WESTERN CATARAQUI REGION GROUNDWATER STUDY

Volume I

Groundwater Inventory and Findings

Prepared for:

Cataraqui Region Conservation Authority
1641 Perth Road
Kingston, Ontario
K0H 1S0

TROW ASSOCIATES INC.

Suite 315 The Woolen Mill
4 Cataraqui Street
Kingston, Ontario
K7K 1Z7

Telephone: (613) 542-1253
Facsimile:(613) 547-3767
Email:kingston@trow.com
www.trow.com

Project # MK16024-01

April 2007

Executive Summary

Study Background

Trow Associates Inc. (Trow), on behalf of the Cataraqui Region Conservation Authority (CRCA), has undertaken a Groundwater Study in the rural areas of the City of Kingston, Loyalist Township, The Town of Greater Napanee and South Frontenac Township, occupying the Western Cataraqui Region Watershed (i.e., Study Area) (Executive Summary Figure 1). This Study examines groundwater in relation to its supply, natural quality characteristics and its potential vulnerability to contamination. The Study was funded by the Ministry of the Environment (MOE), Ontario's Operation Clean Water Initiative, and the participating municipalities.

Groundwater is the primary source of potable water in the Study Area. Municipalities and water managers, including the CRCA, therefore require a better understanding of regional groundwater resources to ensure protection of groundwater serving existing and future development in the Study Area. The following are the general objectives for the Study:

1. To compile a groundwater resource inventory which identifies fundamental groundwater characteristics across the Study Area including:

    - sources of water, including primary areas of groundwater recharge and discharge;
    - water well yields, including areas of low yields;
    - water quality, including areas of poor water quality;
    - directions of groundwater flow;
    - the vulnerability of groundwater to contamination; and
    - pathways from land and surface water to groundwater.

2. To examine the use of groundwater and existing conservation practices.

3. To evaluate and develop region-specific measures to protect existing groundwater resources.

The general sources of information utilized for the Study included: information on geology, hydrogeology, groundwater supply and quantity, on-site wastewater treatment and other data provided by municipalities and government agencies; MOE Water Well Records; available mapping; and relevant published and unpublished reports. Supplementary information was obtained from questionnaires that were sent to citizens and water well drillers in the Study Area, and analytical results from 96 well water samples collected by Trow specifically for this regional study. The Study entailed consultation with the public, including creation of a web site for the Study, public information sessions and distribution of a questionnaire and newsletter.

Physical Setting of the Study Area

The Study Area covers approximately 3,000 km^2 and represents a community of approximately 20,000 households (43,000 people). The Study Area excluded urban areas and their populations. Residents in the Study Area rely on private services consisting of individual water wells and sewage disposal systems with the exception of a small percentage who live in communally or publicly-served areas in the City of Kingston (including residents of the Cana Subdivision in the former Pittsburgh Township), the Town of Greater Napanee and the communities of Amherstview, Bath, Westbrook, Odessa and Sydenham (municipal drinking water only).

The aspects of the regional landscape that are most important for the description of the groundwater setting are surface features, thickness of the overburden (soil overlying bedrock), and geology. Each of these is critical for determination of Study Objectives 1 and 3 outlined above.

Surface Features

Four (4) main areas with distinct surface features (physiography) are present in the Study Area. In the northeast, Shallow Till and Rock Ridges of the Canadian Shield dominate. Limestone Plains that constitute about two-thirds of the Study Area are located in the central western and northern sections of the Study Area. The major river valleys (Greater Cataraqui and Napanee Rivers) and the southern end of the Town of Greater Napanee, Loyalist Township and the City of Kingston are on Clay Plains. Bare Rock Ridges and Shallow Till occur in the vicinity of Perth Road Village.

Overburden Thickness

The thickness of the soils overlying bedrock (overburden) in the Study area is generally less than one (1) metre, with exposed bedrock visible in some areas on the Limestone Plains and the Canadian Shield in the east and northeast. The exceptions to this include the valleys of rivers (Greater Cataraqui and Napanee) and creeks (Wilton, Millhaven, Little Cataraqui and others), the Village of Verona and other limited areas where overburden is thicker. Karst and fractured bedrock are common in the Limestone Plains.

Geology

The Study Area contains three (3) distinct bedrock types. Limestone dominates the centre, western and northern portions of the Study Area. Precambrian rocks of the Canadian Shield dominate the northeast and east. Predominantly sandstone areas are found in the eastern portions of the Study Area interspersed within the Canadian Shield. These geologic variations in the bedrock determine important aspects of the groundwater conditions in the Study Area, including:

- well yield,
- water quantity,
- water quality,

- number of dry wells, and
- vulnerability of the groundwater to surficial contaminants.

Because of the strong correlation between geology and groundwater attributes critical to this Study, three (3) hydrogeologic zones are identified and used as the fundamental descriptors of sub-areas within the Study Area. These hydrogeologic zones are defined as follows:

- Zone 1-A: Gull River Formation Limestone
- Zone 1-B: Verulam and Bobcaygeon Formations Limestone
- Zone 2: Precambrian Rocks of the Canadian Shield
- Zone 3: Sandstone

Zones 1-A and 1-B are the most extensive, comprising about two-thirds of the Study Area. Zone 3 is the smallest, identified in only 4 percent of the Study Area.

These zones are referenced throughout the text and shown in Executive Summary Figure 2 (Figure 29 of report).

Summary of Findings

The findings of the Study are as follows:

Information on Wells

Of the 22,226 well records reviewed for this Study, the majority of wells (63%) obtain groundwater from the limestone (Zone 1-A and 1-B). The Precambrian bedrock (Zone 2) supplies 27 percent of wells. The sandstone (Zone 3) and overburden supply only a small number of wells (6% and 3%, respectively).

Seventy-four (74) percent of wells are drilled; ten (10) percent are dug.

Most wells in the Study Area are shallow, drawing groundwater from a depth between 15 and 30 metres. The larger the depth to the well in most subsurface conditions, the more contaminant attenuation can occur, i.e., the more protected the groundwater supply is from surface contamination. With so many shallow wells across the region, potential contaminants have a short pathway to groundwater.

Groundwater Quantity (Well Yield)

Well yields vary widely depending on the hydrogeologic zone in which they are located. Seventy-six (76) percent of respondents to the Study questionnaire report sufficient water supply; 71 percent practice water conservation. Well yields were reviewed for this Study in five (5) ways:

- The percentage of wells in a zone that produced 13.6 L/min or greater. This yield is the Ministry of the Environment's (MOE's) minimum rate to meet the needs of a single-family residence.
- The average well yield in the zone. This is reported as the Recommended Pumping Rate (RPR) which is a rate recommended by the well driller as a sustainable yield from the well.
- The percentage of dry wells in the zone.
- The number of wells that are unused due to the quantity of available water from the well as reported in the MOE Well Water Record database.
- The percentage of wells that produced 4.5 L/min or less. This yield is the MOE's threshold for a minimum rate to support development.

All of these methods resulted in the same trend. Yields are lowest and dry wells highest in Zones 1-A and 1-B, the limestone formations. Groundwater yields are better based on these measures in Zone 2 and best in Zone 3.

Unused or "Abandoned" Water Wells

According to the MOE database, there are 2,234 registered, drilled wells in the Study Area that are unused. Of these, 84 percent are unused due to insufficient quantity; about 16 percent due to poor quality. The majority of these wells have been left open and unsealed. Because the MOE database only includes registered, predominantly drilled wells, it is not known how many dug and other types of "abandoned" and unused wells also exist. The actual number of unused or "abandoned" wells is expected to be higher than the number of recorded unused/abandoned wells.

Zone 1-B has the largest percentage (78%) of wells unused/abandoned due to quantity. The lowest percentage (64%) occurs in Zone 3.

The number of wells unused/abandoned due to groundwater quality is the highest (36%) in the sandstone. Zone 1-B has the lowest percentage (8%).

Unless the wells have been sealed and plugged as per MOE guidelines, each well represents a potential pathway of contamination from the surface to the aquifer. These wells can also provide the pathway for cross-contamination between different aquifer levels in the subsurface. With so many unused wells in the Study Area, most of which are improperly sealed, these serve as a significant pathway for contamination to travel from the ground surface to the water table.

Groundwater Quality

Groundwater quality across the region was found to be location-and chemical-constituent-specific. Bacteria, nitrates, sodium, and chloride were found to be the only quality constraints to development in the Study Area, although elevated levels of other constituents were detected.

Residents responding to the Study questionnaire reported staining and/or scum residue from their water (40%). Fifty-five (55) percent had their water tested within the previous year. Sixty-two (62) percent of responding households had some form of water treatment, the majority of whom use a water softener.

Results from a bacteria sampling program undertaken by 2,765 homeowners during the period of April to July 2002 indicate that approximately one-third (29%) of the water samples from across the Study Area had coliform bacteria counts in excess of the Provincial criteria. Escherichia Coli (E. coli) bacteria counts in excess of the Provincial health-based Maximum Acceptable Criteria were detected in 11 percent of the water samples. The counts of E. coli exceedances were the highest in Loyalist Township (17%). The number of coliform exceedances were the highest in the Town of Greater Napanee (35%).

Of the 96 groundwater samples collected by Trow from private well supplies in the Fall of 2002, counts of E. coli bacteria exceeded Provincial health-based Maximum Acceptable Criteria in 18 percent of the samples. Counts of fecal and total coliforms both exceeded Provincial health-based Maximum Acceptable Criteria in 37% of the groundwater samples. A greater number of bacteria detections were associated with the areas determined by this Study to have a higher groundwater contamination vulnerability, including Loyalist Township and the Town of Greater Napanee. More testing, however, is required to substantiate this observation.

Nitrates exceeded the Provincial health-based Maximum Acceptable Criteria of 10 mg/L in 6 percent of the wells sampled, with concentrations from 10 to 17.7 mg/L. There is no apparent geographic relationship of nitrate exceedances, the exception being two (2) occurrences that are situated in relative close proximity to one another in the former Pittsburgh Township of the City of Kingston. Accordingly, the nitrate exceedances observed likely represent isolated cases related to site-specific issues. Major sources of nitrates include sanitary and livestock waste, including septic systems, fertilizer and landfill leachate or geological formations containing soluble nitrogen compounds. The intake of nitrates in excess of Provincial standards represent a risk to babies and small children as they may suffer blood related problems (methaemoglobinaemia). Nitrite (which is reduced from the nitrate) reacts with the iron of haemoglobin in red blood cells, which are then prevented from carrying oxygen to the body.

Sodium concentrations in groundwater are variable. Concentrations ranged from 3.2 to 1,130 mg/L, and commonly exceed the 20 mg/L health-related warning limit. Almost three-quarters (74%) of the private well supplies sampled by Trow exceeded the warning limit. Sodium is not toxic. However, sodium levels in drinking water exceeding the Provincial health-related warning limit of 20 mg/L can be harmful to individuals suffering from hypertension or congestive heart disease. These individuals should consult their physician.

Iron and manganese concentrations in excess of Provincial Aesthetic Objectives were each detected in 17 percent of the private well supplies sampled by Trow. However, all wells had concentrations within MOE's treatability limit of conventionally available treatment technology and, therefore, iron and manganese do not represent a constraint to development on private services. Iron and manganese are aesthetic parameters and their presence is objectionable in water supplies because they stain laundry and fixtures and

produce undesirable tastes in beverages.

The MOE Water Well Record database of 22,226 registered, predominantly drilled wells shows that about 3 percent of all wells constructed in the Study Area are "salty" (i.e., have elevated chloride concentrations), with the majority of these wells located in Zone 1 (limestone). The MOE data shows a higher incidence of "salty" wells (i.e., elevated chloride concentrations) in the area encompassing Odessa, Westbrook, Elginburg, Sydenham and Harrowsmith. A second cluster of salty wells exists along Highway 2 at the boundary between Loyalist Township and the Town of Greater Napanee.

The sampling conducted specifically for this Study found chloride above the Provincial Aesthetic Objectives of 250 mg/L in 10 percent of the private well supplies sampled. It found that salty wells generally occur at a depth of 15 to 46 metres in limestone. Slightly more salty wells occur at a depth of 30 to 45 metres in Zone 1–A, suggesting a natural source for the salt. In Zone 1-B chloride is more frequently present in shallow groundwater (between 15 to 23 metres). This might suggest a surficial, anthropogenic source for the salt. Chloride is non-toxic and produces a detectable salty taste at the aesthetic objective of 250 mg/L.

Groundwater in the Study Area is very hard. Hardness concentrations ranged from less than 1.0 to 1,500 mg/L in the Trow samples, averaging 399 mg/L. Samples from 94 percent of the wells have a hardness of 200 mg/L or more. However, hardness is easily treated with readily available conventional treatment equipment and, therefore, it is not a constraint to development on private services. On heating, hard water has a tendency to form scale deposits and can form excessive scum with regular soaps. Water supplies with hardness greater than 200 mg/L are considered poor but tolerable.

The MOE Water Well Record database shows that a "sulphur" odour was encountered by well drillers during the construction of about 5 percent of wells, predominantly in Zone 1, particularly Zone 1-B, at depths ranging from 15 to 30 metres. This sulphur odour is indicative of hydrogen sulphide.

Hydrogen sulphide concentrations were detected in excess of the Provincial Aesthetic Objective in 5 percent of the private well supplies sampled by Trow. Hydrogen sulphide, at the concentrations normally found in groundwater, is easily treated with conventional technology and, therefore, is not considered to be a constraint to development on private services. Sulphide in association with iron will stain laundry black and will produce black deposits on pipes and fixtures. It also adds an unpleasant taste and odour to the water.

Groundwater Recharge, Discharge and Contribution to Surface Water

A potential for groundwater recharge exists over most of the Study Area and in the upgradient municipalities neighbouring the Study Area. Twenty (20) percent of all available water goes to replenish groundwater resources in the limestone zone which accounts for about two-thirds of the Study Area. Significantly less water (about five (5) percent) in the Precambrian bedrock zone replenishes groundwater.

Wetlands, creeks, rivers and lakes represent areas of significant groundwater discharge for the local shallow aquifers (i.e., shallow limestone, sandstone and Precambrian). All major aquifer systems in the Study Area discharge to the North Channel of Lake Ontario, Cataraqui River, or the St. Lawrence River. The actual contribution of groundwater to surface water including wetlands, creeks, streams and lakes is currently not known. Contributions are expected to be the highest in areas that contain sand and gravel deposits and areas where the bedrock is exposed and contains joints, faults, bedding planes, and cavities - any or all of which have been enlarged by dissolution of bedrock (i.e., karst).

Artesian wells exist in the vicinity of certain creeks and lakes, anywhere along the Rideau Canal system, and the west side of Gananoque. Accordingly, there is potential for encountering artesian conditions in these areas at the time of new well construction.

Groundwater Vulnerability

An assessment of groundwater susceptibility in the Study Area was undertaken using two (2) methodologies: the MOE Method for Groundwater Intrinsic Susceptibility and the U.S. EPA DRASTIC: A Standardized System for Evaluating Groundwater Pollution Potential Using Hydrogeologic Settings. The resulting mapping from both methods indicates that groundwater in Zone 1 (limestone) is most vulnerable to contamination. Groundwater in certain areas of Zone 2 (Precambrian) and Zone 3 (Sandstone) is also vulnerable to contamination, but on the whole less so than Zone 1. The areal extent of the higher vulnerability is relatively small, however, in Zone 2. Relative vulnerability, based on interpretation of the DRASTIC mapping, is shown in Executive Summary Figure 3 (Figure 78 of report).

Zone 1 (limestone) contains the largest number of wells, most of which are drilled to limestone (83%). The water bearing zones are relatively shallow in this part of the Study Area. In Zone 1-A, the depth to "first water" ranges from 10 to 25 metres below ground surface. However, the depth is only 0 to 10 metres in Zone 1-B.

The highest density of wells including old wells (i.e., wells established prior to 1974 when the Province mandated separation distance requirements between wells and subsurface sewage disposal systems) and unused/abandoned wells occurs in historical villages including Verona, Harrowsmith, Westbrook, Glenburnie, Kingston Mills, Sydenham, Odessa and Napanee. Old wells are also situated along corridors defined by historical roads such as County Roads 2, 10, 11, 15 and 38, and along the Lake Ontario and St. Lawrence River shorelines. Old sewage disposal systems are also known to exist at these locations. The close proximity of old wells and unused wells to old sewage disposal systems increases the vulnerability of these wells to contamination from the sewage effluent.

Zone 1 (limestone), especially the area that encompasses Verona, Westbrook, Kingston Mills, Glenburnie, Inverary, Sydenham, Odessa, and Napanee has the greatest number of water wells with a shorter casing length (i.e., less than 6.7 metres). This is typical of old wells, likely not constructed to the current well construction standards. Groundwater in such wells is more susceptible to contamination and the wells are themselves potential pathways for contamination from the surface and near surface to the aquifer.

Differences exist between the Loyalist Township and former Pittsburgh Township vulnerability mapping previously prepared and the regional vulnerability mapping created as part of this Study. The reasons for these differences are presented in the report.

Contaminant Sources

Existing and historical activities that may be potential sources of groundwater contamination were identified. Notable point sources of contamination include the 2,234 abandoned and unused water wells existing at various locations in the Study Area. Examples of some other point sources include salting of major highways, about 40 cemeteries, and activities associated with agriculture. Ninety-four (94) percent of the region's respondents to the Study questionnaire had a sewage disposal system. If these are aged, leak or operate improperly, they can be significant contaminant sources

There is a greater number of potential point sources of contamination along roads/highways and in settlements. This correlates directly with a greater number of wells per square kilometre. The majority of the point sources are located within Zone 1 (limestone), which has also been identified as an area of high groundwater vulnerability. In Zone 1, the depth to "first water" is relatively shallow and soils are thin or non-existent; the occurrence of exposed fractured/karstic bedrock is common. Accordingly, there is little opportunity for the contaminant to be absorbed or attenuated by soils and bedrock in the vadose zone, and the potential for migration of the pollutant to the water table is high.

Groundwater Use

An assessment of the different groundwater uses in the Study Area was conducted using available information from the MOE. The bulk (80%) of the existing water wells are used for domestic purposes, with 5 percent used for livestock, and only 1 percent used for public supply. The majority of large users of groundwater/surface water combined removals (i.e., 50,000 L/day or more) are located within the City of Kingston limits and beyond, within the area encompassing Sydenham, Odessa, Westbrook, Kingston Mills and Inverary. Thirteen (13) wells are approved by the MOE to remove more than 50,000 L/day of groundwater, with some wells approved for up to 5 million L/day. The largest non-municipal demand for groundwater is near Lake Ontario, in the southern end of the Town of Greater Napanee, where groundwater is used for agricultural purposes.

Discussion of Findings

The majority of the groundwater in the Study Area is used for domestic purposes and is highly vulnerable to contamination. Groundwater in the karstic limestone plains is most vulnerable with shallow wells, little soil cover (overburden) over bedrock, and fractures and other openings that allow rapid groundwater movement with little attenuation of potential contaminants. The Precambrian rocks of the Canadian Shield (Zone 2) and Sandstone (Zone 3) areas are relatively less vulnerable.

Well yields are lowest in Zones 1-A and 1-B, where the number of dry wells and wells abandoned for lack of yield are highest. Zone 2 (Precambrian) has, on average, better

yields, and Zone 3 (Sandstone) wells have the best yields in the Study Area. Artesian wells occur in the Study Area.

Chemical constituents that impair groundwater quality in a percentage of wells across the Study Area and the percentage of wells in which the constituent exceeded Provincial standards include:

Constituent	% Exceedance	Provincial Standard	Data Source
coliform bacteria	29	0 counts-health-based	1
e-coli bacteria	11	0 counts-health-based	1
nitrates	6	10 mg/L health-based	2
sodium	74	20 mg/L health-based warning limit	2
chloride	10	250 mg/L - AO	2
iron	17	0.3 mg/L - AO	2
manganese	17	0.05 mg/L - AO	2
hardness	94	80 to 100 mg/L - AO	2
hydrogen sulfide	5	0.05 mg/L - AO	2

AO – Aesthetic Objective
1 - 2002 sampling of 2,765 wells by homeowners
2 - 2002 Trow sampling of 93 wells

The last four (4) constituents exceed Provincial standards in the wells, but can be easily treated with residential water treatment systems, so are not constraints to development on private services in the Study Area.

Bacteria, common in wells throughout the Study Area (29%) has the potential to cause significant acute and chronic human health effects. Nitrate and sodium (in certain individuals) have the potential to cause chronic health effects. As such, it is important that residents of the Study Area using groundwater as their primary drinking source be educated about the constituents common in regional groundwater and about the testing and treatment required to ensure that their drinking water is safe for consumption.

The potential threats for new contamination of the aquifers in the Study Area include the following:

- Over 2,000 wells that are unused, but have been left open (i.e., not properly sealed with grout);
- Close proximity of old wells with old sewage disposal systems (or other contamination sources), particularly in the historic villages of the Study Area;

- Surficial activities involving potential contaminants, particularly where the groundwater is most vulnerable to contamination;
- Development that does not take the vulnerability of the aquifer into account when determining separation distances, lot sizes, servicing or well construction; and
- Residents who are uninformed about the vulnerability of the groundwater and the direct impact that their actions can have on their drinking water source.

Each of these threats can be mitigated, but require action to do so. Management measures to mitigate these threats are presented in Volume II of this report.