (Sand, Gravel) Erie Interstade Aquifer 7 Catfish Creek Drift Nissouri Stade Aquitard 8 Paleozoic Bedrock Paleozoic Aquifer / Aquitard 9 15077-527 Long Point Region R 2015-05-01 final.d~~

~~2.7.3 Aquifer Units~~

~~2.7.4 Groundwater resources are found within both overburden and bedrock aquifers. Two overburden aquifers associated with the Norfolk Sand Plain are found in the western portion of Long Point Region and one bedrock aquifer is located in the eastern portion of the region. In the western portion, an upper unconfined overburden aquifer consists of sand and gravel while the lower overburden aquifer is confined by lower permeability layers of silt and clay till. In the eastern extents of the region, in the vicinity of the Haldimand Clay Plain, the Dundee Formation is utilized as a productive aquifer as the clay-rich overburden sediments are not able to yield significant quantities of groundwater, even for domestic water supplies.~~

~~2.7.5 A regional water table elevation map, as produced from Waterloo Hydrogeologic and others, (2003) is shown on Map 2-11Map 2-11. This map~~

~~is based on the static water levels in wells completed in overburden at depths less than 15 m and assumes unconfined conditions (Waterloo Hydrogeologic Inc. and others, 2003). The map was also augmented with the elevation of surface water streams and rivers to constrain the water table map. In general, the elevation of the shallow groundwater table is a subdued reflection of the ground surface topography. Water table elevations range from around 330 masl in the north-western portion of Long Point Region, to 166 masl adjacent to Lake Erie. The groundwater gradient is also consistent throughout the area, except for steeper gradients in the areas of the deep river valleys of Big Otter and Big Creek river courses. Regionally, the direction of groundwater flow is southerly to southeasterly towards Lake Erie. Groundwater flow divides also generally follow surface water boundaries.~~

~~2.7.6 Overburden Aquifers~~

~~2.7.7 The upper, shallow aquifer is unconfined and consists of sand and gravel deposits associated with the Norfolk Sand Plain. The water table surface for Long Point Region is included in Map 2-11Map 2-11. This aquifer supports municipal wells for a number of communities. Thicknesses of the upper aquifer appear to range from <3 m to about 30 m. At the municipal wells in Otterville, the upper aquifer thickness is approximately 10 m and the aquifer essentially occurs at surface.~~

~~2.7.8 The unconfined aquifer is underlain by an aquitard in the morainal areas of the Big Creek drainage area and in much of the area south of Delhi. The aquitard consists of sandy silt and clay glaciolacustrine deposits (Waterloo Hydrogeologic Inc. et al., 2003) and ranges in thickness from 0 to 30 m thick. It is absent in the same areas where the upper aquifer is more than 20 m thick so that the upper and intermediate aquifer are not separated in these areas. Where there is no underlying aquifer, the upper aquitard is underlain by bedrock.~~

~~2.7.9 The middle overburden aquifer is distributed discontinuously in the Region and in places is not separated from the upper unconfined aquifer, where the total thickness of saturated aquifer is greater than about 20 m. The middle aquifer consists of medium sand under the western portion of the Big Creek drainage area, grading to fine sand or silty sand under the central portions of this watershed. Further to the east, the middle aquifer thins and grades into clayey sediments. The middle aquifer is absent at a number of locations, both where the upper aquitard is absent and where it is thick. It is most predominant in the southwestern and southeastern parts of the Big Creek drainage area. Potentially high yield wells (>200 L/min) have been identified east of Delhi (municipal wells). From south of Kelvin, there is generally an upward gradient from the middle aquifer to the upper aquifer.~~

~~2.7.10 Bedrock Aquifer~~

~~2.7.11 Domestic bedrock wells within Long Point Region are typically completed into the upper 10 to 30 m of the Dundee Formation (Waterloo~~

~~Hydrogeologic Inc. et al., 2003) especially in the eastern reaches of the watershed where the overburden is comprised of fine-grained Haldimand Clay Plain sediments. In other areas, including the Norwich municipal wells, the bedrock wells are interpreted as having been completed in the Detroit River Group.~~

~~2.7.12 The bedrock potentiometric surface, created using the reported static water levels of all the bedrock wells in the region, is illustrated on Map 2-12Map 2-12. This map shows that higher elevations (314 masl) are located in the northwestern portion of the Region, sloping towards lows (144 masl) adjacent to the Lake Erie shoreline. Groundwater flow direction in the bedrock is from north to south towards Lake Erie (Waterloo Hydrogeologic Inc. et al., 2003). Under the Norfolk Sand Plain area, there is generally an upward gradient from the lower aquifer / bedrock into the overlying overburden units.~~

2.8 Regional Overburden Aquifers

Overburden aquifers in ~~the~~ Long Point Region are abundant and include coarse-grained interstadial outwash and glaciolacustrine deposits. These deposits lie between till layers (**Table 2-5**) which create a complex aquifer system.

The Norfolk Sand Plain is the most spatially extensive aquifer within Long Point Region. The aquifer is unconfined and lies at surface across much of the central portion of the Region. The thickness of the sands exceeds 20 m in some areas including Delhi (**Map 2-9**). The unit is primarily fine- to medium-grained sand with some silt and gravel in areas.

An intermediate aquifer is located beneath the upper Norfolk Sand Plain aquifer that is commonly confined by either fine-grained Wentworth or Port Stanley Till. The fine- to medium-grained sand aquifer pinches out in the eastern portions of the Long Point Region where the Haldimand Clay Plain is mapped at surface. There are no interpreted overburden aquifers within the eastern portions of Long Point Region beneath the clay plain. Deeper sand aquifers may exist within Long Point Region however, due to the highly transmissive nature of the shallow and intermediate aquifers, few boreholes penetrate to depth and there is little information regarding the spatial extent of these aquifers, or the associated water quality within them.

2.8.1 Regional Bedrock Aquifers

Bedrock aquifers are seldom used in the western and central portions of Long Point Region where overburden aquifers are thick and transmissive. In the eastern portions of ~~the~~ Long Point Region where the Haldimand Clay Plain lies at surface, the uppermost aquifers, consisting of limestone and dolostone units of the Dundee and Onondaga Formations, are used for domestic water supply. The Dundee Formation lies south of Tillsonburg and is a productive aquifer, although water quality is sulphurous (Armstrong and Carter 2010).

2.9 Regional Groundwater Flow

Long Point Region contains both overburden and bedrock aquifers that are used for water supply. Overburden aquifers that lie at depth tend to be localized, while those that lie at or close to ground surface (such as the Norfolk Sand Plain) extend across much of the Region.

Fractured bedrock aquifers are more regional in scale, however due to the abundance of overburden aquifers within the area, the bedrock aquifers are not often used for municipal water supply.

To help visualize the groundwater flow directions across Long Point Region, a map of the shallow (**Map 2-10**) and deeper (**Map 2-11**) water levels was created at a regional scale. Static water levels reported in MOECC water well records (for wells with location reliability less than 200 m) and higher quality observation wells were interpolated across the Region to create these maps. The water levels in the MOECC water well database correspond to water levels measured and recorded by water well drillers after drilling a well. These static water levels were collected over decades and may represent pre-pumping water level conditions that are not indicative of present day levels, which can be influenced by localized pumping (municipal or otherwise).

Despite the limitations, the data used to create the water level maps (**Map 2-10** and **Map 2-11**) are the best available, and the maps are considered a reasonable representation of regional groundwater flow conditions at the scale applied.

Shallow groundwater is interpreted to flow towards and discharge into the deeply incised surface water features such as Big Creek, which runs through Teeterville and Delhi, Big Otter Creek, which runs through Tillsonburg and the Lynn River that runs through Simcoe. The deeper water levels show a similar pattern to the shallow water levels with the highest water level elevations occurring in the northwest and the lowest along the deeply incised surface water features and the Lake Erie shoreline.

2.10 Provincial Groundwater Monitoring

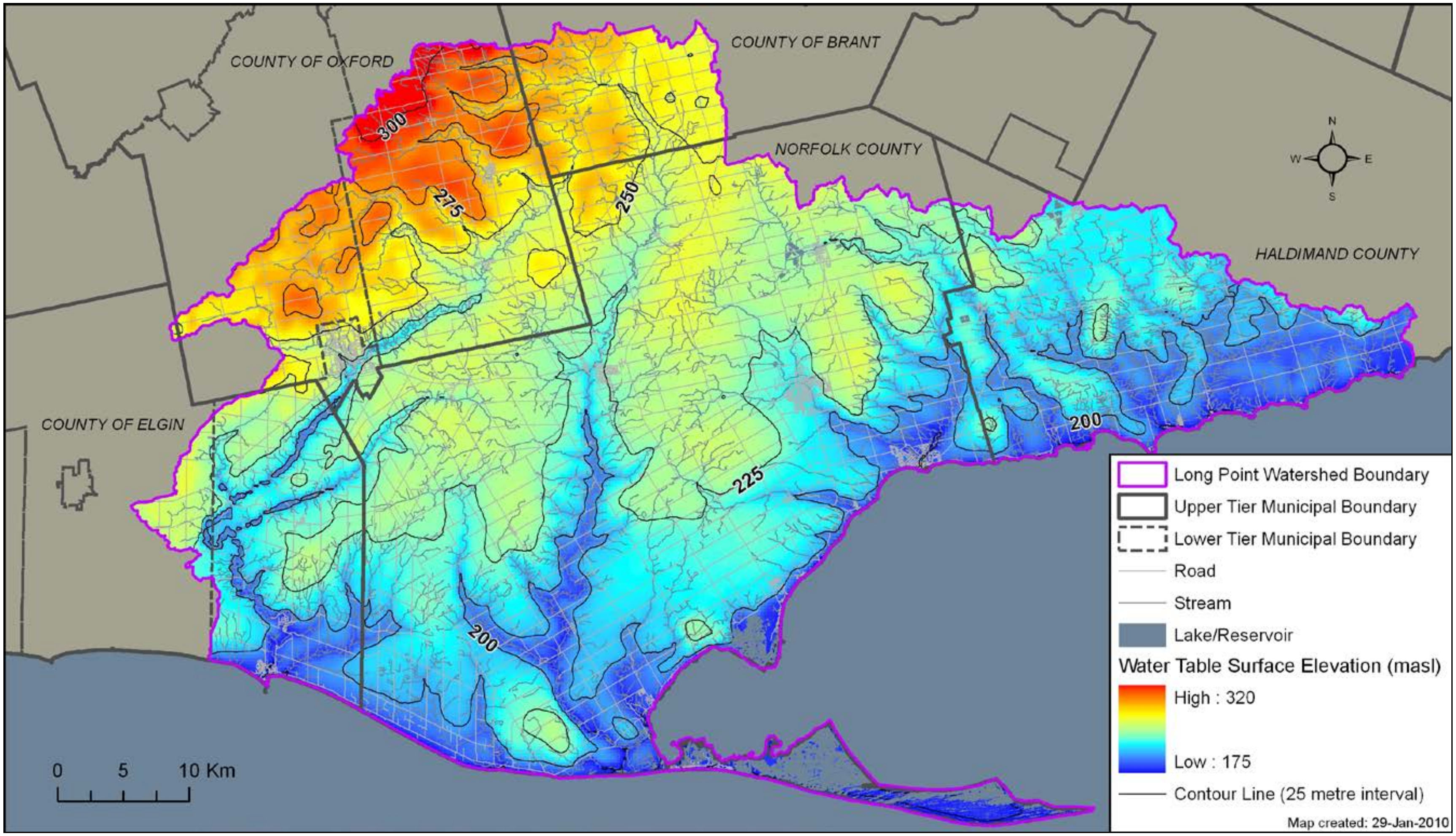
In Long Point Region, long term groundwater conditions are ~~primarily~~ monitored ~~in the Long Point Region~~ through the Provincial Groundwater Monitoring Network (PGMN), a network of wells distributed throughout the province that provide insight on long-term ambient trends and conditions. The monitors are typically sited to be reflective of broad hydrogeologic conditions, away from areas where pumping or contamination may impact the data collected. The Ministry of the Environment and Climate Change owns the monitoring infrastructure and manages the data gathered through the program, but the program is locally administered by the Long Point Region Conservation Authority.

There are currently twelve~~eleven~~ ~~Provincial Groundwater Monitoring Network~~PGMN wells located at nine~~eight~~ sites within Long Point Region (**Map 2-12**). The wells are located throughout the central portion of the Region with ~~ten~~eleven wells completed in overburden and one well completed in bedrock. Each well is equipped with an electronic datalogger which records hourly water levels and the~~. Data from the PGMN~~ wells~~ and~~ are sampled annually for a suite of general water quality parameters. Data collected from the PGMN wells is considered high quality and often used as calibration points in groundwater models, or as background data for land use applications such as urban development or aggregate pits.

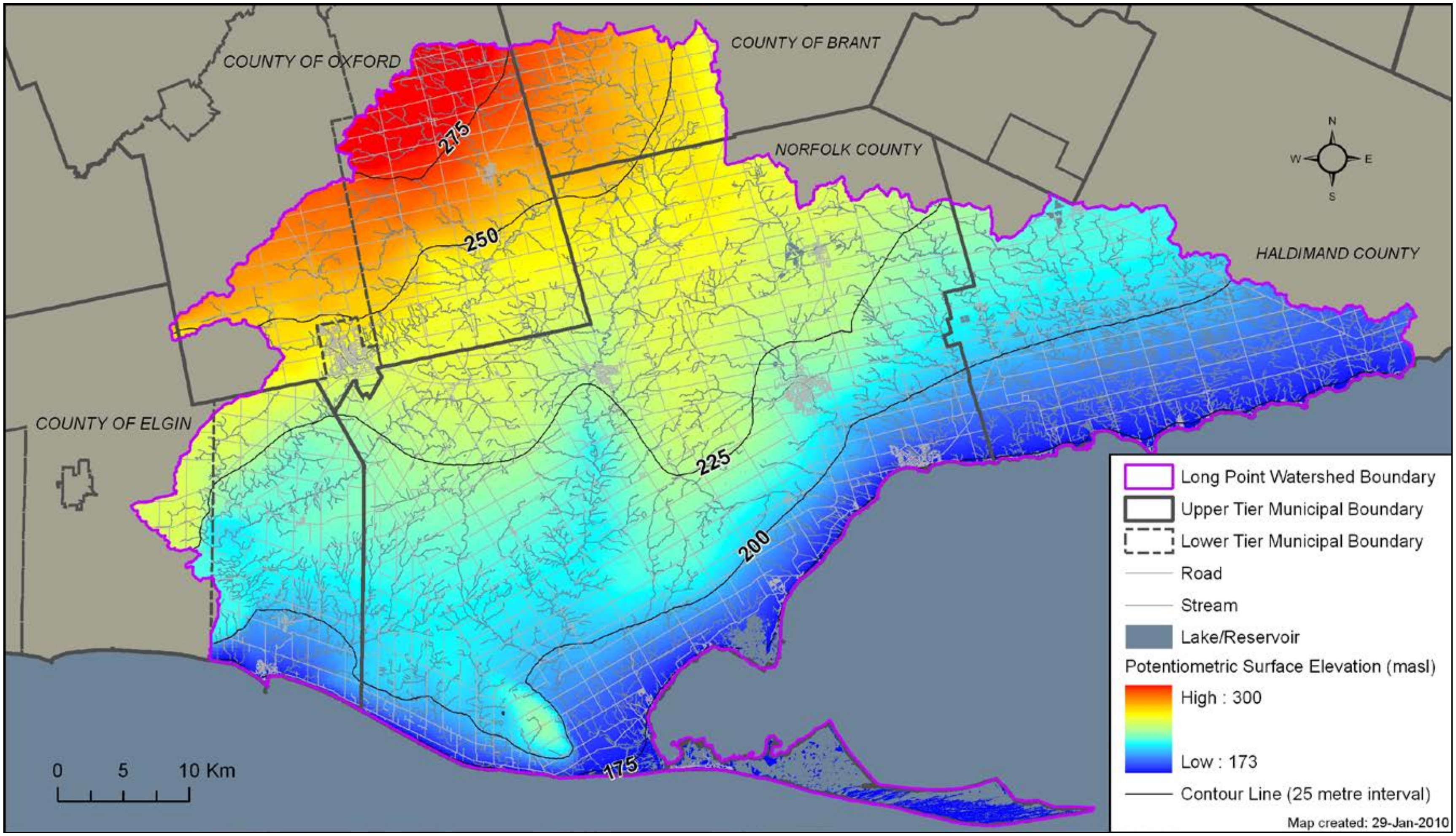
~~Water levels within the wells are monitored through a combination of manual and electronic means. Where electronic dataloggers are in place, water levels are recorded hourly and uploaded to the Ministry of the Environment and Cllimate Change on a prescribed frequency. Manual measurements are made in all wells on a quarterly basis.~~

~~This Provincial Groundwater Monitoring Network is relatively recent, with most wells having been instrumented in the early 2000's. Water well observations from dedicated observation wells associated with municipal supply systems have not yet been collected~~

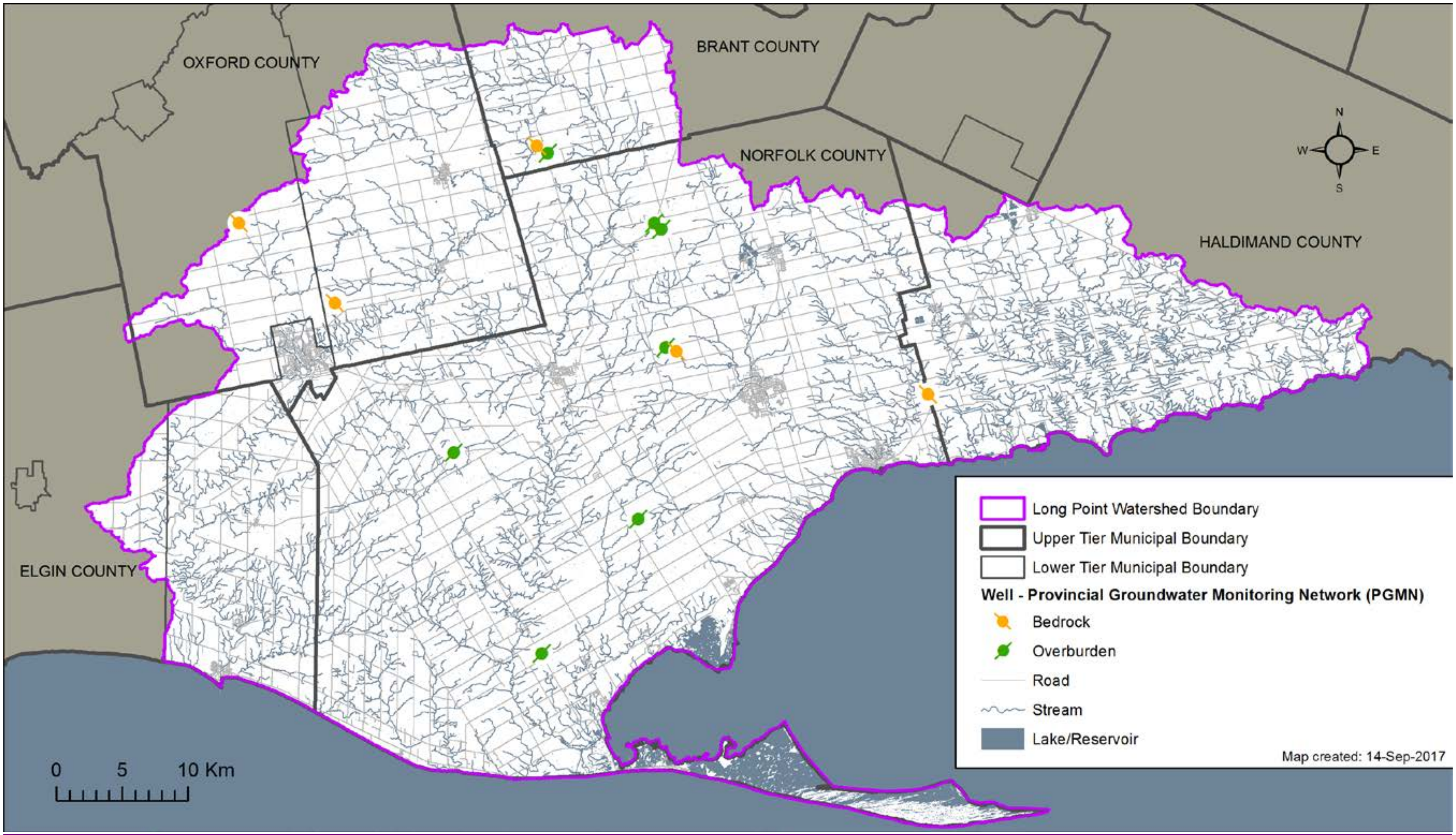
Map 2-10: Water Table Surface in the Long Point Region Watershed



Map 2-11: Bedrock Potentiometric Surface in the Long Point Region Watershed



Map 2-12: Provincial Groundwater Monitoring Well Locations in the Long Point Region Watershed



2.11 Groundwater Quality Across the Watershed

The characterization of groundwater chemistry is an important consideration in hydrogeological studies. As well as being available in sufficient quantities, the geochemical properties of groundwater must be compatible with the intended use (e.g., potable, agricultural, industrial).

The geochemical composition of groundwater is a result of many processes, including interaction with atmospheric gases, reaction with minerals, bacteriological processes, anthropogenic effects, and other subsurface reactions and processes. Although there is a public perception that all instances of undesired compounds in groundwater are a result of anthropogenic contamination, groundwater may be rendered unusable due to entirely natural geochemical processes. For instance, some industrial processes are very sensitive to scaling issues, which may eliminate groundwater high in hardness from use. Groundwater may have attained naturally high concentrations of arsenic or total dissolved solids which would eliminate it from use as a source of potable water. Consequently, there is a need to better understand the ambient quality of groundwater and its controlling processes. This in turn allows for a stronger understanding of the impacts other contaminants may have on groundwater and provides insight into pollution trends and their effects on the aquifer system.

Groundwater geochemistry generally evolves as it moves along its flowpath. Typically, groundwater originates as precipitation and is generally low in total dissolved solids, slightly acidic, and somewhat oxidizing (Freeze and Cherry, 1979). Upon infiltration, the recent precipitation tends to increase in acidity and begins to react with the geologic material it encounters. As groundwater continues along its flowpath, it may evolve from being dominated by the anion bicarbonate and having relatively low total dissolved solids to sulphate domination and finally domination by the anion chloride and having relatively high total dissolved solids (Freeze and Cherry, 1979). This sequence is commonly referred to as the Chebotarev sequence and can account for the spatial variations in geochemistry that are often observed. The process of geochemical mapping and the recognition of geochemical trends can assist in distinguishing provenance and source identification (i.e. natural versus anthropogenic).

Within Long Point Region, there have been no long-term groundwater quality monitoring programs, but there have been several studies which have characterized groundwater quality through small-scale sampling programs. The following is a description of findings from previous studies within Long Point Region:

A. Blackport & Associates (1997) completed a survey evaluating groundwater quality for the Regional Municipality of Haldimand-Norfolk. The report reviewed and evaluated the water quality and septic system survey data from 10 hamlets, the majority of which were located on the Norfolk Sand Plain. The report discussed the potential for contamination of the shallow groundwater system within the Norfolk Sand Plain where the more permeable sandy aquifer commonly overlays less permeable silt and clay. Flow in the shallow system is predominantly horizontal and the direction is locally controlled by streams and topography. Blackport & Associates (1997) concluded that the hamlets situated on the more permeable, shallow hydrogeologic systems were more susceptible to degraded groundwater quality (i.e. bacteria, NO_3^{2-}, Cl^-) from septic system effluent and the application of fertilizer and road salt.

B. As a part of the County of Oxford Phase II Groundwater Protection Study (Golder, 2001), a groundwater quality survey for untreated drinking water was carried out at selected domestic residences within the County. The study focused on sampling wells that were completed in both the shallow overburden aquifer and bedrock aquifer for organic, inorganic and microbiological parameters. The results of the survey concluded that the quality of the raw water within the County was generally good. However, high concentrations of chloride and nitrate in the shallow aquifer reflected a higher susceptibility of that aquifer to surficial sources of contamination such as fertilizer and road salt. The bedrock aquifer was found to contain elevated concentrations of total dissolved solids and SO_4^{2-} and higher levels of specific conductivity. However, these were considered to be natural characteristics of the aquifer.

More recently, in collaboration with the Ontario Geological Survey, Environment Canada and the Grand River Conservation Authority, a small-scale groundwater quality study was completed across Long Point Region (Banks et. al., 2007). As a component of this study, a total of 91 groundwater samples were collected from private residences from the three aquifers across the Region and analyzed for a suite of major/minor ions, metals and general physical properties. The geochemical data was used to understand the chemical processes occurring in the Region and its relation to groundwater quality.

~~Groundwater samples analyzed for this study were collected from three hydrostratigraphic facies: shallow overburden (wells <15 m deep), intermediate to deep overburden (wells >15 m deep), and bedrock. The 15 m depth used to delineate the shallow and deep overburden aquifers was based on the groundwater mapping presented in the Norfolk Groundwater Study (Waterloo Hydrogeologic Inc., 2003). In total, 35 samples were collected from the shallow overburden aquifer, 29 samples from the deep overburden aquifer, and 26 samples from the bedrock aquifer.~~

~~The data collected from the Banks et. al. (2007) study was compared to the Ontario Ministry of the Environment Ontario Drinking Water Quality Standards Maximum Acceptable Concentrations (MAC), Interim Maximum Acceptable Concentrations (IMAC) and Aesthetic Objectives (AO). The MAC is established for parameters, when present above a certain concentration, that have known or suspected adverse health effects whereas the IMAC was established for parameters where there were insufficient toxological data to establish a MAC. An AO is established where the parameter may impair taste, odour or colour of the water or which may interfere with good water quality control practices (Ontario Ministry of the Environment, 2006a).~~

~~**Table 2-6** summarizes the number of samples which exceed their respective MAC, IMAC and AO as given in the Ontario Drinking Water Quality Standards (Ontario Ministry of the Environment, 2006a).~~

~~**Table 2-6: Number of Samples from Each Aquifer that Exceed MOE Ontario Drinking Water Quality Standards**~~

		~~MAC~~	~~IMAC~~	~~AO~~	~~Shallow Overburden (n=31)~~	~~Deep Overburden (n=27)~~	~~Bedrock (n=25)~~
~~As~~			~~0.025~~		~~0~~	~~0~~	~~0~~
~~B~~			~~5~~		~~0~~	~~0~~	~~0~~
~~Ba~~		~~1~~			~~0~~	~~0~~	~~0~~
~~Cd~~		~~0.005~~			~~0~~	~~0~~	~~0~~
~~Cr~~		~~0.05~~			~~0~~	~~0~~	~~0~~
~~Cu~~				~~1~~	~~0~~	~~0~~	~~0~~
~~Fe~~				~~0.3~~	~~2~~	~~0~~	~~0~~

~~**Table 2-6: Number of Samples from Each Aquifer that Exceed MOE Ontario Drinking Water Quality Standards**~~

		MAC	IMAC	AO	Shallow Overburden (n=31)	Deep Overburden (n=27)	Bedrock (n=25)
Mn				0.05	9	2	1
Na				200	0	0	0
Pb		0.01			0	0	0
Sb			0.006		0	0	0
Se		0.01			0	0	0
Zn				5	0	0	0
F		1.5			0	3	8
Cl				250	0	1	1
NO2		1			0	0	0
NO3		10			6	4	2
SO4				500	0	0	6
DOC				5	2	0	1
TDS				500	4	2	9
Colour	TCU			5	3	0	4
Turbidity	NTU			5	0	1	0

~~* All units are in mg/L except where given~~

~~In total, 49% of the shallow overburden samples, 38% of the deep overburden samples and 65% of the bedrock samples exceeded the MAC, IMAC or AO concentrations for at least one parameter. In the shallow overburden, exceedances are believed to be primarily the result of anthropogenic influences such as the application of nitrogen-containing fertilizers and road salts. The bedrock aquifer, which is generally well protected by a layer of glaciolacustrine clay, likely develops its geochemical character from geologic processes.~~

Generally, the groundwater quality found within Long Point Region was found to vary significantly between the 3 different aquifers. These variations were the results of the geologic setting (overburden versus bedrock) and also from surficially-derived chemicals entering the groundwater system. The variation between aquifers suggested different provenance (anthropogenic versus natural) for these parameters.

Comparisons with Ontario Drinking Water Quality Standards (MOE, 2006) show the bedrock aquifer to supply the 'poorest' relative quality and most mineralized groundwater. The nature of this water however, generally appeared to be related to the ambient geochemistry of the groundwater system rather than anthropogenic activity. Where anthropogenic impacts were apparent within the bedrock aquifer, it was likely a result of poorly constructed or improperly maintained wells and less so through recharge entering the groundwater system. The water quality issues within the shallow overburden aquifer also showed poorer quality in accordance to the Ontario Drinking Water Standards, but the degraded quality is likely the result of fertilizer, road salt, manure, septic systems etc. that have entered the aquifer system. Notably higher NO_3^{2-} and associated elevated K^+ concentrations in the overburden aquifers suggests the downward migration of fertilizers into the aquifer systems. The deep overburden aquifer displayed the best relative groundwater quality because it was afforded a certain degree of protection from surficial activities by the overlying confining sediments and has not been affected by the same geologic processes as the bedrock-derived groundwater.

2.12 Climate

The Long Point Region has low latitude and elevation compared to many other parts of southern Ontario, being situated on the northern shore of Lake Erie. The Long Point region has a moderate temperate climate, denoted by evenly distributed precipitation throughout the year and temperatures ranging from warm to hot and humid in the summer to below freezing in winter. Winters are mild compared to the rest of Ontario due to its southerly location, as the proximity to Lake Erie creates a moderating effect. With Lake Erie to the south, winds coming across the lake are often warmer in winter and cooler in summer than the land, thereby moderating air temperatures over the watershed.

This region's climate consists of four seasons, including winters that see some precipitation in the form of snow, and summers that are hot and humid. **Figure 2-1** shows the daily average temperatures for each month of the year, from the Delhi CDA (Canada Department of Agriculture) station and Delhi CS (Climate Station), located centrally in the watershed. Winter is generally considered to have temperatures lower than 0^{o}C, beginning in December and lasting until late February or early March. Spring usually lasts two months, followed by four months (June to September) of summer and two months of autumn. The average annual temperature is about ~~7.5 to~~ 8.0^{o}C.

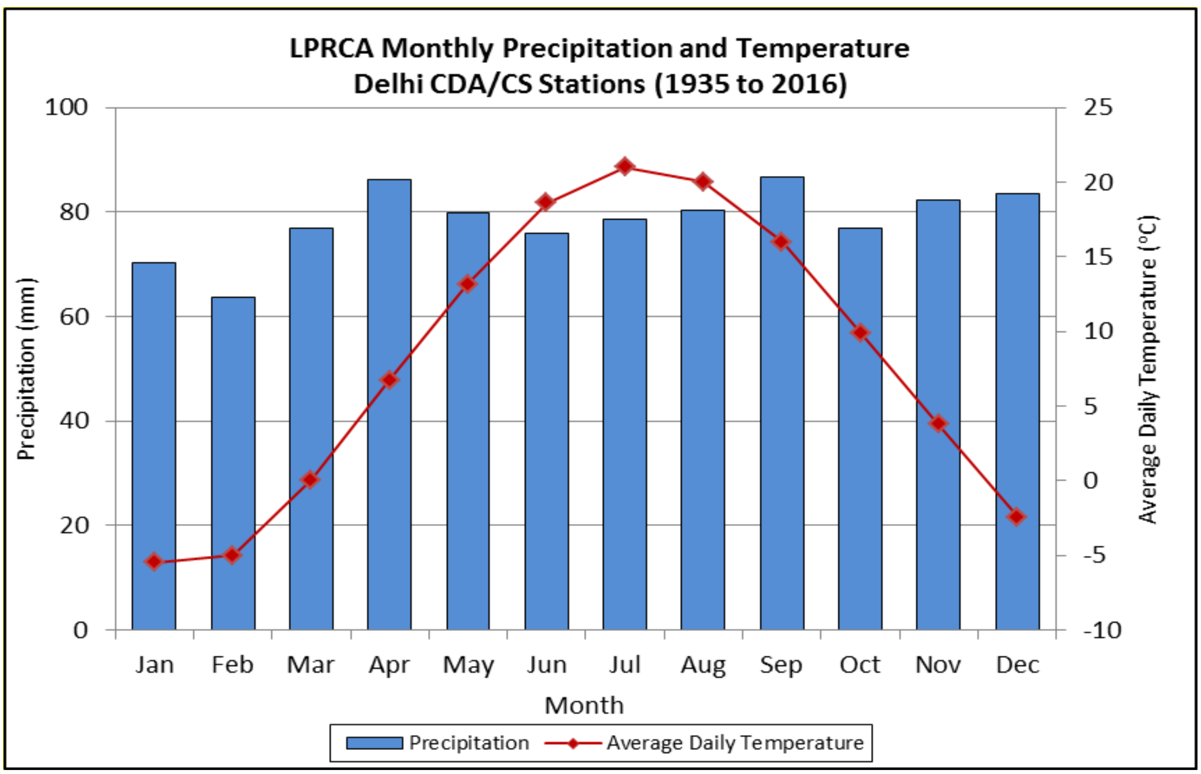


Figure 2-1: Long Point Region Watershed Area Average Monthly Precipitation and Temperature, ~~1971-1997~~1935 to 2016

Precipitation is fairly evenly distributed throughout the year, although the intensity, duration and frequency of precipitation are quite different among the seasons. The accumulation of snow in the winter months prolongs the effects of precipitation, as infiltration is delayed until a thaw. Spring thaw is often accompanied by long, low intensity rainfall; this coupled with the melting snow can make the spring season appear to be constantly wet and overcast. The summer often brings rainfall events that are of high intensity and short duration. The duration of these events, coupled with the high evapotranspiration rates between events, leaves an impression of less rain than in other seasons in terms of frequency of rain-created runoff and recharge.

Annual average precipitation in the watershed from 1935 to 2016 is ~~generally between 950 mm to 1,075 mm~~940 mm. ~~A majority of winter precipitation falls as rain.~~

There is a large annual variation in precipitation (**Figure 2-2**) which can have a large affect on stream flow and water demand in the watershed. The departure from annual precipitation was calculated using the average annual precipitation (1935 to 2016) from the Delhi CDA/CS of 940 mm.

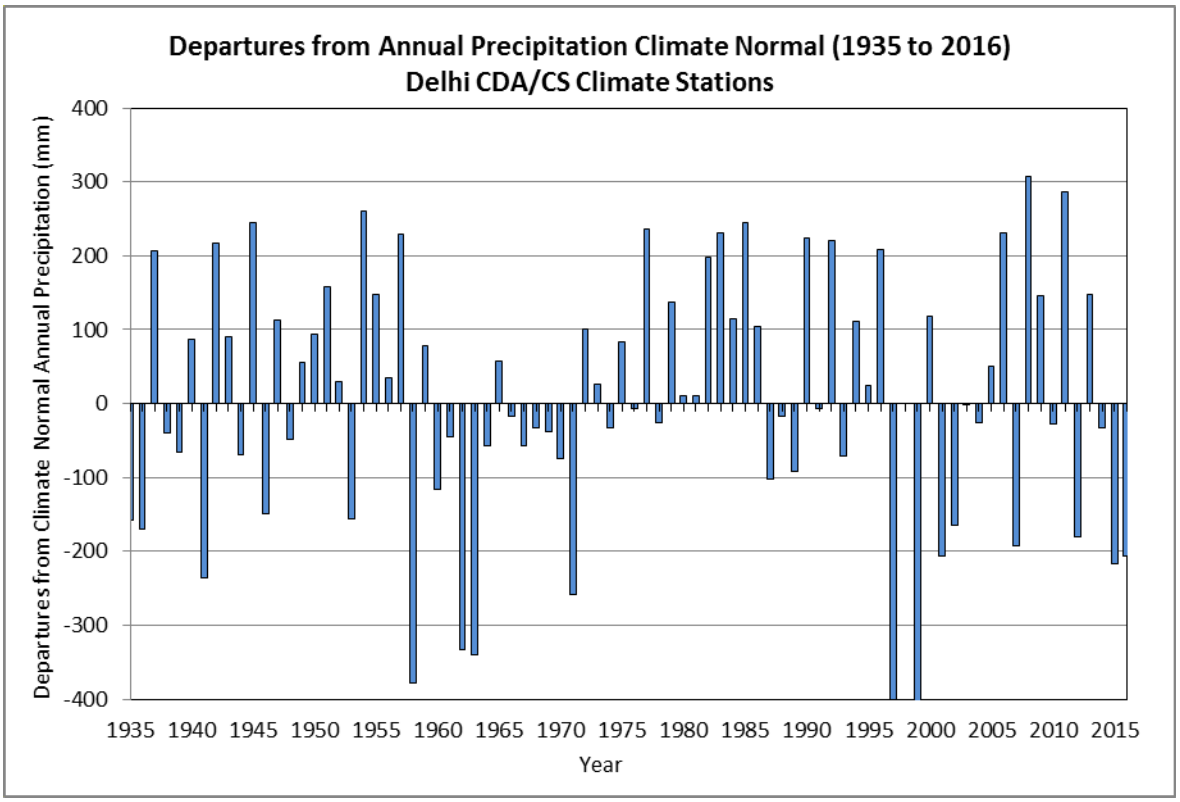


Figure 2-2: Departures from Annual Precipitation (Climate Normal)

2.13 Land Cover and Land Use

Land uses in the Long Point Region watershed area are characterized by a few small urban commercial, industrial and residential centres, surrounded by less-populated rural land used for intensive agricultural production. **Map 2-13** shows the distribution of land cover across the watershed. The map illustrates the dominance of agricultural land uses in rural areas of the watershed; however, it does not specifically identify the significant proportion of resort residential development along the lakeshore. According to the 2001 census, about 78 percent of the total land area of the watershed is actively farmed. In some parts of the watershed, the proportion of farmland is even higher, especially in the Norfolk Sand Plain where soils are well drained and the land is relatively flat.

2.13.1 Forest and Vegetation Cover

The amount of forest cover in the Long Point Region declined from over 70 per cent in the 1850s to less than 15 per cent by the 1960s. In the mid-1800s some of the crop land had started to become less productive due to erosion and loss of nutrients. The loss of useful crop land due to wind and water erosion prompted the establishment of the first Provincial Forestry Station at St. Williams in 1908. Reforestation and other forms of regeneration have regained some of the forest losses and cover ~~is now~~as of 2006 is estimated at about 21 percent, as shown in **Table 2-6** and **Map 2-14**, with areas in the Clay Plain generally having less forest cover than those in the Sand Plain.

The Long Point Region watersheds fall within the Deciduous Forest Region of Canada. Forests within this region are typically dominated by maple, beech, ash and oak species. However, there are significant forest pockets which are representative of the broader Carolinian Life Zone that include species such as Tulip tree, Black Gum, Sassafras, Black Oak, and Cucumber Tree. These tree species are rare in Canada and occur naturally only in southern parts of Ontario north of Lake Erie.

The Long Point Region Conservation Authority has a rich history of forest management dating back to 1948, and is one of the most significant forest land owners in the watershed, along with the Province of Ontario and Norfolk County. Through a private land reforestation program, the Long Point Region Conservation Authority adds close to 45 hectares of future forests to the land cover annually. The Authority continues to recognize the acquisition and wise management of forest lands for integrated uses as an important part of its mandate, including for source water protection. It is now widely accepted that an integrated ecosystem-based approach to forest management is required to maintain the ecological integrity and productive capacity of the forest while providing multiple benefits to society (Heilman, 1990; Kimmins, 1992).

Table 2-6: Land Cover in the Long Point Watershed Area as of 2006

	Area (hectares)	% of Total Watershed Area
Forest and Vegetation Cover	60673.2	21.0%
Wetlands	25540.7	8.8%
Total	86213.9	29.8%

2.13.2 Wetlands

Wetlands are a significant feature of the Long Point Region. Although a large percentage of the original wetlands have been lost through clearing, filling and drainage, there are still almost 260 square kilometres of evaluated wetlands in the Long Point Region watersheds (**Table 2-6** and **Map 2-14**). The Long Point wetland complex, which includes the wetlands at the mouth of Big Creek, covers 75 square kilometres on its own. This wetland is internationally recognized under the Ramsar Convention and as the Long Point Biosphere Reserve.

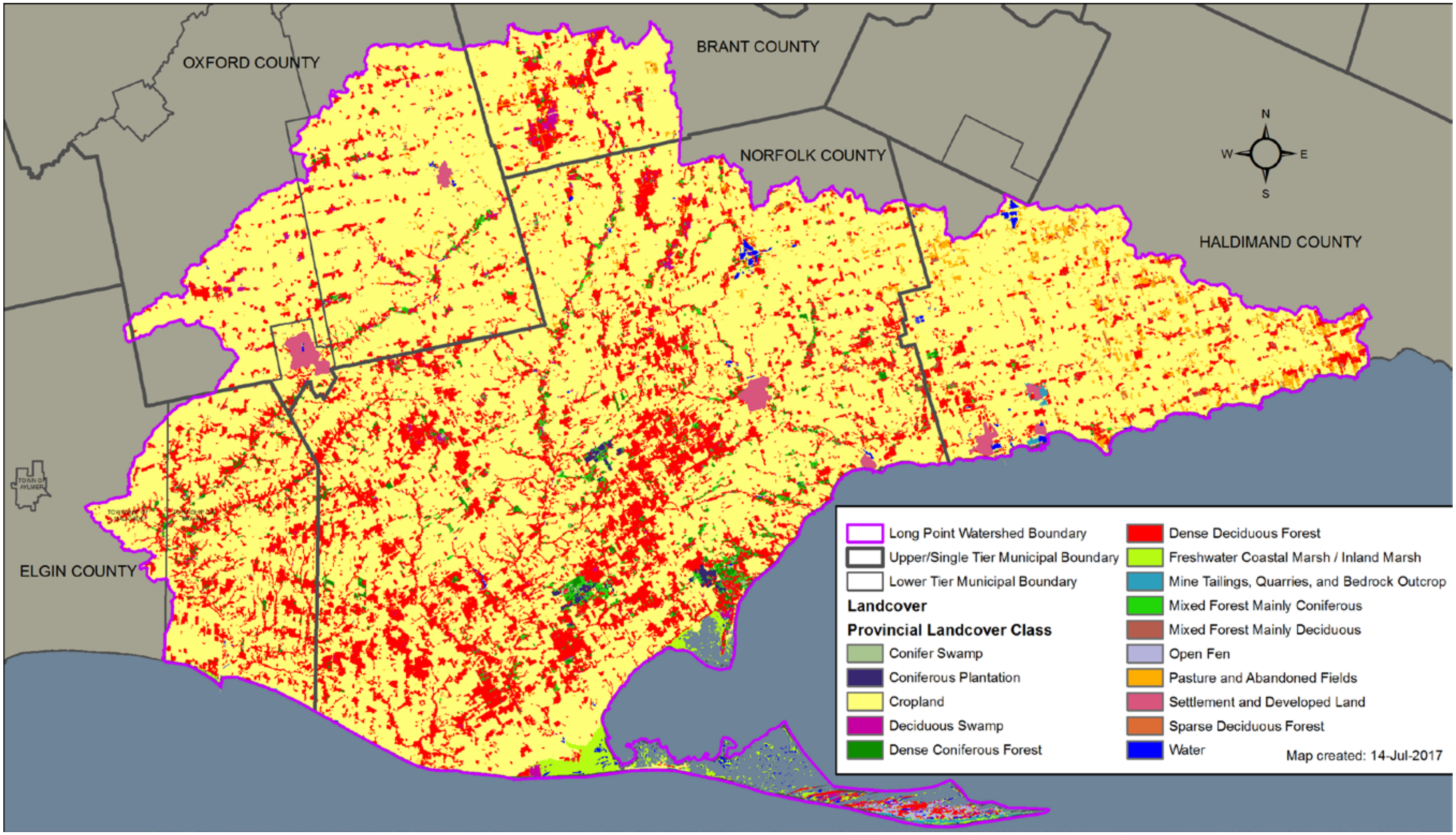
Wetlands play an important role in many of the watersheds' hydrological and ecological processes. The hydrologic function of wetlands vary, with some wetlands being groundwater discharge areas that provide baseflow during low flow periods, while other wetlands provide recharge to the underlying aquifer system during dry periods of the year. Wetlands are also critical as they retain surface runoff and reduce downstream flood flows. They also act as water filters and capture sediment, dissolved nutrients and other contaminants, improving the surface water quality. Wetlands are also typically highly productive ecological habitats, with great biodiversity, and often home to a large number of species.

2.13.3 Wetland and Forest Riparian Areas

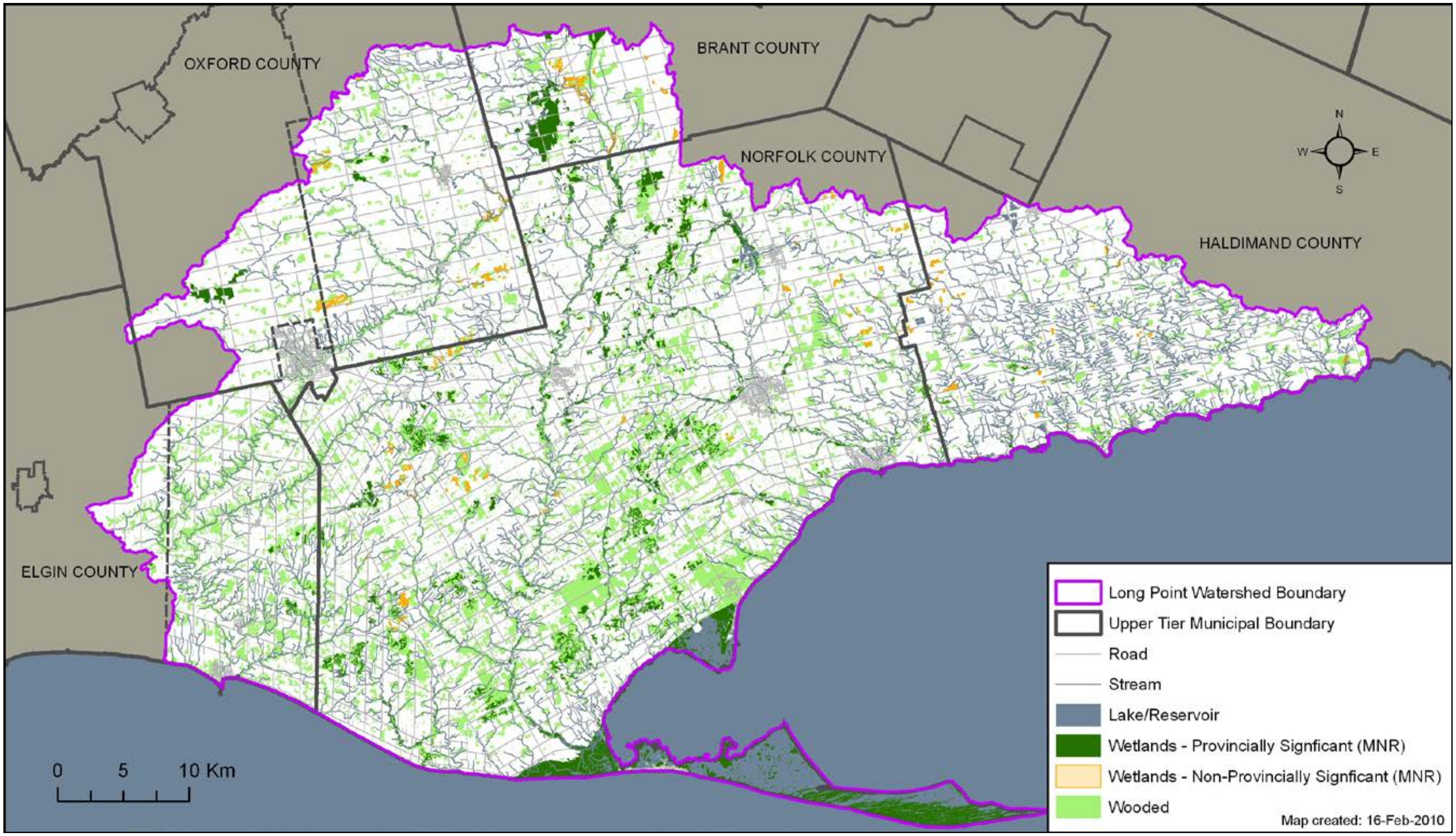
All wetlands and forest cover help protect and enhance water quantity and quality values of the watershed. Depending on the issues impacting the water resources, the forest and wetland cover that acts as an immediate buffer to the surface streamflow can be even more valuable.

Within the Long Point Region watersheds, the amount of riparian forest and wetland along the watercourses are estimated at 40 percent, (based on a 15 metre buffer on each side of the stream). In addition, many of these watercourses have been provided with a grassed buffer by landowners using best management practices.

Map 2-13: Land Cover in the Long Point Region Watershed



Map 2-14: Vegetation in the Long Point Region Watershed



2.14 Surface Water

2.14.1 Surface Water Characterization

The Long Point Region is comprised of numerous watersheds and watercourses. The combined length of all the streams and their tributaries within the Long Point Region is over 3,700 kilometres. Most of the western watersheds are found largely within the Norfolk Sand Plain; an area characterized by low runoff, high soil infiltration and sustained baseflows. The upper and western parts of Big Otter Creek are located in the till plain. The eastern watersheds drain through the Haldimand Clay Plain, an area characterized by high runoff and low soil infiltration. The eastern watersheds have a higher density of tributaries than the western watersheds with the river systems being shallower and with a tendency to dry up during the summer months.

The Long Point Region has among the highest number of permitted surface and ground water users of any area in Southern Ontario (LPRCA, 2008). Demand for irrigation water during the summer months can affect stream flow throughout the region, but is focused in the western watersheds on the Norfolk Sand Plain.

2.14.2 Surface Water Monitoring

Streamflow monitoring within the Long Point Region watershed area is predominantly carried out by the Water Survey of Canada (WSC). Rating curves and gauge infrastructure are frequently maintained, with observed data undergoing extensive quality assurance and quality controls. As such, streamflow data from WSC stations is considered to be the highest quality streamflow data available.

The flow monitoring network in the Long Point Region has been expanded in recent years with the re-opening of a number of historic gauges. There are 10 active WSC gauges in the Long Point Region. The gauge network is denser in the western part of the region and is focused on the larger watercourses. There are three active gauges in the Big Otter Creek Watershed that cover most of the watershed area. Stream flow data is available beginning in 1948 with the longest continuous data set from 1960 to present. There are 4 active stream gauges in the Big Creek Watershed with 2 gauges in continuous operation since 1955 and 2 recently re-opened gauges.

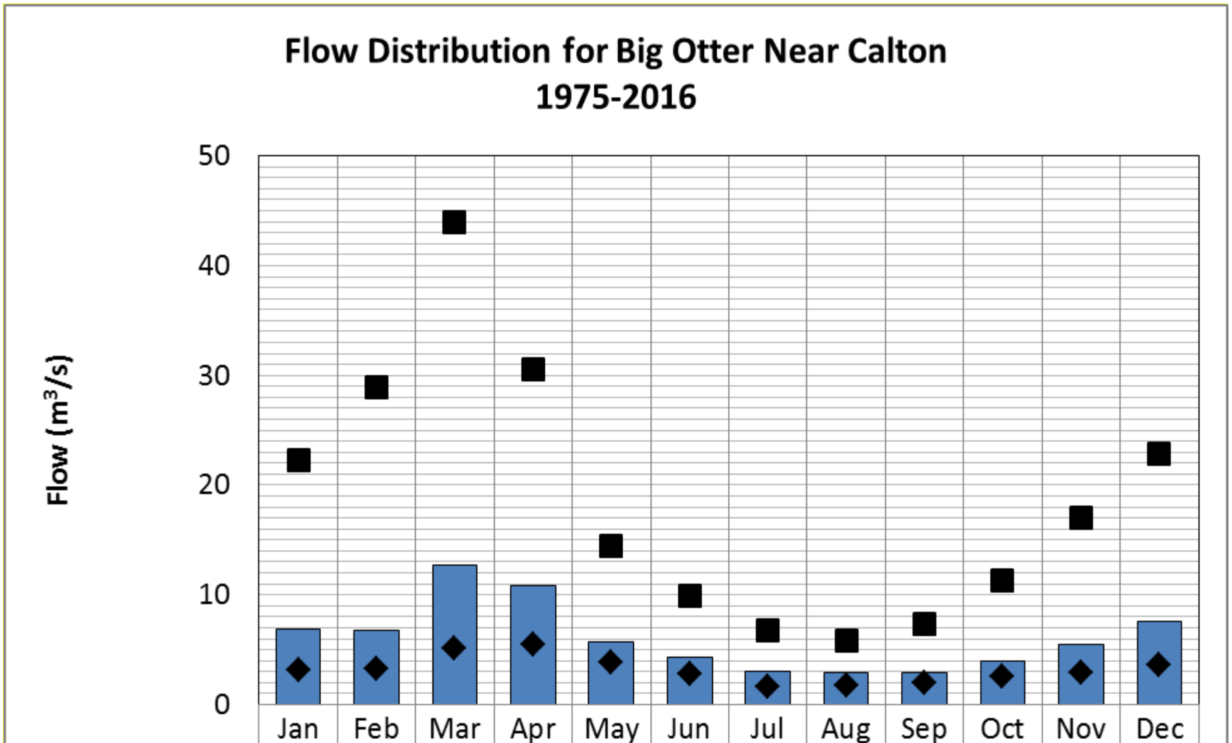
The other 3 stream gauges are on Young Creek, Nanticoke Creek and the Lynn River. The gauge on Young Creek has been operated for various periods since 1963. The Lynn River gauge has a continuous data set beginning in 1957. The Nanticoke Creek gauge is the only gauge in the eastern part of the region and has been in operation since 1969. There is also flow data available from abandoned stations for Hemlock Creek, Little Otter Creek, South Otter Creek, North Creek, Dedrick Creek, Fishers Creek, and Patterson Creek in the western part of the Region, and Sandusk Creek in the eastern part of the Region.

2.14.3 Big Otter Creek

Big Otter Creek is the second largest watershed in the region, draining an area of approximately 712 km^2. The upper part of the watershed in the northwestern corner of the region lies in the till plain. The creek flows southward in the Norfolk Sand Plain through the communities of Norwich, Otterville, and Tillsonburg before draining to Lake Erie at Port Burwell. The Big Otter Watershed is characterized by moderate runoff, soil infiltration, and baseflows. Spittler Creek joins the Big Otter just south of Otterville and drains about 116 km^2. The largest tributary, Little Otter Creek, joins Big Otter Creek past Straffordville. Little Otter is classified as a cold water stream and drains approximately 118 km^2.

There are three active Water Survey Canada gauges in the Big Otter Creek Watershed. The first one is located in the upper part of the watershed above Otterville, and it was installed in 1964. The second gauge is located at the Town of Tillsonburg. This gauge is the oldest active gauge in the Big Otter Creek watershed and has been in operation since 1960, except for a brief period from 1998-2002 when the rating curve was not maintained; however, water levels were continuously recorded during this time. The third gauge is located near the community of Calton, and it has been in operation since 1975 and captures approximately 95% of the drainage area including Little Otter Creek. Prior to 1975 the gauge was located downstream near the community of Vienna where it had been in operation since 1948. The flow distribution at the Calton gauge is illustrated in **Figure 2-3**. A stream gauge operated on the Little Otter between 1963 and 1992.

The distribution in **Figure 2-3** shows both a runoff component with high 10th percentile flows in the spring and a strong groundwater fed baseflow component with steady median and 90th percentile low flows throughout the summer months.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
■ Median	6.8	6.8	12.7	10.8	5.8	4.3	3.1	2.9	2.9	4.0	5.5	7.6
◆ 90 percentile	3.1	3.3	5.2	5.5	3.8	2.8	1.7	1.8	2.0	2.5	2.9	3.6
■ 10 precentile	22.3	28.9	44.0	30.5	14.5	9.9	6.8	5.8	7.3	11.3	17.0	22.8

Figure 2-3: Flow Distribution for Big Otter Creek near Calton Gauge

There are two reservoirs on Big Otter Creek; the Norwich Dam in Norwich, and the Otterville Dam in Otterville. The Norwich Dam is operated by the LPRCA and its functions include supporting recreational activities, water supply, flood control and flow augmentation; the flow through the dam is controlled by a control valve. The Otterville Dam is passively operated by the municipality. Other major control structures in the watershed include Black Bridge and Lake Lisgar. There are also numerous small, private control structures within the watershed that are used to store water for irrigation in the summer months. About 269~~430~~ Permit to Take Water (PTTW) takings presently exist in the watershed.

2.14.4 South Otter and Clear Creeks

South Otter Creek drains an area of approximately 111 km^2 adjacent to the lower portion of Big Otter Creek along the Lake Erie shoreline. Clear Creek is similar in size and drains an area of approximately 106 km^2 to the east of South Otter Creek. Both creeks are within the Norfolk Sand Plain and are characterized by low runoff, high infiltration, and groundwater fed baseflows. There are no active gauges in this watershed grouping, but there was a historic gauge located on South Otter Creek near its outlet to Lake Erie at Port Burwell that operated from 1964 to 1978. About 146~~50~~ Permit to Take Water (PTTW) takings exist in each watershed.

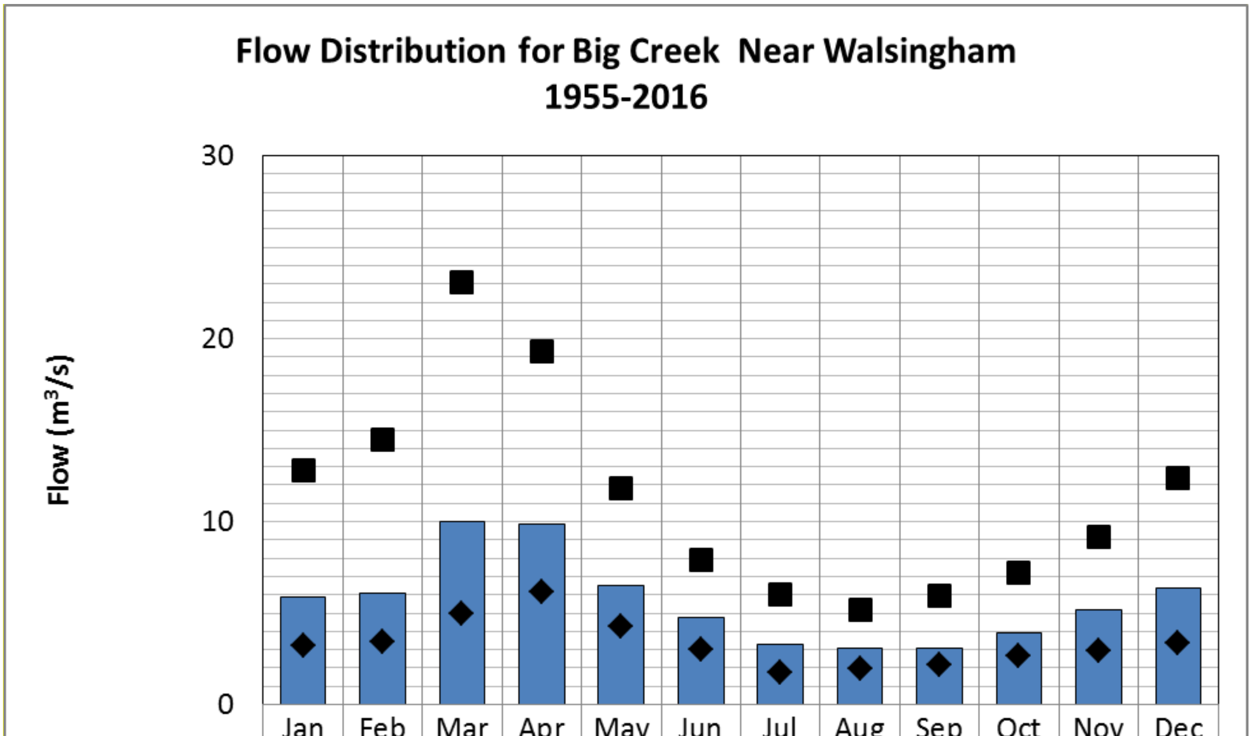
2.14.5 Big Creek

Big Creek is the largest watercourse in the Long Point Region with a total drainage area of 750 km^2. Big Creek's headwaters are at the most northerly part of the Long Point Region. The creek flows predominately southward, passing through the community of Delhi, where it is joined by North Creek via Lehman's Reservoir. From Delhi, stream flow continues southward, merging with Venison Creek (the largest tributary draining 98 km^2) downstream of Walsingham and finally draining into Lake Erie near Port Rowan.

The Big Creek watershed is predominately in the Norfolk Sand Plain, and is characterized by very low runoff and high baseflow. Water use within the drainage area is significant with about 741~~1200~~ Permit to Take Water (PTTW) takings. Irrigation is the primary water use within the watershed and water takings have the potential to reduce summer flows in the creek during dry years.

There are three reservoirs in the Big Creek Watershed; Teeterville, Lehman and Deer Creek Reservoirs. All three reservoirs are operated by the Long Point Region Conservation Authority. The Teeterville Reservoir is located in the upper portion of the watershed on Big Creek, and it is used for recreation, flood control, and low flow augmentation. Lehman's Reservoir is located in the community of Delhi on North Creek and it is used for flow control/augmentation, recreational shore fishing and to supplement the community of Delhi's drinking water supply. The final reservoir is located on Deer Creek, a tributary of Big Creek. Most of the Big Creek tributaries have small private dams and reservoirs used for irrigation.

There are four active Water Survey Canada gauges in the Big Creek Watershed. The first one is located in the upper part of the watershed near Kelvin, which has operated periodically since 1963. The second gauge is located near Delhi and has been in continuous operation since 1955. A gauge on Venison Creek near Walsingham has operated periodically since 1966. A gauge further downstream on Big Creek near Walsingham captures about 75% of the entire drainage area, and has also been in operation since 1955. The flow distribution plot for the Big Creek at Walsingham gauge is included in **Figure 2-4**. The narrow range of median, 10th and 90th percentile flows in **Figure 2-4** shows the moderating effects of large annual recharge amounts, significant groundwater storage volumes, and reservoir operations upstream of the gauge. There is a very high baseflow component throughout the year with fairly steady median and 90th percentile flows. A stream gauge existed on North Creek between 1954 and 1966.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median	5.9	6.1	10.0	9.8	6.5	4.7	3.3	3.1	3.1	4.0	5.2	6.4
90 percentile	3.2	3.5	5.0	6.2	4.3	3.0	1.7	2.0	2.2	2.6	2.9	3.4
10 precentile	12.8	14.5	23.1	19.3	11.8	7.9	6.0	5.2	6.0	7.2	9.1	12.4

Figure 2-4: Flow Distribution for Big Creek near Walsingham Gauge

2.14.6 Dedrick-Young Creeks

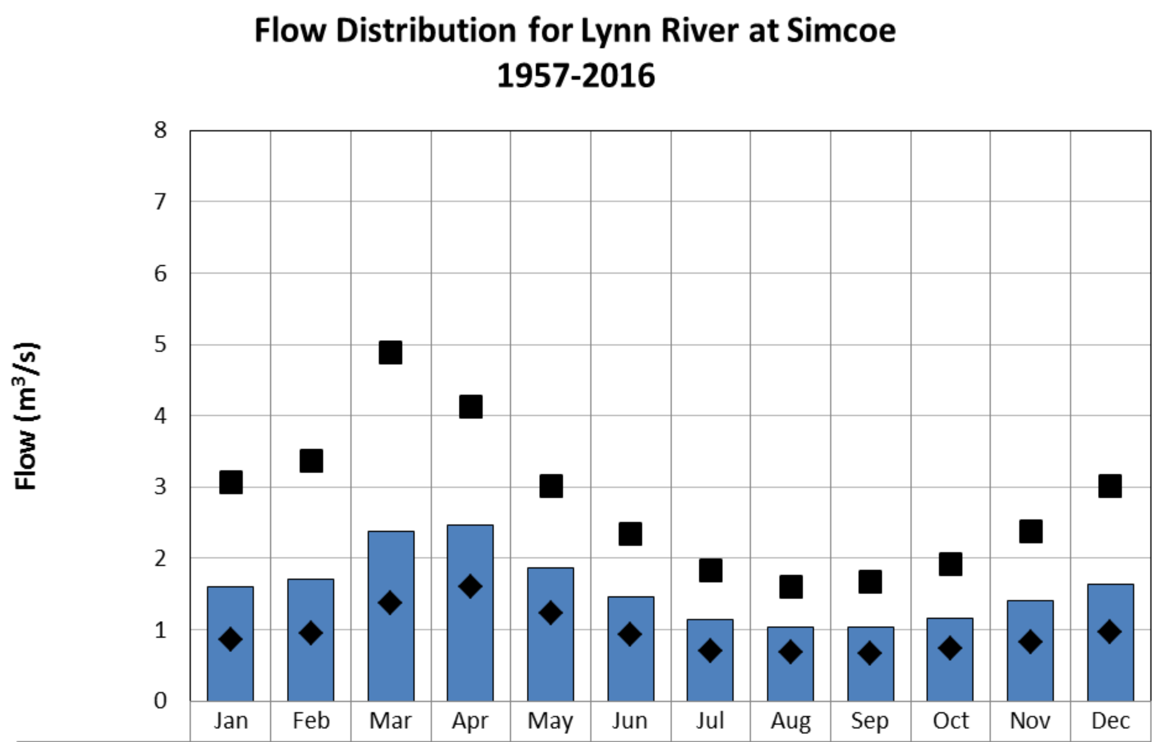
The Dedrick-Young Creek watershed group drains a combined area of 263 square kilometres. The main watercourses in this watershed group are Dedrick, Forestville, Young, and Hay creeks, but this area also includes numerous other small Lake Erie tributaries. These watersheds are mainly located within the Norfolk Sand Plain. With groundwater fed creeks and streams the area contains several significant coldwater fisheries. There are two reservoirs, both used for recreation, the Hay Creek Dam on Hay Creek and Vittoria Pond on Young Creek. Long Point Region Conservation Authority operates both reservoirs. There is one reactivated stream gauge on Young Creek downstream of the Vittoria Pond Reservoir which has been in operation for various periods since 1963. There was also a stream gauge on Dedrick Creek near its outlet to Lake Erie at Port Rowan. This gauge was in operation from 1963 to 1984. Fishers Creek, also had a stream gauge in operation during a period of 8 years beginning in 1969. There are currently about 171~~240~~ active permitted (PTTW) takings in these watersheds.

2.14.7 Lynn River-Black Creek

The Lynn River flows from north of the community of Simcoe to the southeast to Lake Erie at Port Dover. It is joined by Black Creek in Port Dover just prior to draining into Lake Erie. The combined drainage area of this watershed group is approximately 285 km^2.

The watershed drains two different physiographic regions. The Lynn River, a cool water fishery, is largely located in the Norfolk Sand Plain, where there is low surface runoff, high recharge amounts, and sustained baseflows. Black Creek, drains through the Haldimand Clay Plain, and this part of the watershed is characterized by high runoff, low baseflows, and predominantly warmwater fish communities. There are about 203~~260~~ current permitted ~~water~~ (PTTW) takings in this watershed, with most of these concentrated in the western area on the Sand Plain.

There is one active stream gauge on the Lynn River located in the Village of Simcoe. It has been in continuous operation since 1957, with the flow regime for this gauge illustrated in **Figure 2-5**. The narrow monthly flow distribution and high baseflows show the moderating influence of the Norfolk Sand Plain and the relatively small drainage area upstream of the gauge. There are also two controlled reservoirs on the Lynn River, Crystal Lake (Quance Dam) in Simcoe and Silver Lake (Misner Dam) in Port Dover, both of which are operated by Norfolk County. A stream gauge operated on Patterson Creek for a period of 29 years beginning in 1963. There are no stream gauges on Black Creek.

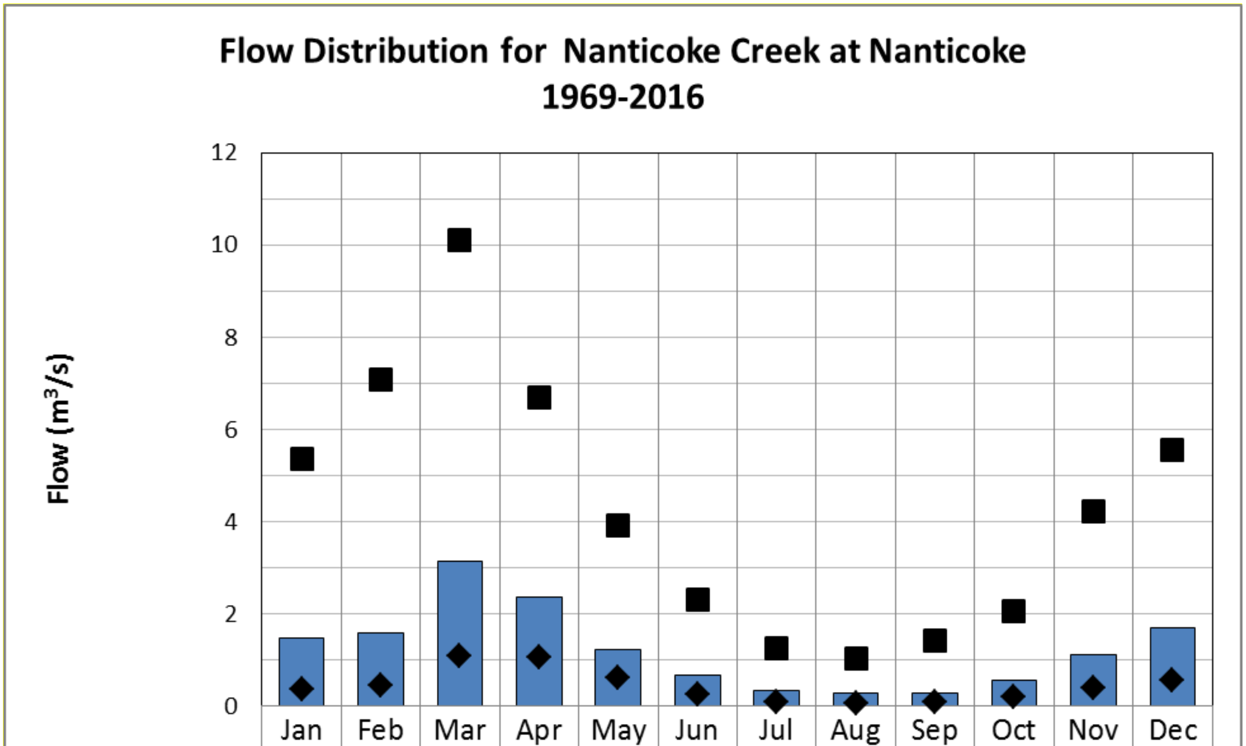


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
■ Median	1.6	1.7	2.4	2.5	1.9	1.5	1.2	1.0	1.0	1.2	1.4	1.6
◆ 90 percentile	0.9	0.9	1.4	1.6	1.2	0.9	0.7	0.7	0.7	0.7	0.8	1.0
■ 10 precentile	3.1	3.4	4.9	4.1	3.0	2.3	1.8	1.6	1.7	1.9	2.4	3.0

Figure 2-5: Flow Distribution for Lynn River at Simcoe Gauge

2.14.8 Nanticoke Creek

The headwaters of Nanticoke Creek contain cool water fisheries, as these headwaters sit within the Norfolk Sand Plain where groundwater discharge is strong. The Creek migrates through the Waterford Ponds, a series of lakes, ponds, and wetlands near the community of Waterford and then heads southeastward onto the Haldimand Clay Plan where it changes to a warm water fishery on its way to discharging in Lake Erie at Nanticoke. There is one stream gauge near Nanticoke which captures most of the watershed. The gauge has been in operation since 1969 and its flow distribution is given in **Figure 2-6**. Low flows, shown by the 90th percentile flow, are very low throughout the year. Median flows are also low during the summer months. The wide monthly distribution shows a large runoff component to the flow regime as is expected due to the influence of the Haldimand Clay Plain. There are about 146~~200~~ permitted takings ~~permits to take water~~(PTTW) in this watershed.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median	1.47	1.60	3.15	2.37	1.23	0.69	0.35	0.30	0.29	0.57	1.11	1.70
90 percentile	0.38	0.46	1.08	1.06	0.62	0.25	0.08	0.06	0.09	0.22	0.40	0.56
10 precentile	5.35	7.07	10.10	6.68	3.93	2.32	1.25	1.03	1.42	2.07	4.23	5.57

Figure 2-6: Flow Distribution for Nanticoke Creek at Nanticoke Gauge

2.14.9 Eastern Tributaries

The Eastern Tributaries includes many relatively small watercourses such as Sandusk, Stoney, Evans, Hickory and Fories-Stelco Creeks covering a combined area of about 367 km^2. The largest of these systems are Sandusk (158 km^2) and Stoney (118 km^2) Creeks. These watercourses drain directly into Lake Erie and their drainage areas are entirely contained within the Haldimand Clay Plain. They have high runoff, low soil infiltration and very little baseflow. There are no active stream gauges within this watershed; however two historical gauges on Sandusk Creek operated for short periods in the 1990's. There are relatively few permits to take water in these watersheds compared to those to the west.

2.14.10 Water Control Structures

In addition to the large water control structures described in the previous sections, several hundred small dams have been constructed on virtually every tributary of Big Creek and Big Otter Creek and other small watercourses in the Norfolk Sand Plain, to store water as a source for irrigation. They were constructed mainly in the last half of the 20th century. There are also several old mill dams that were constructed in the 1800’s and replaced or maintained in various states since. In addition the LPRCA, MNR and municipalities in the Region operate a number of small dams for multipurpose uses, including flood control, low flow augmentation, drinking water supply, irrigation, recreation and wildlife habitat. Selected dams and reservoirs in the Long Point Region are shown on **Map 2-15**.

2.15 Surface Water Quality

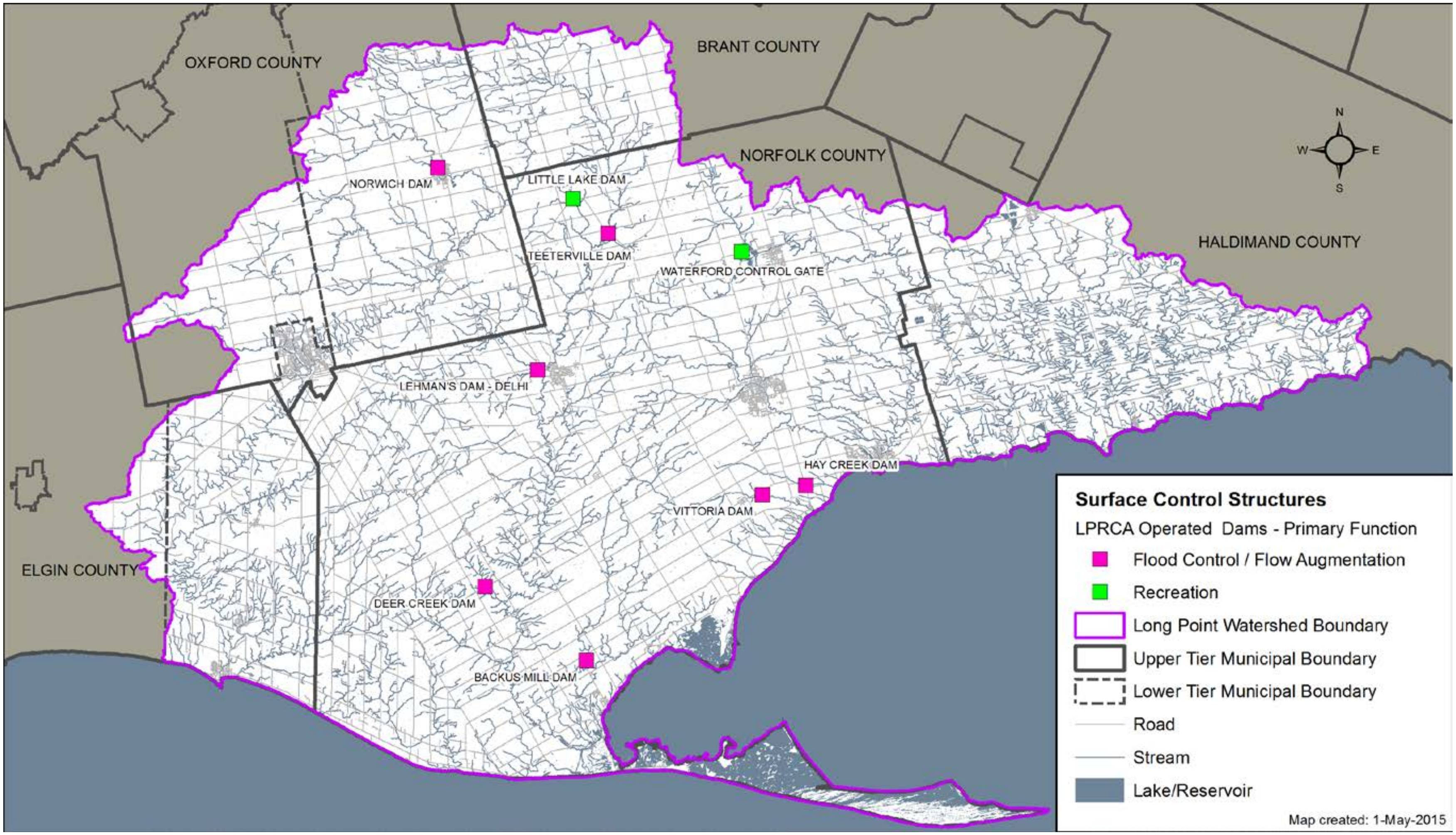
The following describes the general surface water quality conditions found in the rivers and creeks in the Long Point Region Conservation Authority (LPRCA), as described in the Long Point Region Water Quality and Conditions report (Evans, 2007). The observations are based on data from the Ministry of the Environment’s Provincial Water Quality Monitoring Network in addition to specific reports that describe the conditions within each watershed.

The most recent five year contiguous set of water quality data for Provincial Water Quality Monitoring Network sites were used to evaluate surface water quality conditions. Ten Provincial Water Quality Monitoring Network sites in the region had a sufficient number of data points to make meaningful observations. The Region was divided into six subbasins: Big Otter Creek, Big Creek, Lynn River, Nanticoke Creek, Sandusk Creek and Dedrick-Young Creek. See **Map 2-16** for the location of the ten monitoring sites. The most complete dataset for these sites was for the period of 2002-2005.

Water quality sampling for chemical and physical parameters in the Long Point Region watersheds resumed in 2002 following a lengthy period of not participating in the provincial water quality monitoring network. When LPRCA resumed sampling at ten sites, samples were collected on a routine basis however flow was not always considered. Generally, sampling was completed during low to moderate stream flows and peak flows were missed routinely. Therefore, the description of water quality conditions for the Long Point Region is generally limited to low/base flow conditions.

In general, the inherent geology and current landuse practices appear to influence surface water quality Issues in the Long Point Region. For example, watersheds draining the clay and till plains tend to have the highest non-filterable residue and phosphorus concentrations (e.g. Big Otter Creek and Nanticoke Creek). These areas support livestock operations and general cash crop production. Conversely, irrigated specialty crops are produced on the Norfolk Sand Plain but the high recharge and subsequent discharge of cool groundwater helps to sustain cold water fisheries. Consequently, water quality in the creeks draining the Norfolk Sand Plain (e.g. Young, Trout, Venison and Kent Creeks) tends to have better water quality with the exception of elevated nitrate levels. In addition to land use, point source discharges such as water pollution control plants also influence stream water quality in the Region. There are nine small towns/cities with municipal wastewater treatment plants or lagoons that discharge continuously or seasonally into the creeks and rivers of the Region; there is also one municipal industrial lagoon that discharges into a local stream. Summary and descriptive statistics for priority chemical parameters (e.g. nutrients and chloride) are listed in **Table 2-7** for each of the ten sampling sites.

Map 2-15: Selected Surface Water Control Structures in the Long Point Region Watershed



Map 2-16: Provincial Water Quality Monitoring Network Sites in the Long Point Region Watershed

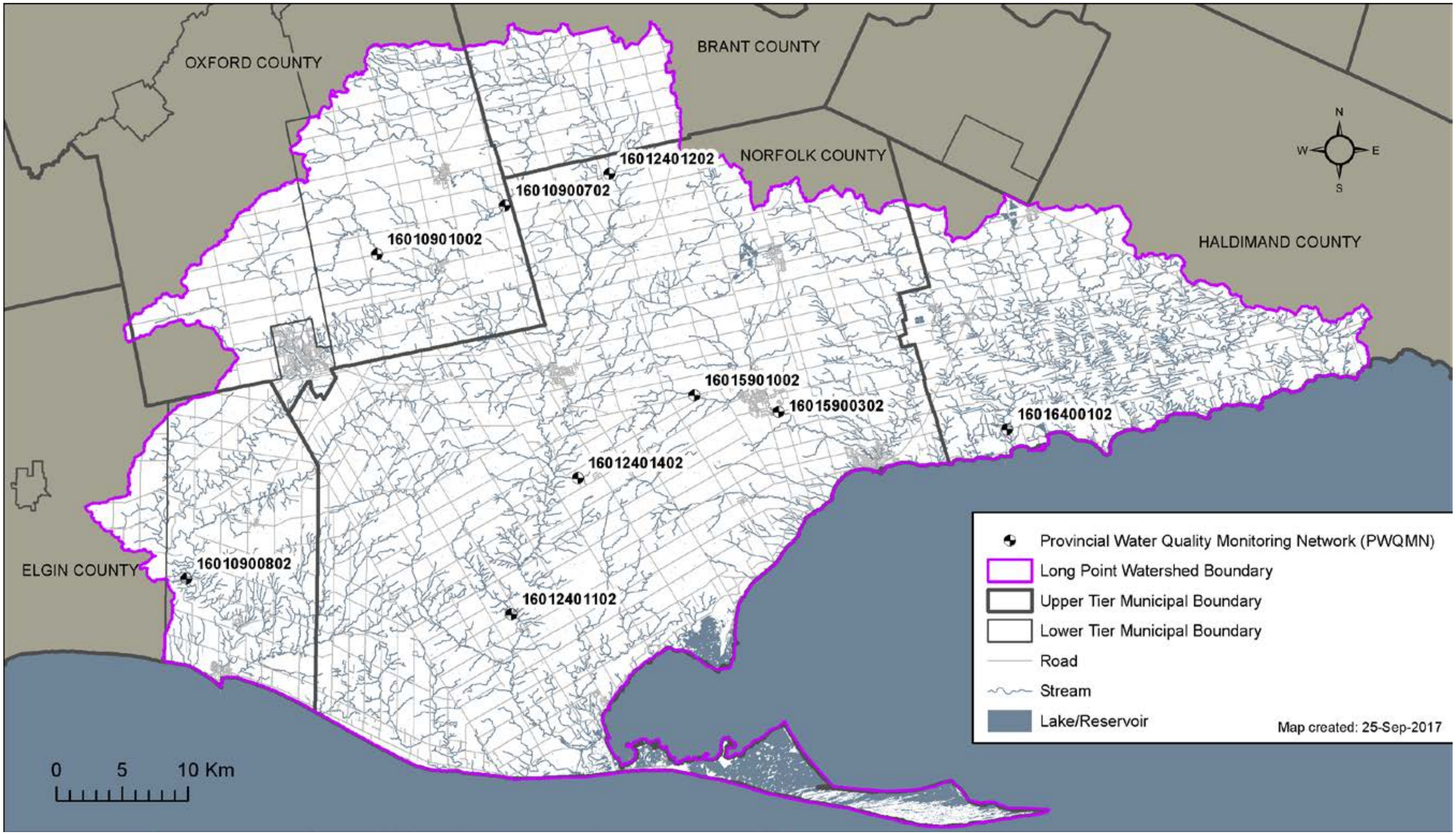


Table 2-7: Summary and Descriptive Statistics for Priority Chemical Parameters

Variable	Statistic	Big Otter Watershed			Big Creek Watershed				Lynn River Watershed		Nanticoke Watershed	Guideline or Benchmark
		Big Otter		Spittler Creek	Big Creek		Venison	Trout	Kent	Lynn River	Nanticoke Creek	
		PWQMN Site Number										
		9007	9008	9010	24012	24011	24013	24014	59010	59003	64001	
Nitrates (mg/L)	5th %	2.67	2.56	0.00	2.70	2.38	2.09	2.33	1.98	2.33	0.07	2.93
	Median	3.76	3.43	4.13	3.23	2.97	2.39	2.76	2.49	2.86	1.31	
	75th %	5.11	4.39	9.12	4.14	3.20	2.57	2.87	3.00	3.21	2.50	
	95th %	6.70	6.14	11.64	6.32	4.15	3.05	2.96	3.28	3.93	4.65	
Nitrite (mg/L)	5th %	0.018	0.007	0.004	0.012	0.016	0.013	0.005	0.009	0.049	0.008	0.06
	Median	0.032	0.022	0.027	0.022	0.026	0.025	0.008	0.018	0.159	0.024	
	75th %	0.042	0.040	0.076	0.039	0.031	0.030	0.009	0.022	0.185	0.038	
	95th %	0.060	0.054	0.148	0.055	0.039	0.047	0.014	0.032	0.309	0.143	
Un-ionized Ammonia (mg/L)	5th %	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.016
	Median	0.001	0.001	0.002	0.001	0.001	0.001	0.000	0.000	0.007	0.002	
	75th %	0.001	0.001	0.003	0.002	0.001	0.001	0.000	0.001	0.021	0.005	
	95th %	0.005	0.003	0.011	0.006	0.003	0.005	0.001	0.004	0.065	0.020	
Total Nitrogen (mg/L)	5th %	3.24	3.01	0.73	3.17	2.86	2.47	2.63	2.45	3.18	0.94	n/a
	Median	4.45	3.92	5.02	3.88	3.50	2.75	3.00	2.92	4.05	2.26	
	75th %	6.27	5.29	10.21	4.79	3.92	3.15	3.09	3.37	4.42	3.63	
	95th %	7.61	7.53	12.53	7.35	4.86	3.79	3.32	3.60	5.20	5.88	
Total Phosphorus (mg/L)	5th %	0.029	0.020	0.020	0.018	0.014	0.016	0.014	0.008	0.030	0.051	0.03
	Median	0.057	0.063	0.053	0.032	0.051	0.046	0.027	0.020	0.061	0.113	
	75th %	0.071	0.119	0.082	0.039	0.061	0.063	0.038	0.026	0.100	0.143	
	95th %	0.208	0.526	0.287	0.149	0.195	0.108	0.078	0.037	0.171	0.402	
Non Filterable Residue (mg/L)	5th %	2.0	3.0	2.2	1.3	2.9	3.0	2.9	0.7	3.8	12.0	25
	Median	7.6	26.9	11.3	2.7	20.8	18.8	7.7	3.4	12.4	38.4	
	75th %	12.2	77.8	17.6	4.3	31.0	25.3	11.9	4.8	17.7	63.2	
	95th %	25.8	367.3	91.0	13.0	95.2	36.6	34.8	9.9	29.1	154.5	
Chloride (mg/L)	5th %	17.5	19.5	19.4	17.5	18.6	10.4	15.3	21.6	36.8	24.6	250
	Median	28.5	30.3	36.5	24.5	26.2	12.7	17.2	26.8	57.7	39.6	
	75th %	33.4	32.5	45.6	28.4	27.6	13.9	17.5	28.2	61.4	44.1	
	95th %	43.2	34.8	60.8	30.9	28.6	22.5	19.3	30.6	71.6	49.4	

2.15.1 Conditions Specific to the Big Otter Creek Watershed

Nitrate, phosphorus, and non-filterable residue concentrations were found to be the major water quality issue within the Big Otter Creek watershed.

Nitrate and phosphorus concentrations were consistently above the Canadian Environmental Quality Guideline and Provincial Water Quality Objective, and as a result, are the most serious nutrient issues within the Big Otter Creek watershed. In fact, median nitrate levels within Spittler Creek, a tributary of Big Otter Creek, were among the highest across the entire Long Point Region. Spittler Creek was the most impaired area within the watershed with respect to all water quality parameters tested, except for phosphorus and total non-filterable residue levels, which were higher downstream on lower Big Otter Creek.

Land-use including intensive agricultural production, urban development, water pollution control plant effluents, and the underlying geology and the topography within the Big Otter Creek watershed are all likely contributing to the degradation in water quality. The higher nitrate concentrations found in Spittler Creek are likely a result of the intensive agriculture within this region but may also be from nitrate-rich groundwater that discharges to the stream; further research is required to confirm this. Fausto & Finucan (1992) found that phosphorus inputs to Big Otter Creek were mainly anthropogenically driven by fertilizers, household effluent, industry and improper milk-house wash water disposal.

Big Otter Creek has been identified as Canada's largest source of sediment contamination to Lake Erie (Cridland, 1997). Although median values were just over the 25 mg/L benchmark, the 95^{th} % value (367.25 mg/L) indicated that there were events when significant concentrations were measured. Big Otter Creek reacts to event flows extremely quickly and tends to be flashy (Stone, 1993) resulting in increased erosion and sedimentation. This phenomenon is also compounded by the soil type (clayey-till), lack of riparian vegetation and the deeply incised banks within the lower portion of the watershed.

Bacterial concentrations have also been identified as an issue within the Big Otter Creek watershed. Regular beach postings within the watershed prompted the start of the Clean Up Rural Beaches (CURB) program in 1992. As a result of this study, tributaries within the upper watershed were found to have higher bacterial counts relative to the main branch, and therefore improvement measures were focused within those areas (e.g. Spittler Creek). Since the implementation of the program, bacterial counts have decreased; however, beach postings still occur at Port Burwell. It has been hypothesized that some of the bacteria found at the Port Burwell beaches may be originating from the high bacterial concentrations emptying into Lake Erie from Silver Creek in the Catfish Creek watershed (McCarron and McCoy, 1992).

2.15.2 Conditions Specific to the Big Creek Watershed

Generally, water quality is better in Trout Creek compared to other sites sampled in the Big Creek watershed. The upper Big Creek region was the most impaired with respect to nitrogen and chloride concentrations but Venison Creek and lower Big Creek were the most impaired with respect to phosphorus and non-filterable residue concentrations.

The intensive agricultural production in the upper region of the Big Creek watershed is likely contributing to the high nitrate concentrations found in the creek. The relatively low nitrate concentrations found in the downstream tributaries of Trout and Venison Creeks is likely having a positive impact on the water quality in lower Big Creek, which is likely why nitrogen levels are lower downstream.

Phosphorus levels were routinely above the provincial objective (0.03 mg/L) in lower Big Creek and Venison Creek and are likely a result of the cumulative inputs from the Delhi Water Pollution Control Plant and the intensive agricultural production in the watershed.

Compared to other watersheds within the Long Point Region, Big Creek is not a major contributor of nutrients or non-filterable residue (NFR) to Lake Erie (Stone, 1993). Flow in Big Creek is partially regulated through several wetlands. Stone (1993) suggests that the wetlands likely reduce the intensities of flow which helps to keep the sediment in the watershed as opposed to discharging to Lake Erie. Due to the wetlands, light soils and high degree of riparian cover, the Big Creek watershed does not react as quickly to event flows relative to Big Otter Creek.

The Lehman Dam Reservoir was built to supply the Town of Delhi with a municipal drinking water system. The reservoir itself is situated on North Creek, a tributary to Big Creek, and is equipped with an operational dam but it is not used for flood control. The reservoir is also fed by South Creek which similar to North Creek has a good rainbow and brown trout fishery. Spawning has been noted to occur in both South and North Creeks so the dam on North Creek has been fitted with a fish ladder to accommodate this. The water quality in the Lehman reservoir is fairly good and meets the Canadian Environmental Quality Guidelines for all parameters (nitrate, nitrite, phosphorus, dissolved oxygen, pH, and temperature) except turbidity within the deeper sections of the reservoir (Gagnon 1995). The reservoir is thermally stratified and as a result the bottom waters tend to be anoxic. Large algal blooms have been evident indicating the potential for high productivity within the reservoir.

2.15.3 Conditions Specific to the Lynn River Watershed

The impact of urban development on the Lynn River is reflected by the extremely high concentrations of nitrite, ammonia and phosphorus found in the river directly downstream to the town of Simcoe. Tributaries such as Kent Creek, which is a groundwater fed creek with minimal urban or agricultural impacts, have significantly better water quality than the Lynn River. Rarely do samples taken on the Lynn River, downstream of the Water Pollution Control Plant (WPCP), meet the Canadian environmental quality guideline for nitrite or the Provincial Water Quality Objective for total phosphorus. High nitrite and un-ionized ammonia levels found in aquatic systems tend to be associated with organic pollution through the disposal of sewage or organic waste (Hem, 1985; Hydromantis Inc. et al., 2005). In the Lynn River, the high nitrite and un-ionized ammonia levels are likely a result of the Simcoe WPCP. Both un-ionized ammonia and nitrite are considered toxic to aquatic life which likely is having a negative effect on the aquatic life downstream of the plant.

Non-filterable residue (NFR) did not appear to be an issue in the Lynn River; however, the numerous impoundments upstream of the monitoring site along the Lynn River may be acting as sediment sinks.

Although the Lynn River below Simcoe does not appear to have the best water quality, it does support a very good brown trout fishery downstream of Simcoe and below Brook’s Dam (Gagnon and Giles. 2004). The higher ammonia and nitrite concentrations are likely buffered by the higher water quality in the groundwater being discharged into this section of the Lynn River. This combined with reduced siltation in the lower Lynn River from Brook's Dam, likely results in more exposed gravel substrate suitable for sustaining fish populations. Other tributaries in the Lynn River watershed are fairly good cold water streams (e.g. Kent & Patterson Creeks).

The better water quality found in Kent Creek is likely having a positive influence on the Lynn River further downstream of its confluence and thereby improving the quality of the water reaching Lake Erie.

Another concern with the high nutrient concentrations occurring in the Lynn River is its limited assimilative capacity especially in light of the population growth forecasted for the town of Simcoe. Currently Norfolk County is carrying out an assimilative capacity study to better understand the Lynn River's ability to effectively assimilate the WPCP effluent from the Simcoe Plant (pers. comm. Bob Fields).

The primary water quality issues in Black Creek, a major tributary of the Lynn River, were high non-filtered residue (NFR), intermittent stream flow and low dissolved oxygen (Gagnon & Giles, 2004).

2.15.4 Conditions Specific to Nanticoke Creek Watershed

The upper-most headwaters of Nanticoke Creek reside in the Norfolk Sand Plain and tend to have better water quality when compared to the rest of the creek which flows through the Haldimand Clay Plain (Van De Lande, 1987). For instance, nitrogen and phosphorus concentrations significantly increase as Nanticoke Creek flows out of the Norfolk Sand Plain and into the Haldimand Clay Plain. The increase in nutrient levels is likely a result of the cumulative urban impact from the town of Waterford, the WPCP effluent and the transition in soil types in the contributing drainage area from sandy- to clay-based soils.

High total phosphorus and non-filterable residue concentrations are the most significant water quality issues in the watershed and appear to progressively increase from upstream to downstream. Phosphorus has been shown to historically increase during the summer low flow season which could be related to the increased NFR levels that also occur during this time (LPRCA, 1979a). Although Nanticoke Creek was not historically considered a major contributor of nutrient concentrations to Lake Erie (LPRCA, 1979a), recent data indicates that the highest median NFR and phosphorus concentrations are found near the mouth of Nanticoke Creek relative to other tributaries in the Long Point Region. However, Nanticoke Creek does not appear to be as event-driven as Big Otter Creek whose maximum concentrations for NFR and phosphorus were much higher.

Dissolved oxygen levels have been found to decrease downstream of Waterford rendering the creek beyond this point unsuitable cold water fish habitat (Van De Lande, 1987). G. Douglas Vallee Ltd. (2004) speculated that the low dissolved oxygen levels found in the summer were likely as a result of the effluent from the Waterford WPCP making up a substantial percentage of the summer base-flow. Norfolk County has since developed a contingency plan detailing the necessary monitoring and appropriate actions required to mitigate these impacts. Currently, an assimilative capacity study is underway to help determine if an upgrade to the Waterford WPCP is required for Nanticoke Creek to effectively assimilate its effluent (pers. comm. Bob Fields). Upgrades such as tertiary treatment, or the addition of sand filters and disinfectants could potentially help reduce effluent contaminants levels thereby resulting in improved downstream water quality.

2.15.5 Conditions Specific to Sandusk Creek

High phosphorus and non-filterable residue levels are the primary water quality issues in Sandusk Creek. Levels tend to progressively increase from upstream to downstream. Sandusk Creek drains the Haldimand Clay Plain which has a natural tendency for higher sedimentation and sediment associated nutrient concentrations, such as phosphorus. There are no natural retention areas within the Sandusk Creek watershed to help augment summer low flows (Morse et al., 1982). Therefore, Sandusk Creek tends to be 'flashy' during rain events due to soil type (clay), lack of forest cover and the lack of infiltration capacity of the soils (LPRCA, 1979b). However, given the relatively low flows found in this creek, it is only considered to be a moderate contributor of nitrate and phosphorus to Lake Erie yet potentially significant source of atrazine (a common herbicide for row-crops) (LPRCA, 1979b).

2.15.6 Conditions Specific to Dedrick-Young Creek

Water quality in the Dedrick - Young Creek tends to be fairly good. Young Creek has been identified as a significant salmonid cold water stream (LPRCA, 1979c; Edmonds et al., 1976). Young Creek tends to be of better water quality compared to Dedrick Creek, which is likely due to the numerous groundwater springs in the creek that recharge higher quality water into the system (Van de Lande, 1987).

2.16 Summary of Water Use

2.16.1 Municipal Systems

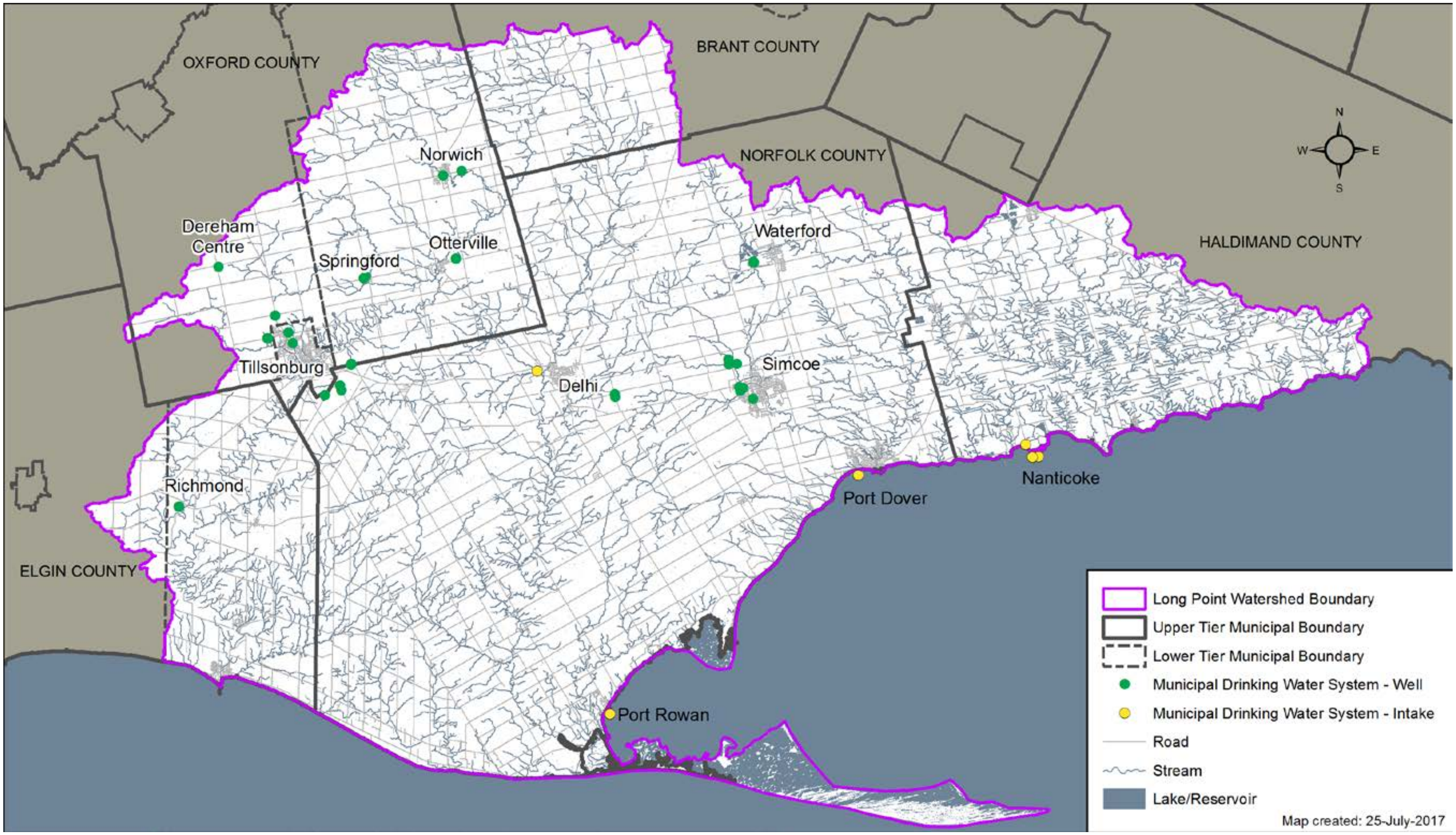
Municipalities within the Long Point Region rely on groundwater, Lake Erie, and inland surface water for their municipal drinking water needs. The communities on groundwater supplies include Simcoe, Tillsonburg, Waterford, Norwich, Otterville, Springford, Dereham Centre and Richmond. A groundwater source in the Upper Thames Region Source Protection supplies water to residents of Mount Elgin in South-West Oxford.

Communities reliant on Lake Erie for their municipal water supply include Port Rowan, Saint Williams, Port Dover, Hagersville, Jarvis and Townsend. Some communities within the Municipality of Bayham and the Township of Malahide also obtain their water supplies from Lake Erie through the Elgin Primary Water System.

The Delhi-Courtland water system is a combined system obtaining water from both groundwater wells and an inland surface water reservoir, Lehman Reservoir on North Creek.

Municipal water use within the watershed is estimated at 10.4 million m^3/yr, ~~and~~ with this volume servicing approximately 60,000 residents. The location of the municipal water wells and surface water intakes ~~in this area~~within Long Point Region are illustrated on **Map 2-17**.

Map 2-17: Municipal Water Wells and Intakes in the Long Point Region Watershed



2.16.2 Private Drinking Water Supplies

As of the year 2009, ~~A total of~~ 7,613 domestic wells ~~exist~~were identified in ~~the~~ Long Point Region Protection~~ Area official boundaries~~, according to the MOECC's Water Well Information System (WWIS). Of these domestic wells, ~~with~~ 1,531 (20%) ~~of these wells being~~were classified as bedrock wells and 5,922 (78%) as overburden wells. The locations of these wells are shown on **Map 2-18** and **Map 2-19,** respectively.

Domestic bedrock wells ~~for domestic use~~ are ~~predominantly~~generally located in the eastern and north-western portions~~watersheds~~ of Long Point Region~~, and along the shore of Lake Erie~~ (**Map 2-18**~~**Map 9-4**~~). These areas correspond to the locations of ~~These regions of the watershed are located on~~ the Haldimand clay plain and Mount Elgin Ridges ~~the till plain where drilling down to bedrock is needed to find productive groundwater sources~~which often do not ~~support supply~~provide an adequate supply of groundwater ~~supply in The overburden~~for domestic use within overburden deposits.~~ Domestic bedrock and overburden wells as given in the Ministry of the Environment's Water Well Information System (WWIS) are illustrated on **Map 2-18Map 9-4** and **Map 2-19Map 9-5**, respectively.~~

Domestic overburden wells (**Map 2-19**~~**Map 9-5**~~) ~~dominate~~ are most frequently located in the west-central portion of~~ the region~~Long Point Region, corresponding to the location of ~~where~~ the Norfolk Sand Plain.~~ is dominant. Overburden wells are evenly spread out across the central and western subwatersheds coinciding with the Norfolk Sand Plain. Overburden wells are also found in the till plain, but generally these wells tap into deeper overburden aquifers. Overburden wells in this region range from 1.8 to 83.8 m in depth, but the median is 11.9 m, indicating that sufficient water is available close to surface~~

Unserviced domestic water use was estimated across Long Point Region ~~closely~~ by following the methodology ~~from~~ documented in the Grand River Water Use Study (Bellamy & Boyd, 2005). Rural ~~These~~ domestic water use was estimated~~estimates were made~~ by combining Census of Population data for areas known not to be serviced by a municipal system with a per capita water use rate of 160 L/d/cap (Vandierendonck and Mitchell, 1997).~~ A per capita rate of 160 L/d/cap was estimated by Vandierendonck and Mitchell (1997), and is consistent with the Ministry of the Environment Groundwater Studies Technical Terms of Reference (2001) which suggests an unserviced per capita rate of 175 L/d/cap. The estimates~~Unserviced domestic water use, which is summarized in **Table 2-8**, ~~were~~ was pro-rated by area to the subwatershed areas and assumed all water takings were groundwater sourced~~ and are included in **Table 2-10Table 9-4**~~.

Consistent with the water consumption ratios for other Water Supply categories, the consumptive ratio (water not returned to it's source) was assumed to be 0.2. For domestic water wells, this assumption implied that 80% of pumped water is returned to groundwater system through septic systems.

Table 2-8: Un-serviced Domestic Water Use

Subwatershed		Rural Domestic Demand (m^3/s)
Big Otter	Otter Above Maple Dell Road	0.003
	Otter at Otterville	0.003
	Otter at Tillsonburg	0.006
	Spittler Creek	0.004
	Lower Otter	0.007

Table 2-8: Un-serviced Domestic Water Use

Subwatershed		Rural Domestic Demand (m³/s)
	Little Otter	0.005
Lake Erie Tribs	South Otter	0.004
	Clear Creek	0.003
Big Creek	Big Above Cement Road	0.003
	Big Above Kelvin Gauge	0.002
	Big Above Delhi	0.005
	North Creek	0.002
	Big Above Minnow Creek	0.003
	Big Above Walsingham	0.004
	Venison Creek	0.003
	Lower Big	0.006
Lake Erie Tribs	Dedrick Creek	0.005
	Young/Hay Creeks	0.009
Lynn River	Lynn River	0.007
	Black Creek	0.004
Nanticoke Creek	Nanticoke Upper	0.003
	Nanticoke Lower	0.006
Eastern Tribs	Sandusk Creek	0.007
	Stoney Creek	0.005

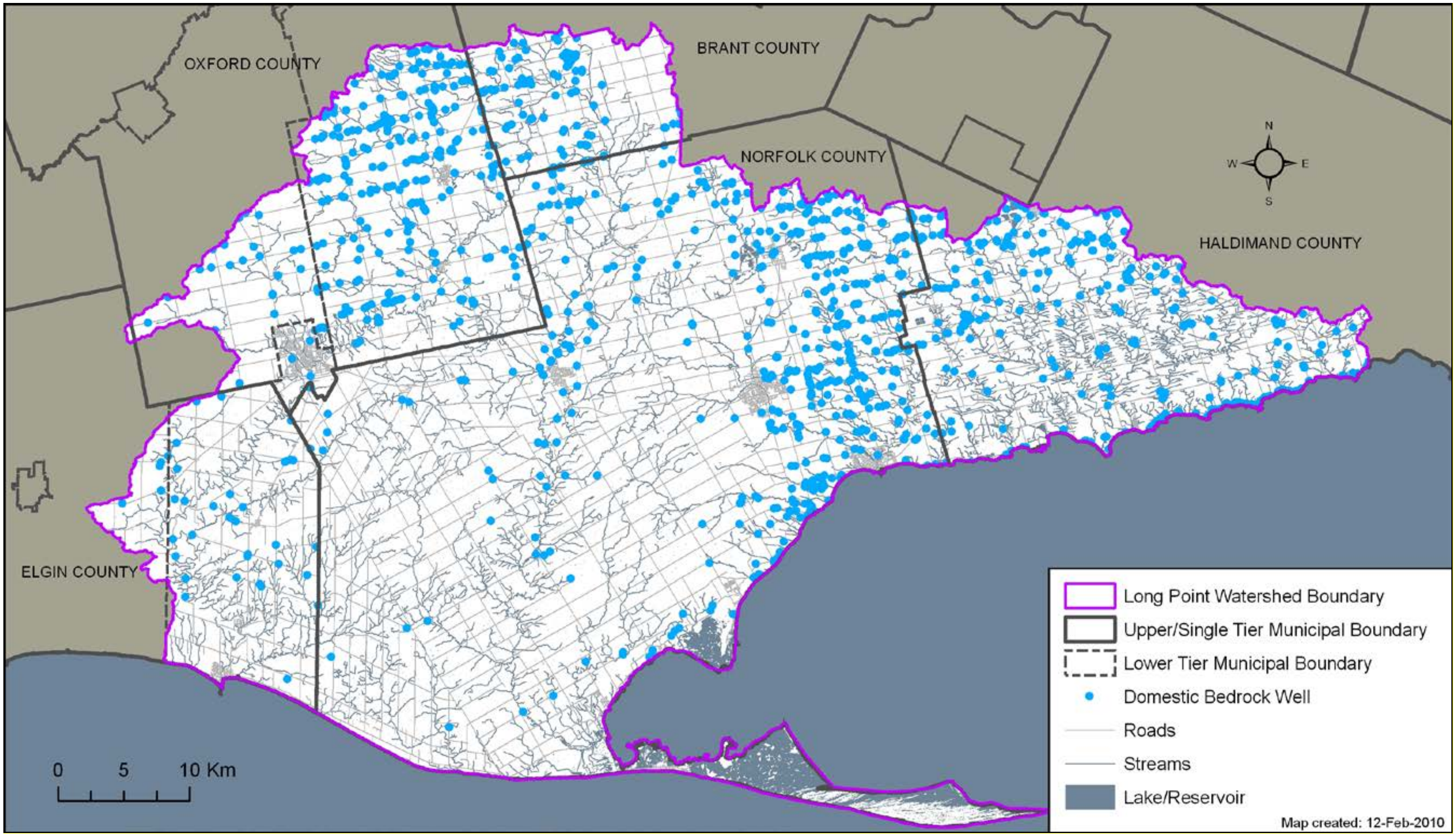
~~Due to concerns about poor water quality, this unserviced domestic demand is almost exclusively obtained from groundwater. Therefore, it is assumed that all unserviced domestic demand draws water from groundwater supplies. Consistent with the water consumption ratios for other Water Supply categories, the consumptive ratio is assumed to be 0.2. For domestic water wells, this assumption implies that 80% of pumped water is returned to groundwater through septic systems.~~

2.16.3 Non Drinking Water Use

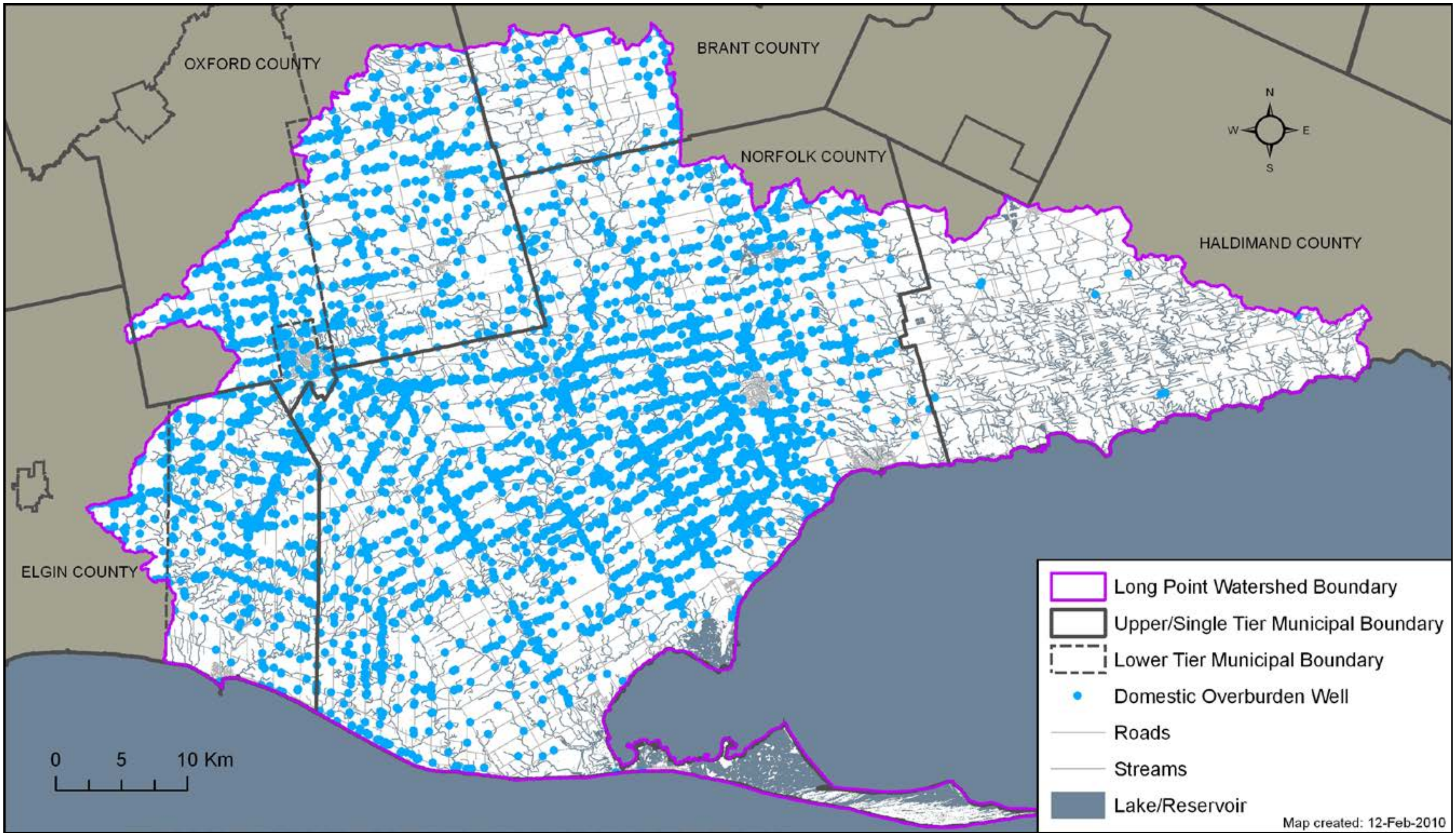
Long Point Region has one of the highest densities of permitted water takings in the Province. ~~After filtering out expired or cancelled permits and permits from the Great Lakes,~~ As of 2017~~09~~, Long Point Region had approximately 1701~~2650~~ active individual permits, ~~extracting water from 3740 different sources. The permits are~~ focused primarily within the Norfolk Sand Plain as is illustrated on **Map 2-20**~~**Map 9-6**~~.

Approximately ~~60~~51% of the permits withdraw water from groundwater sources, 2~~3~~5% from surface water bodies, and 24~~5~~% from both groundwater and surface water supplies. Agricultural irrigation accounts for over 92~~0~~% of the total number of permits in the region, with permits for commercial uses (e.g. golf courses), municipal water supply systems, and miscellaneous uses comprising the remainder of the permits.

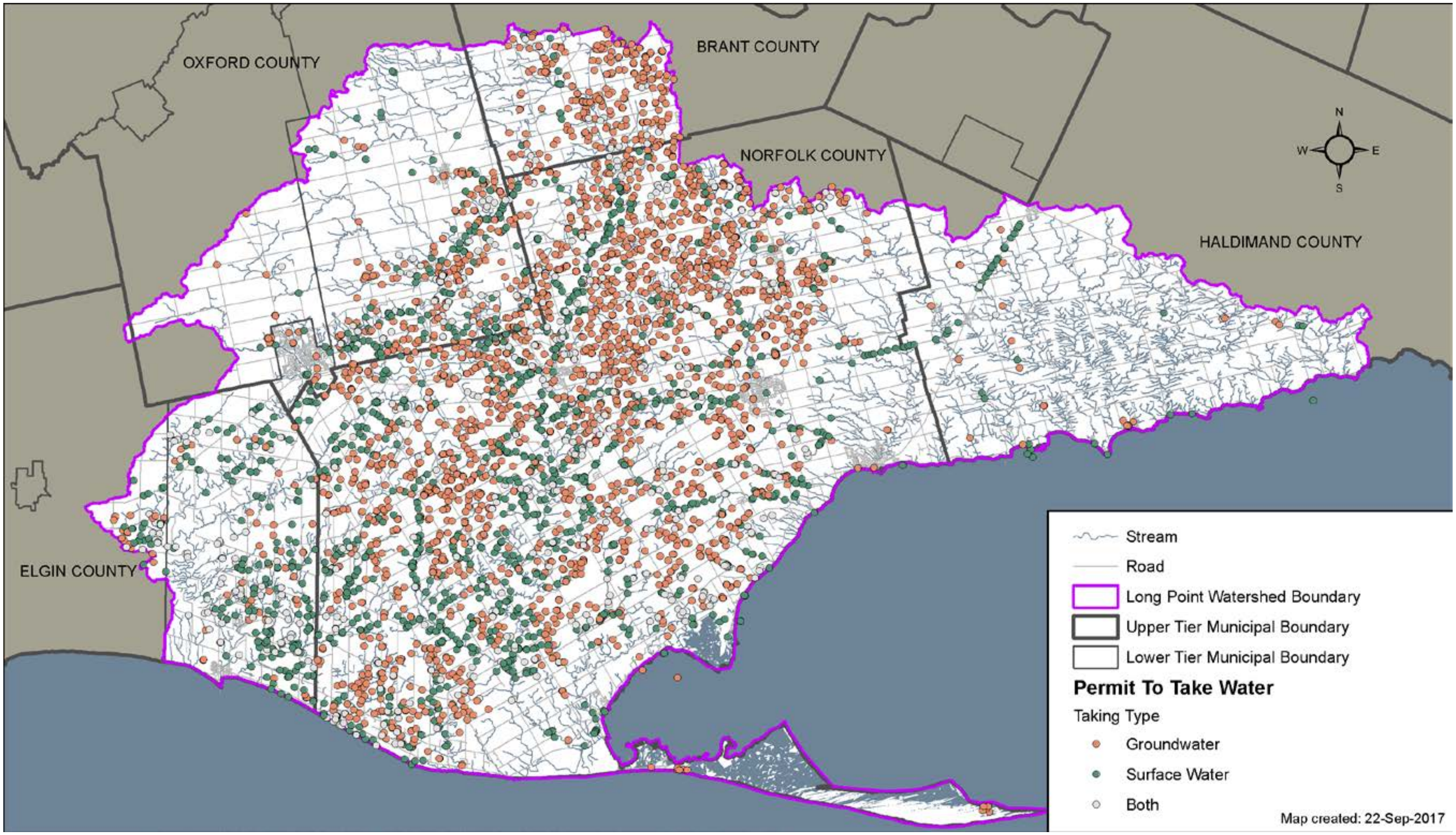
Map 2-18: Domestic Bedrock Wells in the Long Point Region Watershed



Map 2-19: Domestic Overburden Wells in the Long Point Region Watershed



Map 2-20: Permits to Take Water in the Long Point Region Watershed



2.16.4 Permitted Rate

Permitted rates ~~were obtained from~~ are provided in the MOECC's ~~the Ministry of the Environment~~ Permit-To-Take-Water (PTTW) database. **Table 2-9** shows the total permitted rate of active permitted water takings categorized by subwatershed and source. The total permitted rates are 34 m^3/s for groundwater and 20 m^3/s for surface water sources, representing a total rate of 54 m^3/s.

Table 2-9: Permitted Rate~~3~~ (based on 2009 PTTW data)

Subwatershed	Permitted (m^3/s)		Permitted (mm)	
	Groundwater	Surface Water	Groundwater	Surface Water
Otter Above Maple Dell Road	0.57	0.31	182	99
Otter at Otterville	0.69	0.50	291	210
Otter at Tillsonburg	1.39	1.41	286	291
Spittler Creek	0.07	0.07	19	18
Lower Otter	0.57	1.52	108	285
Little Otter	1.15	0.89	309	239
South Otter	1.23	1.88	324	496
Clear Creek	1.41	0.61	512	220
Big Above Cement Road	0.28	0.12	97	41
Big Above Kelvin Gauge	1.91	0.08	937	39
Big Above Delhi	4.90	2.09	1000	427
North Creek	1.00	1.04	545	565
Big Above Minnow Creek	2.65	1.02	1156	443
Big Above Walsingham	1.89	2.32	486	596
Venison Creek	1.76	1.84	570	593
Lower Big	0.68	0.64	224	209
Dedrick Creek	1.27	1.20	291	275
Young/Hay Creeks	1.48	0.94	387	247
Lynn River	3.70	0.92	680	168
Black Creek	0.61	0.03	144	6
Nanticoke Upper	4.20	0.61	1160	168
Nanticoke Lower	0.01	0.00	5	0
Sandusk Creek	0.19	0.00	32	0
Stoney Creek	0.00	0.02	1	3
Total	**34**	**20**		

2.16.5 Pumped Rate

Pumped rates include the estimated pumped rates from both permitted uses and non-permitted uses. To calculate the pumped rates from permitted uses, reported rates were used where available. If reported rates were not available, pumped rates for non-agricultural permits were estimated based on maximum permitted rates and a monthly demand factor based on the specific purpose listed for the permit to take into consideration the seasonality of the taking based on the work in the Grand River Water Use Study (Bellamy & Boyd, 2005).

For agricultural permits, pumping rates were estimated by applying an irrigation demand model (Bellamy & Wong, 2005) which uses soil moisture generated by the hydrologic model to determine the occurrence of an irrigation event. By multiplying the number of days of active pumping for each irrigation event (4) with the median number of irrigation events (8), the typical irrigation system is estimated to be pumping water for 32 days per year. A pumping factor of 60% of the permitted rate was determined based on a number of reported pumping rates. The number of irrigation dates and the pumping factor were used to determine pumping rates on an average annual basis.

For non permitted (permit exempt) water uses, the GRCA developed a methodology to quantify non-permitted agricultural water use as part of the Grand River Water Use Study (Bellamy & Boyd, 2005). Legal non-permitted agricultural water use includes livestock watering, equipment washing, pesticide/herbicide application or any other minor use of water. Kreutzwiser and de Loë (1999) developed a series of coefficients, that when applied to the Census of Agriculture Data, can be used to estimate agricultural water use. The Water Use Assessment applied this methodology to estimate water use on a watershed basis. **Table 2-10** pro-rates these watershed-based estimates for each subwatershed by area.

Table 2-10: Non-Permitted Agricultural Water Use

Subwatershed	Non-Permitted Agricultural Demand (m^3/s)
Otter Above Maple Dell Road	0.006
Otter at Otterville	0.005
Otter at Tillsonburg	0.006
Spittler Creek	0.007
Lower Otter	0.004
Little Otter	0.003
South Otter	0.001
Clear Creek	0.001
Big Above Cement Road	0.003
Big Above Kelvin Gauge	0.002
Big Above Delhi	0.006
North Creek	0.000
Big Above Minnow Creek	0.002
Big Above Walsingham	0.002
Venison Creek	0.002
Lower Big	0.001
Dedrick Creek	0.001
Young/Hay Creeks	0.006
Lynn River	0.005
Black Creek	0.004
Nanticoke Upper	0.003
Nanticoke Lower	0.006
Sandusk Creek	0.004
Stoney Creek	0.003

Due to the census-based estimation technique, it is not possible to reliably determine the source of water for the agricultural water users. In the absence of this information, it is assumed that half of the demand is serviced through groundwater sources, and half is serviced through surface water sources.

Table 2-11 summarizes the estimates of the volume of water pumped, expressed as an annual average rate, for all users. The pumped rate is the average annual amount of water that has been withdrawn from watercourses or aquifers, without allowing for the consumptive nature of the taking. Pumped demand shows approximately 3.6 m^3/s pumped on an annual average basis, compared to 54 m^3/s that is permitted. This large difference is attributed primarily to the seasonality of agricultural permits, which are the dominant water use within the region.

Table 2-11: Average Rate Pumped

Subwatershed	Groundwater (m^3/s)	Surface Water (m^3/s)
Otter Above Maple Dell Road	0.04	0.07
Otter at Otterville	0.03	0.02
Otter at Tillsonburg	0.15	0.06
Spittler Creek	0.01	0.01
Lower Otter	0.03	0.05
Little Otter	0.07	0.03
South Otter	0.05	0.07
Clear Creek	0.06	0.02
Big Above Cement Road	0.02	0.01
Big Above Kelvin Gauge	0.14	0.00
Big Above Delhi	0.21	0.12
North Creek	0.11	0.09
Big Above Minnow Creek	0.14	0.04
Big Above Walsingham	0.06	0.31
Venison Creek	0.06	0.08
Lower Big	0.03	0.03
Dedrick Creek	0.05	0.47
Young/Hay Creeks	0.10	0.18
Lynn River	0.24	0.04
Black Creek	0.05	0.00
Nanticoke Upper	0.18	0.02
Nanticoke Lower	0.00	0.00
Sandusk Creek	0.02	0.00
Stoney Creek	0.01	0.01
Total	**1.86**	**1.73**

* Total = Estimated +Reported. Due to rounding errors, small summing discrepancies may exiStreet

2.16.6 Consumptive Use

Table 2-12 summarizes the estimated consumptive demand (source scale) within each subwatershed. The consumptive nature of water use is a point of uncertainty. In the absence of source specific information, standard consumptive use factors (AquaResource, 2009a) were used based on the specific purpose as listed on the permit to take water.

The table shows the maximum and minimum monthly and average annual demand for both surface water and groundwater sources. On an average annual basis, 1.45 m^3/s of water is estimated to be consumed from aquifers and 0.79 m^3/s is consumed from rivers and creeks.

There is significant monthly variability within most subwatersheds in the Long Point Region due to the dominant agricultural sector water usage, which removes water only during the summer months. Consumptive demands for groundwater are larger than for surface water due to the fact that groundwater takings are not recycled back to the aquifer.

Table 2-12: Consumptive Demand (By Hydrologic Source Unit)

Subwatershed	Groundwater Demand (m^3/s)			Surface Water Demand (m^3/s)		
	Maximum Monthly	Minimum Monthly	Average Annual	Maximum Monthly	Minimum Monthly	Average Annual
Otter Above Maple Dell Road	0.09	0.01	0.03	0.04	0.00	0.02
Otter at Otterville	0.10	0.00	0.03	0.07	0.00	0.02
Otter at Tillsonburg	0.24	0.08	0.12	0.18	0.00	0.06
Spittler Creek	0.02	0.01	0.01	0.01	0.00	0.01
Lower Otter	0.08	0.00	0.02	0.17	0.00	0.05
Little Otter	0.17	0.03	0.06	0.08	0.00	0.02
South Otter	0.15	0.00	0.03	0.23	0.00	0.07
Clear Creek	0.19	0.00	0.04	0.06	0.00	0.02
Big Above Cement Road	0.04	0.00	0.01	0.02	0.00	0.01
Big Above Kelvin Gauge	0.32	0.05	0.11	0.01	0.00	0.00
Big Above Delhi	0.67	0.01	0.16	0.26	0.01	0.08
North Creek	0.20	0.06	0.09	0.11	0.01	0.04
Big Above Minnow Creek	0.40	0.02	0.11	0.12	0.00	0.04
Big Above Walsingham	0.20	0.00	0.05	0.25	0.04	0.10
Venison Creek	0.20	0.00	0.05	0.17	0.00	0.05
Lower Big	0.08	0.00	0.02	0.06	0.00	0.02
Dedrick Creek	0.15	0.00	0.03	0.12	0.05	0.07
Young/Hay Creeks	0.24	0.03	0.08	0.13	0.01	0.05
Lynn River	0.60	0.07	0.20	0.14	0.00	0.04
Black Creek	0.09	0.02	0.04	0.01	0.00	0.00
Nanticoke Upper	0.54	0.02	0.14	0.06	0.00	0.02
Nanticoke Lower	0.00	0.00	0.00	0.00	0.00	0.00
Sandusk Creek	0.01	0.01	0.01	0.00	0.00	0.00
Stoney Creek	0.01	0.00	0.00	0.01	0.00	0.00
Total			**1.45**			**0.79**

Although efforts have been made to determine actual pumping rates for permit holders, there is still a number of permits without reported pumping rates in which standard seasonality and consumption factors had to be used. The biggest water use sector, agricultural, has the most uncertainty since this use is climate driven. Ongoing changes in the dominant crops being grown also contributes to the uncertainty. Production of high water use crops, such as tobacco, has been in decline in the past decade, and the choice of long term replacement crops for these fields is not yet clear. At the same time, domestic water use in the Long Point Region subwatersheds is relatively steady. The low population growth forecast outlined in **Table 2-2** (approximately 0.7%) combined with recent trends in water conservation may result in reduced domestic consumption. Therefore, currently there is no indication of increasing water use over time.

2.17 Aquatic Habitat

The Long Point Region consists of nine major watersheds draining the Horseshoe Moraine, Norfolk Sand Plain and the Haldimand Clay Plain. Given the predominance of agricultural production and the numerous small cities, towns and villages throughout the region, there are very few areas with limited anthropogenic impact in the Long Point Region. The physiographic features, along with land use and management characteristics in the watershed establish the quality and quantity of aquatic habitat available for aquatic life.

Human actions can have a dramatic impact on aquatic habitats. Water habitats can be impacted by the deforestation of riparian areas – those lands adjacent to streams and rivers. This reduces the amount of shade available to keep waters cool during the summer. Losses of forests and wetlands can lead to degraded aquatic habitat through the reduction in groundwater recharge and subsequent reduced baseflows; increased erosion; and the loss of nutrient and sediment filtration. Further, many streams and watercourses in the Region have been straightened or modified in urban and rural areas to promote drainage. Numerous small dams have also been constructed to impound water for water supply or flood reduction. Besides creating thermal regimes more conducive to warm water fish species, these dams can also create barriers for migratory cold-water fish. Consequently, land use and management including intensive agricultural production, tile drainage, urban development, and wastewater treatment plant effluents have all contributed to the degradation of water quality and aquatic habitats found in the Long Point Region (Evans, 2007).

In addition to the chemical characteristics of the waterway, the suitability of aquatic habitat is dependent on three physical factors: temperature, oxygen and clarity. The thermal regimes in the waterways in the Long Point Region include cold-, cool- and warm-water (**Map 2-21**). For example, the waterways along the western and central portion of the Long Point Region (e.g. lower Big Otter, Big and Dedrick-Young creeks) contain many cold-water fish species however; this region also boasts the highest number of permits to take water. The high number of permitted agricultural water takings on the sand plain can also impact stream flow levels and temperatures as these takings tend to be most active during dry periods in the summer/fall when streamflows are typically at their lowest. On the other hand, watersheds draining the clay plain in the eastern portion of the Region tend to be warm water habitats.

Many of the tributaries within the Long Point Region are thermally stressed (P. Gagnon, pers. comm.). The warming trend in summer stream temperatures across several watersheds, including Big and Patterson creeks, is a concern (Evans, 2007). High temperatures can limit the diversity of aquatic species present as well as impact dissolved oxygen levels. Therefore, prolonged periods of time that temperatures are above the threshold for cold-cool water fish (24°C) limits the creeks ability to support these species. Although there appears to be a warming trend across the Region, there continues to be streams within the Long Point Region that have temperatures and habitats still suitable for supporting cold water fish species (e.g. Young Creek, Trout Creek and Kent Creek).

Dissolved oxygen is also an important indicator of a river's ability to sustain aquatic life. Levels can be affected by reduced streamflows, increased water temperatures, and increases in pollutants loads that have a high oxygen demand (e.g. wastewater discharges). Although dissolved oxygen has routinely been measured in streams and rivers within the Long Point Region, spot measurements typically occur during the day – the time oxygen tends to be produced through photosynthesis and therefore, does not provide for a good assessment of the dissolved oxygen regime in the river. However, spot measurements showed levels that were rarely below six milligrams per litre (*Evans, 2007*). Continuous monitoring, as opposed to spot measurements, is recommended to properly characterize dissolved oxygen levels in streams and rivers in the Long Pont Region.

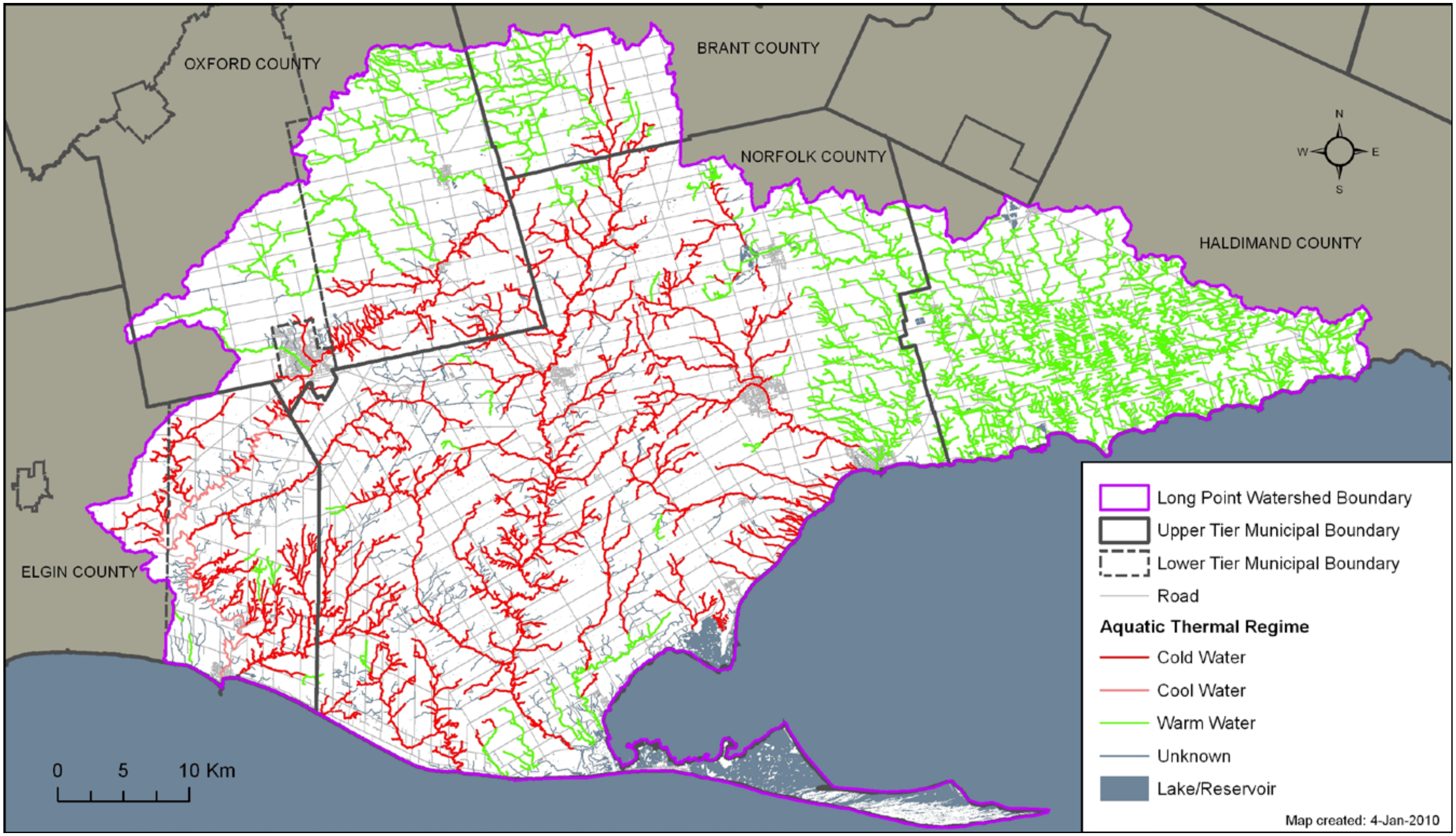
The Long Point Region watersheds sustain a variety of fish species and habitats. Some of the local cold water streams support resident and migratory salmonid populations that include brook, brown and rainbow trout, and pacific salmon. Young Creek, for instance, has been identified as a biologically significant salmonid cold water stream habitat (Long Point Region Conservation Authority, 1979c; Edmonds et al., 1976). In many places, however, poor land use practices have degraded the salmonid habitat, which has impacted their populations. Further, dams, impoundments and other anthropogenic drainage features (e.g. tile drains) have led to the degradation of many of the natural cold-water habitats in the Region.

Warm water systems in the Region support bass, pike, perch, sunfish, bull head, channel catfish and other panfish species (Ontario Ministry of Natural Resources, 1990b). Warm water systems are usually found where heavier soils are dominant such as the Haldimand Clay Plain; till moraines of the north-west; near the Lake Erie shoreline; and in some areas where water is held back through artificial storage. For example, Nanticoke Creek transitions from a cold-water system on the Norfolk Sand Plain upstream of Waterford, passing through the Waterford Ponds area, and into a warm-water system as it progresses downstream through the Haldimand Clay Plain. Further, the flows and habitats of this creek have been greatly altered since pre-settlement times. Dissolved oxygen levels have been found to decrease downstream of Waterford, rendering the creek beyond this point unsuitable as cold water fish habitat (Van De Lande, 1987). G. Douglas Vallee Ltd. (2004) speculated that the low dissolved oxygen levels found in the summer were likely a result of the effluent from the Waterford WWTP making up a substantial percentage of the summer base-flow.

In addition to a wide variety of lotic or stream aquatic habitats in the Long Point Region, there are also significant lentic or lake and lake-like aquatic habitats. Many of the inland lakes and ponds are small reservoirs or rehabilitated gravel extraction pits (e.g. Waterford Ponds). Fish populations in these lakes and ponds include large mouth bass, yellow perch, sunfish and crappie. In addition, Lake Erie provides valuable spawning and nursery habitat through shoreline marshes, an example of which includes the Long Point Bay. Species found in Long Point Bay include largemouth and smallmouth bass, yellow perch, northern pike, sunfish, rock bass, carp and bull head (Ontario Ministry of Natural Resources, 1990b). Long Point Region watersheds mainly encompass the eastern basin of Lake Erie, which includes species such as: rainbow smelt, yellow perch, rainbow and brown trout, pacific salmon, lake whitefish, lake herring and lake trout.

Two fisheries management plans are followed within the watersheds: the Aylmer District Fisheries Plan 1987-2000 (Ontario Ministry of Natural Resources, 1990a); and the Simcoe District Fisheries Management Plan 1987-2000 (Ontario Ministry of Natural Resources, 1990b). The Aylmer District Fisheries Plan focuses mainly on the Big Otter watershed. The focus of the fisheries management plan for the Big Otter watershed is to decrease sediment loading due to siltation, decrease nutrient levels in the river and maintain or decrease where possible the temperature of the river. The Simcoe District Fisheries Management Plan 1987-2000 outlined four key fish management issues for the Region: habitat destruction; demand/supply imbalances; resource use conflict; and inadequate knowledge about the fishery. These issues can have significant implications on the fish population and habitat and therefore a fisheries management plan is needed to help reduce impacts, protect habitat and increase and protect resident fish populations in the Region.

Map 2-21: Aquatic Habitat in the Long Point Region Watershed



2.18 Species at Risk

A complete list of species of animals and plants known to be at risk, rare or endangered in the Long Point Region watersheds is included in **Table 2-13**.

Table 2-13: List of Species at Risk in Long Point Region Watersheds*

Taxonomy	Common Name	Scientific Name	OMNR Status	Notes
Fish	Lake Sturgeon (Upper Great Lakes/St. Lawrence population)	Acipenser fulvescens	Threatened	Lake Sturgeon is found in all the Great Lakes, and in all drainages of the Great Lakes
Plants	Colicroot	Aletris farinosa	Threatened	Charlotteville
Amphibians	Jefferson Salamander	Ambystoma jeffersonianum	Threatened	SW part of Norfolk County
Fish	Eastern Sand Darter	Ammocrypta pellucida	Threatened	Norfolk, Western Haldimand, Southern Brant and Oxford, Eastern Elgin
Birds	Henslow's Sparrow	Ammodramus henslowii	Endangered	Southern Norfolk County
Amphibians	Fowler's Toad	Anaxyrus fowleri	Threatened	southern part of Long Point Region
Reptiles	Spiny Softshell	Apalone spinifera	Threatened	SW Norfolk
Plants	Green Dragon	Arisaema dracontium	Special Concern	
Birds	Short-eared Owl	Asio flammeus	Special Concern	Eastern part of Long Point Region
Insects	Frosted Elfin	Callophrys irus	Extirpated	last recorded near St. Williams in Norfolk County in 1988
Birds	Whip-poor-will	Caprimlugus vociferus	Threatened	
Plants	American Chestnut	Castanea dentata	Endangered	
Birds	Chimney swift	Chaetura pelagica	Threatened	
Reptiles	Snapping turtle	Chelydra serpentina	Special Concern	
Plants	Spotted Wintergreen	Chimaphila maculata	Endangered	SE Norfolk
Birds	Black Tern	Chlidonias niger	Special Concern	
Birds	Common nighthawk	Chordeiles minor	Special Concern	
Reptiles	Spotted Turtle	Clemmys guttata	Endangered	
Fish	Redside Dace	Clinostomus elongatus	Endangered	Brant & Haldimand Counties
Birds	Olive-sided flycatcher	Contopus cooperi	Special Concern	
Plants	Eastern Flowering Dogwood	Cornus florida	Endangered	Long Point Region, except NW part
Plants	Small White Lady's-slipper	Cypripedium candidum	Endangered	near St. Williams in Norfolk County
Insects	Monarch	Danaus plexippus	Special Concern	
Birds	Cerulean Warbler	Dendroica cerulea	Special Concern	
Plants	Horsetail Spike-rush	Eleocharis equisetoides	Endangered	Near Long Point
Birds	Acadian Flycatcher	Empidonax virescens	Endangered	
Reptiles	Blanding's Turtle	Emydoidea blandingii	Threatened	
Fish	Lake Chubsucker	Erimyzon sucetta	Threatened	Elgin, in the drainages of Lake Erie
Insects	Eastern Persius Duskywing	Erynnis persius persius	Extirpated	SW Norfolk, but not observed in Ontario in over 18 years

Table 2-13: List of Species at Risk in Long Point Region Watersheds*

Taxonomy	Common Name	Scientific Name	OMNR Status	Notes
Fish	Grass Pickerel	Esox americanus vermiculatus	Special Concern	SW Norfolk
Mosses	Pygmy Pocket Moss	Fissidens exilis	Special Concern	NW Norfolk
Reptiles	Northern Map Turtle	Graptemys geographica	Special Concern	
Plants	Kentucky Coffee-tree	Gymnocladus dioicus	Threatened	SE Oxford
Birds	Bald Eagle	Haliaeetus leucocephalus	Special Concern	
Reptiles	Eastern Hog-nosed Snake	Heterodon platirhinos	Threatened	except eastern part of Long Point Region in Haldimand
Plants	Swamp Rose-mallow	Hibiscus moscheutos	Special Concern	coastal marshes of S Norfolk
Fish	Northern Brook Lamprey	Ichthyomyzon fossor	Special Concern	S drainages of Lake Erie
Birds	Yellow-breasted Chat	Icteria virens	Special Concern	
Plants	Large Whorled Pogonia	Isotria verticillata	Endangered	SW Norfolk
Birds	Least Bittern	Ixobrychus exilis	Threatened	
Plants	Butternut	Juglans cinerea	Endangered	
Plants	American Water-willow	Justicia americana	Threatened	W Norfolk, E Elgin
Reptiles	Milksnake	Lampropeltis triangulum	Special Concern	
Fish	Spotted Gar	Lepisosteus oculatus	Threatened	SE Elgin
Insects	Karner Blue	Lycaeides melissa samuelis	Extirpated	Near St. Williams in S. Norfolk, but considered extirpated provincially
Fish	Silver Chub	Macrhybopsis storeriana	Special Concern	Lake Erie
Plants	Cucumber Tree	Magnolia acuminata	Endangered	S. Norfolk
Birds	Red-headed Woodpecker	Melanerpes erythrocephalus	Special Concern	
Mammals	Woodland Vole	Microtus pinetorum	Special Concern	
Fish	Pugnose Shiner	Notropis anogenus	Endangered	W&S Norfolk, SW Haldimand
Fish	Silver Shiner	Notropis photogenis	Special Concern	Oxford, Brant, N. Norfolk
Plants	American Ginseng	Panax quinquefolius	Endangered	
Reptiles	Eastern Foxsnake (Carolinian population)	Pantherophis gloydi	Endangered	Lake Erie shore in Norfolk, Bayham
Reptiles	Gray Ratsnake (Carolinian population)	Pantherophis spiloides	Endangered	SW Norfolk, central Haldimand
Fish	Channel Darter	Percina copelandi	Threatened	tributaries of Lake Erie in E. Elgin, S. Oxford, W. Norfolk
Plants	Broad Beech Fern	Phegopteris hexagonoptera	Special Concern	
Insects	West Virginia White	Pieris virginiensis	Special Concern	
Molluscs	Round Pigtoe	Pleurobema sintoxia	Endangered	May persist around Long Point
Birds	Prothonotary Warbler	Protonotaria citrea	Endangered	

Table 2-13: List of Species at Risk in Long Point Region Watersheds*				
Taxonomy	**Common Name**	**Scientific Name**	**OMNR Status**	**Notes**
Plants	Common Hoptree	Ptelea trifoliata	Threatened	SE Elgin & SW Norfolk Lake Erie shoreline, Long Point
Mammals	Mountain Lion or Cougar	Puma concolor	Endangered	
Molluscs	Mapleleaf Mussel	Quadrula quadrula	Threatened	large rivers draining into Lake Erie
Birds	King Rail	Rallus elegans	Endangered	in large marshes on shore of Lake Erie in Elgin, SW Norfolk
Reptiles	Queen Snake	Regina septemvittata	Threatened	sites in W. Norfolk & W. Haldimand
Plants	Toothcup	Rotala ramosior	Endangered	Norfolk
Birds	Louisiana Waterthrush	Seiurus motacilla	Special Concern	
Plants	Round-leaved Greenbrier	Smilax rotundifolia	Threatened	SW Norfolk
Reptiles	Eastern Musk Turtle	Sternotherus odoratus	Threatened	Southern Charlotteville and Walsingham, Long Point
Plants	Crooked-stem Aster	Symphyotrichum prenanthoides	Threatened	E. Elgin, SW Oxford, & W. Norfolk
Mammals	American Badger	Taxidea taxus	Endangered	largest population in Ontario
Plants	Virginia Goat's-rue	Tephrosia virginiana	Endangered	Norfolk: only known populations in Ontario
Reptiles	Eastern Ribbonsnake	Thamnophis sauritus	Special Concern	
Molluscs	Fawnsfoot	Truncilla donaciformis	Endangered	Lower portions of large Great Lakes tribs.
Birds	Greater Prairie-Chicken	Tympanuchus cupido	Extirpated	Extirpated in Ontario
Birds	Barn Owl	Tyto alba	Endangered	SE Oxford, S Brant, N&E Norfolk, Haldimand
Mammals	Grey Fox	Urocyon cinereoargenteus	Threatened	
Birds	Golden-winged Warbler	Vermivora chrysoptera	Special Concern	SW Norfolk
Plants	Bird's-foot Violet	Viola pedata	Endangered	Central Norfolk
Birds	Canada warbler	Wilsonia canadensis	Special Concern	
Birds	Hooded Warbler	Wilsonia citrina	Special Concern	
Insect	Rusty-patched Bumble Bee	Bombus affinis	Endangered	
Insects	Northern Barrens Tiger Beetle	Cicindela patruela	Endangered	Charlotteville
Birds	Bobolink	Dolichonyx oryzivorus	Threatened	
Plants	Virginia Mallow	Sida hermaphrodita	Endangered	Oneida
Insects	Laura's Clubtail	Stylurus laurae	Endangered	Big Creek, Big Otter Creek
* Source: Species at Risk in Ontario (SARO) List, 2009				

2.19 Interactions Between Human and Physical Geography

Land use practices in the watershed can have an increased risk to ground and surface water depending on the geology of the area. The geology can determine the infiltration, runoff and recharge rate of precipitation which corresponds to how fast and easily contaminants may be able to move and infiltrate the ground and surface water. The Norfolk Sand Plain is very permeable, and this can be a concern as runoff from agricultural practices such as fertilizers and pesticides can easily move into the soil and into groundwater supplies. In addition, agricultural crops in the area often require higher levels of water for irrigation since the available soil moisture available for crop uptake may be depleted quickly due to high infiltration rates.

The Haldimand Clay Plain provides moderate to good protection to the groundwater as infiltration of clay is low. However, precipitation moves very quickly over clay which can increase surface runoff. Agricultural land uses in this area may benefit from having water storage on the surface; however, fertilizers, pesticides and manure have an increased chance of moving into water systems through runoff. In addition, paved land in and surrounding the area increases the runoff rate and quickly moves precipitation over the clay and possibly into ground and surface water systems.

The geology and current land use practices appear to be driving some of the chronic groundwater and surface water quality issues within the Long Point Region watersheds. Watersheds that drain the clay and till plains tend to have the highest non-filterable residue and nutrient concentrations in the Long Point Region (e.g. Big Otter Creek, and Nanticoke Creek) (Evans, 2007). Land use practices such as intensive agricultural production or urban development (such as in the Lynn River watershed) are also contributing to the overall high nutrient levels found within the Long Point Region (Evans, 2007).

2.20 Watershed Characterization Data Gaps

The following data gaps have been identified in the Watershed Characterization component of the Long Point Region Source Protection Area Assessment Report.

Data	Plan to Address Data Gap	Progress to Address Data Gap
Location of federal lands in the watershed	Data on the location of federal lands is not currently available. As new information is released, it will be included in an updated Assessment Report.	Data on the location of federal land is not available as of October 2017.
List of non-municipal drinking water systems	Working with the public health units and the Ministry of the Environment to improve the available data on non-municipal drinking water systems. This information will be included in an amendment to the Assessment Report.	This item remains as a data gap as efforts are still being made to fully characterize existing non-municipal drinking water systems.
Location of monitoring wells related to drinking water systems	Working with municipalities to improve the available data on non-municipal drinking water systems. This information will be included in an amendment to the Assessment Report.	Municipal monitoring well data is provided where there have been studies to delineate WHPAs. Although the data is used in local groundwater models for model calibration it has not been documented in the updated Assessment Report.

Data	Plan to Address Data Gap	Progress to Address Data Gap
Geologic characterization	While the regional flow system is thought to be insensitive to the varying geologic characterizations, local flow systems may be significantly impacted. To reduce uncertainty associated with local studies, it is recommended that additional effort be expended on accurately characterizing the subsurface, including, interpreting cross sections and drilling additional boreholes (LESPR, 2010).	One of the key uncertainties identified during the Tier 2 Assessment (AquaResource, 2009a) was the lack of detailed geological and hydrogeological data beneath the upper sand aquifer. To address these data gaps, a drilling program was undertaken to improve the understanding of the geology across the Focus Area of the Long Point Region Tier 3 Water Budget Study and Local Area Risk Assessment. Twenty six boreholes were drilled into the top of bedrock as part of the drilling program with the main purpose of refining the regional geology of the area. The 26 boreholes were converted into monitoring well nests with typically one to three monitoring wells per location and a total of 58 monitoring wells were installed. Nine drive-point piezometers were installed in various reaches of Patterson Creek, Stoney Creek and Kent Creek to refine the understanding of how groundwater and surface water interact in these creeks. Water level monitoring was conducted, water quality was sampled in 51 wells, and hydraulic testing was undertaken at 48 monitoring wells. The data collected in the field program was assembled and used to develop an improved understanding of the geology and hydrogeology of the Long Point area.

2.21 Watershed Characterization Section Summary

- The Long Point Region watershed is located in south western Ontario and covers an area of approximately 2,900 km^2, being almost 100km at its widest and 60km running north to south.

- The watershed has 225 km of Lake Erie shoreline, including the internationally renowned Long Point sand spit.

- Many different watercourses make up the Long Point Region, each with their own traits and values. The combined length of all streams and tributaries in Long Point Region watershed is over 3,700 km.

- Much of the land area of the watershed is used for agricultural purposes. Several medium-sized urban centres including Tillsonburg (Oxford County), Simcoe and Delhi (Norfolk County) make up the majority of the watershed area's population.

- Long Point Region watershed is home to over 114~~2~~,528~~000~~ residents, with over 54% serviced by municipal water supplies.

- Long Point Region is divided into 24 subwatersheds for the purpose of the water budget; prominent streams in the region include Big Creek, Big Otter Creek, Lynn River, Nanticoke Creek, and Sandusk Creek.

- There are 3 major physiographic regions in Long Point region: the Norfolk Sand Plain, the Haldimand Clay Play and the Horseshoe Moraine/Mount Elgin Ridges.
    - Much of the central and western portion of the watershed is within the Norfolk Sand Plain, with high infiltration, high groundwater recharge and good baseflows in the creeks.
    - The eastern side of the watershed is in the Haldimand Clay Plain, characterized by fine-grain silts and clays resulting in high runoff from poorly drained soils.
    - The northwestern portion of the watershed is comprised of low to moderate relief till moraines of the Horseshoe Moraine/Mount Elgin Ridges.
- The watershed is underlain by a series of gently dipping sedimentary rocks consisting of shales, carbonates and sandstone. These rocks are overlain by unconsolidated sediments of variable thickness and porosity.
- Two overburden aquifers are the main source of water for private supplies in the central portion of the watershed, while bedrock aquifers are used in the eastern portion of the Haldimand Clay Plain.
- The shallow upper overburden aquifer mainly supports most of the private water supplies, for domestic and agricultural purposes, as well as some municipal wells in the Norfolk Sand Plain.
- The deeper overburden aquifer can range from 0 to 30 m thick, disappearing when the shallower aquifer is more than 20 m thick.
- The Long Point Region has amongst the highest density of Provincial Permits-to-take-water in Southern Ontario. Most of these permits are for agricultural irrigation.
- Annual average precipitation from the years 1935 to 2016 ~~ranges between 950-1075~~is 940 mm, which is distributed fairly evenly throughout the year. ~~The majority of the precipitation falls as rain.~~
- Streamflows are quite variable throughout the year, with high flows in the spring from snowmelt, and much lower flows in the summer months which can be exacerbated by high irrigation demand in the Norfolk Sand Plain, or lack of groundwater contribution in the Haldimand Clay Plain.
- There are 10 active streamflow (WSC) gauges, 10 water quality monitoring stations (PWQMN) and 10 LPRCA operated water control structures for flow augmentation, flood control and recreation across the Long Point Region watershed.
- The land area is dominated by intensive agriculture, yet forest cover has recovered to 21%. Wetlands are a significant feature of the watershed area, making up almost 9% of the land area.
- Stream water quality and temperature is influenced by the geology and current land use.
    - The Haldimand Clay Plain and moraine areas support livestock operations and general cash crop production. Lack of vegetative cover and low groundwater recharge and

discharge results in both higher water temperatures and phosphorus concentrations from runoff.

- o Specialty crops and high irrigation rates in the Norfolk Sand Plain result in elevated nitrate levels due to runoff and infiltration. However, high groundwater recharge and discharge rates create sufficient water quality to support cold water fisheries.

- There are ten municipal wastewater treatment plants and lagoons that discharge continuously or seasonally into the creeks, and two that discharge into Lake Erie.

- Nutrient levels, primarily nitrate, phosphorus and non-filterable residue, are the main surface water quality concerns throughout the Long Point Region watershed area.

- As of 2009, there are 85 species at risk found in Long Point Region watershed area, including 14 reptiles and amphibians, 30 birds and insects, 14 fish and mollusks, 23 plants and mosses and 4 mammals.

3.0 WATER QUALITY RISK ASSESSMENT

~~Groundwater vulnerability assessments involve identification of vulnerable areas, characterization of relative vulnerability of the municipality's supply aquifers and assignment of vulnerability scores to zones within the vulnerable areas. The Technical Rules: Assessment Report, Clean Water Act, 2006 (Technical Rules; MOE 2009) provide legal definitions of vulnerable areas, vulnerability scoring, and the assessment of water quality threats; however, the Technical Rules do not prescribe specific methods for the delineation of wellhead protection areas (WHPAs).~~

~~A WHPA is the area around the municipal wellhead where land use activities have the greatest potential to affect the quality of water that flows into the well. A WHPA consists of up to four separate areas (WHPA-A to WHPA-D) based on how long it takes water within the aquifer to reach the well. This is also known as the time-of-travel (TOT). The exception is the WHPA closest to the well (WHPA-A), which is simply a 100m radius around the well established to offer maximum protection to the well. Other WHPAs include; WHPA-B (2 year TOT), WHPA-C (5 year TOT), WHPA-D (25 year TOT).~~

~~The area and shape of a WHPA is influenced by a variety of factors including the amount of water being pumped out of the well, aquifer permeability, and the direction and speed that groundwater travels. All these factors are included in a hydrogeological model which is used to estimate the time-of-travel for each well.~~

~~In situations where surface waters, such as rivers or streams, have the potential to influence the likelihood of a contaminant entering the well, additional WHPAs are delineated – WHPA-E and F. WHPAs considered to be under the influence of surface water are also sometimes referred to as GUDI systems - Groundwater Under Direct Influence. So that the potential for surface water contamination is accounted for, the WHPA-E incorporates the surface water course and contributing sewershed within a minimum of 2 hours. WHPA-F is to be added to cover the remaining upstream contributing area but would only be delineated in the event that a Drinking Water Issue is observed.~~

~~The Province of Ontario released the Assessment Report: Draft Guidance Module 3; Groundwater Vulnerability Analysis (Guidance Module 3; MOE 2006), and it recommends methodologies to delineate vulnerable areas. This document was developed for guidance purposes and was superseded by the Technical Rules; however, the methods outlined in the Guidance Module 3 are valid and consistent with the Technical Rules. The methods documented in this report are consistent with the approaches laid out in Guidance Module 3 and Technical Rules.~~

3.1 Overview of the Source Protection Risk Assessment Process

A Source Protection Area Assessment Report is a summary of technical studies that have the objective of: ~~identify:~~

- Mapping areas surrounding municipal drinking water sources in which land use activities could impact the water quality or water supply to the municipal water source. These are termed Wellhead Protection Areas (WHPAs).~~The vulnerable areas around municipal-residential drinking water sources~~
- ~~How "vulnerable" the vulnerable areas are~~ Ranking areas within WHPAs that have an increased potential or vulnerability for impacting the municipal supply

- ~~Where~~ Identifying potential water quality and water quantity threats to the municipal supply within the WHPAs. ~~to water quality and quantity can be found in each vulnerable area~~
- ~~The~~ Identifying activities that pose the ~~biggest~~ largest potential threat to ~~human health~~to the quality or quantity of the municipal supply.
- Ranking the significance of threats and activites to potentially impacting the quality or quantity of the municipal supply.
- ~~How significant the risk of the threat is of contaminating or depleting the water supply~~

3.1.1 Vulnerable Areas

What are vulnerable areas?

The *Clean Water Act, 2006* identifies four types of vulnerable areas related to drinking water sources:

- Highly Vulnerable Aquifers (HVA) ~~areas~~
- Significant Groundwater Recharge Areas (SGRA)
- Wellhead Protection Areas (WHPA)
- Intake Protection Zones (IPZ)

~~HVAs, SGRAs, and WHPAs are associated with groundwater, while IPZs are associated with surface water (rivers and lakes). The~~ Highly Vulnerable Aquifers ~~areas~~, Significant Groundwater Recharge Areas and Wellhead Protection Areas are ~~determined~~ delineated through ~~complex modeling~~qualitative and quantitative assessments of the geology and groundwater flow in an area. ~~, as well as the permeability of surface material above the groundwater (aquifers). The~~ Intake Protection Zones are ~~determined~~ generated ~~by assessing~~through the assessment of surface water ~~the~~ flow ~~of surface water in~~ in the ~~river~~ watercourse or lake where a municipal intake is located.

Wellhead Protection Areas and Intake Protection Zones are developed specifically ~~around~~ for municipal groundwater and surface water supplies ~~(around groundwater wells or surface water intakes)~~. Highly Vulnerable Aquifers and Significant Groundwater Recharge Areas are assessed at the watershed scale, and are not necessarily associated with an existing municipal drinking water system.

What is vulnerability?

~~The word~~ "Vulnerability" describes ~~how easily~~ the sensitivity a of drinking water source such as an aquifer or surface water feature to negative water quality impacts from anthropogenically derived materials. ~~a source of water (aquifer, river or lake) can become polluted with a dangerous material.~~ The vulnerability of an area is applied as a score, ~~can~~ ranging from 1 to 10, with 10 being the most vulnerable. The process for ~~measuring~~ assessing vulnerability differs between~~is different for~~ aquifers and surface water~~, rivers and lakes~~.

~~Groundwater~~ Aquifer Vulnerability

Municipal wells draw their water from underground areas called “aquifers.” These are places where water fills cracks in bedrock or spaces between grains of sand or gravel.

Aquifers are replenished when water from rain and melting snow soaks into the ground. Sometimes, the water can carry pollutants from the surface to an aquifer.

It can take years, or even decades, for water to move from the surface to the aquifer or to move within an aquifer toward a well. The ~~speed~~ rate at which groundwater moves depends on the characteristics of the soil, bedrock in the area and the pumping rate of other nearby wells.

Sometimes, water can find a shortcut from the surface to the aquifer, such as through an abandoned well or an old gravel pit. These are referred to in the Assessment Report as transport pathways.

To determine the vulnerability score for an aquifer, the following questions must be ~~question 1 had to be answered~~considered:

1. How quickly does water move vertically from the surface down to the aquifer?
   - This is called “intrinsic vulnerability” and is ranked as low, medium or high, depending on the ~~nature~~ characteristics of the soil and bedrock in the area.
   - The answer to this question was used to ~~determine where the~~delineate Highly Vulnerable Aquifers ~~areas are~~within Long Point Region.
2. How quickly does water move horizontally through an aquifer to the well?
   - This information was used to ~~draw~~ map Wellhead Protection Areas (WHPAs) around ~~each~~ municipal groundwater supply wells. ~~WHPAs are divided into rings called Time-of-Travel zones. The innermost zone is a 100-metre circle around the well. The other zones are set at times-of-travel of 2 years, 5 years and 25 years.~~ A WHPA is the area around the municipal wellhead where land use activities have the greatest potential to affect the quality of water that flows into the well. A WHPA consists of up to four separate areas (WHPA-A to WHPA-D) based on how long it takes water within the aquifer to reach the well. This is also known as the time-of-travel (TOT). The exception is the WHPA closest to the well (WHPA-A), which is simply a 100m radius around the well established to offer maximum protection to the well. Other WHPAs include; WHPA-B (2 year TOT), WHPA-C (5 year TOT), WHPA-D (25 year TOT).

~~Therefore, t~~To obtain the vulnerability score for a WHPA, both the rates of vertical and horizontal movement of water through the ground are used and a scoring matrix is applied according to the Technical Rules (MOE, 2009). ~~Generally, the scores are highest immediately around the well and lower further away. Because of proximity to the well, the 100-metre zone around the well is automatically given a vulnerability score of 10, as required by the Ministry of the Environment Assessment Report Technical Rules (2009). Beyond this,~~Usually, the most vulnerable area in a WHPA ~~(score of 8 to 10) is usually~~are ~~in the 2 year Time-of-Travel zone, which often has a score of 8 or 10. For some wells, land may still be highly vulnerable in the 5 year time-of-travel zone as well.~~

Surface Water Vulnerability

River intakes can be contaminated when dangerous materials are spilled into the water or on nearby land. It may take only a few minutes or hours for spilled material to reach a drinking water intake on a river or lake.

Intake Protection Zones (IPZ) have been established around each municipal intake. These are areas within which a spill or leak may get to the intake too quickly for the operators of the municipal water treatment plant to shut the intake down ~~while~~ before the pollutant passes by.

As part of the technical studies, researchers determined how quickly water moves downstream or across a lake in various conditions. They identified streams, municipal storm sewers or rural drains that enter the river or lake upstream of, or close to the intake. Vulnerability scores range from 1 to 10, with 10 being the most vulnerable.

River Intakes

The vulnerability of river-based intakes is assessed differently than lake-based intakes. River intakes have three Intake Protection Zones:

IPZ-1

The 200-metre area immediately upstream of the intake. Vulnerability scores range from 9 to 10.

IPZ-2

This is the area where water can reach the intake in a specified time, usually two to six hours, based on how much time the operator needs to shut down the intake when a spill occurs upstream. Vulnerability scores range from 6.3 to 9.

IPZ-3

Areas further upstream that may affect an intake. The vulnerability score would be less than the IPZ-2 score for that intake.

Great Lake Intakes

For Lake Erie intakes, researchers studied how water moves in the area around the intake, based on currents, winds and other factors. They also identified onshore areas drained by rivers, streams, storm sewers and other drains that empty into the lake near the intake.

There are three types of Intake Protection Zones for lake intakes:

IPZ-1
A one-kilometre circle around the intake, which may include some onshore areas. Vulnerability score ranges from 5 to 7.

IPZ-2
This is the area where water can reach the intake in a specified time, usually two to six hours, based on how much time the operator needs to shut down the intake when a spill occurs upstream. Vulnerability scores range from 3.5 to 6.3.

IPZ-3

~~3.1.2~~ **An area where the storage or handling of a chemical in large amounts could, if the facility fails, seriously affect the quality of water at the intake. All such activities are**

considered significant threats. No vulnerability score is assigned to a Great Lake IPZ-3.

~~3.1.3~~3.1.2 Municipal Drinking Water Threats

The Ontario *Clean Water Act, 2006* defines a Drinking Water Threat as "an 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, and includes an activity or condition that is prescribed by the regulation as a drinking water threat."

What are threats to drinking water?

Researchers have studied the areas around municipal wells and intakes to identify the human activities that could threaten municipal water supplies.

There are three categories of threats – chemicals, pathogens and water quantity threats.

Chemical threats include ~~things like~~ solvents, fuels, fertilizers, pesticides and similar products. They can be found in many different places such as factories, storage depots, gasoline stations or farms.

A **pathogen** is a dangerous micro-organism (e.g. bacteria or virus) found in human or animal waste. For example, human pathogens can be found in septic tanks; farm manure contains animal pathogens.

Water quantity threats are activities that reduce the ability of water to "recharge" or ~~move~~ migrate from the ground surface to an aquifer, and activities that contribute to the overuse of water in an area.

How are the locations of potential threats identified?

The Technical Rules (MOE, 2009a) list five ways in which to identify a drinking water threat:

a) Through an activity prescribed by the Act as a Prescribed Drinking Water Threat;
b) Through an activity identified by the Source Water Protection Committee as an activity that may be a threat and (in the opinion of the Director) a hazard assessment confirms that the activity is a threat;
c) Through a condition that has resulted from past activities that could affect the quality of drinking water;
d) Through an activity associated with a drinking water issue; and
e) Through an activity identified through the events based approach (this approach has not been used in this Assessment Report).

Threats can fall into one of the following four categories:

- Chemical threats can include toxic metals, pesticides, fertilizers, petroleum products and industrial solvents;
- Pathogenic threats are microorganisms that could cause illness; and
- Dense non-aqueous phase liquids (DNAPLs) are chemicals which are denser than water and do not dissolve in water, such as chlorinated solvents.

- Through a condition that has resulted from past activities that could affect the quality of drinking water.

Researchers working for municipalities or conservation authorities have used a variety of means to identify the locations of potential threats. They include things such as provincial pesticide registries, publicly available industrial databases, interviews with property owners, questionnaires and other means.

Details on individual threats, including their location and information will not be identified in the Assessment Report. Property owners are notified directly if it is believed that an activity on their land is a potential threat in order to confirm the information.

Assigning 'Hazard Ratings' to Activities

Not all threats are equal. The level of risk to human health posed by particular chemicals and pathogens depends on several factors including:

- The amount
- The toxicity
- How it behaves in the environment (e.g. Does the chemical move rapidly or slowly through the ground? How long do bacteria live in groundwater?)

The Ontario Ministry of the Environment and Climate Change has produced a table identifying hundreds of potential chemical and pathogen threats. The threats have been given a score on a scale of 1 to 10 with 10 being the most dangerous. This is known as the "hazard rating." The table indicates where activities will be threats, based on the level of vulnerability. This information is available online at: http://swpip.ca.

Calculating Threat Level: Low, Moderate or Significant

The goal of the *Clean Water Act, 2006* is to reduce the risk posed by significant threats to water and to prevent new significant threats from developing. So, it is necessary to sort out which potential threats are significant and which pose low or moderate risks. This is done by calculating the "risk score."

The risk score is a combination of two factors: the vulnerability of the water source (on a scale of 1 to 10) and the hazard rating of the threat (also on a scale of 1 to 10).

The risk score is calculated by multiplying the two factors together to provide a score out of 100. The score is then put into one of three categories; significant, moderate, or low.

Threat	Risk Score
Significant	80 – 100
Moderate	60 -79
Low	41 - 59
(Threats with risk scores lower than 40 do not have to be dealt with under the *Clean Water Act, 2006*.)	

Examples

<u>*Significant Chemical Threat*</u>

A chemical used in manufacturing has been identified as a possible cause of cancer in humans. It moves easily through the ground and does not break down. It has a hazard rating of 9. A factory just 100 metres upstream from a river intake has a storage tank containing a large amount of the chemical. If the tank were to leak, the chemical could get to the intake in a few minutes. The vulnerability score where the tank is located is 9. The risk score (vulnerability x hazard) would be 81, making it a significant threat.

Significant Pathogen Threat - Residential
A home near a municipal well has an old, failing septic system and untreated sewage is leaking into the ground. The area has a vulnerability score of 10 and the sewage has a hazard rating of 10. The result is a risk score of 100 making it a significant threat.

Significant Pathogen Threat – Farm
A farmer spreads manure on his fields to fertilize them. There is a municipal well on the property next door. The vulnerability score for the farmer's land is 8. The hazard rating for manure is 10. The result is a risk score of 80, making it a significant threat.

What does this mean for your property?

A property owner or business can use the Assessment Report to determine whether an activity on their property might be classified as a significant threat. If your property is close to a municipal drinking water system, you can use the vulnerability maps in Sections 4~~5~~ to 7 and 10 of this report and the Tables of Drinking Water Threats complied by the Ministry of the Environment and Climate Change (http://swpip.ca), to determine whether your property is in a vulnerable area where Source Protection Plan policies may apply. ~~with a score of 8 to 10. If your property is located in a wellhead protection area or intake protection zone with a score of 8 to 10, then you can use the Tables of Drinking Water Threats compiled by the Ministry of the Environment to determine whether any activities on your property might be considered a significant threat. The Tables of Drinking Water Threats can be accessed using the following link: www.sourcewater.ca.~~

If an activity is identified as a significant threat, the owner will be required to reduce the risk posed by the activity, or demonstrate that actions taken by the owner have already reduced the risk.

That is why it is a good idea to think about any opportunities you have right now to decrease the risk that an activity on your land could pollute a municipal water source.

That action might include:

- For an industry: developing a spill response program or upgrading chemical storage facilities
- For a rural resident: upgrading an old septic system or decommissioning an old well
- For a farmer: upgrading fuel tanks or developing a nutrient management plan

~~The Province of Ontario has made funding available under the Ontario Drinking Water Stewardship Program to help landowners undertake some of these actions and more. To learn more, go to www.sourcewater.ca and look under Stewardship Program or contact your local conservation authority.~~

~~As of 2014 the Province has discontinued the Ontario Drinking Water Stewardship Program.~~

3.2 Aquifer Vulnerability in Long Point Region Watershed Area

An aquifer's susceptibility to contaminants introduced at the ground surface can be evaluated through an aquifer vulnerability assessment: a physically based evaluation of the geologic and hydrogeologic character of the overlying sediments. The resulting vulnerability is highly dependent upon a number of factors which include the geologic structure, the hydraulic character of the sediments, the vertical hydraulic gradient, and the hydraulic connection between the surficial recharge water and the aquifer of interest.

Numerous models are available to evaluate groundwater vulnerability [i.e. Intrinsic Susceptibility Index (ISI), Aquifer Vulnerability Index (AVI), Surface to Well Advective Time (SWAT), Surface to Aquifer Advective Time (SAAT). For the majority of the Long Point Region~~ Source Protection Area~~, the SAAT model was chosen to estimate aquifer vulnerability on the watershed scale (Earthfx, 2008). The modelling to determine groundwater vulnerability is based upon ~~the most current information and vulnerability assessment. As~~information current to 2008.~~ updated information is available previous versions of the mapping and assessment may exist. Therefore, the mapping and analysis presented in this report is based on the most current information available at the time of publishing.~~

The SAAT method ~~involves~~ estimates the travel time for a particle of water to move vertically from the ground surface to the top of the aquifer that is being pumped. Areas of common travel time are mapped as being less than 5 years (high vulnerability), greater than or equal to 5 and less than 25 years (medium vulnerability), or greater than or equal to 25 years (low vulnerability).

Aquifer vulnerability mapping across ~~the LPRSPA~~Long Point Region is shown on **Map 3-1~~Map 3-3-1~~**. North-south trending areas of high and medium vulnerability located throughout the central portion of the watershed generally correspond to the shallow unconfined aquifer of the Norfolk Sand Plain. The western and eastern extents of the watershed are predominantly mapped as low vulnerability. These two areas are generally comprised of the clay-rich Port Stanley Till to the west and the Haldimand Clay Plain to the east, both of which provide protection to the deeper, confined aquifers.

3.2.1 Methodology

The ~~basis~~ primary source of data for the SAAT vulnerability calculation was the MOECC's~~Ministry of the Environment~~ Water Well Information System (WWIS). This database was then further built upon by adding information from the Ministry of Transportation's GEOCRES database. Datasets were ~~also improved~~then refined to remove low-quality data using the following methods:

- Location Quality Assurance (QA) update: Much of the pre-2004 data in the Lake Erie Source Protection Region database had location information that was processed and corrected by the MNR. More recent information, made available by the MOE in August 2006, did not include the MNR location assessment and corrections and, instead, relied on an older location classification system. The different QA classification codes were reconciled and a consistent classification system was developed.
- Ground surface elevations assigned to all boreholes: Consistent surface elevations are required for assessing aquifer geometry, water table and potentials in the deeper aquifers. The ~~latest~~ digital elevation model ~~elevation~~ (MNR Version 2.0 DEM) elevation was assigned to the ground surface recorded for each borehole. All elevation related information, including well construction, geology and water level data was then corrected

to the new reference elevation. Boreholes with ground elevations based on engineering surveys (QA code 1) were assumed to have better elevation data than the DEM and were not assigned the DEM elevation.

- Selection of high quality wells: Wells with an integrated QA code of less than 6 were considered to be of “high quality” and were used in the vulnerability calculations.
- Bedrock flags updated: Shallow bedrock wells were handled specially. Although the number and extent of these wells is limited, they are important in some areas. The bedrock flag code in the database was checked against the bedrock lithology material codes for consistency. Other internal consistency checks were also performed to confirm the selection of these wells.
- Well screen classifications updated: Correct well screen data is important for identifying the target aquifer. Many wells in the MOE WWIS database have missing or incomplete information on well construction and do not have a well screen zone defined. A series of procedures and QA checks were made to assign screen zones to those wells.

The SAAT method estimates aquifer vulnerability in units of time. The travel time has two components: unsaturated zone advective time (UZAT) and the water table to aquifer advective time (WAAT).

The input parameters and data sources for each parameter for the unsaturated zone advective time (UZAT) and water table to aquifer advective time (WAAT) calculations are listed below.

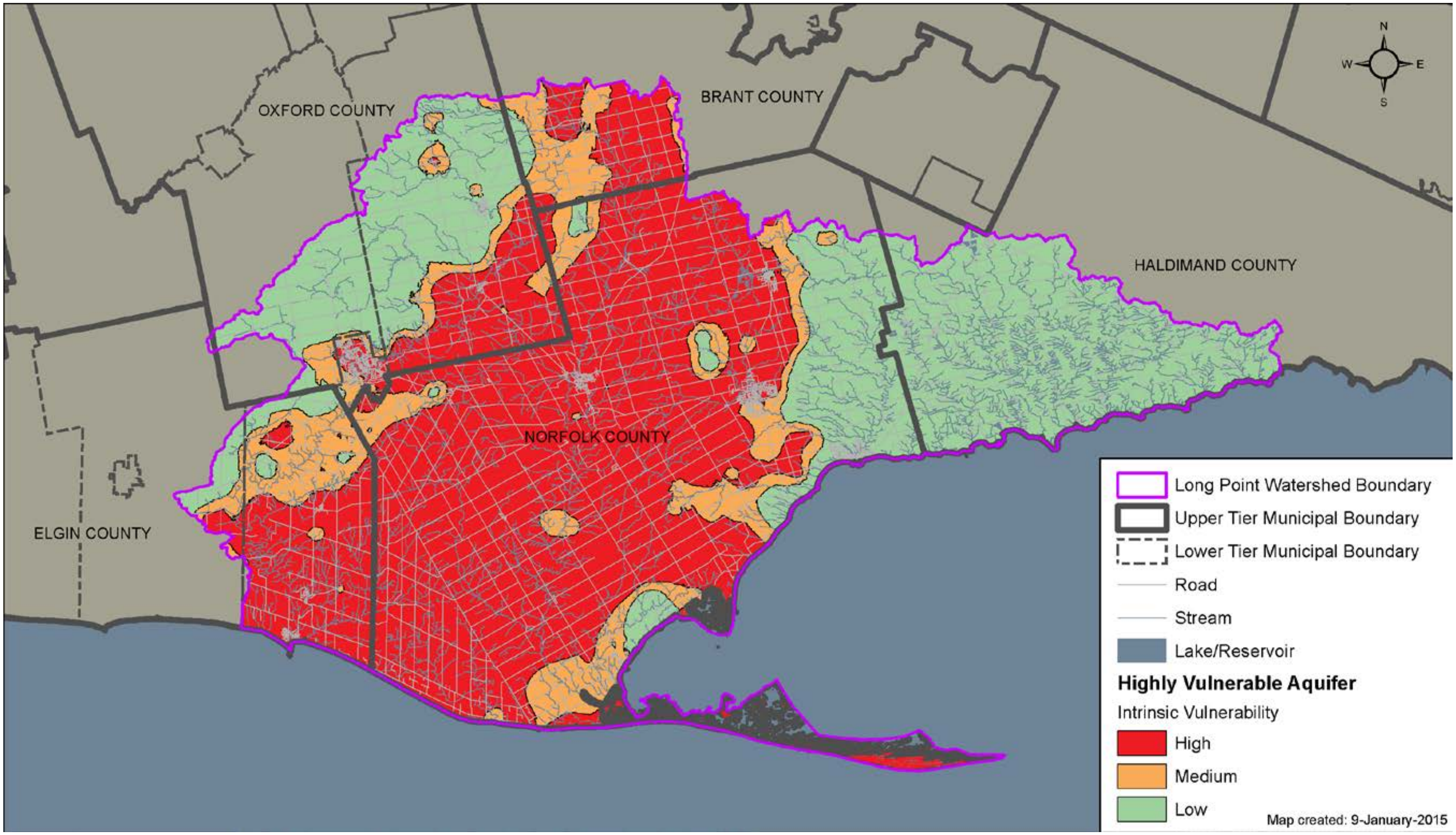
For the unsaturated zone advective time (UZAT) calculation, the following inputs were required:

- Depth to water table; computed by subtracting the interpolated water table surface from the land surface digital elevation model (MNR Version 2.0 DEM),
- Mobile moisture content; assigned to each geologic material based on specific yield values obtained from Todd (1980), and
- Infiltration rate; assumed to be equal to recharge rates developed by Schroeter & Associates (2006c).

The water table to aquifer advective time (WAAT) calculation required the following inputs:

- Aquifer porosity; estimated for each geological material from Todd (1980),
- Thickness of the geologic layer; calculated from the borehole logs, and
- Vertical hydraulic conductivity; estimated based on the geologic materials listed in the borehole logs.

Map 3-1: Aquifer Vulnerability



Estimated depth to water table was computed by subtracting the interpolated water table surface from land surface elevation. The mobile moisture content of the surface material was used as a surrogate for the average moisture content of the soil under steady-state drainage at the infiltration rate. The value of average moisture content under steady state drainage should lie somewhere between field capacity and porosity for the particular soil. Guidance Module 3 (MOE, 2006b) suggests values for mobile moisture content that can be applied to a map of the quaternary geology. However, it was felt that the mobile moisture content in the unsaturated zone was more likely to be related to the drainable porosity than to field capacity. Accordingly estimates of mobile moisture content were assigned to each geologic material based on representative specific yield and porosity values obtained from Table 2.5 in Todd (1980).

It was assumed that the infiltration rate was equal to the recharge rate determined from maps developed by Schroeter & Associates (2006a, 2006b, 2006c) using the GAWSER model.

If multiple layers of different types of unsaturated materials were present, the travel time through each layer was calculated and then summed over the total depth to get a total travel time.

Finally, the Technical Rules (MOE, 2009a) indicate SAAT values are translated into aquifer vulnerability categories according to the following thresholds:

- <5 years represents high vulnerability
- ≥ 5 years, < 25 years represents medium vulnerability
- ≥ 25 years represents low vulnerability

Vulnerability for the Erie Spits physiographic region, located at the south east portion of the Long Point Region, was assigned a high vulnerability based on professional review of the surficial geology layer and other resources available for this location. This region is comprised of predominantly sand deposits with a limited elevation above the lake with groundwater levels at or near lake level.

Peer Review

The Earthfx (2008) SAAT report was peer reviewed by Chris Neville of S.S. Papadopulos and Associates. The review found the Earthfx (2008) report to be in compliance with the *Clean Water Act, 2006* Technical Rules. The reviewer's general impression was that the SAAT evaluation approach described in Sections 4, 5 and 6 of the report is consistent with the MOE Technical Rules for Groundwater Vulnerability. In the reviewer's opinion, the examination of uncertainty in the evaluation was particularly well done. In general, the results of the vulnerability assessment are reasonable.

Given that the peer review comments would not change the overall outcome of the Earthfx (2008) study, no changes were made to the report following the review.

3.2.2 Limitations and Uncertainty

Although numerous steps were taken to exclude WWIS data of lower reliability, the uncertainty associated with several of the components of the WWIS (location accuracy, reliability of geologic log, measurement of water level, etc.) represent a significant limitation in the assessment. There is also natural variability in the hydraulic conductivity which is not captured in the analysis.

However, given that the SAAT analysis uses the most current methods (under the *Clean Water Act, 2006* Technical Rules) and data available, the uncertainty rating at this time can be considered low.

3.3 Highly Vulnerable Aquifers

Areas ~~calculated as being of~~classified as having a high vulnerability are considered Highly Vulnerable Aquifers (HVAs). Highly Vulnerable Aquifer areas in the Long Point Region Source Protection Area are identified as the red areas on **Map 3-2**.

3.3.1 Vulnerability Scoring in Highly Vulnerable Aquifers

According to the Technical Rules, highly vulnerable aquifer areas outside of the Wellhead Protection Areas are assigned a vulnerability score of 6. The highly vulnerable aquifer areas illustrated on **Map 3-2** therefore, receive a vulnerability score of 6.

3.3.2 Managed Lands and Livestock Density for Highly Vulnerable Aquifers

This section provides a description of the methodology used to calculate the percent managed land and the livestock density for the HVA areas in the Long Point Region watershed.

The methods to calculate the managed lands and livestock density follow 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*" issued by the Province in September 2009, and following guidance provided in the "*Preliminary Technical Memo issued by GRCA for Lake Erie Region technical studies: Managed Lands and Livestock Density*" on September 23, 2009.

Managed Lands Area Methodology

Managed lands are divided into two categories; agricultural managed lands (AML) and non-agricultural managed lands (NAML). Agricultural managed land includes cropland, fallow and improved pasture land that may receive agricultural source material (ASM). Non-agricultural managed lands include golf courses, residential lawns and other turf that may receive commercial fertilizer or non-agricultural source material (NASM).

Land use classifications for land area are based on data from the Municipal Property Assessment Corporation (MPAC), who provide a parcel layer in GIS format (**Table 3-3**). Each parcel has a code describing the main land cover classification, including codes for agricultural land, residential, commercial and industrial land. All MPAC farm codes (3-digit numbers starting with 2) were considered in the agricultural managed lands calculation, if they were within or partially within (intersecting) the HVA areas. All other categories were considered in the non-agricultural category to determine the amount of non-agricultural managed lands, if they intersected the HVA areas.

In some cases, additional classification was required where the MPAC data layer did not provide enough information on which to determine the land use on a parcel of land. Using the 2006 ortho-photo (**Table 3-3**), air photo interpretation was used to determine whether a parcel of land should be classified as agricultural or non-agricultural.

In the managed lands calculations, areas of wetlands, impervious area, wooded areas, water bodies and aggregate license areas were removed from consideration. To account for buildings and other areas that may not receive nutrients, all farm parcels were given a managed lands ratio of 0.9, meaning that 90% of the parcel was subject to ASM and considered agriculturally managed land.

Agricultural Managed Lands Calculation
All parcels of land classified as agricultural within the HVA were used in the calculation of agricultural managed lands. For each separate (discontinuous) unit of HVA, the total area of agricultural managed land was summed. Where a parcel of land fell only partially within a HVA area, only that portion contained by the HVA was included in the calculation. This agricultural managed lands area would be summed with the non-agricultural managed lands area to get the total percent managed land in each HVA area.

Non-Agricultural Managed Land Calculation
All parcels touching the HVA areas that had a non-agricultural MPAC code or were classified as non-agricultural using air photo interpretation were used in the calculation of non-agricultural managed lands. To account for buildings and other areas that may not receive nutrients, all parcels were given a managed lands ratio as seen in **Table 3-1**.

The non-residential values in **Table 3-1** were generated through aerial photo interpretation. Areas that were deemed to be managed lands in each category were compared to the rest of the area within the parcel to determine an appropriate ratio. The average value for each parcel estimated in each category was rounded to the nearest 5% to give an overall managed land ratio.

The managed land ratio for residential areas is based on impervious cover analysis completed for the Alder Creek Subwatershed Study in the City of Kitchener (Rungis, G., pers. comm.). The percentage of pervious cover used in this study provides a good estimate of the area that may receive commercial fertilizer on residential properties.

For each discontinuous unit of HVA, the total area of non-agricultural managed land within the HVA was summed. Where a parcel of land fell only partially within a HVA area, only that portion contained by the HVA was included in the calculation. The non agricultural managed lands and the agricultural managed lands areas were then summed and divided by the area of the HVA area to get the total percent managed land.

Table 3-1: Managed Land Ratios for land use categories

Major Category	Specific Category	Managed Land Ratio
Farm	all types of farms	0.9
Golf Course	Driving range/golf centre - stand alone, not part of a regulation golf course	0.6
	Golf course	0.95
Institutional	Non-school, i.e. hospitals	0.6
	School (elementary or secondary, including private)	0.65
Open Space	Residential development land	0.55
	Vacant land condominium (residential)-defined land that is described by a condominium plan	0.55
Other	Cemetery	1
	Large office building (generally multi - tenanted, over 7,500 s.f.)	0.45
	Local government airport	0.9
	Place of worship - with a clergy residence	0.55
	Place of Worship - without a clergy residence	0.55
	Private airport/hangar	0.65
	Property in process of redevelopment utilizing existing structure(s)	0.55
Recreational	Amusement park	0.5
	Commercial sport complex	0.45
	Exhibition grounds/fair grounds	0.7
	Municipal park (excludes Provincial parks, Federal parks, campgrounds)	0.65
	Non-commercial sports complex	0.5
	Recreational sport club - non commercial (excludes golf clubs and ski resorts)	0.6
Residential	High-density, multi-unit	0.55
	Residential-Low Density (standard single dwelling units)	0.45

The calculation of livestock density within HVA areas utilized the calculation of agricultural managed lands to determine the Nutrient Units per acre (NU/ac).

Barn Identification and Nutrient Units

To determine the Nutrient Units, each parcel of land that intersects the HVA areas was assessed using air photo interpretation for the presence of a livestock barn. The size of the barn is used as a surrogate for the number of livestock and the amount of nutrients that could be generated by those livestock on that farm unit. The description in the MPAC farm code was used initially to screen for the livestock parcels in determining the livestock type. Barns on these parcels were inspected for livestock housing areas. Other parcels on agricultural lands were also scanned for the presence of livestock barns using interpretation of the 2006 air photo. Assistance from in-house stewardship staff familiar with agricultural livestock practices increased confidence in the interpretation of housing structures in the imagery. Where housing structures could potentially house livestock but appeared in the 2006 air photo to be empty, the housing structure was included in the livestock density calculation.

Partial coverage of building footprints was available for the study area, but where data gaps existed, the buildings on parcels having a farm code were digitized based on images seen through air photo interpretation of ortho-imagery from 2006.

Each type of livestock has a unique NU conversion factor, to determine the number of animals that generate 1 NU. For instance, one beef cow produces 1 NU and requires 100 sq.ft. of living space in a barn, so the relationship for beef barns is 100 sq.ft./NU. The ratio assumes that the capacity of each livestock barn is at the maximum to generate or have the potential to generate that amount of nutrients.

Through air photo interpretation, the type of livestock housed in each barn was determined, and the area of the housing area was measured using the ArcMap geometry calculation function. A table provided in the technical memos provided by GRCA (GRCA, 2009) and MOE (MOE, 2009b) summarize the relationship between barn area, livestock type and Nutrient units generated. This table is provided in **Table 3-2** below. By multiplying the area of the barn by the NU per area ratio, the total number of NU for the farm unit was determined.

Table 3-2: Barn/Nutrient Unit Relationship Table

Livestock Type	sq.ft./NU	sq.m/NU
Dairy	120	11
Swine	70	7
Beef	100	9
Chickens	267	25
Mixed	140	13
Turkeys	260	24
Horse	275	26
Goat	200	19
Sheep	150	14
Fur	2400	223

<u>*Livestock Density Calculation*</u>
To determine the nutrient units generated only within the HVA areas, NU values for each farm unit were area weighted for the percent of the farm unit land area within the HVA. For the calculation livestock density, all the NU values for all the barns were summed and then divided by the total acreage of agricultural managed land for that particular HVA area, as calculated and detailed in previous sections (**Map 3-4**).

Input Data

The calculations for managed land and livestock density were completed as a desk-top exercise. The input data used to calculate the percent managed land and the livestock density are listed in **Table 3-3.** Information is given on the source of the data layer, the purpose for using the data and a description of where the data originated.

Verification of the results through field inspection could provide more accurate estimates of the type of livestock and the identification of housing structures; however this was not completed for the HVA areas in the Long Point Region.

Table 3-3: Data used for Managed Land and Livestock Density Calculations

Data Input	Description	Source	Purpose
Parcels (polygon)	Municipal Property Assessment Corporation parcel fabric with primary roll number	Sub-license from Municipal Property Assessment Corporation (MPAC) under the Ontario Parcel Agreement	Minimum map unit for identifying different classes of property and farm operation types
Tax assessment record (partial) (table)	Municipal Property Assessment Corporation tax assessment database by primary roll number containing property code and farm operation code	Sub-license from Municipal Property Assessment Corporation (MPAC)	Linked to parcels, identifies tax-assessed land use, and for agricultural properties identifies primary farm operation, livestock or crop.
Wetlands (polygon)	Natural Resources Values Information System (NRVIS)	Sub-license from Ontario Ministry of Natural Resources (MNR)	Used to mask for non managed land
Water body (polygon)	Natural Resources Values Information System (NRVIS)	Sub-license from Ontario Ministry of Natural Resources (MNR)	Used to mask for non managed land
License Aggregate Areas (polygon)	Pits and quarries from the Natural Resources Values Information System (NRVIS)	Sub-license from Ontario Ministry of Natural Resources (MNR)	Used to mask for non managed land
Wooded Areas (polygon)	Southern Ontario Land Resource Information System (SOLRIS)	Sub-license from Ontario Ministry of Natural Resources (MNR)	Used to mask for non managed land
Building footprints (polygon)	Building outlines digitized from digital orthorectified aerial photography from spring 2006	Grand River Conservation Authority (GRCA)	Minimum map unit for calculating livestock density per structure identified as contributing animal nutrient units
SGRA/HVA (polygon)	Significant Groundwater Recharge Area polygon and Highly Vulnerable Area	Lake Erie Source Protection Area	Reporting unit

Known Limitations and Data Gaps

The property code and farm operation code values used to identify a candidate parcel is a single descriptor assigned by MPAC during the generation of the tax assessment record. It does not necessarily represent the current land use activities on each property. None of the data used as input to the analysis was verified in the field. A quantitative estimate of data accuracy is not known. Therefore the results should be considered as only an approximation.

The input data layers used to identify the non-managed land areas (wetlands, water bodies, wooded areas, etc.) have spatial and content accuracies of varied and unknown degrees. The NRVIS data is intended to represent 1:10,000 scale hardcopy mapping. The data layers were acquired from Land Information Ontario, and represent the best available data for their thematic content at the time of the analysis.

The values of nutrient unit per square metre of livestock type were generated by the Ontario Ministry of Agriculture, Food and Rural Affairs (Table 1 of the Nutrient Management Tables of O.

Reg. 267/03 made under the *Nutrient Management Act, 2002*). The values are meant to approximate the maximum potential nutrient unit production for the size of the livestock barn structure based on best management practices. The livestock NU calculations were not field verified, therefore, the results should be considered as only an approximation.

The estimation of barn size was also approximate, as air photo interpretation cannot decipher between areas of the barn that house livestock and areas that do not. Also, the ability to determine whether the barn had one storey or two stories of housing areas was impossible through air photo interpretation and all barns were assumed to be single storey. Where there was question on livestock type, the more conservative conversion factor was used. For example, housing structures are similar between cattle and horses, but as beef generate more NU than horses per unit area, the beef conversion factor was used. Verification of the livestock type and size of actual livestock housing area may yield more accurate results.

The ratios for non-agricultural managed lands were done using averages estimated through air photo interpretation. However, each parcel category could show very different percentages of managed land area and should only be used as approximation. Additional information from municipal by-laws on pervious cover requirements may be very useful in refining the estimates.

3.3.3 Percent Impervious Surfaces for Highly Vulnerable Aquifers

To determine whether the application of road salt poses a threat to the HVA areas, the percent impervious surface where road salt can be applied per square kilometre in each HVA area was calculated as per Technical Rule 16(11) (MOE, 2009a). The input data used to calculate the percent impervious surfaces per square kilometre are listed in **Table 3-4**.

Impervious surfaces in HVA areas in Long Point Region watershed constitute less than 8 percent of the total area, as shown in **Map 3-5** which represents a low percentage. Based on these results, the application of road salt does not pose a threat to Highly Vulnerable Aquifers in Long Point Region watershed.

Methodology

To calculate the percent impervious surfaces, information on land cover classification was used. The Southern Ontario Land Resource Information System (SOLRIS) represents the land surface data, including road and highway transportation routes, as continuous 15x15 metre grid cells with land cover classifications. All the cells that represent highways and other impervious land surfaces used for vehicular traffic were re-coded with a cell value of “1” and all other land cover classifications were given a “0” value, to identify only the road areas.

Using the Spatial Analyst module of ArcGIS software, the total number of road cells was summed for each square kilometre area in all HVA areas. The summed value for each cell in the output equaled the total number of road cells within each 1km x 1km window. The value of summed cells was converted to the square kilometer equivalent to determine the percent impervious road surface per square kilometer. The analysis is the most representative analysis of road density and adheres to the principle of the Technical Rules.

Known Limitations and Data Gaps

Impervious surfaces such as parking lots, pedestrian walkways and other related surfaces that may receive salt application were not considered, as data was not available for these features within the study area.

Table 3-4: Input Data for Impervious Surfaces in Highly Vulnerable Aquifers

Data Input	Description	Source	Purpose
Road areas (raster)	Road and highway transportation routes as represented by the Southern Ontario Land Resource Information System (SOLRIS) version 1.2 May 2008, 15 metre raster cell format	Sub-license from Ontario Ministry of Natural Resources (MNR)	Continuous 15 x 15 metre cells represent surface areas of all highways and other impervious land surfaces used for vehicular traffic
HVA (polygon)	Highly Vulnerable Aquifer area polygon	Lake Erie Source Protection Region	Boundary of reporting unit

3.3.4 Drinking Water Threats in Highly Vulnerable Aquifers

Table 3-5 indicates the possible levels of threat posed by chemicals, pathogens and dense non-aqueous phase liquids (DNAPL) within the Highly Vulnerable Aquifer areas in the Long Point Region watershed, which are illustrated on **Map 3-2.** A checkmark indicates that the threat classication is possible; a blank cell indicates that it is not. The level of threat that an activity poses to a drinking water supply depends on the vulnerability scores within a vulnerable area. Since Highly Vulnerable Aquifer areas receive a vulnerability score of 6, even the most hazardous activities are not classified as significant threats. However, some chemicals and DNAPLs are or would be considered moderate and low drinking water threats in the areas illustrated in red on **Map 3-2**.

The Ontario Ministry of the Environment and Climate Change produced tables that list all of the threats and associated circumstances that are or would be moderate and low drinking water threats in Highly Vulnerable Aquifer areas. These tables are no longer in use, but corresponding information is available on the following website: http://swpip.ca. Thisinformation can be used along with **Map 3-2** and **Table 3-5** to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.

Table 3-5: Identification of Drinking Water Quality Threats in Highly Vulnerable Aquifers (HVA)

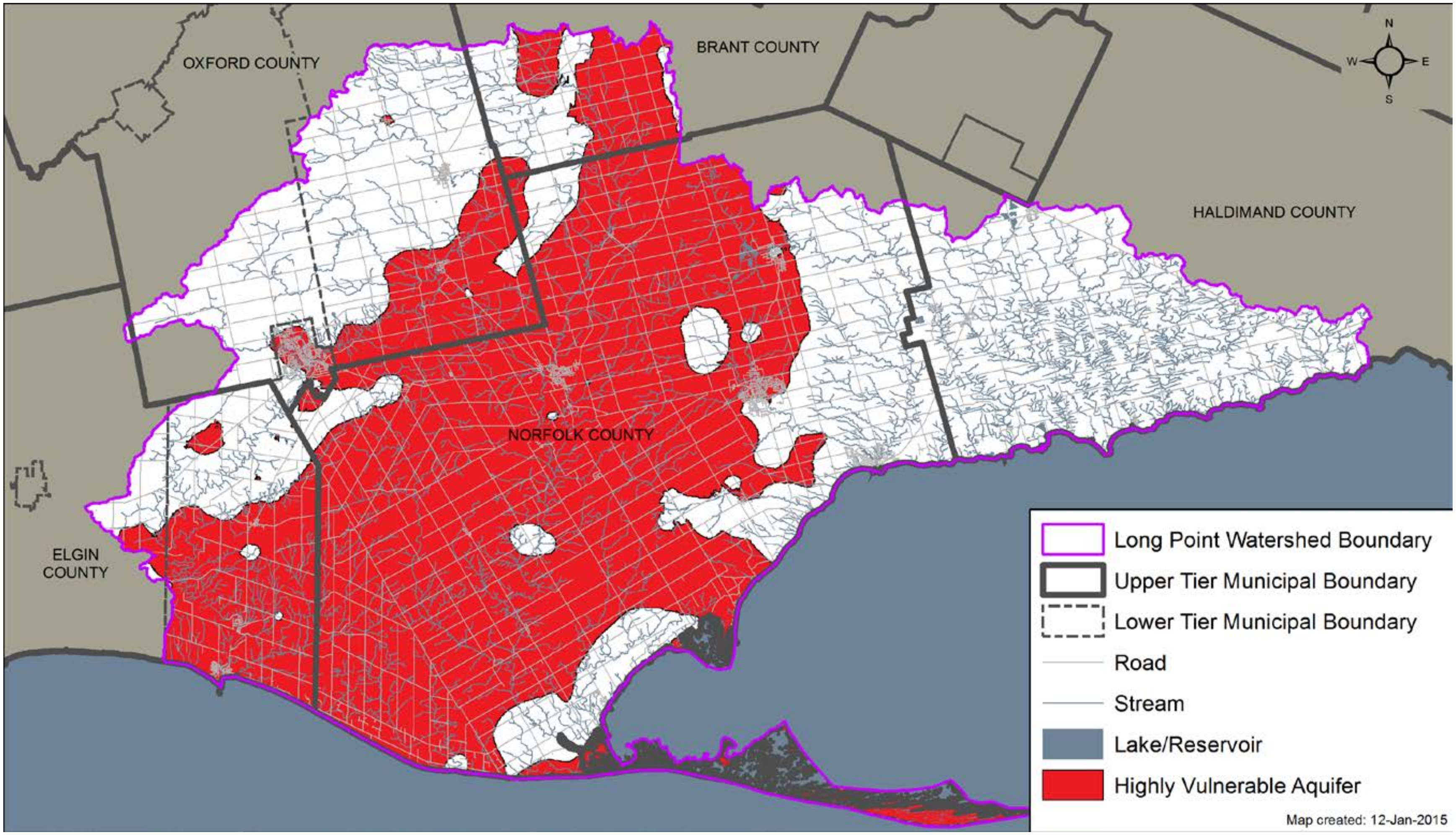
Threat Type	Vulnerability Score in HVA	Threat Classification Level		
		Significant 80+	Moderate 60 to <80	Low >40 to <60
Chemical Threats	6		✔	✔
Handling / Storage of DNAPLs	6		✔	✔
Pathogens	6			

At the time of this report, a drinking water threats analysis is not necessary for Highly Vulnerable Aquifers, since no significant threats can occur in a Highly Vulnerable Aquifer with a vulnerability score of 6. Additionally, no conditions resulting from past activities have been identified in the Highly Vulnerable Aquifer areas in the Long Point Region watershed.

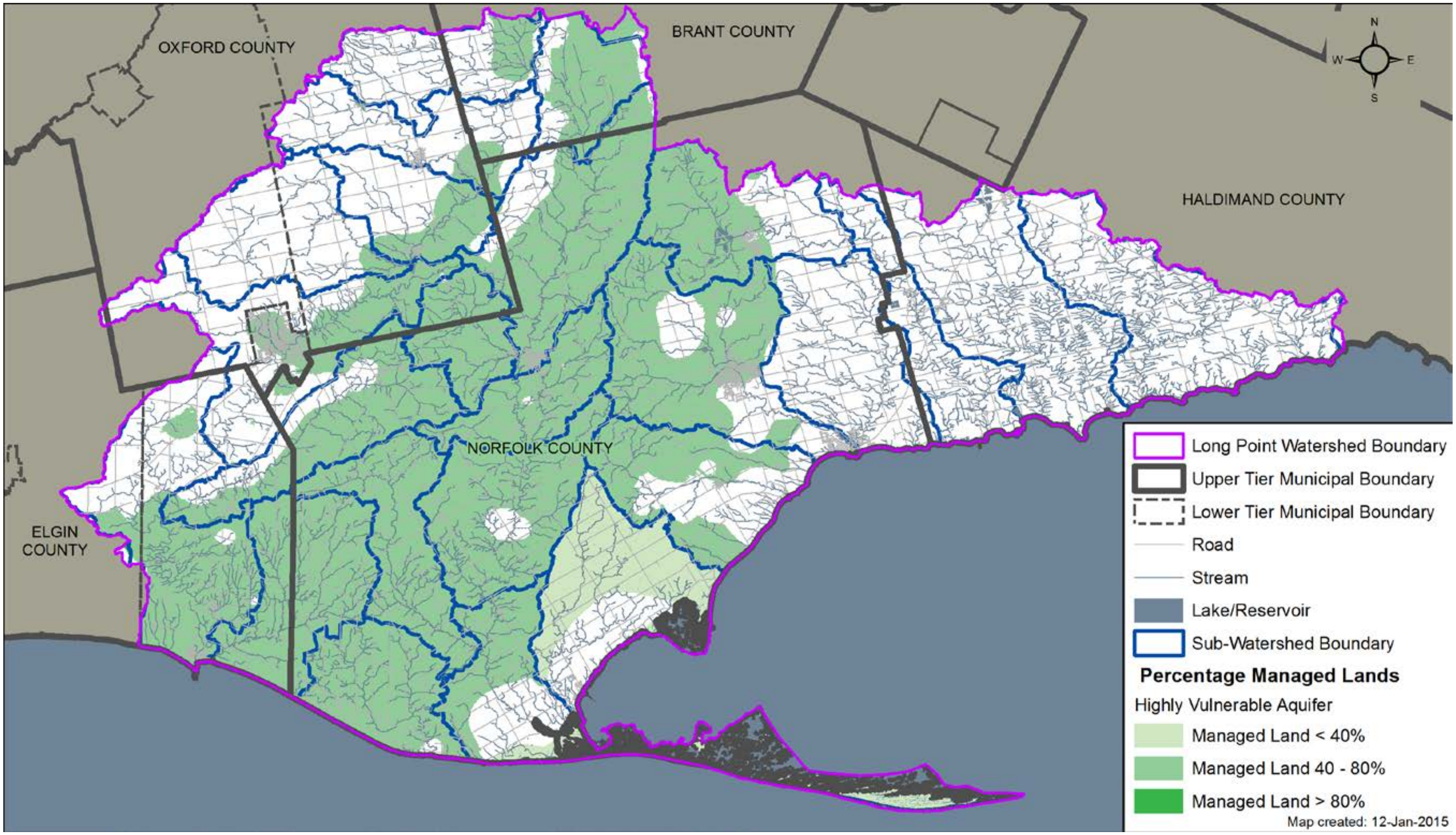
3.3.5 Drinking Water Issues in Highly Vulnerable Aquifers

No Issues have been identified in the Highly Vulnerable Aquifers to date. Public Health Units are undertaking risk assessments of all small drinking water systems, and may, through that process, identify possible Issues for an updated Assessment Report.

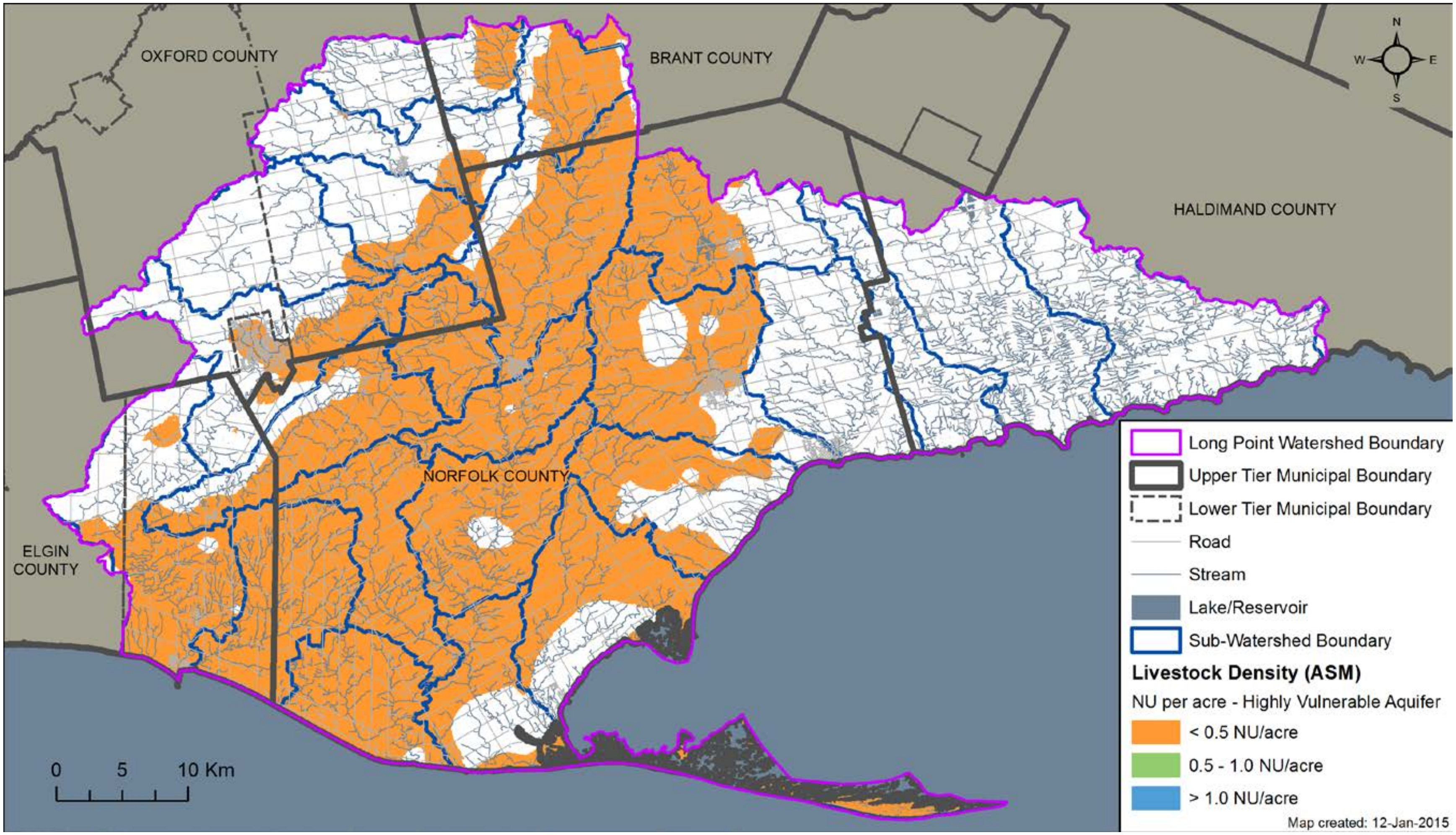
Map 3-2: Highly Vulnerable Aquifers



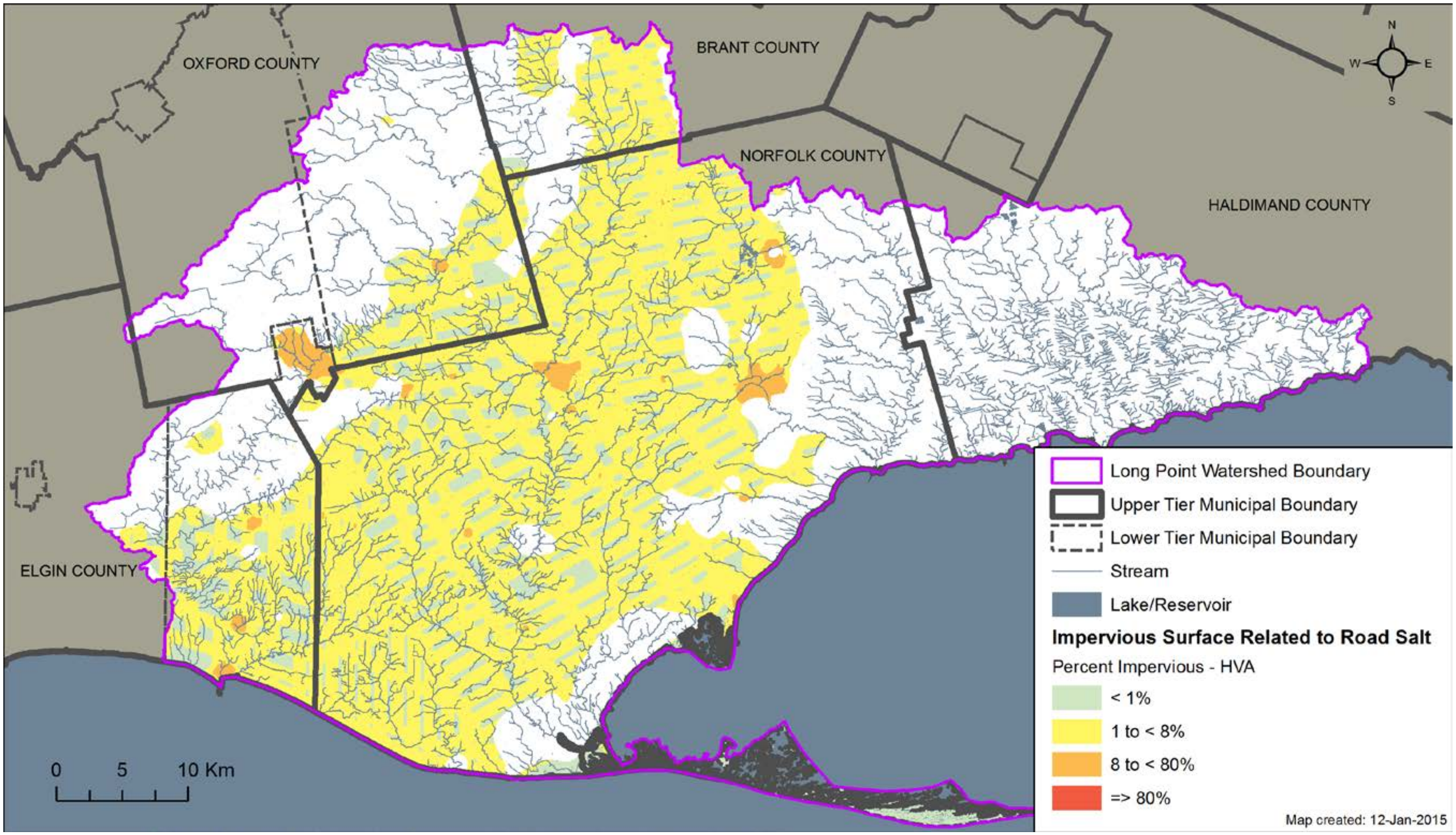
Map 3-3: Percent Managed Lands in Highly Vulnerable Aquifers



Map 3-4: Livestock Density in Highly Vulnerable Aquifers



Map 3-5: Impervious Surface Related to Road Salt in Highly Vulnerable Aquifers



~~3.4 Significant Groundwater Recharge Areas~~

~~A Significant Groundwater Recharge Area (SGRA) is defined as a specific type of vulnerable area which has a hydrologic connection to a surface body of water or aquifer that is a source for a municipal drinking water system. SGRAs are protected under the *Clean Water Act, 2006*. The role of significant groundwater recharge areas is to support the protection of drinking water across the broader landscape. A regional-scale groundwater flow model, developed as part of the Tier Two2 Stress Assessment, was updated with a revised conceptual model based on data gathered during the Tier 3 field program.Significant groundwater recharge areas were delineated using the water budget tools described in Section 3.~~

~~Recent average groundwater recharge rates were developed during Tier 3 work (referenceMatrix, 2015) using both regional scale groundwater flow model model (FEFLOW) and regional and local scale groundwater and surface water flow model (MIKE SHE). Groundwater recharge was estimated using the hydrologic model. The hydrologic model results provide an estimate of groundwater recharge based on Hydrological Response Units (HRUs), which are designed to reflect soil mapping, surficial geology and land cover, and climatic conditions over the period 1980 to 2004. Groundwater model results provide an estimate on average recharge rates for 1960 to 2010 and are influenced by surficial geolgy, topography (slope), imperviousness, and groundwater vertical hydraulic gradients. Calibrated recharge estimates ranged from a low value of less than 50 mm/yr (Haldimand Clay Plain) to a high of over 400 mm/yr (Norfolk Sand Plain). The high recharge areas tend to be located in areas of fine sand due to the infiltration capacity of the soils and relatively flat topography. High recharge also occurs in the hummocky topography of the moraine features due to the storage of water in surface depressions. Low recharge rates occur in less permeable material (till, clay and silt).~~

~~Threshold values were calculated as set out in the Technical Rules, and areas with annual average recharge above those values were labeled as significant.Threshold values for significant groundwater recharge areas were defined by taking 115 per cent of the annual average recharge for the related groundwater recharge area. For the Long Point Region Source Water Protection Area, the “related groundwater recharge area” was taken as the watershed. The average annual groundwater recharge rate for the Long Point Region is 224 310 mm/year. The threshold, calculated as 115 per cent of the average annual rate, is 356257 mm/year.~~

~~After estimating significant groundwater recharge areas, small, isolated areas (<1 km^2) were removed to create mapping that focuses the delineated significant groundwater recharge areas to larger geologic and physiographic features that are considered more representative of mapped Quaternary geology features.~~

~~**Map 3-6** shows the significant groundwater recharge areas mapped based on the calculated threshold and with isolated polygons of less than 1 km^2 removed. All of the significant groundwater recharge areas mapped within the Long Point Region Source Protection Area are considered hydrologically connected to groundwater sources used for drinking water because of the extensive cover of domestic overburden wells in the study area (**Map 3-6Map 3-5**).~~

~~Delineation of significant groundwater recharge areas is limited by the processes used by the hydrologic model to estimate recharge, the mapping used to create hydrologic response units, and the climate data available. The hydrologic model is a simplification of natural processes. Advancements in Tier 3 models allowed for better representation of evapotraspiration rates both in sandy soils and clay/silt soils. The updated model also incorporated a better representation of overland runoff estimates by having individual runoff that is generated by an individual cell, which flows on a neighbouring cell, to include factors such as land slope, surface roughness,~~

~~soil water content, and infiltration potential.~~ ~~Recharge is based on water that infiltrates through two soil layers and is not lost to runoff or evapotranspiration. This recharge may include interflow as well as true recharge to the aquifer system. The mapping used to create hydrologic response units is landscape based and only represents a point in time. Land cover mapping may change significantly over a short time period and this may not be represented in the land cover mapping used. Finally, only two climate stations were used for the hydrologic model. Although over 20 years of data were used to calculate the average annual recharge rate, this rate does not represent changes to the climate due to climate change nor focus on the importance of seasonal and annual variability.~~

~~3.4.1 Vulnerability Scoring Within Significant Groundwater Recharge Areas~~

~~Vulnerability scoring within the significant groundwater recharge areas was completed by intersecting the aquifer vulnerability mapping with the significant groundwater recharge areas. Significant groundwater recharge areas that have high intrinsic vulnerability (coincident with highly vulnerable aquifers) were given a score of 6. Significant groundwater recharge areas that have a moderate and low intrinsic vulnerability were given vulnerability scores of 4 and 2 respectively.~~ ~~**Map 3-7**~~ ~~shows the vulnerability scoring within the significant groundwater recharge areas.~~

~~3.4.2 Managed Lands and Livestock Density within Significant Groundwater Recharge Areas~~

~~Percent managed lands and livestock density within SGRAs were calculated using the same methodology and data sources as described in Section 4.2.2 for HVA areas. Since Percent Managed Land and Livestock Density need only be calculated for areas where the application of agricultural source material, non-agricultural source material and commercial fertilizer can be a threat to drinking water supplies (i.e. vulnerability score greater than or equal to 6), the calculation for Significant Groundwater Recharge Areas is a subset of the calculation for HVA.~~

~~**Map 3-8**~~ ~~and~~ ~~**Map 3-9**~~ ~~show that in the SGRAs in the Long Point Region watershed, the managed lands percentage is between 40 and 80% (moderate); while the livestock density is less than 0.5 nutrient units per acre (low).~~

~~3.4.3 Calculation of Impervious Surfaces for Significant Groundwater Recharge Areas~~

~~To determine whether the application of road salt poses a threat to SGRAs in the Long Point Region watershed, the percent impervious surface where road salt can be applied per square kilometre in each SGRA was calculated in accordance with Technical Rule 16(11) (MOE, 2009a). The input data used to calculate the percent impervious surfaces per square kilometre are listed in~~ ~~**Table 3-6**~~~~.~~

~~Impervious surfaces in SGRAs in Long Point Region watershed constitute less than 8 percent of the total area, representing a low percentage. Based on these results, and as illustrated on~~ ~~**Map 3-10**~~~~, the application of road salt does not pose a threat to SGRAs.~~

~~***Methodology***~~

~~To calculate the percent impervious surfaces, information on land cover classification was used. The Southern Ontario Land Resource Information system (SOLRIS) represents the land surface data, including road and highway transportation routes, as continuous 15x15 metre grid cells with land cover classifications. All the cells that represent highways and other impervious land~~

~~surfaces used for vehicular traffic were re-coded with a cell value of "1" and all other land cover classifications were given a "0" value, to identify only the road areas.~~

~~Using the Spatial Analyst module of ArcGIS software, the total number of road cells was summed for each square kilometre area in all SGRAs. The summed value for each cell in the output equaled the total number of road cells within each 1km x 1km window. The value of summed cells was converted to the square kilometer equivalent to determine the percent impervious road surface per square kilometer. The analysis is the most representative analysis of road density and adheres to the principle of the Technical Rules.~~

~~Known Limitations and Data Gaps~~

~~Impervious surfaces such as parking lots, pedestrian walkways and other related surfaces that may receive salt application were not considered as data was not available for these features within the study area.~~

~~Table 3-6: Input Data for Impervious Surfaces in Highly Vulnerable Significant Recharge Areas~~

~~Data Input~~	~~Description~~	~~Source~~	~~Purpose~~
~~Road areas (raster)~~	~~Road and highway transportation routes as represented by the Southern Ontario Land Resource Information System (SOLRIS) version 1.2 May 2008, 15 metre raster cell format~~	~~Sub-license from Ontario Ministry of Natural Resources (MNR)~~	~~Continuous 15 x 15 metre cells represent surface areas of all highways and other impervious land surfaces used for vehicular traffic~~
~~SGRA (polygon)~~	~~Significant Groundwater Recharge Area polygon~~	~~Lake Erie Source Protection Region~~	~~Boundary of reporting unit~~

~~3.4.4 Drinking Water Threats within Significant Groundwater Recharge Areas~~

~~indicates the possible levels of threat posed by chemicals, pathogens and dense non-aqueous phase liquids (DNAPL) within the Significant Groundwater Recharge Areas in the Long Point Region watershed, which are illustrated on **Map 3-7**. A checkmark indicates that the threat classification level is possible; a blank cell indicates that it is not. As indicated in the table, no activities can be classified as a significant threat in the SGRAs. The level of threat that an activity poses to a drinking water supply depends on the vulnerability scores within a vulnerable area. Since Significant Groundwater Recharge Areas receive a vulnerability score of 2, 4 or 6, even the most hazardous activities are not classified as significant threats based on the described scoring method. However, some chemicals and DNAPLs are or would be considered moderate and low drinking water threats in the areas illustrated in yellow and green on **Map 3-7**.~~

~~The Ontario Ministry of the Environment and Climate Change produced tables that list all of the threats and associated circumstances that are or would be moderate and low drinking water threats in SGRAs. These tables are no longer in use, but corresponding information is available on the following website: http://swpip.ca. The information can be used along with **Map 3-7** and to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.~~

~~Table 3-7: Identification of Drinking Water Quality Threats in Significant~~

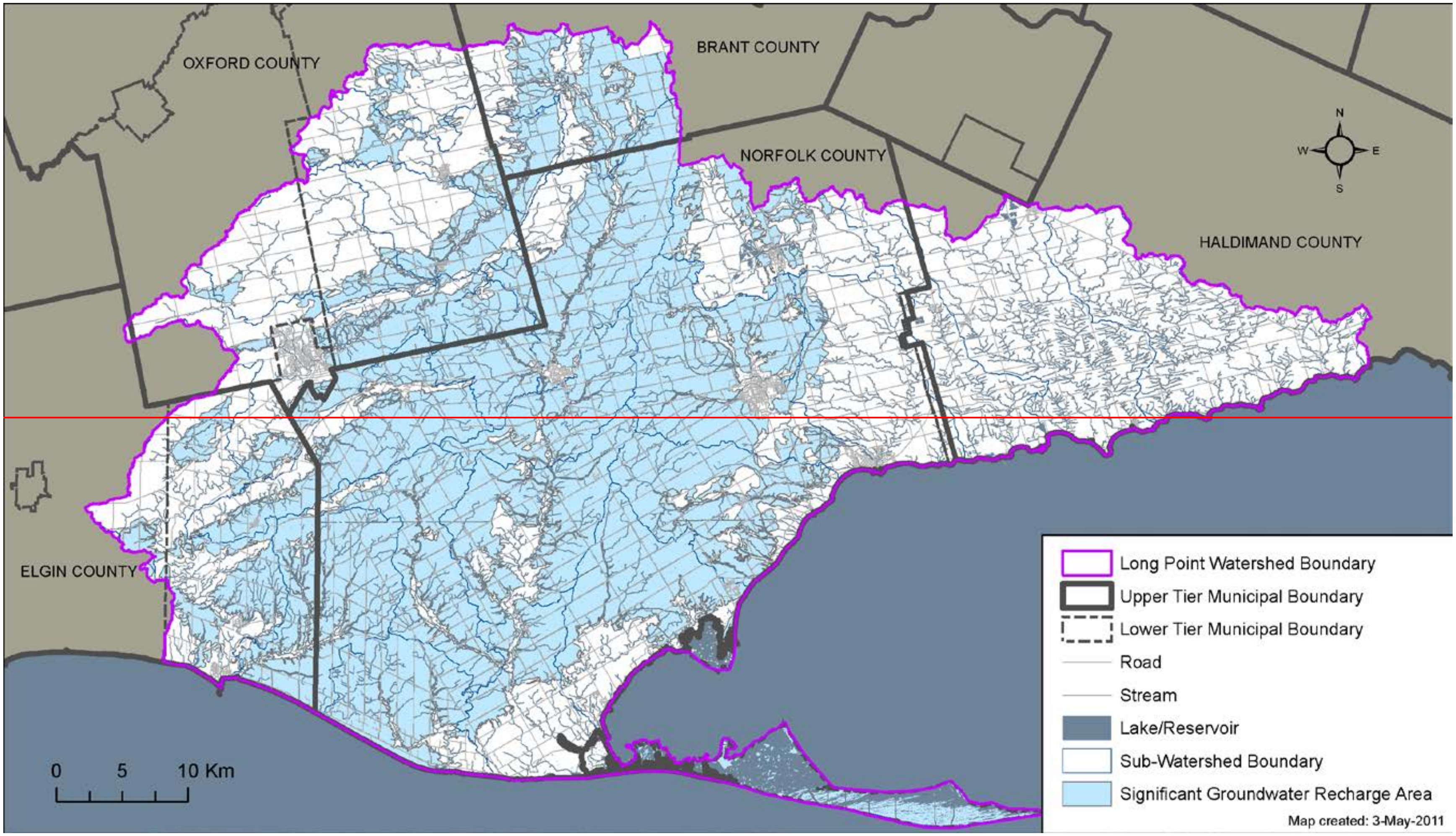
~~Groundwater Recharge Areas (SGRAs)~~				
~~Threat Type~~	~~Vulnerability Score in SGRA~~	~~Threat Classification Level~~		
		~~Significant 80+~~	~~Moderate 60 to <80~~	~~Low >40 to <60~~
~~Chemical Threats / Handling & Storage of DNAPLs~~	~~6~~		~~✓~~	~~✓~~
	~~2 – 4~~			
~~Pathogens~~	~~Any Score~~			

~~At the time of this report, a drinking water threats analysis is not required within the Significant Groundwater Recharge Areas, since no significant threats can occur in a Significant Groundwater Recharge Area with a vulnerability score of 6 or lower. Additionally, no conditions resulting from past activities have been identified in the Significant Groundwater Recharge Areas in the Long Point Region watershed.~~

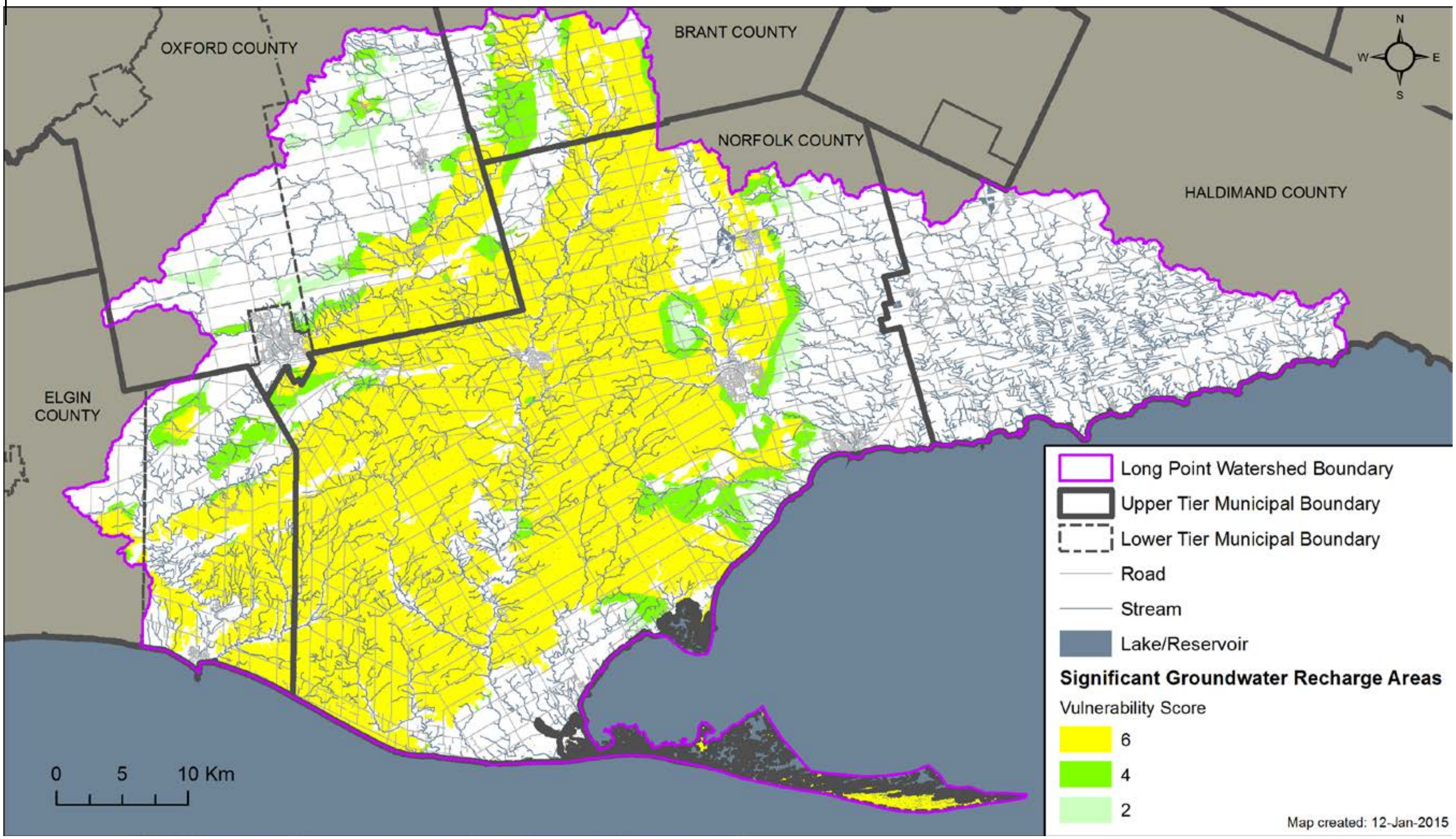
~~3.4.5 Drinking Water Issues within Significant Groundwater Recharge Areas~~

~~No Issues have been identified in the Significant Groundwater Recharge Areas to date. Public Health Units are undertaking risk assessments of all small drinking water systems, and may, through that process identify possible Issues for a future Assessment Report.~~

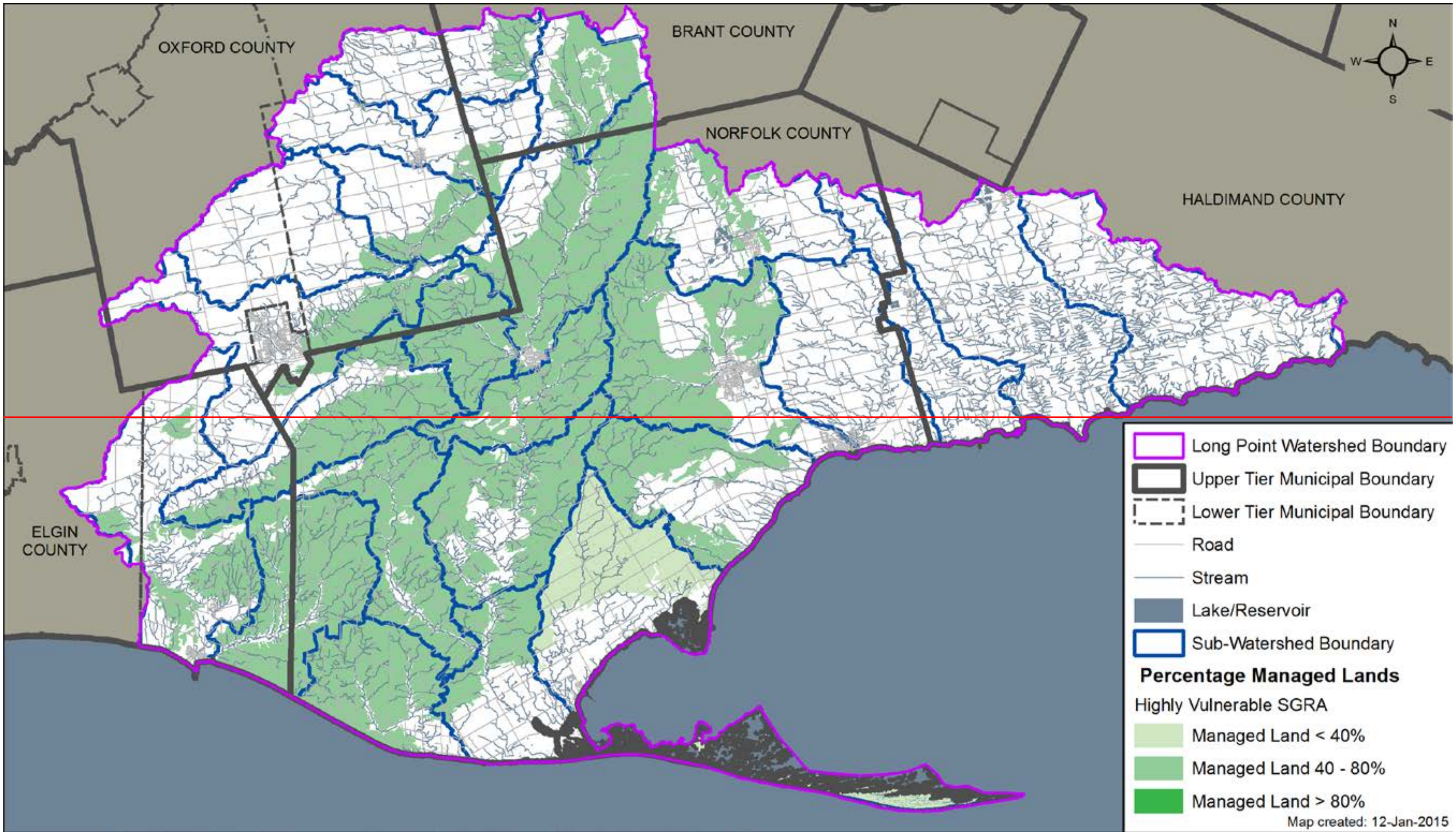
~~Map 3-6: Significant Groundwater Recharge Areas~~



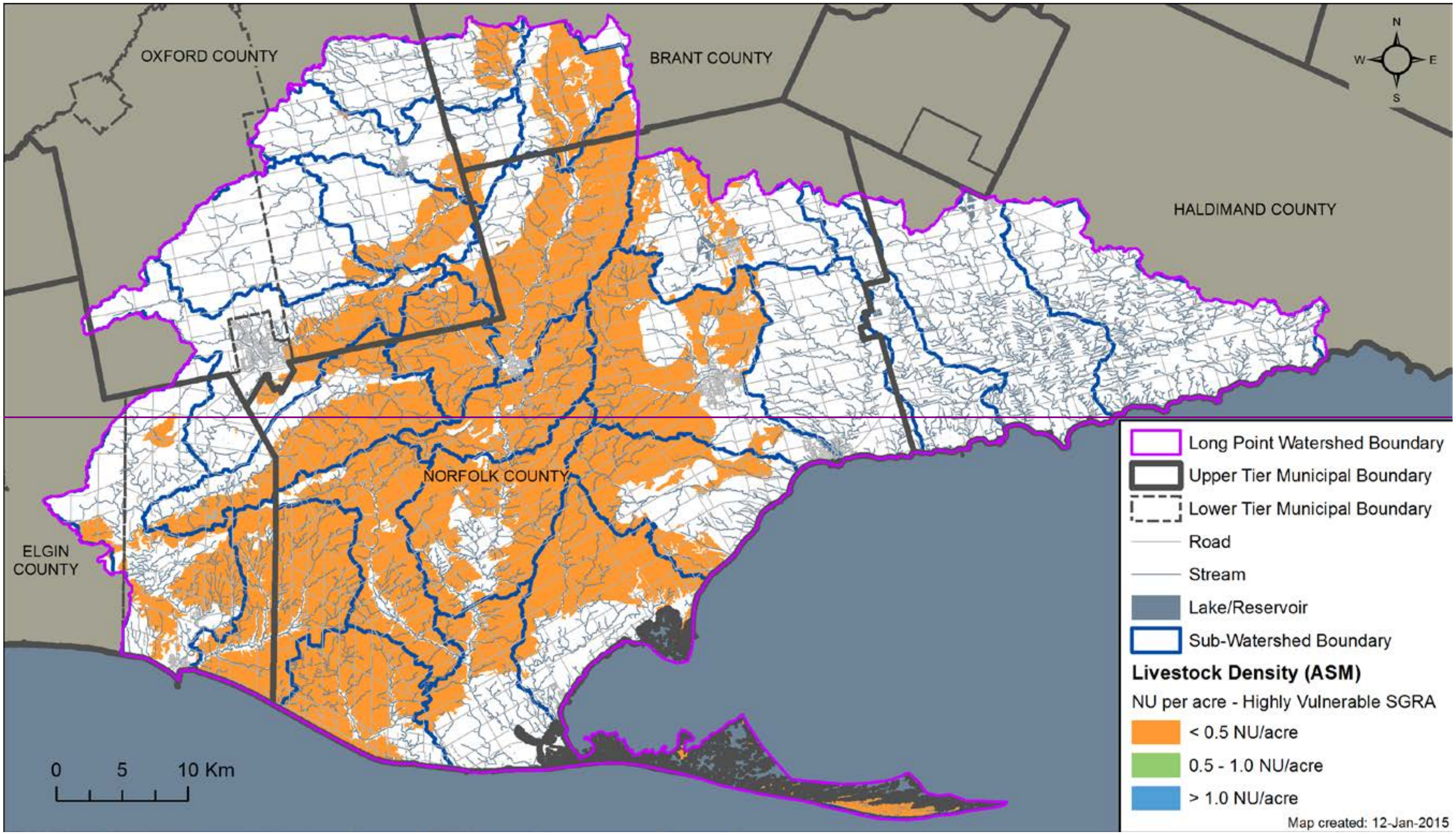
~~Map 3-67: Significant Groundwater Recharge Areas with Vulnerability Scoring~~



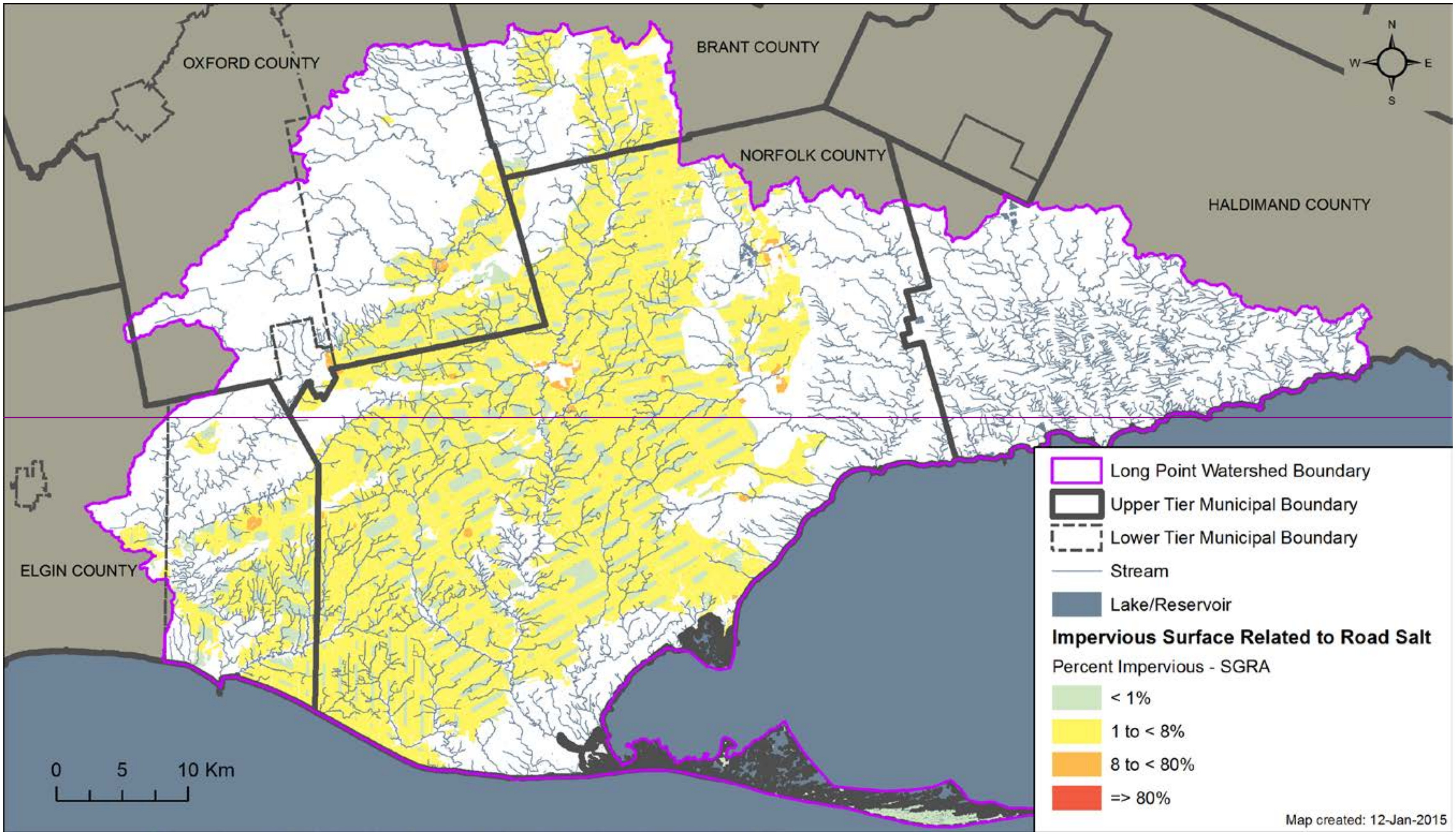
~~Map 3-78: Percent Managed Lands in Significant Groundwater Recharge Areas~~



~~Map 3-89: Livestock Density in Significant Groundwater Recharge Areas~~



~~Map 3-910: Impervious Surface Related to Road Salt in Significant Groundwater Recharge Areas~~



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