Highly Vulnerable Aquifers in the Mississippi-Rideau Source Protection Region

Draft Groundwater Study Findings – June 2009

The Clean Water Act

This study was done under Ontario's *Clean Water Act* which requires municipalities and the local community to work together to protect local drinking water sources from becoming contaminated or depleted. The Act is primarily focused on minimizing risks to municipal drinking water sources (lakes, rivers and aquifers that supply "village water" to residents). Where drinking water sources face significant threats, mandatory action could be required. The key steps under this Act are:

2007 – Source Protection Committee Created

The Mississippi-Rideau Source Protection Committee is made up of 16 people representing a wide variety of local interests and sectors. This Committee is overseeing the development of science-based Source Protection Plans for the Mississippi River and Rideau River watersheds.

2009 – Complete Scientific Studies

Technical studies are mapping local sources of drinking water, determining if they are vulnerable to contamination or overuse, and identifying potential threats. This science will show us where source protection policies are needed, and what threats they need to address.

2012 – Develop Policies to Protect Source Water

Source Protection Plans will contain a combination of voluntary and mandatory land use policies to protect drinking water sources. Under the Act, policies must moderate significant threats and prevent others from becoming significant.

What is an Aquifer?

An aquifer is an underground layer of sand, gravel, or rock that contains enough water to supply a well. In general, the following main aquifers have been identified in the Mississippi-Rideau Source Protection Region:

- An Upper Precambrian bedrock aquifer is located in the western portion of the region.
- Nepean Sandstone and Oxford-March bedrock aquifers are located in the central portion of the region.
- Sand and gravel aquifers are located along the eastern and northern portions of the region.

Often, different aquifers are used by different types of wells. For example, shallow aquifers (the 1st aquifer below the ground surface) are often used for private wells that do not require high volumes of water. Deeper aquifers may transmit more water, and so are often used to supply municipal drinking water systems.

In the Mississippi-Rideau region, the Upper Precambrian and the Oxford-March formations are shallow aquifers, and are generally used to supply private wells. The Nepean Sandstone formation is a deep aquifer, and is the source for most of the municipal groundwater systems in the region.

What is a Highly Vulnerable Aquifer?

A highly vulnerable aquifer, or HVA, is an aquifer that is susceptible to contamination from sources at the surface.

Factors that can affect an aquifer's vulnerability are:

1. the depth from the ground surface to top of the aquifer
2. the water table, if the aquifer is exposed at ground surface
3. the type of soil and rock between the aquifer and the ground surface

This study is focused on delineating the vulnerability of the shallow aquifer.

In the Mississippi-Rideau Source Protection Region the location of highly vulnerable aquifers is most important for those supplied by private wells.

Regional Groundwater Study

Step 1 – Delineate Highly Vulnerable Aquifers

Experts gather relevant information and use established, scientific methods to determine where the aquifer is most vulnerable to contamination from the surface.

Step 2 – Assess Vulnerability

Next, experts assign a vulnerability score to the Highly Vulnerable Aquifer areas. The scoring process is set out in the Assessment Report Technical Rules issued under the *Clean Water Act*.

Step 3 – Identify Threats and Issues

The province created a list of land uses and activities that could pose a low or moderate threat to highly vulnerable aquifers.

The Experts

For the Mississippi-Rideau Source Protection Region, Step 1 was completed by water resource engineers, hydrogeologists and GIS/database specialists at Golder Associates Ltd. (Golder). This work was completed in 2003 as part of the Renfrew-Mississippi-Rideau Regional Groundwater Study, and was peer reviewed by an independent third party. Step 2 was completed by Conservation Authority staff at the Mississippi-Rideau Source Protection Region. Step 3 is currently underway, and is also being completed by Mississippi-Rideau Source Protection Region staff. With the exception of the modification described below, this work conforms to the Assessment Report Technical Rules (dated December 12, 2008) issued under the *Clean Water Act*. The Technical Rules can be found at http://www.ene.gov.on.ca/en/water/cleanwater/cwa-technicalstudies.php

Step 1 – Delineate Highly Vulnerable Aquifers

Highly Vulnerable Aquifers for the Mississippi-Rideau Source Protection Region were delineated as part of the Renfrew-Mississippi-Rideau Regional Groundwater Study, completed in 2003.

MOE Intrinsic Susceptibility Index

In 2002, the Ontario Ministry of the Environment (MOE) developed an approach called the Intrinsic Susceptibility Index (ISI) protocol to provide a consistent approach to determining aquifer vulnerability across the province. The ISI approach is used to assess the vulnerability of the '1st aquifer', or the aquifer closest to the surface.

The MOE ISI protocol is a step-wise approach, with a clearly defined process.

I. Prepare Data

   Experts gather water well records from the Ministry of the Environment water well database. These records are analyzed and improved if better information is available. For example, records may contain incorrect or incomplete coordinates for well locations, or vary in how the types of rock and soil are described. The reliability of the study results can be improved by using standard descriptions, adjusting well location coordinates, or screening incorrect records out altogether.

II. Map the Water Table

   Next, experts use the water well record data, or improved data, to determine the 'depth to water', or water table level, at each well location. Using this information, the overall depth to water for the aquifer is modeled for the region.

III. Calculate Intrinsic Vulnerability Index

In this step, experts evaluate each of the different soil and rock layers and assign an intrinsic susceptibility index (ISI) value to each well. Specifically, each soil or rock layer is evaluated in terms of its 'hydraulic conductivity' and associated 'K-factor' – that is, how easily water can travel vertically through it. For each soil or rock layer from the ground surface down to where water is found in the well, a K-factor is assigned and a resulting ISI value calculated.

This process also allows the experts to map the location and type of aquifers (confined, unconfined, or semi-confined) in the region, by comparing ISI and water depth information between wells. This information can provide a picture of the depth and extent of an aquifer.

IV. Categorize Well Vulnerability

In this step, each well is categorized as 'High', 'Medium', or 'Low' vulnerability, based on the ISI value that was calculated in the previous step. ISI values less than 30 are high, values between 30 and 80 are medium, and values above 80 are low vulnerability.

V. Map Intrinsic Vulnerability Index Values

The last step is to map the calculated ISI values, and to identify regions of similar vulnerability. Experts use mathematical methods to find the best way to group the different ISI values from each well together. The end result is a map that shows the vulnerability of the aquifer across the entire region.

Modification to the MOE Approach – Using Geological Information

The ISI approach to determining aquifer vulnerability was originally intended by the MOE for use in assessing the vulnerability of unconfined aquifers (also called 'overburden' aquifers).

Golder recognized the limitations of using this method 'as is' for the Renfrew-Mississippi-Rideau study area. Because confined aquifers are present in much of the region, and some of these aquifers are layered on top of each other, they modified the ISI approach to better suit the unique characteristics of the region. This modification was developed in consultation with MOE staff, and the study's technical advisory group.

The modification involves the addition of a new step. This step uses information about the types of rocks and soils found at the ground surface (called 'surficial geology') as an indicator of vulnerability. The geology of the Renfrew-Mississippi-Rideau study area is unique in several ways:

- the bedrock of the Canadian Shield is at or very close to the ground surface for a significant part of the study area
- this rock is very old, and very fractured near surface, comprising a shallow aquifer
- significant deposits of sand and gravel are also present

As a result, Golder modified the ISI approach as follows: **all areas that were mapped as either bare rock, covered with less than 1.5m of material (soil,**

glacial till, etc), or covered by sand or gravel were automatically classed as highly vulnerable. All other areas were assessed according to the described MOE ISI protocol.

Isolating Highly Vulnerable Aquifers

The last step is to isolate Highly Vulnerable Aquifers (HVAs) from the regional aquifer vulnerability assessment.

First, experts selected those areas that were assigned a vulnerability of 'High' during the ISI assessment. Then, these areas were combined with the areas automatically designated as 'High' according to the Golder modification.

The result delineates the highly vulnerable aquifers for the Renfrew-Mississippi-Rideau study area.

Results

Mississippi-Rideau Regional Geologic Cross-Section

Figure 1, below, shows three geologic cross-sections for the Mississippi-Rideau Source Protection Region. Cross-sections A-A^{I} and C-C^{I} run from west to east, and clearly show how the bedrock of the Canadian Shield is at the surface in the western portion of the region. Moving east, the Nepean and Oxford/March formations appear. These are the confined aquifers that are the source of drinking water for many of the region's municipal systems.

Mississippi-Rideau Depth to Water

To create the shallow (1st aquifer) water table dataset, Golder followed the process as described in Step 2, above. From the water well records, they determined the depth from the surface down to the 'static' water level. The static water level is the stable level of water in a well.

Map 1 shows the water table map (the depth of the shallow 1st aquifer) for the Mississippi-Rideau Source Protection Region.

Mississippi-Rideau Aquifer Vulnerability

The aquifer vulnerability map was developed according to the MOE ISI approach, and modified to account for local geology as described above.

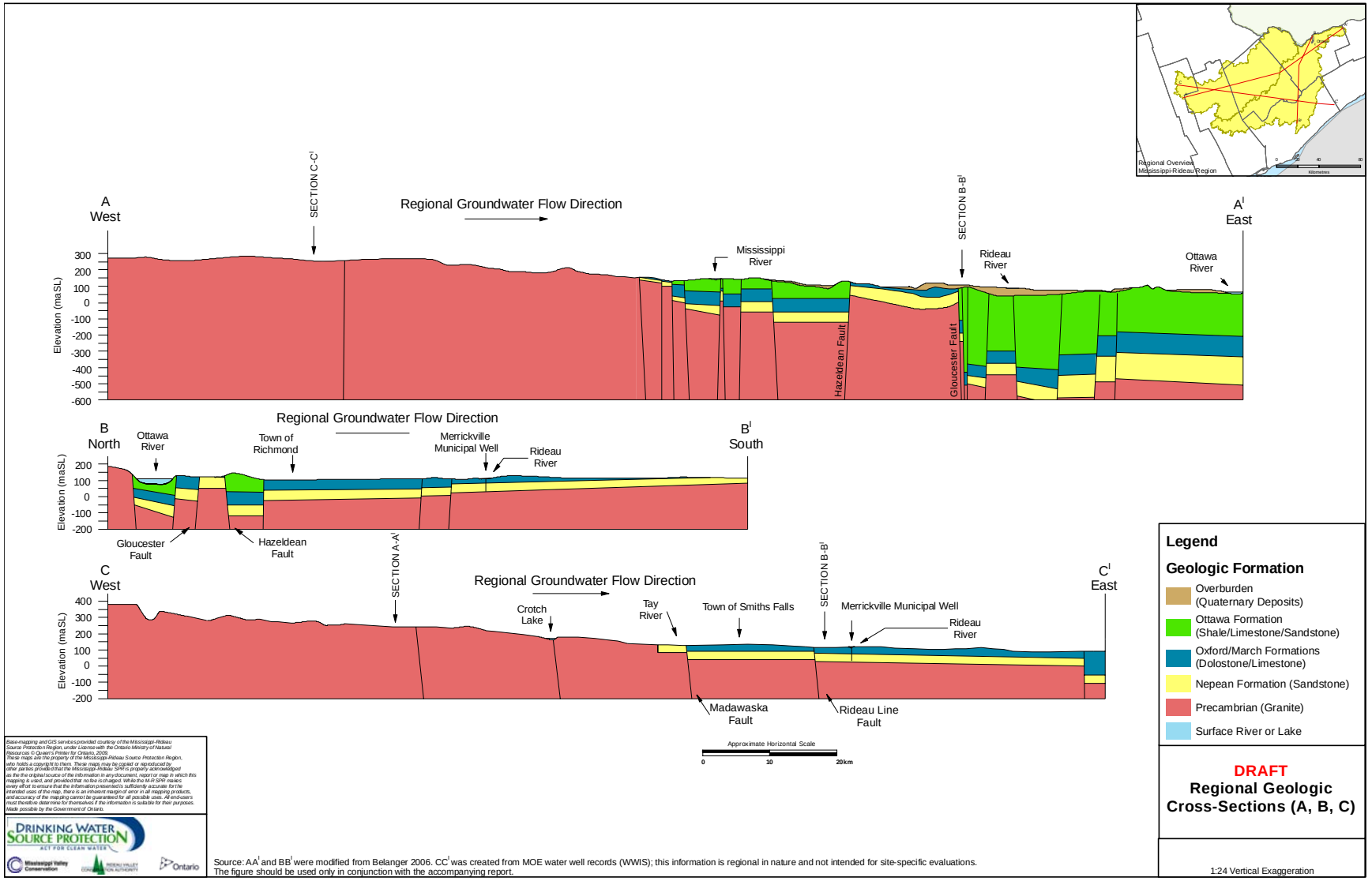
Map 2 shows the final shallow aquifer vulnerability for the Mississippi-Rideau Source Protection Region.

Mississippi-Rideau Highly Vulnerable Aquifers

The final aquifer vulnerability map shows only where the shallow aquifer is assigned a vulnerability of 'High'. These are the Highly Vulnerable Aquifers for the Mississippi-Rideau source protection region.

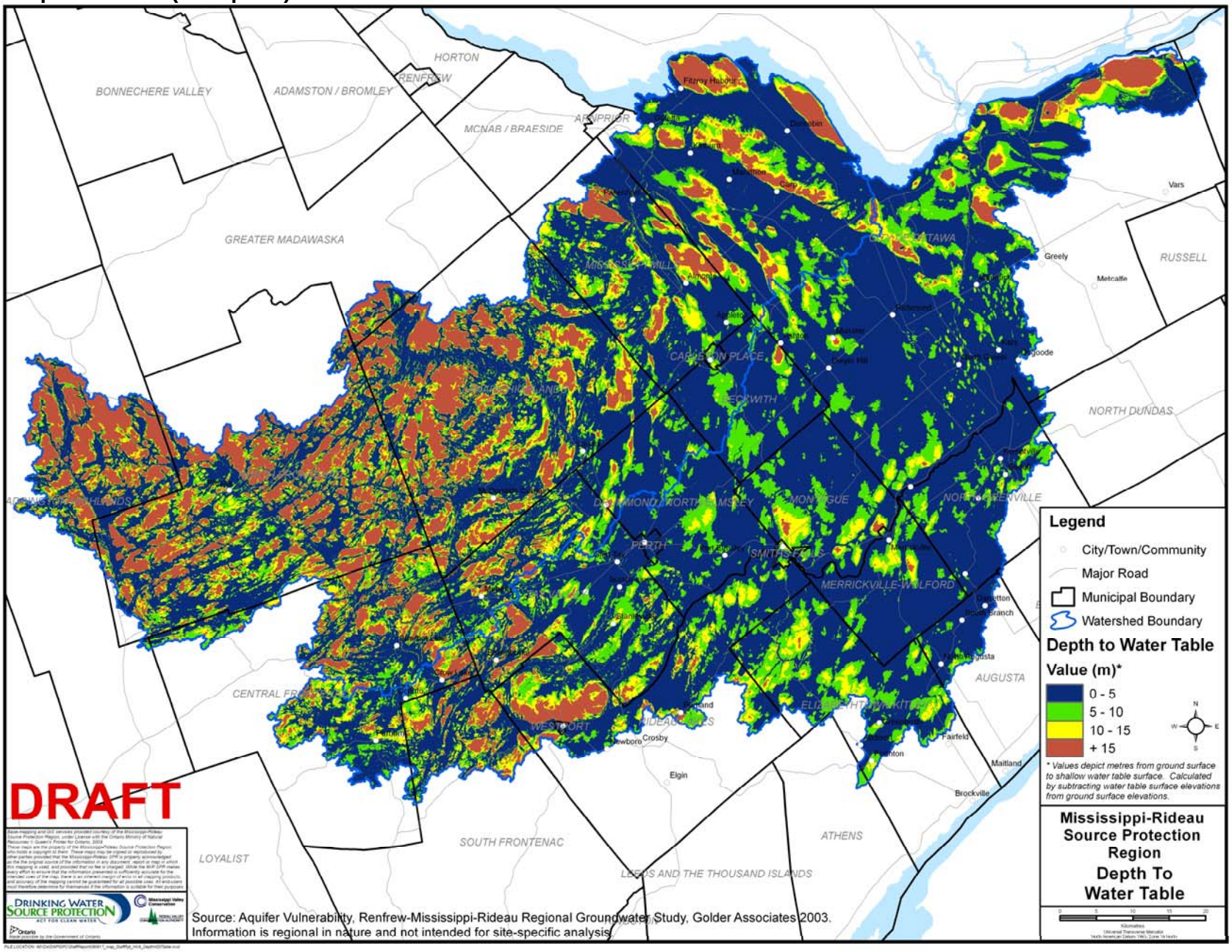
Map 3 shows the Highly Vulnerable Aquifer areas for the Mississippi-Rideau Source Protection Region.

Figure 1. Regional Geological Cross-Sections

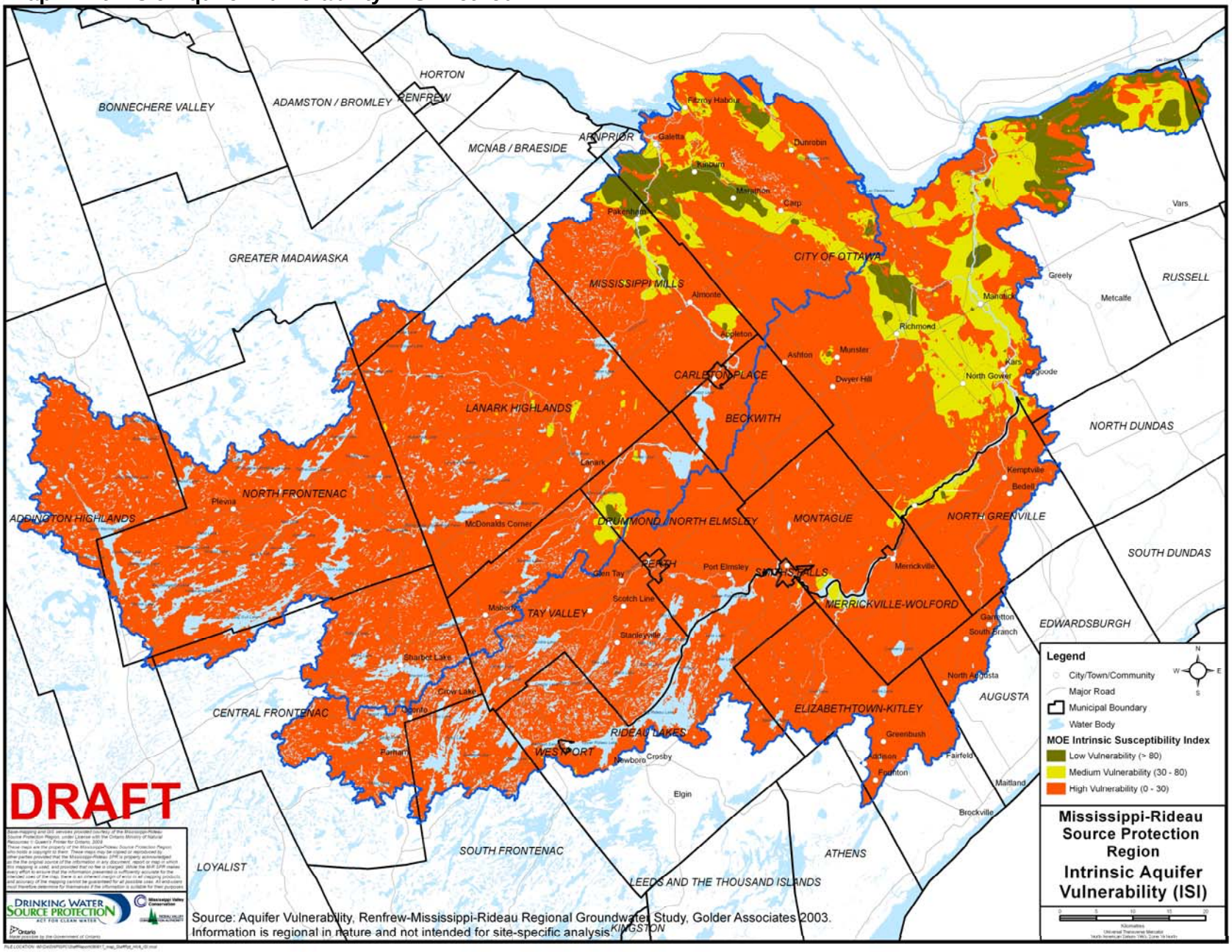


Source: AA' and BB' were modified from Belanger 2006. CC' was created from MOE water well records (WWIS); this information is regional in nature and not intended for site-specific evaluations. The figure should be used only in conjunction with the accompanying report.

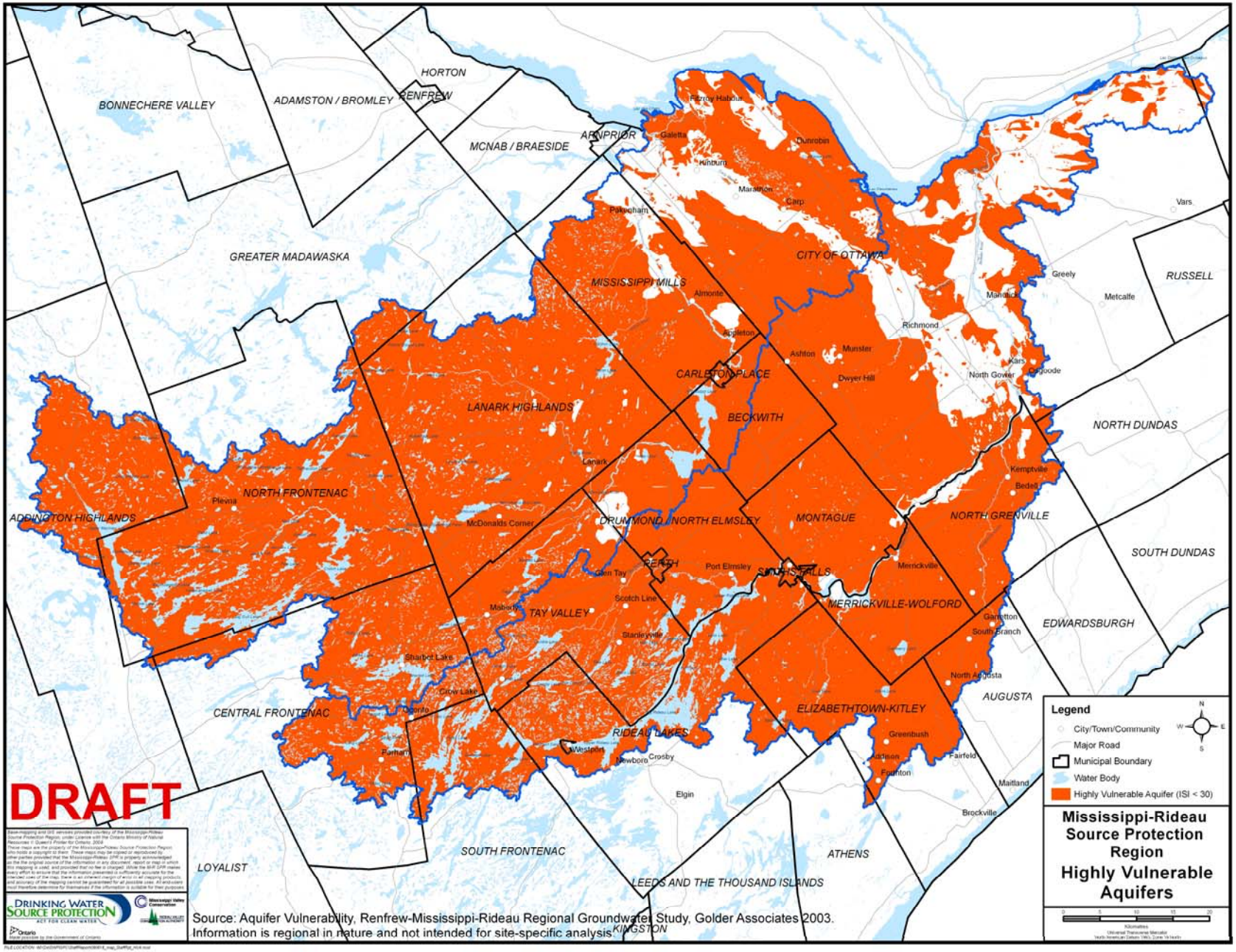
Map 1. Shallow (1st Aquifer) Water Table



Map 2. Intrinsic Aquifer Vulnerability – ISI Method



Map 3. Highly Vulnerable Aquifers (ISI < 30)



Step 2 – Assess Vulnerability

The next step is to determine a vulnerability score for the HVAs in accordance with the technical rules. For highly vulnerable aquifers, the scoring process is straightforward. Because HVAs and wellhead protection areas (WHPAs) can overlap, and vulnerability scoring is completed separately for WHPAs, any part of an HVA that overlaps a WHPA is excluded from vulnerability scoring. These areas are scored as part of the WHPA study. Remaining areas are automatically assigned a score of **6**.

It must be noted that there is a discrepancy between the prescribed scoring approach and the methodology as it applies to the Mississippi-Rideau region.

Five of the seven municipal groundwater systems in the Mississippi-Rideau region draw water from two aquifers – a shallow aquifer (the Oxford/March formation) and a deep aquifer (the Nepean formation). As a result, experts delineated WHPAs for each of these aquifers.

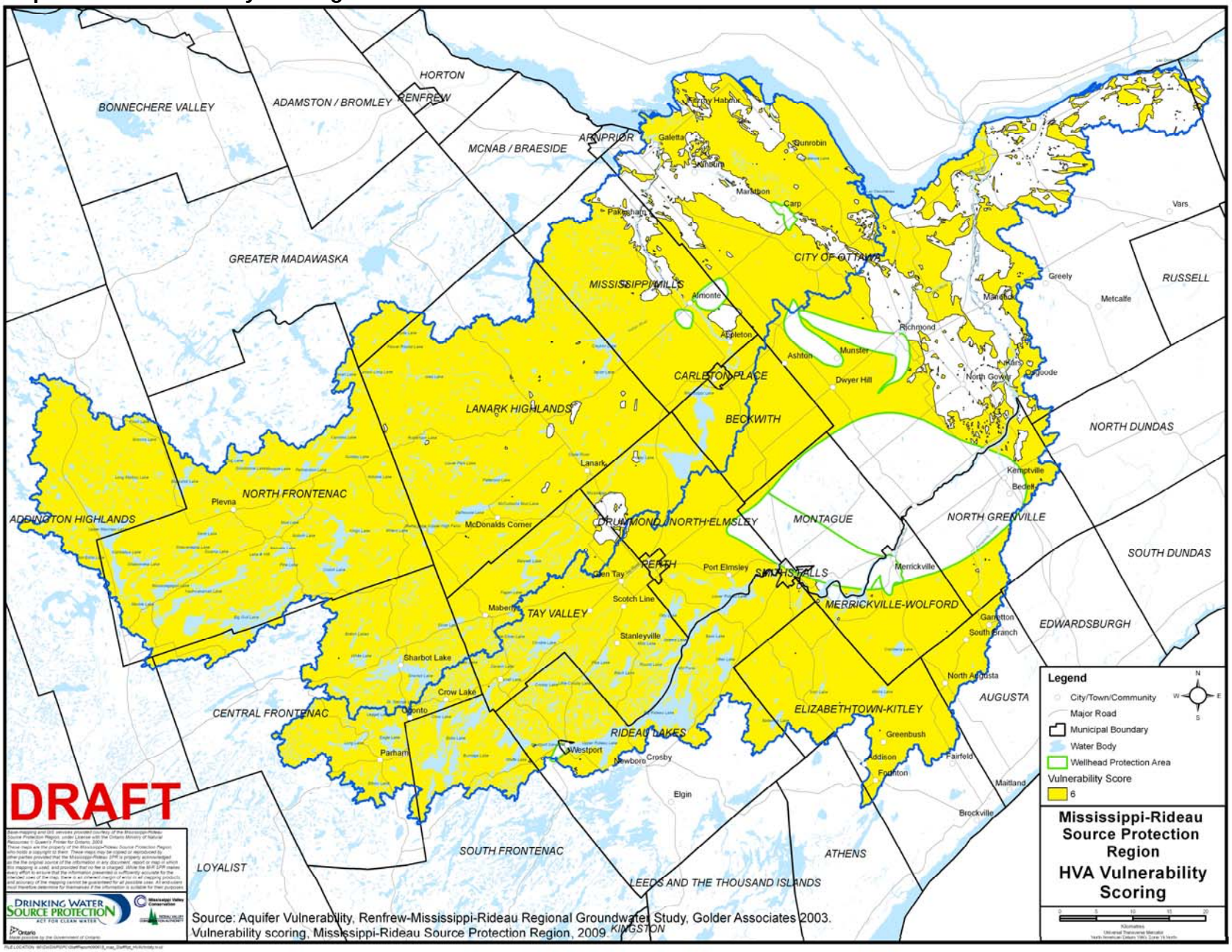
Since the ISI approach for the delineation of HVAs identifies the vulnerability of the 1st (shallow) aquifer, it follows that only areas that overlap the shallow aquifer WHPA should be excluded from the HVA vulnerability scoring.

However, to comply with the Technical Rules, both the shallow and the deep aquifer WHPAs must be excluded from the HVA. As a result, it is possible that an area that has been identified as an HVA, but that overlaps a deep aquifer WHPA, will receive a vulnerability score that is not representative of the actual vulnerability of the shallow aquifer.

Results

Map 4 shows the vulnerability scores for HVAs in the Mississippi-Rideau Source Protection Region. Any areas that overlap with a wellhead protection area are excluded. The vulnerability score is **6** for all HVA areas.

Map 4. HVA Vulnerability Scoring



Step 3 – Identify Threats and Issues for Water Quality

Once experts determine where a drinking water supply is vulnerable to contamination, they need to identify what land use activities could pose a contamination risk in those areas (threats). Experts also need to identify any existing water quality problems (issues) and link them back to the land use(s) causing the contamination.

(1) **Threats** are existing conditions (i.e., contaminated sediment, soil or groundwater) or existing or future land use activities that could contaminate a drinking water supply;

(2) **Issues** are documented cases of water quality contamination approaching or exceeding acceptable provincial levels. While some issues are naturally occurring, many are caused by an existing or historic land use activity.

3a) Threats

The Assessment Report Technical Rules identify the three ways that a water quality threat can be identified:

I. Through an activity prescribed by the Clean Water Act;

II. Through an activity identified by the Source Protection Committee; and

III. Through a condition resulting from past activities.

I. Activities Prescribed by the Clean Water Act

Before threats could be identified, the province had to decide what activities pose a threat, and to what extent. Section 1.1 of Ontario Regulation 287/07 (made under the Clean Water Act) lists 21 broad land use activities as '*prescribed drinking water threats*'.

The province then broke each of the 21 broad activities into various scenarios called *circumstances* (e.g. activity A involving the storage of chemical X in an above ground storage tank greater than 50,000 litres). There are 500 pages of specific circumstances in the provincial Technical Rules and they are divided into two tables – chemical threats and pathogenic threats. The tables of drinking water threats can be found at:
http://www.ene.gov.on.ca/en/water/cleanwater/cwa-technicalstudies.php

These tables identify if a circumstance is a 'significant', 'moderate', or 'low' threat in each vulnerability score (2, 4, 6, 8 and 10). For example, a circumstance may be a *significant* threat in an area with a vulnerability score of 10, and a *moderate* threat in an area with a vulnerability score of 8.

List low and moderate threats:

Using the threats tables, the first step is to list all land use activities (circumstances) that pose a low or moderate threat to highly vulnerable aquifers in the Mississippi-Rideau region. This is simply a summary of the provincial drinking water threats tables; it does not reflect what activities are actually taking place in the HVA.

Since all HVAs outside of a WHPA have a vulnerability score of 6, land use activities are categorized as low or moderate threats in the provincial threats tables. No activities can scored (or labeled) as significant threats within an HVA.

II. Activity identified by the Source Protection Committee

A drinking water threat can be identified by the Source Protection Committee if the activity is not included in the provincial list of 21 prescribed drinking water threats. This can only occur if a hazard assessment confirms that the activity is a threat, and this assessment is approved by the MOE.

III. Through a condition resulting from past activities.

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

4. the presence of contamination in sediment;
5. the presence of non-aqueous phase liquid (i.e., gasoline) in groundwater;
6. the presence of a single mass of 100 litres of dense non-aqueous phase liquids in surface water.

3b) Issues

A drinking water issue is a documented problem with the quality of drinking water. This can be a chemical or pathogenic problem discovered in the source water of a municipal, monitoring, or private well that exceeds Ontario's established drinking water standards, or shows the potential to exceed these standards in the future.

Under the Technical Rules, for non-municipal wells, issues are limited to chemical or nuclear contaminants. The specific parameters can be found in Schedules 1, 2, or 3 of the Ontario Drinking Water Quality Standards, and in Table 4 of the Technical Support Document for the Ontario Drinking Water Quality Standards, Objectives and Guidelines. The Ontario Drinking Water Quality Standards can be found here: http://www.search.e-laws.gov.on.ca/en/isysquery/4911a9de-3fbb-4359-ad9f-4bb28526e99e/5/frame/?search=browseStatutes&context.

The Technical Support Document for the Ontario Drinking water Standards can be found here: http://www.ontario.ca/drinkingwater/stel01_046947.pdf

The identification of known issues is a way to include historic or cumulative activities in the source protection planning process. For example, an old industrial site could be leaching a contaminant into the aquifer, resulting in poor water quality.

If a parameter or pathogen has been identified in the source water of a well, the following information is required:

- the area or location that is causing the parameter or pathogen, and
- the land use activities, conditions (including naturally occurring conditions), or past activities at that location that are associated with the parameter or pathogen.

If the above information cannot be readily determined, a plan must be developed to collect it for inclusion in a future Assessment Report.

For More Information Contact:

Sommer Casgrain-Robertson
Co-Project Manager
Mississippi-Rideau Source Protection Region
Tel.: 613-692-3571 or 1-800-267-3504 ext 1147
Email: sommer.robertson@mrsourcewater.ca
www.mrsourcewater.ca