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3.0 WATER QUALITY THREAT ASSESSMENT METHODOLOGY

3.1 Introduction

The *Clean Water Act, 2006* identifies two types of water quality policy areas related to drinking water sources:

- Wellhead Protection Areas (WHPAs)
- Intake Protection Zones (IPZs)

WHPAs delineate defined times of travel to the municipal well using qualitative and quantitative assessments of the geology and groundwater flow in an area. IPZs are generated through the assessment of surface water flow in the watercourse or lake where a municipal intake is located.

3.2 Groundwater

Within the source protection program, all groundwater-based municipal supplies have completed an assessment of the 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.

3.2.1 Wellhead Protection Areas

A WHPA is a planning term used to describe scientifically based capture zones delineated for water supply wells. The Technical Rules (MOECC, 2017) 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

Two other WHPAs (E and F) can be delineated for wells which are under the direct influence of surface water (Groundwater Under the Direct Influence or GUDI). WHPA-E's are delineated for GUDI-designated wells when the interaction between surface water and groundwater decreases the time of travel of water to the well when compared to the time it would take water to travel to the well if the raw water supply for the well was not under the direct influence of surface water. Delineation of a WHPA-F is required if a WHPA-E is delineated, and the well is subject to issues (known to be partially or wholly due to anthropogenic causes), which originate from outside of the WHPA.

3.2.2 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.

WHPA-E's were mapped from the point of interaction between the aquifer and the surface water body. In cases where the point of interaction was unknown, the WHPA-E was delineated from the point of interaction between the aquifer and the surface water body that was located nearest to the municipal well. WHPA-F zones were only delineated where an issue had been confirmed for a GUDI well.

3.2.3 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. **Table 3-1** outlines the intrinsic vulnerability based on an ISI or AVI scores.

Table 3-1: Intrinsic Vulnerability Based on ISI/AVI Scores

ISI/AVI Score	Intrinsic Vulnerability
<30	High
30 - 80	Medium
>80	Low

The SAAT and 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). **Table 3-2** outlines the intrinsic vulnerability based on an SAAT or SWAT scores.

Table 3-2: Intrinsic Vulnerability Based on SAAT/SWAT Scores

SAAT/SWAT Score	Intrinsic Vulnerability
<5 years	High
≥ 5 years, < 25 years	Medium
≥ 25 years	Low

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.

3.2.4 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 3-3** and **Table 3-4** below, are dependent on the method used for the vulnerability analysis.

Table 3-3: 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

Table 3-4: 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). WHPA- Fs do not require a vulnerability score.

3.2.5 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 as described in Section 3.2.2 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.

3.2.6 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), 2017). 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.

3.3 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.

3.3.1 Intake Protection Zones

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.

3.3.2 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 in **Table 3-5**.

Table 3-5: Methods for Delineating Vulnerable Areas around Surface Water Intakes

	Intake Type	Delineation
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	A and D	Defined by a 1 km radius centered on the crib of the intake
	B	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
	C	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	A, B, C, D	The IPZ-2 is 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	A, B,C,D	The IPZ-3 is 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.
	C and D	For type C and D intakes 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.

Note: This table 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 (MOECC, 2017), 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.

3.3.3 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) as expressed below:

$$V = B \times C$$

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.

3.3.4 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), 2017). 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.

3.4 Highly Vulnerable Aquifers

Areas calculated as being of high vulnerability are considered Highly-Vulnerable Aquifers (HVAs) and can have water quality policies associated with them. Highly Vulnerable Aquifer areas in Grand River Source Protection Area are identified as the red areas on **Map 4-2.** According to the Technical Rules, highly vulnerable aquifer areas outside of the Wellhead Protection Areas are assigned a vulnerability score of 6. The highly vulnerable aquifer areas illustrated on **Map 4-2** therefore receive a vulnerability score of 6. Areas of highly vulnerable aquifers generally correspond to shallow and/or unconfined aquifers across the Norfolk sand plain to the southwest and through the Waterloo Moraine across the central portion of the watershed.

3.4.1 Managed Lands and Livestock Density in Highly Vulnerable Aquifers

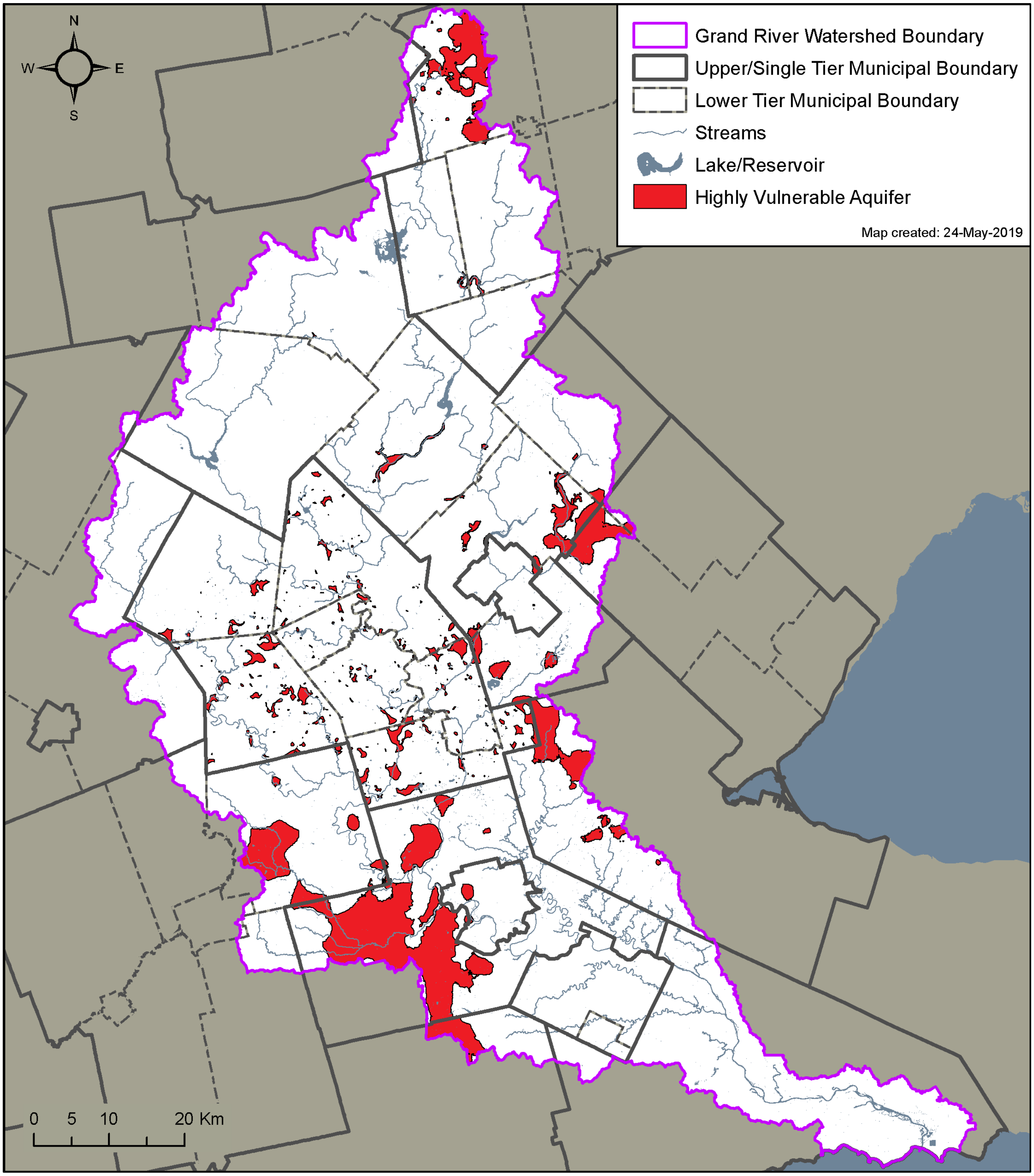
This section provides a description of the results of calculations of the percent managed lands and the livestock density within HVA areas. **Map 4-3** and **Map 4-4** show that of the highly vulnerable aquifer areas in the Grand River watershed, the managed lands percentage is between 40 and 80% (moderate); while the majority of 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 and are described in detail in Section 3.6 below.

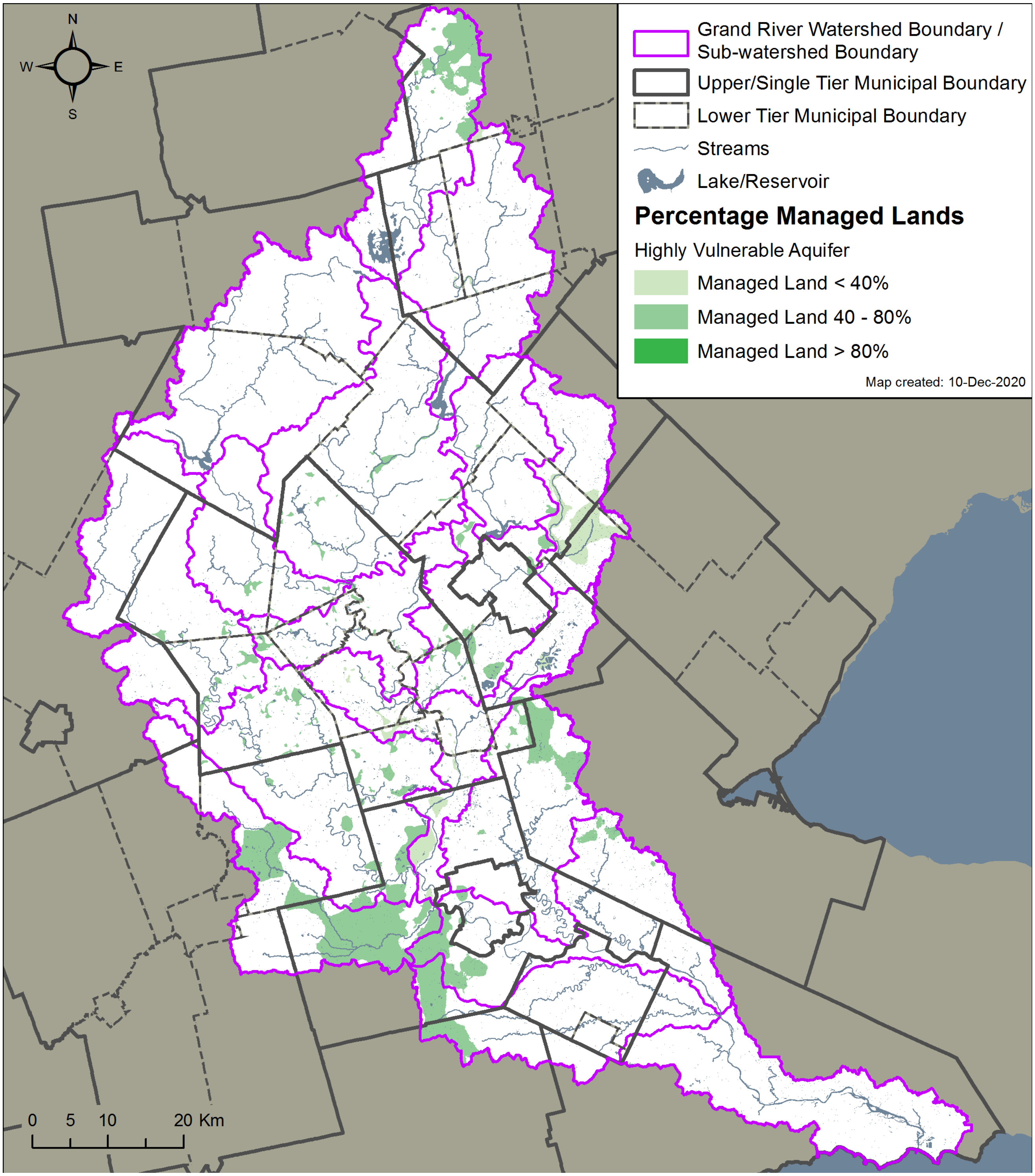
3.4.2 Percent Impervious Surfaces for Highly Vulnerable Aquifers

To determine whether the application of road salt poses a threat to the HVA areas, the percentage of impervious surface where road salt can be applied per square kilometre in each highly vulnerable aquifer area was calculated under the guidance provided by section 16(11) of the amended Technical Rules (MOE, 2009). Impervious surfaces in highly vulnerable aquifer areas in the Grand River 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 Grand River watershed.

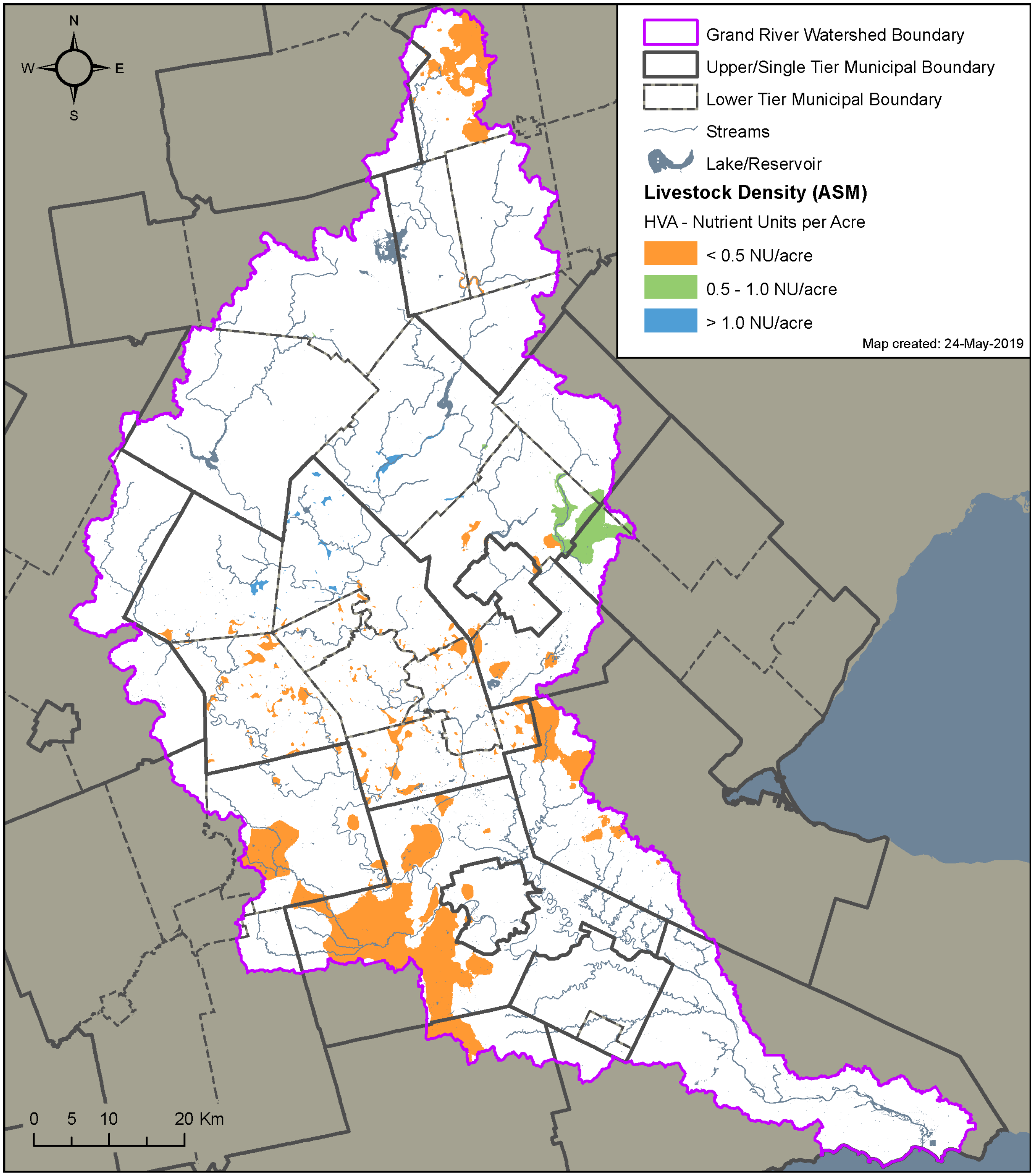
Map 3-1: Highly Vulnerable Aquifers



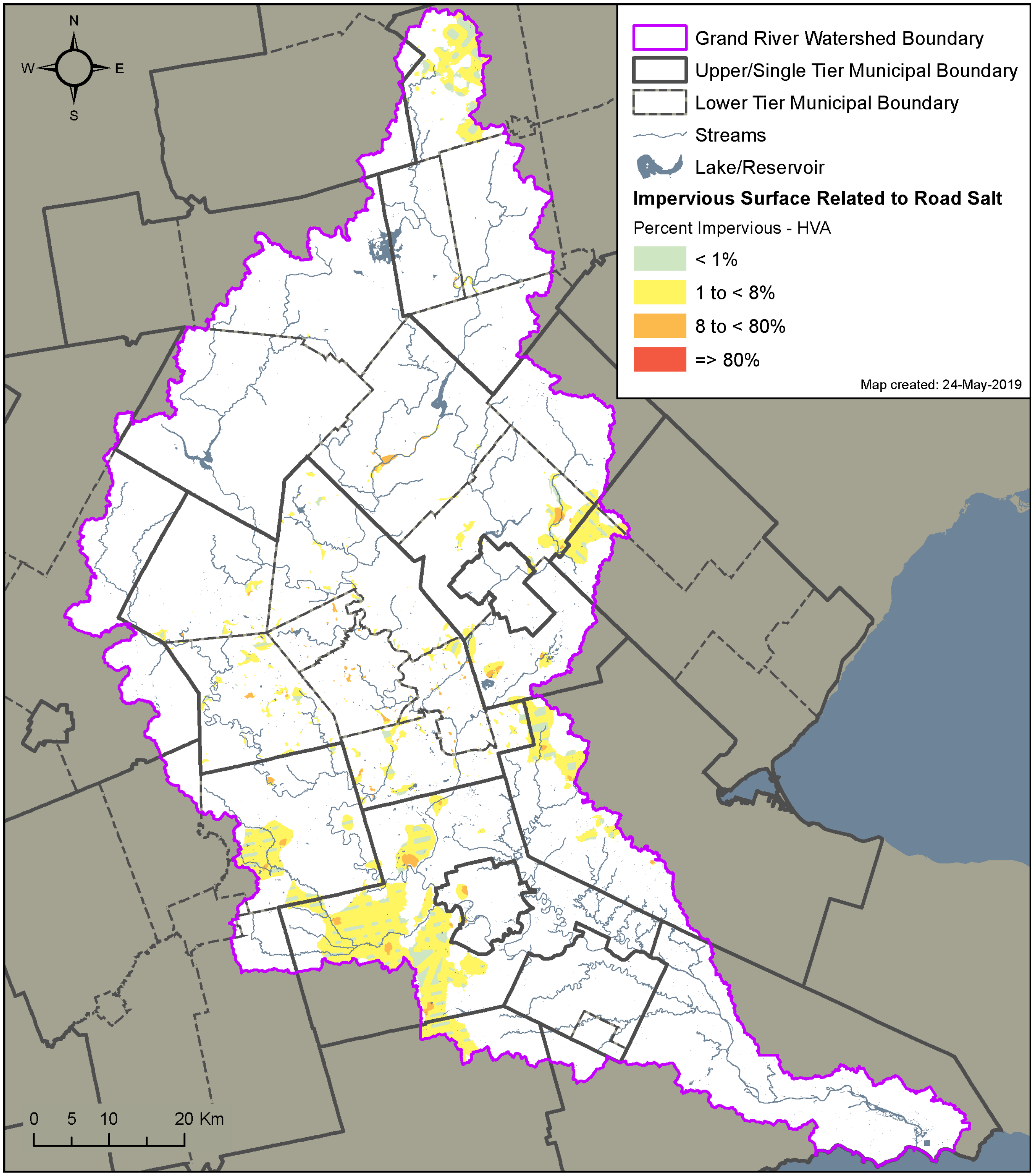
Map 3-2: Percent Managed Lands in Highly Vulnerable Aquifers



Map 3-3: Livestock Density in Highly Vulnerable Aquifers



Map 3-4: Percent Impervious Surfaces in Highly Vulnerable Aquifers



3.5 Significant Groundwater Recharge Areas

The role of significant groundwater recharge areas (SGRAs) is to support the protection of drinking water across the broader landscape. Groundwater recharge was estimated using the Tier 2 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 and land cover, and climatic conditions over the period 1980 to 2004. Threshold values were calculated as set out in the Technical Rules, and areas with annual average recharge above those values were labelled as significant.

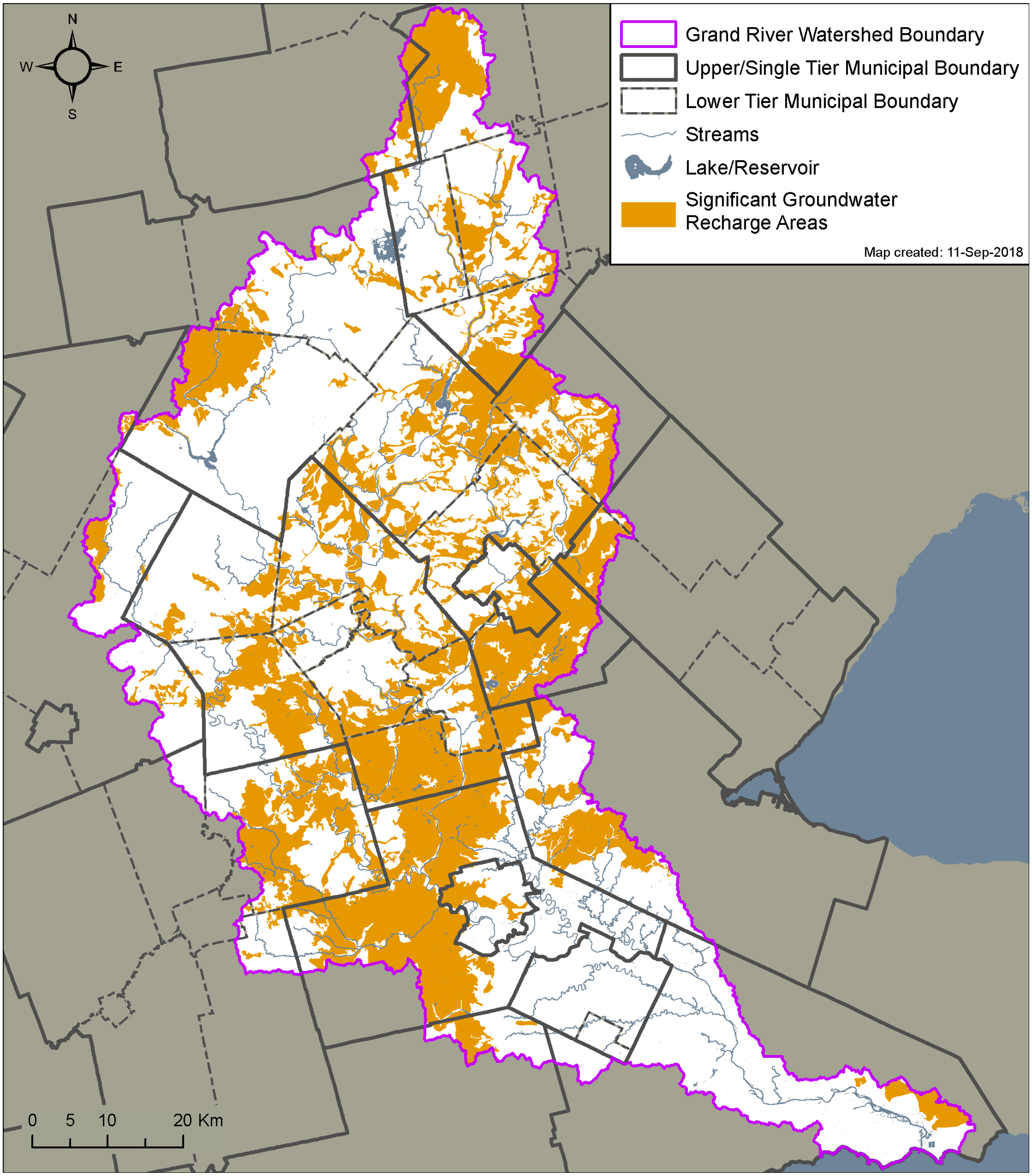
The average annual groundwater recharge rate for Grand River watershed is 176 mm/year. The threshold, calculated as 115 per cent of the average annual rate, is 202 mm/year. This threshold methodology was developed and presented to the MNR in a technical memo by AquaResource Inc. in April 2009 in response to questions raised by the Lake Erie Source Protection Water Budget Peer Review Team regarding the delineation of the SGRAs as defined in the Technical Rules (MOE, 2008). The key concern raised was that the SGRA covered more than 50% of the area, which conceptually did not make sense since the basis of the assessment is to identify the most significant recharge area within the watershed.

The SGRA delineation for the Grand River watershed was analyzed, including the effects of using different calculation procedures, regional boundaries, and consideration of uncertainty. After estimating significant groundwater recharge areas, small, isolated areas (<1km^2) were removed to create mapping that focuses the delineated significant groundwater recharge areas to larger geologic and physiographic features that are considered more representative of mapped Quaternary geology features.

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

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. Firstly, 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. Secondly, the mapping used to create hydrologic response units is landscape based and only represents a point in time. Land cover mapping may change significantly over a short time period and this may not be represented in the land cover mapping used. Finally, only 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 due climate change nor focus on the importance of seasonal and annual variability.

Map 3-5: Significant Groundwater Recharge Areas in the Grand River Watershed



3.6 Managed Lands, Livestock Density and Impervious Surfaces

In determining the potential impact of certain types of land use activities on municipal water quality, the percentage of managed lands and the livestock density in the surrounding area must be considered.

Managed lands are those lands to which agricultural source material, commercial fertilizer, or non-agricultural source material are applied. Livestock density is a surrogate measure of the potential generation, storage, and application of agricultural source material within a given area, and is expressed in nutrient units generated per year, per acre.

The percentage of managed lands and the livestock density is calculated for all vulnerable areas with a vulnerability score high enough that the following activities can be significant threats:

- the application of agricultural source material,
- the application of non-agricultural source material; and
- the application of commercial fertilizer to land.

The methodology to determine managed lands, livestock density and impervious surfaces is detailed below.

Methodology

<u>Managed Lands</u>

Managed lands are categorized into two groups: agricultural managed lands and non-agricultural managed lands. Agricultural managed lands include areas of cropland, fallow and improved pasture that may receive nutrients. Non-agricultural managed land includes golf courses (turf), sports fields, lawns (turf) and other built-up grassed areas that may receive nutrients, primarily commercial fertilizer (MOECC Technical Rules, 2017).

Orthoimagery analysis was used to manually identify and measure the area of managed land within each feature of interest (i.e. a vulnerable scoring area). The area of managed land was then divided by the total area of the feature, and multiplied by 100 to give the percentage of managed land.

For areas where the manual delineation of managed land would have been too time-consuming, analysis was simplified by determining the percentage of managed lands in sample areas instead, and then using this to estimate the percentage across the entire study area:

- For some urban areas, sample areas were selected from within large areas that show relatively uniform land-use patterns. The proportion of managed land in the sample areas was delineated manually, and the resulting percentage of managed land was then applied directly to the larger area.
- For other urban areas, the Create Random Points tool in ArcGIS was used to create a random series of 1000+ points in the study area. Each point was quickly reviewed in turn, recording if the point falls on managed or non-managed land. This was then used to estimate the proportion of managed land for the entire area.
- For some larger / regional study areas, the percentage of managed land was estimated for specific land-use types instead (e.g. residential, industrial, etc.), as defined by the Municipal Property Assessment Corporation's (MPAC) land-use codes. These estimates were assisted by an earlier impervious surface study in some cases. The resulting percentages were then

applied to all the properties in the study area, based on their assigned land-use codes, in order to estimate the percentage of managed land for the entire area. To account for certain types of non-managed lands that can vary widely within the land-use codes, (wetlands, wooded areas, water bodies, and aggregate license areas), such lands were removed from the study area before the final calculation was made. This was done by overlaying data from the Southern Ontario Land Resource Information System (SOLRIS) and the Natural Resources and Values Information System (NRVIS).

The MECP has determined a conservative estimate of risk and assumed that all managed lands receive some type of nutrient application. Categories were defined to evaluate the risk of over application of nutrients in vulnerable areas (MOECC Technical Rules, 2017):

- Total managed lands < 40% of vulnerable area – area considered to have low potential for nutrient application to cause contamination of drinking water sources.
- Total managed lands between 40% and 80% of vulnerable area – area considered to have moderate potential for nutrient application to cause contamination of drinking water sources; and
- Total managed lands > 80% of vulnerable area – area considered to have high potential for nutrient application to cause contamination of drinking water sources.

Livestock Density

Livestock density is a surrogate measure of the potential generation, storage and application of agricultural source material as a source of nutrients to a given area, and is measured in nutrient units (NU) per year per acre. 1 NU is the amount of nutrients that give the fertilizer replacement value of the lower of 43 kilograms of nitrogen or 55 kilograms of phosphate as established by reference to the Nutrient Management Protocol (O.Reg.267/03). The number of NUs generated yearly by a livestock operation depends on the number and type of livestock. Alternatively, where no animals are housed, the NU can be determined from the weight or volume of manure or other biosolids used annually.

Livestock density was calculated by using orthoimagery analysis to identify all livestock operations and their type within the study area, assisted in some cases with street imagery from Google Earth, and property codes data from the Ontario Municipal Property Assessment Corporation (MPAC), for reference. For each operation, the footprint area of all livestock housing barns was then measured using the measure tool in ArcGIS, assisted by a layer of building footprints from the Natural Resources and Values Information System (NRVIS). The footprint area for each barn was then converted directly into an estimated number of nutrient units per year, using a conversion table provided by the Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA). This factor is based on the type of livestock, and is given in **Table 3-6**. The estimated nutrient units per year value for all barns in each study area was then summed, and divided by the total area of agricultural managed land, in order to calculate the final livestock density value.

Table 3-6: Nutrient Unit Conversion Factors

MPAC Classification	Square Meters/NU
Mixed Farming	13
Beef	9
Dairy	11
Poultry	25

Table 3-6: Nutrient Unit Conversion Factors

MPAC Classification	Square Meters/NU
Swine	7
Sheep	14
Horse	26
Goat	19
Fur	223

Source: MOE Technical Bulletin, 2009

The MECP defined categories to evaluate the risk of over-application of ASM are:

- Livestock density < 0.5 NU/acre – area considered to have low potential for nutrient application exceeding crop requirements;
- Livestock density between 0.5 and 1.0 NU/acre – area considered to have moderate potential for nutrient application exceeding crop requirements; and
- Livestock density > 1.0 NU/acre – area considered to have high potential for nutrient application exceeding crop requirements.

Risk Assessment using Managed Lands and Livestock Density
The percentage of managed land and livestock density of an area are used together as a surrogate for representing the quantity of nutrients present as a result of nutrient generation, storage and application within an area. Table 1 of the "Tables of Drinking Water Threats" as provided by MECP, requires the consideration of both managed lands and livestock density when evaluating the circumstances with regard to each of the thresholds for land application of nutrients (MOECC Technical Rules, 2017). **Table 3-7** shows the chemical hazard scorings for various combinations of percentage of managed lands and livestock densities. These are the consolidated hazard scores, which include the quantity, toxicity and fate scores.

Table 3-7: Chemical Hazard Scores for Managed Lands and Livestock Density

Percent Managed Land Category	Livestock Density Category		
	<0.5 NU/acre	0.5 to 1.0 NU/acre	>1.0 NU/acre
Groundwater			
>80%	8.0	8.4	8.4
40% to 80%	6.8	7.6	8.4
<40%	6.0	6.8	8.0
Surface Water			
>80%	8.8	9.2	9.2
40% to 80%	7.6	8.4	9.2
<40%	6.8	7.6	8.8
Significant in area of Vulnerability score =10		Significant in area of Vulnerability score =10 or 9	

This table has been modified from the Implementation Guide: Module 2 – Understanding Where Policies Apply

<u>Impervious Surfaces</u>

Impervious surface area mapping is used in the scoring and assessment of threats related to road salt application. Total impervious surface area is defined in the Technical Rules (MOECC, 2017) as the surface area of all highways and other impervious land surfaces used for vehicular traffic and parking, and all pedestrian paths. It does not include impervious surfaces where road salt is not normally applied, such as rooftops and other building surfaces.

Three methods were used to generate impervious surface calculations across the Grand River Source Protection Area, in different drinking water systems:

- Use of a 1x1km grid. This method was originally prescribed by the MOECC, 2017 which required the generation of a 1x1km polygon grid draped over the study area. The proportion of impervious surfaces was then determined in each grid cell by calculating the total area of impervious surfaces in the cell and then dividing by the total area of the cell. The location of impervious surfaces was determined using a variety of data sources, including manual digitization of orthoimagery and analysis of National Road Network (Natural Resources Canada) data.
- Use of a moving-window average. Using this method, the SOLRIS (Southern Ontario Land Resource Information System) raster layer was used as an input layer to provide the location of roads and highways. The Focal Statistics tool in ArcGIS was then used to create a 15x15m grid, calculating in each output grid cell the proportion of road surface raster cells from the SOLRIS layer, within a 1x1km search neighbourhood. The resulting values were then classified into the four categories prescribed by the MOECC, 2017, and then converted to a polygon layer that merged adjacent cells of the same category together.
- Use of a Salt Loading Approach. This method, introduced by the Region of Waterloo, calculates a single “salt loading” value for each vulnerable area. It takes into account the density of roads and other impervious surfaces within the area, with primary roads weighted twice as heavily as secondary roads to account for more frequent application of road salt on them. The resulting salt loading value is expressed in units of 2 lane roadway length (in kilometres) per the size of the vulnerable area (in square kilometres). The value is then classified into one of the four classes prescribed by the MOECC, 2017, based on a predefined matrix generated by the Region of Waterloo.

There are four possible categories for the percentage of impervious surface area based on the MECP guidelines: < 1% impervious; 1% to < 8% impervious; 8% to < 80% impervious and ≥ 80% impervious. Under the threats based approach, for road salt to be considered a significant threat, the percent of impervious surface must be greater than 80%.

3.7 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 (MOECC, 2017) list five ways in which to identify a drinking water threat:

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

3.7.1 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 O. Reg. 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 3-8** 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 3-8: Drinking Water Threats

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, whey, etc.
4	The storage of agricultural source material.	e.g. manure, whey, etc.
5	The management of agricultural source material.	aquaculture
6	The application of non-agricultural source material to land.	Organic Soil Conditioning Biosolids
7	The handling and storage of non-agricultural source material.	Organic Soil Conditioning Biosolids
8	The application of commercial fertilizer to land.	Agriculture Fertilizer
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. O. Reg. 385/08, s. 3.	Agricultural Operations
22	The establishment and operation of a liquid hydrocarbon pipeline	Liquid Hydrocarbon Pipelines

Reference: Clean Water Act, 2006 O.Reg 287/07 Section 1.1

3.7.2 Threats from Conditions

Conditions relate to past or historic activities. Conditions must fall into one of the statements below which are listed in the MOECC 2017 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, significant groundwater recharge area 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, significant groundwater recharge area or a wellhead protection area, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, 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.

To identify potential conditions, a review of available data regarding potential contamination within the WHPAs was completed. Data reviewed included databases from the Ecolog ERIS results such as Record of Site Condition, MOECC Spills Database and Occurrence Reporting Information System and MOECC Historical Waste Disposal Sites. The review process also included information obtained during consultations with municipal staff.

3.7.3 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 O. Reg 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 (ICA) and manage these threats appropriately. All threats related to a particular Issue within the ICA are classified as significant drinking water threats, regardless of the vulnerability.

3.7.4 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 MOECC Provincial Tables of Circumstances show the threat for circumstances under which a given activity is classified as a low, moderate, or significant threat (http://swpip.ca). 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 Ministry's Table of Drinking Water Threats (TDWT) can be used for accuracy (Ministry's TDWT).

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 F, IPZ-1, IPZ-2 and IPZ-3). Vulnerability scores are assigned as outlined in Chapter 3.2.3 and Chapter 3.2.4. 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.