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REGION

Catfish Creek Source Protection Area

ASSESSMENT REPORT

Prepared on behalf of:
Lake Erie Region Source Protection Committee

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

Version 2.1
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www.sourcewater.ca

This project has received funding from the Government of Ontario.

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Note: Please refer to Volume I of the Catfish Creek Source Protection Plan for a complete list of version numbering and a high-level description of amendments that have been made since original approval.

EXECUTIVE SUMMARY

The Catfish Creek Source Protection Area Assessment Report was submitted to the Ministry of the Environment on May 7, 2010 and received approval on October 7, 2010. Additional revisions have been made to the assessment report following the October 2010 approval, including the most recent update in 2022. These recent revisions are included in the updated Catfish Creek Assessment Report which was posted for a 35-day public consultation period from January 25 to February 28, 2023. Comments received during the public consultation period are summarized in **Appendix A.**

The Assessment Report summarizes the technical studies undertaken in the Catfish Creek 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 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 Catfish Creek watershed, while Section 3 summarizes the water budget and stress assessment findings. Groundwater vulnerability, including Highly Vulnerable Aquifers, Significant Recharge Areas and Wellhead Protection Areas are described in Section 4. Section 4 also provides a summary of the threats assessment and issues evaluation undertaken in each vulnerable area.

Sections 5 and 6 provide 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. Section 7 summarizes the findings in the Assessment Report and provides an outline of the next steps in developing a source protection plan for the Catfish Creek Source Protection Area.

Catfish Creek watershed contains one municipal drinking water system, located in the village of Brownsville in Oxford County. The system serves approximately 490 people from two groundwater wells. The wells are located in an area of low vulnerability, which results in medium to low vulnerability scores in most of the wellhead protection area, and an area of high vulnerability within the 100-metre area around the wells. To date, thirty-two potential significant drinking water threats have been identified in the wellhead protection area surrounding the Brownsville wells. No drinking water issues have been identified to date.

The findings of the water budget and stress assessment studies indicate that the groundwater subwatershed within which the Brownsville wells are located has a low potential for stress. As such, no water quantity threats have been identified.

Additional studies were undertaken in 2010 to gather more detailed information on the land use activities occurring within the Brownsville Wellhead Protection Area. Municipal and conservation authority staff worked with residents and businesses in the wellhead protection area to determine whether the activities identified as potential significant threats in the Assessment Report are occurring. The results of the more detailed threats identification process are included in the Assessment Report. In addition, the Aquifer Vulnerability Index (AVI) scoring method used to develop the vulnerability maps in Oxford County was updated.

The results of the technical studies were used to develop policies to protect sources of municipal drinking water. Policies have been developed by 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 has played a significant role throughout the process.

In 2022, updates were completed for the watershed characterization section, water quality issues evaluation, significant drinking water threats for the Brownsville wellhead protection areas and the state of climate change research in Lake Erie Region. The updated Assessment Report also includes minor administrative and editorial updates.

Note: In June 2014, the Ministry of the Environment changed its name to the Ministry of the Environment and Climate Change, and in June 2018, to the Ministry of the Environment, Conservation and Parks. In June 2014, the Ministry of Natural Resources changed its name to the Ministry of Natural Resources and Forestry, and in June 2021, was re-organized into the Ministry of Northern Development, Mines, Natural Resources and Forestry. In 2022 the name was changed back to the Ministry of Natural Resources and Forestry. The new and former names of these 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 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 Ministries of the Environment, Conservation and Parks (MECP) and Ministry of Natural Resources and Forestry (NDMNRF) , and other stakeholders to facilitate the development of local, science based source protection plans.

The Clean Water Act 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:

- adequate treatment,
- secure distribution system,
- monitoring and warning systems, and
- well thought-out responses to adverse conditions.

After the Walkerton Inquiry, the Government of Ontario enacted the Safe Drinking Water Act, which provides new requirements and rules for the treatment, distribution and testing of municipal drinking water supplies. Together, the Clean Water Act and Safe Drinking Water Act, 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 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. The MECP provides more information on how water resources are protected in Ontario on its website or by calling 1-800-565-4923.

1.1 Source Protection Planning Process

The key objectives of the Drinking Water Source Protection 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 Catfish Creek Source Protection Area (watershed area).

The draft Catfish Creek Assessment Report was the first version of the report made available for public consultation in 2010. The Catfish Creek Updated Assessment Report was approved by the Ministry of the Environment on October 7, 2010 and is available on the Lake Erie Source Protection Region website. Further technical studies have been undertaken since and changes are included in this updated Catfish Creek Assessment Report. These changes are consulted on together with the amendments to the Catfish Creek Source Protection Plan.

Updates to the Source Protection Plan require one formal round of consultation with the public and stakeholders.

The public could submit comments on the Assessment Report by email or by regular mail.

All comments received during this comment period were forwarded to the Ontario Ministry of the Environment, Conservation and Parks with the submission of the Catfish Creek Source Protection Plan.

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 draft proposed Source Protection Plan was submitted to the Minister of the Environment on April 10, 2014 for review and was approved on September 19, 2014. Following Source Protection Plan approval, annual progress reports on implementation are required. Implementation of the Source Protection Plan is led by municipalities in most cases. In some cases, conservation authorities, public health units, or other organizations are involved in implementing policies in the Source Protection Plans. The implementers use a range of voluntary and regulatory programs and tools, including outreach and education; 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 current activities found to be significant threats are mandatory, since the Clean Water Act requires that all existing significant threats cease to be significant.

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. The Catfish Creek watershed is called the Catfish Creek Source Protection Area. Similarly, conservation authorities are referred to as Source Protection Authorities under the Clean Water Act, and are responsible for facilitating and supporting the development of source protection plans.

For the purposes of source protection, the Catfish Creek Source Protection Authority is partnered with the Grand River Source Protection Authority, Kettle Creek Source Protection Authority and Long Point Region 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.

1.3 Source Protection Committee

In the Catfish Creek watershed, 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 draft proposed Catfish Creek Source Protection Plan was submitted to the Ministry of the Environment in April 2014. Since then the Committee has generally met on a quarterly basis. The Committee has been responsible for directing the development of the Assessment Reports and Source Protection Plans for each of the four Source Protection Areas in the Lake Erie Region. The list of current and past members is published on the Lake Erie Source Protection Region website.

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 the 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.

In December 2008, the Committee submitted to the Minister of the Environment their Terms of Reference for the Catfish Creek Source Protection Area Assessment Report and Source Protection Plan. The Terms of Reference sets out the work plan for completing both the Assessment Report and Source Protection Plan, and received Ministerial approval on May 11, 2009. A copy of the Catfish Creek Source Protection Area Terms of Reference can be found on the Lake Erie Source Protection website.

1.4 Framework of the Assessment Report

The Catfish Creek Source Protection Area Assessment Report was completed in compliance with Ontario Regulation 287/ 07 (General) under the Clean Water Act, 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 Ontario Regulation 287/ 07. The technical work was undertaken by the County of Oxford and by 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 Province of Ontario.

Within the Catfish Creek watershed, there is one municipal drinking water source in the village of Brownsville in the Township of Southwest Oxford. The Brownsville drinking water supply draws water from two groundwater wells. Several communities in the Catfish Creek Watershed also receive water from the Elgin Area Primary Water Supply, a municipal source on Lake Erie located offshore of the town of Port Stanley in the Kettle Creek Watershed. The technical studies for the Elgin Area Water Supply are included in the Kettle Creek Source Protection Area Assessment Report.

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, Conservation and Parks have the power to add additional non-municipal systems. To date, no municipalities in the Catfish Creek Watershed 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; 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 reports available online in full on the Lake Erie Source Protection Region website.

Appendix B of the Assessment Report includes copies of confirmation of approval received from the Director for occurrences where alternate methods were used than those in the Technical Rules: Assessment Report (November 16, 2009).

1.5 Continuous Improvement

The findings of this 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 the 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 amended Assessment Reports will be made available to those affected by the proposed changes.

1.6 Public Consultation

Updates to the assessment report require one formal round of consultation with the public and stakeholders.

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. The Committee in turn, considers these comments following each period of public consultation.

The draft updated Catfish Creek Assessment Report was posted for a 35-day public consultation period between January 25 and February 28, 2023. The public was invited to review the assessment report on Lake Erie Region's website or at the Township of South-West Oxford municipal office.

All comments received during this comment period will be forwarded to the Ontario Ministry of the Environment, Conservation and Parks with the submission of the Catfish Creek Assessment Report and Source Protection Plan. Comments received during the public consultation period are summarized in **Appendix A.**

1.7 Overview of the Source Protection Risk Assessment Process

Source Protection Area Assessment Reports are summaries of technical studies that identify:

- The vulnerable areas around municipal-residential drinking water sources;
- How "vulnerable" the vulnerable areas are;
- Where potential threats to water quality and quantity can be found in each vulnerable area;
- The activities that pose the biggest threat to human health; and
- How significant the risk of the threat is of contaminating or depleting the water supply.

1.7.1 Vulnerable Areas and Vulnerability

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

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

The first three vulnerable areas are associated with groundwater, while intake protection zones are associated with surface water (rivers and lakes). The Highly Vulnerable Aquifer areas, Significant Groundwater Recharge Areas and Wellhead Protection Areas are determined through complex modeling 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 by assessing the flow of surface water in the river or lake.

Wellhead Protection Areas and Intake Protection Zones are developed specifically around municipal 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.

Groundwater
Within the source protection program, all groundwater-based municipal supplies have completed an assessment of vulnerability of the system to quality-related threats, and also enumerated and classified threats within WHPAs as having a significant, moderate, or low potential for risk to the quality of the municipal drinking water supply. Following the completion of the threats assessment, it is each municipalities' goal to manage threats and reduce the number of significant threats to the drinking water system through policies identified in the source protection plan.

The following sections outline the methods used to map WHPAs, determine vulnerability scoring and enumerate and classify quality-related threats to the municipal supply.

Wellhead Protection Areas
A WHPA is a planning term used to describe scientifically based capture zones delineated for water supply wells. The Technical Rules (MECP, 2021) require that WHPAs for water quality be delineated for each municipal drinking water supply well. WHPAs are mapped based on a quantitative assessment of lateral

groundwater flow in the vicinity of the municipal wellfield. A WHPA consists of four zones which are based on the time it takes for groundwater to travel from the water table surface to the municipal well. The zones are defined as follows:

- WHPA - A: 100 m radius around the municipal well
- WHPA - B: Time of travel to the municipal well is 2 years or less
- WHPA - C: Time of travel to the municipal well is equal to or less than 5 years and greater than 2 years
- WHPA - D: Time of travel to the municipal well is equal to or less than 25 years and greater than 5 years

A WHPA - E can be delineated for groundwater wells when there is an interaction between the surface water and ground water supply that may impact the water quality at the well (Technical Rules, 2021).

Methodology for WHPA Delineation

Delineating WHPAs is an important step in protecting the quality of municipal groundwater. WHPAs, which are a planning term, are based on the technical delineation of capture zones. A capture zone is the area of land surrounding a groundwater extraction well where water located at and below the ground surface may travel toward that well within a defined period of time.

Within the Grand River watershed, numerical groundwater flow models calibrated to steady state and often transient conditions have been used to delineate capture zones. A groundwater flow model is a simplified representation of a complex physical, hydrologic and hydrogeologic system where natural and anthropogenic processes affect the rates and direction of groundwater flow.

Using the calibrated groundwater flow models, capture zones in the Grand River watershed have been delineated through time of travel assessments using backward and forward particle tracking. To complete this, virtual particles were released in the groundwater flow model and either tracked forward in time towards the municipal well or backward (particles released at the municipal and tracked backward) in time through the aquifer for specified time intervals. The resulting paths that the particles take were then projected to ground surface and plotted on a plan view. Time-of-travel capture zones were subsequently created by drawing polygons around the wells and the particles path lines at specific times. As such, capture zones represent the land areas beneath which groundwater and associated contaminants may migrate toward a well within a specified period.

Aquifer Vulnerability

Municipal wells draw their water from aquifers located beneath the ground surface. Aquifers are replenished when surface water infiltrates into the groundwater system. Sometimes, the water infiltrating from the ground surface can carry pollutants such as road salt, nitrate from fertilizers, or industrial chemicals into the groundwater system.

The vulnerability of an aquifer is its susceptibility to impacts from land use activities such as the application of road salt, manure, or fertilizers. Vulnerability is assessed based on the travel time from ground surface to the municipal aquifer.

An aquifer vulnerability analysis is a physically-based evaluation of the geologic and hydrogeologic character of the sediments and bedrock overlying the municipal aquifer. The resulting calculations provide a rating of the intrinsic vulnerability for the aquifer of interest. The calculated 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.

The quantification of groundwater vulnerability is not a straightforward calculation, as there are many unknowns in the process. Numerous approaches are available to estimate groundwater intrinsic vulnerability such as the Intrinsic Susceptibility Index (ISI) , Aquifer Vulnerability Index (AVI) , Surface to Well Advective Time (SWAT) , Surface to Aquifer Advective Time (SAAT) , all of which are approved under the Clean Water Act (2006) Technical Rules.

The ISI and AVI methods use a scoring system that reflects the thickness and the type of overburden or bedrock material. Aquifers which have a high calculated vulnerability have an ISI or AVI score less than 30, meaning the overlying material is thin and/or permeable. While aquifers with a low vulnerability have an ISI or AVI score greater than 80, meaning the overlying material is thicker and/or less permeable. Aquifers with a medium vulnerability will have a score that falls between 30 and 80.

The SAATand SWAT methods for determining aquifer intrinsic vulnerability are determined through use of the calibrated numerical groundwater flow models. SWAT is determined as the zone in which all particles are assumed to be able to travel from ground surface down to a well screen. SWAT is equivalent to the Unsaturated Zone Advective Time (UZAT) plus the Water table to Well Advective Time (WWAT) SAAT is determined as the zone in which all particles are assumed to be able to travel from ground surface to the top of the pumped aquifer (or top of the water table if the pumped well is in an unconfined aquifer). Aquifers which have a high calculated vulnerability have an SAAT / SWAT score less than five years. While aquifers with a low calculated vulnerability have a SAAT / SWAT scores 25 years or greater. Aquifers with a medium vulnerability will have a score that fall between five and 24 years.

The approach applied to each drinking water system was dependent on the local conditions and method applied for each municipality is outlined within the municipal water quality sections. The results from the aquifer vulnerability assessment are classified to map areas of high, medium and low intrinsic vulnerability.

Vulnerability Scoring within WHPAs

To obtain the vulnerability score within a WHPA, a scoring matrix is applied which intersects the WHPA zones with the aquifer vulnerability classification. The scores applied, as shown in **Table 1-1** and **Table 1-2** below, are dependent on the method used for the vulnerability analysis.

Table 1-1: Wellhead Protection Area Vulnerability Scores – ISI/ AVI

Groundwater Vulnerability Category for the Area	WHPA- A	WHPA- B	WHPA- C	WHPA- D
High	10	10	8	6
Medium	10	8	6	4
Low	10	6	4	2

Vulnerability within WHPA- Es is assessed relevant to how an IPZ- 2 is assigned vulnerability scores. The area vulnerability factor for IPZ- 2 is assigned by a value ranging between 7 and 9 using professional judgement, where 9 is the highest vulnerability score (Technical Rule 89).

Table 1-2: Wellhead Protection Area Vulnerability Scores – SAAT / SWAT

Groundwater Vulnerability Category for the Area	WHPA- A	WHPA- B	WHPA- C	WHPA- D
High	10	10	8	6
Medium	10	8	6	4
Low	10	6	2	2

Vulnerability within WHPA- Es is assessed relevant to how an IPZ- 2 is assigned vulnerability scores. The area vulnerability factor for IPZ- 2 is assigned by a value ranging between 7 and 9 using professional judgement, where 9 is the highest vulnerability score (Technical Rule 89).

Transport Pathways

A constructed transport pathway is a shortcut, which can make it easier for a contaminant to be transported to a drinking water source. The vulnerability of the municipal aquifers accounts only for the natural protection provided by the materials overlying the aquifers of interest; however, anthropogenic activities can bypass this natural physical protection thereby increasing the vulnerability.

Examples of transport pathways includes private water wells, unused or improperly decommissioned water wells, construction of underground services, subsurface excavations, pits and quarries.

The vulnerability of the aquifer may be increased by any land use activity or feature that disturbs the surface above the aquifer, or which artificially enhances flow to that aquifer. In areas where transport pathways exist, the vulnerability can be increased to reflect the higher vulnerability caused by the constructed pathway (i.e., from low to moderate or high, and moderate to high). In some cases the intrinsic vulnerability index is already high and cannot be further increased.

The vulnerability of the aquifer is only increased to account for a transport pathway where there is sufficient confidence in the available data to justify the increase in vulnerability.

Uncertainty Assessment

An analysis of the uncertainty, characterized by “high” or “low” is made on the vulnerability of each delineated WHPA (Technical Rules (13 and 14), 2021). The uncertainty rating should consider the following:

1. The distribution, variability, quality and relevance of data used in the preparation of the assessment report.
2. The ability of the methods and models used to accurately reflect the flow processes in the hydrological system.
3. The quality assurance and quality control procedures applied.
4. The extent and level of calibration and validation achieved for models used or calculations or general assessments completed.
5. The accuracy to which the groundwater vulnerability categories effectively assess the relative vulnerability of the underlying hydrogeological features.
6. The accuracy to which the area vulnerability factor and the source vulnerability factor effectively assesses the relative vulnerability of the hydrological features.

Surface Water

Some municipalities rely on surface water to supply drinking water to their residents. Surface water is transported through an intake pipe directly from the lake or river into a water treatment system. Protecting the area around a surface water intake means protecting the surrounding water and, in most cases, the land that surrounds the water. This area of water and land is known as an intake protection zone, or IPZ.

Intake Protection Zone

The IPZ is the primary vulnerable area to be delineated to ensure the protection of the municipal surface water supply. For each drinking water system, an IPZ-1, IPZ-2 and IPZ-3 can be delineated.

Intake Protection Zone 1 (IPZ- 1) is the area immediately adjacent to the intake. This zone is considered the most vulnerable area for surface water intakes due to its proximity to the intake. Contaminants of concern entering this area would experience little to no dilution before reaching the intake.

Intake Protection Zone 2 (IPZ- 2) acts as a secondary protective zone that generally extends upstream of the IPZ- 1. The IPZ- 2 is defined as the area within and around the surface water body that may contribute water to an intake within a 2 hour time of travel.

Intake Protection Zone 3 (IPZ- 3) includes parts of the watershed that may be impacted by extreme events such as storms, strong winds, or high waves. The IPZ-3 included the area within each surface water body that may contribute water to the intake and where this area abuts land. The IPZ- 3 also includes the portion of land within the Conservation Authority Regulation Limit or 120 m, whichever is greater. Additionally, IPZ- 3s are delineated to capture all water courses / bodies that contribute water to the sources.

The Technical Rules classify surface water intakes according to their location, with slightly different rules for delineating the Intake Protection Zone and Vulnerability Score for the four different classifications.

The four classifications are:

- Type A: Intakes or the planned intake is or would be located in a Great Lake;
- Type B: Intake or the planned intake is or would be located in a connecting channel;
- Type C: Intake or the planned intake is or would be located in a river and neither the direction nor velocity of the flow of the water at the intake is affected by a water impoundment structure; or
- Type D: If the intake is not a Type A, B or C.

With the written consent of the Director, the source protection may reclassify the intake or planned intake and shall include in the assessment report a rationale and evidence to support the reclassification (Technical Rule 55.1, 2021).

Delineation of Intake Protection Zones
For each of the four surface water intake types, three IPZs are identified. The methodologies for delineation of the vulnerable areas around a surface water intake are detailed below.

IPZ- 1 is a fixed distance from the intake based on the sensitivity analysis of a massive sudden spill in the vicinity of the intake. Intake types A and D are defined by a 1 km radius centered on the crib of the intake. Intake type B is defined by a semi-circle that has a radius of 1 km extending upstream from the crib of the intake and a rectangle with a length of 2 km centred on the crib of the intake and a width of 100 metres extending downstream from the crib of the intake. Intake type C is defined by a semi-circle that has a radius of 200 metres extending upstream from the crib of the intake and a rectangle with a length of 400 metres centred on the crib of the intake and a width of 10 metres downstream of the intake.

IPZ-2 represents the operator response time to shut down the drinking water system in case of a spill. Intake types A, B, C and D are defined as the area that may contribute water to the intake where the time of travel to the intake is equal to or less than the time that is sufficient to allow the operator of the system to respond to an adverse condition in the quality of the surface water. The Technical Rules indicate that a minimum 2-hour time of travel should be used to delineate the IPZ-2 (excluding IPZ-1) .

IPZ-3 is an area beyond the IPZ-1 and 2 and is delineated differently based on the intake type. Intake types A, B, C and D are defined as the area of the water and land that may lead to contaminants reaching an intake during an extreme event such as a one in one hundred year rainfall as determined through modeling or other methods (contaminant transport, boundary approach, combined approach). Significant threats are then identified if it can be shown through modeling that a release of a contaminant during an extreme event may be transported to the intake. Intake types C and D not located in Lake Nipissing, Lake Simcoe, Lake St. Clair, or the Ottawa River, the IPZ-3 is defined as the area within each surface water body that may contribute water to the intake within the watershed boundary.

The information above has been modified from the Implementation Guide: Module 2 – Understanding Where Policies Apply.

For all intake types where the IPZ-1, IPZ-2 and IPZ-3 abuts land, a setback of less than or equal to 120m or the Conservation Authority Regulation limit is included, whichever, is greater. The set-back is measured from the high water mark of the surface water body that encompasses the area where overland flow drains into the surface water body and the areas of the Conservation Authority Regulation limit along the abutted land.

According to Technical Rule 72 and 73 (MECP, 2021), where an area that is an IPZ-2 or IPZ-3 includes a setback from a surface waterbody delineated with sub rules 65(1), 68(2), 70(2) the area may be extended to include an area that contributes water to the IPZ-2 or IPZ-3, through a natural or anthropogenic transport pathway. The following factors shall be considered when determining the extended area:

- The hydrological conditions of the area where the transport pathway is located.

- Where a transport pathway is anthropogenic in origin, the type and design of the pathway.
- In respect of an IPZ-2, the time of travel for water to enter into and pass through the transport pathway.

Vulnerability Scoring of Intake Protection Zones

The vulnerability score (V) is a numerical expression of the susceptibility of the intake to contamination. Vulnerability scores are assigned for each type of intake for IPZ-1 and IPZ-2 and for type C and type D intakes for IPZ-3. The vulnerability scores are based on the attributes of the intakes (e.g. length and depth), type of source water body, and the physical characteristics of the environment it is situated in. The vulnerability score (V) is a unitless factor and is calculated by multiplying area vulnerability factor (B) by the source vulnerability factor (C) .

The area vulnerability factor (B) is unique for each IPZ and relates to features and processes in the local environment that may impact the intake. The area vulnerability factor was prescribed by the Technical Rules for all IPZ-1s, which receive a score of 10, regardless of the type of intake. Typical factors that may dictate the area vulnerability factor for IPZ-2s include percentage of the area of the IPZ-2 that is composed of land, land cover, soil type, permeability and slope and hydrological conditions in the area that contribute water to the area via transport pathways. The area vulnerability factor for IPZ-3s must be based upon the above listed factors as well as proximity to the intake. The source vulnerability factor (C) relates to the type of water body, intake characteristics (length, depth) and number of recorded drinking water issues.

The IPZ-3 related to type A intake or type B intake is not assigned a vulnerability score, while areas within an IPZ-3 related to type C intake and type D intakes are. According to Technical Rule 91, the area vulnerability factor for the IPZ-3, or an area within it, cannot be greater than the area vulnerability factor for IPZ-2.

Uncertainty Assessment

An analysis of the uncertainty, characterized by “high” or “low” is made on the vulnerability of each delineated IPZ (Technical Rules (13 and 14), 2021). The uncertainty rating should consider the following:

1. The distribution, variability, quality and relevance of data used in the preparation of the assessment report.
2. The ability of the methods and models used to accurately reflect the flow processes in the hydrological system.
3. The quality assurance and quality control procedures applied.
4. The extent and level of calibration and validation achieved for models used or calculations or general assessments completed.
5. The accuracy to which the groundwater vulnerability categories effectively assess the relative vulnerability of the underlying hydrogeological features.

6. The accuracy to which the area vulnerability factor and the source vulnerability factor effectively assesses the relative vulnerability of the hydrological features.

1.7.2 Drinking Water Threats Assessment – Water Quality

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.”

The Technical Rules (MECP, 2021) 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.

Threats from Activities

The Province has identified 22 activities where, if present in vulnerable areas, now or in the future, could pose a threat to drinking water quality or quantity (listed in Section 1.1 of Ontario Regulation 287/ 07). Twenty of these activities are relevant to drinking water quality threats, while two are relevant to drinking water quantity threats (Threats 19 and 20). **Table 1-3** lists the activities that are prescribed drinking water threats. Listed beside the prescribed drinking water threats are the typical land use activities that are associated with the threat.

Table 1-3: Drinking Water Threats

Threat Number	Prescribed Drinking Water Threat	Land Use / Activity
1	The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act.	Landfills – Active, Closed Hazardous Waste Disposal Liquid Industrial Waste
2	The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage.	Sewage Infrastructures Septic Systems, etc.
3	The application of agricultural source material to land.	e.g. manure, anaerobic digestion output , organic soil conditioners, etc.
4	The storage of agricultural source material.	e.g. manure, anaerobic digestion output , organic soil conditioners, etc.
5	The management of agricultural source material.	aquaculture
6	The application of non-agricultural source material to land.	e.g. organic waste derived from the production of biodiesel, organic soil conditioners, pulp, paper and sewage biosolids
7	The handling and storage of non-agricultural source material.	e.g. organic waste derived from the production of biodiesel, organic soil conditioners, pulp, paper and sewage biosolids
8	The application of commercial fertilizer to land.	Agriculture Fertilizer

Threat Number	Prescribed Drinking Water Threat	Land Use / Activity
9	The handling and storage of commercial fertilizer.	General Fertilizer Storage
10	The application of pesticide to land.	Pesticides
11	The handling and storage of pesticide.	General Pesticide Storage
12	The application of road salt.	Road Salt Application
13	The handling and storage of road salt.	Road Salt Storage
14	The storage of snow.	Snow Dumps
15	The handling and storage of fuel.	Petroleum Hydrocarbons
16	The handling and storage of a dense non-aqueous phase liquid.	DNAPLs
17	The handling and storage of an organic solvent	Organic Solvents
18	The management of runoff that contains chemicals used in the de-icing of aircraft.	De-icing
19	An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body.	Private water taking
20	An activity that reduces the recharge of an aquifer.	Impervious Surfaces
21	The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. Ontario Regulation 385/ 08, s. 3.	Agricultural Operations
22	The establishment and operation of a liquid hydrocarbon pipeline. Ontario Regulation 206/ 18, s.1.	Liquid Hydrocarbon Pipelines

Threats from Conditions

Conditions relate to past or historical activities. Conditions must fall into one of the statements below which are listed in the MECP 2021 Technical Rule (126). If the source protection committee is aware of one of the following conditions that results from a past activity, the committee shall list it as a drinking water threat.

- The presence of a non-aqueous phase liquid in groundwater in a highly vulnerable aquifer or wellhead protection area.
- The presence of a single mass of more than 100 litres of one or more dense non- aqueous phase liquids in surface water in a surface water intake protection zone.
- The presence of a contaminant in groundwater in a highly vulnerable aquifer or a wellhead protection area, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table, and the presence of the contaminant in groundwater could result in the deterioration of the groundwater for use as a source of drinking water.
- The presence of a contaminant in surface soil in a surface water intake protection zone if, the contaminant is listed in Table 4 of the Soil, Ground Water and Sediment Standards is present at a concentration that exceeds the surface soil standard for industrial/ commercial/ community property use set out for the contaminant in that Table and the presence of the contaminant in surface soil could result in the deterioration of the surface water for use as a source of drinking water.
- The presence of a contaminant in sediment in an intake protection zone, if the contaminant is listed in Table 1 of the Soil, Ground Water and Sediment Standards and is present at a concentration that exceeds the sediment standard set out for the contaminant in that Table, and the presence of the contaminant in sediment could result in the deterioration of the surface water for use as a source of drinking water.
- The presence of a contaminant in groundwater that is discharging into an intake protection zone, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, the concentration of the contaminant exceeds the potable groundwater standard set out for that contaminant in the Table, and the presence of the contaminant in groundwater could result in the deterioration of the surface water for use as a source of drinking water.

1.7.3 Threats from Issues and Issue Contributing Areas

A drinking water Issue is defined as the presence of a parameter, listed in Schedules 1, 2, or 3 (listed below) of Ontario Regulation 170/ 03, or Table 4 of the Technical Support Document for the Ontario Drinking Water Quality Standards (ODWQS) Objectives and Guidelines, at a concentration or a trend of increasing concentration, that may result in the deterioration of the quality of water for use as a source of drinking water. Pathogens are also considered an Issue if they are present at concentrations or a trend of increasing concentrations that may result in the deterioration of the quality of water for use as a source of drinking water. In addition to these parameters, the SPC may identify other parameters for the Issues evaluation.

Schedule 1 Parameters: These include two indicator microorganisms namely E. coli and total coliform. These microorganisms are present in fecal matter (e.g. sewage effluents) and their presence indicates the presence of harmful pathogens, such as Giardia and Cryptosporidium.

Schedule 2 Parameters: Schedule 2 parameters include chemical parameters (e.g. metals, inorganics, pesticides and neurotoxins). These parameters are potentially toxic and may adversely affect human health at or above certain concentrations in drinking water. Some of these parameters occur naturally in the environment, while others are results of human activities.

Schedule 3 Parameters: These parameters include radio-active materials such as uranium-235. These parameters are potentially toxic and may adversely affect human health at or above certain concentrations in drinking water.

Schedule 4 Parameters: These consist mostly of parameters that may impair the taste, odour or colour of the water. These parameters may adversely impact the treatment, disinfection and the distribution of the treated water. The ODWQS identifies either aesthetic objectives (AOs) or operational guidelines (OGs) for the parameters.

Where a drinking water Issue is identified, the objective is to identify all sources and threats that may contribute to the Issue within an Issue Contributing Area (WHPA - ICA or IPZ- ICA) and manage these threats appropriately. All threats related to a particular Issue within the WHPA - ICA or an IPZ- ICA are classified as significant drinking water threats, regardless of the vulnerability.

Assessing Threats from Activities

Once lists of threats have been compiled, the next step is to determine circumstances under which the threats may be low, moderate, or significant for each vulnerable area. The Source Water Protection Threats Tool show the threat for circumstances under which a given activity is classified as a low, moderate, or significant threat. These tables list specific descriptions of situations where chemicals and pathogens pose threats to sources of drinking water. The information from these tables is used with the vulnerability scores to help determine where certain activities are significant, moderate and low drinking water threats. Additionally, the 2021 Technical Rules can be used for accuracy.

The enumeration of land use activities that may be associated with prescribed drinking water threats is based on a review of multiple data sources, including public records, data provided by municipal officials, previous contaminant/ historical land use information, and data collected during windshield surveys. When available, site specific information is collected to confirm the presence of drinking water threats and the level of management determined.

The method for determining when an activity is a threat is based on a semi-quantitative risk assessment. The assessment considers both the nature of the activity or condition (the hazard rating) and the vulnerability of the affected area

(WHPA - A to E, IPZ- 1, IPZ- 2 and IPZ- 3) . Both the vulnerability and calculated hazard scores are used to determine a risk score.

All significant threats must be addressed in the Source Protection Plan. The LESPR SPC may choose to develop policies to address low or moderate drinking water threats.

2.0 WATERSHED CHARACTERIZATION

Understanding the human and physical characteristics of the watershed is important to protecting and managing water. Interactions between surface water, groundwater and potential sources of contamination 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 overall health of the ecosystem. The following sections are intended to provide information on the physical and human characteristics of the Catfish Creek Watershed.

2.1 Lake Erie Source Protection Region

In an effort to share knowledge and resources for the purposes 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 territory covered by the Lake Erie Region, including municipal boundaries and the 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 their respective watersheds. The watersheds have a long history of partnership and cooperation, and also have a natural association by containing most inland rivers and streams flowing from Ontario directly into Lake Erie.

Combined, 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 Dundalk. The area includes, in whole or in part, 49 upper, lower and single tier municipalities, as well as two First Nations communities.

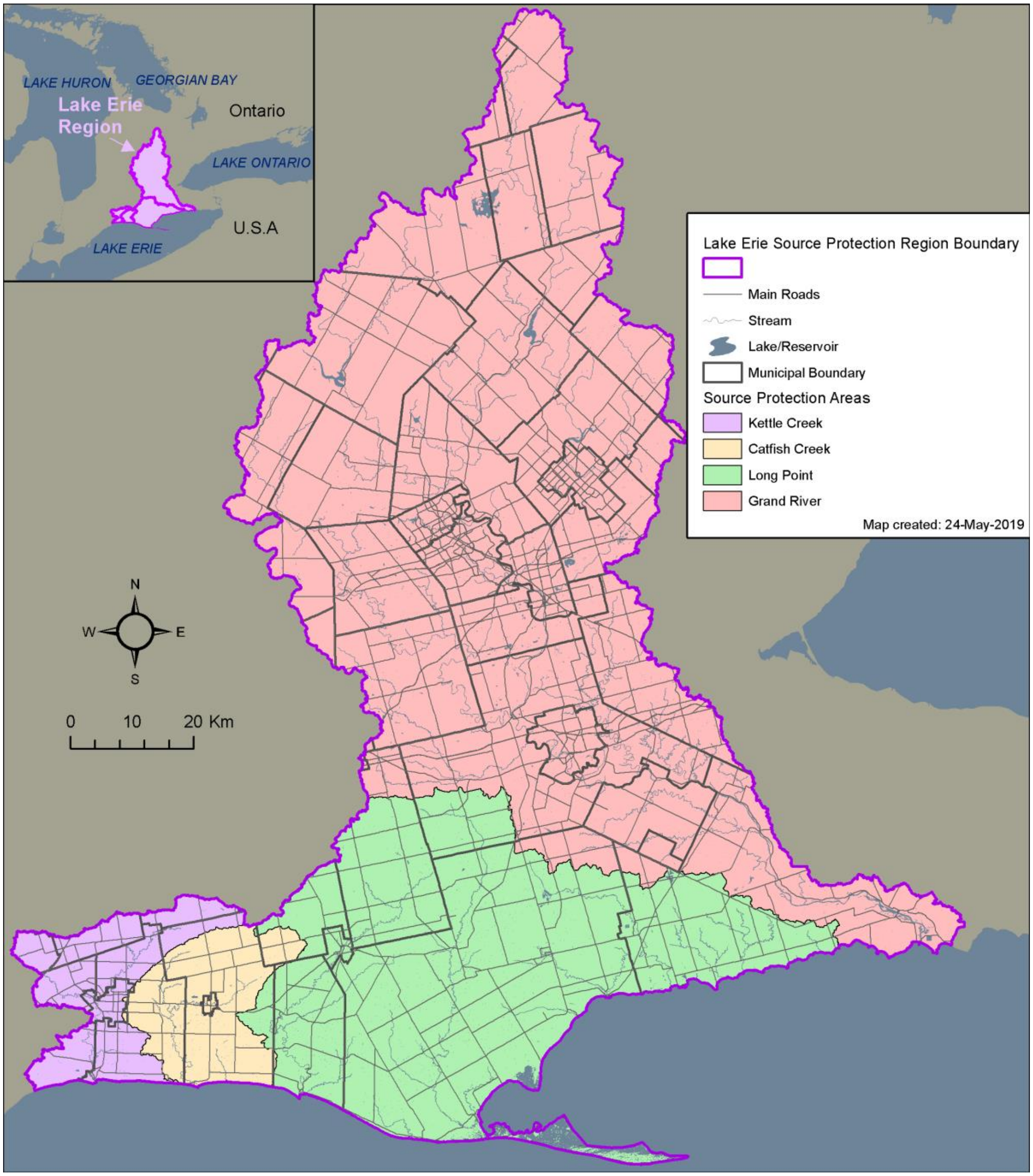
2.2 Catfish Creek Source Protection Area

The Catfish Creek Source Protection Area is located in the heart of the Carolinian zone in southwest Ontario. The watershed boundaries are illustrated on **Map 2-2.** Catfish Creek and its tributaries drain an area of approximately 490 km^2 in Elgin and Oxford counties. It enters Lake Erie at Port Bruce. There are three upper-tier municipalities in the Catfish Creek Source Protection Area: Oxford County, Elgin County and the City of St. Thomas. The Township of Southwest Oxford is a lower-tier municipality of the County of Oxford, and the Township of Malahide, Town of Aylmer and Municipality of Central Elgin are lower-tier municipalities of Elgin County.

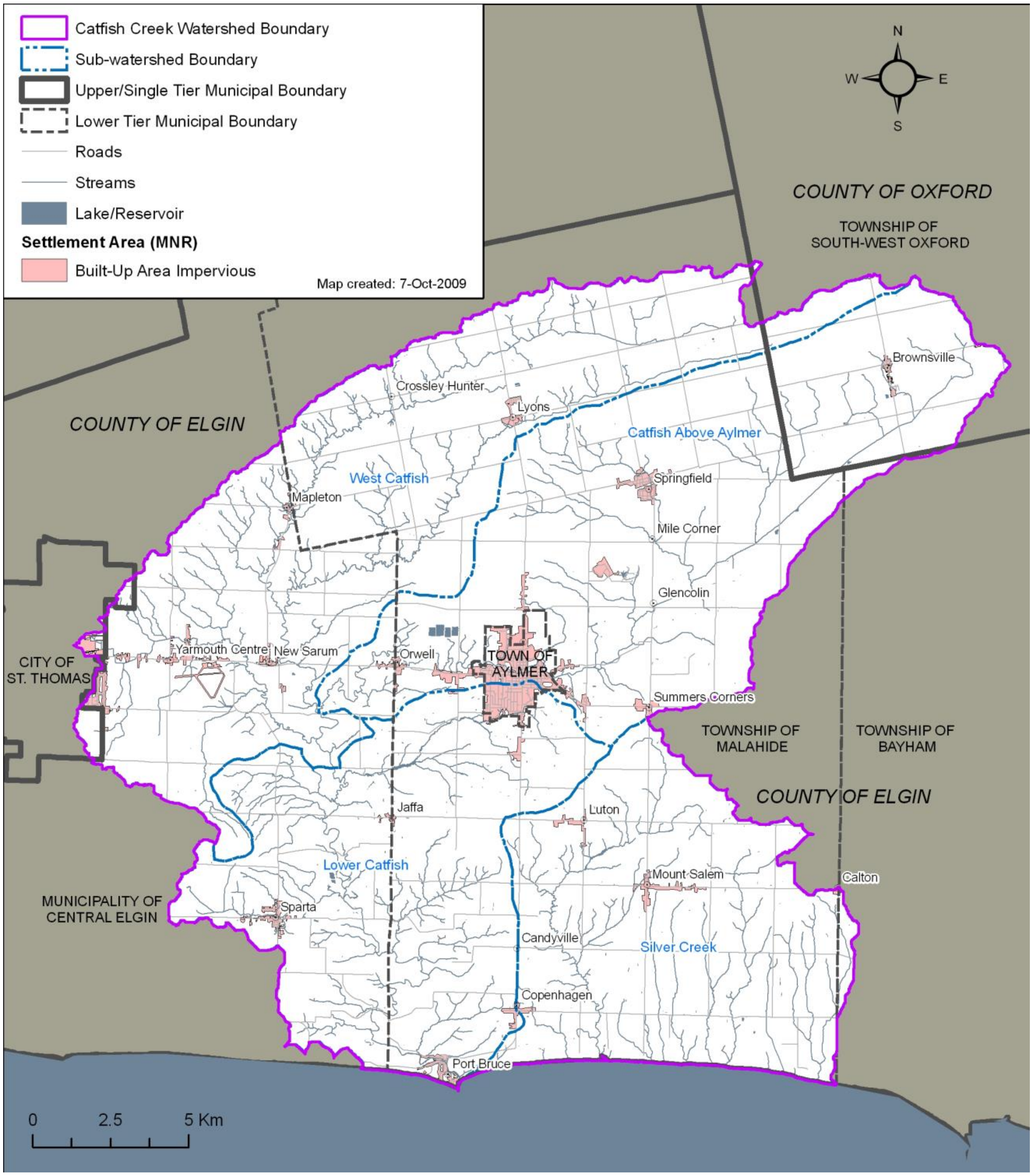
The watershed can be broken down into four sub-watersheds: West Catfish, Catfish Above Aylmer, Lower Catfish Creek and Silver Creek. West Catfish includes two branches of Catfish Creek: West Catfish Creek and East Catfish Creek. The two most significant tributaries joining Catfish Creek in the lower part of the watershed are: Nineteen Creek and Bradley's Creek. Along the Lake Erie shoreline on the east side of Catfish Creek are a number of small watersheds that drain directly into Lake Erie; the largest being Silver Creek.

Much of the land of the watershed is used for agriculture. The City of St. Thomas and the Town of Aylmer are the main urban areas, with other settlements at Springfield and Port Bruce. According to the Catfish Creek Conservation Authority (2021), the population of the Kettle Creek Source Protection Area is approximately 22,017 people.

Map 2-1: Lake Erie Source Protection Region



Map 2-2: Catfish Creek Watershed



2.2.1 Physiography

The physiographic features (as mapped by Chapman and Putnam, 1984) within the Catfish Creek Watershed are presented in **Map 2-3.** These landforms were shaped by glacial processes occurring during the Late Wisconsinan glaciation. This occurred 10,000 to 25,000 years ago when glaciers and glacial lobes extended into southern Ontario and as far south as Michigan, Indiana, Illinois and Ohio (Barnett, 1992).

The main physiographic regions within the Catfish Creek Watershed are the Mount Elgin Ridges, the Ekfrid Clay Plain, and the Norfolk Sand Plain.

2.2.2 Mount Elgin Ridges

The Mount Elgin Ridges within the Catfish Creek watershed include several end moraines that provide low to moderate relief above the surrounding low-lying topography. These moraines were deposited at the front of the Lake Erie ice sublobe during the Wisconsinan Glaciation (Chapman and Putnam, 1984), and include the St. Thomas, Tillsonburg, and Sparta Moraines.(**Map 2-3**)

The St. Thomas Moraine was built by a submerged ice front and is the largest moraine of the series, varying in width up to 5 km between London and Tillsonburg and is prominent as far as Wallacetown (Barnes, 1967). This moraine provides the surface water divide between Catfish and Kettle Creek northeast of St. Thomas. (**Map 2-3**).

The Sparta Moraine divides the Catfish and Kettle Creek Conservation Authorities just north of Lake Erie. The Tillsonburg Moraine is topographically subtle through the east-central portion of the watershed and the Norwich Moraine trends east-west in the northern area of the Catfish Creek watershed. All three of these moraines are capped by the clayey silt Port Stanley Till.

2.2.3 Ekfrid Clay Plain

The Ekfrid Clay Plain comprises a fairly large area in the Lake Erie region and is the dominant feature in the west-central portion of the Catfish Creek watershed. The flat lying area is characterized by clay and silt deposits providing little relief and poor drainage.

2.2.4 Norfolk Sand Plain

The Norfolk Sand Plain is extensive and dominates the southern portion of the Catfish Creek watershed, extending to the Lake Erie shoreline. It is wedge-shaped with a broad curved base along the shore of Lake Erie tapering northward to a point at Brantford on the Grand River. The sands and silts of this region were deposited as a delta in glacial Lakes Whittlesey and Warren. The great discharge of meltwater from the Grand River area entered the lake between the ice front and the moraines to the north-west, building the delta from west to east as the glacier withdrew. Thus it covered most of the area west of the Galt Moraine. From observations in exposed river valleys and along the Lake Erie shoreline bluffs, there are records of sand beds up to 23 m deep but usually silt or clay strata or beds of boulder clay occur within 9 m of the surface (Barnett, 1976).

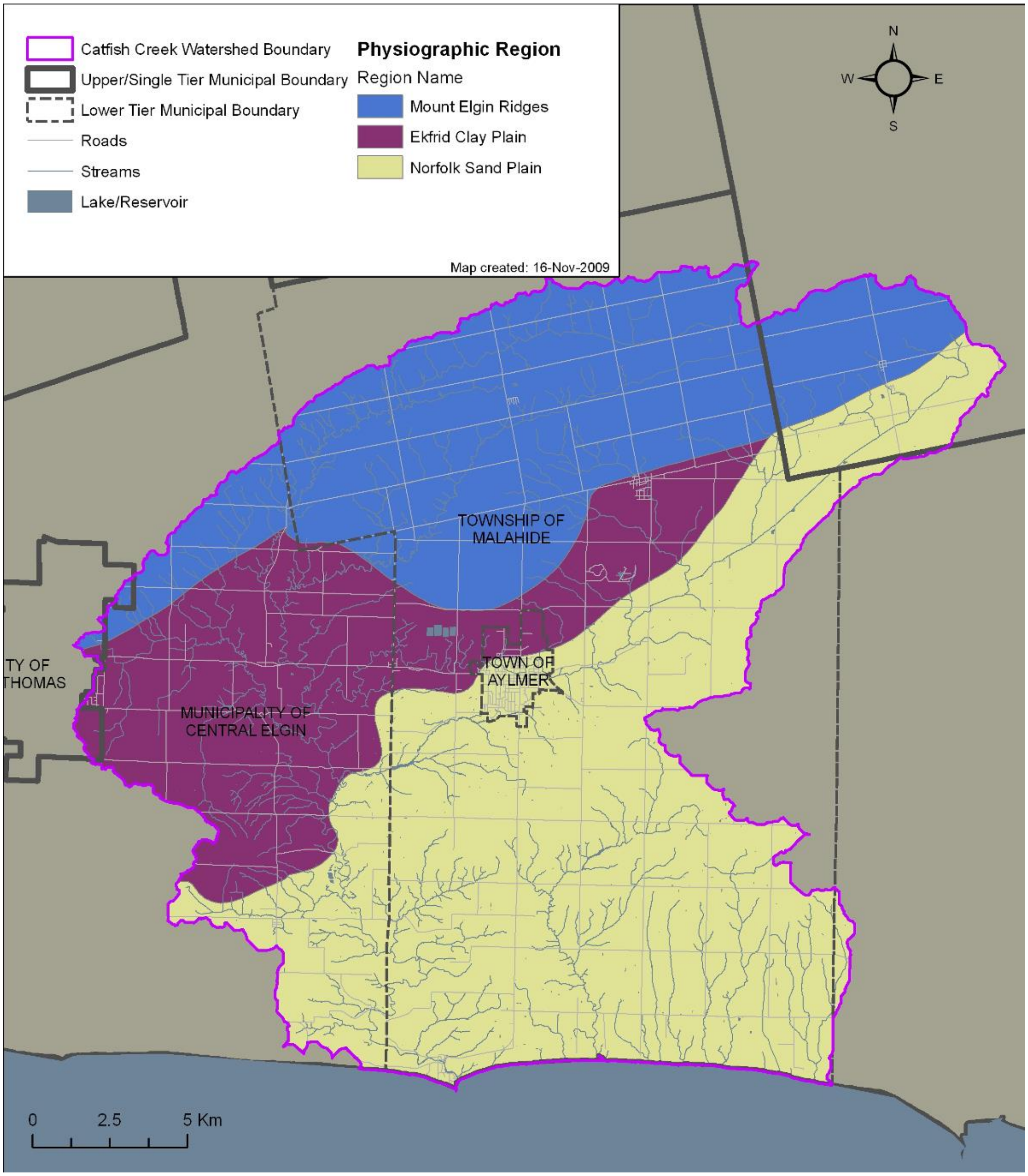
2.3 Ground Surface Topography

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 ground surface topography of the Catfish Creek watershed, which varies from 275 metres above sea level (masl) in the north to approximately 180 masl along the Lake Erie shoreline. The topographic highs within the watershed correspond to the St. Thomas Moraine and Sparta Moraines. The lowest elevations occur along the incised river valleys and along the Lake Erie shoreline. Hummocky topography is shown on **Map 2-4** and is generally limited to the topographic divides.

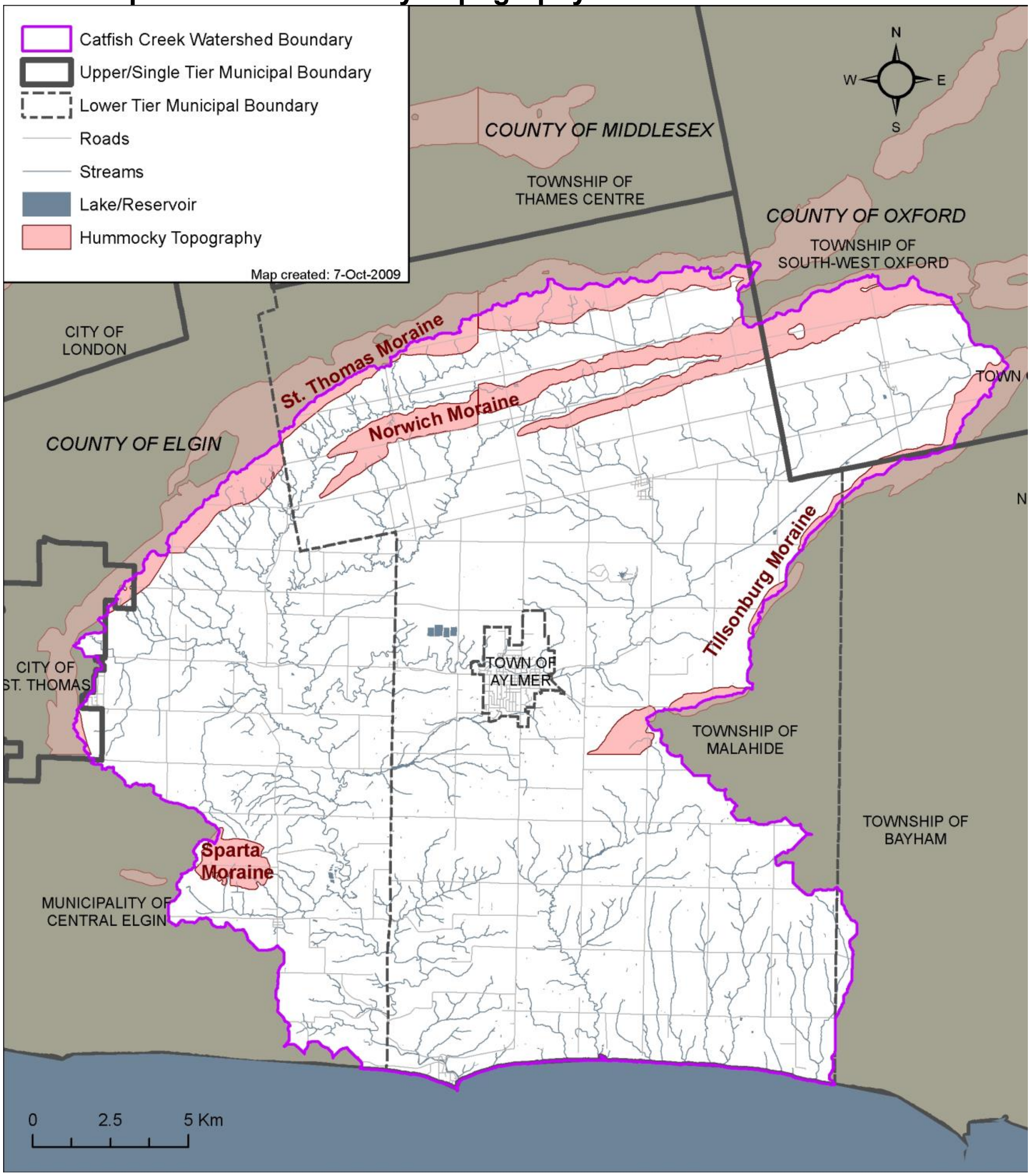
2.3.1 Bedrock Topography

There was an extensive period of time between the final deposition of the Paleozoic sedimentary rocks (approximately 350 million years ago) and the earliest record of glacial deposition (in Ontario) during the Late Wisconsinan Glaciation approximately 115,000 years ago. During this period, it is believed that the exposed bedrock surface was subjected to glacial and fluvial erosion and weathering that shaped the underlying bedrock surface. Much of the irregular topography on the bedrock surface is attributed to fluvial erosion whereby paleo-drainage was focused along the bedrock for extensive periods of time. This leads 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 Catfish Creek watershed.

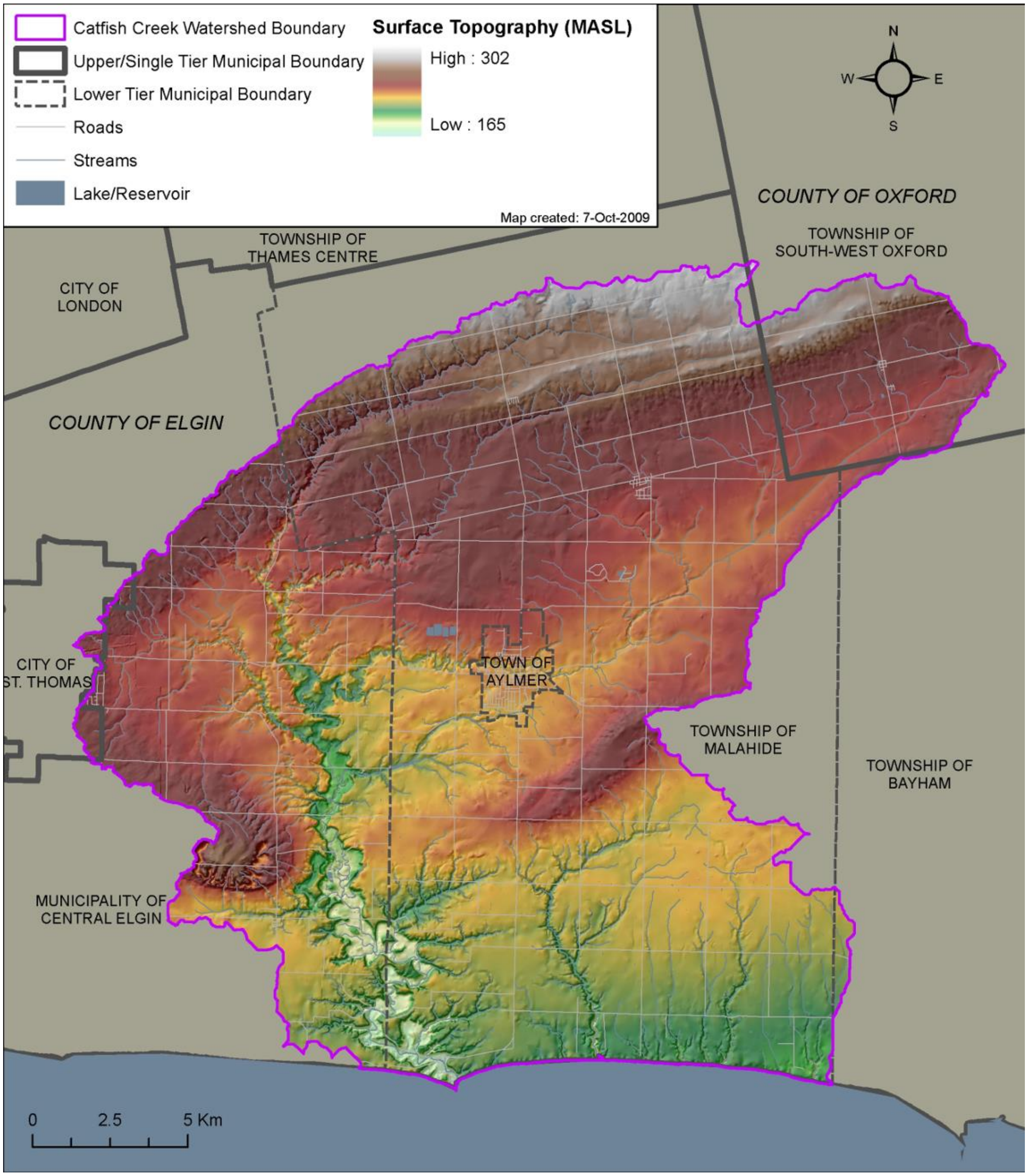
Map 2-3: Physiography of the Catfish Creek Watershed



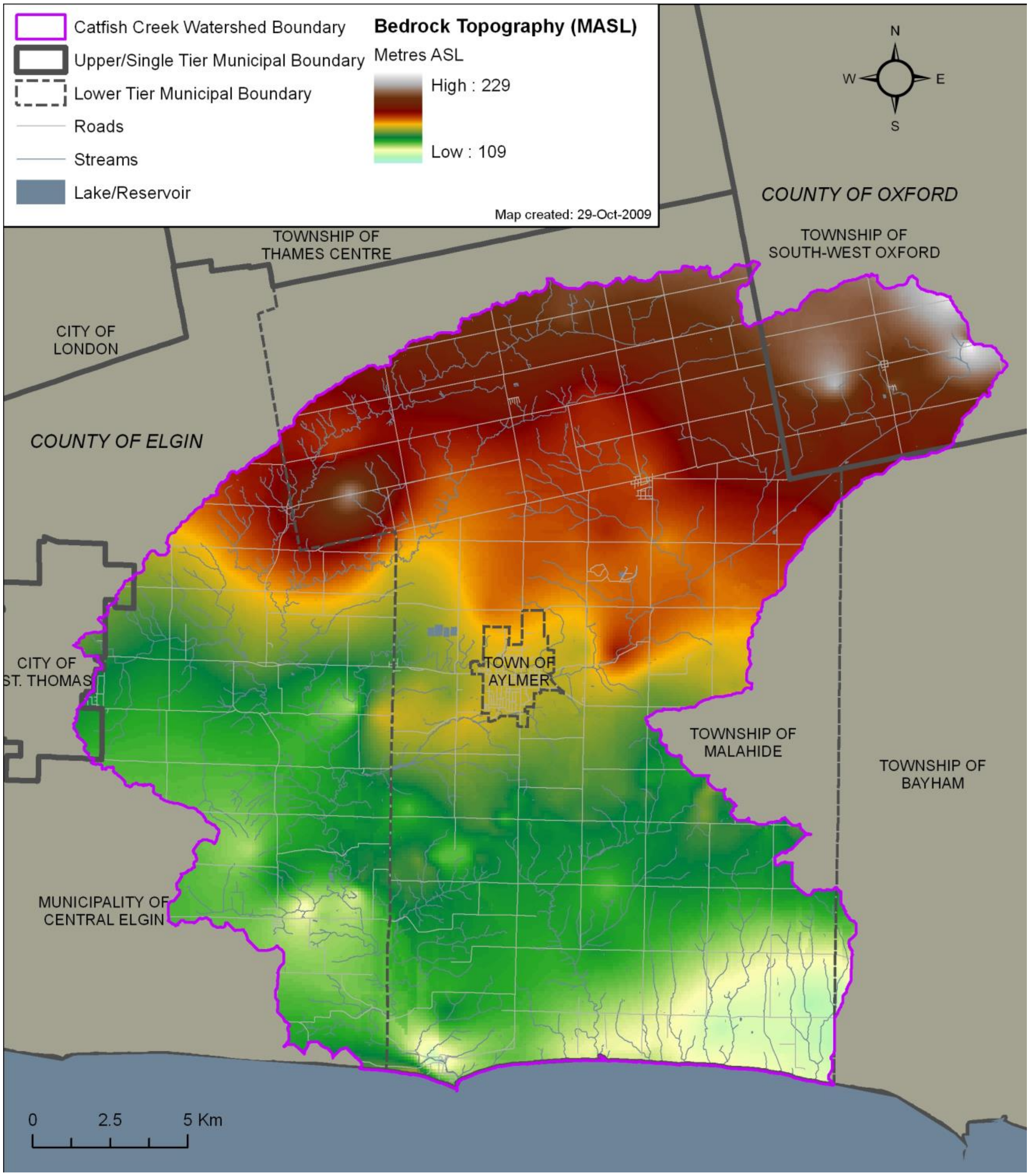
Map 2-4: Hummocky Topography



Map 2-5: Ground Surface Topography



Map 2-6: Bedrock Topography



2.4 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. Dundee Formation dolostone and limestone underlie the northern portion of the watershed, with Marcellus Formation shales situated throughout the south of the watershed along the north shore of Lake Erie.

2.4.1 Bedrock Geology

The bedrock geology within the watershed consists of Middle Devonian Michigan Basin (Dundee Formation) and Appalachian Basin (Marcellus Formation) sedimentary rocks. Bedrock is not exposed at surface as a thick layer of Quaternary sediment (30 m to 140 m) covers the entire watershed. The bedrock geology presented in **Map 2-7** was assembled by the Ontario Geological Survey (OGS) in 2001.

The Dundee Formation is the oldest bedrock unit in the watershed and subcrops throughout most of the northern portions of the watershed. The formation is characterized as a fossiliferous limestone with bituminous partings and chert nodules (Johnson et al., 1992). In Ontario, the average thickness of the Dundee Formation ranges from 35 to 45 m. Both Singer et al. (1997) and MacRitchie et al. (1994) identified the Dundee Formation as a major hydrogeologic unit stretching across Ontario. As a regional aquifer, well yields depend on secondary permeability, created through enhanced porosity resulting from features such as fracturing, dissolution, and dolomitization. Relatively high well yields observed in the top 1.5 m of the Dundee Formation suggest that flow is confined to joint and fracture zones developed as a result of differential glacial stresses (Schwartz, 1974).

The Marcellus Formation, which conformably overlays the Dundee Formation, subcrops throughout the southern portion of the watershed between the town of Aylmer and the Lake Erie shoreline. The Marcellus Formation within southwestern Ontario has been characterized as a black, organic-rich shale with grey shale interbeds and sparse fossils. The Formation was deposited in a marine environment with a stratified water column and can range up to 12 m in thickness (Dillon, Golder, 2004; Johnson et al., 1992).

2.4.2 Quaternary 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 (**Map 2-9**). During the Late Wisconsinan stage, glacial ice advanced and retreated into the lower Great Lakes region. The three primary advances (stades) were the Nissouri, Port Bruce, and Port Huron

Stades. These stades were separated by two periods of temporary ice retreat (interstades; the Erie and Mackinaw Interstades).

The most extensive subglacial till sheet in southern Ontario is the Catfish Creek Till (deVries and Dreimanis, 1960; Barnett, 1978; 1992; 1993). 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 primarily occurs as a buried till plain across the Catfish Creek watershed, but outcrops near the community of Sparta and within the Lake Erie bluffs near Port Talbot.

Catfish Creek Till and the overlying Port Stanley Till are separated by a discontinuous layer of glaciolacustrine sediments that are up to 4 m thick and texturally vary from well-sorted sand to clay (Schwartz, 1974). 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). Within the northern portions of the Catfish Creek watershed, the Port Stanley Till is the dominant surficial unit. The younger overlying till units were deposited during retreat cycles of the Erie ice lobe. This generated a depositional environment of subaquatic flow in glaciolacustrine conditions and produced lacustrine silt and sand interbeds within the Port Stanley Till (Dillon and Golder, 2004).

The Wentworth Till is the youngest till within the watershed, and is commonly buried beneath glaciolacustrine sediments (Barnett, 1982). Glacial Lake Whittlesey followed by Glacial Lake Warren, each flooded a large portion of the watershed throughout the Port Huron Stade (Barnett, 1992). The Ekfrid Clay Plain was laid down under calm conditions where the fine-grained suspended sediment settled out onto the floor of glacial Lakes Whittlesey and Warren.

The Norfolk Sand Plain lies across the watershed 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). Sands of the Norfolk Sand Plain 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 Catfish Creek watershed, the Norfolk Sand Plain is located across the southern portions of the region and it continues northward along the eastern boundary of the watershed. The Norfolk Sand Plain forms an important aquifer across the area and is extensively used for private groundwater supply.

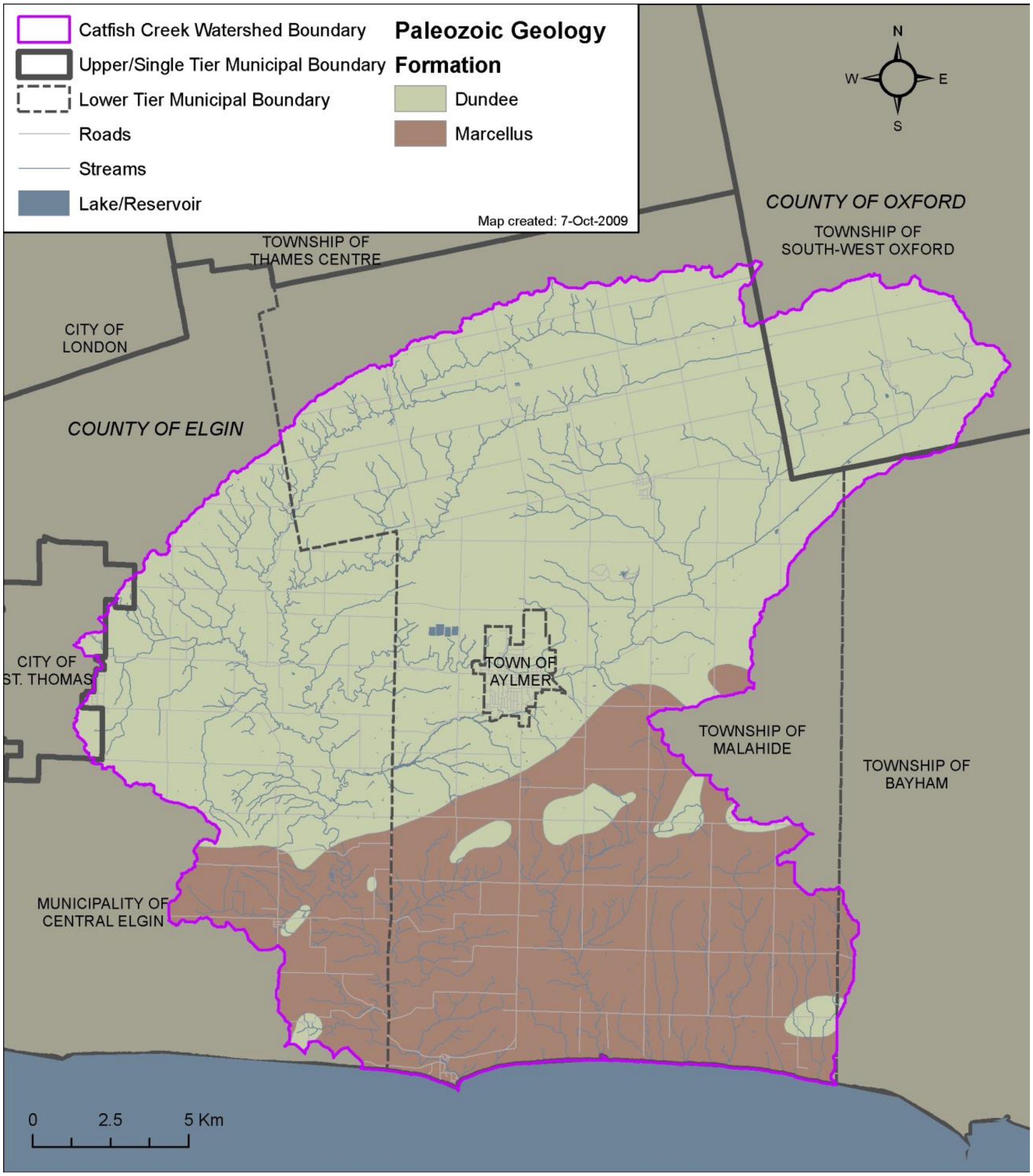
2.4.3 Overburden Thickness

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.

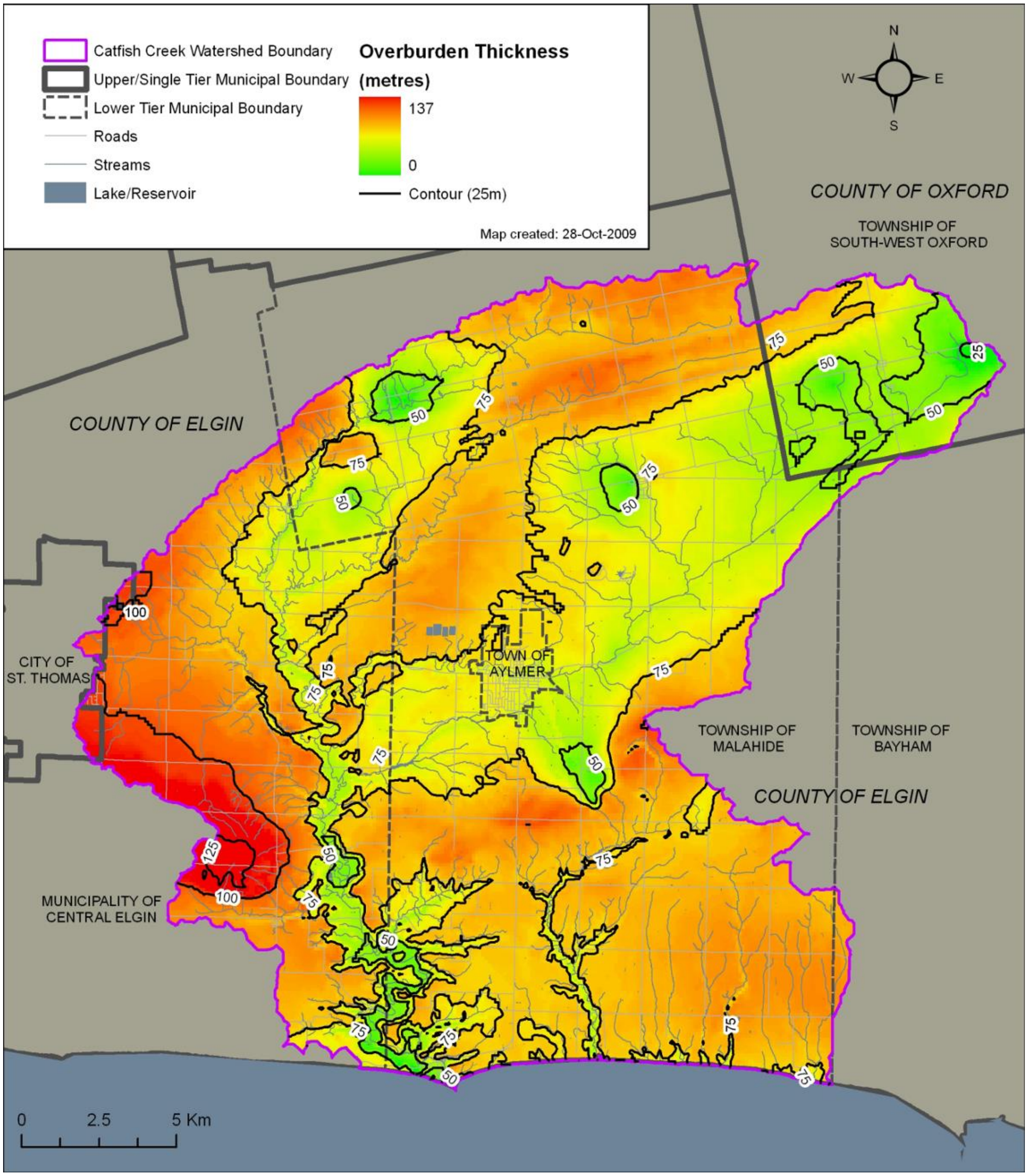
Overburden thickness was derived by subtracting the bedrock topographic surface (see above) from the ground surface elevation. **Map 2-8** shows the distribution of overburden throughout the watershed, and illustrates the presence of moraines and incised river valleys.

Overburden thickness ranges from 7m along some river valleys, to 97m in areas where the end moraines overlie thick till deposits. The thickest overburden materials are located in the southern regions of the watershed along the Lake Erie shoreline. In addition, the thicknesses of the St. Thomas, Sparta, Norwich and Tillsonburg Moraines are also readily identifiable on this map.

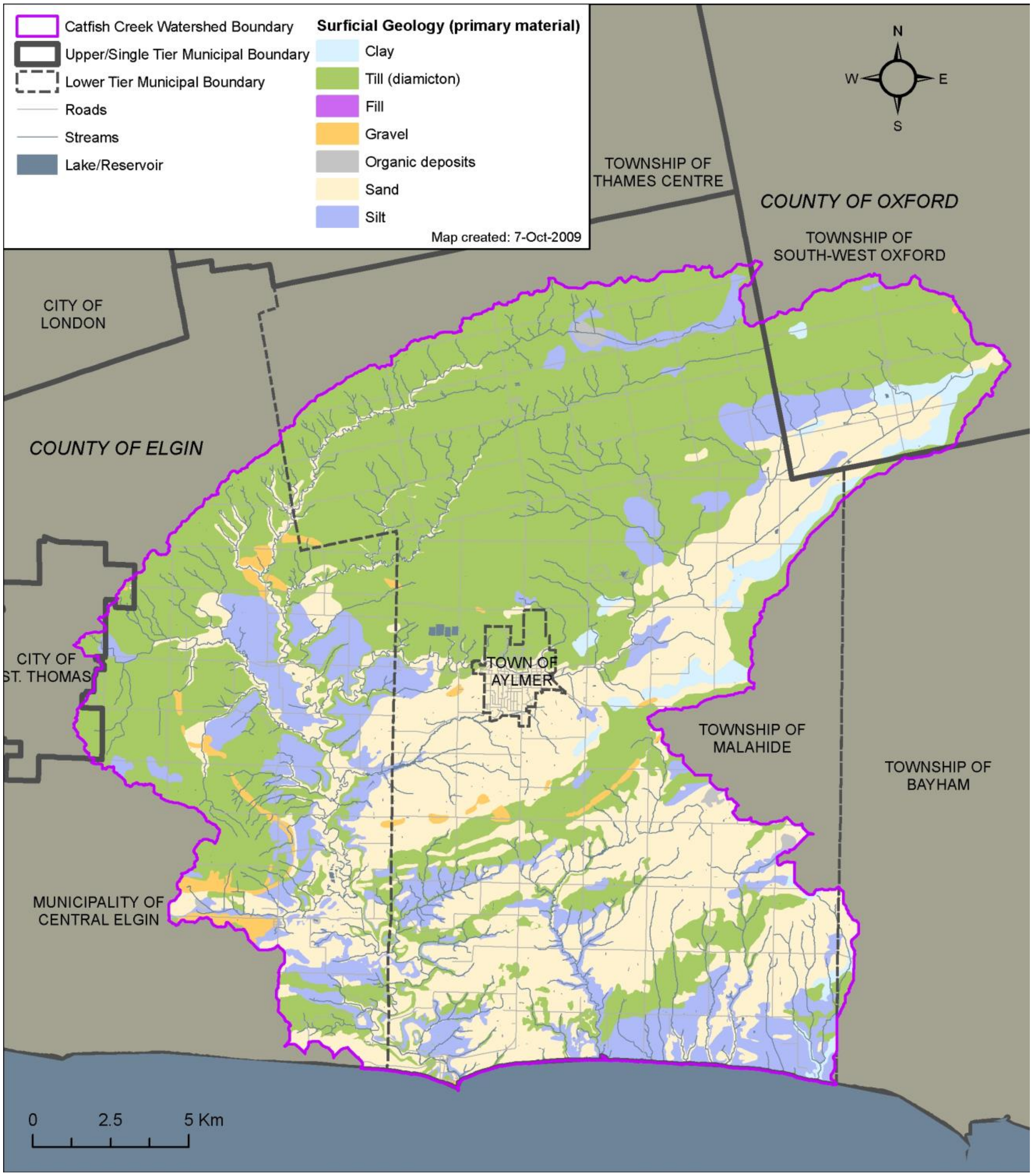
Map 2-7: Bedrock Geology



Map 2-8: Overburden Thickness



Map 2-9: Quaternary Geology



2.5 Groundwater

2.5.1 Aquifer Units

The location and spatial distribution of these 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.

The Catfish Creek watershed contains three aquifer units; shallow overburden, deep overburden and bedrock. Shallow overburden aquifers in this area are unconfined to semi-confined and defined by water wells that are completed less than 20 m below ground surface. Deep overburden aquifers are defined as wells completed over 20 m below ground surface. These aquifer categories were developed from work completed by Dillon (2004) and Waterloo Hydrogeologic Inc. (2003).

The primary aquifer within the Catfish Creek watershed is a broad shallow unconfined sand and gravel aquifer located between Aylmer and Lake Erie. Deeper confined overburden aquifers are located in the central portions of the watershed within the basal portions of the Port Stanley Till where discontinuous sand and gravel lenses exist. A local aquifer is located near the community of Brownsville. These aquifer units were defined through work completed by Strynatka et al. (2006), Dillon (2004) and Waterloo Hydrogeologic Inc. (2003).

Within the Catfish Creek watershed area, the most commonly used bedrock aquifer is the Dundee Formation; however, this carbonate aquifer is largely unused as there are sufficient overburden groundwater resources in the watershed.

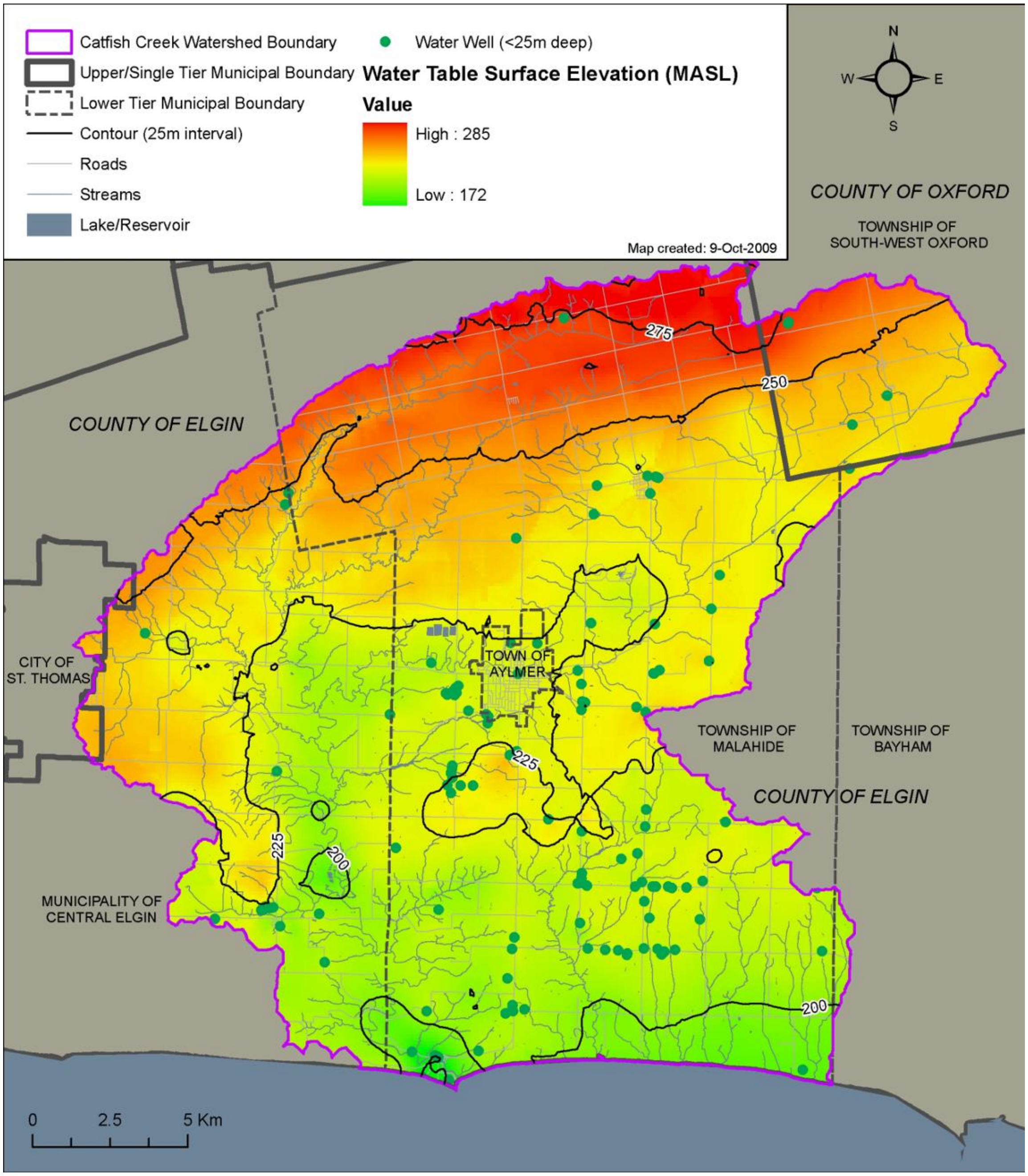
2.5.2 Shallow Overburden Aquifer

The water table elevation surface represents groundwater conditions within the shallow aquifer under unconfined conditions. Within the Catfish Creek watershed, the water table surface was generated from the static water level elevations of overburden wells that were completed less than 20 m below ground surface (**Map 2-10**).

Map 2-10 indicates that shallow wells are generally associated with the surficial sand deposits located throughout the Catfish Creek watershed, primarily between Aylmer and Lake Erie. There are very few shallow overburden wells in the central portion of the watershed and along the western boundary with the Kettle Creek watershed as the upper aquifer is absent in this area; the upper 20 to 30 m of overburden in this area are Port Stanley Till and similar fine-grained sediments. Due to the lack of data across the watershed boundaries between Catfish Creek and Kettle Creek, it is not possible to determine if a shallow groundwater divide exists between the two watersheds.

Water table elevations vary from approximately 290 masl across the northern portions of the watershed to 170 masl along Catfish Creek and the Lake Erie shoreline. Shallow groundwater flow is predominantly from north to south towards Lake Erie, with local shallow flow influenced by Catfish Creek.

Map 2-10: Water Table Surface



2.5.3 Deeper Overburden Aquifer

Static groundwater elevations within the deep overburden sediments were used to generate a potentiometric surface for the deep aquifer unit. General groundwater flow directions and groundwater divides within the deep overburden can be inferred using the interpreted surface. The deep overburden potentiometric surface was generated by interpolating a surface of all static water levels in overburden wells completed more than 20 m below ground surface. **Map 2-11** illustrates the deeper overburden potentiometric surface. The deep overburden unit is considered to be semi-confined to confined, yet the general groundwater flow directions are very similar to the water table surface whereby the dominant groundwater flow direction is from north to south towards Lake Erie. Flow directions within the southern half of the watershed are also locally influenced by Catfish Creek. There is also evidence of a groundwater divide located in a similar position to the surface water divide between the Catfish Creek and the Kettle Creek watersheds. As shown on **Map 2-11,** overburden potentiometric surface elevations vary from approximately 290 masl across the north of the watershed to 150 masl along Catfish Creek and the Lake Erie shoreline.

The deeper overburden hydrostratigraphic unit includes spatially discontinuous sand and gravel deposits related to lenses within the Port Stanley Till and the underlying Catfish Creek Till. Sand and gravel units that lie at depths greater than 20 m are generally less than 5 m thick.

2.5.4 Bedrock Aquifer

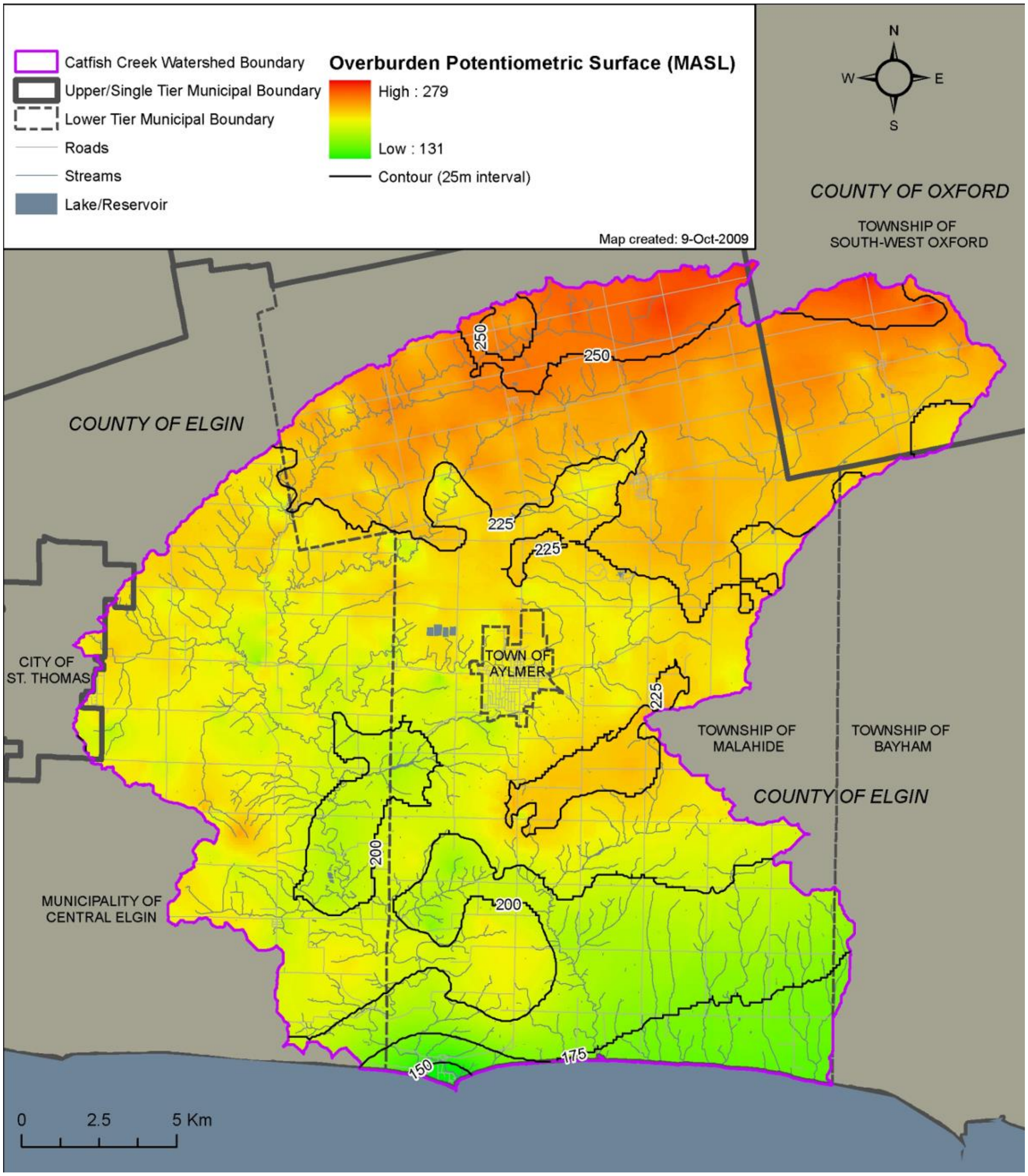
Static groundwater elevations measured within the bedrock water wells were used to develop the bedrock potentiometric surface. This surface was used to determine groundwater flow directions in the bedrock. The bedrock potentiometric surface is shown on **Map 2-12**. The bedrock potentiometric surface is similar, but more subdued when compared to the overburden potentiometric surface. Groundwater flows from the north- northeast to the south towards Lake Erie. Bedrock groundwater elevations are similar to the deep overburden potentiometric surface, and range from 270 masl in the northeast of the watershed, to 170 to 190 masl along the Lake Erie shoreline.

2.5.5 Groundwater Monitoring

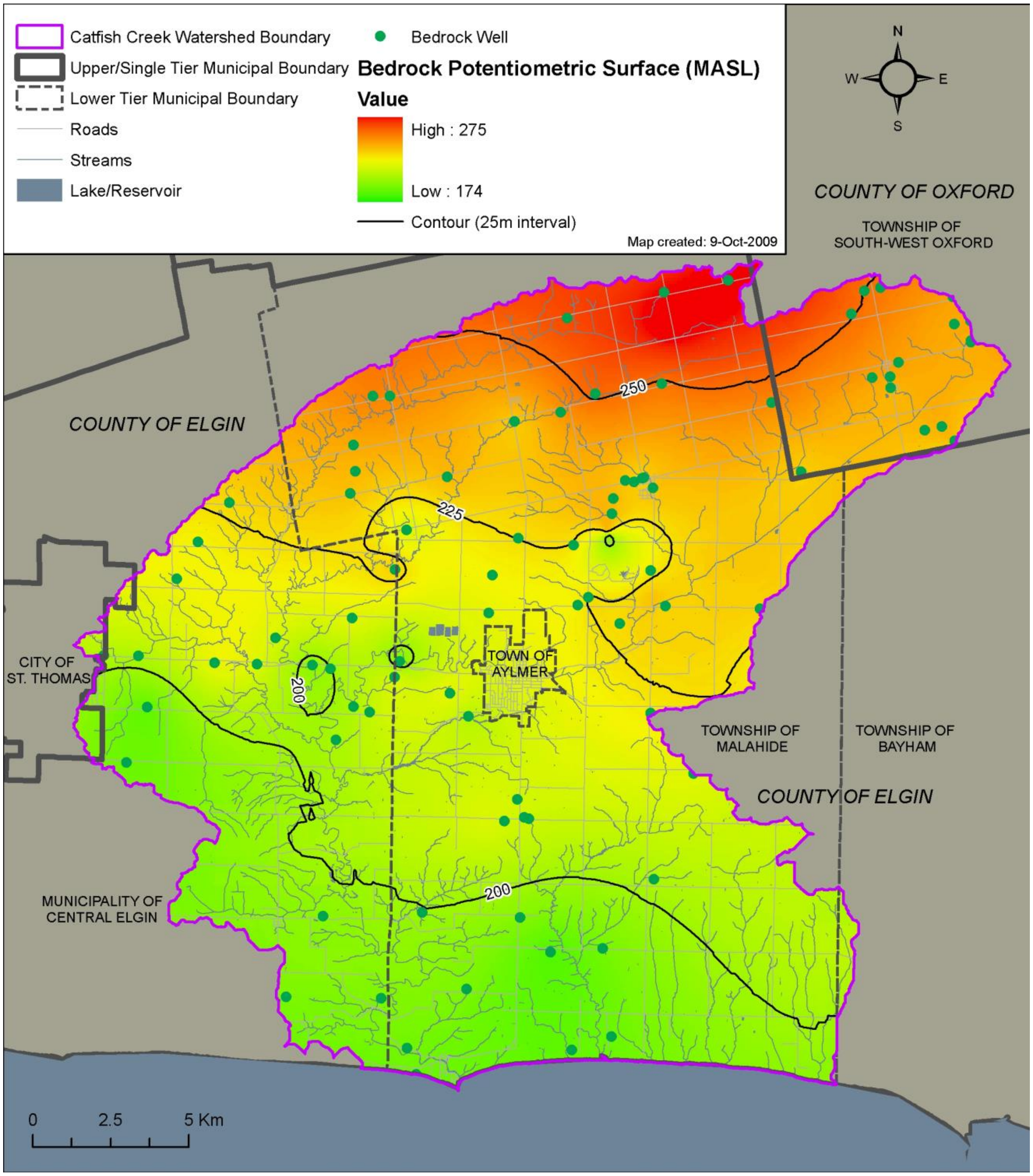
Groundwater conditions are primarily monitored in the Catfish Creek watershed through the Provincial Groundwater Monitoring Network (PGMN) , a network of wells distributed throughout the province that provide insight on long-term ambient trends and conditions. The monitors are typically sited to be reflective of broad hydrogeologic conditions, away from areas where pumping or contamination may impact those data collected. The Ministry of the Environment, Conservation and Parks owns the monitoring infrastructure and manages the data gathered through the program, but in many cases the program is locally administered by Conservation Authorities.

There are currently five Provincial Groundwater Monitoring Network wells at two locations within the Catfish Creek watershed (**Map 2-13**). The wells are located in the eastern extents of the watershed generally located next to wetlands. Each of the wells is completed within overburden sediments. Water levels in the wells are monitored through a combination of manual and electronic means.

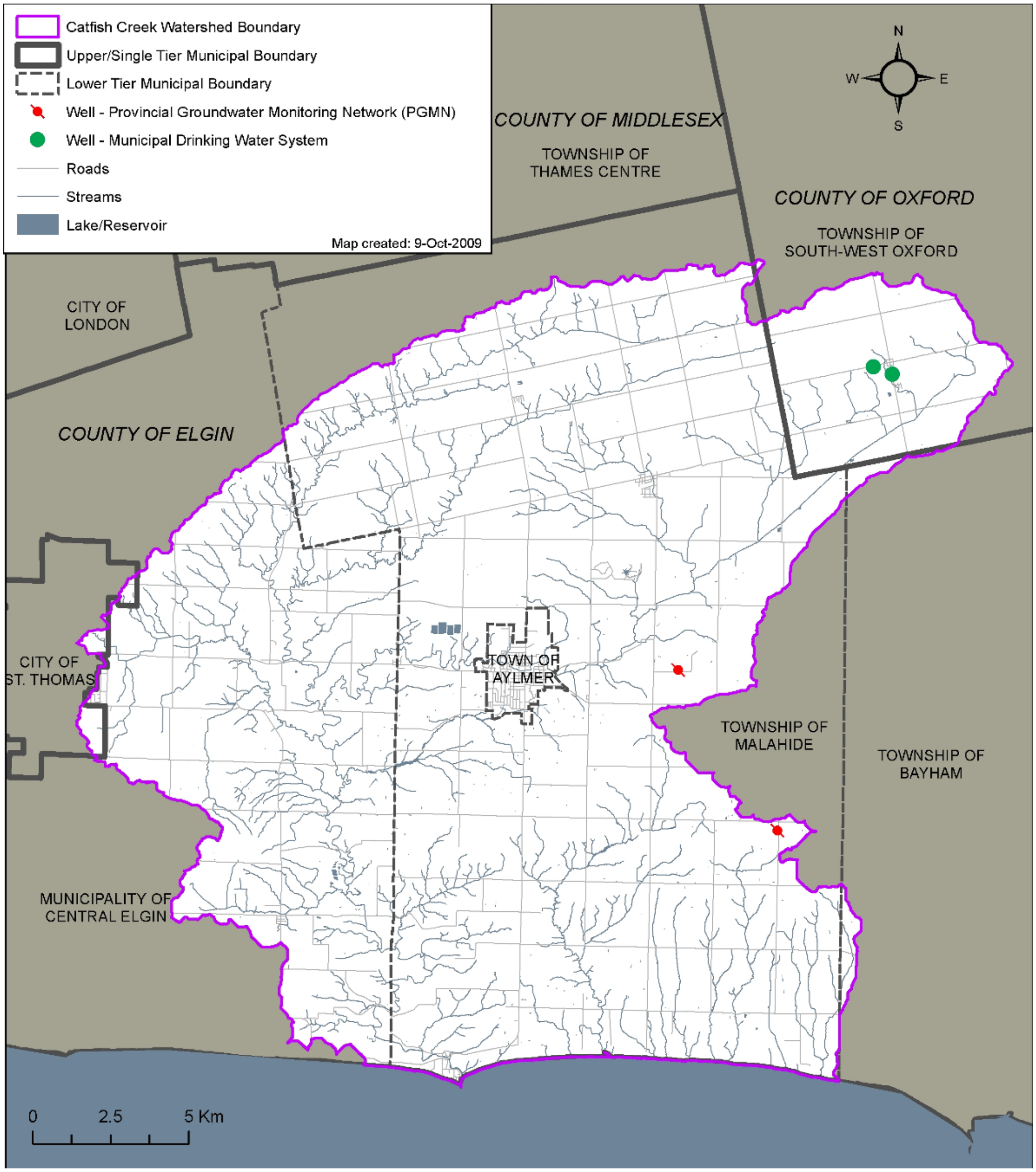
Map 2-11: Overburden Potentiometric Surface



Map 2-12: Bedrock Potentiometric Surface



Map 2-13: Provincial Groundwater Monitoring Well Locations in the Catfish Creek watershed



2.6 Groundwater Quality Across the Watershed

In 2018, a Watershed Report Card was completed for the Catfish Creek Watershed. The watershed report card provides a snapshot of current conditions in the Catfish Creek watershed and helps to identify environmental issues that need to be protected, restored or managed. Catfish Creek Conservation Authority prepared the report card using data collected from 2014 to 2018.

Concentrations of nitrate and chloride were measured at two MECP monitoring wells across the Catfish Creek Watershed. The Catfish Creek Watershed Report Card reported the following for groundwater quality (Catfish Creek Conservation Authority, 2018):

- Chloride concentrations are better than the drinking water guidelines in all wells,
- Concentrations of nitrate approach or exceed the drinking water guidelines at one well (South East portion of the Main Catfish Creek subwatershed, and
- The quality of private well water may vary from that of the monitoring wells. In some instances, the location of wells was chosen to monitor local issues.

Groundwater quality has the potential to be negatively impacted by human actions. Optimizing fertilizer application, regular maintenance of septic systems, decommissioning unused wells and the reduction of in use of ion exchange water softeners can help to reduce the potential degradation of water quality resources (Kettle Creek Conservation Authority, 2018).

2.7 Climate

The Catfish Creek watershed, situated on the northern shore of Lake Erie, has a geographic location that provides a more temperate climate compared to other parts of Southern Ontario. The temperate climate denotes moderate, even precipitation throughout the year, summers that are warm to hot and humid, and freezing temperatures in winter. Winters are mild compared to the rest of Ontario due to the watershed’s southerly location and the moderating effect of Lake Erie.

General weather patterns in this region consist of four seasons. Winter is generally considered to have temperatures lower than 0ºC, beginning in December and lasting until late February or early March. Spring lasts approximately two months, followed by four months (June to September) of summer and two months of autumn (Sanderson, 1998). The average annual temperature from 1981 to 2010 was 8.7ºC. Daily minimum, maximum and average temperatures are presented for each month on

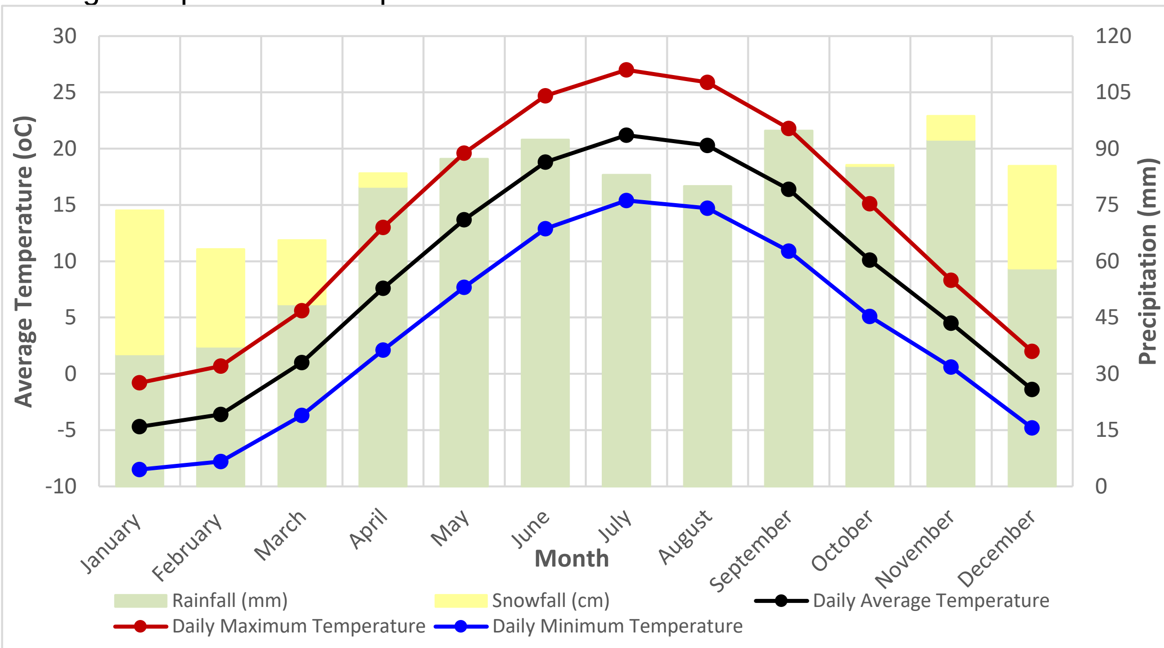


Figure 2-1.

Annual average precipitation, from 1981 to 2010, in the watershed was 993 mm. The majority of precipitation falls as rain. Precipitation climate normal from 1981 to 2010 are presented in **Figure 2-1**.

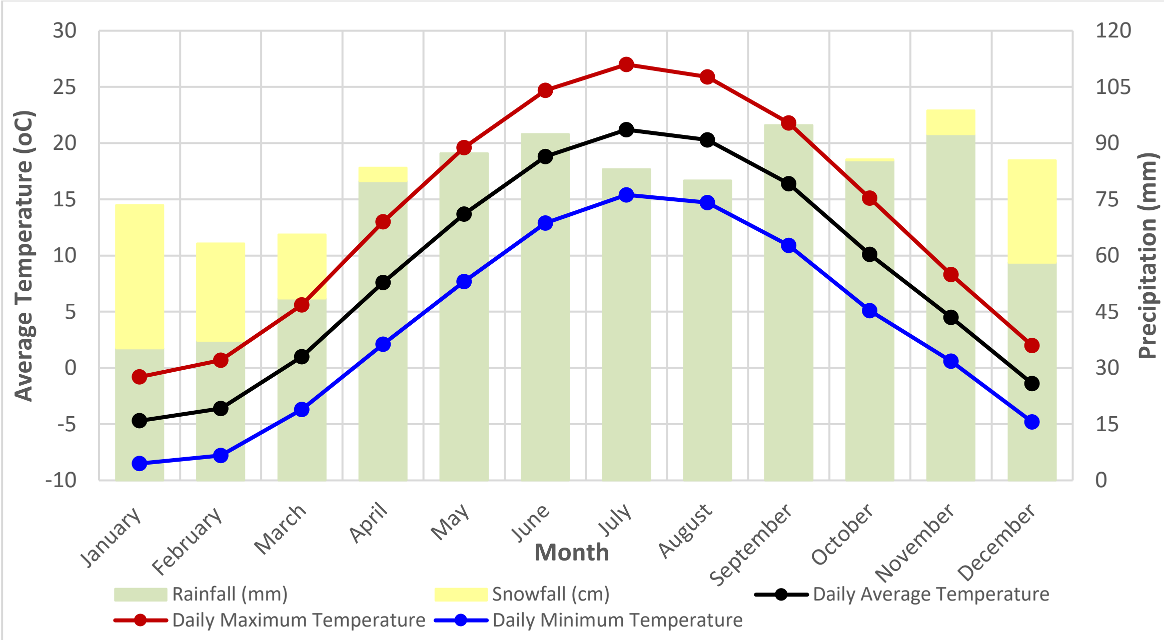


Figure 2-1: Monthly Temperature and Precipitation for St Thomas WPCP Climate Station – 1981 to 2010 Climate Normals

Precipitation is 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 often brings long, low intensity rainfall and when coupled with the melting snow can make the spring season appear to be constantly wet and overcast. In summer, many of the rainfall events are intense with short durations. The duration of 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.

2.8 Land Cover and Land Use

Land uses for the Catfish Creek watershed are characterized by small urban commercial, industrial and residential centers, surrounded by less-populated rural land used for intensive agricultural production. **Map 2-14** shows the distribution of land cover across the watershed.

2.8.1 Valley lands

The Catfish Creek valley system, from the outlet in Port Bruce to the Archie Coulter Conservation Area south of Highway 3, provides outstanding vistas of floodplain terraces and forested valley slopes.

At the heart of the valley is an area referred to as the Catfish Creek Slope and Floodplain Forest. A unique 233 hectare portion of the valley has been designated an Area of Natural and Scientific Interest (ANSI) by the province and identified as Elgin County's only Carolinian Canada Signature Site. The site supports 358 different species of plants, representing one-sixth of the total found in Canada including distinctive Carolinian trees. Also found on this site are five provincially rare and threatened species of plants such as Blue-eyed Mary and Oswego tea. The red shouldered hawk, Acadian flycatcher and Louisiana waterthrush are some of the rare birds that frequent this site.

2.8.2 Forest and Vegetation Cover

Approximately 16 % of the Catfish Creek watershed is forested as shown in **Map 2-14**. Upper Catfish Creek is less forested as compared to the lower watershed and smaller tributaries flowing into Lake Erie (CCCA, 2018).

Upper Catfish Creek

The woodlots that remain in this part of the watershed are small and fragmented in comparison to the woodlands that once covered over 75 per cent of the region.

Poorly drained soils have protected a few larger patches of forest cover. Regulatory controls for woodlot clearing have stabilized the loss of forest cover allowing stewardship initiatives to increase forest cover in portions of the watershed. Other disturbances such as logging, livestock, alien species introduction, disease, insect pest infestations and urban encroachment are still negatively impacting forest ecosystem form and functions.

The woodlots in this northern section of the watershed are made up of climax shade tolerant, deciduous species, including ash, beech, maple and hickory. Coniferous forests in the upper watershed make up less than one per cent of forest cover in the upper watershed, the majority of which were established through various tree planting initiatives.

The largest contiguous forests in this area include the East Aylmer Forest, a 103 hectare woodlot that includes a locally significant wetland, and the North-East Glencolin Forest, a 90 hectare woodlot containing rare plant species with sections that exhibit wetland characteristics.

Lower Catfish Creek and Lake Erie Tributaries

A large part of this portion of the watershed is comprised of loamy/ sandy soils of the Norfolk Sand Plain. The nature of the soils and the principal forces that shaped the landscape has created deeply incised valley systems throughout this area. The relatively well-drained soils have allowed extensive land clearing to occur to the edge of the steep gully systems. As a result, most of the forest cover is found along steep valleys and associated floodplains. The linear nature of these ravines allows for good connectivity of ecological processes including wildlife movement and dispersal of flora and fauna.

This region exhibits a higher composition of rare Carolinian tree species such as tulip, sassafras, Oswego tea, blue ash, paw-paw and sycamore. The sweet

American chestnut trees survived an outbreak of Chestnut blight which decimated this once important species in the early 1900s and persist only as isolated, widely scattered trees. The remaining chestnut trees are still very susceptible to the blight and usually have a short life span.

Although the majority of the woodlots south of Highway 3 can be characterized as climax shade tolerant hardwoods (maple, beech and ash) , there is a higher component of mid-tolerant species such red oak, white oak, basswood, black cherry and ash. The southern portion of the watershed also exhibits a higher component of native coniferous trees such as white pine and isolated stands of eastern hemlock.

Although there is a general absence of large woodland patches that contain deep interior habitats (less than 100 metres from forest edge) , a few remnant woodlots remain to provide valuable habitat for rare birds and plants.

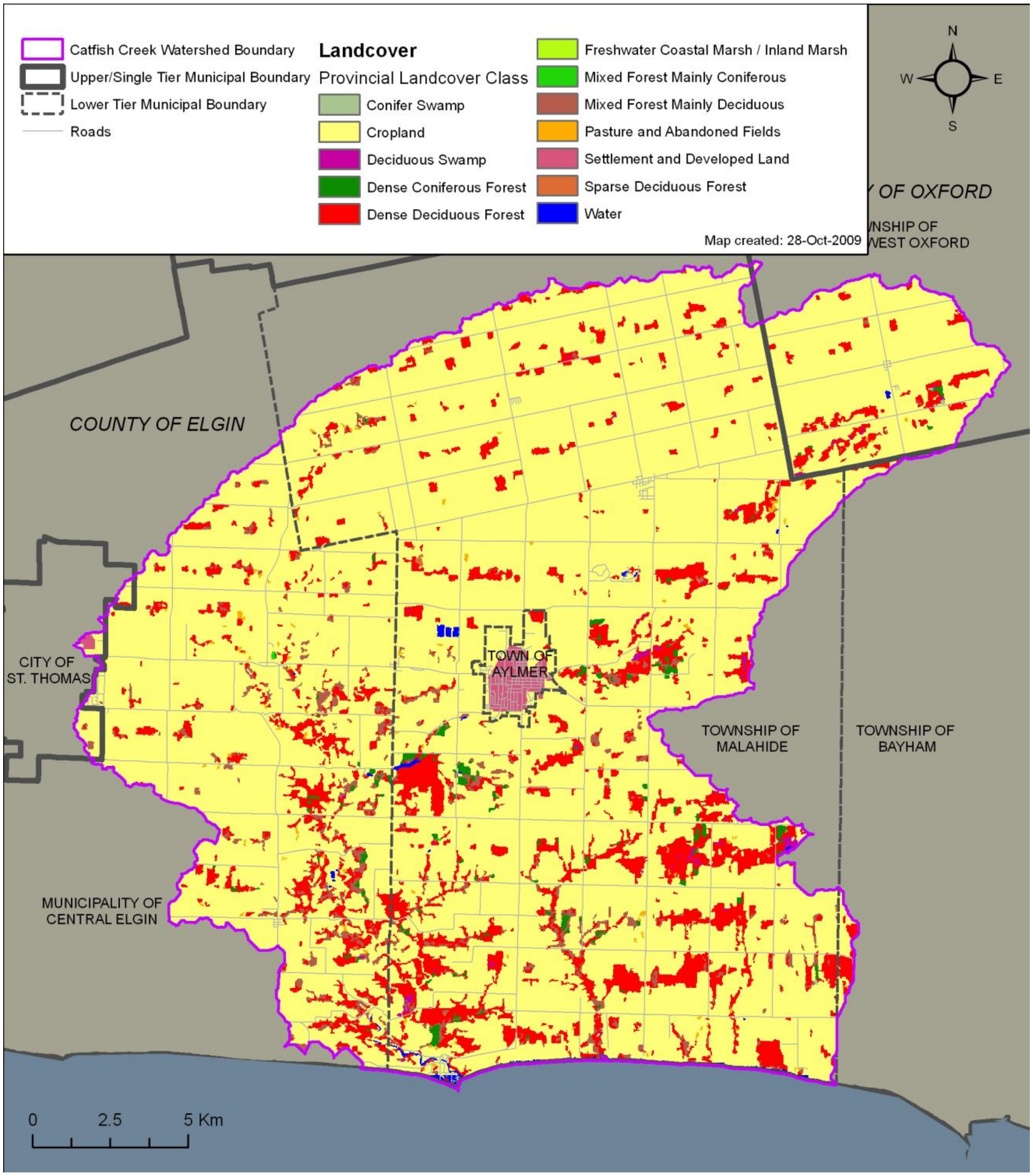
2.8.3 Wetlands

It has been estimated that over 80% of the original wetlands have been drained in the Upper Catfish area. Today, less than 1% of the land area is wetland. The total area of wetlands in Catfish Creek in 477 hectares (CCCA, 2018).

The Elgin Landscape Strategy has identified a need to increase the wetland component in the headwaters of the watershed. The poorly drained soils in the low-lying areas of the St. Thomas Moraine may provide an opportunity to increase the wetland component from the existing levels. The largest contiguous forests in this area include the East Aylmer Forest, a 103 hectare woodlot that includes a locally significant wetland, and the North-East Glencolin Forest, a 90 hectare woodlot containing rare plant species with sections that exhibit wetland characteristics.

The Lower Catfish is home to the largest wetland ecosystem in the watershed, the Calton/ Stewart Swamp. The forest basin is 356 acres and contains 13 wetlands ranging from 0.4 to 20 hectares. These wetlands fulfill an important hydrologic function and provide critical habitat.

Map 2-14: Land Cover in the Catfish Creek Watershed



2.9 Surface Water

2.9.1 Surface Water Characterization

Catfish Creek and its Lake Erie tributaries drain approximately 490 km^2. The surficial materials of the Watershed dominate the surface hydrology. Upper and western portions of the Watershed are largely comprised of low relief tight soils with high surface runoff and little soil infiltration. The lower and eastern portions of the Watershed contain areas of Norfolk Sand Plain with little runoff and high groundwater recharge, but also high irrigation water use.

The Catfish Creek watershed is predominantly influenced by two hydrologic processes: surface runoff and shallow groundwater-surface water interactions. In the north-western portion of the watershed, the surficial geology is predominantly Port Stanley Till, a fine-grained clay till with a low permeability. The surficial geology inhibits water flow through the upper overburden layers and creates an effective barrier between the surface water and groundwater systems. Subsequently, the surface water hydrology of this area is almost entirely driven by runoff.

Lower in the watershed, groundwater has a larger influence in the surface water flow regime. The southeastern portion of the watershed contains deposits of coarse-grained sands and gravels, part of the Norfolk Sand Plain. This highly permeable surficial geology allows water to flow through it fairly easily. Watercourses in this area have higher and more stable baseflows as a result of groundwater discharge.

2.9.2 Surface Water Monitoring

Stream flow monitoring within the Catfish Creek watershed 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, stream flow data from WSC stations is considered to be the highest quality stream flow data available.

Flow monitoring in the Catfish Creek watershed area consists of three Water Survey of Canada (WSC) stream gauges. The first gauge is located within the Town of Aylmer on the main branch of Catfish Creek. It was originally opened in 1987 and operated for 11 years until 1998. The gauge was reopened in 2002. The other gauge on Catfish Creek is located near Sparta. It has been in continuous operation since 1964. This gauge captures 290 km^2 of the watershed or approximately 74% of the area drained by Catfish Creek. Flow data from both gauges on Catfish Creek is available in real time. The last stream gauge in the watershed is located on Silver Creek near Grovesend. This gauge is a recent addition to the network in 2007. It replaces a historic stream gauge, located upstream of the current gauge, that was in operation from 1970 to 1978.

2.9.3 West Catfish and Catfish Above Aylmer

Much of these subwatersheds are comprised of low relief tight soils. This relatively flat terrain with little soil infiltration has caused the need for extensive drainage networks for agriculture. As a result, much of the area has been tiled and many watercourses re-channelized, changing the natural drainage characteristics of the subwatershed.

There are two branches in the West Catfish Subwatershed: West Catfish Creek and East Catfish Creek. The West and East branches of Catfish Creek drain approximately 149 km^2 of Ekfrid Clay Plain in the western and central portions of the subwatershed. These branches are characterized by high runoff and low recharge. Flow can be quite low during the summer months. There are no stream gauges located in the West Catfish Creek Subwatershed.

The Catfish Above Aylmer sub-basin contains the main branch of Catfish Creek that originates in the northeastern portion of the watershed and flows in a southwesterly direction to the Town of Aylmer. It then joins with the East and West branches of Catfish Creek west of the Town of Aylmer. The Catfish Above Aylmer sub-basin drains approximately 143 km^2 of mostly Ekfrid Clay Plain, but the main channel of the creek runs through Norfolk Sand Plain. This allows for higher baseflows than in the West and East Catfish branches. It also leads to higher water use for irrigation. There is one stream gauge located within the Town of Aylmer on the main branch of Catfish Creek that has been in operation periodically since 1987.

2.9.4 Lower Catfish Creek

Lower Catfish Creek has two major tributaries, Nineteen Creek and Bradley's Creek, as well as numerous minor tributaries that join with the main branch of Catfish Creek between the confluence of the upper branches of Catfish Creek to the outlet at Lake Erie.

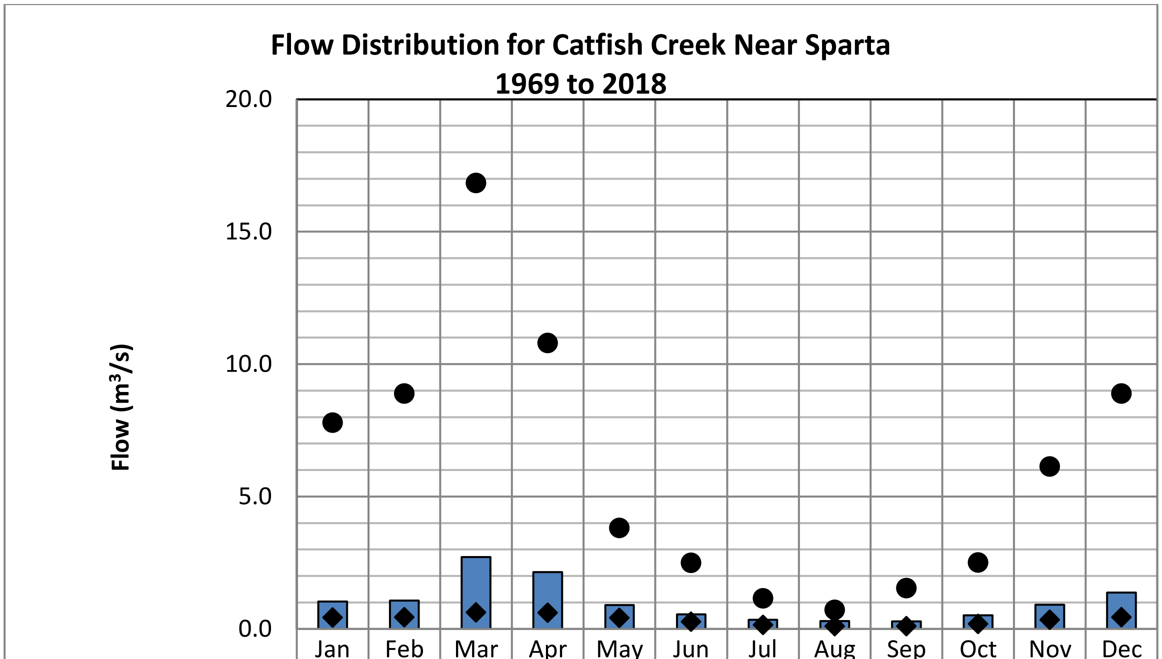
Nineteen Creek drains an area of approximately 41 km^2 in the most western part of the Watershed. Although most of the drainage area consists of agricultural land uses, part of the urban area of City of St. Thomas is also in the drainage area. Flows in the creek are variable because of the high runoff and low groundwater recharge in the till plain drainage area. There is no stream gauge on Nineteen Creek.

Nineteen Creek joins Catfish Creek upstream of the Catfish Creek near Sparta stream gauge. The flow regime for the Catfish Creek at Sparta gauge is shown in **Figure 2-2**. High flows are flashy as shown by the difference between median and 10th percentile flows. Baseflows, as shown with 90th percentile flows, are low and variable throughout the year. This distribution is typical of a runoff dominated system with till plain drainage characteristics.

Bradley's Creek joins Catfish Creek less than one kilometre downstream of the Catfish Creek near Sparta gauge. The watershed of Bradley's Creek has a drainage area of approximately 28 km^2 and contains the only controlled reservoir within the Catfish Creek watershed. Springwater Reservoir is used primarily for recreation. Bradley's Creek subwatershed lies mainly within the Norfolk Sand Plain. This area is characterized by higher recharge rates than runoff rates. There are a number of significant wetland features within this watershed as well.

The lower portions of Catfish Creek run through a steep sloped valley with a well defined floodplain. The creek widens significantly as it approaches the outlet to Lake Erie at Port Bruce. Catfish Creek drains a total area of approximately 392 km^2.

Figure 2-2: Flow Distribution for Catfish Creek near Sparta Gauge



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
■ Median Flow	1.0	1.1	2.7	2.2	0.9	0.6	0.4	0.3	0.3	0.5	0.9	1.4
◆ 10th Percentile Flow	0.4	0.4	0.6	0.6	0.4	0.3	0.1	0.1	0.1	0.2	0.3	0.4
● 90th Percentile Flow	7.8	8.9	16.8	10.8	3.8	2.5	1.2	0.7	1.5	2.5	6.1	8.9

2.9.5 Silver Creek

Along the Lake Erie shoreline on the east side of Catfish Creek are a number of small watersheds that drain directly into Lake Erie. The largest is Silver Creek with a drainage area of approximately 41 km^2. Much of the drainage area of Silver Creek is sand plain with high rates of groundwater recharge and low runoff. Flows in the creek can be greatly affected by water taking for irrigation purposes. There was an historic stream gauge located on Silver Creek near Copenhagen that was in operation from 1970 to 1978 and a current stream gauge is located downstream of the site of the Silver Creek near Copenhagen gauge. It has been in operation since 2007.

The remaining small watercourses along the shoreline are within the sand plain or sand plain that is interspersed with silt till, and they drain a total area of approximately 52 km^2.

2.9.6 Water Control Structures

There are two main water control structures within the watershed. The first, and most significant structure, is Springwater Reservoir, which is a structure with approximately three metres of available head. Two spillways are available for outflows, and are controlled by stoplogs and a sluicegate. No low-flow valve exists to allow drawdown below the spillway crest. The surface area of the reservoir is approximately 10 ha, and the upstream drainage area is approximately 22 km^2. While no detailed operation rule has been imposed for the reservoir, it is generally drawn down over a two week period starting in late October, and filled in mid-March. Elevations remain at their maximum throughout the summer. The location of Springwater Reservoir is included in **Map 2-15**.

The second water control structure is located just downstream of Springwater Reservoir in Bradley's Creek, and is relatively insignificant in terms of watershed hydrology. It is an uncontrolled spillway structure with 3 m of available head.

2.10 Surface Water Quality

Catfish Creek drains a clayey till plain and has relatively low natural base-flows. Upper Catfish Creek has intermittent flows during periods of low precipitation. The water quality in Catfish Creek reflects the physiography of the watershed and is likely highly variable as a result of significant rainfall or snowmelt events. Water quality is also reflective of the land use in the watershed. Although the predominant land use is rural / agricultural, the towns of Aylmer and Springfield can also influence the quality of Catfish Creek through urban stormwater and municipal wastewater discharges. Agricultural land-use within the watershed such as row cropping, tile drainage and livestock access to the creek can contribute to increased stream flows but it can also contribute to the high nutrient concentrations seen in the creek throughout the watershed.

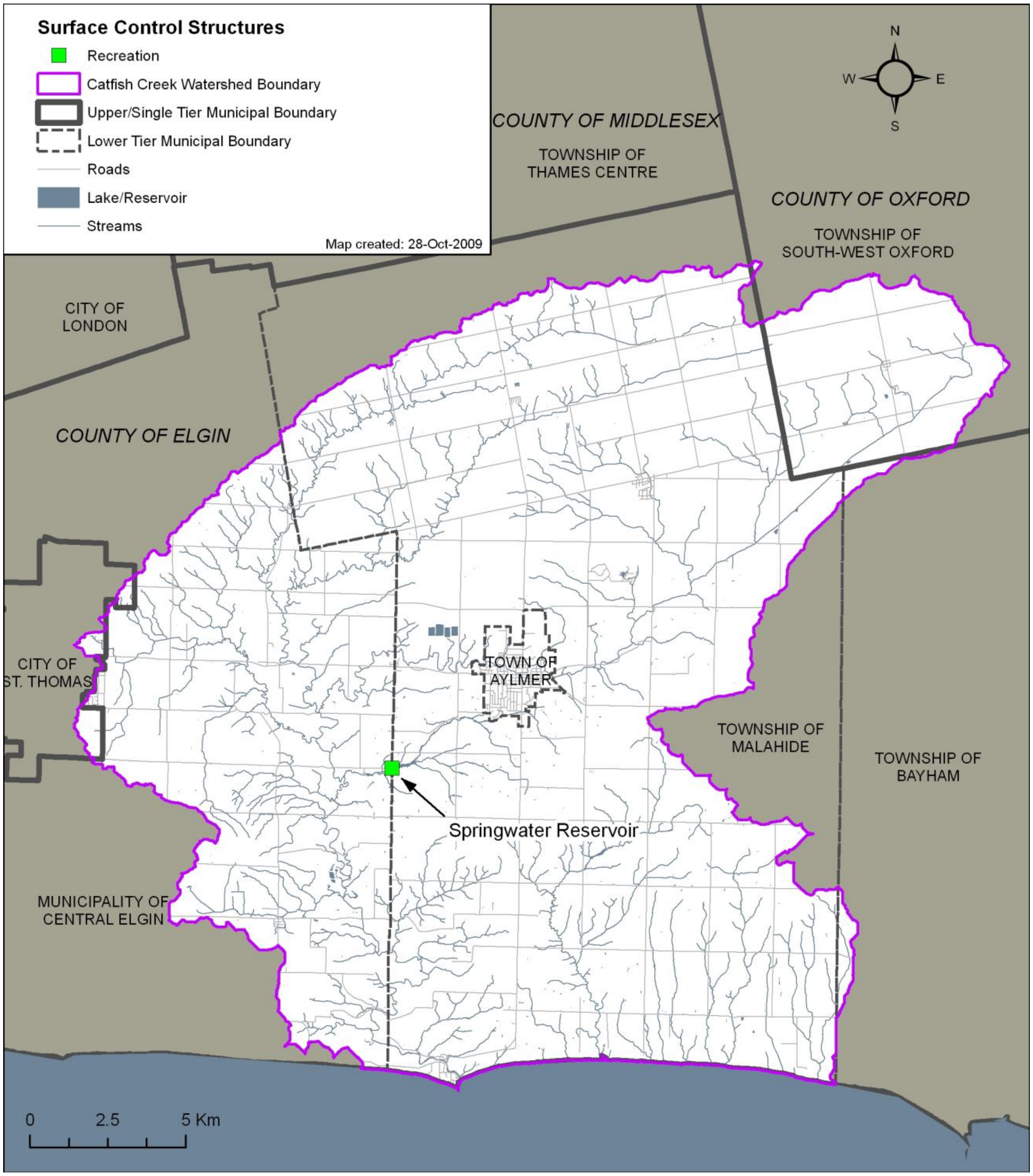
In 2018, a Watershed Report Card was completed for the Catfish Creek Watershed. The watershed report card provides a snapshot of current conditions in the Catfish Creek watershed and helps to identify environmental issues that need to be protected, restored or managed. Catfish Creek Conservation Authority prepared the report card using data collected from 2014 to 2018.

The following describes the general surface water quality conditions found in Catfish Creek. The observations are based on data collected as part of the Catfish Creek Watershed Report Card (2018).

Concentrations of phosphorus and Escherichia coli (bacteria) were measured at Ontario Ministry of the Environment, Conservation and Parks and Catfish Creek Conservation Authority stations. Benthic invertebrates (small aquatic animals living in the sediment) were also identified. The type and number of these animals are measures of water quality.

Surface water quality has improved within the main branch of the Catfish Creek branch, however the surface water quality of Silver Creek has worsened (CCCA, 2018).

Map 2-15: Catfish Creek Watershed Surface Water Control Structures



2.11 Aquatic Habitat

The location of cold, cool and warm water aquatic habitats in the Catfish Creek are shown on **Map 2-16.** Human activities can have a dramatic impact on aquatic habitats, which are defined generally by the temperature of the water. Cold water habitats can be impacted by deforestation of river and stream banks, thereby reducing the amount of shade and increasing the temperature of the water.

There is limited information available on how specific aquatic habitats have been impacted by anthropogenic factors in the Catfish Creek watershed. Generally, water quality conditions are described according to chemical and physical characteristics of stream water. However, biological indicators such as benthic macroinvertebrates and fish species should also be used in conjunction with chemical and physical characteristics to further describe the overall health of a watershed. Programs that monitor surface water (PWQMN) and ground water (PGMN) quality, and benthic macroinvertebrate sampling can be used to assess the health of aquatic habitats (Evans, 2007).

The predominant historical impacts leading to changes in aquatic habitats were the deforestation and removal of wetlands that took place after the settlement of the area by European settlers, and also the subsequent agricultural utilization of large areas of the watershed. Prior to settlement, approximately 98 percent of the land was covered by forests. The forest acted as a reservoir for summer rains and winter snowfalls. The clearing of these trees and wetlands eventually led to the dissipation of water storage, fall of the water table, and the shrinking of Catfish Creek. The hydrologic regime of the watershed changed from a steady, even flow of water year-round into a more seasonal rhythm. Flooding continues to be an intermittent problem, partly because of the seasonal flows of the creek.

The clearing of forests and draining of wetlands contributes to the warming of surface water flows and decreased water quality. Losses of forests and wetlands can also lead to degraded aquatic habitat through reduction in recharge contributing to reduced baseflows, increased erosion, loss of filtration of nutrients and sediments, and reduced shade, which can warm streams.

Land uses including intensive agricultural production, tile drainage, and urban development, wastewater treatment plant effluents, and the underlying geology and topography in Catfish Creek likely have all contributed to the degradation in water quality and aquatic habitats found in the watershed (Evans, 2007).

Watercourses in the northern section of the watershed, which bisect the Ekfrid Clay Plain, tend to be warm water fish habitat. Extensive clearing of woodlots, riparian vegetation and wetlands have adversely impacted fish communities and habitat in this region. Data collected as part of the Department of Fisheries and Oceans (DFO) Municipal Drain Classification Project (Catfish Creek Conservation Authority and Department of Fisheries and Oceans, 2002) have confirmed the presence and distribution of similar fish communities in the Catfish Creek watershed.

In the lower part of the watershed, the number of dams and online ponds used for irrigation could also negatively affect the natural base-flow and temperatures in some streams. In general, base flow within lower Catfish Creek is higher relative to the rest of the watershed, which could be the cause for lower nutrient concentrations in that part of watershed. Generally, water quality within lower Catfish Creek tends to be better relative to that found upstream (Evans, 2007).

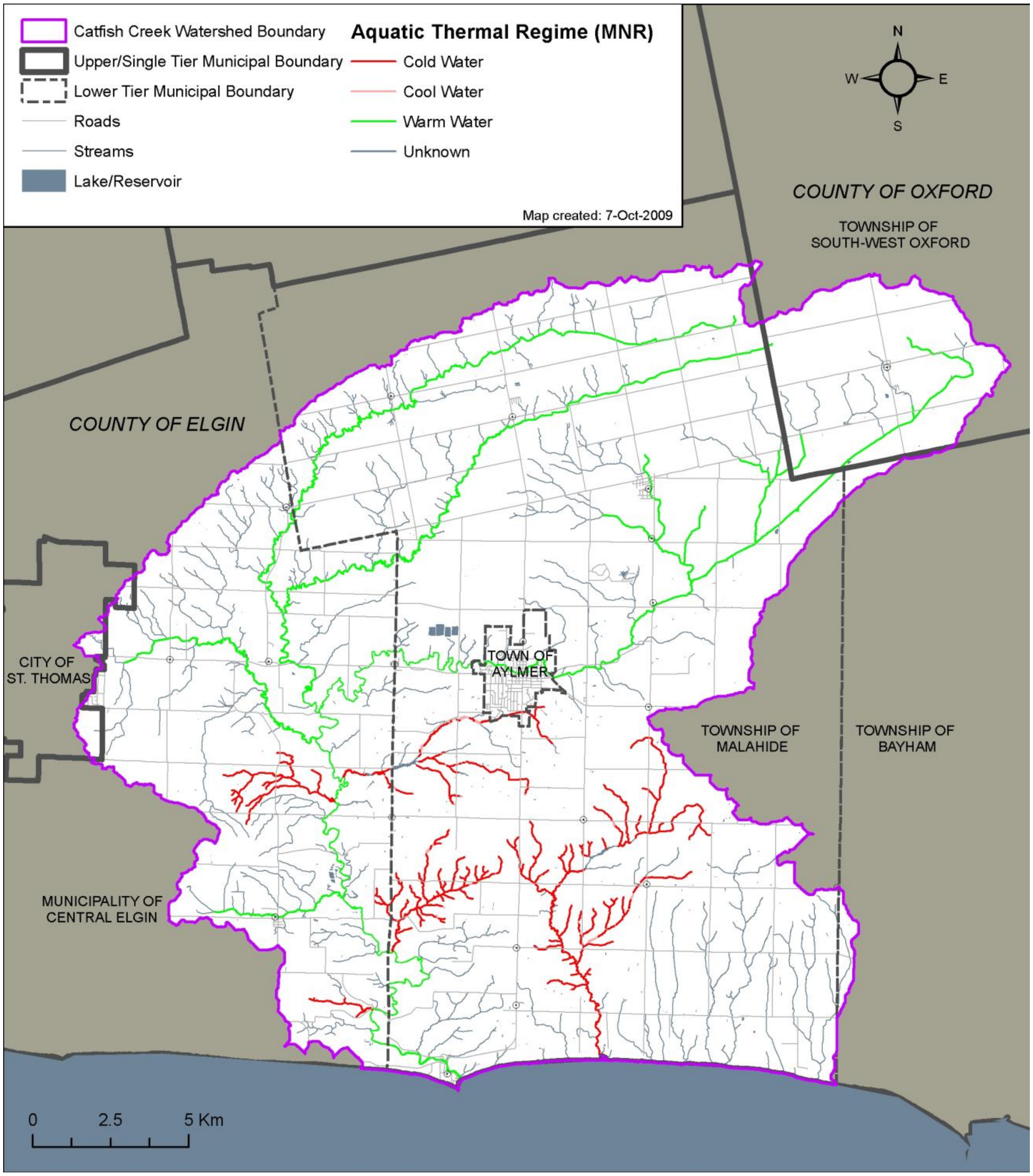
The District Fisheries Management Plan identified and lists four watercourses that exhibit coldwater characteristics. Three streams, Bradley Creek, Burnt Mill Creek and Tributary Creek, outlet to the main branch of Catfish Creek. The fourth includes the main branch of Silver Creek and numerous unnamed tributaries of Silver Creek, which outlet directly to Lake Erie. The majority of these coldwater systems are associated with deeply incised valleys that bisect portions of the Norfolk Sand Plain. The interaction of groundwater discharge and the effects of shade associated with the extensive forest cover in the ravines all contribute to the cooling of water.

Data Gaps

Water quality monitoring has historically focused on characterizing the chemical and physical attributes of the watershed. However, the utility of the data has been compromised by inconsistencies in the number and location of sites being monitored, and the sampling frequency due to time and funding restraints.

Routine monitoring of benthos in the watershed has not occurred on a regular basis, thereby limiting the possible analysis of macroinvertebrate communities.

Map 2-16: Aquatic Habitat



2.12 Species at Risk

A list of species known to be threatened, endangered, extirpated or of special concern the Catfish Creek watershed are listed below (2013).

Threated Species

- Amphibians - Fowler's Toad
- Birds - Whip-poor-will, Chimney Swift, Least Bittern
- Fish - Lake Sturgeon, Eastern Sand Darter, Lake Chubsucker, Spotted Gar
- Mammal - Grey Fox
- Molluscs - Mapleleaf Mussel
- Plants - False Rue-anemone, American Water-willow, Crooked-stem Aster
- Reptiles - Blanding's Turtle, Eastern Hog-nosed Snake

Endangered Species

- Birds - Acadian Flycatcher, Prothonotary Warbler, Pugnose Shiner
- Mammals - Mountain Lion or Cougar, American Badger
- Molluscs – Fawnsfoot
- Plants - American Chestnut, Eastern Flowering Dogwood, Small Whorled Pogonia, Butternut, American Ginseng
- Reptiles – Spotted Turtle, Eastern Foxsnake

Extirpated

- Birds - Greater Prairie-Chicken
- Plants - Spring Blue-eyed Mary

Special Concern

- Birds – Black Tern, Common nighthawk, Olive-sided flycatcher, Cerulean Warbler, Bald Eagle, Yellow-breasted Chat, Red-headed Woodpecker, Louisiana Waterthrush, Canada warbler, Hooded warbler
- Fish – Northern Brook Lamprey, Silver Chub, Silver Shiner
- Insects – Monarch, West Virginia White,
- Mammals – Woodland vole

- Plants – Green Dragon, Blue Ash, Broad Beech Fern
- Reptiles – Snapping Turtle, Northern Map Turtle, Milksnake, Eastern Ribbonsnake

2.13 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 physical geography of the area. 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 amount of forest cover and extent of wetlands in a watershed can impact both surface water and groundwater quality, as well as surface water flows and the rate of groundwater recharge.

The predominant land use in Catfish Creek watershed is agriculture, given the fertile soils of the Norfolk Sand Plain. This has led to extensive deforestation and draining of wetlands to increase agricultural production. The relatively flat terrain in the northern portion of the watershed offers little soil infiltration and has caused the creation of extensive drainage networks for agriculture. As a result much of the area has been tiled and many watercourses re-channelized, thereby changing the natural drainage characteristics of the sub-watershed. Agriculture in the lower and eastern portions of the watershed is heavily reliant on irrigation, given the little runoff and high groundwater recharge characteristic of the Norfolk Sand Plain.

The impact of the urban development in the Catfish Creek watershed is reflected by the increase in phosphorus levels downstream of Aylmer and the reported algae blooms and poor water colour downstream of the Aylmer sewage lagoons during times of discharge. These algal blooms may be indicating that the creek does not have the assimilative capacity for the bi-annual discharge from the sewage lagoons. However, further investigations are needed to determine if this is the case.

The Catfish Creek watershed has relatively low natural base-flows, and areas within the upper portion of the watershed have intermittent flow during dry seasons. This phenomenon is amplified by the numerous tile and municipal drains and the impervious soils, which do not allow for sufficient recharge within the region. Other land-use practices such as the increased number of dams and online ponds for irrigation found within the lower sub-basin could also be negatively affecting the natural base-flow in some creeks (e.g. Silver Creek).

2.14 Summary of Watershed Characterization Peer Review

The descriptions in this section of the Assessment Report are excerpts or summaries taken from the Catfish Creek Watershed Characterization Report (Glauser et al, 2008). The Characterization Report is based on the best available information on the watershed at the time of writing. The components of the Characterization Report were based on the requirements of technical guidance documents provided by the Ontario Ministry of the Environment (Module 1, the Watershed Characterization Technical Guidance, April 2006).

In 2007, the draft Characterization Report was reviewed by a Peer Evaluation Committee made up of conservation authority experts in hydrology, hydrogeology and water quality. The peer evaluators reviewed the draft reports for consistency with the requirements of the MOE Technical Guidance modules, which have since been replaced by the Assessment Report: Technical Rules under Ontario Regulation 287/ 07 (O.Reg. 287/07).

Comments provided by the Peer Evaluation Committee that referred to requirements of the Assessment Report: Technical Rules were taken into consideration, where data was available, in the development of Section 2 of the Catfish Creek Assessment Report.

2.15 Watershed Characterization Data Gaps

The following data gaps have been identified in the Watershed Characterization component of the Assessment Report:

- 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 amendment to the Assessment Report.
- Location 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.
- Location of monitoring locations 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.

2.16 Section Summary

- The Catfish Creek watershed is located in the heart of the Carolinian zone in southwest Ontario and covers an area of approximately 490 km^2 draining to Lake Erie.
- Much of the land of the watershed is used for agriculture with the Town of Aylmer being the main urban centre.
- The watershed is broken up into four subwatersheds: West Catfish, Catfish Above Aylmer, Lower Catfish Creek and Silver Creek.

- West Catfish and Catfish Above Aylmer are largely comprised of low relief tight soils with high surface runoff and little soil infiltration. Stream flows are flashy with high flows following storm events and low baseflow.
- Lower Catfish and Silver Creek contain areas of sandy soils with little runoff and high groundwater recharge. Groundwater discharge through the incised river valleys contributes to baseflow and generally improved water quality.
- The main physiographic regions within the Catfish Creek watershed are the Mount Elgin Ridges, the Ekfrid Clay Plain, and the Norfolk Sand Plain.
- The watershed is underlain by a series of gently dipping sedimentary rocks overlain by unconsolidated sediments of variable thickness and porosity.
- The primary aquifer is a broad shallow unconfined sand and gravel aquifer located between Aylmer and Lake Erie. Deeper confined overburden aquifers are located in the central portions of the watershed.
- Overburden aquifers are the main source of water for private supplies. Bedrock aquifers are rarely used for water supply because of the sufficient overburden groundwater resources in the watershed.
- Extensive deforestation and draining of wetlands has contributed to the warming of surface water and the degradation of water quality in parts of the watershed.
- Fisheries are limited by factors including reservoir management practices; the fragmentation of habitat and water quality impairment resulting from in-stream barriers; maintenance of environmentally sensitive areas; watercourse alterations for urban and rural development; and agricultural practices.
- The water quality in Catfish Creek reflects the physiography and land use in the watershed.
- Surface water quality tends to be most impaired in the Silver Creek subwatershed. The main Catfish Creek surface water quality has improved since the last reporting period.

3.0 WATER QUANTITY RISK ASSESSMENT

A Water Budget is an understanding and accounting of the movement of water and the uses of water over time, on, through and below the surface of the earth.

The Water Quantity Risk Assessment provides a framework to evaluate the reliability of surface water intakes or wellheads in the context of the local watershed. The objective of the framework is to help managers identify: 1) drinking water sources which may not be able to meet current or future demands and 2) the drinking water threats contributing to the water quantity problem. The risk assessment is carried out using three tiers that have been designed to minimize the amount of water budgeting work needed for wells and surface water intakes that are not under hydrologic stress.

A water budget study and Tier 2 stress assessment was carried out for the Catfish Creek watershed as part of a larger study for Catfish Creek, Kettle Creek, and Long Point Region. Because the study began as a more detailed Tier 2 study in 2005, no separate studies were completed at the Conceptual Understanding and Tier 1 assessment stages. The results of the Catfish Creek Water Budget and Tier 2 Stress Assessment are summarized in this Assessment Report.

The Catfish Creek water budget and Tier 2 stress assessment are documented in two reports: *Long Point Region,* Kettle Creek and Catfish Creek Integrated Water Budget – Final Report, April 2009 and Long Point Region, Catfish Creek and Kettle Creek Tier 2 Water Quantity Stress Assessment – Final Report, May 2009.

3.1 Tier 2 Water Budget

The Tier 2 Water Budget and Water Quantity Stress Assessment were completed by AquaResource Inc. as part of a larger suite of studies to increase the understanding of water pathways in the Catfish Creek Watershed. The following provides a summary of the reports and tools which comprise of the larger suit of studies that document the full Water Budget as given in this Assessment Report:

- Long Point Region, Kettle Creek and Catfish Creek Integrated Water Budget (AquaResource, 2009a): conceptual water budget, integrated water budget including quantity and movement of water within and across subwatersheds

- Long Point Region, Kettle Creek and Catfish Creek Tier 2 Water Quantity Stress Assessment (AquaResource, 2009b): Water quantity stress assessment.

- Water Use in the Catfish Creek Watershed (Bellamy & Wong, 2005a): water use.

- Westward Expansion of the Norfolk GW model for the Catfish and Kettle Creek Watersheds (WHI, 2007): groundwater quantity and flow assessment and water levels.

- Catfish Creek Watershed Hydrologic Model (Schroeter & Associates, 2006): surface water quantity and flow assessment and recharge abstraction.

- Catfish Creek Watershed Characterization (Gauser et al, 2008): describe the physical and human characteristics of the watershed.

- Norfolk County Groundwater Flow Model (WHI, 2003): groundwater quantity and flow assessment and water levels.

The Integrated Water Budget Report was completed using a set of water budget tools (groundwater flow and hydrologic numerical models) . To simulate surface water flows and partitioning of precipitation, a continuous hydrologic model for the Catfish Creek watershed was built using the Guelph All-Weather Sequential-Events Runoff (GAWSER) (Schroeter & Associates, 2006). Hydrologic modelling included an enhanced approach to incorporating water takings for agricultural water use and was able to simulate stream flows that reflect seasonal hydrologic processes. To simulate groundwater flows, a regional-scale groundwater flow model (FEFLOW (Finite Element Subsurface Flow & Transport Simulation System)) was developed and calibrated to available water level and stream flow data. The regional groundwater flow model was designed to represent average annual groundwater flow conditions, with particular focus on volumetric flow from one subwatershed to another. Together these modelling tools provide a physical means of quantifying flows through the system for determining available water resources in the Study Area.

Significant efforts were undertaken to better quantify and characterize the consumptive water demand throughout the Study Area. The water demand characterization completed in this study included efforts to verify Permit-To-Take-Water (PTTW) information, gathering “actual pumping” data, estimating agricultural demand based on discussions with the farming community, validating actual use information through calibration of the surface water model, and gathering relevant information contained within the Ministry of the Environment's Permit to Take Water (PTTW) paper files. Improved understanding of water demand provides an enhanced ability to characterize the water demand throughout the Study Area.

The Tier 2 Water Quantity Stress Assessment (AquaResource, 2009b) was prepared as a structured means of evaluating the degree of potential water quantity stress throughout an area by comparing the volume of water demand to that which is practically available for use. The results of stream flow and groundwater flow modelling and water demand estimates from the Integrated

Water Budget were incorporated into the Tier 2 Water Quantity Stress Assessment.

3.1.1 Methods of Analysis Applied to Water Budget Data

The methods of analysis for the Water Budget are discussed in detail throughout at the appropriate water budget sections. The main methods used in the Water Budget include complex numerical modeling, watershed characterization, analysis of continuous long term data sets, analysis of current data sets, field observations, and verification of data sets and model output. The Water Budget and Water Quantity stress assessment were carried out based on four subwatersheds as shown in **Map 2-2** and listed below**.**

- West Catfish Subwatershed – no municipal drinking water system
- Catfish Above Aylmer Subwatershed – Brownsville drinking water system
- Lower Catfish Subwatershed – no municipal drinking water system
- Silver Creek Subwatershed – no municipal drinking water system

3.2 Water Use

Water use is expressed in two ways: the amount of water pumped and the amount of water consumed. Consumed water is the amount of water pumped and not returned to the source from which it was pumped.

The amount of water pumped was determined by contacting municipalities for information on public water supplies, surveying non-agricultural Permit-To-Take-Water holders, utilizing Statistics Canada data to estimate rural domestic and agricultural water use, reviewing Permit-To-Take-Water information from the Ministry of the Environment including the Permit-To-Take-Water database and Permit-To-Take-Water paper records at the Ministry of the Environment offices, and running an irrigation demand model. The seasonality of a water taking sector was considered when estimating the annual volume of extracted water.

The amount of water consumed was determined by applying a consumptive factor to each taking based on the specific purpose of the taking, while taking into account the source of water and the return of waste water. Specific consumptive use factors are based on work by AquaResource (2005) with modifications to agricultural water use based on Isidoro et. al. (2003) and comments from the peer review committee.

There are seven water use sectors active within Catfish Creek watershed. **Table 3-1** ranks the seven sectors by their proportion of total demand.

Table 3-1: Top Water Users in the Catfish Creek Watershed (Bellamy & Wong, 2005a)

Rank	Purpose	Takings (m^3/ year)	Percentage of Total Demand
1	Agricultural Irrigation	2,551,000	42%
2	Municipal Water Supply*	1,317,000	22%
3	Rural Domestic	1,026,000	17%
4	Agriculture (Livestock watering)	637,000	11%
5	Aquaculture	398,000	7%
6	Communal Water Supply	98,000	2%
7	Golf Course Irrigation	7000	0.1%

* including water use from Lake Erie

** amount of water pumped based upon reported takings in the MOE PTTW database and estimates

3.2.1 Municipal Systems

Brownsville (approximately 500 residents) has the only groundwater source for municipal water takings in the Catfish Creek watershed. All other municipalities receive their drinking water from Lake Erie from either primary or secondary water systems from the Elgin Area Primary Water Supply System intake in Lake Erie, located near Port Stanley. These communities include Aylmer (approximately 2,600 residents) , and smaller communities in Central Elgin and Malahide Townships. There are no municipal surface water intakes located within the Catfish Creek watershed.

The Brownsville municipal water supply system obtains its water from two groundwater wells (Well 5 and Well 6) shown on **Map 3-1**. Both wells are completed within a deep overburden aquifer, with Well 5 screened in a confined sand and gravel layer approximately 45 m below ground surface. Well 6 is also screened in a confined sand and gravel aquifer approximately 28 m below ground surface.

The system operates under a Permit to Take Water (PTTW 00- P- 1339) issued by the Ministry of the Environment. The system has a maximum permitted rate of 379 m^3/ day. Based on 2003 records from the County of Oxford, the average annual daily demand was 90.9 m^3/ day and the maximum day demand was 200 m^3/ day. The average monthly daily demand factor varied from 0.89 to 1.14.

3.2.2 Private Drinking Water Supplies

A total of 1,422 domestic wells are located in the Catfish Creek watershed official boundaries, with 15 (1%) of these wells being classified as bedrock wells and 1,395 (98%) as overburden wells. Bedrock wells are generally completed between 64 and 99 m below ground surface. The median bedrock well depth is 77.1 m, indicating that bedrock is deeply situated and may explain why there are few bedrock wells in this region used for domestic purposes. Domestic bedrock and overburden wells as given in the Ministry of the Environment's Water Well Information System (WWIS) are illustrated on **Error! Reference source not found.** and **Map 3-3** respectively.

Overburden wells are much more abundant, and are scattered throughout the watershed with clusters in the hamlet of Sparta and in Springfield. The median overburden well depth is 25.6 m, and well depths range from 3.7 to 96 m. The Norfolk Sand Plain touches the southern portion of this watershed, and this is where the most shallow overburden wells are located. Further from Lake Erie, the well depth increases as the sand plain gives way to the till plains.

Un-serviced domestic water use was estimated closely following methodology from the Grand River Water Use Study (Bellamy & Wong, 2005b). These 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 0.16 m^3/day. A per capita rate of 0.16 m^3/day 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 un-serviced per capita rate of 0.175 m^3/day. The estimates were pro-rated by area to the subwatershed areas with corresponding rural domestic demand calculated:

- West Catfish Subwatershed – 10 L/s
- Catfish Above Aylmer – 9 L/s
- Lower Catfish – 7 L/s
- Silver Creek 7 L/s

Due to appropriate concerns about poor water quality, this un-serviced domestic demand is almost exclusively obtained from groundwater. Therefore, it is assumed that all un-serviced 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.

3.2.3 Non Drinking Water Use

There are numerous Permits to Take Water within the Catfish Creek watershed. Permits are focused along the portion of the Norfolk Sand Plain that extends into Catfish Creek watershed. There are a total of 200 individual permits within the watershed and these permits extract water from 315 different locations (**Map 3-4**).

3.2.4 Permitted Rate

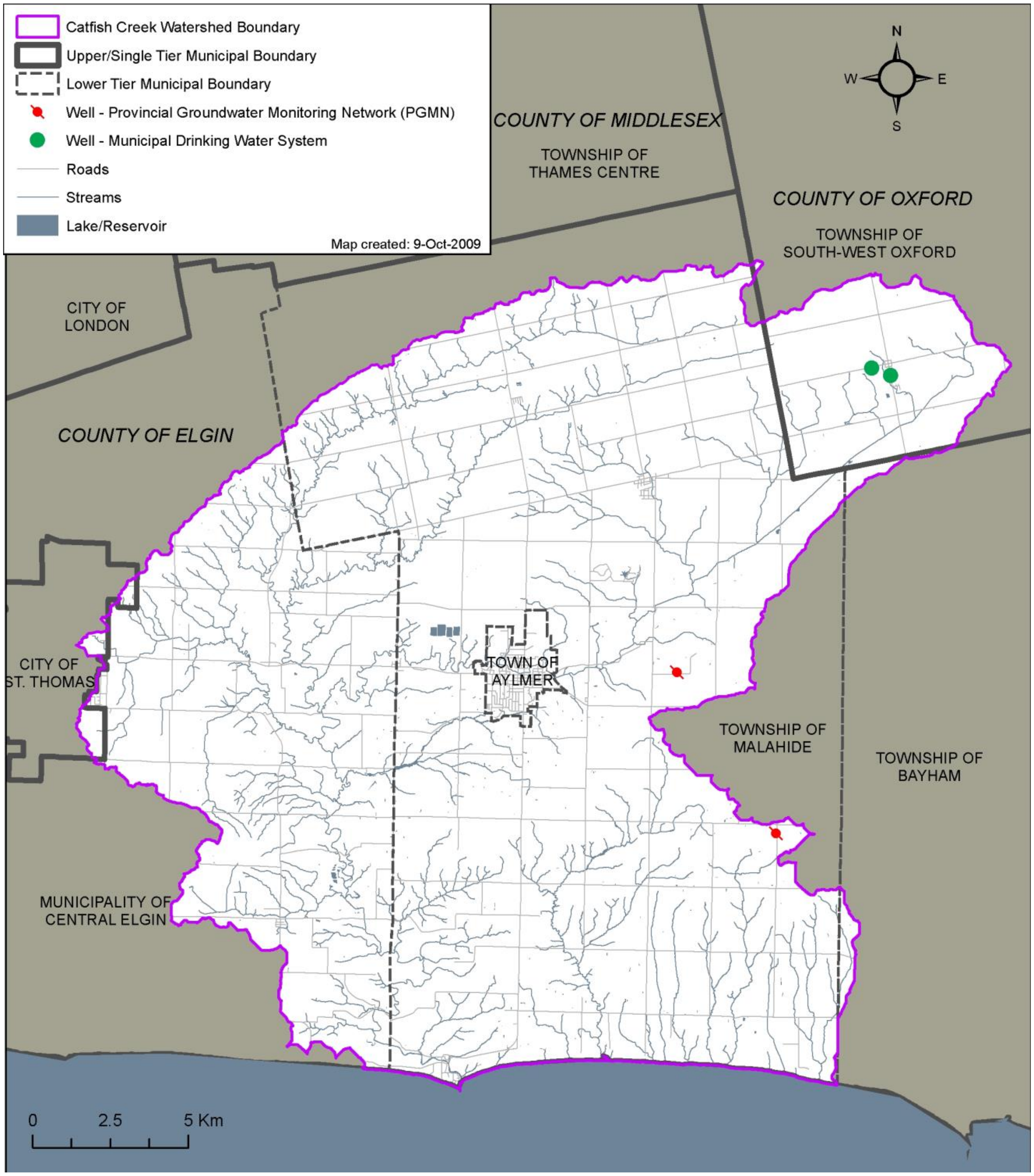
Permitted rates were obtained from the Ministry of the Environment Permit-To-Take-Water database. **Table 3-2** shows the total permitted rate of active permitted water takings categorized by subwatershed and source. The total permitted rates are 2.51 m^3/s for groundwater and 1.58 m^3/s for surface water sources, representing a total rate of 4.09 m^3/s.

Table 3-2: Permitted Rate

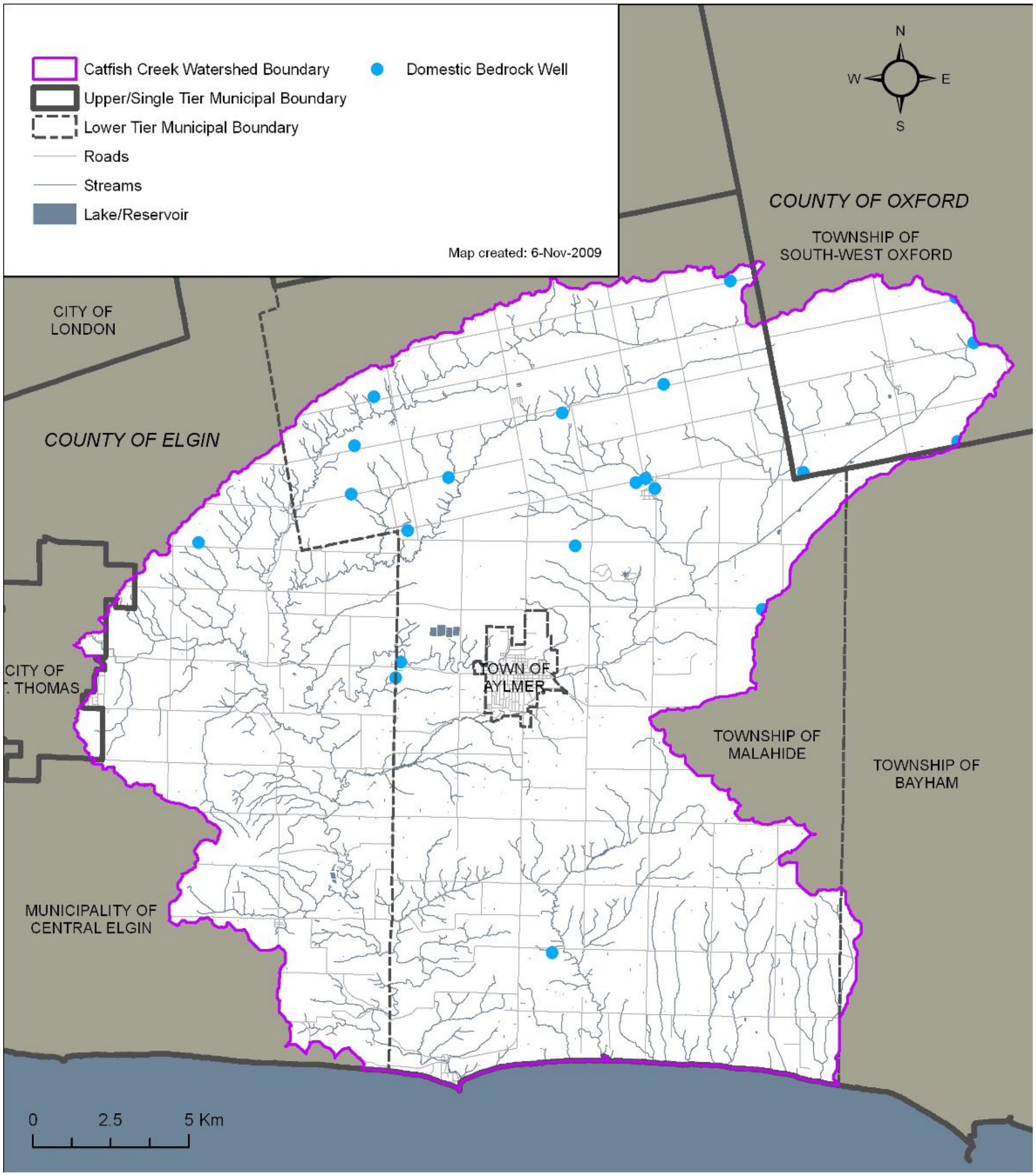
Subwatershed	Permitted (m^3/s) Groundwater	Permitted (m^3/s) Surface Water	Permitted (mm) Groundwater	Permitted (mm) Surface Water
West Catfish	0.01	0.00	2	0
Catfish Above Aylmer	0.23	0.15	51	33
Lower Catfish	1.31	0.72	402	220
Silver Creek	0.96	0.71	325	240
Total	2.51	1.58	780	493

Of all the permits within the Catfish Creek Watershed, 48% obtain their water from groundwater sources, while 35% rely on surface water bodies, and 17% from both groundwater and surface water supplies. Ninety percent of permitted water takings within the watershed are classified as agricultural irrigation, while permits for water supply and miscellaneous users make up the remaining 10% of permitted water takings.

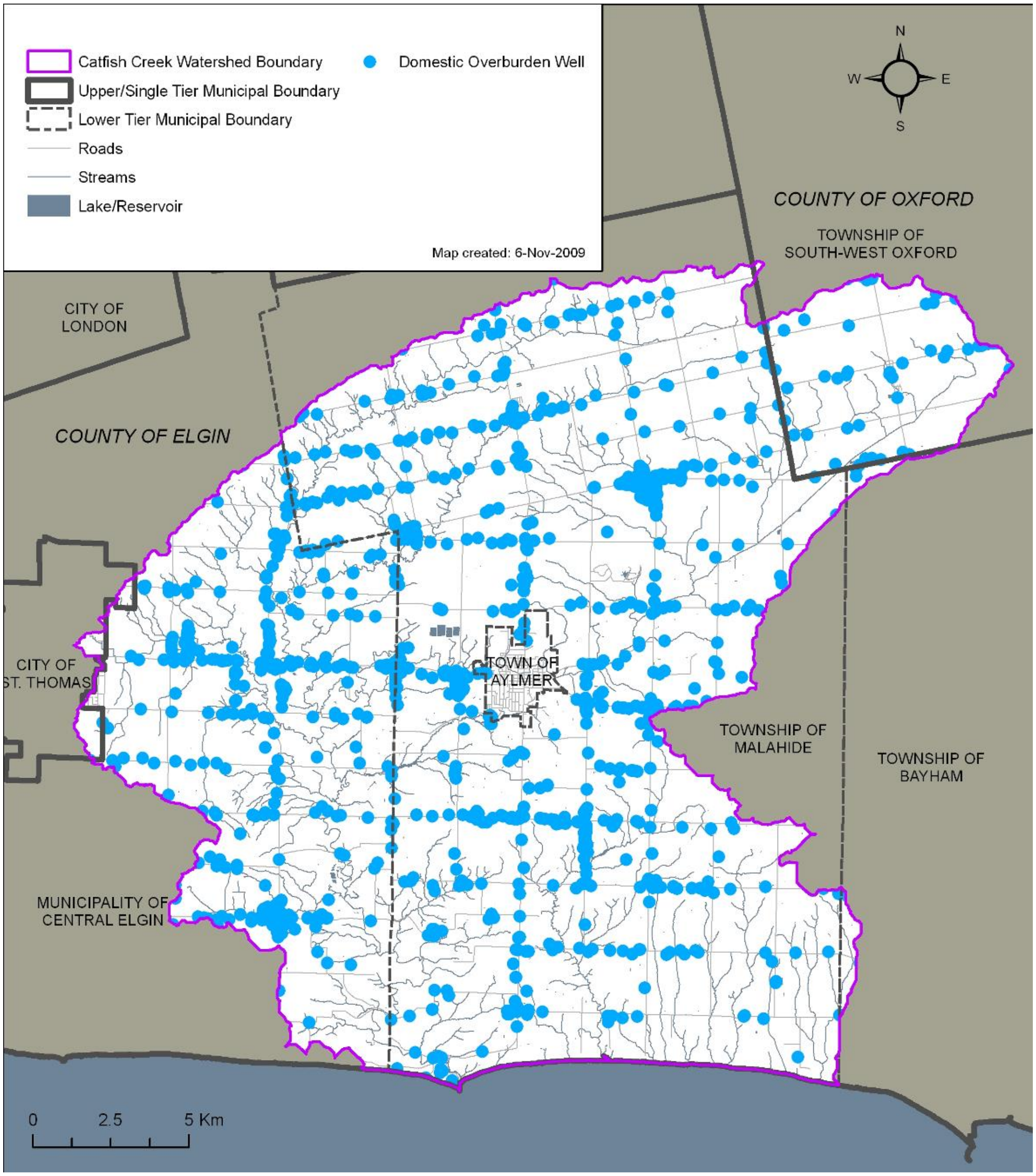
Map 3-1: Municipal Water Wells



Map 3-2: Domestic Bedrock Wells



Map 3-3: Domestic Overburden Wells



Of the 200 Permits-To-Take-Water within the Catfish Creek Watershed, four permits were identified that were considered to be active non-agricultural/ non-municipal water takers, and these permit holders were contacted via a phone survey. Two permit holders responded to the survey, and provided information that was used to refine the estimates of water use. The demand from the remaining two permits was estimated from information contained within the Permit-To-Take-Water database. Wherever possible, the reported water use rates, obtained from the phone survey and the Ministry of the Environment paper files, were used to quantify water demand.

3.2.5 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 & Wong, 2005b).

For agricultural permits, pumping rates were determined by applying an irrigation demand model (Bellamy & Wong, 2005a), which uses soil moisture generated by the hydrologic model to determine the occurrence of an irrigation event. The results show that irrigation is required, on average, 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 water use, the Grand River Conservation Authority developed a methodology to quantify non-permitted agricultural water use as part of the Grand River Water Use Study (Bellamy & Wong, 2005b). 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 sub-watershed basis:

- West Catfish Subwatershed – 6 L/s
- Catfish Above Aylmer – 7 L/s
- Lower Catfish – 2 L/s
- Silver Creek – 2 L/s

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 3-3 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 0.23 m^3/s pumped on an annual average basis, compared to 4.09 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 3-3: Average Rate Pumped

Subwatershed	Groundwater (m^3/s)	Surface Water (m^3/s)
West Catfish	0.01	0.00
Catfish Above Aylmer	0.02	0.01
Lower Catfish	0.05	0.04
Silver Creek	0.04	0.06
Total*	0.12	0.11

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

3.2.6 Consumptive Use

Table 3-4 summarizes the estimated consumptive demand (source scale) within each subwatershed. The consumptive nature of the non-permitted agricultural water use is a point of uncertainty. In the absence of such information, and to arrive at a conservative estimate of the consumptive non-permitted agricultural water demand, it was assumed that 100% of the water taken is consumed. Based on the relatively small volumes estimated within this category as compared to the total consumptive water demand, this assumption is considered acceptable.

The table shows the maximum and minimum monthly and average annual demand for both surface water and groundwater sources. On an average annual basis, 0.08 m^3/s of water is estimated to be consumed from aquifers and 0.07 m^3/s is consumed from rivers and creeks.

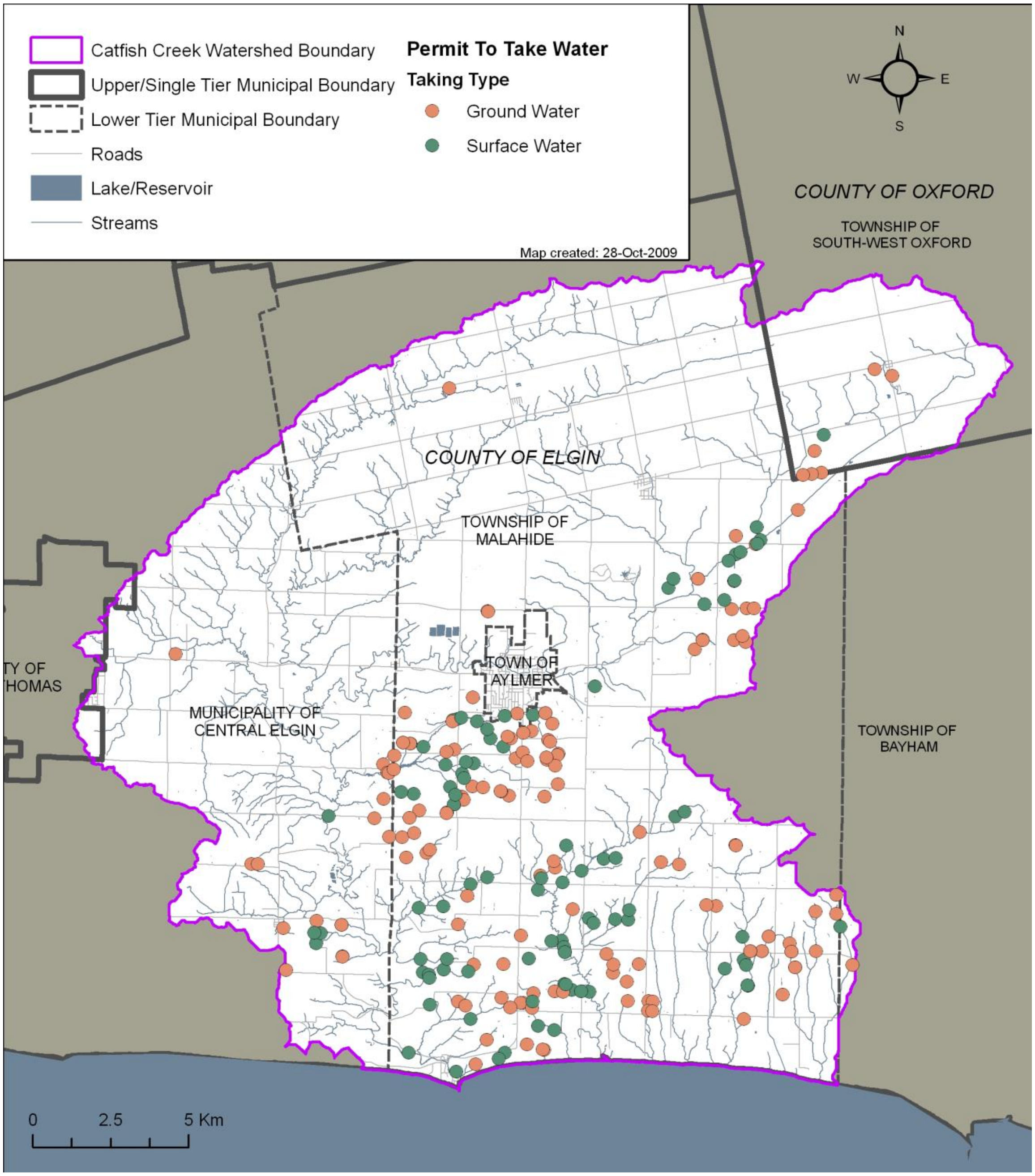
There is significant monthly variability within most subwatersheds in the Study Area due to the dominant agricultural sector, which removes water only during the summer months. Consumptive demands for groundwater are larger than for surface water due to the fact that groundwater takings are not recycled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

Table 3-4: Consumptive Demand (By Hydrologic Source Unit)

Subwatershed	Ground water Demand (m^3/s) Maximum Monthly	Ground water Demand (m^3/s) Minimum Monthly	Ground water Demand (m^3/s) Average Annual	Surface Water Demand (m^3/s) Maximum Monthly	Surface Water Demand (m^3/s) Minimum Monthly	Surface Water Demand (m^3/s) Average Annual
West Catfish	0.01	0.01	0.01	0.00	0.00	0.00
Catfish Above Aylmer	0.03	0.01	0.01	0.02	0.00	0.01
Lower Catfish	0.15	0.00	0.04	0.09	0.00	0.03
Silver Creek	0.10	0.00	0.02	0.08	0.00	0.03
Total	-	-	0.08	-	-	0.07

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.

Map 3-4: Permits to Take Water in the Catfish Creek Watershed



3.3 Surface Water Budget

3.3.1 Surface Water Model

The Catfish Creek Watershed continuous hydrologic model was built using the Guelph All-Weather Sequential-Events Runoff (GAWSER) model program. This modelling software is a physically-based deterministic hydrologic model that is used to predict the total stream flow resulting from inputs of rainfall and/ or snowmelt. The infiltration routine uses the Green-Ampt equation to partition precipitation into runoff and infiltrated water (recharge) . Potential evapotranspiration is calculated using the Linacre model. Evapotranspiration is then calculated by removing available water from depression storage and the soil layers until wilting point is reached. Modelling procedures are fully documented in the GAWSER Training Guide and Reference Manual (Schroeter & Associates, 1996). Runoff, recharge and evapotranspiration were then aggregated to the subwatershed scale for the water budget.

The Catfish Creek Watershed hydrologic model was built by Schroeter and Associates in 2006. The study area was modeled with 75 catchments, which range in size from 0.9 km^2 to 16 km^2, with an average size of 6.5 km^2. Each catchment was assigned to one of ten Zones of Uniform Meteorology (ZUMs) for climate data input. Climate data from Environment Canada's Atmospheric Environment Service (AES) climate station at Aylmer was used for the Catfish Creek Watershed hydrologic model, but was adjusted on an individual basis for each zone of uniform meteorology (ZUM) based on additional historic climate data sets from AES, the conservation authority and private sources (Schroeter and Associates, 2006).

Each catchment is comprised of nine hydrologic response units (HRU) , one impervious and eight pervious. The hydrologic response units were delineated by overlaying the quaternary geology with land cover information. Prior to the overlay, both the quaternary geology and land cover information were grouped into categories of similar hydrologic response, which then creates 18 hydrologic response units (HRUs) (**Table 3-5**). Then the eight pervious hydrologic response units that cover the most land area in each catchment, along with the impervious hydrologic response units, are applied to each catchment in the model.

Table 3-5: Summary of Catfish Creek Hydrologic Response Units

HRU	Description	Groundwater Reservoir
1	Impervious	Not Applicable
2	Wetland	Fast
3	Clay Till Low Vegetation	Fast
4	Clay Till Medium Vegetation	Fast

HRU	Description	Groundwater Reservoir
5	Clay Till High Vegetation	Slow
6	Silt Till Low Vegetation	Fast
7	Silt Till Medium Vegetation	Fast
8	Silt Till High Vegetation	Slow
9	Sand Till Low Vegetation	Fast
10	Sand Till Medium Vegetation	Fast
11	Sand Till High Vegetation	Slow
12	Sand Gravel Low Vegetation	Slow
13	Sand Gravel Medium Vegetation	Slow
14	Sand Gravel High Vegetation	Slow
15	Urban Clay	Fast
16	Urban Silt	Fast
17	Urban Sand	Slow
18	Urban Sand Gravel	Slow

Contributions from human sources were also modeled by including wastewater treatment plant outflow and agricultural water use. Wastewater treatment plant outflow from the Town of Aylmer was added as part of the baseflow from the catchment in which the outfall is located. Agricultural water use was included by creating a water demand hydrograph based on the irrigation demand model for each subwatershed and information from the permit to take water (PTTW) database. The demand hydrograph was input into the hydrologic model and deleted from the outflow of the subwatershed on a daily basis.

Initial calibration of the model to observed stream flow at all three historic gauges in the watershed was completed by Schroeter and Associates (2006) as part of the model building exercise. The model was recalibrated following the addition of agricultural water users. Recalibration focused on the average and median monthly flows as well as median and 90th percentile flows at the Catfish Creek at Sparta stream gauge.

3.3.2 Surface Water Budget

The surface water budget components are determined from the hydrologic model (precipitation, evapotranspiration, runoff and recharge) and from the water use study for surface water takings. Surface water budget components have significant temporal variability. Results presented are based on average annual conditions for the 1980-2004 period and it is recognized that these results may vary significantly based on climate conditions. The analysis does not account for changes in water storage that would occur from one time period to the next.

The average annual precipitation is approximately 914 mm/year. The hydrologic model has estimated average annual evapotranspiration to be 573 mm/year, which compares favourably with the evapotranspiration estimates included within the Water Resources of Ontario (MNR, 1984) estimate of 550-600 mm/year. The average runoff rate across the Study Area is 185 mm/year, with an average groundwater recharge rate of 157 mm/year. Water taken from watercourses, that is not immediately returned to the surface water system, is approximately 0.07 m^3/s, or 5 mm/year. While precipitation and evapotranspiration rates have some degree of spatial variability, runoff and recharge rates have the most significant spatial variability due to changing soils, surficial geology, and land cover.

Many elements of the water budget modelling process using the hydrologic model are subject to uncertainty. Although the calibration process is performed in an attempt to reduce uncertainty, the model results and water budgets reflect the uncertainty in the input parameters as well as limitations in the modelling approach. The model is designed to reflect general characteristics of each catchment relating to land cover, climate, soils and vegetation, and stream and river hydraulics. Calibration is limited to the available stream flow data and does not include many of the smaller Lake Erie Tributaries.

3.4 Groundwater Water Budget

3.4.1 Groundwater Model

The steady-state groundwater flow model developed for the Long Point Region watershed, Catfish Creek Watershed, and Kettle Creek Watershed was developed using FEFLOW (Finite Element Subsurface Flow & Transport Simulation System). The model builds upon earlier work completed by WHI (2003, 2007). The original modelling effort was completed as part of the Norfolk County Groundwater Study (WHI, 2003). The Norfolk County model was extended by WHI (2007) to encompass the Catfish Creek and Kettle Creek watersheds. The groundwater model is a regional flow model encompassing an area of approximately 4,000km^2 with 31 subwatersheds. It has six overburden/ unconsolidated layers, two bedrock layers and approximately one million nodes.

The mesh designed by WHI (2007) was redesigned to enhance the ability to conform to key features. The horizontal distribution of node points (discretization) was redesigned to incorporate all major river features as well as permitted pumping locations and to conform to all subwatershed boundaries.

The number of vertical layers applied within the current version of the model was also modified from that developed by WHI (2007). The WHI version of the model contained four bedrock layers (one weathered and three un-weathered) that extended more than 500m into the underlying bedrock (with ~ 100m overburden). A review of available borehole data and reflection from experienced hydrogeologists suggested that the active, fresh-water portion of the bedrock was limited to the upper 50m (Theo Beukeboom, pers. comm.) . As a result, flow through the bedrock layers was simulated using two layers (one weathered and one un-weathered) with a thickness of 5m and 50m respectively. Overburden layers were not modified from the earlier version. The model was developed to have layers follow a series of hydrostratigraphic units (WHI, 2007). However, a review of this representation as well as the stratigraphic sequences in the area suggests that more work would be needed to explicitly delineate and represent physical hydrostratigraphic units. Consequently, the overburden layers are considered to represent a means of subdividing the unconsolidated sediments, without a direct link to specific stratigraphic units. To compensate for this, properties within each model layer are assigned based on the lithology of the surrounding boreholes.

Recharge estimates were taken from the hydrologic model and applied to the groundwater model to provide a connection between the surface and groundwater numerical models. Streams and rivers within the groundwater model were given specified head values. Stream stage was taken from the available Digital Elevation Model. To determine appropriate lateral boundary conditions for the model, water level trends around the perimeter of the model were carefully reviewed. Where water level trends suggested that natural flow boundaries exist (groundwater divides), a no-flow boundary was applied. In other areas where water level trends indicated cross-boundary flow, fixed water level boundary conditions equivalent to the equipotential heads in those layers were applied. The review process also included evaluation of all cross-boundary flows to ensure that the direction and magnitude of cross-boundary flows was reasonable.

The best available data was used to determine the location, screened interval and pumping rate for wells. Reported “actual” pumping rates were used where available (municipal pumping wells and through surveys) . For other permits to take water, the consumptive use estimate for the source was applied. Non-permitted water takings are not represented within the model.

Initial overburden hydraulic conductivity estimates were derived based on borehole lithology records within each model layer, while bedrock values were applied to be consistent with values from previous studies. Initial estimates of hydraulic conductivity were subsequently modified through the model calibration process. Layer thicknesses, however, were not modified during model calibration. As a result, the calibration of the ability of the groundwater system to transmit flow was primarily accomplished by varying hydraulic conductivity.

Observed groundwater levels (head) and groundwater discharge (portion of stream baseflow) were used as calibration targets for the groundwater model. Water levels selected for use in calibration included those with high location reliability and with static water levels observed in the period 1980-onward (2450 well water levels) from the Ministry of the Environment water well information system. Only wells with Ministry of the Environment reliability codes of five or better were used. In addition to the water level calibration targets used, baseflow discharge estimates at 15 locations throughout the model domain for the 1980-2005 period were also used as calibration targets.

3.4.2 Groundwater Budget

The average annual groundwater budget for the Study Area is linked to the surface water budget by the recharge rate. Water taken from aquifers, that is not immediately returned to the groundwater system, is approximately 0.1 m^3/s, or 7 mm/per year. The groundwater model estimates average annual groundwater discharge to surface water features to be 2.69 m^3/s or 174mm/ year. Additionally, a net flow of approximately 0.52 m^3/s or 34 mm/ year flows into the Study Area from adjacent watersheds and 0.16 m^3/s or 10 mm/ year flows out of the area to Lake Erie.

Any model developed to represent a natural system is inherently a simplification of that system. One of the largest points of uncertainty in the groundwater flow model is in the geologic conceptual model. This uncertainty has led to the definition of numerical model layers that are neither representative of hydrostratigraphic conditions, nor are they uniformly distributed. A lack of borehole logs that penetrate to depth in this area exacerbate the uncertainty associated with the geologic conceptual model and the assigned hydraulic conductivities. Every effort was made to minimize the uncertainty, but results should only be viewed from a regional flow system scale.

3.5 Integrated Water Budget

This section presents the integrated water budget for the Catfish Creek Watershed. This integrated water budget considers average annual estimates of key hydrologic parameters relating to both surface water and groundwater resources, and the integration between the two.

Values reported are based on annual averages and may exhibit significant seasonal variation. Due to the regional perspective of this analysis, the subwatershed descriptions may lack local details that may have local hydrologic significance. Local scale interpretation and/ or models may provide differing results than those presented here averaged spatially and temporally. **Table 3-6, Table 3-7**, **Table 3-8** and **Table 3-9** summarize the water budget components for each of the subwatersheds in mm and m^3/s, respectively. **Table 3-10** describes the components of the water budget.

Table 3-6: Integrated Water Budget (mm/ year) for Surface Water System

Subwatershed	Precipitation	ET	Runoff	Recharge	Average Inflow	Average Outflow	Flow Yield	SW Taking
West Catfish	904	560	235	109	--	246	246	-1
Catfish above Aylmer	905	568	202	135	--	345	345	-2
Lower Catfish	931	586	142	203	837	1314	477	-9
Silver Creek	924	585	124	215	--	343	343	-9
Total Area	914	573	185	157	--	--	342	-5

Table 3-7: Integrated Water Budget (mm/ year) for Groundwater System

Subwatershed	Lake Erie Discharge	Outside watershed	Surface Water Discharge	Inter-Basin Transfer	Flow In Ratio
West Catfish	--	140	-77	-171	-27%
Catfish above Aylmer	--	-18	-169	53	28%
Lower Catfish	-3	-3	-344	156	76%
Silver Creek	-51	17	-149	10	-26%
Total Area	10	34	-174	--	---

Table 3-8: Integrated Water Budget (m3/ s) for Surface Water System

Subwatershed	Precipitation	ET	Runoff	Recharge	Average Inflow	Average Outflow	Flow Yield	SW Taking
West Catfish	4.26	2.26	1.11	0.51	--	1.16	1.16	0.00
Catfish above Aylmer	4.11	2.58	0.91	0.61	--	1.56	1.56	-0.01
Lower Catfish	3.03	1.90	0.46	0.66	2.72	4.27	1.55	-0.03
Silver Creek	2.74	1.73	0.37	0.64	--	1.02	1.02	-0.03
Total Area	14.14	2.85	2.85	2.42	--	--	5.29	-0.07

Table 3-9: Integrated Water Budget (m3/ s) for Groundwater System

Subwatershed	GW Taking	Lake Erie Discharge	Outside watershed	Surface Water Discharge	Inter-Basin Transfer	Flow In Ratio
West Catfish	-0.01	--	0.66	-0.36	-0.81	-27%
Catfish above Aylmer	-0.02	--	-0.08	-0.77	0.24	28%
Lower Catfish	-0.04	-0.01	-0.01	-1.12	0.51	76%
Silver Creek	-0.03	-0.15	-0.05	-0.44	0.03	-26%
Total Area	-0.10	-0.16	0.52	-2.69	--	--

Table 3-10: Summary of Water Budget Components

Parameter	Source	Description
Precipitation	Data Analysis / GAWSER	Climate data used to represent the precipitation over each of the subwatersheds is summarized by GAWSER.
Evapotranspiration	GAWSER	GAWSER estimates actual evapotranspiration for each hydrologic response unit (HRU).
Runoff	GAWSER	When the precipitation exceeds the infiltration capacity of a soil, overland runoff is created.
Recharge	GAWSER	GAWSER estimates the amount of groundwater recharge for each HRU.
Average Inflow	GAWSER	The total streamflow entering the subwatershed from upstream subwatersheds.
Average Outflow	GAWSER	The total average annual streamflow leaving the subwatershed. This includes any upstream inflows to the subwatershed as well as flow generated by the specific subwatershed in question.
Flow Yield	GAWSER	This component quantifies the amount of streamflow increase seen in the particular subwatershed, on an average annual basis. The value is the difference between the average inflow and the average outflow.
Surface Water Taking	Water Use Estimates	The amount of water taken from a surface water source and not immediately returned to that source. Includes estimates from permits as well as rural domestic and permit-exempt agricultural use.
Groundwater Taking	Water Use Estimates	The amount of water taken from an aquifer and not immediately returned to that source. Includes estimates from permits as well as rural domestic and permit-exempt agricultural use.
Lake Erie Discharge	FEFLOW	This component identifies groundwater flow through the boundary of the groundwater flow model at Lake Erie. This is representative of groundwater flux to Lake Erie.
Outside Watershed	FEFLOW	This component identifies groundwater flow through the boundaries of the groundwater flow model, except for Lake Erie. This is representative of groundwater flow out of, or into,

Parameter	Source	Description
		the Study Area. Negative flows indicate water leaving the basin, positive flows indication water entering the basin.
Surface Water Discharge	FEFLOW	This parameter quantifies the groundwater flux to rivers and streams in the particular subwatershed. Negative values indicate that flow is leaving the groundwater system to the surface water system
Inter-Basin Transfer	FEFLOW	The amount of groundwater flow to another subwatershed within the Study Area. Positive values indicate where the subwatershed is experiencing a net increase of groundwater flow from adjacent subwatersheds. Negative values indicate where the subwatershed is experiencing a net loss of groundwater flow to adjacent subwatersheds.
Flow In Ratio	FEFLOW	River discharge plus well extractions divided by recharge, minus one. This parameter is the ratio of groundwater discharge (river discharge + extractions) to the amount of recharge in a particular subwatershed. Where the value is negative, it indicates a percentage of recharge that is leaving the basin. Where the value is positive, it indicates how much water, with respect to existing recharge, is entering the subwatershed.

3.5.1 West Catfish Creek Subwatershed

The West Catfish Creek Subwatershed is located in the northwest portion of the Catfish Creek watershed, and the surficial materials almost exclusively comprise Port Stanley Till. A small pocket of sand & gravel is mapped in the southeast portion of the Subwatershed. The precipitation for this subwatershed (904 mm) is slightly below the average (914 mm) , and the estimated evapotranspiration (560 mm) is slightly below the average (573 mm) . Due to the low permeability surficial materials, surface runoff (235 mm) is higher than the average (185 mm) , and groundwater recharge is predicted to be lower (109 mm) than average (157 mm) .

Overburden aquifers are generally limited to pockets of granular material located within the Port Stanley and Tavistock Tills. Initially, it was thought these pockets were relatively isolated and disconnected, but modelling results indicate that some degree of connectivity may exist. Simulated groundwater discharge is generally minimal, with some reaches of locally significant discharge predicted to occur in the southwestern portion of the Subwatershed, where granular materials are present at surface. The modelling predicts a net groundwater outflow of approximately 0.15 m^3/s, which may be providing flow into the Lower Kettle Creek, Lower Catfish Creek or Catfish Creek Above Aylmer Subwatersheds.

Water demand within West Catfish is very low, with only 0.01 m^3/s of groundwater permitted and ~ 0 m^3/s of surface water permitted. Of total takings, including non-permitted uses, it is estimated that 0.01 m^3/s is pumped, and all of this is considered to be a consumptive demand.

3.5.2 Catfish Creek Above Aylmer

The Catfish Creek Above Aylmer Subwatershed drains the eastern portion of Catfish Creek, and predominantly comprises Port Stanley Till. Granular surficial deposits are mapped along the southeastern boundary of the subwatershed which is shared with the Big Otter Creek watershed area. Precipitation is estimated to be 905 mm, which is less than the area average of 914 mm. Evapotranspiration of 568 mm is estimated to be similar to the average (573 mm) . The predominance of low permeability materials within the subwatershed results in a surface runoff estimate (202 mm) slightly higher than the area average (185 mm) , and estimated groundwater recharge (135 mm) that is lower than the area average (157 mm) .

Singer et al. (2003) have described an extensive aquifer located within the central portion of the Catfish Creek watershed area. The Central Catfish Creek Aquifer has been identified in the Springfield area, as well as near Aylmer and to the east of Aylmer. Wells completed in this aquifer typically penetrate less than 10 m; however, some deeper wells have been found that log more than 20 m of continuous sand and gravel. This aquifer is mostly confined, except where it enters Malahide Township, and crosses several subwatershed boundaries. Singer et al. (2003) also described a local overburden aquifer in the Brownsville area, which is mostly confined, but not laterally extensive. Groundwater discharge is predicted to be moderate in the easterly portion of the Subwatershed. However, it should be noted that in this area, due to uncertainties with the conceptual hydrogeologic model, simulated groundwater levels are higher than observed. Due to this, the predicted groundwater discharge may be overestimated. There is an overall net groundwater inflow to this subwatershed, likely from the West Catfish Creek Subwatershed, approximately equal to 0.16 m^3/s.

Water demand within Catfish Creek Above Aylmer Subwatershed is moderate, with 0.23 m^3/s of groundwater permitted and 0.15 m^3/s of surface water permitted. It is estimated that all water uses, including non-permitted uses, pump an annual average rate equal to 0.03 m^3/s. Roughly 0.02 m^3/s is not returned to the source from which it was drawn and is considered consumed. This subwatershed contains the Brownsville municipal system.

3.5.3 Lower Catfish Creek Subwatershed

The Lower Catfish Creek Subwatershed consists predominantly of granular deposits, with isolated deposits of Port Stanley till. The average precipitation is 931 mm which is slightly higher than the area average precipitation (914 mm) . Average evapotranspiration is 586 mm which is slightly higher than the area average. Due to the prevalence of permeable surficial materials, surface runoff (142 mm) is lower than in the upper subwatersheds, and is also lower than the area average (185 mm) . Groundwater recharge for the subwatershed is estimated to be 203 mm, which is higher than the area average (157 mm) .

The primary groundwater aquifer is the Central Catfish Creek Aquifer, which described in **Section 3.5.2**. Extensive surficial granular deposits are also associated with numerous local unconfined aquifers. Simulated groundwater discharge is predicted to be very significant through the incised lower reaches of Catfish Creek. Approximately 1.1 m^3/s of discharge is predicted within Lower Catfish; however, due to uncertainties with the conceptual geologic model in the area, this value is uncertain. A moderate groundwater inflow of 0.5 m^3/s is expected to come from the two upstream subwatersheds.

Water demand within the Lower Catfish Creek Subwatershed is relatively high, with approximately 1.31 m^3/s of groundwater permitted and 0.72 m^3/s of surface water permitted. Of the total amount pumped, including non-permitted uses, it is estimated that 0.09 m^3/s is pumped on an annual average basis. Approximately 0.07 m^3/s of the pumped water is not returned to the source from which it came.

3.5.4 Silver Creek Subwatershed

The Silver Creek Subwatershed includes a number of tributaries and gullies that flow directly into Lake Erie. The granular deposits that exist in Lower Catfish Creek Subwatershed extend into this Subwatershed, and continue northeast, merging with the Norfolk Sand Plain. There are a few isolated deposits of Port Stanley Till. Precipitation for the Silver Creek Subwatershed is 924 mm, which is slightly higher than the area average of 914 mm. Evapotranspiration is estimated to be 585 mm, which is higher than the area average of 573 mm. The predominance of permeable surficial materials causes surface runoff (124 mm) to be significantly lower than the average (185 mm) , and recharge is estimated to be approximately 215 mm, which is higher than the average of 157 mm.

The Central Catfish Creek Aquifer, as described above, also extends into Silver Creek. The pervious surficial materials are reflected by local unconfined aquifers. Approximately 0.44 m^3/s of discharge is predicted to flow into Silver Creek with the majority of this discharge being received by a tributary of Silver Creek. The Silver Creek Subwatershed discharges a fairly minimal amount of flow to Lake Erie, 0.15 m^3/s.

Due to a high number of irrigation operations, water demand is significant within the Silver Creek Subwatershed. Approximately 0.96 m^3/s of groundwater is permitted, and 0.71 m^3/s of surface water is permitted. In total, it is estimated that approximately 0.10 m^3/s of water is pumped for anthropogenic purposes on an annual average basis, and 0.05 m^3/s is not returned to the original source.

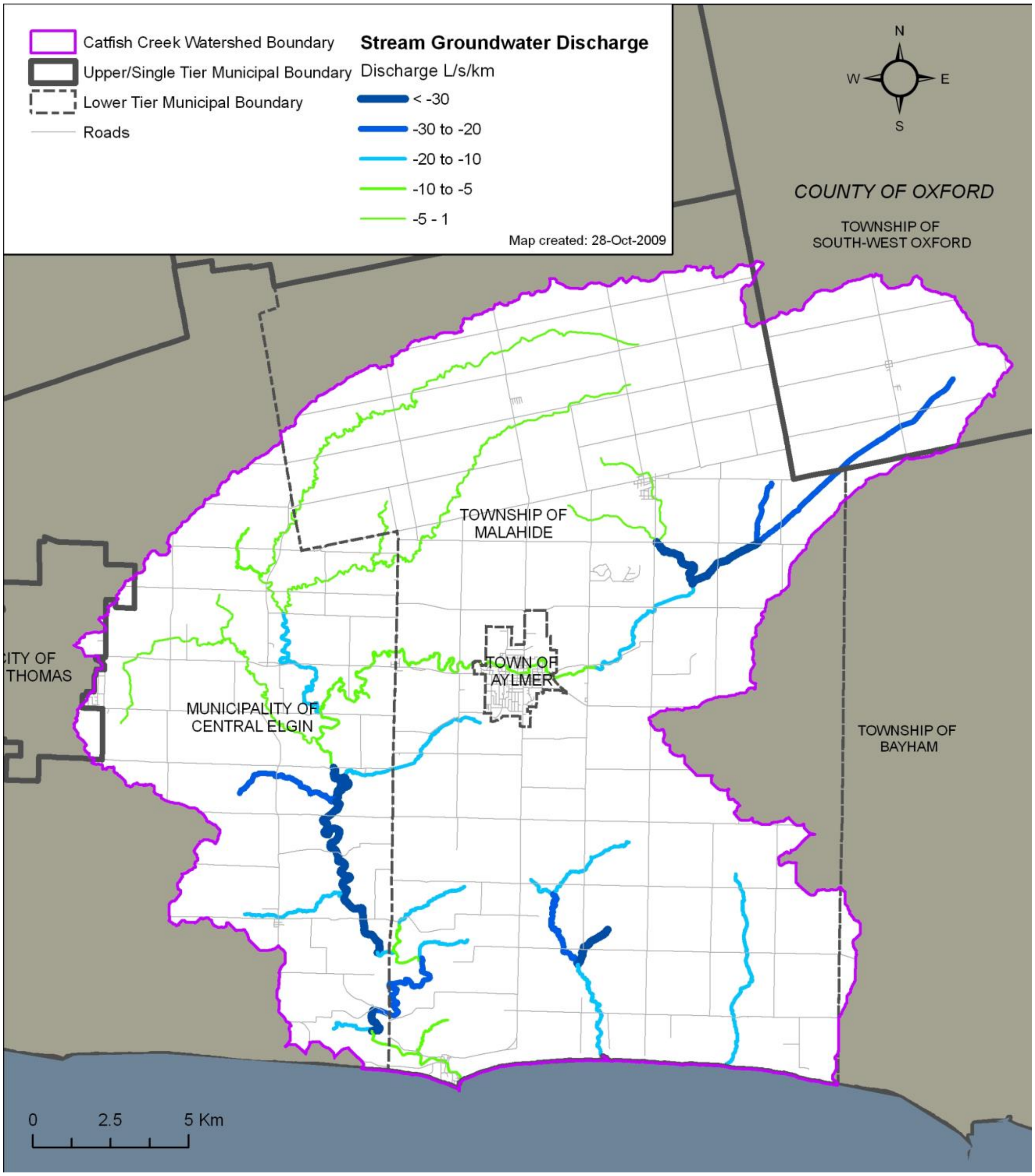
3.6 Interactions between Groundwater and Surface Water

The calibrated groundwater model provides a synthesis of available information that can be used to increase the understanding about the groundwater flow system and its interaction with the surface water system. **Map 3-5** presents the distribution of groundwater discharge flux to the streams and rivers throughout the Study Area. As is expected in an area of relatively low topographic relief, the majority of groundwater discharge occurs along major stream reaches, such as along the lower portion of Catfish Creek. The headwater regions primarily receive smaller discharge volumes with very low amounts in the upper reaches of the West Catfish Subwatershed.

Thick deposits of low permeability till located in the northern and eastern parts of the watershed inhibit the interaction between the groundwater and surface water systems. There are low baseflows during dry periods in the upper branches of Catfish Creek, which lie within the till plain. In the southern part of the watershed, surficial sands of the Norfolk Sand Plain are the dominant surficial sediments and stronger interactions between surface and groundwater are reported. Catfish Creek has eroded a deep valley into the overburden and intersects the water table allowing for discharge from groundwater to supply baseflows to the creek. Similarly, Silver Creek, located in the southeastern part of the watershed in the Norfolk Sand Plain, has flows supported by groundwater discharge. Most water courses in the southern part of the watershed are classified as coolwater with sustained baseflows indicating discharge from groundwater.

Inflow from surface water bodies into the groundwater system are not well understood in this area.

Map 3-5: Groundwater Discharge



3.7 Tier 2 Water Quantity Stress Assessment

All subwatersheds in the Catfish Creek Watershed were evaluated at the Tier 2 level for water quantity potential stress for both groundwater and surface water Subwatersheds with either a 'moderate' or 'significant' potential for stress and a municipal drinking water system would then be recommended to have a more detailed Tier 3 Water Quantity Risk Assessment conducted.

Being classified as having a Moderate or Significant potential for stress does not necessarily imply that a subwatershed is experiencing local hydrologic or ecologic stress. This classification indicates where additional information is required to understand local water supply sustainability and potential cumulative impacts of water withdrawals.

3.7.1 Surface Water Stress Assessment

For surface water systems, the percent water demand equation is carried out using monthly estimates. The maximum Percent Water Demand for all months is then used to categorize the surface water quantity potential for stress into one of three levels; Significant (>50%), Moderate (20% to 50%) or Low (<20%).

3.7.2 Existing Conditions Percent Water Demand

The monthly unit consumptive surface water demand estimates are shown in **Table 3-11** for each subwatershed and were calculated as described in the Water Use Section.

Table 3-11: Surface Water Unit Consumptive Demands (L/ s)

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
West Catfish	3	3	3	3	3	3	3	3	3	3	3	3
Catfish Above Aylmer	4	4	4	4	4	17	18	19	18	4	4	4
Lower Catfish	2	2	2	2	2	66	80	93	80	2	2	2
Silver Creek	5	5	5	5	5	59	70	80	70	5	5	5

The monthly QSupply (Median Flow) and QReserve (90^{th} percentile flow) were calculated using hydrologic model predicted stream flow at the outfall of each subwatershed for the period 1980-2004. A longer-term period was not used for averaging as it was felt that the current water demand estimates would not be representative of historical water use. **Table 3-12** shows the supply and reserve terms, in addition to their difference, used in the Stress Assessment equation (QSupply- QReserve).

Table 3-12: Surface Water Supply Flows (L/ s)

Subwatershed	Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
West Catfish	QSupply	939	753	791	913	827	595	86	46	42	43	374	931
West Catfish	Qreserve	259	411	625	764	230	77	36	19	11	8	11	11
West Catfish	Difference	680	341	165	149	597	517	50	27	31	36	364	920
Catfish Above Aylmer	Qsupply	1,026	901	972	1,346	1,054	756	261	147	120	181	690	1,002
Catfish Above Aylmer	Qreserve	308	477	627	1,069	598	236	114	61	36	61	240	105
Catfish Above Aylmer	Difference	718	425	345	277	456	520	147	86	84	120	450	897
Lower Catfish	Qsupply	2,909	2,579	2,784	3,450	2,886	2,124	777	406	348	498	1,573	2,784
Lower Catfish	Qreserve	887	1,325	1,776	2,615	1,598	673	309	150	80	115	338	286
Lower Catfish	Difference	2,022	1,254	1,008	835	1,287	1,450	468	256	268	383	1,235	2,498
Silver Creek	Qsupply	931	890	938	1,099	1,026	739	393	234	179	235	450	818
Silver Creek	Qreserve	337	392	540	724	669	365	165	93	53	38	66	122
Silver Creek	Difference	594	498	398	375	357	374	228	141	126	197	384	696

Monthly Percent Water Demand for surface water is calculated using the Percent Water Demand equation, as well as the values shown in **Table 3-11** and **Table 3-12**. The results of this calculation are included in **Table 3-13**.

Table 3-13: Percent Water Demand Estimate (Surface Water)

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max
West Catfish	0%	1%	2%	2%	1%	1%	6%	12%	10%	9%	1%	0%	12%
Catfish Above Aylmer	1%	1%	1%	1%	1%	3%	12%	22%	22%	3%	1%	0%	22%
Lower Catfish	0%	0%	0%	0%	0%	5%	17%	36%	30%	1%	0%	0%	36%
Silver Creek	1%	1%	1%	1%	1%	16%	31%	57%	56%	2%	1%	1%	57%

Note: shaded cells have Percent Water Demand greater than the Moderate Stress Threshold (20%)

The potential for stress classification is determined based on the thresholds presented above. The stress classification for each of the 4 subwatersheds, as well as whether uncertainty evaluation is required, is as follows:

- West Catfish Subwatershed – low potential stress classification; uncertainty evaluation not required
- Catfish Above Aylmer Subwatershed – moderate potential stress classification; uncertainty evaluation not required
- Lower Catfish Subwatershed – moderate potential stress classification; uncertainty evaluation not required
- Silver Creek Subwatershed – significant potential stress classification; uncertainty evaluation not required

3.7.3 Additional Surface Water Scenarios

There are no planned systems in this study area and as such no evaluation of planned systems was completed.

The West Catfish subwatershed is the only subwatershed with a low potential for stress classification and therefore the only one in which a future water use scenario needs to be applied. There are no municipal systems in this subwatershed and therefore there is no change in municipal demand.

The Catfish Creek watershed does not have a surface water municipal intake, therefore evaluation of a drought scenario is not required.

3.7.4 Surface Water Stress Assessment Results

The Surface Water Subwatershed Stress Assessment classifies the Catfish Above Aylmer and Lower Catfish subwatersheds as having a Moderate potential for hydrologic stress, Silver Creek subwatershed as having a Significant potential for stress and West Catfish as having a low potential for stress. The results of the Tier 2 Surface Water Stress Assessment are illustrated on **Map 3-6**.

Catfish Creek Above Aylmer
The Catfish Creek Above Aylmer Subwatershed has been identified as having a **Moderate** potential for stress in terms of surface water. There are a total of 15 takings located within the Subwatershed, and all are for agricultural purposes. The Percent Water Demand is minimal for most of the year; however, it reaches the Moderate threshold for potential stress in the months of August and September, when the Percent Water Demand reaches 22% for the Subwatershed. Demand is evenly distributed between the takings, with no single taking being responsible for a significant proportion of demand. None of the takings have reported pumping rates associated with them.

There are no municipal surface water takings within this Subwatershed.

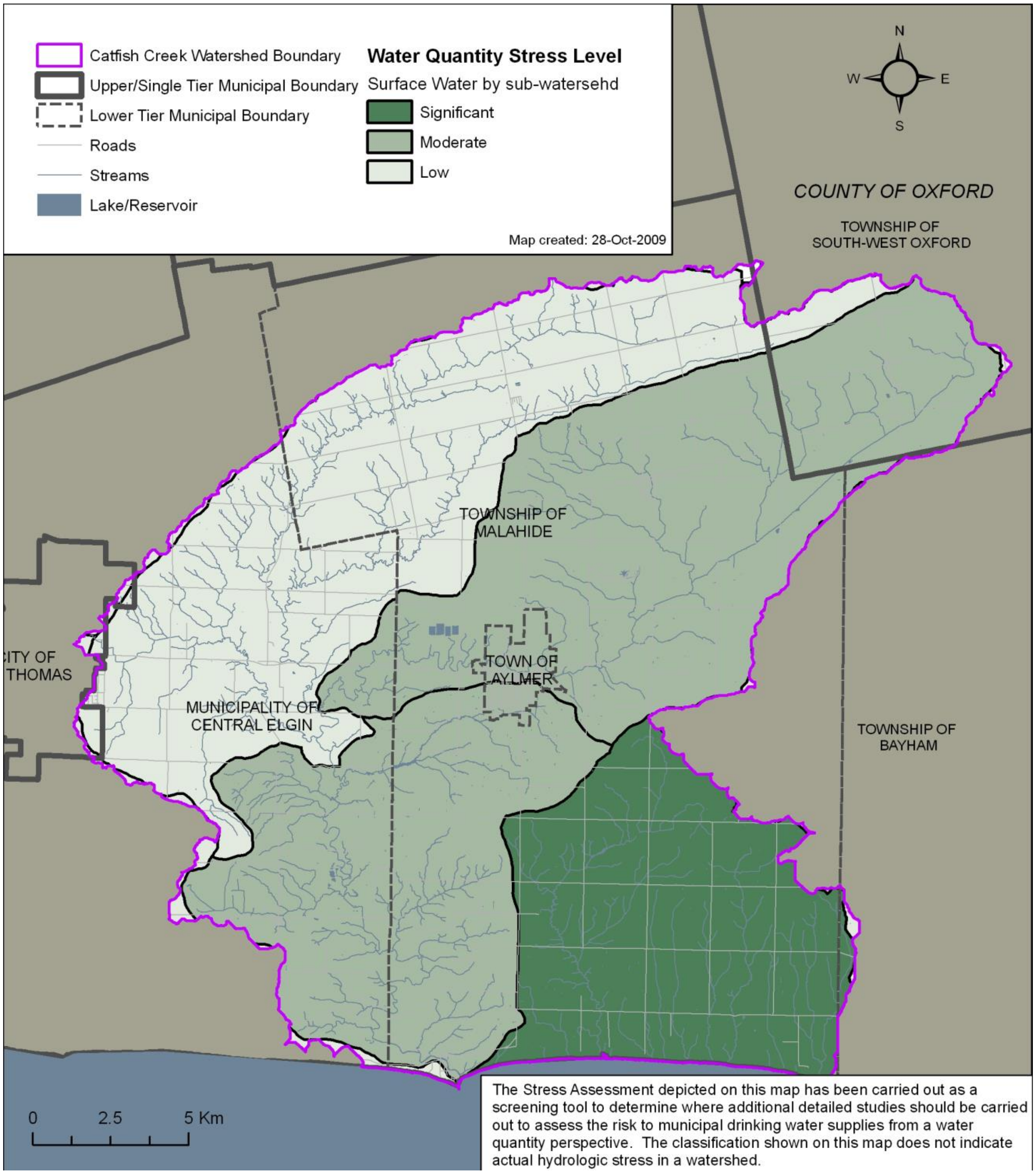
Lower Catfish Creek Subwatershed
The results of the Stress Assessment analysis suggest that the Lower Catfish Subwatershed has a **Moderate** potential for stress in terms of surface water. There are 43 surface water takings within the Subwatershed, which are all assigned for agricultural purposes, with the exception of a single Wildlife Conservation taking. The Percent Water Demand is close to zero for most months; however, the seasonally variable agricultural takings cause the Percent Water Demand to rise to 36% and 30% in the months of August and September, respectively. Water demand is well distributed between all the takings, with no single taking being responsible for the majority of the demand. Only one taking has reported actual pumping rates available.

There are no municipal surface water intakes within the Lower Catfish Subwatershed.

Silver Creek Subwatershed
Based on the stress assessment analysis, the Silver Creek Subwatershed has a **Significant** potential for stress. There are 39 takings within Silver Creek, of which 36 are for agricultural purposes and 3 assigned for Wildlife Conservation. Like the Lower Catfish Creek Subwatershed, the Silver Creek Subwatershed has a Percent Water Demand that is close to 0 for most months, but rises to 31% , 57% , and 56% for the months of July, August, and September. Water demand is well distributed throughout the takings, with no single taking being responsible for more than 10% of the total demand. There are no reported rates available for the water takings associated with this Subwatershed.

There are no municipal surface water intakes within Silver Creek.

Map 3-6: Tier 2 Surface Water Stress Assessment



3.7.5 Groundwater Stress Assessment Results

For groundwater systems, the Stress Assessment calculation is carried out for the average annual demand conditions and for the monthly maximum demand conditions; groundwater supply is considered constant. The stress level for groundwater systems is categorized into three levels (Significant, Moderate or Low) according to the thresholds listed in **Table 3-14**.

Table 3-14: Groundwater Potential Stress Thresholds

Groundwater Potential Stress Level Assignment	Average Annual	Monthly Maximum
Significant	> 25%	> 50%
Moderate	> 10%	> 25%
Low	0 – 10%	0 – 25%

3.7.6 Existing Conditions Percent Water Demand

Table 3-15 contains the monthly estimates of unit consumptive groundwater demands calculated for each subwatershed. The average and maximum monthly demands are shown in the table; they are used to estimate subwatershed potential stress in the groundwater stress assessment.

Table 3-15: Estimated Current Groundwater Unit Consumptive Demands (L/s)

Subwatershed	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg	Max
West Catfish	0	0	0	0	0	1	1	2	1	0	0	0	0	2
Catfish Above Aylmer	1	1	1	1	1	10	19	28	19	1	1	1	7	28
Lower Catfish	0	0	0	0	2	50	99	146	98	0	0	0	33	146
Silver Creek	0	0	0	0	0	31	62	93	62	0	0	0	21	93

Groundwater supply is calculated as the sum of the average annual recharge and the total amount of groundwater flowing laterally into each subwatershed. The groundwater Flow In for each subwatershed is calculated from the model results as the sum of all positive flow vectors into each area. Groundwater reserve is calculated as 10% of the estimated groundwater discharge to surface water streams in each subwatershed. The groundwater reserve for each subwatershed is given in **Table 3-16**

Table 3-16: Groundwater Stress Assessment

Subwatershed	Supply and Demand (L/s) GW Flow In	Supply and Demand (L/s) Groundwater Recharge	Supply and Demand (L/s) Groundwater Reserve	Supply and Demand (L/s) Average Demand	Supply and Demand (L/s) Maximum Demand	% Water Demand Average Water Demand	% Water Demand Maximum Water Demand
West Catfish	600	513	39	6	7	1%	1%
Catfish Above Aylmer	849	613	74	13	34	1%	2%
Lower Catfish	532	659	113	36	149	3%	14%
Silver Creek	25	637	45	23	96	4%	16%

The results of the Groundwater Stress Assessment are shown in **Table 3-16.** The estimated potential for hydrologic stress for the West Catfish, Catfish Above Aylmer, Lower Catfish and Silver Creek subwatershed are low. The Catfish Above Aylmer has the Brownsville groundwater municipal supply system.

There are no planned systems in this study area and as such no evaluation of planned systems was completed.

3.7.7 Future Conditions Percent Water Demand

The Percent Water Demand was also calculated using future demand estimates. Future demand only accounts for projected increases in municipal demand. All other non-municipal water demand was assumed to be equal to current demand. Since the urban areas within the Study Area were seen as areas of low-growth, future land use changes were expected to have minimal, to no, impact on average subwatershed water budget parameters. Therefore, water budget parameters for existing land use conditions were used for the supply and reserve terms.

Municipal future water demand was estimated by applying future population estimates to current average daily per capita water use, for each municipal water system. Future population is based on municipal official plans current to 2006, while current water use data was collected from water system owners and operators. All future water demand is projected to 2031. Further explanation of future water demand calculations is given in the Status Report on Municipal Long Term Water Supply Strategies (Shifflett, 2007). The only municipal water system is the community of Brownsville. The estimated average day increase in groundwater demand was calculated to be 7 m^3/d or 0.1 L/s.

Groundwater supply and reserve remained unchanged for the Groundwater Stress Assessment estimated for future conditions. Future average monthly demand and maximum monthly demand were estimated by summing the demands under current conditions with the additional average increase in demand for future conditions. The results of the Percent Groundwater Demand under future conditions are presented in **Table 3-17**.

No subwatersheds were classified as having a potential for stress relating to groundwater takings equal to Moderate or Significant, under existing and future conditions.

Table 3-17: Groundwater Stress Assessment Components with Future Demand Estimates

Subwatershed	Supply and Demand (L/s) GW Flow In	Supply and Demand (L/s) Groundwater Recharge	Supply and Demand (L/s) Groundwater Reserve	Supply and Demand (L/s) Average Demand	Supply and Demand (L/s) Maximum Demand	% Water Demand Average Water Demand	% Water Demand Maximum Water Demand
West Catfish	600	513	39	6	7	1%	1%
Catfish Above Aylmer	849	613	74	13	34	1%	2%

Subwatershed	Supply and Demand (L/s) GW Flow In	Supply and Demand (L/s) Groundwater Recharge	Supply and Demand (L/s) Groundwater Reserve	Supply and Demand (L/s) Average Demand	Supply and Demand (L/s) Maximum Demand	% Water Demand Average Water Demand	% Water Demand Maximum Water Demand
Lower Catfish	532	659	113	36	149	3%	14%
Silver Creek	25	637	45	23	96	4%	16%

3.7.8 Drought Scenario

Both a two year and a ten year drought scenario were considered. These scenarios are designed to capture probable periods of drought conditions; both short and long term duration droughts. With the surface water simulation producing groundwater recharge estimates for the 1960-2004 time period, the impacts of any drought within this time period can be assessed.

The 1960's represent a recorded period of low precipitation, for which estimated recharge is available from the hydrologic model simulations. Since this information is readily available, the two-year and ten-year scenarios were evaluated during the same simulation for this Stress Assessment. Information relating to the planned pumping rates for municipal wells was not available and therefore the drought assessment is only carried out for existing pumping rates.

The maximum drawdown resulting from the drought scenario for the two Brownsville municipal wells in the Catfish Creek watershed are 0.64 m and 0.65 meters below the initial water level in Well 5 and Well 6, respectively. These results are based on a regional groundwater flow model that is not calibrated to the local scale of individual well fields.

It is assumed that all municipal wells would be constructed with an available drawdown of approximately 5 metres. As both municipal wells are shown to have a maximum drawdown less than this threshold it is unlikely that there are instances of a municipal well being unable to pump water due to drought impacts. Therefore no subwatersheds will be classified as having a moderate potential for stress based on the drought scenario.

3.7.9 Groundwater Stress Assessment Results

Based on the Percent Water Demand calculations for current and future demand conditions, and the results of the Drought Scenario, the groundwater stress classifications are low for the West Catfish, Catfish Above Aylmer, Lower Catfish and Silver Creek subwatersheds.

Since the Catfish above Aylmer subwatershed was not classified as having a Moderate or Significant potential for stress under either demand condition, the

Brownsville municipal water supply does not require a Tier 3 Water Quantity Risk Assessment. **Map 3-7** shows that there are no Catfish Creek subwatersheds requiring further stress assessment review.

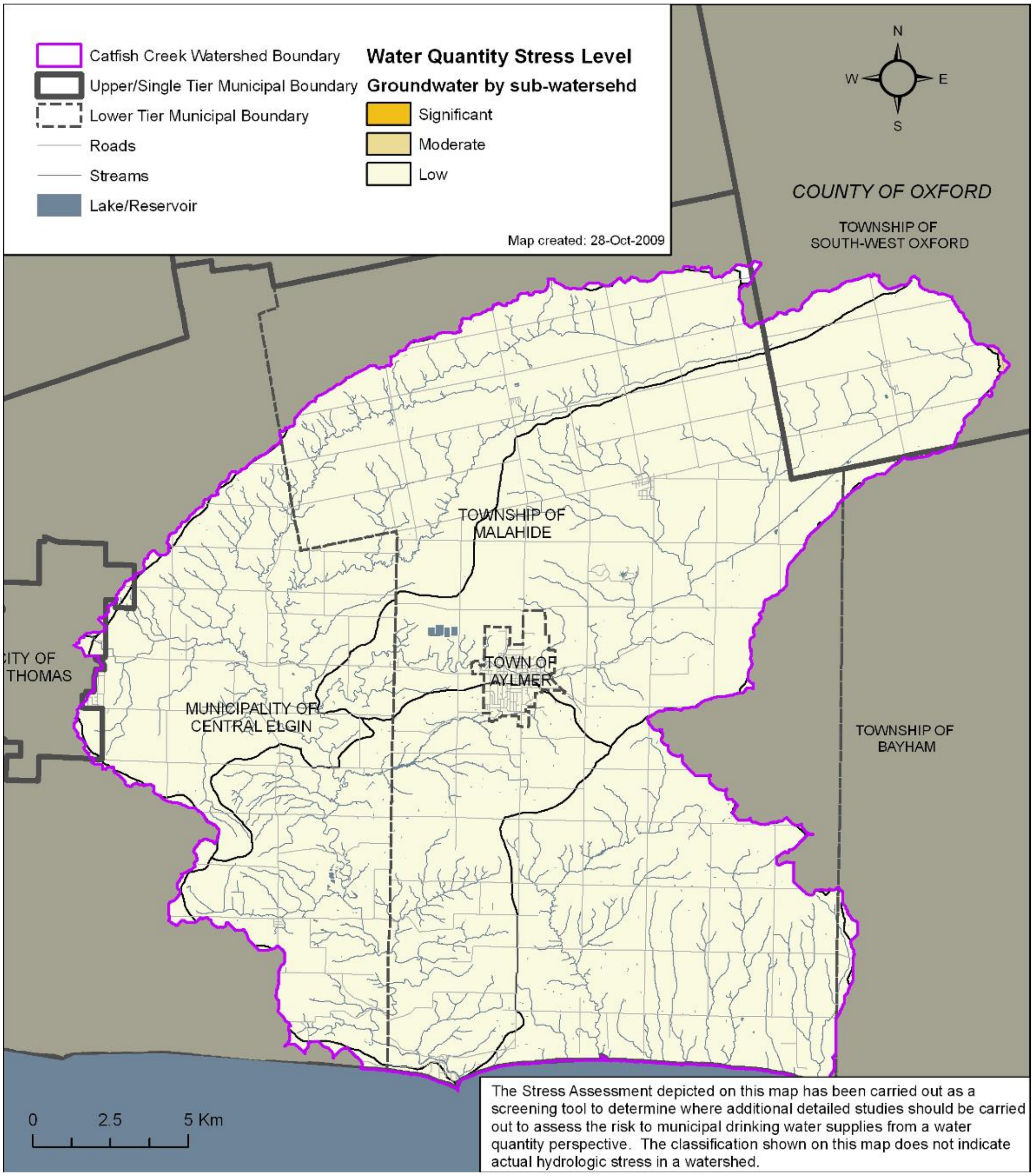
3.8 Uncertainty/ Limitations

All water budget calculations contain inherent uncertainty due to incomplete data, data inaccuracies, and imperfect estimation and simulation tools. Many of the sources of uncertainty have been documented throughout the Water Budget sections. It is important to consider the regional-scale nature of the analysis and interpretation presented. The methods used and the amount of data available were suitable for regional water budgeting purposes.

Any model developed to represent a natural system is inherently a simplification of that natural system. Part of the reason for this is that the complexities of the physical system can never be known well enough to incorporate all details into a numerical context. In reality, most of the scientific approach involves representing physical conditions observed using approximations of larger-scale functionality; hydraulic conductivity is an example of this. This approximation does not negate the ability of scientists and practitioners to utilize numerical models as tools to help understand and manage natural systems; however, there is a need to recognize the limitations of such tools when interpreting model results.

Every effort was made to minimize uncertainty in the Water Quantity Risk Assessment: data was cross checked with additional sources, models were calibrated to the highest quality of monitoring data available, and an external peer review team was consulted.

Map 3-7: Water Quantity Stress Levels by Groundwater Sub-watershed



3.9 Tier 2 Water Budget & Water Quantity Stress Assessment Peer Review

In October 2006, Lake Erie Region Source Protection Region staff developed a Terms of Reference (TofR) to guide the peer review process for the Long Point Region, Catfish Creek and Kettle Creek Tier 2 Water Budget & Water Quantity Stress Assessment. A peer review committee was established early in the water budget development process and was involved frequently throughout the water budget and water quantity stress assessment studies from terms of reference development through to finalization of the reports. The TofR was developed in accordance with the provincial guidance document, entitled Peer Review Water Budget Interim Direction, Version 2.0 (draft) (dated August 9, 2005). The Peer Review Committee consisted of the following external reviewers:

- Dr. Dave Rudolph, University of Waterloo
- Dr. Hugh Whiteley, University of Guelph
- Dr. Rob Schincariol, University of Western Ontario
- Chris Neville, S.S. Papadopulos and Associates
- John Warbick, Ministry of Agriculture & Rural Affairs (intermittent)

The preparation of the Water Budget and Water Quantity Stress Assessment was broken into two phases. Phase 1 involved the collection of background information for the preparation of a Draft Interim Report in November 2007 for peer review. Although the report was initially signed-off by the Peer Review Committee in March 2008 as the Interim Water Budget Report, the report was revised and posted in April 2009 using new information and a revised modeling approach applied in Phase 2.

Phase 2 of the Water Budget and Water Quantity Stress Assessment involved the completion of existing, future and drought scenarios and the identification of significant groundwater recharge areas (SGRAs) in accordance with the Source Protection Technical Rules. The removal of vulnerability scoring from SGRAs was completed due to updates to the Technical Rules (2021). The report was revised and ultimately posted in August 2009 based upon final Peer Reviewer input and sign-off. A summary report of the peer review process (Etienne, 2009), including materials used by the Peer Reviewers along with their comments was also posted in August 2009.

3.9.1 Water Budget Peer Review

The Peer Review Committee, which was assembled in March 2007, was invited to comment on the Terms of Reference for the project. Upon selection of the consultant for the preparation of the Water Budget report, a kick off meeting was held on May 31, 2007. At this meeting the team considered the uncertainty of the geological conceptual model based on the paucity of deep bedrock data within the study area. It was agreed that the consultant could develop a calibrated model within an acceptable level of confidence for the peer reviewers using the available data and appropriate assumptions.

The Peer Review Committee reconvened in September 2007 to review the initial findings of the consultant and to advise the consultant on their modeling approach. New information gathered from the Ontario Geological Survey (OGS) generated some concerns about the conceptual model, forcing the consultant to rethink some of their initial assumptions. In addition, the consultant identified the significant amount of calibration required to balance potential irrigation demand with observed summer baseflows. As a result of these significant uncertainties, the consultant requested an additional month to conduct groundwater sensitivity runs in the FEFLOW model and to fine tune the irrigation assumptions in the GAWSER model.

The draft Water Budget report was circulated for peer review in November 2007 and the committee met to receive a presentation of the report on November 22, 2007. The Peer Reviewers were asked to submit their initial comments and questions for discussion at a subsequent meeting on December 17, 2007. A comment matrix was prepared and circulated to the peer review team prior to the December 17th meeting. The written comments in the matrix were discussed at this meeting, and responses (leading to actions) were added to the matrix which directed the consultant's revisions to the draft report.

In January of 2008, the consultant took the consolidated comments from the matrix and developed a strategy for revising the Integrated Water Budget Report. One of the main points raised by the Peer Reviewers throughout Phase 1 was the need clarify the certainty in the modeling. The revised Integrated Water Budget Report was delivered in March 2008 and circulated to the Peer Reviewers for another round of document review during which the team compared the revisions to their comments in the matrix. The comments received indicated that it would be appropriate for the consultant to proceed with the next phase of work on the Water Quantity Stress Assessment.

3.9.2 Water Quantity Stress Assessment Peer Review

The Peer Review Committee reconvened in March 2009 to review the draft Water Quantity Stress Assessment report. The committee met to receive a presentation of the report on March 19, 2009. By this time, the consultant had revisited the FEFLOW and GAWSER models developed in Phase 1 to address a number of the uncertainties raised by the Peer Review Committee. New water use data and revised models were used to bring the Integrated Water Budget report up to date for posting in April 2009.

The Peer Reviewers were asked to submit their initial comments and questions for discussion at a subsequent teleconference on April 7, 2009. As was the case in Phase 1, a comment matrix was prepared and circulated to the team prior to the conference call. The written comments in the matrix were discussed at the teleconference, and responses (leading to actions) were added to the matrix which directed the consultant's revisions to the draft report.

As another part of the review process, the consultant solicited specific comments from the Peer Reviewers on the preferred approach to SGRA delineation as required by the Technical Rules. The final document was subsequently circulated to the Peer Reviewers for another round of document review during which the team compared the revisions to their comments in the matrix. The Peer Reviewer sign-off correspondence received indicates that the Tier 2 Integrated Water Budget and Water Quantity Stress Assessment reports are scientifically defensible and satisfy the provincial guidelines for water budget documents. For the most part, the Peer Reviewers were satisfied that their comments had been received and addressed in a professional manner by the consultant. As a result, the documents provide clear direction for further municipal Tier 3 Water Quantity Risk Assessments.

In August 2009, the Peer Review of the Catfish Creek Tier 2 Integrated Water Budget and Water Quantity Stress Assessment was considered complete and all reports were posted on the Lake Erie Region Source Protection website.

The removal of vulnerability scoring from SGRAs was completed due to updates to the Technical Rules (2021).

3.10 Section Summary

- A Water Budget is an understanding and accounting of the movement of water and the uses of water over time, on, through and below the surface of the earth. The Water Quantity Stress Assessment was undertaken at a Tier 2 level.

- The methods used and the amount of data available were suitable for regional water budgeting purposes. Every effort was made to minimize uncertainty in the Water Quantity Risk Assessment. Data was cross checked with additional sources, models were calibrated to the highest quality of monitoring data available, and an external peer review team was consulted.

- The Brownsville groundwater wells are the only municipal water taking in the Catfish Creek Watershed.

- Water budget components were aggregated to the subwatershed and watershed scale.

- Three levels of water taking were used: water use permitted, water pumped, and water not returned to the source from which it was pumped.
- Surface water components of the water budget were determined using a continuous numerical hydrologic model, while the groundwater components of the water budget were determined using a steady-state numerical groundwater flow model.
- Recharge estimates were taken from the hydrologic model and applied to the groundwater model to provide a connection between the surface and groundwater numerical models.
- West Catfish and Catfish Above Aylmer subwatersheds have high surface runoff and low groundwater recharge. There is low to moderate groundwater discharge to surface water in these subwatersheds. Water demands are low in West Catfish and moderate in Catfish Above Aylmer.
- Lower Catfish and Silver Creek subwatersheds have low runoff and high recharge. There is a moderate amount of groundwater inflow to the subwatersheds and outflow to Lake Erie. There are moderate amounts of groundwater discharge to surface water and water demands are fairly high.
- The Surface Water Subwatershed Stress Assessment classifies Silver Creek subwatershed as having a significant potential for stress, Catfish Above Aylmer and Lower Catfish subwatersheds as having a Moderate potential for hydrologic stress, and West Catfish as having a low potential for stress.
- The Groundwater Subwatershed Stress Assessment classified all four subwatersheds as having low potential for stress under existing, future and drought scenarios.
- No municipal systems require a Tier 3 Stress Assessment in the Catfish Creek Watershed.
- Being classified as having a Moderate or Significant potential for stress does not necessarily imply that a subwatershed is experiencing local hydrologic or ecologic stress. This classification indicates where additional information is required to understand local water supply sustainability and potential cumulative impacts of water withdrawals.

4.0 WATER QUALITY RISK ASSESSMENT

4.1 Aquifer Vulnerability in the Catfish Creek Watershed

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 Catfish Creek Watershed, the SAAT model was chosen to estimate aquifer vulnerability citation (Earthfx, 2008). Within the portion of the watershed that extends into Oxford County, located in the northeast, the AVI method was used to calculate vulnerability. The County of Oxford mapped aquifer vulnerability as part of its groundwater protection study completed by Golder (2001) and has opted to continue to use their AVI mapping. Both methods are approved under the Clean Water Act (2006) Technical Rules.

The SAAT method involves estimating 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).

The AVI method used for Oxford County involves assigning a numerical score at each known well location that is related to the hydraulic conductivity and thickness of the geological layers overlying the aquifer. The aquifer vulnerability is then classified on the basis of the AVI scoring as follows: High Vulnerability (AVI score <30), Medium Vulnerability (AVI score ≥30 and ≤80) or Low Vulnerability (AVI score >80). The AVI scoring method was used to develop vulnerability maps for the four primary aquifers identified in Oxford County: shallow overburden, intermediate overburden, deep overburden, bedrock.

Aquifer vulnerability mapping across the CCSPA is shown on Error! Reference source not found.**.** Areas of high and medium vulnerability across the southern extents of the watershed generally correspond to the shallow unconfined aquifer of the Norfolk Sand Plain. The northern extents of the watershed have been predominantly mapped as low vulnerability. This area is generally composed of the clay-rich Port Stanley Till, which provides protection to the deeper, confined overburden aquifers.

4.1.1 Methodology

SAAT

The basis for the SAAT vulnerability calculation was the MECP Water Well Information System (WWIS) . However, the base database was built upon by adding information from the Ministry of Transportation's GEOCRES database. Data were also improved 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 MNRF. More recent information, made available by the MECP in August 2006, did not include the MNRF 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.

- Assigning ground surface elevations 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 (DEM, MNR Version 2.0 DEM) elevation was assigned to the 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.

- Update Bedrock Flags: Shallow bedrock wells are 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.

- Update well screen classifications: Correct well screen data is important for identifying the target aquifer. Many wells in the MECP 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 are 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 (2006).

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.

Estimated depth to water table was calculated 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 (MECP, 2006) 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).

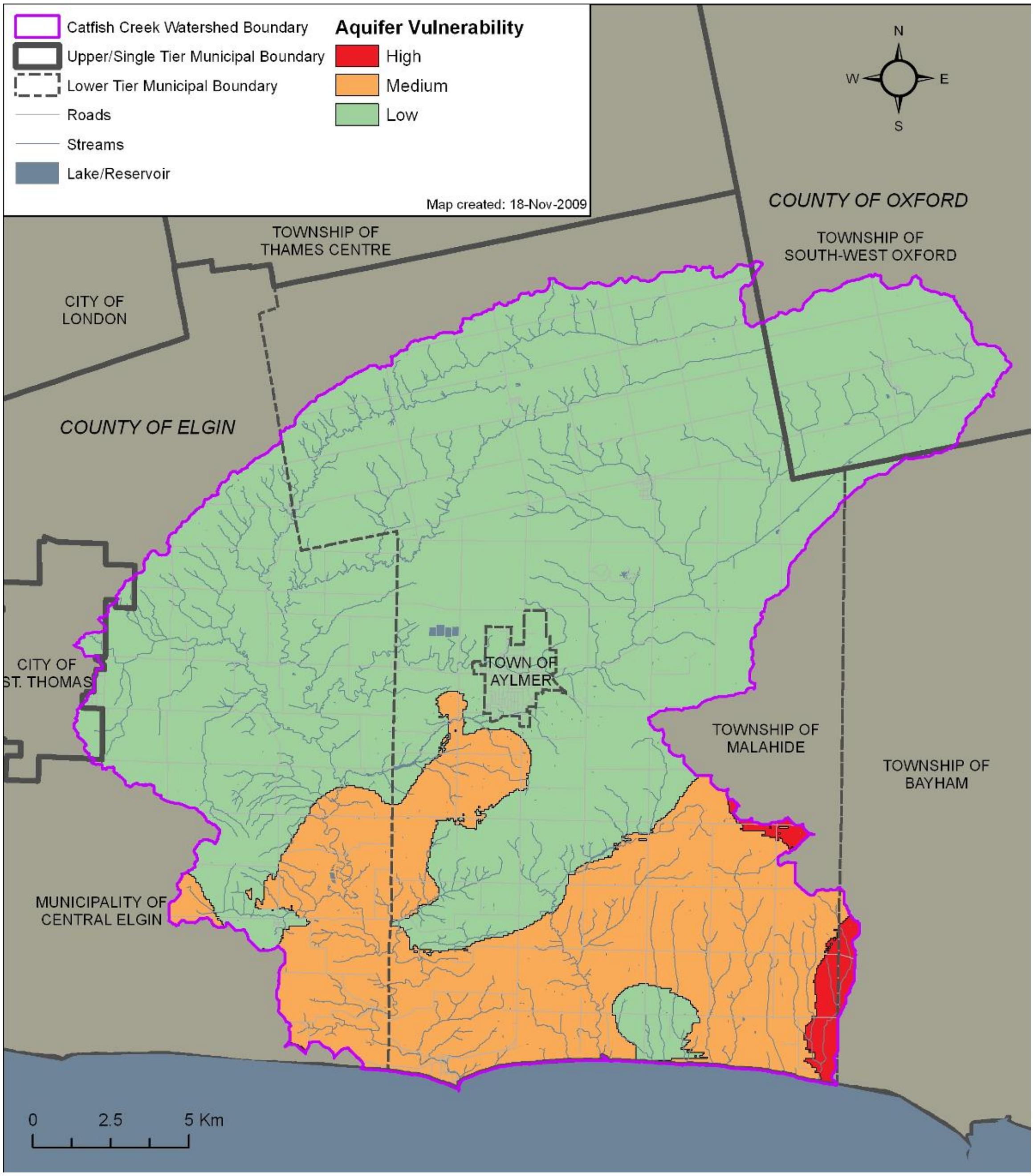
It was assumed that the infiltration rate was equal to the recharge rate determined from maps developed by Schroeter & Associates (2006a, 2006b, 2006c) using the GAWSER model.

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 (MECP, 2021) indicate SAAT values are translated into aquifer vulnerability categories according to the following thresholds:

- SAAT value <5 years translate to high vulnerability;
- SAAT value ≥ 5 years, < 25 years translate to medium vulnerability; and
- SAAT value ≥ 25 years translate to low vulnerability.

Map 4-1: Aquifer Vulnerability



4.1.2 Aquifer Vulnerability Index

The basis for the Aquifer Vulnerability Index calculation within Oxford County was also based on the MECP's Water Well Information System (WWIS).

The County of Oxford is underlain by both overburden and bedrock aquifers. The limestone/ dolostone bedrock aquifer underlies the entire county. The overburden is comprised of numerous aquifers at various depths, which have been previously termed and mapped as Shallow, Intermediate and Deep Aquifers (Goff and Brown, 1981).

To simplify the geological information in the MECP WWIS, a geological correlation table was established that focused on the information as indicative of aquifers or aquitards. Seven main categories were established, with the following "geocodes" : bedrock; shale; clay; silt; sand; gravel; and fill.

Geological cross-sections were then constructed and reviewed to identify reasonable depth intervals for the overburden aquifers and to examine them in the third dimension. The following depth intervals were established: Shallow Aquifer (2 metres below ground surface (m bgs) to 15 m bgs) ; Intermediate Aquifer (15 m bgs to 30 m bgs); and Deep Aquifer (> 30 m bgs). The well record database was then queried to identify the thickness of aquifer material at each well within each depth interval. A minimum thickness of 1 m in the well record was required to constitute an aquifer. Where the thickness of the aquifer was less than 1 m, a value of zero metres was applied. After compiling the aquifer thickness at each well, the data were interpolated across the County to provide a separate contour map of the thickness of the Shallow, Intermediate and Deep Aquifers. The aquifers are inferred to be present where the interpolated thickness values are greater than about 1 m. During the interpolation process, a visual screening of the data was completed to remove anomalous data from the interpolation program.

The AVI method involves assigning a numerical score related to the hydraulic conductivity (K) of the material in each stratum; 1 for gravel, 2 for sand, 4 for silt and 8 for clay. This number is then multiplied by the thickness of the stratum to which it is assigned. Finally, the resulting products for each of the strata overlying the aquifer are summed to give the AVI for that well location. The geocode method used for developing aquifer maps was also used in the Aquifer Vulnerability Index calculation.

Following the calculation of the Aquifer Vulnerability Index for each well which penetrated the aquifer of interest, a numerical rating of 1 was applied to each score of less than 24, indicating a high vulnerability; a rating of 2 was applied to each score of 24 to 80, indicating a moderate vulnerability; and a rating of 3 to each score of greater than 80, indicating a low vulnerability. The results for all wells in each aquifer were then mapped using an interpolation routine and provided as a zoned contour map in each area where the aquifer was determined to be present. For the bedrock, the AVI calculation is provided assuming the bedrock aquifer lies at the top of the bedrock surface.

Peer Review of Aquifer Vulnerability

The Earthfx (2008) SAAT report was peer reviewed by Chris Neville of S.S. Papadopulos. The review found the Earthfx (2008) report to be in compliance with the Clean Water Act Technical Rules, and concluded the evaluation to be an excellent report with the analyses conducted at a high level of expertise. A number of detailed comments were provided for the report, however these were provided as additional commentary and did not point to any particular flaws in the assessment.

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.

4.1.3 Limitations and Uncertainty

SAAT

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 vulnerability analysis used the most current methods (under the Clean Water Act Technical Rules) and data available, the uncertainty rating at this time can be considered low.

AVI

Similar to the SAAT method, the lack of reliability associated with certain components of the WWIS represents a significant source of uncertainty in the calculation.

Given that the portion of Oxford County that extends into the Catfish Creek SPA is low vulnerability, the uncertainty rating at this time can be considered low.

Highly Vulnerable Aquifers

Areas calculated as being of high vulnerability are considered Highly-Vulnerable Aquifers (HVAs). Highly Vulnerable Aquifer areas in Catfish Creek Watershed are identified as the red areas on **Map 4-2**.

4.1.4 Vulnerability Scoring in Highly Vulnerable Aquifers

According to the Technical Rules (2021), 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 4-2** therefore, receive a vulnerability score of 6.

4.1.5 Managed Lands and Livestock Density for Highly Vulnerable Aquifers

This section provides a description of the results of calculations of the percent managed lands and the livestock density within Highly Vulnerable Aquifer (HVA) areas. **Map 4-3** and **Map 4-4** show that in the highly vulnerable aquifer areas in the Catfish Creek 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).

The methods to calculate the managed lands and livestock density calculations 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 Ontario Ministry of the Environment in September 2009.

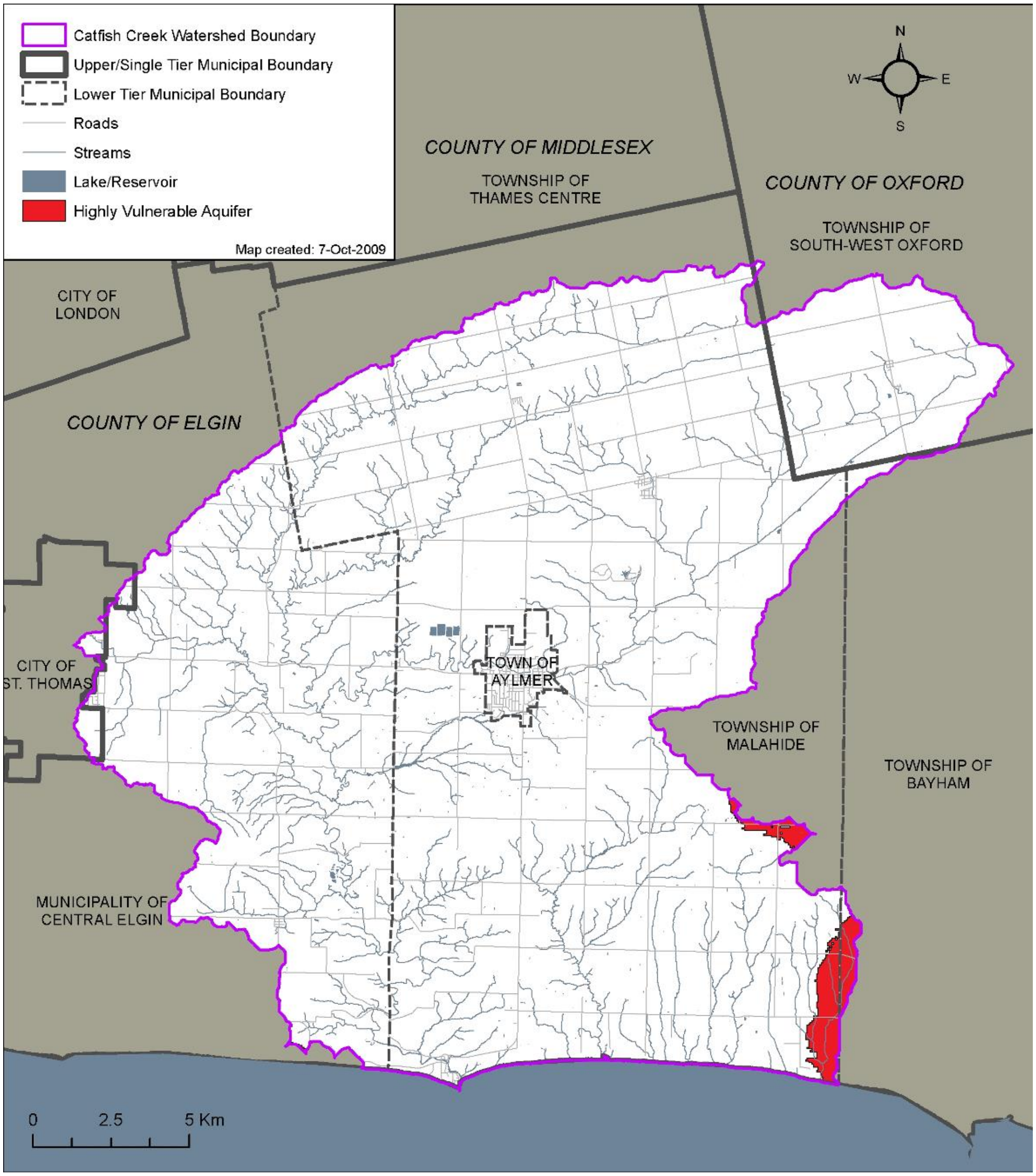
Managed Lands Area Methodology

Managed lands are divided into 2 categories of agricultural managed lands 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).

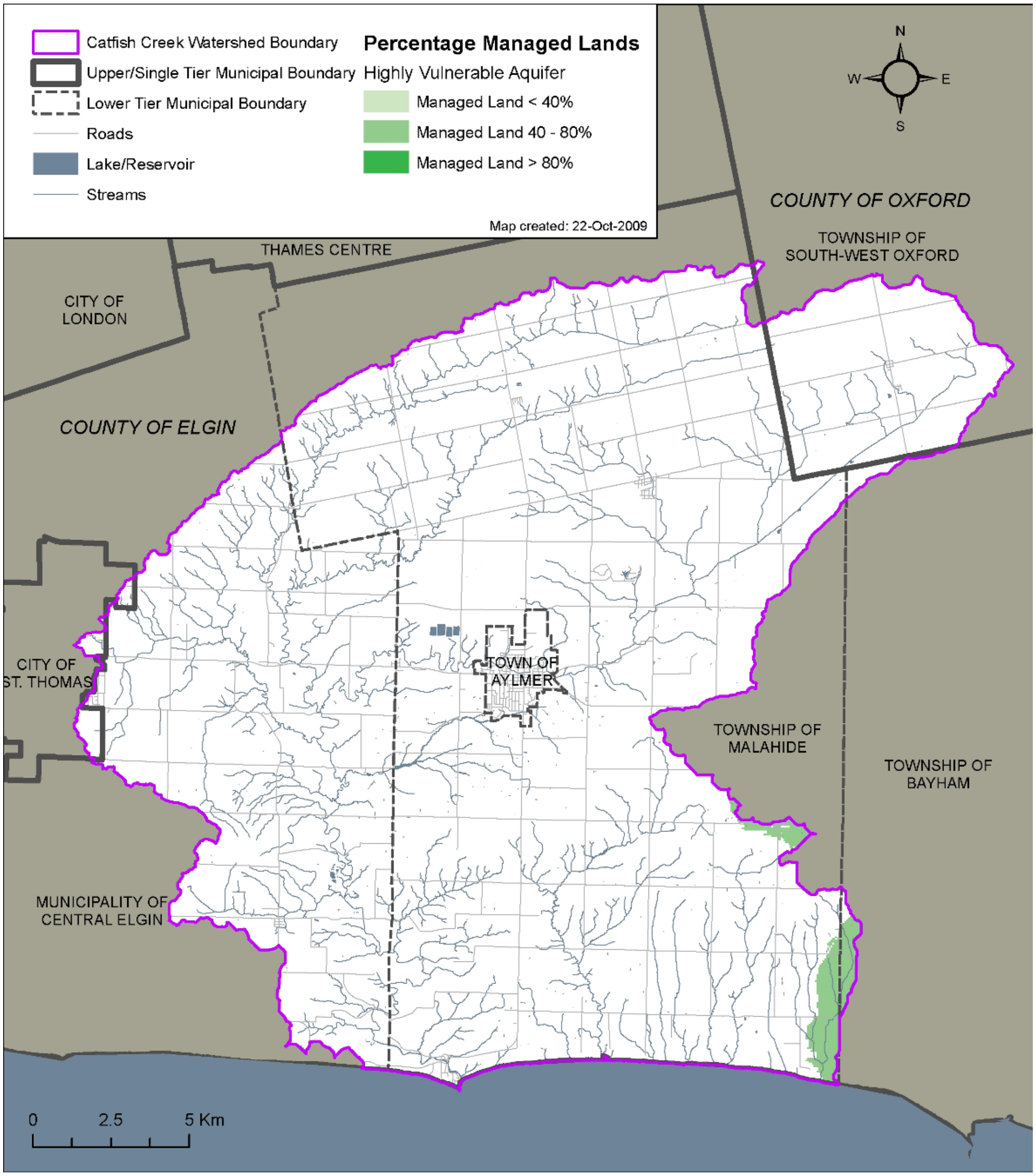
Land use classifications for land area are based on data from the Municipal Property Assessment Corporation (MPAC), who provide a parcel layer in GIS format (see **Table 4-2** for description). Each parcel has a code describing the main land cover classification, including codes for agricultural land, 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 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 2006 ortho-photo (see **Table 4-3**Table 4-2 for description**)**, air photo interpretation was used to determine whether a parcel of land should be classified as agricultural or non-agricultural. If possible, air photos were used to determine the type of agricultural or non-agricultural activity on a parcel of land. In the calculation of managed lands, areas of wetlands, impervious areas, wooded areas, water bodies and aggregate license areas were removed from consideration. The calculations for agricultural managed lands and non-agricultural managed lands are described below. The non-agricultural managed lands and agricultural managed lands areas will be added together and divided by all the parcel areas that intersect the HVA areas to get a percent managed land value.

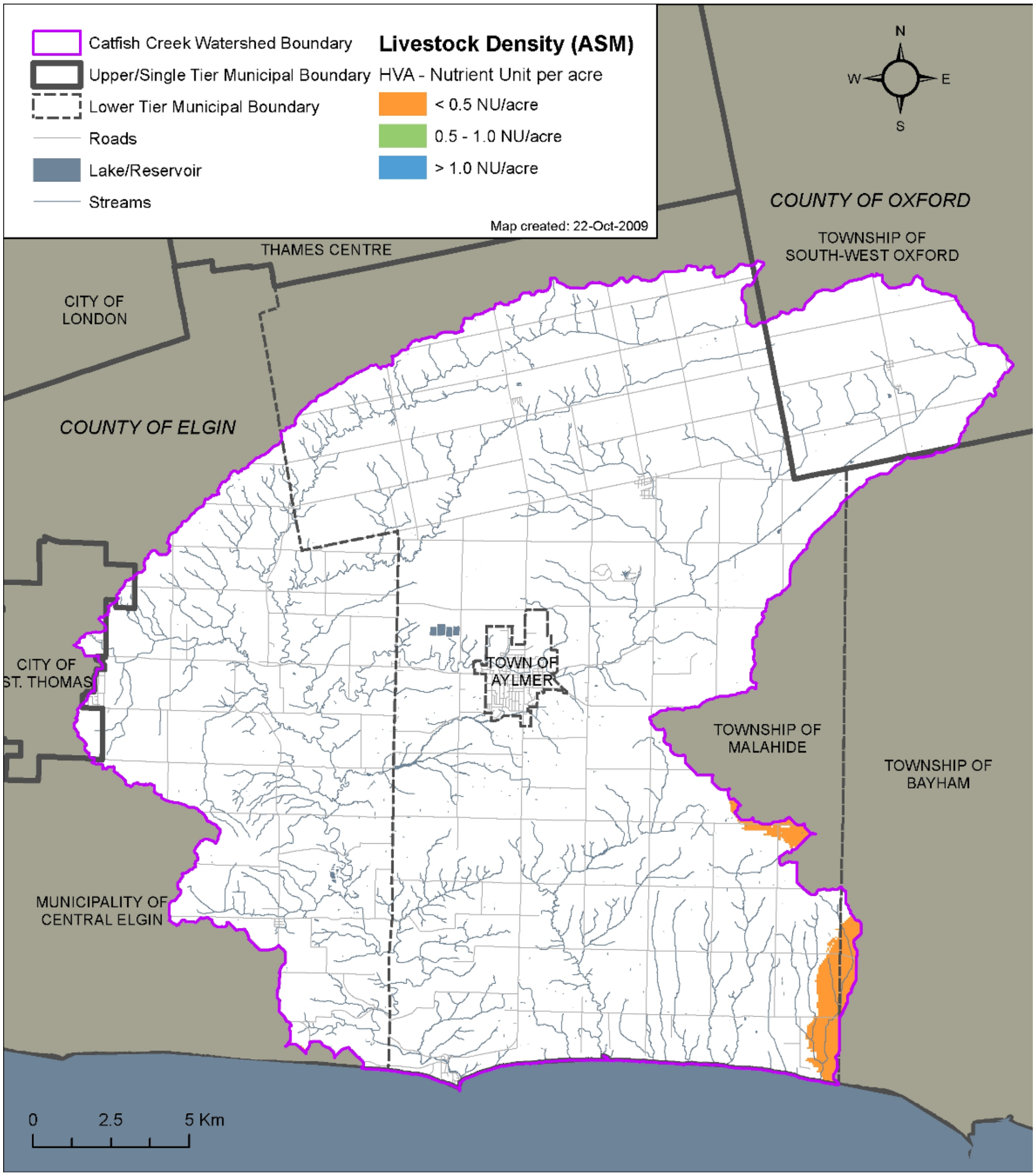
Map 4-2: Highly Vulnerable Aquifers



Map 4-3: Managed Lands in Highly Vulnerable Aquifers



Map 4-4: Livestock Density in Highly Vulnerable Aquifers



Agricultural Management Land Calculation

All parcels of land classified as agricultural within or touching the HVA were used in the calculation of agricultural managed lands. To account for buildings and other areas that do not receive nutrients, all farms were given a managed lands ratio of 0.9, meaning that it was estimated that 90% of the total area of farmland is applied with agricultural source material.

For each separate (discontinuous) unit of Highly Vulnerable Aquifer, the area of agricultural managed land within or touching the HVA was summed. Where a parcel of land fell only partially within a HVA area, the entire parcel area was included in the calculation. This area was then added to the area within the HVA classified as non-agricultural managed lands to get the total percent managed land in each HVA area.

Non-Agricultural Managed Land Calculation

All parcels within or touching the highly vulnerable aquifer 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 do not receive nutrients, all parcels were given a managed lands ratio as seen in **Table 4-1**.

The non-residential values in **Table 4-1** were generated through air 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 estimates used for the City of Kitchener Alder Creek Subwatershed Study. 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 or touching the HVA was summed. Where a parcel of land fell only partially within a HVA, the entire parcel area was included in the calculation. This area was then added to the area within HVAs classified as agricultural managed lands to get the total percent managed land in each HVA area.

Table 4-1: 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	Golf course	0.95
Institutional	Non-school, i.e. hospitals	0.6
Institutional	School (elementary or secondary, including private)	0.65
Open Space	Residential development land	0.55
Open Space	Vacant land condominium (residential)-defined land that's described by a condominium plan	0.55
Other	Cemetery	1
Other	Large office building (generally multi - tenanted, over 7,500 square feet)	0.45
Other	Local government airport	0.9
Other	Place of worship - with a clergy residence	0.55
Other	Place of Worship - without a clergy residence	0.55
Other	Private airport/ hangar	0.65
Other	Property in process of redevelopment utilizing existing structure(s)	0.55
Recreational	Amusement park	0.5
Recreational	Commercial sport complex	0.45
Recreational	Exhibition grounds/ fair grounds	0.7
Recreational	Municipal park (excludes Provincial parks, Federal parks, campgrounds)	0.65
Recreational	Non-commercial sports complex	0.5
Recreational	Recreational sport club - non commercial (excludes golf clubs and ski resorts)	0.6
Residential	High-density, multi-unit	0.55
Recreational	Residential-Low Density (standard single dwelling units)	0.45

Livestock Density Methodology

The calculation of livestock density within HVA areas was based on the calculation of Nutrient Units per acre (NU/ ac) of agricultural managed lands.

Barn Identification and Nutrient Units

To determine the nutrient units, each parcel of land that intersects the HVA areas was assessed 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. Livestock housing areas were estimated for barns on these parcels.

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 interpretation of 2006 air photos.

Each type of livestock has its own nutrient unit conversion factor, to determine the number of animals that generate 1 NU. For instance, one beef cow produces 1 NU and requires 100 square feet of living space in a barn, so the relationship for beef barns is 100 square feet/ 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. A table included in the technical memo provided by the Ministry of the Environment summarizes the relationship between barn area, livestock type and nutrient units generated. By multiplying the area of the barn by the nutrient unit per area ratio, the total number of nutrient units for the farm unit was determined.

Livestock Density Calculation

For the calculation of livestock density, all nutrient unit values for barns in each separate HVA area were summed and then divided by the total acreage of agricultural managed land for that particular HVA area.

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 4-2**. 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 would be beneficial; however, this has not been completed to date for the Highly Vulnerable Aquifer areas in the Catfish Creek watershed.

Table 4-2: 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

Data Input	Description	Source	Purpose
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
HVA (polygon)	Highly Vulnerable Area polygon	Lake Erie Source Protection Region	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. The values are meant to approximate the maximum potential nutrient unit production for the size of the livestock barn structure. The livestock nutrient unit calculations were not field verified and 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 storeys of housing areas was impossible through air photo interpretation and all barns were assumed to be single storey. Interpretation of the imagery was done to the best of the interpreter's ability. Verification of the livestock type and size of actual livestock housing area is suggested for 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.

4.1.6 Percentage of Impervious Surfaces for Highly Vulnerable Aquifers

To determine whether the application of road salt poses a threat to the Highly Vulnerable Aquifer (HVA) areas, the percentage of impervious surface where road salt can be applied per square kilometre in each HVA area was calculated under the guidance provided by section 16(11) of the amended Technical Rules: Assessment Report (MECP, 2021). The input data used to calculate the percentage of impervious surfaces per square kilometre are listed in **Table 4-3**.

Impervious surfaces in HVA areas in Catfish Creek watershed constitute less than 8 percent of the total area, as shown in **Map 4-5** which represents a low percentage. Based on these results, the application of road salt does not pose a threat to Highly Vulnerable Aquifers in Catfish Creek 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 15 x 15 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 kilometre equivalent to determine the percentage of impervious road surface per square kilometre. 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 4-3: 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

4.1.7 Drinking Water Threats in Highly-Vulnerable Aquifers

Activities and conditions that are or would be drinking water threats in Highly Vulnerable Aquifer areas cannot be significant threats, given that the vulnerability score is 6. However, moderate and low drinking water threats and conditions could be identified within highly vulnerable aquifers. Identification of moderate and low drinking water threats is not required at this time.

Table 4-4 indicates the possible levels of threat posed by chemicals, pathogens and dense non-aqueous phase liquids (DNAPL) within the Highly Vulnerable Aquifer areas in Catfish Creek Watershed, which are illustrated on **Map 4-2**. A checkmark indicates that the threat classification is possible; a blank cell indicates that it is not. As indicated in the table by the blank cell, no activities can be classified as a significant threat in the Highly Vulnerable Aquifer areas; whereas some chemicals and DNAPLs are or would be considered moderate and low drinking water threats in the areas illustrated in red on **Map 4-2**.

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.

The MECP 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 Source Water Protection Threats Tool. This information can be used along with **Map 4-2**and **Table 4-4** to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.

Table 4-4: Classification of Possible Drinking Water Threats in Highly Vulnerable Aquifers (HVA)

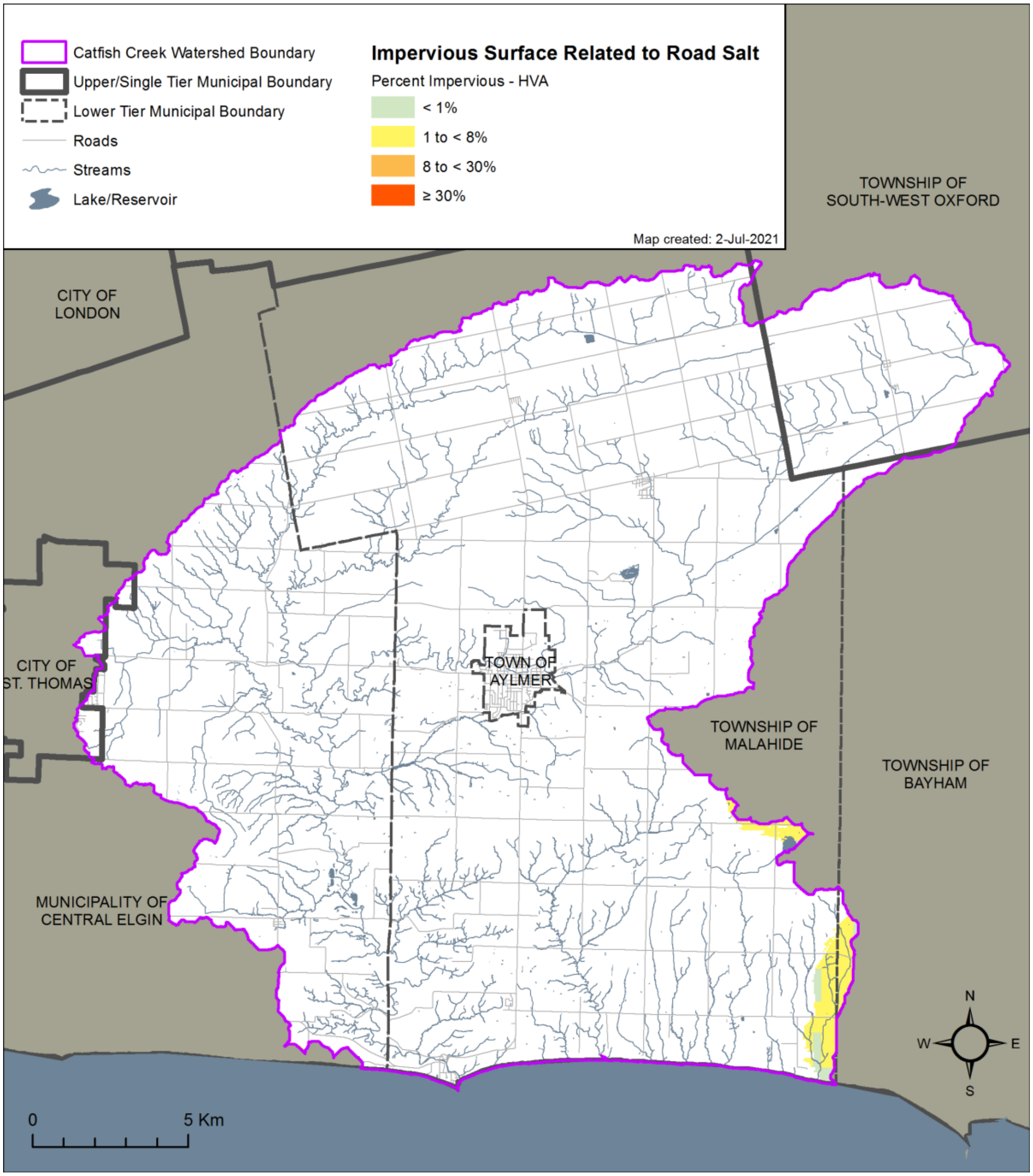
Threat Type	**Vulnerability Score in HVA**	**Threat classification level Significant 80+**	**Threat classification level Moderate 60 to <80**	**Threat classification level Low >40 to <60**
Chemical Threats	6	-	✔	✔
Handling / Storage of DNAPLs	6	-	-	✔
Pathogens	6	-	-	-

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 Catfish Creek Watershed.

4.1.8 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 a future Assessment Report.

Map 4-5: Impervious Surface Related to Road Salt in Highly Vulnerable Aquifers



4.2 Significant Groundwater Recharge Areas

Significant Groundwater Recharge Areas (SGRAs) are defined as a specific type of vulnerable area that will be 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. Significant groundwater recharge areas were delineated using the water budget tools.

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 surficial geology (soil type) and land cover, and climatic conditions over the period 1980 to 2004. Threshold values were calculated and areas with annual average recharge above those values were labeled as significant. In 2021, vulnerability scoring within SGRAs was removed to align with the updates to the Technical Rules.

Threshold values for SGRAs were defined by taking 115% of the annual average recharge for the related groundwater recharge area. For the Catfish Creek watershed area, the "related groundwater recharge area" was taken as the entire Conservation Authority area. This is consistent with the guidance which recommends that this assessment is performed at the watershed scale. The average annual groundwater recharge rate for Catfish Creek Watershed is 157 mm/year. The threshold, calculated as 115% of the average annual rate, is 180 mm/year.

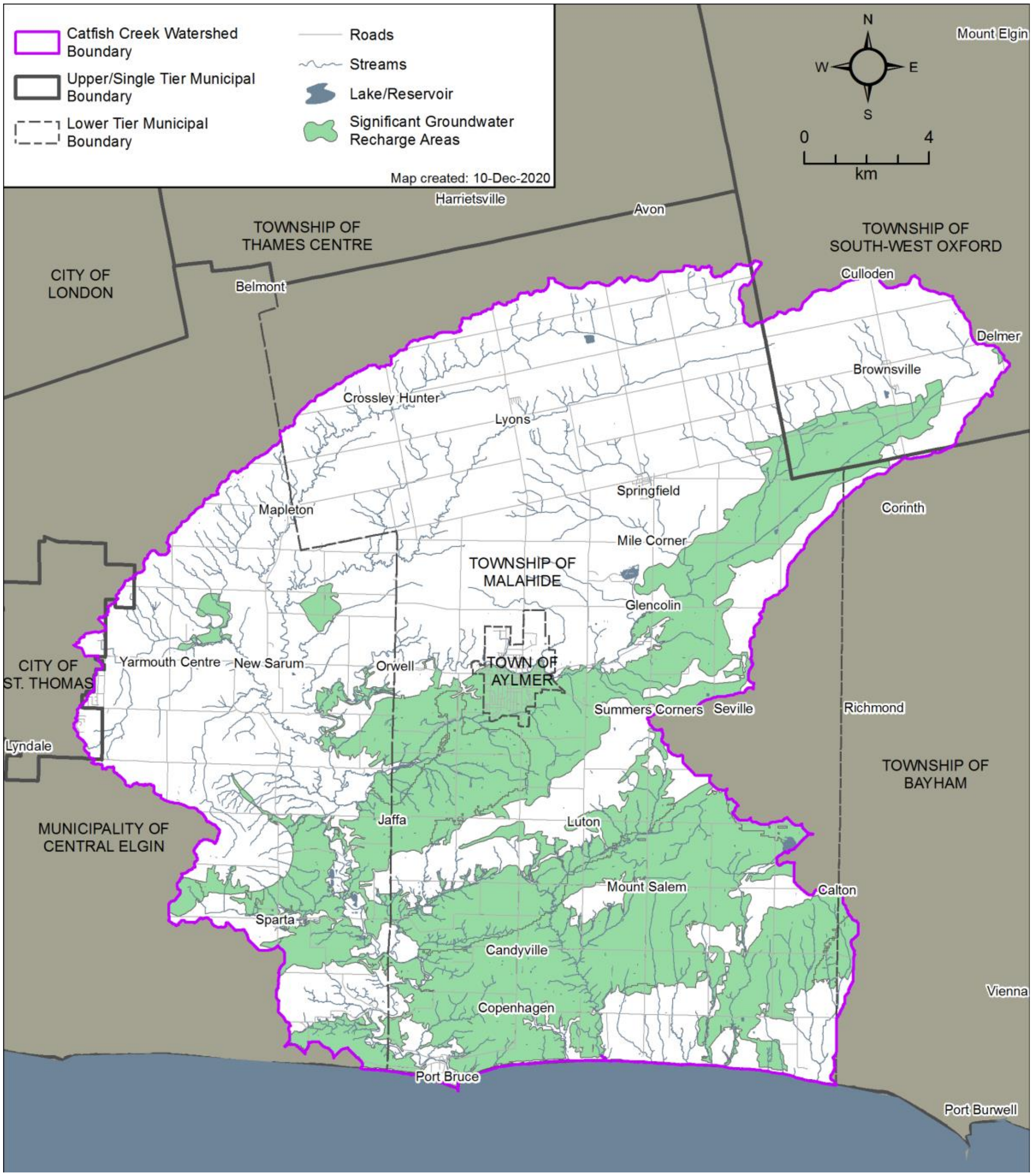
After estimating significant groundwater recharge areas, small, isolated areas (<1 km^2) were removed to create mapping that focuses the delineated significant groundwater recharge areas to larger geologic and physiographic features that are considered more representative of mapped Quaternary geology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

Map 4-6 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 Catfish Creek Watershed 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 3-3**Error! Reference source not found.**)**.

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. 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 HRUs 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 one climate station was 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 from climate change nor does it recognize the importance of seasonal and annual variability.

Map 4-6: Significant Groundwater Recharge Areas



4.3 Brownsville Water Supply

Located within the County of Oxford, the village of Brownsville was originally serviced by private wells until 1954. In 1986, the County reportedly took over the operation of the communal water system serving the village and since that time has overseen improvements to the system.

Currently, the village of Brownsville obtains its water supply from two wells, Well 5 and Well 6, completed in overburden sediments. Well 5 is located towards the west end of the village on the south side of County Road 20 (Brownsville Road) and Well 6 is located in the south central area of the village on the east side of County Road 10 (Culloden Line) . The system serves a population of approximately 490 people within the village of Brownsville. The location of these wells and the area they service is shown on **Map 4-10**.

Well 5 is screened in sand and gravel materials between depths of 45.1 metres below ground surface (m bgs) and 46.6 m bgs. This sand and gravel unit is overlain by a thick unit of low permeability clayey material. Well 6 is screened in sand and gravel between depths of 28.4 m bgs to 31.7 m bgs and is also overlain by a thick unit of clay-rich material. Both wells are considered to be situated within the 'deep overburden aquifer' which is generally found at depths greater than 30 meters.

4.3.1 Brownsville Water Supply Wellhead Protection Areas (WHPAs)

The delineation of WHPAs represents the foundation of a municipal groundwater protection strategy. The development of WHPAs for a municipal well field are based on the delineation of the time of travel capture zones for that municipal well field. The capture zones represent the area projected to land surface where groundwater can be captured by pumping at the municipal wells. Capture zones represent time of travel within the saturated zone of the aquifer to the well and do not account for travel time from ground surface down to the water table.

Capture zones for the village of Brownsville groundwater supply were estimated using a finite-difference numerical groundwater flow model (MODFLOW) calibrated to available hydrogeological data. The groundwater flow model was developed using local and regional hydrogeological conditions and is documented in the County of Oxford's Phase II Groundwater Protection Study (Golder, 2001). The total forecasted pumping rate used to model the WHPAs was 97.6 m^3/day where Well 5 and 6's individual forecasted pumping rates were 72.9 m^3/day and 24.7 m^3/day respectively. These amounts are equal to the annual volume pumped in 1999 as reported by Golder (2001). Maximum permitted annual amounts for Wells 5 and 6 were 71,482 m^3 and 66,751 m^3 respectively as reported by Golder (2001). At the time of this report average monthly pumping rates were not available.

The capture zones produced through the groundwater model were refined into WHPAs by incorporating a degree of 'safety' in their delineation to account for uncertainty in the model. This was addressed by first expanding the capture zones by 20% in width and length to account for uncertainty in the hydraulic characteristics of the aquifer supplying the municipal well, and secondly by adjusting the orientation of the capture zone by 5 degrees along its centre line to account for uncertainty in the regional flow direction.

WHPAs associated with the municipal water supply represent the areas within the aquifer that contribute groundwater to the well over a specific time period. Four WHPAs have been delineated for the Brownsville supply wells, one is a proximity zone and the others are time-related capture zones:

- WHPA - A 100 m radius from well head
- WHPA - B 2-year Time of Travel (TOT) capture zone
- WHPA - C 5-year TOT capture zone
- WHPA - D 25-year TOT capture zone.

The following sections provide an overview of the Brownsville groundwater model.

Model Construction, Aquifer Data, Assumptions and Calibration
The Brownsville groundwater model covers an area of approximately 22 km², and is oriented in a north to south direction, parallel to the direction of regional groundwater flow in the overburden (Deep) aquifer. The following provides a summary of the Brownsville Groundwater Flow Model (Golder, 2001) based on the available hydrogeological information at that time:

Stratigraphy
The principal aquifer in the Brownsville area is considered to be the Deep Aquifer. The Intermediate Aquifer is inferred to overlie the Deep Aquifer, while the Shallow Aquifer is not present. Overlying the Intermediate and Deep Aquifers is a thick deposit of relatively low permeability till. Based on the above, the Brownsville Groundwater Model was constructed using three overburden layers; a thick layer (approximately 28 metres thick) to represent the till; a 4 metre thick layer for the Intermediate Aquifer; and a relatively thick layer at the bottom of the model representing the Deep Aquifer. The base of the model was defined by the base of the Deep Aquifer.

Groundwater Flow Boundaries
Groundwater flow in the Deep Aquifer at Brownsville is inferred to occur in a southerly direction and the Brownsville Groundwater Model was therefore oriented in this direction. To the north and south of Brownsville the model boundaries follow inferred groundwater contours and were assigned as constant

head boundary conditions. To the north, a constant head boundary elevation of 260 masl was assigned. Groundwater will flow into the model across this boundary. To the south, a constant head boundary elevation of 225 masl was assigned.

Groundwater will flow out from the model across this boundary. To the east and west of the water supply wells, the model boundaries follow inferred groundwater flowlines, and were, therefore, assigned as "no flow" boundaries. It is assumed that groundwater flow in the overburden does not occur across these boundaries.

Groundwater/Surface Water Interaction

The Deep and Intermediate Aquifers at Brownsville are isolated from the surface water systems by a considerable thickness of low permeability clayey materials. They are assumed to be hydraulically isolated from the surface drainage systems in the Brownsville area. Catfish Creek was included in the model as a constant head boundary; however, this boundary was applied to the top (till) layer only and would not significantly affect groundwater flow conditions in the Intermediate or Deep Aquifers.

Recharge

Recharge into the till was applied in the groundwater model uniformly across the model area at a rate of 20 mm/year.

Hydraulic Conductivity and Porosity

A long term (forty-eight hour) aquifer test was completed at Brownsville Well 6 in 1998, with the local transmissivity estimated in the range of 100 to 190 m^2/d, and an effective regional transmissivity of 30 to 35 m^2/d. Assuming an aquifer thickness of 2 m at Well 6, the hydraulic conductivity may locally be on the order of 8.4×10^{-4} m/s. Regionally, assuming the aquifer thickness is still on the order of 2 m, the hydraulic conductivity estimate would be about 2×10^{-4} m/s. The hydraulic conductivity of the Deep and Intermediate Aquifer in the Brownsville Groundwater Model was assigned at 1×10^{-4} m/s, with an effective porosity of 25% . The hydraulic conductivity of the overlying till was assigned at 1×10^{-8} m/s. These values were established through the model calibration process.

Other Water Takings

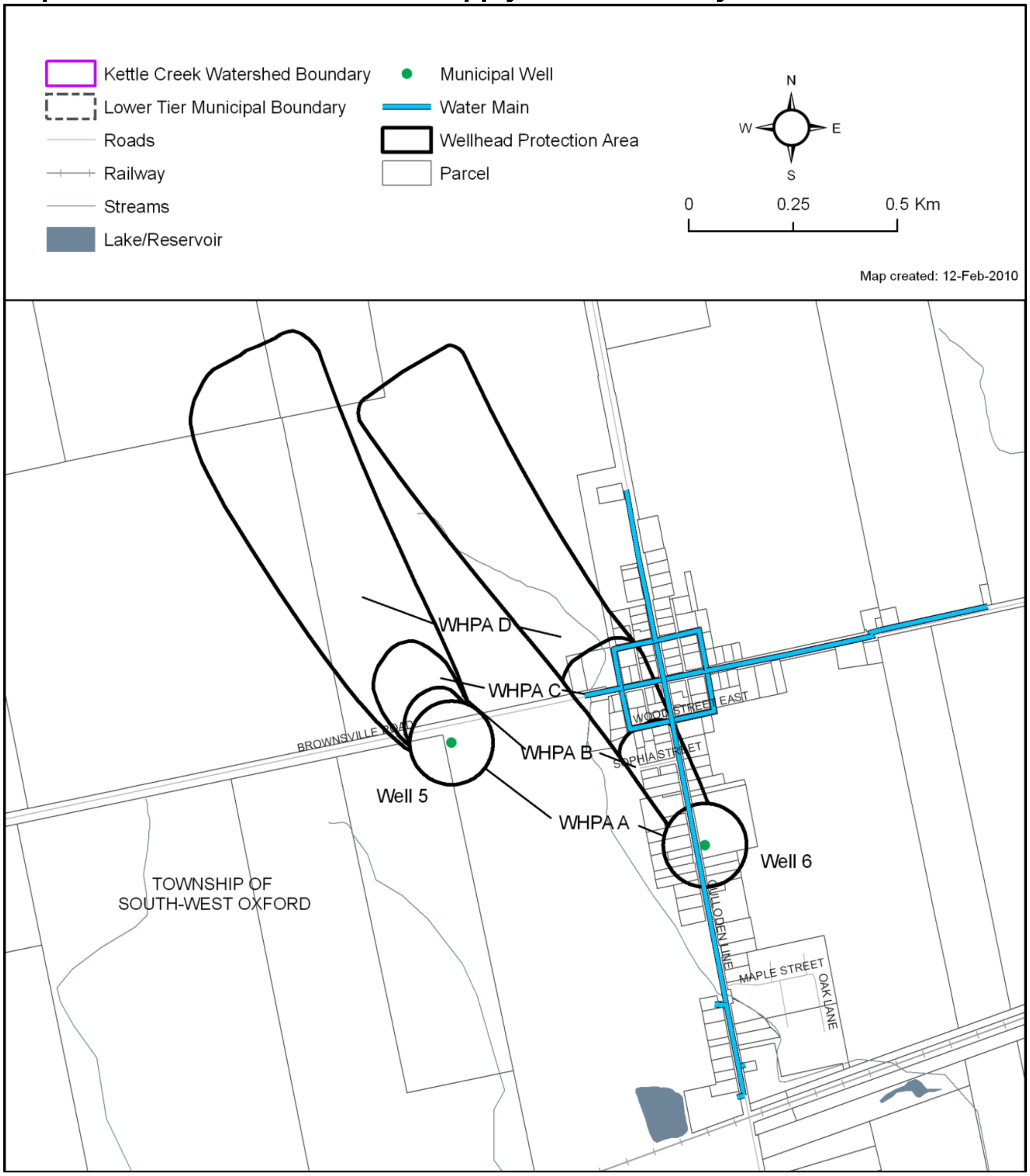
There were no large private water takings from the Intermediate or Deep Aquifer identified in the review of the MOE PTTW Database for the Brownsville area at the time of the Golder (2001) report. It was assumed that the Brownsville water supply wells were the only water taking from these aquifers in this area.

Calibration of the Brownsville Groundwater Model involved the adjustment of the recharge rate into the till and the hydraulic conductivity of the Intermediate and Deep Aquifer until there was a reasonable match between the simulated groundwater elevations and the recorded groundwater elevations for Brownsville area overburden wells in the MOE Well Record Database. As defined above, the hydraulic conductivity of the Intermediate and Deep Aquifer was estimated to be

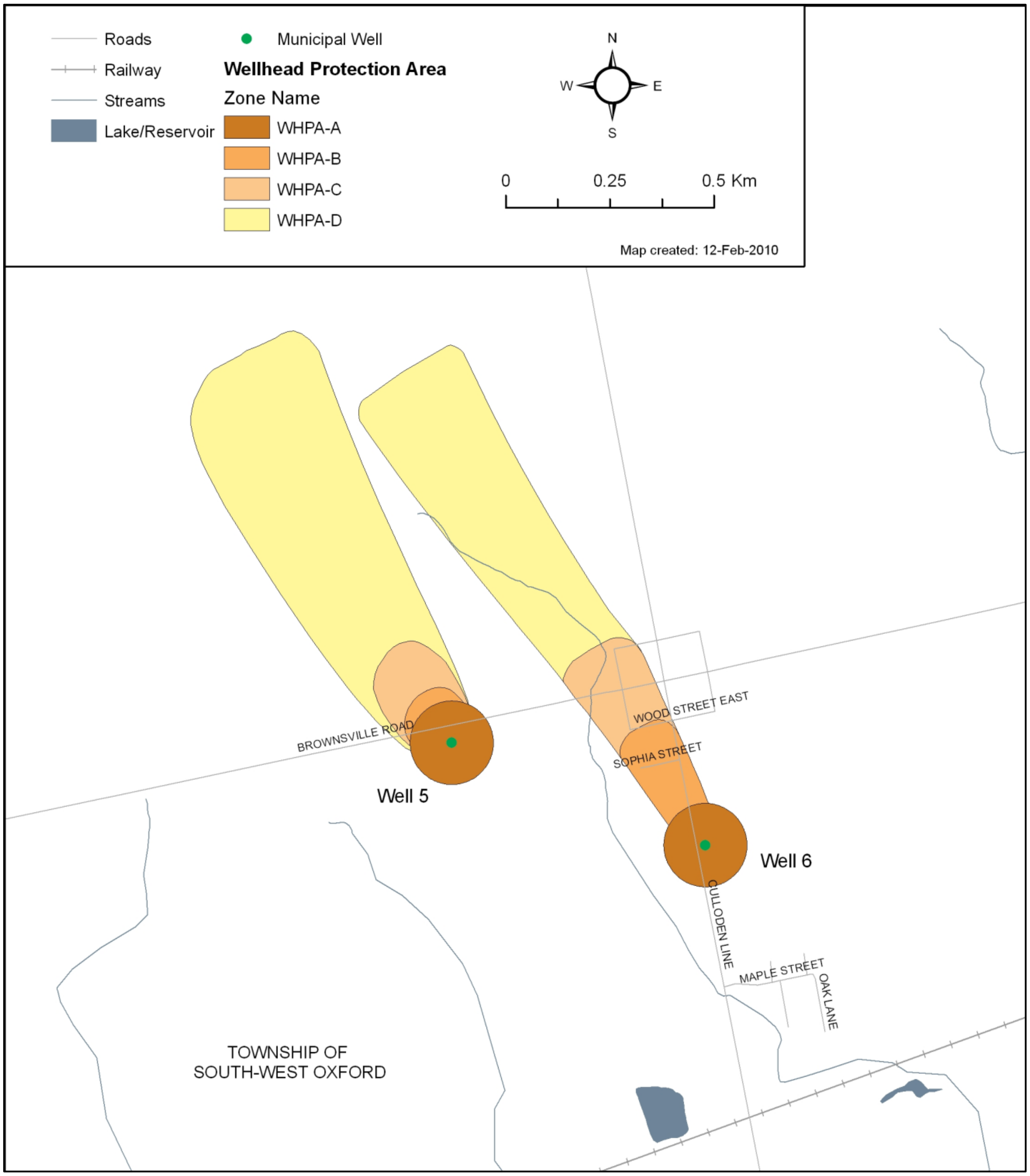
1 x 10^{-4} m/s, with a recharge rate of 20 mm/year into the till. The average annual pumping rate in 1999 (of 97.6 m^3/d) was used in the calibration process.

The Brownsville WHPAs, shown on **Map 4-8** extend to the northwest over a distance of approximately 1 km from Well 5 and 1.4 km from Well 6.

Map 4-7: Brownsville Water Supply Distribution System



Map 4-8: Brownsville Wellhead Protection Area



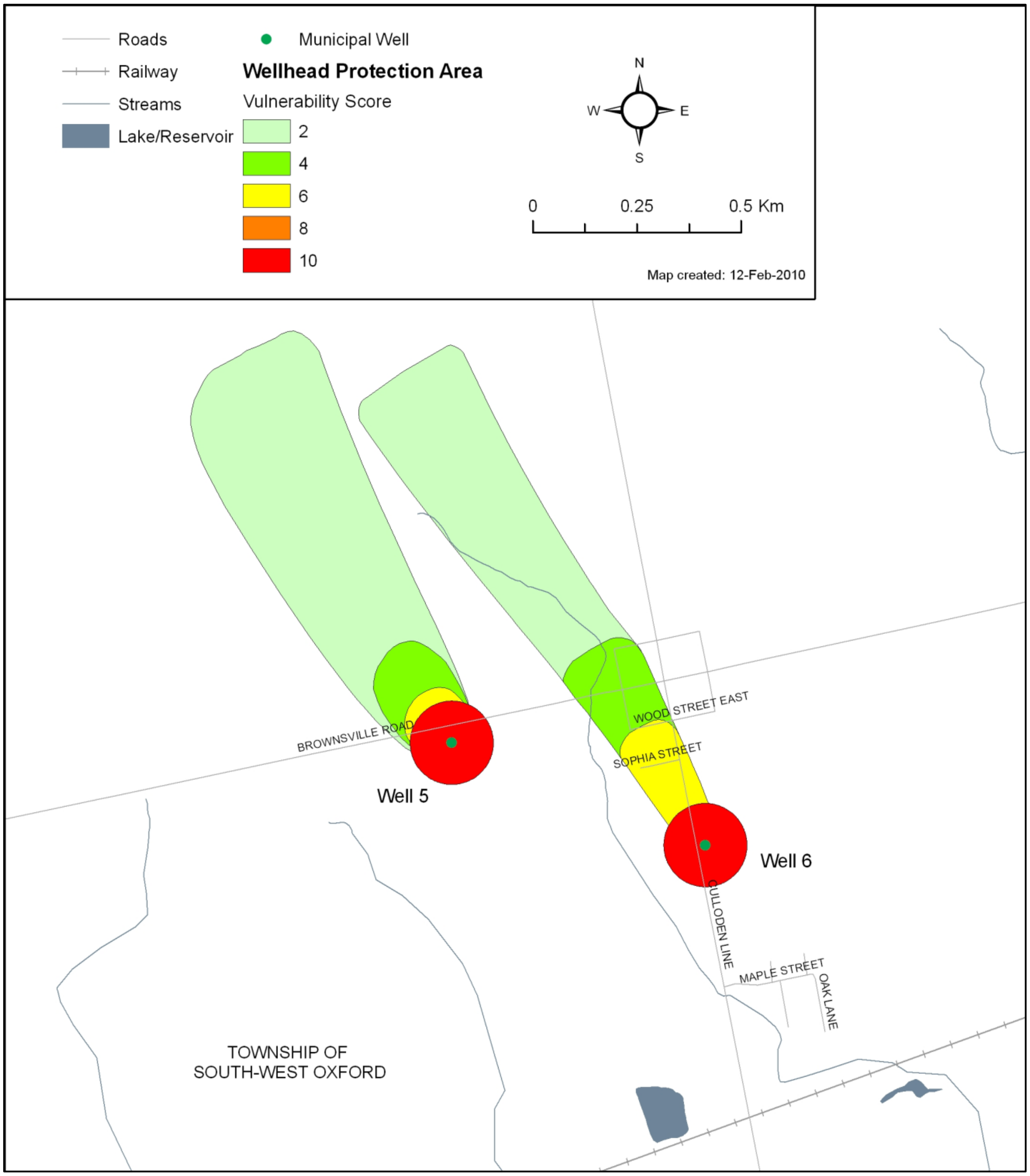
4.3.2 Vulnerability Scoring in Brownsville Wellhead Protection Areas

Aquifer vulnerability for the Brownsville system was calculated using the Aquifer Vulnerability Index (AVI) method. The vulnerability calculated for the deep overburden aquifer within the vicinity of Brownsville is low (Golder, 2001). This result is considered appropriate for the municipal aquifer given the confined groundwater conditions and the thick overlying sequence of clay-rich till.

The vulnerability scores within the WHPAs were calculated by overlaying the mapped WHPAs with the aquifer vulnerability. Vulnerability scores were determined from areas of intersection between the WHPAs and the vulnerability, as outlined in **Table 1-1**.

Vulnerability scoring results are shown on **Map 4-12**. As indicated, the majority of vulnerability scores are low with a score of 10 only within Zone A. Zone B has a score of 6, Zone C has a score of 4, while Zone D has a vulnerability score of 2.

Map 4-9: Brownsville Wellhead Protection Area Vulnerability Scoring



4.3.3 Identification of Transport Pathways within Wellhead Protection Areas

Transport pathways were assessed with respect to aquifer vulnerability as these features may increase the vulnerability of a given aquifer in areas where transport pathways are concentrated.

To identify transport pathways, the County of Oxford evaluated the following datasets within the WHPAs:

- 2006 aerial photography
- Locations of water wells obtained from the MOE water well information system (WWIS)
- Sanitary sewers
- Septic systems
- Storm water infiltration facilities
- Pits and quarries
- Petroleum wells located within 100 m of the WHPAs

4.3.4 Adjusted Vulnerability Scoring

The Technical Rules allow investigators to modify the vulnerability scoring if there is concern that the identified transport pathways within the WHPAs may increase the vulnerability of the aquifer beyond that which was originally mapped. Vulnerability scores are modified by increasing the vulnerability of the underlying aquifer vulnerability map from either a low to moderate value or moderate to high value. An initial aquifer vulnerability value of high cannot be increased.

For the Brownsville system, the transport pathway assessment resulted in only a small number of private wells (as identified in the MECP WWIS) located within the WHPAs. As a result, the County of Oxford did not adjust the vulnerability scoring within the Brownsville WHPAs.

4.3.5 Peer Review of WHPAs and Vulnerability

The Brownsville WHPAs (Golder, 2001) were completed in advance of the Clean Water Act through the MOE-funded Municipal Groundwater Protection Studies. Oxford County has reported that the WHPAs were reviewed at the time of the report by MECP staff and peer reviewed by professional staff at the Grand River Conservation Authority, University of Western Ontario and two consultants as a component of these groundwater protection studies.

4.3.6 Limitations of Data and Methods

Delineation of Wellhead Protection Areas

Sources of uncertainty associated with the capture zones were recognized and addressed as part of the Phase II Groundwater Protection Study (Golder, 2001). One example was the effect of uncertainty in the hydraulic conductivity (K) . It was noted that a lower K can result in a wider, but shorter capture zone, whereas a higher K can result in a narrower, but longer capture zone. A second example was the effect of uncertainty in the direction of regional groundwater flow, which was based on interpretation of MECP water well record data. It was noted that a difference of 5 degrees in the direction of groundwater flow may be insignificant near the production wells but would be much more significant further upgradient of the wells (Golder 2001). To address these uncertainties, the shape of the capture zone was adjusted using two shape factors. The first shape factor was a 20% increase in the overall shape of the capture zone (20% increase in width at the centerline, and a 20% increase in length upgradient and downgradient of the production well). The second shape factor was the addition of a 5 degree angle added to the centerline of the capture zone, in effect increasing the width at increasing distances from the pumping well. The objective of applying the second shape factor was to compensate for uncertainty in the regional groundwater flow direction. Golder (2001) noted that for capture zones intersecting groundwater flow divides and recharge boundaries (i.e. river boundaries) , those boundaries were still used to limit the extent of the capture zone, notwithstanding the adjustments made in applying the shape factors.

Groundwater Vulnerability Assessment and Mapping

The intrinsic groundwater vulnerability within Brownsville was estimated using the AVI method and is documented in the Golder (2001) report. Oxford County reports that considerable thought and interpretation went into the work and as a result the intrinsic vulnerability map products used in the groundwater vulnerability assessment to have a low uncertainty.

4.3.7 Uncertainty Assessment

Vulnerability mapping within the Brownsville WHPAs was completed using the AVI method. Uncertainty within the capture zones was addressed through the addition of 'safety factors' in their delineation. As previously discussed, capture zones were expanded 20% in width and length and then adjusted by 5 degrees along their centre line. Further, WHPAs the were modelled using a 3-dimensional, finite difference groundwater model (MODFLOW). Municipal pumping rates used in the model were provided by the municipality and are not expected to be updated within the near future. Given these circumstances, the uncertainty rating for the WHPAs is considered low.

4.3.8 Managed Lands and Livestock Density

Managed Lands are lands to which nutrients are applied. Managed lands can be categorized into two groups: agricultural managed land and non-agricultural managed land. Agricultural managed land includes areas of cropland, fallow, and improved pasture that may receive nutrients. Non-agricultural managed land includes golf courses, sports fields, lawns and other grassed areas that may receive nutrients (primarily commercial fertilizer). Determining the location and percentage of managed lands, the location of agricultural managed lands, and the calculation of livestock density are used to determine whether the application of agricultural source material (ASM) , non-agricultural source material (NASM) , and fertilizer were significant threats within the Brownsville wellhead protection areas.

As per the Technical Rules, subrule 16(9), the location and percentage of managed lands were only calculated where the vulnerability score was 6 or greater, which for Brownsville, include WHPA - A and WHPA - B for each well.

The location of managed lands in each wellhead protection area zone was determined by subtracting woodlots, wetlands, impervious surfaces and structures from the total area in the each vulnerable area. Following the subtraction of these layers, the resulting file was edited manually using air photo interpretation to ensure only managed lands were included.

The percentage of managed land was calculated by dividing the area of managed land for each WHPA by the total area of land for that WHPA. The resulting percent managed land values are shown in **Table 4-5** and **Map 4-10.**

Table 4-5: Managed Land Calculations

Scenario	Total Area (m^2)	Managed Land Area (m^2)	% Managed Land
Well 5 WHPA– A	31,413	22,495	71.6%
Well 5 WHPA– B	5,515	4,986	90.4%
Well 6 WHPA– A	31,413	18,784	59.8%
Well 6 WHPA– B	29,773	16,757	56.3%

Agricultural Managed Lands

The location of agricultural managed land was determined from the Oxford County zoning and from the Municipal Property Assessment Commission (MPAC) property descriptions. This data was further edited to ensure all woodlots, wetlands, impervious surfaces, structures and non-agricultural turf was removed.

The total area of agricultural managed lands in each WHPA is required to calculate livestock density. These resulting areas of agricultural managed lands are shown below.

- Well 5 WHPA– A total Agricultural Managed Lands is 5.56 acres.

- Well 5 WHPA– B total Agricultural Managed Lands is 1.23 acres.
- Well 6 WHPA– A total Agricultural Managed Lands is 0.15 acres.
- Well 6 WHPA– B total Agricultural Managed Lands is 0 acres.

Calculation of Livestock Density (NU/ Acre)
Livestock density is calculated as the number of nutrient units associated with livestock on farm properties that intersect vulnerable areas, divided by the corresponding area of agricultural managed land.

For each farm property that intersects WHPA– A and WHPA– B, the type of livestock was determined based on 2006 aerial photos, MPAC property descriptions, roadside assessment and County staff's local knowledge.

The number of livestock on each farm property was estimated based on the capacity of the farm infrastructure. Farm buildings that house livestock were identified on the 2006 aerial photographs and their area measured. The nutrient units associated with the identified type of livestock were then interpreted from the Barn/ Nutrient Unit Relationship Table (GRCA, 2009). **Table 4-6** provides an average square feet/ NU ratio for each livestock type.

Table 4-6: Nutrient Unit Calculations

Farm Unit	Livestock Barn Structure Area (feet^2)	Type of Farm Operation	Barn/per N U Relationship Value	Nutrient units
Farm 1	15,092	beef	100	151
Farm 2	No livestock barns	cash crops	Not Applicable	Not Applicable
Farm 3	6,265	dairy	120	52
Farm 4	1 structure, not a livestock barn	cash crops	Not Applicable	Not Applicable

For each WHPA, the livestock densities for each farm were applied to the portion of that farm in the vulnerable area and nutrient units for all farms summed. The total number of nutrient units was then divided by the area of agricultural managed lands in that vulnerable area. These calculations are shown in **Table 4-7** and **Map 4-11.**

Table 4-7: Livestock Density (NU/ Acre) Calculations

Scenario	Total NU	Total Acreage	Livestock Density (NU / Acre)
Well 5 WHPA– A	1.60	5.56	0.29

Scenario	Total NU	Total Acreage	Livestock Density (NU / Acre)
Well 5 WHPA– B	0.86	1.23	0.70
Well 6 WHPA– A	None	0.15	0.00
Well 6 WHPA– B	none	0.00	0.00

4.3.9 Percentage of Impervious Surface Area

To calculate the percentage of impervious surfaces for the Brownsville system, a 1 km by 1 km grid was created over the two WHPAs for Wells 5 and 6. Since roadways, sidewalks and parking lots all receive applications of road salt, these surfaces were considered impervious. Grid cells were established by placing the centre of a 1 km by 1 km grid cell over the centroid of each WHPA. The grid was then extended outward from this point by adding adjacent 1 km by 1 km grid cells until the entire WHPA was covered.

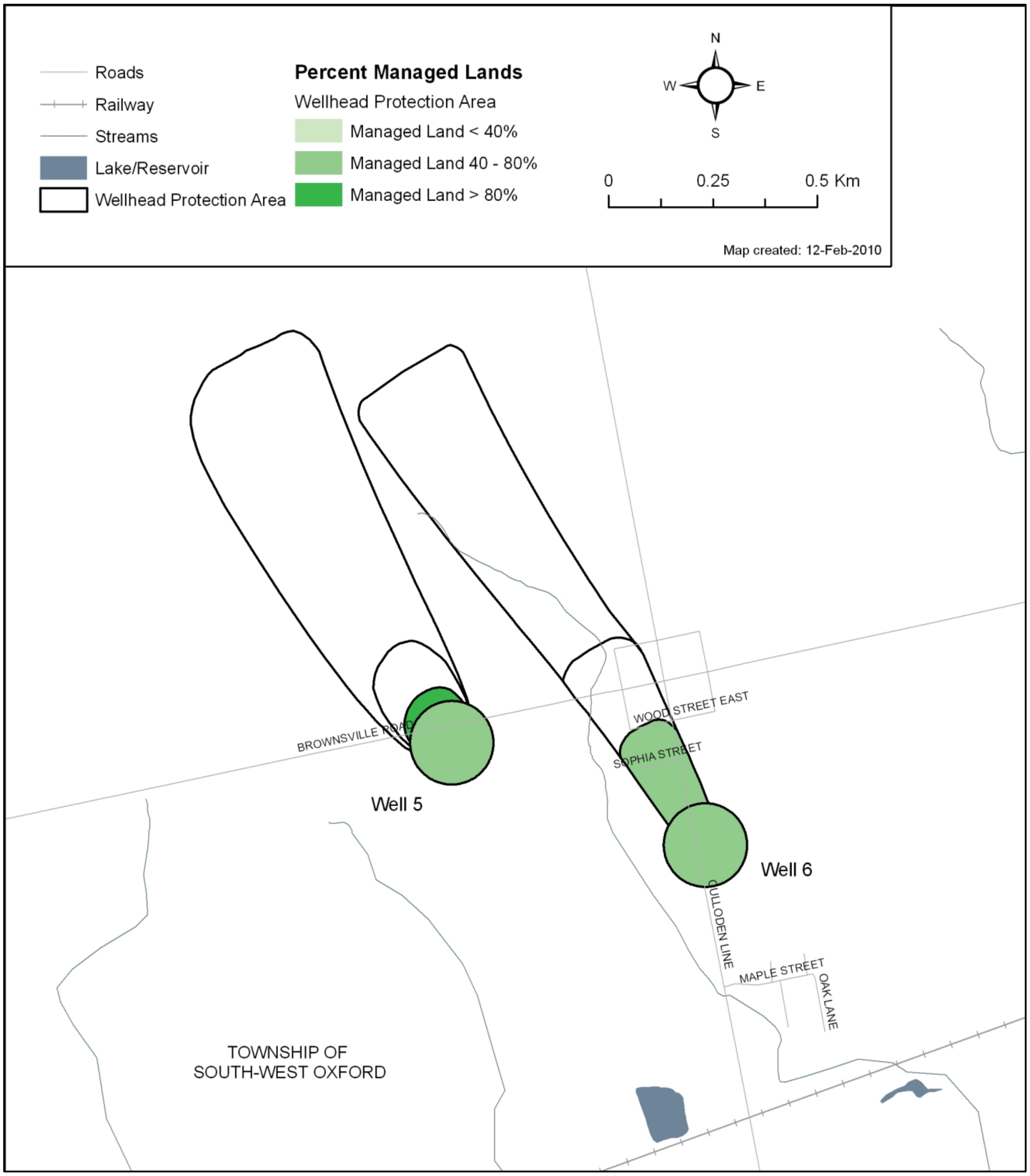
Technical Rule 17 was removed in the amended December 2021 update to the Technical Rules allowing flexibility in methods used to calculate impervious surfaces. Since the application of road salt can only be a significant threat in areas with a vulnerability score of 6 or greater, the percent impervious calculation was only completed in areas with a score of 6 or greater (WHPAs A and B) for each well.

The percentage of impervious surface in each grid cell was calculated by dividing the total impervious surface area within the vulnerable area of each grid cell by the total vulnerable area of that same grid cell. The results show that due to the low percentage of impervious surfaces in Brownsville, the application of road salt is not a significant threat. The calculations for Brownsville are shown in **Table 4-8** and **Map 4-12.**

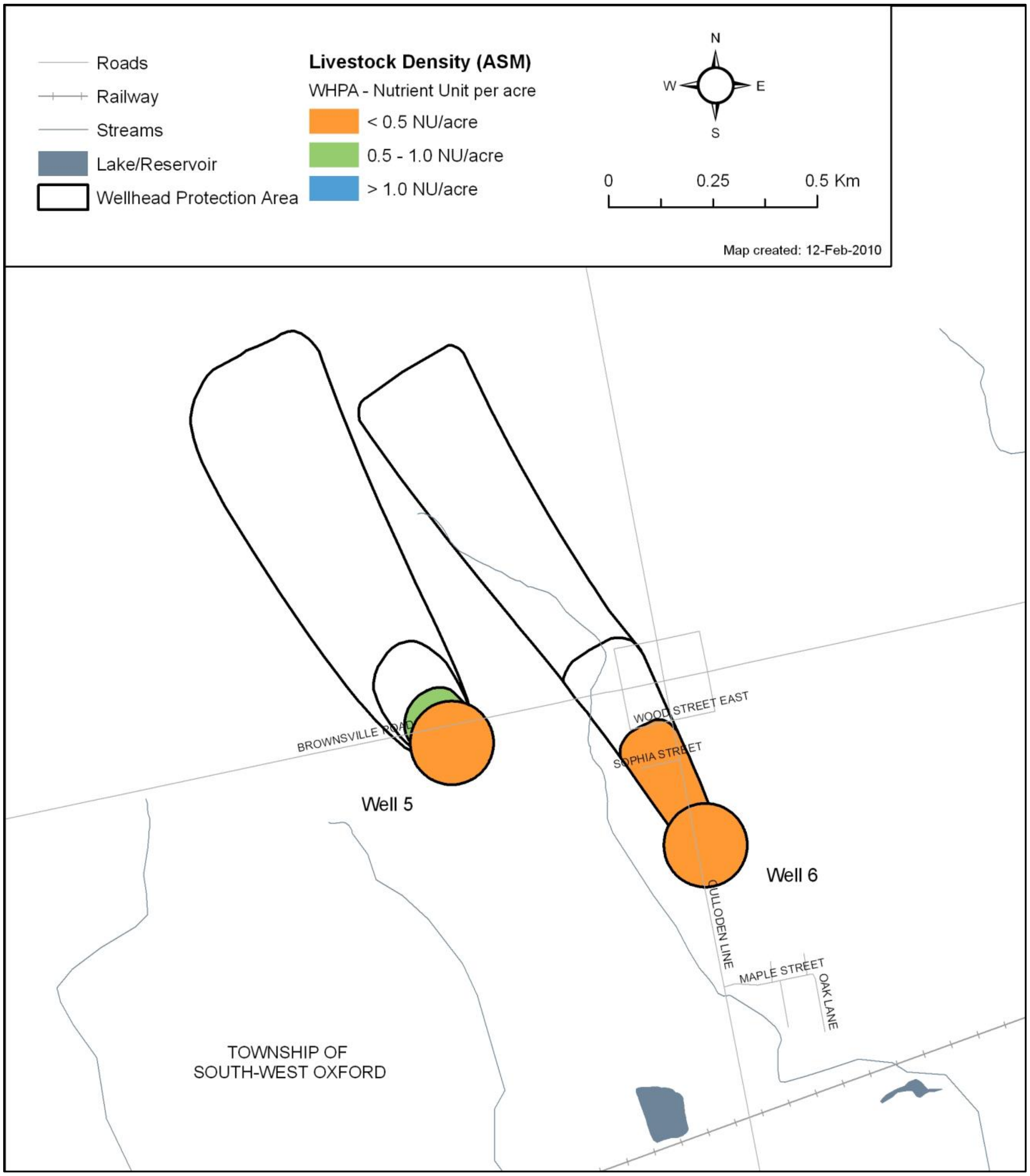
Table 4-8: Impervious Surface Calculations

Grid Cell	Impervious Surface Area (m^2)	Vulnerable Area (m^2)	Impervious Surface (%)
Well 5	2,860	316,757	0.77%
Well 6 (North Cell)	10,319	248,824	4.15%
Well 6 (South Cell)	3,339	34,346	9.72%

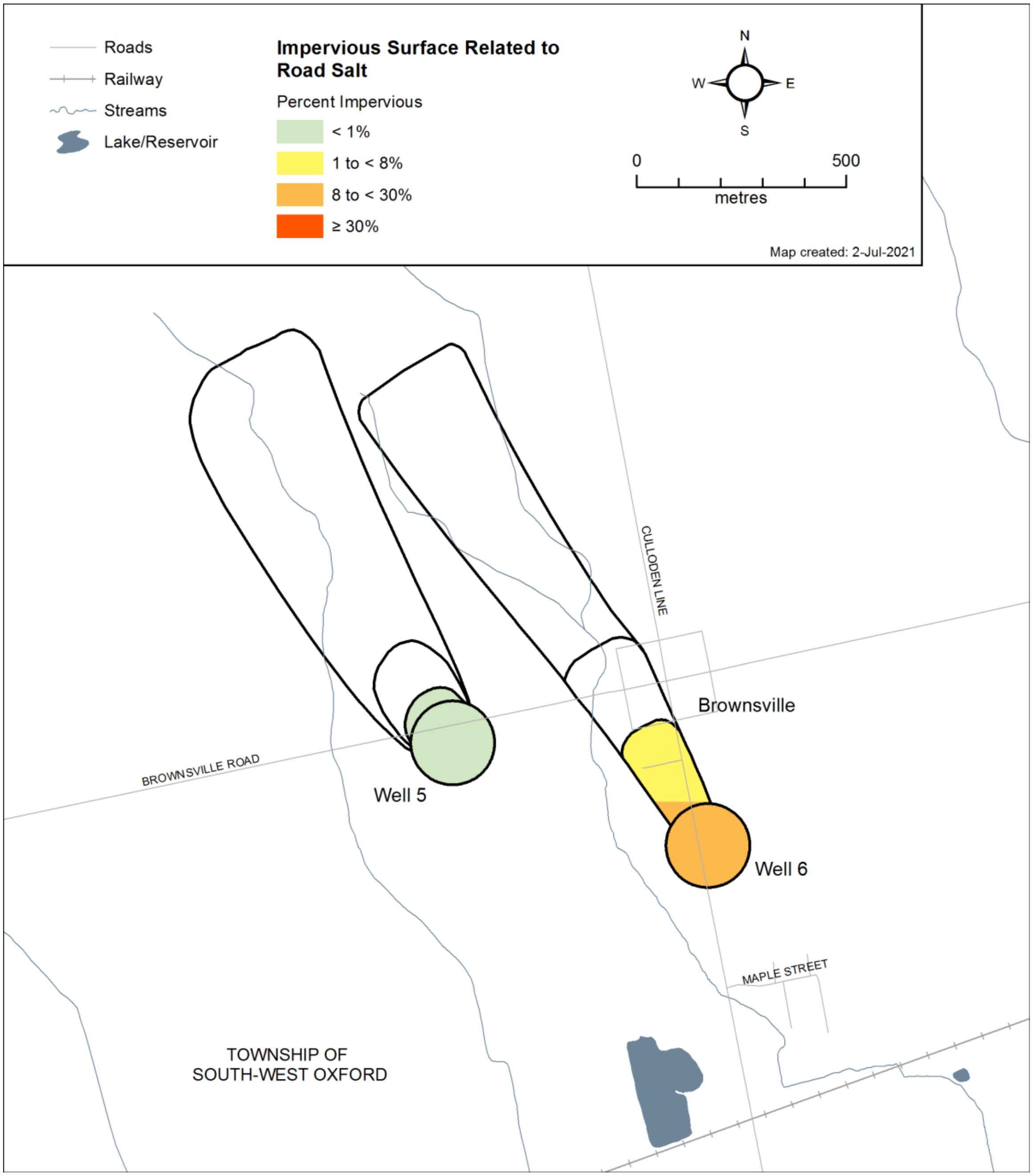
Map 4-10: Managed Lands in Brownsville Wellhead Protection Areas



Map 4-11: Livestock Density in Brownsville Wellhead Protection Areas



Map 4-12: Impervious Surfaces in Brownsville Wellhead Protection Areas



4.4 Brownsville Water Quality Threat Assessment

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."

The Technical Rules (MECP, 2021) list five ways in which to identify a drinking water threat:

a) through an inventoried 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 (local 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.

Significant threats to the Brownsville groundwater supply were assessed through the development of a desktop land use inventory for the original 2010 version of the assessment report. Since that time, threat assessments have relied on different sources of information. Threats are currently assessed through a combination of windshield surveys and local knowledge / field verification.

The identification of a land use activity as a significant, moderate, or low drinking water threat depends on its risk score, determined by considering the circumstances of the activity and the type and vulnerability score of any underlying protection zones, as set out in the 2021 Technical Rules. Information on drinking water threats is accessible through the Source Water Protection Threats Tool. The information above can be used with the vulnerability scores shown in **Map 4-9** to help the public determine where certain activities are or would be significant, moderate and low drinking water threats.

Table 4-9 provides a summary of the threat levels possible in the Brownsville Well Supply for Chemical, Dense Non-Aqueous Phase Liquid (DNAPL) , and Pathogen threats. A checkmark indicates that the threat classification level is possible for the indicated threat type under the corresponding vulnerable area / vulnerable score; a blank cell indicates that it is not.

Table 4-9: Classification of Possible Drinking Water Threats in the Brownsville Wellhead Protection Areas

Threat Type	Vulnerable Area	Vulnerability Score	Significant 80+	Moderate 60 to <80	Low >40 to <60
Chemicals	WHPA– A	10	✔	✔	✔
Chemicals	WHPA– B	6	-	✔	✔
Chemicals	WHPA– C/ D	2 and 4	-	-	-
Handling / Storage of DNAPLs	WHPA– A/ B/ C	Any Score	✔	-	-
Handling / Storage of DNAPLs	WHPA-D	2 and 4	-	-	-
Pathogens	WHPA– A	10	✔	✔	-
Pathogens	WHPA– B	6	-	-	✔
Pathogens	WHPA– C/ D	Any Score	-	-	-

4.4.1 Prescribed Activities that Are or Would be Drinking Water Threats in Wellhead Protection Areas check

Ontario Regulation 287/07, pursuant to the Clean Water Act, provides a list of Prescribed Drinking Water Threats that could constitute a threat to drinking water sources. **Table 1-3Error! Reference source not found.** lists the activities that are prescribed as water quality related Prescribed Drinking Water Threats. Listed beside the Prescribed Drinking Water Threats are the typical land use activities that are associated with the threat.

4.4.2 Land Use Inventory Methodology

To associate the prescribed drinking water threats listed in **Table 1-3Error! Reference source not found.** with land use activities, the County of Oxford compiled a land use inventory for the original 2010 version of the assessment report. The inventory was based on a review of multiple data sources which included previous groundwater-related work undertaken by the County, public records, local knowledge and windshield surveys.

No site specific information was collected for the inventory. All threats identified through this assessment were considered potential and required further site specific assessments to confirm their presence.

The datasets used to form the basis of the threats inventory are provided in **Table 4-10**.

Table 4-10: Datasets for Threats Inventory

Name	Purpose	Comments
Water Wells Record Database (MOE) The database includes locations of both private and municipal wells, as well as additional information including the operating status of the well.	To identify potential transport pathways.	- Current to 2000 - Accuracy of all points is questionable
Certificates of Approval (MOE) Contains Certificates of Approval for Air, Industrial Wastewater and Municipal/Provincial Sewage and Waterworks	To flag potential circumstances.	- Dataset received October 2003 - Dataset incomplete
Existing Land Uses (County of Oxford) A detailed inspection of land use in the County's WHPAs, identified according to its NAICS code.	To flag potential circumstances	- Completed in 2004 - Updated in 2007
O. Reg 347 – Waste Generators Summary, Waste Receivers Network (HWIN) HWIN is a web-based service that allows hazardous waste generators, receivers, and carriers to register their activities with the MOE on-line	To flag potential circumstances.	- Database last received January 2004
Historical Land Uses (County of Oxford) Represent sites where industrial operations were formerly established. Identification of sites was completed using historical fire insurance maps.	To flag potential conditions.	- Maps dated 1876 to 1984 - No record on quantity or type of contaminants
Patrol Yards (Oxford) Potential salt storage.	To identify salt storage locations	- Updated as required by County

Name	Purpose	Comments
Ontario Inventory of PCB Storage Sites (MOE)	To flag potential circumstances	- Current to 2000
Petroleum Wells (MNR) Petroleum wells, both producers and those that are abandoned, have been included in the inventory.	To identify potential transport pathways.	- This information ranges in date from 1967 to 1973.
Private Fuel Storage Tanks (TSSA) The Technical Standards and Safety Authority (TSSA) maintains a database of all registered commercial and industrial underground storage tanks.	To flag potential threats.	- Database received October 2003 - Database contains no date information
Wastewater Treatment Facilities (County of Oxford)	To flag potential threats.	-Updated as required by County Staff
Pits and Quarries (Oxford) The County's LRIS contains a data layer of operating pits and quarries. This layer was varied using air photo interpretation.	To identify potential transport pathways.	- Inventoried in 2007 - Requires periodic update
Storm Water Infiltration (Oxford) This dataset was compiled based on information about stormwater ponds provided by the Chief Building Official's of the area municipalities.	To identify Potential transport pathways.	- Inventoried in 2007 - Requires periodic update
Septic Systems (Oxford) This data layer was created based on the absence of sanitary sewer infrastructure and the presence of a dwelling.	To flag potential threats or transport pathways.	- Will require updates as certain settlements are serviced with sanitary sewers.
Sanitary Sewer Infrastructure (Oxford) This data layer was created and provided by the County of Oxford Public Works Department.	Potential threat circumstance.	- Will require updates as new infrastructure is installed
Gas pipelines (Sun Canada, Enbridge, Union Gas, Imperial Oil) Data provided by gas companies	Potential threat circumstance.	- May require periodic updates

Name	Purpose	Comments
2006 Orthoimagery (SWOOP)	Air photo Interpretation	- 30 cm Resolution

Previous Work
In 2004, the County of Oxford participated in a groundwater protection pilot project known as the Land Use and Chemical Occurrence (LUCO) , Inventory. The objective of the inventory was to identify past and present sources of potential threats that may represent risks to aquifers or are within WHPAs. The inventory was based on the guidelines from the provincial Groundwater Studies' Technical Terms of Reference (2001). Data was obtained primarily through government and commercial databases. This information was used as the starting point for the current threats inventory.

Local Knowledge
Wherever possible, County and Township staff's local knowledge was used to supplement the datasets. Local knowledge was used to confirm road salt application, details of activities undertaken on properties, and type and number of livestock on agricultural properties.

Windshield Surveys
Windshield surveys were conducted to:

- Gain information on current land uses,
- Confirm land uses, and
- Confirm locations of potential drinking water threats

The survey was conducted within the County of Oxford between the spring and fall of 2007. The windshield survey was often used for verification of data obtained from various other sources.

Government Databases
The County of Oxford obtained a number of government and commercial databases during the 2004 LUCO study. Updated versions of these datasets were obtained for the current land use inventory wherever possible.

Other Sources
Data sources other than those described above were primarily used for data verification and improvement. These sources include the County of Oxford On-Line Directory (COOLOxford) , the County of Oxford's Land Related Information System (LRIS) , the North American Industry Classification System (NAICS) , Industry Canada's website, and the Yellow Pages.

The COOLOxford website provides access to a database of public notices, events, businesses, organizations, and services in Oxford County.

The County's LRIS, which is maintained by the County of Oxford, is a Geographic Information System (GIS) , that combines digital maps of the area with related information, such as:

- Property owner and registry,
- Assessment and apportionments,
- Property dimensions,
- Structure locations and characteristics,
- Topographic features including flood plains and vegetation,
- Cultural information including zoning and Official Plan designation, and
- Aerial photography.

For the purposes of the initial threats inventory, NAICS codes were used to determine land use activity names and potential associations with land uses that constitute threats.

Industry Canada provides business and consumer information via the internet. Their website was used to obtain business/industry profiles. The on-line version of the yellow pages was used to locate businesses and provided links to business websites which helped determine activities undertaken by companies.

4.4.3 Water Quality Risk Assessment Methodology

The land use activities listed in **Table 1-3Error! Reference source not found.** (Prescribed Drinking Water Threats) could pose a threat to drinking water, but only under certain circumstances.

For a given threat, the selection of applicable circumstances was key to the implementation of the Water Quality Risk Assessment for the original 2010 version of the assessment report. Circumstances were assigned to a threat based on site-specific knowledge of activities on a given property.

Results were then assessed to determine whether the resulting circumstances were relevant based on Oxford County staff knowledge of land use activities. Professional judgment and assumptions were applied in each case since the information gathered did not confirm the presence of particular circumstances that would be associated with land use activities.

Land Use Activity Assumptions
A standardized set of assumptions were made for each land use type and activity. The assumptions are summarized below.

- Agricultural property with residence and outbuildings: Storage and handling of pesticides, fuel, commercial fertilizer, Agricultural source material, septic system. Application of pesticide, commercial fertilizer, agricultural source material.
- Agricultural property with residence and outbuilding – buildings not in WHPA: Circumstances related to storage and handling or septic systems are not applied. Those related to application are applied.
- Agricultural property without farm buildings and structures: Circumstances related to storage and handling or septic systems are not applied. Those related to application are applied.
- Residence with no gas line: Oil furnace
- Organic solvent: storage below grade in a quantity that would make it a significant threat
- No sanitary sewer infrastructure: septic system
- Presence of any chemical: Storage is below grade
- Multiple PINs associated with one Assessment Roll number: One threat point assigned to the entire assessed property.
- Where an assessment line transects a property, but has one PIN: One threat point assigned to the entire property.
- Lawn/ turf: Potential application of commercial fertilizer (ID dependent on the percent of managed land and the application of NU to the surrounding properties)
- Municipal well sites: commercial fertilizer not applied unless the well is within a municipal park, in which case there is potential that fertilizer is applied.
- All properties: If buildings and structures are located outside the vulnerable area – circumstance IDs associated with storage and handling are not applied.
- Septic system: In serviced villages where sanitary services are being phased in, but have not yet reached the mandatory connection date, it is assumed private septic systems are still present.

Assumptions are further discussed as part of the enumeration of significant threats.

Enumeration of Significant Threats

The 2021 version of the Technical Rules was used to confirm the latest threats enumeration. A list of all significant threat subcategories is shown in **T**able 4-11. In the case of Brownsville, all twenty significant threats occur in a WHPA – A, the 100 metre radius circle around the well.

Table 4-11: Brownsville Significant Threats – current as of March 2022

PDWT[1] #	Threat Subcategory	Number of Activities	Vulnerable Area
2	Sewage System Or Sewage Works – Septic System	14	WHPA – A
3	Application Of Agricultural Source Material (ASM) To Land	4	WHPA – A
6	Application Of Non-Agricultural Source Material (NASM) To Land	1	WHPA – A
15	Handling and Storage Of Fuel	1	WHPA – A

1: Prescribed Drinking Water Threat Number refers to the prescribed drinking water threat listed in Ontario Regulation 287/ 07s.1.1.(1).

Total number of properties with significant drinking water threats: 18.

Total number of significant drinking water threat activities: 20.

Discussion of Significant Threats

Residential Properties

Since Brownsville is not serviced by a municipal sanitary sewer system, it has been determined that private septic systems are located on each property.

Residential properties within WHPA – A in Brownsville are serviced with natural gas; however, Oxford County staff confirmed one dwelling is heated with oil.

Crop and Livestock Agriculture

Since numerous significant threats can be associated with this land use, careful consideration was given to the location of structures on each farm property. If farm dwellings, barns or other structures were not within the vulnerable area, then storage threats were excluded from the analysis (including the storage and handling of fuel, the storage of pesticides, agricultural source material and commercial fertilizer) . For farm dwellings specifically, the threats associated with a private septic system and the handling and storage of heating fuel were considered, as discussed for residential properties.

Limitations, Data Gaps and Uncertainty in the Threats Assessment

As a part of the threats assessment, available land use information and air photo interpretation was used to determine the types of land use information and therefore, the threats and circumstances associated with these land uses.

The type and amount of chemicals stored at commercial and industrial operations within the WHPAs is unknown. Further, for other land use types, the types and amounts of potential contaminants often had to be assumed based on the land use practice.

Since no agricultural census information was available to the County at the time of the assessment, reasonable assumptions regarding the type of livestock housed in a farm structure were based on the best available information. This information included local knowledge, land use information, and air photo interpretation to determine barn type, and therefore, livestock type.

The inventory conducted was a desktop exercise and therefore preliminary in nature. Consultation with property owners will be required in order to reduce the uncertainty in this preliminary assessment of significant threats.

Additional studies were undertaken in 2010 to gather more detailed information on the land use activities occurring within the Brownsville Wellhead Protection Area. Municipal and conservation authority staff worked with residents and businesses in the wellhead protection area to determine whether the activities identified as potential significant threats in this Proposed Assessment Report are occurring.

Source Protection Committee Designated Threats
At the time of this report, no additional activities beyond the Prescribed Drinking Water Threats listed in **Error! Reference source not found.**have been identified by the Source Protection Committee as potential threats.

4.4.4 Conditions

The Technical Rules (MECP, 2021) require a list of conditions that are drinking water threats resulting from a past activity where the following conditions are present:

1) The presence of a non-aqueous phase liquid in groundwater in a highly vulnerable aquifer or wellhead protection area.
2) The presence of a single mass of more than 100 litres of one or more dense non- aqueous phase liquids in surface water in a surface water intake protection zone.
3) The presence of a contaminant in groundwater in a highly vulnerable aquifer or a wellhead protection area, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table, and the presence of the contaminant in

groundwater could result in the deterioration of the groundwater for use as a source of drinking water.

4) The presence of a contaminant in surface soil in a surface water intake protection zone if, the contaminant is listed in Table 4 of the Soil, Ground Water and Sediment Standards is present at a concentration that exceeds the surface soil standard for industrial/commercial/community property use set out for the contaminant in that Table and the presence of the contaminant in surface soil could result in the deterioration of the surface water for use as a source of drinking water.
5) The presence of a contaminant in sediment in an intake protection zone, if the contaminant is listed in Table 1 of the Soil, Ground Water and Sediment Standards and is present at a concentration that exceeds the sediment standard set out for the contaminant in that Table, and the presence of the contaminant in sediment could result in the deterioration of the surface water for use as a source of drinking water.
6) The presence of a contaminant in groundwater that is discharging into an intake protection zone, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, the concentration of the contaminant exceeds the potable groundwater standard set out for that contaminant in the Table, and the presence of the contaminant in groundwater could result in the deterioration of the surface water for use as a source of drinking water.

No documented evidence of such conditions outlined above has been identified for the Brownsville Drinking Water System. As a result, no condition-related drinking water threats (if present) have been identified.

4.5 Brownsville Drinking Water Issues

The Clean Water Act Technical Rules (MECP, 2021) requires that Issues associated with the drinking water quality for the municipal system be identified. The activities that contribute to identified Issues that have an anthropogenic origin are deemed a significant drinking water threat.

The issues evaluation for Brownsville focused on the water quality parameter groupings outlined in the Ontario Drinking Water Quality Standards (ODWQS) identified in Ontario Regulation 169/03 under the Safe Drinking Water Act and the related technical support document. These parameters include: a) Pathogens, b) Schedule 1 parameters, c) Schedule 2 and 3 parameters and, d) Table 4 parameters. In addition to these parameters, the Source Protection Committee may identify other parameters that are to be evaluated; however, to date, no additional parameters have been identified.

4.5.1 Data Sources and Methodology

Water quality parameters were screened for closer investigation where any of the following criteria were met:

- Consistent presence of microbiological parameters
- The parameter has a health related Maximum Acceptable Concentration (MAC) associated with it and the concentration in the raw or treated water exceeds half of the MAC level (with the exception of fluoride: see 'Fluoride and Sodium')
- The parameter does not have a health related MAC but the concentration observed exceeds the objective or guideline associated with the Ontario Drinking Water Quality Standards (ODWQS)

The 2019 to 2021 Annual Drinking Water System summary reports were used to compare current water quality parameters to the previous 2001-2010 results presented in the previous version of the assessment report. The water quality data used in the 2010 evaluation was compiled by the Oxford County Public Works Department. The data comprises the analytical results taken as part of operating the systems in addition to water quality results received as part of other programs/ projects.

Pathogenic Issues

Pathogens are disease-causing bacteria, viruses or protozoa. They can cause severe or fatal waterborne illness in humans. Some are resistant to commonly used disinfectants at water treatment plants. Reliable laboratory detection methods for pathogenic protozoa are yet to be established. There are no established Canadian water quality guidelines for these microbiologic organisms.

Oxford County has not completed any testing for pathogenic organisms. Engineer's Reports were completed for all County systems in 2000/ 2001 in accordance with Ontario Regulation 459/ 00. These reports include an assessment of the wells with respect to the potential to be Groundwater Under the Direct Influence of surface water (GUDI) . The Brownsville municipal wells were found to be a secure groundwater source. Therefore, no pathogenic issues have been included in this report.

Fluoride and Sodium

Fluoride has a MAC of 1.5 mg/l; however, the ODWQS states that where naturally occurring fluoride is present at levels between 1.5 mg/l and 2.4 mg/l and the operating authority does not fluoridate, the 1.5 mg/l level is a reporting requirement and treatment is not required where the concentration is below 2.4 mg/l. In Oxford County, several of the municipal bedrock wells have elevated levels of naturally occurring fluoride. As Oxford does not add fluoride at any system, the screening threshold for this parameter has been set at half of the treatment level of 2.4 mg/l.

Sodium has an aesthetic objective of 200 mg/l at which level the water will have a discernable salty taste. A reporting limit of 20 mg/l has been set in order to provide information to individuals with sodium restricted diets. For the purpose of this report, sources with sodium above 20 mg/l will be mentioned; however, the screening threshold of 200 mg/l will be utilized.

Issue Identification
Water quality parameters meeting the screening threshold were further reviewed to determine whether to identify them as issues. The considerations included:

- Whether the concentration is at or trending towards a health related MAC
- The frequency with which the parameter meets the screening threshold
- Capabilities of the treatment facility
- The ability of the parameter to interfere with/upset the treatment process
- Whether the parameter is related to concerns/issues raised by the public
- Importance of the well to the overall supply

4.5.2 Issues Evaluation Results

Both raw and treated chemistry results have been reviewed since the treatment process does not substantially alter the water quality.

Health Related Parameters
No parameters were found to exceed their MAC. Microbiological results are consistently good and indicate no concerns. Fluoride concentrations in 2001-2010 ranged from 1.7 to 1.9 mg/L which is above half of the MAC of 2.4 mg/ slash L. Fluoride concentrations in 2020 and 2021 are similar to those reported in 2001-2010 with average concentrations of 1.7 mg/L and 1.8 mg/L. Fluoride is naturally occurring in the groundwater and does not appear to be trending upwards. Its presence does not impact the treatment process.

Trihalomethanes (THMs) are a group of chemicals that are known to be carcinogenic and have a MAC of 100 mg/l. Typically THMs are found in treated drinking water due to a reaction between the chlorine used for disinfection purposes and organic material in the raw water. In the 2001-2010 reporting period, the THMs in the Brownsville system are above half the MAC value and range from 57 to 65 mg/l. Average THM concentrations in 2020 and 2021 are 60 mg/L and 66 mg/L. The levels are stable and not trending upwards.

Aesthetic or Operationally Significant Parameters
The system has several operational or aesthetic parameters that exceed the associated objectives or guidelines as detailed below.

Hardness has an operational guideline range of 80 to 100 mg/L. The average hardness for the Brownsville Drinking Water System is 74 mg/L based on samples collected from 2006 to 2019. Hardness remains stable compared to the

2001 to 2010 average of 70 to 75 mg/L. This parameter is naturally occurring in the groundwater and does not pose a health risk nor does it impact the treatment process.

The most recent (2019) reported concentration of sodium at the Brownsville water supply is 82 mg/L, which is within the range of sodium concentrations from 2001 to 2010 (79 to 85 mg/L). Sodium concentrations at the Brownsville water supply are above the reporting level of 20 mg/L, but below the aesthetic objective of 200 mg/l and remain stable. Reported chloride levels in the system from 2001 to 2010 are low suggesting that the sodium is not caused by road salt application but rather is naturally occurring. There are no reported chloride concentrations in the 2020 or 2021 Brownsville drinking water annual reports.

Nitrate concentrations were evaluated every three months in normal operation for the Brownsville water supply. Nitrate has a MAC of 10 mg/L. The 2019 to 2021 reported concentrations for nitrate range from non-detect to 0.009 mg/L, which is below the MAC.

4.5.3 Summary of Identified Issues and Concerns

The parameters in the Brownsville Water Supply System that meet the screening threshold are fluoride, nitrate, THMs and hardness. These parameters are all naturally occurring and typical to groundwater sources. They do not affect the treatment process and there is no evidence of upward trending. As a result, no issue-based threats were identified for the Brownsville water supply.

4.6 Section Summary

Regional Aquifer Vulnerability

- Aquifer vulnerability was assessed using the SAAT method within all areas of the watershed with the exception of Oxford County, where the AVI method was used.

- The resulting analysis showed areas of high and medium aquifer vulnerability across the southern extents of the watershed. These areas generally correspond to the shallow unconfined aquifer of the Norfolk Sand Plain. The northern extents of the watershed have been found to have predominantly low vulnerability. This area is generally composed of the clay-rich Port Stanley Till, which provides protection to the deeper, confined overburden aquifers.

- Areas mapped as highly vulnerable are considered Highly Vulnerable Aquifer (HVAs). These areas received a vulnerability score of 6.

- Managed lands were calculated to be between 40 and 80% of the total land area within the Highly Vulnerable Aquifers.

- Livestock density was calculated to be <0.5 Nutrient Units per acre within the Highly Vulnerable Aquifers.

- Impervious surfaces as related to road salt application were calculated to be between 1 and <8% of the total area within the Highly Vulnerable Aquifers.

- Given that the maximum vulnerability score a Highly Vulnerable Aquifer can receive is a 6, activities cannot become significant threats within Highly Vulnerable Aquifers.

- To date, no drinking water issues have been identified in the Highly Vulnerable Aquifers.

Significant Groundwater Recharge Areas

- Significant Groundwater Recharge Areas were delineated using water budget tools. Groundwater recharge was estimated using a hydrologic model.

Village of Brownsville Groundwater Supply

- Located within the County of Oxford, the village of Brownsville obtains water from two municipal wells screened at depths greater than 30m in a deep overburden aquifer.

- Four Wellhead Protection Areas were delineated for each well: a 100 metre proximity zone and three time-related (2-year, 5-year and 25-year) capture zones generated through a groundwater model.

- A transport pathway assessment was completed for the Wellhead Protection Areas, and resulted in no change to the vulnerability scoring.

- Impervious surfaces as related to road salt application were calculated for Wellhead Protection Area A (100m zone) and B (2-year zone). Road salt application does not pose a significant threat to the Brownsville municipal water supply.

- A water quality threats assessment was completed for Wellhead Protection Area A for both municipal wells. Results of the analysis indicated the presence of 20 potential significant threats within the two Wellhead Protection Areas.

  An issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No issue-based threats were identified within the municipal groundwater system

5.0 STATE OF CLIMATE CHANGE RESEARCH IN THE LAKE ERIE SOURCE PROTECTION REGION

Human-induced warming reached approximately 1°C above pre-industrial levels (1850 -1900) in 2017, increasing at 0.2°C per decade (Allen et al., 2018). Warming greater than the global average has already been experienced in many regions and seasons, with higher average warming over land than over the ocean (Allen et al., 2018).

Ontario borders four of the five Great Lakes, and has more than a quarter of a million inland lakes, over half a million kilometres of rivers and streams, and numerous aquifers (MOECC, 2016a). Overall, climate change is expected to bring a 3.6˚C increase in average annual temperatures by 2050 in Ontario (compared to the period between 1981 and 2010), along with milder and shorter winters, earlier snowmelt, a decline in ice cover on lakes, changes in precipitation intensity and frequency, and more evapotranspiration (MNRF, 2014). These changes can impact both the quantity and quality of water for both surface water and groundwater systems.

Many studies agree that climate change will result in greater and more frequent extremes in temperature and precipitation throughout the Lake Erie basin (Bruce et al., 2006; Chiotti and Lavender, 2008; Kunkel et al., 2009; Zhang et al., 2000, McDermid et al., 2015). There is high evidence and agreement by modeling studies in predictions of greater increases in winter air temperatures, increased frost-free period and growing season and an increase in air temperature of 1.5 C to 7 C by the 2080s in the Great Lakes Basin (McDermid et al., 2015).

Annual total precipitation trends are expected to increase in the Great Lakes basin (McBean and Motiee 2008 and McDermid et al., 2015); but, the distribution throughout the year will be significantly altered. There is high evidence and agreement by modeling studies in predictions of a 20 percent increase in annual precipitation across the Great Lakes Basin by the 2080s under the highest emissions scenario (McDermid et al., 2015). An increase in extreme precipitation events will be more intense and occur at a higher frequency (McBean and Motiee 2008), with a decrease of rain in the summer months (McDermid et al., 2015). Warmer winter temperatures will likely be the most influential change for water resources in Catfish Creek watershed. Some of the predicted changes include more winter precipitation as rain, a smaller snowpack, higher evaporation from open water bodies that no longer freeze, and an earlier and weaker freshet in the spring (Environment Canada, 2004 ; Jykrama and Sykes, 2007; Barnett et al., 2005; Bruce et al., 2000; Mortsch et al., 2000). Soil moisture will be higher in the spring, but drop lower in summer with anticipated higher evapotranspiration. This will lead to greater demand for water resources for irrigation and higher drought occurrence (Brklacich, 1990; McBean and Motiee 2008). Precipitation occurring during more intense storms will cause a decrease in infiltration and groundwater recharge (McLaren and Sudicky, 1993; de Loe and Berg, 2006), higher sediment and nutrient loading in the creeks due to greater erosion (McBean and Motiee 2008), and fewer days with rain and longer dry periods (Mortsch et al., 2000).

Net basin water supplies are projected to decrease as a result of decreases in runoff, infiltration, higher surface water temperatures, and greater evapotranspiration (Lofgren et al., 2002; Mortsch et al., 2000). In general, studies predict that climate change is expected to shift the means in temperature, precipitation and evaporation, which will lead to increased seasonal variability, and more frequent and intense storm events (Francis and Hengeveld, 1998 in de Loe et al., 2001, McDermid et al., 2015).

5.1 Potential Effects of Climate Change on Water Quantity and Quality

The predictions on climate change in the Kettle and Catfish Creek watersheds have implications to both water quality and quantity. In terms of water quality, the increase in air temperature and greater occurrence of extreme precipitation events will lead to degraded water quality, including lower dissolved oxygen rates and higher stream temperatures (Bruce et al., 2000; Chiotti and Lavender, 2008; Cunderlik and Simonovic, 2004). Higher sediment and nutrient loading are expected in the creeks due to greater erosion (McBean and Motiee, 2008) and coupled with increase in water temperature, will allow for an increase in nutrient concentrations and a rise in the number of cyanobacteria and algal blooms. Surface water temperature is forecasted to increase as a result of climate change. This may exacerbate other changes expected to occur, such as increased nutrient loading, increased frequency, duration and severity of algal growth and cyanobacterial blooms, increased variability in the quantity and character of runoff, and increased frequency of floods and wildfires (Health Canada, 2021).

Nutrients (primarily nitrogen and phosphorous) run off from farms into surface waters during intense rain events. These excess nutrients threaten human health both directly (e.g., “blue baby” syndrome) and indirectly by contributing to toxic harmful algal blooms in shallow water bays of the Great Lakes. In 2011, Lake Erie experienced the largest harmful algal bloom in its recorded history, with peak intensity more than three times greater than any previously observed blooms. Algal blooms will likely become more frequent in the future as higher temperatures and heavy precipitation mix heavy nutrient loads with warmer waters. These pollutants have dramatically raised the cost of water treatment (Chiotti and Lavender, 2008; de Loe and Berg, 2006; Environmental Law and Policy Centre, 2019; Hunter, 2003). It will be important for drinking water system owners to understand seasonal trends to allow for process adjustments or additional processes that may be required to manage the impacts of temperature and effectively treat water throughout the year (Health Canada, 2021).

Decreases in runoff and baseflows from climate change are also important changes with respect to the dilution of sewage treatment effluent because less water will be available for waste assimilation (de Loe and Berg, 2006). The problem of reduced waste assimilation capacity is exacerbated by the projected increase in future populations in these areas and the ability of the system to meet wastewater discharge criteria (James Bruce et al., 2000; Cunderlik and Simonovic, 2004).

In terms of water quantity, climate change is expected to shift the timing of seasonal events, including an earlier and lower spring freshet and changing levels in Lake Erie to rise and fall one month earlier, on an annual basis due to increased lake surface temperatures (Lenters, 2001; Brent M. Lofgren et al., 2002; Millerd, 2006). The longer frost-free periods lead to increased potential evapotranspiration and an increase in drought occurrence (Environment Canada, 2004; McBean and Motiee, 2008), meaning that longer, drier and warmer growing seasons will lower soil moisture (more deficit) and increased demand for irrigation (Brklacich, 1990; McBean and Motiee, 2008). Rainfall is expected to fall with more intensity but on fewer days, leaving longer dry spells that may exacerbate seasonal water shortages during low flow periods (Mortsch et al., 2000). Projected reductions in groundwater recharge to drawdowns of 2 – 7m will require wells to be drilled deeper, increasing costs to land owners and municipalities and could lead to rural domestic and urban water use conflicts (de Loë and Berg, 2006; McLaren and Sudicky, 1993). The reliability of water resources is compromised and unpredictability of the hydrologic cycle will demand more planning and adaptation by water managers (de Loe and Berg, 2006).

5.2 Effect of Projected Climate Changes on Assessment Report Conclusions

Projected climate changes are not expected to effect the assessment report conclusions with respect to the Brownsville drinking water supply. The water quantity stress analysis (Section 3) shows that the Brownsville wells are in an area with low potential for stress. The aquifer that is the source of the supply is confined and well protected, with low vulnerability to contamination (Section 4) .

5.3 Consideration of Climate Change Vulnerability Assessment Tool

Revised 2021 Technical Rules, under the *Clean Water Act,* include the consideration of climate change in source water quality risk assessments. A climate change vulnerability assessment tool, developed by Conservation Ontario in 2018, is being considered in the Lake Erie Source Protection Region and can provide municipalities, source protection authorities, and the Lake Erie Region Source Protection Committee with a practical and consistent approach to assess drinking water sources/systems for considerations of local climate change impacts.

Lake Erie Region staff have engaged with Oxford County in the Catfish Creek Source Protection Areas to assess their interest in completing a climate change vulnerability assessment on the Brownsville drinking water system using the tool developed by Conservation Ontario. At this time, Oxford County will not be completing a climate change vulnerability assessment on the Brownsville drinking water system because it is a deep groundwater system. The County is planning to use the tool on other systems outside of the Catfish Creek Source Protection Area that are more susceptible to the impacts of climate change. The use of the climate change vulnerability tool for the Brownsville drinking water system may be considered in the future.

6.0 CONSIDERATION OF GREAT LAKES AGREEMENTS

Under the Clean Water Act, the following Great Lakes agreements must be considered in the work undertaken in Assessment Reports:

- Canada-United States Great Lakes Water Quality Agreement (GLWQA)
- Canada – Ontario Agreement Respecting the Great Lakes Basin Ecosystem (COA)
- Great Lakes Charter
- Great Lakes – St. Lawrence River Basin Sustainable Water Resources Agreement

The Great Lakes Water Quality Agreement and the Canada – Ontario Agreement generally deal with water quality concerns, while the Great Lakes Charter and the Great Lakes – St. Lawrence River Basin Sustainable Water Resources Agreement provide principles for joint water resources management and water quantity concerns in the Great Lakes Basin.

6.1 Catfish Creek Watershed and Great Lakes Agreements

Catfish Creek watershed drains directly into Lake Erie and has the potential to contribute pollutants to the lake. These pollutants, including sediments, nutrients and others, contribute to the overall water quality of the nearshore of Lake Erie.

In order to achieve water quality goals and objectives set under the Great Lakes Water Quality Agreement, Canadian and U.S. federal governments are developing Lakewide Management Plans (LaMP) in conjunction with the Province of Ontario and the States within the Great Lake watersheds. Lakewide Management Plans are broad plans to restore and protect water quality in ~~the~~ each Great Lake (Environment Canada, 2005). Information compiled as part of the Lake Erie LaMP was incorporated into the technical studies completed for the Elgin Area Primary Water Supply, which serves communities in the Catfish Creek watershed.

The work undertaken and described in this Assessment Report, and the Kettle Creek Source Protection Area Assessment Report, contributes to the achievement of Goal 6 under Annex 3: Lake and Basin Sustainability under the Canada-Ontario Agreement Respecting the Great Lakes Basin Ecosystem (Environment Canada, 2007). The Reports address two key results identified under Goal 6 of Annex 3 by identifying and assessing the risks to drinking water sources on Lake Erie (Result 6.1) , and developing knowledge and understanding of water quality and water quantity issues of concern to Lake Erie (Result 6.2) .

The Great Lakes – St. Lawrence River Basin Sustainable Water Resources Agreement is a good faith agreement between the 8 U.S. Great Lakes States and the Provinces of Ontario and Quebec that is intended to implement the 2001 Great Lakes Charter Annex. The Agreement sets out objectives for the signatories related to collaborative water resources management and the prevention of significant impacts related to diversions, withdrawals and loses of water from the Great Lakes basin (Ontario Ministry of Natural Resources, 2005). The Agreement sets out conditions under which transfers of water from one Great Lake watershed into another (intra-basin transfer) can occur.

The City of London currently receives water from the Elgin Area Primary Water Supply. Wastewater from the City of London is discharged into the Thames River, which drains into Lake St. Clair, rather than Lake Erie. The Agreement does not specify whether Lake St. Clair is considered part of the watershed of Lake Huron, Lake Erie, or both. This ambiguity has created uncertainty over whether the Elgin Area Primary water supply constitutes an intra-basin transfer under the Agreement, and whether further action is required on the part of the Joint Board of Management.

At this time, the work described in this Assessment Report has not included considerations of the impact of this agreement on the water supplies of the communities in Catfish Creek supplied by the Elgin Area Primary intake, given the level of uncertainty related to the definition of the Lake Erie and Lake Huron watersheds. Further clarification from the Government of Ontario is required regarding this situation prior to determining whether the water supplies may be impacted in the future.

7.0 CONCLUSIONS

The Catfish Creek Source Protection Area Assessment Report provides a summary of the results of technical studies undertaken to identify the threats to municipal drinking water sources in the Catfish Creek watershed. Assessment Report findings have been used to develop policies for a Source Protection Plan to protect the sources of drinking water for the Brownsville drinking water system.

The Catfish Creek Watershed is located in the heart of the Carolinian zone in southwest Ontario and covers an area of approximately 490 km^2 draining to Lake Erie. Much of the land of the watershed is used for agriculture with the Town of Aylmer being the main urban centre.

Residents in the Catfish Creek watershed receive water from both private and municipal sources. The village of Brownsville is the only municipal drinking water supply located in the watershed; however, several communities also receive drinking water from the Elgin Area water supply located off-shore of Port Stanley in the Kettle Creek watershed. Many residents of the watershed obtain their drinking water from private wells.

The northern portion of the watershed is comprised of low relief tight soils with high surface runoff and little soil infiltration. Stream flows are flashy with high flows following storm events and low baseflow. The southern portion of the watershed is comprised of areas of sandy soils that produce little runoff and high groundwater recharge. Groundwater discharge through the incised river valleys contributes to baseflow and generally improves water quality.

Extensive deforestation and draining of wetlands has contributed to the warming of surface water and the degradation of water quality in parts of the watershed.

Water demands are low in West Catfish and moderate in Catfish above Aylmer. Water demands are fairly high in the Lower Catfish Creek subwatershed. The Surface Water Subwatershed Stress Assessment, completed in conjunction with water budget studies, classifies Silver Creek subwatershed as having a significant potential for stress, Catfish Above Aylmer and Lower Catfish subwatersheds as having a moderate potential for hydrologic stress, and West Catfish as having a low potential for stress. The Groundwater Subwatershed Stress Assessment classified all four subwatersheds as having low potential for stress under existing, future and drought scenarios. Since the Brownsville drinking water supply is located in an area with low potential for stress, further water quantity risk assessment studies (i.e. Tier 3 Stress Assessment) is not required.

Aquifer vulnerability was assessed using the Surface to Aquifer Advective Time (SAAT) method within all areas of the watershed, with the exception of Oxford County, where the Aquifer Vulnerability Index (AVI) method was used. The resulting analysis shows areas of high and medium aquifer vulnerability across the southern extents of the watershed. These areas generally correspond to the shallow unconfined aquifer of the Norfolk Sand Plain. The northern extents of the watershed have been found to have predominantly low vulnerability. This area is generally composed of the clay-rich Port Stanley Till, which provides protection to the deeper, confined overburden aquifers.

Given that the maximum vulnerability score a Highly Vulnerable Aquifer can receive is a 6, activities cannot become significant threats within Highly Vulnerable Aquifers. To date, no drinking water issues have been identified in the Highly Vulnerable Aquifers.

Significant Groundwater Recharge Areas were delineated using water budget tools. Groundwater recharge was estimated using a hydrologic model.

Located within the County of Oxford, the village of Brownsville obtains water from two municipal wells screened at depths greater than 30m in a deep overburden aquifer. Four Wellhead Protection Areas were delineated for each well: a 100 metre proximity zone and three time-related (2-year, 5-year and 25-year) capture zones generated through a groundwater model. The wells are located in an area of low vulnerability, which results in medium to low vulnerability scores in most of the wellhead protection area, and an area of high vulnerability within the 100-metre area around the wells.

A water quality threats assessment was completed for Wellhead Protection Area for both municipal wells. Results of the analysis indicated the presence of 20 potential significant threats within the two Wellhead Protection Areas. An issues-based threats analysis was also completed through a review of water quality data collected from the municipal wells. No issue-based threats were identified within the municipal groundwater system.

Climate change is not expected to effect the assessment report conclusions with respect to the Brownsville drinking water supply. The water quantity stress analysis shows that the Brownsville wells are in an area with low potential for stress. The aquifer that is the source of the supply is confined and well protected, with low vulnerability to contamination.

The results of the technical studies were used to develop policies to protect sources of municipal drinking water. Policies were developed by 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. Formal public comment periods were held on the draft and proposed Assessment Report and Source Protection Plan before the respective documents were finalized and submitted to the Minister of the Environment, Conservation and Parks.

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9.0 MAP REFERENCES

These maps are for information purposes only and the Catfish Creek Conservation Authority takes no responsibility for, nor guarantees, the accuracy of the information contained within them.

The following references apply to all maps, unless otherwise noted:

Map 2 - 3: Physiography of Catfish Creek Watershed
Physiography of Southern Ontario Geological Survey dataset MRD228, Chapman, L.J. and Putnam, D.F. 2007. Ministry of Northern Development and Mines, Copyright © Queen's Printer, 2010.

Map 2 - 4: Hummocky Topography
Various Authors, 1967-1993, Quaternary and Pleistocene Geology, Southern Ontario, Ontario Geological Survey. Ministry of Northern Development and Mines, Copyright © Queen's Printer, 2010.

Map 2 - 7: Bedrock Geology
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Map 2 - 8: Overburden Thickness
Strynatka, S., Pitcher, J., and Dragunas, P. 2006. Draft Report on the Groundwater Resources of the Catfish Creek Conservation Authority and Kettle Creek Conservation Authority. Ontario Geological Survey.
Mapping based partially on data contained within the Ontario Ministry of the Environment's electronic water well database.

Map 2 - 9: Quaternary Geology
Various Authors, 1967-1993, Quaternary and Pleistocene Geology, Southern Ontario, Ontario Geological Survey. Ministry of Northern Development and Mines, Copyright © Queen's Printer, 2010.

Map 2 - 10: Water Table Surface
Strynatka, S., Pitcher, J., and Dragunas, P. 2006. *Draft Report* on the Groundwater Resources of the Catfish Creek Conservation Authority and Kettle Creek Conservation Authority. Ontario Geological Survey.
Mapping based partially on data contained within the Ontario Ministry of the Environment's electronic water well database.

Map 2 - 11: Overburden Potentiometric Surface
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Mapping based partially on data contained within the Ontario Ministry of the Environment's electronic water well database.

Map 2 - 12: Bedrock Potentiometric Surface
Strynatka, S., Pitcher, J., and Dragunas, P. 2006. *Draft Report* on the Groundwater Resources of the Catfish Creek Conservation Authority and Kettle Creek Conservation Authority. Ontario Geological Survey.
Mapping based partially on data contained within the Ontario Ministry of the Environment's electronic water well database.

Map 3 - 2: Domestic Bedrock Wells
Wells based on data contained within the Ontario Ministry of the Environment's electronic water well database.

Map 3 - 3: Domestic Overburden Wells
Wells based on data contained within the Ontario Ministry of the Environment's electronic water well database.

Map 3 - 4: Permits to Take Water in the Catfish Creek Watershed
Mapping based partially on data contained within Permits To Take Water issued by the Ontario Ministry of the Environment.

Map 3 - 5: Groundwater Discharge
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Map 3 - 6: Tier 2 Surface Water Stress Assessment
Waterloo Hydrogeologic Inc., 2007. Draft Final Report: Westward Expansion of the Norfolk FEFLOW Groundwater Model for the Catfish and Kettle Creek Watersheds. Report to the Grand River Conservation Authority.

Map 3 - 7: Water Quantity Stress Levels by Groundwater Sub-watershed
Waterloo Hydrogeologic Inc., 2007. Draft Final Report: Westward Expansion of the Norfolk FEFLOW Groundwater Model for the Catfish and Kettle Creek Watersheds. Report to the Grand River Conservation Authority.

10.0 APPENDIX A: SUMMARY OF PUBLIC COMMENTS AND HOW COMMENTS WERE ADDRESSED

This appendix provides a summary of each comment received during the public consultation period on the draft updated Catfish Creek Source Protection Area Assessment Report from January 25 to February 28, 2023. Public consultation comments and how they were addressed can be found in Table 1. Detailed public consultation comments and how they were addressed for previous iterations of the Catfish Creek Assessment Report are available upon request.

Table 1: Public consultation comments that address the amendments proposed in this update

Number	AR Section	Comment	How Comment is Addressed
1	S1, Introduction	Source: Ministry of the Environment, Conservation and Parks Table 1.4 – Please update the Table to identify organic soil conditioners as both non-agricultural source materials (NASM) and agricultural source materials (~~N~~ASM). Please refer to ASM and NASM materials per definitions and NASM Tables 1, 2, and 3 of Schedule 4 under O. Reg. 267/03.	Table 1 amended to include organic soil conditioners under ASM and NASM examples.
2	S1, Introduction	Source: Ministry of the Environment, Conservation and Parks Under "Assessing Threats from Activities" (Page 1.25) , the link directs readers to the 2013 and 2017 Tables of Drinking Water Threats (TDWTs) for short. Please update the link to the 2021 Technical Rules, as the TDWT is now embedded in the Technical Rules (Ministry's TDWT).	Link updated to the 2021 Technical Rules.
3		Source: Ministry of the Environment, Conservation and Parks In AR Table 1.4, add the reference to O. Reg. 206/18, s.1 for pipelines as follows: The establishment and operation of a liquid hydrocarbon pipeline. O. Reg. 206/18, s.1.	"O. Reg. 206/18, s.1" added to threat #22: the establishment and operation of a liquid hydrocarbon pipeline.

Number	AR Section	Comment	How Comment is Addressed
4	S2, Watershed Characterization	Source: Ministry of the Environment, Conservation and Parks AR Sec. 2.10, Pg. 2-39, second paragraph: In the following sentence, please confirm whether the reference underlined in the excerpt below was meant to read Catfish Creek watershed instead of Kettle Creek watershed: ▪ "In 2018, a Watershed Report Card was completed for the Catfish Creek Watershed. The watershed report card provides a snapshot of current conditions in the Kettle Creek watershed and helps to identify environmental issues that need to be protected, restored or managed."	Sentence amended to read, "…conditions in the Catfish Creek watershed…"
5	S5, State of Climate Change Research in the Lake Erie Source Protection Region	Source: Ministry of the Environment, Conservation and Parks In AR Sec. 5.0, Pg. 5-2, please correct the year of publication for the McDermid et al., 2025, to read 2015.	Reference corrected to read "2015".

11.0 APPENDIX B: REQUESTS FOR APPROVAL OF ALTERNATIVE APPROACHES