Ganaraska Region Watershed Monitoring Plan

towards an integrated approach

2014

The *Ganaraska Region Watershed Monitoring Plan: towards an integrated approach* was written to document monitoring and reporting activities and provide guidance to deliver a comprehensive monitoring program that is working towards an integrated monitoring approach within the Ganaraska Region Conservation Authority (GRCA).

The *Ganaraska Region Watershed Monitoring Plan: towards an integrated approach* was written with input from the following staff:

Pam Lancaster, B.Sc., Stewardship Technician
Bob Betcher, M.Sc., P.Geo., Hydrogeologist
Brian Morrison, B.Sc., Fisheries Biologist
Mark Peacock, P. Eng., Director, Watershed Services
Mike Smith, B.Sc., Water Resource Technician
Ken Towle, M.E.S., Ecologist

Correct citation for this document:

Ganaraska Region Conservation Authority. 2014. Ganaraska Region Watershed Monitoring Plan: towards an integrated approach. Ganaraska Region Conservation Authority. Port Hope, Ontario.

Ganaraska Region Watershed Monitoring Plan

towards an integrated approach

2014

Table of Contents

1.0 Introduction

The *Ganaraska Region Watershed Monitoring Plan: towards an integrated approach* documents and generally describes monitoring programs that are implemented by the GRCA, either independently or through partnerships. The Plan also contains considerations regarding integration between disciplines, and annual reporting recommendations. Details regarding individual monitoring programs can be found in Appendix A and in other documentation and databases.

Project specific monitoring initiatives that occur at the request of member municipalities and other partners are not documented in this Plan. These initiatives tend to be question/issue specific, occur for a short duration and are stand alone. Examples of these programs include:

- GUDI (groundwater under direct influence of surface water) investigations at the Community of Orono municipal well.
- Surface water quality associated with a septic study in the Community of Orono.
- Stormwater Management Pond studies within the Town of Cobourg.

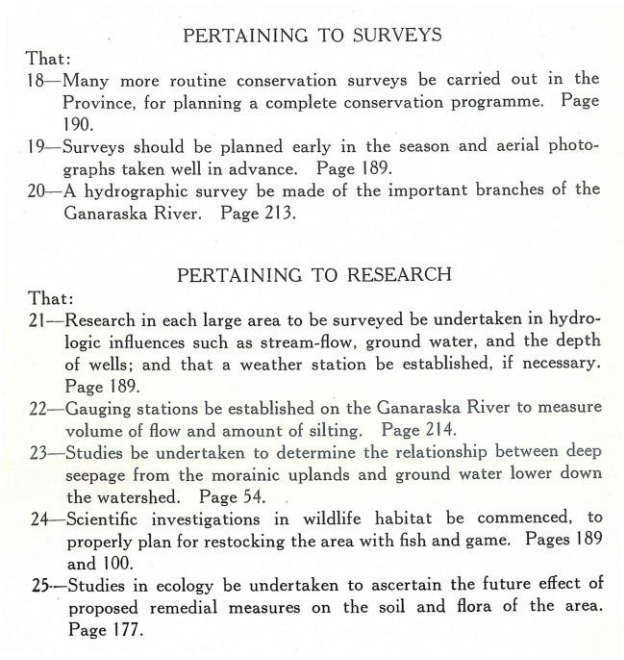
This Plan documents GRCA monitoring programs that are fundamental to understanding watershed health in the GRCA, and are intended to be implemented over the long-term. It is only with long-term commitment that meaningful trends can be accurately identified. Understanding these trends leads directly to changes in how the GRCA manages and addresses impacts to watershed health.

2.0 History of Monitoring

In 1944, *The Ganaraska Watershed: a Study in Land Use with Recommendations for the Rehabilitation of the Area in the Post-war Period*[1] by A.H. Richardson was published. This study provides recommendations based on local information from a series of surveys that occurred within the Ganaraska River watershed. These surveys were a combination of field studies (soils, soil erosion and land use, resources, vegetation communities, forest insects and diseases, and fish), interviews (economic aspects of agriculture, social and cultural considerations), and desktop exercises with maps and aerial photography.

[1] Richardson, A.H. 1944. The Ganaraska Watershed: A study in land use with recommendations for the rehabilitation of the area in the post-war period. Ontario Department of Planning and Development, Toronto, Ontario.

Significant conservation measures were recommended within *The Ganaraska Watershed Study*, such as the establishment of the Ganaraska Forest, reforestation, flood and erosion control projects and riparian protection. However, future surveys and research recommendations were also provided (Figure 1).



PERTAINING TO SURVEYS

That:

18—Many more routine conservation surveys be carried out in the Province, for planning a complete conservation programme. Page 190.

19—Surveys should be planned early in the season and aerial photographs taken well in advance. Page 189.

20—A hydrographic survey be made of the important branches of the Ganaraska River. Page 213.

PERTAINING TO RESEARCH

That:

21—Research in each large area to be surveyed be undertaken in hydrologic influences such as stream-flow, ground water, and the depth of wells; and that a weather station be established, if necessary. Page 189.

22—Gauging stations be established on the Ganaraska River to measure volume of flow and amount of silting. Page 214.

23—Studies be undertaken to determine the relationship between deep seepage from the morainic uplands and ground water lower down the watershed. Page 54.

24—Scientific investigations in wildlife habitat be commenced, to properly plan for restocking the area with fish and game. Pages 189 and 100.

25—Studies in ecology be undertaken to ascertain the future effect of proposed remedial measures on the soil and flora of the area. Page 177.

Figure 1: Survey and research recommendations from Richardson, 1946

In 1946, the Ganaraska Region Conservation Authority (GRCA)[2] was formed under the *Conservation Authorities Act*. With *The Ganaraska Watershed a Study* as a resource, along with the 1966[3] and 1976[4] supplement reports, the Ganaraska Region Conservation Authority began managing local watersheds. Over the years many monitoring programs have been implemented to collect various watershed and natural resource data to assist in watershed management. This is in part due to the powers under the *Conservation Authorities Act* (Section 21) whereby Conservation Authorities have the ability to study and investigate the watershed.

[2] Ganaraska River Conservation Authority (1946 to 1966), Ganaraska Region Conservation Authority (1966 to present).

[3] Department of Energy and Resources Management. 1966. Ganaraska Region Conservation Report: A supplement to the Ganaraska Report 1944. Toronto, Ontario.

[4] Ontario Ministry of Natural Resources. 1976. Ganaraska Region Conservation Report Water. Conservation Authorities Branch, Ontario Ministry of Natural Resources.

3.0 Current Monitoring Programs

Many monitoring programs have been implemented by the GRCA and its partners to collect data both generally across the jurisdiction and specifically in local watersheds. These programs vary spatially and temporally based on their intended purpose. Table 1 lists a summary of current or recent monitoring programs administered by the GRCA through field data collection. Details regarding these monitoring programs are found in Appendix A. Unless status otherwise in Section 8, the current programs described in Table 1 and in Appendix A are recommended to remain in place.

GRCA monitoring programs have been implemented to:

- describe baseline conditions (e.g., parameter concentration comparison to provincial standards);
- answer specific watershed health or ecosystem state questions in relation to changes in land uses (e.g., absence or presence of particular species, or species assemblages);
- assist in primary Authority functions (e.g., flood forecasting and warning, regulations and planning); or
- provide data for larger research questions (e.g., water budget, watershed health, and climate change effects evaluation).

Table 1: Summary of current monitoring programs

Area of Monitoring	Monitoring Programs	Focus	Primary Purpose
Meteorology	Climate Stations • Air temperature • Precipitation • Wind speed • Wind direction • Relative humidity • Barometric pressure • Soil moisture • Solar radiation	Weather	• Flood forecasting and warning • Water budgets • Climate change evaluation • Ontario Drought Program
Groundwater Quantity (Hydrogeology)	• Piezometers • PGMN[1] • GRGMN[2]	Groundwater level	• Water budgets • Climate change evaluation • Groundwater resource evaluation • Planning and regulations • Watershed management

Table 1: Summary of current monitoring programs

Area of Monitoring	Monitoring Programs	Focus	Primary Purpose
Surface Water Quantity (Hydrology)	• Hydrometric stations • Staff gauges • Baseflow • Temporary flow gauges • Snow courses • Flood debris/damage	Flow regime	• Flood forecasting and warning • Water budget • Climate change evaluation • Ontario Drought Program • Watershed management
Groundwater Quality	• PGMN • GRGMN[2]	Water chemistry • Nutrients • Metals • Bacteria • Ions	Watershed management
Surface Water Quality	• PWQMN[3] • High Water Event monitoring • GRWQMN[4] • Baseflow Water Quality • Chloride monitoring • Benthic surveys	Water chemistry • Nutrients • Metals • Bacteria • Ions High flow versus low flow Community composition	Watershed management
Aquatic Resources	• Fish community sampling • Spawning surveys • Lamprey barrier monitoring • Benthic surveys • Habitat evaluation (OSAP[4])	• Fish species • Fish communities • Benthic species • Benthic communities • Habitat characterization	• Planning and Regulation • Watershed management • Climate change adaptation
Terrestrial Natural Heritage	• Marsh monitoring (birds and frogs) • Forest bird monitoring • Roadside frog and bird surveys • Field verification of vegetation communities • Land cover change	• State of terrestrial ecosystems • Species state (presence/absence) • Species communities	• Planning and Regulation • Watershed management • Climate change adaptation • Natural heritage management

[1] Provincial Groundwater Monitoring Network, [2] Ganaraska Region Groundwater Monitoring Network, [3] Provincial Water Quality Monitoring Network, [4] Ganaraska Region Water Quality Monitoring Network, [5] Ontario Stream Assessment Protocol

4.0 Watershed Plan Monitoring Recommendations

Since 2008, the GRCA has completed or updated watershed plans for Cobourg Creek, the Ganaraska River, Wilmot Creek, Graham Creek, and Lovekin Creek, Bouchette Point Creek and Port Granby Creek. A Fisheries Management Plan has been completed for Wilmot Creek and are being developed for the Ganaraska River and Cobourg Creek. In 2013, a Terrestrial Natural Heritage Strategy was completed.

In order to develop these plans, scientific information and local knowledge was compiled, analyzed and synthesized. Staff at the GRCA examined the abiotic, biotic and cultural features of the particular study area using locally collected data. This background information formed the foundation for recommended management actions.

With the implementation of the numerous management plans and reports, there is a need to re-evaluate monitoring programs in order to:

1. Determine if the implementation of recommended strategies are having a desired effect on the local environment and watershed(s).
2. Determine if recommended strategies are appropriate.
3. Continually understand baseline conditions, and changes to those conditions.
4. Conduct large scale/topic specific research projects to fill identified knowledge gaps.

Along with monitoring and research, reporting of results to the public, partners, municipalities and stakeholders is an important step in ensuring planning tools are being implemented and positive changes are occurring. Reporting will be done in a way that focuses on the intended target audience and provides suggestions for local actions.

5.0 Users of a Watershed Monitoring Program

At its core, a monitoring program is designed to assist those with a vested interest in appropriately managing, conserving and protecting local watersheds, natural resources and the environment. In order to assist those individuals, agencies or government bodies, the GRCA is a logical organization to design and implement a local watershed monitoring program (Figure 2). Data collected can be used, analyzed, or reported to a variety of audiences or data users.

Figure 2: Intended users of a watershed monitoring program

The intended audience of the *Ganaraska Region Watershed Monitoring Program: towards and integrated approach* document includes GRCA staff, GRCA Full Authority Board Members, municipalities and stakeholders involved in water resource management.

6.0 Concepts used in Refining a Watershed Monitoring Program

Many concepts must be considered when developing or refining a watershed monitoring program. The following is intended to outline some important concepts needed to be considered to appropriately manage local natural resources and watersheds.

6.1 Developing an Effective Program

Something that is effective can be generally defined as a thing that answers its purpose. Effectiveness, for the purposes of this document is expanded to describe something that exhibits quality, efficiency, risk management and ultimately has an impact. Further to this definition, GRCA has evaluated recommended monitoring programs by testing programs based on the following:

- **Quality:** Does the degree of excellence expected of the program meet standards and does the resultant product have the attributes to defend the answers that the data provides?
- **Efficiency:** Is the product created by the program appropriate given the resources used to generate that product? Can the same results be developed with fewer resources?
- **Risk:** Is risk addressed to the person and to the organization. Can the data be gathered safely and does the organization have the skills necessary to draw and/or address conclusions generated from the data.
- **Impact:** Does the data that is gathered further the purpose and goals of the Ganaraska Region Conservation Authority. Will the results influence decisions?

6.2 Quality Assurance/Quality Control (QA/QC)

When discussing collection of data, the following concepts, and definitions will be used:

Quality Assurance –Quality assurance answers the question of: Were the methods used sufficient to gather the data to the accuracy needed? More formally, quality assurance is the maintenance of a desired level of quality in the data, especially by means of attention to every step of the process of collection. QA deals with project design and is undertaken at the initiation of the project thereby addressing the following:

- Ensures consistency with standards and generally accepted approaches (project design)
- Validates the work plan/planned deliverables

Quality Control – Quality control answers the question of: Did the data that was gathered meet the accuracy or specifications that were intended? More formally, quality control is a system of maintaining standards in data by testing a sample of the output against the specification. QC deals with project results and is undertaken throughout the project work addressing the following:

- Ensures consistency with standards and generally accepted approaches (product)
- Ensures scientifically defensible results

6.3 Temporal and Spatial Considerations

A watershed monitoring program needs to be flexible and adaptable enough to address temporal and spatial variability. In addressing the temporal variability it is important to determine appropriate reference/baseline conditions. These conditions should not reflect a degraded status. Time or temporal considerations are straight forward; however spatial variability needs to be addressed in terms of scale. Generally the scales used in watershed monitoring are as follows:

Regional: Monitoring at regional scale should address GRCA or provincial wide questions. These questions can be associated with jurisdictional wide issues (e.g., transportation corridor effects on natural resources) or topics that exist beyond the GRCA but influence natural resources within the GRCA (e.g., habitat connectivity/fragmentation on the Oak Ridges Moraine or along the Lake Ontario shoreline).

Watershed: Although many topics cover a large spatial scale, many are specific to a particular watershed or sub-watershed. Monitoring programs must be adaptable to answer specific questions at a particular watershed scale (e.g., what is the quality of surface water?).

Site Specific: Site specific questions must be able to be answered or understood at a scale smaller than a watershed or sub-watershed. These questions will most likely come from an individual landowner, community, or from a planning/development application.

6.4 Indicators and Targets

When developing a monitoring program, indicators that will best represent the monitoring question or the state of a watershed condition must be considered. Indicators are selected to best represent conditions within a study area (regional, watershed/sub-watershed, or site specific). For example local water quality indicators are typically nutrients, bacteria, ions and metals. Water quantity indicators are normally flow (surface water) and level (groundwater). Aquatic and terrestrial indicators are typically sensitive species (amphibians and birds), species at risk, and species with unique life history traits (species specialists).

When selecting indicators it is important to consider the variables that influence or control indicators, other than the variable being monitored. For example a certain fish species may be chosen to understand landscape use (riparian/forest cover versus agriculture) on watershed health, while the amount of groundwater or in-stream barriers also influences its presence or absence. In designing a watershed monitoring program, an indicator (item to be measured) must be carefully selected.

In order to measure environmental changes, targets must be considered so that comparisons can be made to determine a particular condition. Targets can be quantitative or qualitative in nature. However, the scale of the target will define how the target can be used as a comparison against monitored data. Targets used can be defined at a provincial scale as is the case with water quality guidelines or standards. Others may be more

appropriately defined through modeling at a watershed or jurisdictional scale as is the case with forest cover. Regardless of the target, it must be selected to be rational and defensible.

6.5 State and Trend

In understanding the watershed it is often beneficial to look backwards when asking the question of why something arrived to its current condition. Additionally one can also try to look forward when asking what condition will be created in the future. Researchers generally define results for these questions in terms of a point in time (state) or in terms or how things change (trend). Both understandings are important to consider.

The continuum looks as follows:

Historical Conditions - information often defined by anecdotal or recorded data.
Past Trend - the change between the past and the current condition.
Current Conditions - information relating to the current state (the measured condition).
Predicted Trend - the change between the current state and the predicted future.
Future Conditions - the future predicted state of the parameter (often modelled).

6.6 Integration

Integration means combining multiple considerations in order to be effective and to better understand the drivers of watershed health. Integration should be considered at each step of a watershed monitoring program (Section 7).

*An **effective** program is one that addresses:*
- *Quality*
- *Efficiency*
- *Impact*
- *Minimized risk*

Prior to data collection, site selection should consider the ability of a site to support monitoring of a number of disciplines. For example surface water quality monitoring sites may benefit being located at stream gauge stations to allow for an understanding of water quality results related to stream flow (total load versus concentration only).

To be efficient in data collection, staff may choose to integrate different disciplines when out in the field. For example, it may be practical to collect baseflow water quality samples at the same time baseflow quantity is being monitored to reduce the need to visit the same site multiple times during the data collection time period.

Although integration could occur at the time of data analysis, in-depth integration should defiantly occur at the data synthesis step thereby allowing a more comprehensive picture of the health of the watershed.

7.0 From Monitoring to Reporting – Program Steps

A watershed monitoring program is not simply collecting a piece of data and reporting the result; a number of intervening steps must be considered. It is important to note that the sequence of steps and the implementer of each step may vary depending on the monitoring

activity. It is acknowledged that prior to data collection specific questions must be identified to support the actual collection of data. It is further acknowledged that integration of questions, monitoring stations, methods and analysis should be considered at each step (see Section 6.6). The following describes the five steps normally used in monitoring (see also Figure 3).

Step 1 **Data collection** is one of the first steps in any monitoring program. Data collection in its raw form is just collecting information. In terms of watershed data collection this could be in the form of collecting information on water level, water quality parameters, flora or fauna species presence, or climate conditions. It could also imply capturing information remotely from statellites, the air (via an airplane) or from new technologies such as LiDAR. It is critical that the methods employed in collection are sufficient to obtain data that has quality that appropriately answers the monitoring question.

Step 2 Once raw data is collected it must be **evaluated** for quality assurance/quality control (QA/QC) and entered into usable databases/data repositories. By this step, the data should be geo-referenced for site management and data analysis purposes.

Step 3 **Data analysis** should follow shortly after data collection and evaluation. This could be comprised of basic statistical analysis (e.g., median, ranges, comparison to guidelines/standards, presence/absence, distribution). Analysis should allow staff to understand basic findings of the data collected and evaluate whether questions are able to be answered and if the intended purpose(s) of collecting the data is being met. Further in-depth analysis should occur to allow greater understanding of the particular topic, however this step may not occur until there is a trigger (e.g., reporting need, data request, project need).

Step 4 Once an understanding of a particular dataset is obtained further **data synthesis** may occur. This allows staff to investigate the data to understand potential cause and effects. This step will bring other disciplines together to gain greater insight. It is understood that this step requires greater staff time, staff participation, sharing of data sets, and additional tools (software, models, GIS). This step may also not occur until there is a trigger (e.g., reporting need, project need).

Step 5 The final step is **reporting**, which could occur after any of the above noted steps. The need to report will vary for many reasons. Reasons include:

- the intended reporting audience (public, municipality, consultant, funder, developer); the need to report (answer a specific question, developer need, general information);
- the benefit of reporting (satisfy a single need, funding request, build rapport); and
- the effort (staff time and budget resources) required to report.

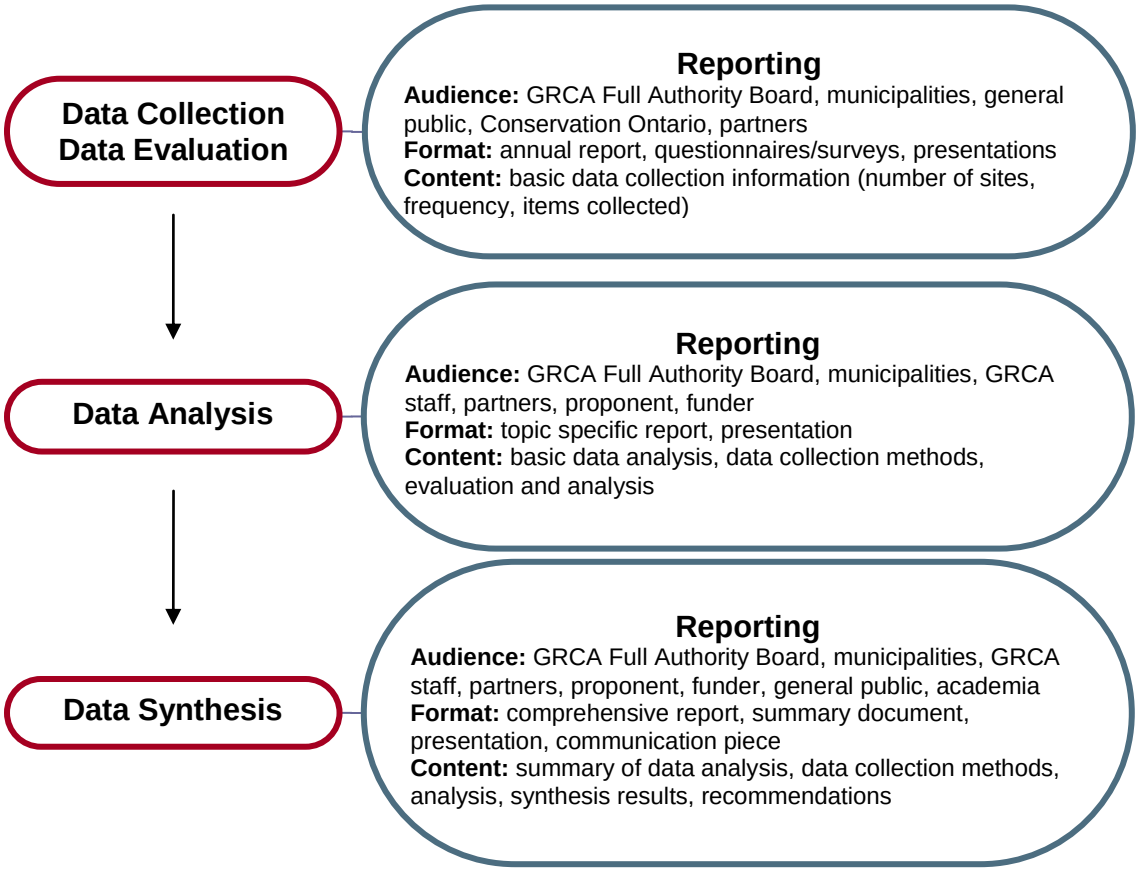


Figure 3: Steps from monitoring to reporting

8.0 Ganaraska Region Watershed Monitoring Program

The health of watersheds and their features and functions within the GRCA vary, and local watersheds are neither static nor isolated. Even with historic and current watershed management efforts, local watersheds do have some identifiable issues and exhibits signs of stress in certain areas that can be, in some part, attributed to current land use.

Monitoring within the GRCA have been divided based on areas of study to facilitate the development of the program. The areas of study include the following:

- Groundwater and Surface Water Interactions
- Groundwater Quantity and Quality
- Surface Water Quantity
- Surface Water Quality
- Aquatic Resources
- Terrestrial Natural Heritage

8.0.1 Purpose

The purpose of monitoring is to support the conservation, enhancement and management of local watersheds and resources for current and future generations through data collection, evaluation, synthesis and reporting.

8.0.2 Goal

The goal of the GRCA watershed monitoring program is to collect scientifically defensible and locally relevant data and information on abiotic and biotic features and functions in an effective and efficient manner. The data and information collected is to be the basis for understanding current watershed conditions, predicting trends, evaluating local regulations, programs and management plans, predicting effects from climate change, and reporting.

8.0.3 Objectives

In order to implement an effective GRCA watershed monitoring program multiple objectives must be satisfied.

- Analyze and evaluate the past, current and future quality and quantity of watershed features and functions.
- Identify areas and activities (natural or human) that have a negative impact on watershed features or functions.
- Create a program that is flexible and adaptable to emerging issues (e.g., invasive species or climate change) and changes in science and technology (e.g., larger monitoring initiatives or new methods).
- Build upon existing data and programs, and support continued research.
- Readily provide reliable data for watershed management decisions.
- Determine effectiveness of locally implemented land use management tools (e.g., regulations) and environmental programs (e.g., stewardship).

- Provide technically sound information to municipalities, governments, agencies/stakeholders and the public.

8.0.4 Questions

In developing a watershed monitoring program, questions should be posed that need be considered when developing methods, selecting sites, and identifying indicators and targets. The following are some generalized questions being asked regardless of spatial scale.

- What is the **current status** (concentration, population, level, range) of X?
- Can a **"range of normality"** be determined for X?
- Does X have a target? If so can X be evaluated against a **target**?
- What is the **trend** of X?
- Has there been a **negative change** in X in relation to Y?
- Has there been a **positive change** in X in relation to Y?
- **Why are changes occurring** in X in relation to Y?
- Was an **expected change** seen in X as a result in a change with Y?

8.0.5 How Monitoring Programs are Described in this Plan

Section 8.1 onwards describes areas of study that should be monitored within the GRCA. The following summarizes the structure of how this laid out.

- **Background:** a description of what monitoring has been conducted and some general understanding of the results/findings.
- **Purpose:** a description of why the monitoring program is being carried out.
- **Recommended Program:** a description of what program(s) should be continued, which programs or sites should be discontinued, and what new programs should be implemented.
- **Methods:** a general description of the methods used to carry out the program.
- **Integration:** a description of how the particular monitoring program fits into other programs, and/or considerations for integration.

Please note that additional details regarding existing programs are found in Appendix A. In addition, in many cases, current monitoring protocol documentation can be found in external references.

8.1 Monitoring Groundwater and Surface Water Interactions

8.1.1 Background

Groundwater and surface water interactions have been monitored since 2005 through a network of 16 piezometers installed in streambeds at locations where staff believed that groundwater was actively discharging (upwelling) to the stream. Most piezometers are located in or near the Oak Ridges Moraine. For the first several years after installation, monthly water level measurements were taken during the snow free seasons in the piezometers and the elevation of surface water was recorded at the same time to allow calculation of the vertical hydraulic gradient. The gradient was found to be upward at all but one site. A paper on findings from the monitoring was presented at a conference in Ottawa in 2007[5].

Briefly, the paper reported that the piezometer network confirmed the upward discharge of groundwater at the piezometer sites and also presented a discussion of the relationship between the magnitude of the gradient and monthly/seasonal precipitation. The paper also proposed a number of improvements and changes to the network and data analysis. Monitoring of the piezometers has continued although neither the suggested improvements in the 2007 paper nor subsequent analysis have been carried out. Water level monitoring at the piezometers continues on a somewhat less regular basis than what was done during the first several years.

The GRCA baseflow monitoring program is a second element of monitoring groundwater/surface water interaction (see Section 8.3). Baseflow consists of groundwater discharge to a stream so changes in baseflow volume can be related to groundwater levels in contributing aquifers and changes in baseflow quality can be related to impacts from such anthropogenic sources such as road salt or agricultural chemicals. The site locations for the programs discussed above are found in Section 8.2.

[5] Widaatalla, M. and Peacock, M. 2007. Using streambed piezometers as a tool in the assessment of different catchment responses to precipitation and verification of mapping outputs. Ganaraska Region Conservation Authority, Port Hope. Paper published and presented in the 60th Canadian Geotechnical Conference and 8th Joint CGS/IAH-CNC Specialty Groundwater Conference – Ottawa 2007

8.1.2 Purpose of Monitoring

Continued monitoring of water levels in the piezometer network is an alternate way to examine the "health" of groundwater levels in contributing aquifers; and in many ways is a more efficient or representative manner in which to do this than maintaining a comprehensive network of monitoring wells in each watershed or sub-watershed. If groundwater levels are in a long-term state of decline this will be reflected in a reduction in the upward gradient observed in the piezometer network and of course will also be observed as a decline in baseflow and perhaps as well by changes in baseflow water quality. The piezometer network, baseflow volume and quality monitoring, and the PGMN program should be considered as important components of an integrated groundwater monitoring program in the GRCA.

8.1.3 Recommended Groundwater and Surface Water Interactions Monitoring Program

The current objectives of a groundwater/surface water monitoring program are to examine changes in rates of groundwater discharge to streams, and changes in groundwater quality with the focus being on regional to intermediate scale systems, rather than intensive studies of smaller areas. These changes can be related to groundwater levels and quality in aquifers contributing to baseflow, recognizing that in almost all cases with the current piezometer and baseflow monitoring network the contributing aquifers are shallow sand/gravel bodies.

To meet current objectives the existing program structure is considered to be adequate and should be continued but could be supplemented by mapping of springs (location, flow rate, water quality, elevation) contributing to baseflow at the piezometer and baseflow monitoring sites and selecting a representative number of springs to be monitored over the long-term. This would allow a better relationship to be established between water quality and quantity and land use/land use changes when impacts or changes in baseflow/quality are observed.

More intensive groundwater/surface water monitoring should be considered in the future, particularly in areas where development based on individual wells and septic systems has occurred and is likely to continue. Any such program would involve considerable monetary and human resources to carry out properly and so needs clear objectives that are of importance to potential funding agencies. GRCA should consider the need for such studies and if clear objectives can be established for local studies, should attempt to obtain the resources and/or partnerships to carry them out.

8.1.4 Methods

Measurements at piezometer sites include the stream temperature, the water level of the stream and the water level in the piezometer. The temperature is taken using a laser thermometer that is shined onto the surface of the water. The thermometer is calibrated before each field trip. Several water temperature measurements are taken

at various locations in the area immediately surrounding the piezometer to ensure accuracy and representativeness of the values, an average of the values was then taken. The stream level measurements are taken using a measuring stick. Again several measurements were taken and an average is used as the value.

For the purposes of the measurements, the streambed is considered the top of the sediment in all streams including those streams with soft, yielding sediments. Finally the water level in the piezometer is taken using an electric water level measuring tape. For the data to be used in analysis, it is converted to metres above sea level (mASL). Using this data and the known distance between the streambed and the bottom of the piezometer, the vertical hydraulic gradient is calculated in order to determine areas of discharge.

8.1.5 Integration

The purpose of examining the relationship between groundwater and surface water is to determine the interaction of groundwater and surface water. This program provides many answers to questions posed in the areas of groundwater quality, groundwater quantity, surface water quality, surface water quantity, and aquatic resources.

Some thought should also be given to more frequent baseflow measurements and sampling at selected sites and incorporating this more intensive baseflow monitoring and the streambed piezometer monitoring into a low water level monitoring program. This may allow indicators and targets to be established for the monitoring drought. Baseflow is further described in Section 8.3.

8.2 Monitoring Groundwater Quality and Quantity

8.2.1 Background

Groundwater level monitoring was carried out in a number of monitoring wells in the 1970's by the Ontario Water Resource Commission as part of regional groundwater studies in the province being undertaken at the time. However, this monitoring was discontinued after just a few years and a groundwater monitoring network was not re-established until 2002 when, as part of a joint program being set up between the province and the Conservation Authorities, a local network which eventually consisted of 17 monitoring wells at 12 locations was established in the GRCA (part of what is known as the Provincial Groundwater Monitoring Network (PGMN)).

The primary objective of the PGMN is to monitor groundwater levels and quality in major and/or important aquifers in the province but subsidiary objectives considered at the time included monitoring the impacts of development and climate change and monitoring drought conditions. This network is currently supplemented by two additional monitoring wells installed by the Conservation Authorities Moraine Coalition (CAMC). Both wells are completed into the Oak Ridges Moraine.

Groundwater quality samples are collected from 10 of the 17 PGMN wells (Figure 4) on an annual basis and analysed for a fairly complete set of inorganic constituents at the MOE lab. Water quality results are also posted on partner and publicly accessible web sites. Water samples are not collected from the CAMC wells.

Following a thorough data correction and review process (QA/QC) carried out in 2012/2013 by GRCA staff, it was recognized that significant changes to the current PGMN program in the GRCA should be considered, including deleting a number of the existing wells from the network and adding new wells at up to 10 additional locations to carry out ambient groundwater monitoring in regional aquifers. Supplementary monitoring carried out by the GRCA was also recommended, using existing private wells where co-operation of the well owner could be obtained. To date only one supplementary site has been established. At this site water levels are recorded hourly by a pressure transducer and the data stored in a data logger for download by the well owner or GRCA staff.

8.2.2 Purpose of Monitoring

The primary purpose of the current groundwater monitoring network is to record ambient water levels and water quality conditions in regional and/or important aquifers. This type of monitoring can provide a record of “natural” groundwater levels and quality changes over long periods of time. In turn, this data can provide a baseline for other monitoring such as evaluating water level or quality impacts from developments or to view changes which can be related to climate change. Since this is ambient monitoring, there are no established targets.

Other purposes of monitoring include:

- observing water level responses in drought-prone aquifers so that information can be provided to water users during times of low groundwater levels, and groundwater drought responses can be implemented;
- observing long-term water level and water quality impacts from intensive development reliant on individual wells and septic systems; and
- recording impacts on water quality in shallow aquifers from rural land uses and changes. This last purpose can be achieved by non-traditional monitoring of water quality in springs and baseflow.

8.2.3 Recommended Groundwater Monitoring Program

It is important to continue the program of ambient monitoring of regional and/or important aquifers as part of the PGMN network. However, the GRCA should work with MOE to evaluate the current program in detail and make improvements that may be necessary. If funding cannot be found to undertake the necessary changes within a relatively short period then consideration should be given to modifying the PGMN program to incorporate monitoring in private wells that are actively used as a source of water supply. This is done in many jurisdictions and provides good quality information.

An updated PGMN program would meet the objective of monitoring ambient conditions in regional/important aquifers but additional monitoring should be done to meet objectives which are outside the scope of this program. For instance, a monitoring network should be established to provide groundwater level information into the Ontario Drought Program. The current PGMN network was not designed to meet this objective although some of the wells in the network may be suitable for low water monitoring. GRCA should lead a program to set up a dedicated and properly designed program, preferably in co-operation with provincial agencies (MNR and MOE). It is important to recognize that the analysis techniques for such a program have been established and are currently being applied on a trial basis in a number of other Conservation Authorities.

The GRCA should also take the lead in developing a program to monitor groundwater levels and quality in areas where there has been significant sub-urban development based on individual wells and septic systems. Many of our deeper confined aquifers likely receive very little recharge so sustainability is an issue. Water quality degradation of shallow aquifers may also be a long-term problem. It

may be possible to incorporate monitoring into new developments with the developer paying the cost to establish monitoring wells and GRCA assuming the cost of monitoring.

Finally, the current program of baseflow quality and quantity monitoring should continue and be supplemented by annual measurement of flow and water quality from up to 50 selected significant springs. This should be done in combination with continued water level monitoring in the current network of streambed piezometers (Figure 4). At this time an expansion of the piezometer network is not recommended.

8.2.4 Methods

Groundwater water quality samples are collected using appropriate sampling techniques. This includes triple rinsing bottles without preservatives, wearing latex gloves, sampling with purged pumps and piping or appropriately sampling spring discharges and appropriate sample storage, chain of custody and transportation. Infield data is collected using a hand held YSI, or other appropriate instruments. All samples are sent to an accredited laboratory for analysis.

Groundwater water quantity samples are collected using appropriate sampling techniques as defined within the PGMN protocols. Water levels are recorded in each monitoring well on an hourly basis using a pressure transducer with the data being stored in a data logger. At most PGMN sites the data is accessed remotely by MOE and downloaded approximately each month but at several sites the transducer must be pulled from the well for data download by GRCA staff and e-mailed to MOE. Data is stored in the Provincial Groundwater Monitoring Information System, (PGMIS) database maintained by MOE but accessible to program partners. Raw pressure readings are converted to groundwater level elevations based on the elevation datum for the well and the depth of the transducer then corrected to remove atmospheric pressure. The barometric pressure corrected data is subject to periodic review and correction after which the corrected data is plotted as a hydrograph and placed on partner and publicly accessible web sites. Quality control includes recording manual water level measurements on each monitoring well against which the transducer data can be compared. GRCA staff have in the past collected manual readings on a monthly basis but in 2013 lowered the frequency to every two months. A similar program is followed in the two CAMC wells although water level readings are stored by the GRCA and reported to CAMC for inclusion in their database.

7.2.5 Integration

Groundwater quality and quantity can be integrated into many areas of investigation. The quality and quantity of groundwater affects the terrestrial and aquatic environments as groundwater discharges to the surface or forms the shallow water that supports vegetative growth. Characterization of aquifer water quality can also assist in defining rural development potential which in turn will required sustainable groundwater resources.

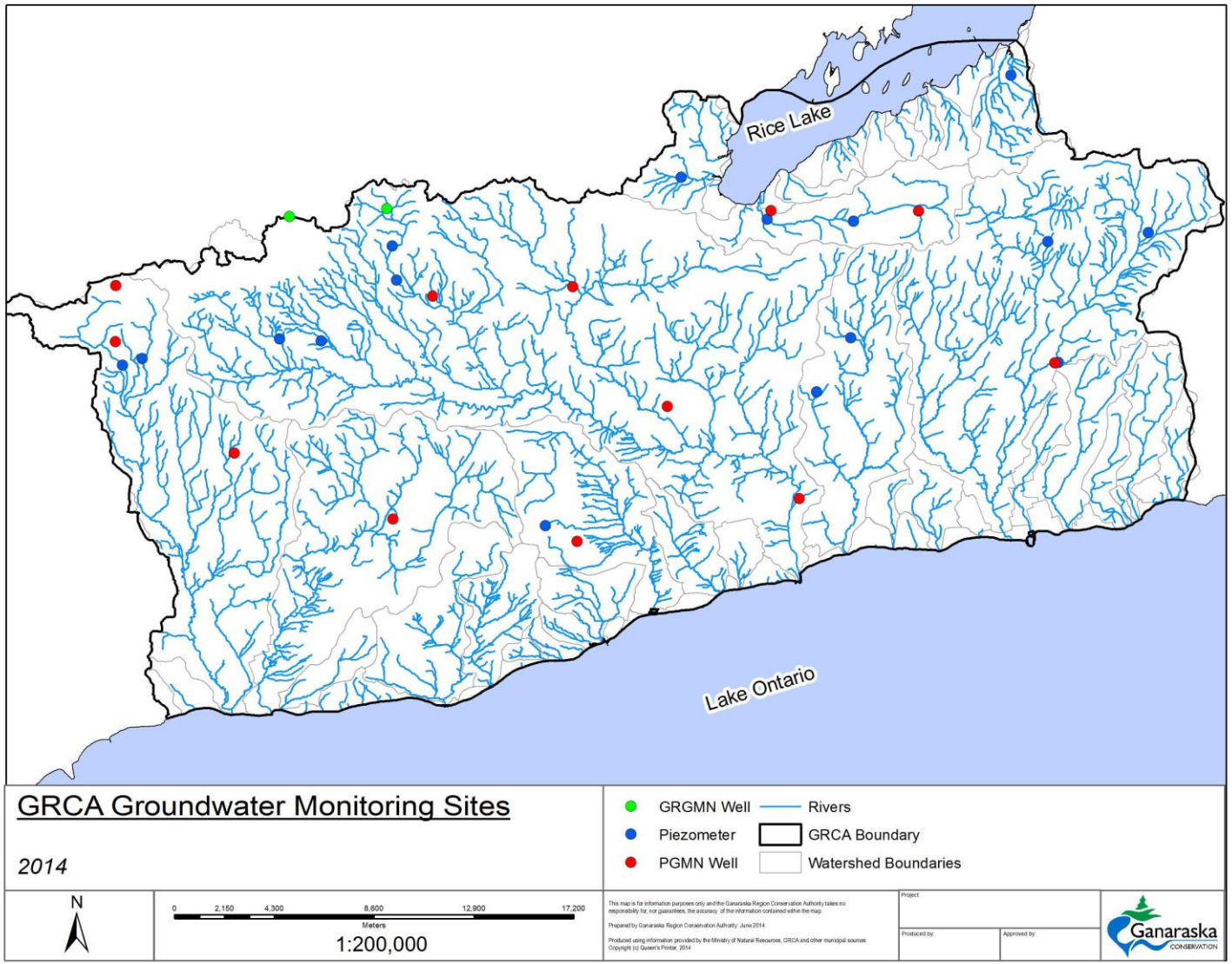


Figure 4: Groundwater monitoring sites

8.3 Monitoring Surface Water Quantity

8.3.1 Background

Stream gauging stations were first established in the GRCA in the 1950's by Environment Canada's Water Survey Division to quantify water resources. A recent network expansion resulted in two new stations and increased coverage to eight locations. GRCA staff have added six more stream gauges since 2010.

Surface water quantity monitoring at the GRCA also includes snow courses, where snow depth and water equivalent is measured. Snow as well as other parameters (rainfall, air temperature, wind speed and direction, soil moisture, barometric pressure, and solar radiation) is measured at weather stations across the GRCA. All surface water quantity stations are shown in Figure 5.

As a result of current surface water quantity monitoring programs, the following benefits and understanding has been gained.

- Enhancements to the surface water quantity monitoring network have allowed GRCA staff to better understand runoff response to rainfall and snowmelt in different watersheds as well as drought and historic flow conditions.
- Good rain gauge coverage makes quality assurance of data easier to accomplish with more accurate results.
- More rain gauges also allows for better interpretation of different rainfall patterns across the GRCA and reduces the probability of missing localized and sometimes extreme rain events (i.e., intense rainfall associated with thunderstorms).
- Snow courses indicate the potential for runoff during periods of melting. A new snow course located in the Southern till plain provides a good indicator of runoff potential to the smaller creeks around the Municipality of Port Hope and the Town of Cobourg.

Another component of surface water quantity to be monitored is baseflow. The quantity of baseflow in a stream is dependent on the discharge of groundwater to the surface through seeps and springs in the absence of other sources of runoff. This component determines the long-term resiliency of a stream as baseflow describes the streams ability to maintain flows during periods of dry weather. Each watershed has been surveyed during periods of low-flow to characterize the quantity (and quality) of baseflow at as many locations as possible. More recently, a number of baseflow monitoring sites have been selected across the GRCA jurisdiction to be monitored annually with the goal of determining long-term fluctuations and trends in baseflow. These permanent, long-term baseflow monitoring sites are shown in Figure 5.

8.3.2 Purpose

The surface water quantity monitoring programs are operated to collect data for direct use in GRCA programs such as Flood Forecasting and Warning and Low Water Response; as well as supporting data analysis in other GRCA programs such as determining watershed health, fisheries and surface water quality. Surface water quantity data is regularly provided to partners such as academic institutions and provincial programs (e.g. Permit to Take Water), and occasionally to consultants and the public.

Specifically, surface water quantity data is used in the following ways.

- Low Water Response includes surface water indicators that use streamflow and rainfall data to determine the severity of low water conditions, providing a basis for water management decisions.
- Determining runoff potential is a critical component in the Flood Forecasting and Warning program.
- During periods of high runoff, GRCA operates “River Watch” to intensively document surface water quantity; staff are dispatched to record manual water levels (staff gauges), photograph and take notes on flood impacts.
- Ongoing monitoring allows the establishment of statistically normal conditions with long-term data.
- Determine long-term changes in water quantity, especially baseflow.
- Identify streams that are sensitive to drought and may be in need of restoration or enhancement.

8.3.3 Recommended Surface Water Quantity Monitoring Program

The surface water quantity monitoring programs should continue with existing surface water monitoring stations as they will ultimately have long-term (30 years) data sets to establish statistically normal conditions. Data analysis will show if current conditions are different than the normal, trending up or down and how this trend relates to land use and other variables.

In regards to research and data analysis, the following should occur with regards to stream flow:

- Hydrograph separation on time series data needs to occur to determine normal and current baseflow conditions in each watershed with available data.
- Long-term average baseflow data needs to be used as an indicator of drought and watershed health.

In regards to research, data analysis, and modeling the following should occur with regards to flood forecasting:

- Surface water quantity data should be used to calibrate runoff models for flood forecasting.
- Flood prediction model(s) should be calibrated and verified to provide more accurate flood forecasts.

- The link between weather forecasts and real-time data to a flood prediction model needs to be automated.
- Triggers for water levels, flows and rainfall for issuing flood messages and initiating the River Watch need to be continually refined.

8.3.4 Methods

Stream gauging stations are instrumented with a pressure transducer or shaft encoder both of which are designed to measure water levels. Sensors are connected to a datalogger that records data on 15 minute intervals. Some stations have telemetry for remote access, while others require site visits for manual downloading. Manual observations are necessary for calibration, quality assurance and quality control. Water Survey of Canada standards are used in the set-up and operation of these stations.

Tipping bucket rain gauges and temperature sensors are connected at many of the surface water gauging stations. Annual maintenance and calibration is necessary to ensure good quality data is being collected.

Manual stream gauging by wading with a current meter will continue to be instrumental in determining baseflow quantity at specific locations. Water Survey of Canada standards are used in this program. Many of the sites have perched culverts, which provide an easy opportunity to gauge small streams very quickly. Maps and GPS may be used in locating spots to measure baseflow.

8.3.5 Integration

Surface water quantity data collected by the GRCA is used to interpret many other program data. Surface water quantity stations are located in suitable locations to provide adequate coverage of the GRCA jurisdiction, providing ample opportunity to integrate surface water quantity data into the data analysis of other disciplines.

Surface water quantity data is collected primarily for operational programs (e.g., Flood Forecasting and Warning and Low Water Response). Within this monitoring program, integration of rainfall, snow accumulation and other weather parameters are often used to understand surface water quantity.

When accurate and long-term baseflow data is available, it may be possible to detect changes or trends in surface water quantity. Integration with long-term land use data and stewardship program data may be useful in explaining why baseflow has changed. Integrating this data with biotic data may be useful in identifying sensitive features worth conserving or enhancing.

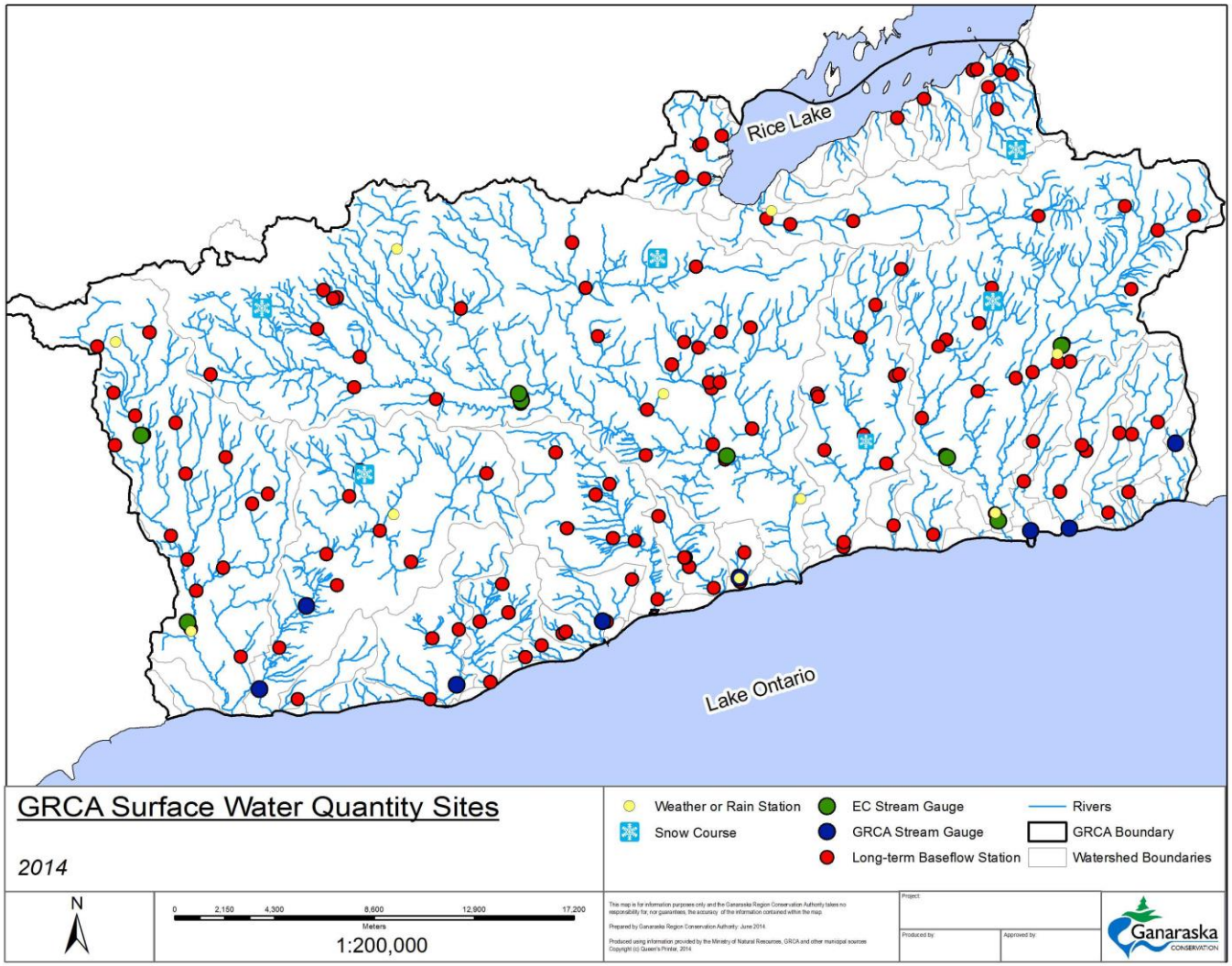
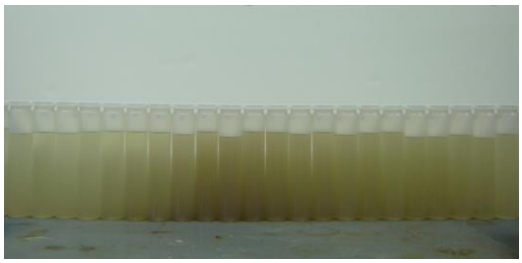


Figure 5: Surface water quantity monitoring sites

8.4 Monitoring Surface Water Quality

8.4.1 Background



Surface water quality has been monitored intensively across the GRCA since 2002; however, some water quality stations have been monitored since the 1960s and 1970s through the Provincial Water Quality Monitoring Network (PWQMN). Over the past decade, the following programs have been implemented by the GRCA either independently or in partnership with other agencies. Additional details regarding these programs are found in Appendix A.

- *PWQMN* – evaluation and trending background surface water quality to understand general location and cause of water quality problems.
- *High Water Event Monitoring* – evaluation of surface water quality related to high flows caused by rainfall or snowmelt.
- *Ganaraska Region Water Quality Monitoring Network* - evaluation and trending background surface water quality to understand general location and cause of water quality problems throughout a watershed.
- *Baseflow Water Quality Monitoring* - evaluation of background surface water quality to understand general location and cause of water quality problems during baseflow conditions.
- *Chloride Monitoring* - Evaluation and trending background chloride concentrations to understand general location and concentrations of chloride through the GRCA.

7.4.2 Purpose of Monitoring

In 2013, the above noted programs and sampling sites were evaluated based on watershed health questions; watershed plan recommendations; various management plan background reports; staff knowledge of local watersheds; and staff capacity and monitoring budgets. As a result of this evaluation, five programs were revised, expanded or created to answer the following questions related to the parameters outlined in Table 2.

- What is the current state of water quality as defined by selected parameters?
- What is the trend of water quality parameters?
- What is the “range of normality” of water quality parameters?
- How do the water quality parameters compare to established targets?
- How have changes in land use/cover impacted water quality?

Table 2: Surface water quality indicators and targets

Indicator	Parameters	Target
Nutrients	Nitrate	2.9 mg/L*
	Nitrite	0.197 mg/L*
	Total Phosphorus	0.03 mg/L
	Phosphate (total reactive P)	None
	Total Kjeldahl Nitrogen (TKN)	None
	Ammonia+Ammonium	None
Ions	Chloride	250 mg/L*
	Total Hardness	None
Bacteria	*Escherichia coli*	100 cfu/100ml (recreation)
Sedimentation	Total Suspended Solids	25 mg/L^
	Turbidity	None
Stream Condition	pH	6.5-8.5
	Alkalinity	None
Metals	Aluminum	0.075 mg/L
	Zinc	0.030 mg/L
	Copper	0.050 mg/L
	Lead	0.050 mg/L

All targets are Provincial Water Quality Objectives unless otherwise indicated. *Environment Canada, ^Department of Fisheries and Oceans

8.4.3 Recommended Surface Water Quality Program

Provincial Water Quality Monitoring Network

Currently 9 stations (Figure 6) are sampled 8 times a year for nutrients, sediments, metals, and basic chemistry (Table 2) at a MOE accredited laboratory. Sampling occurs during non-runoff events in the spring, summer and fall. Starting in 2013, sampling frequency increased to 12 times per year (one sample taken each month for four additional months) to understand winter conditions. Samples are sent to a private accredited laboratory for analysis. These four additional samples per station will be analyzed for parameters listed in Table 2 except for metals, due to budget constraints.

High Water Event Monitoring

Four automated ISCO samplers have been used since 2010 to monitor high flow events for indicators listed in Table 2 with the exception of metals. Watersheds sampled include Wilmot Creek at Concession Road 3, Graham Creek at Mill Street, Ganaraska River at Peter Street and Cobourg Creek at William Street (Figure 6). Sampling occurs when rainfall or snow melt events cause high flows in these watercourses. Typically rainfall events greater than 20 mm are required. It is acknowledged that this monitoring program requires staff time during possible flood events. As a result, other program priorities (e.g., Flood Forecasting and Warning) will take priority.

Ganaraska Region Water Quality Monitoring Network (GRWQMN)

The GRCA has a general understanding of surface water quality from past sampling programs and analysis; however data gaps exist due to the limited spatial and temporal coverage. In 2013, new dedicated water quality stations have been added to increase spatial coverage across the GRCA. Eighteen new sites (Figure 6) are now being monitored monthly for parameters indicated in Table 2 with the exception of metals.

Eighteen new sites have been selected based on the following criteria:

- Distribution between catchments representing urban, agricultural and natural land cover as the dominant feature.
- Distribution between major watersheds across the jurisdiction.
- Distributed between the major physiographic regions across the jurisdiction.
- Representation of major sub-catchments within Wilmot Creek, Ganaraska River and Cobourg Creek.
- Consideration of PWQMN site locations and permanent stream gauges.
- Sites can be located within road allowance, with sampling occurring upstream of the road crossing.

Bacteria Sampling

Historic bacteria data is available from various programs. In most cases *E. coli* is the parameter of choice. *E. coli*, starting in 2013, is sampled monthly at all PWQMN and GRWQMN sites.

Chloride Sampling

Since 2005, chloride sampling has occurred bi-weekly from November (or first snow fall) to April at 56 sites (maximum in one year) across the GRCA. In 2013, intensive sampling ceased given the general understanding of chloride concentrations at the sample sites. Chloride is now monitored monthly at all the PWQMN and GRWQMN sites.

8.4.4 Methods

Surface water quality samples are collected using appropriate sampling techniques. This includes triple rinsing bottles without preservatives, wearing latex gloves, sampling the middle of the water column with water flowing into the bottle (hands downstream), and appropriate sample storage, chain of custody and transportation. Infield data is collected using a hand held YSI, or other appropriate instruments. All samples are sent to an accredited laboratory for analysis.

8.4.5 Integration

Surface water quality data synthesis will evaluate surface water quality results from the above noted programs in association with the following watershed features and functions when data availability and model/software permits. Water quality results can be integrated with:

- upstream catchment land use/cover identified through Ecological Land Classification;
- stream flow;
- biotic conditions (presence and absence of sensitive species);
- groundwater discharge/springs/baseflow conditions;
- implementation of stewardship projects aimed at protecting surface water quality;
- new development/changing land use;
- stormwater discharge locations; and
- permitted water takings/water uses.

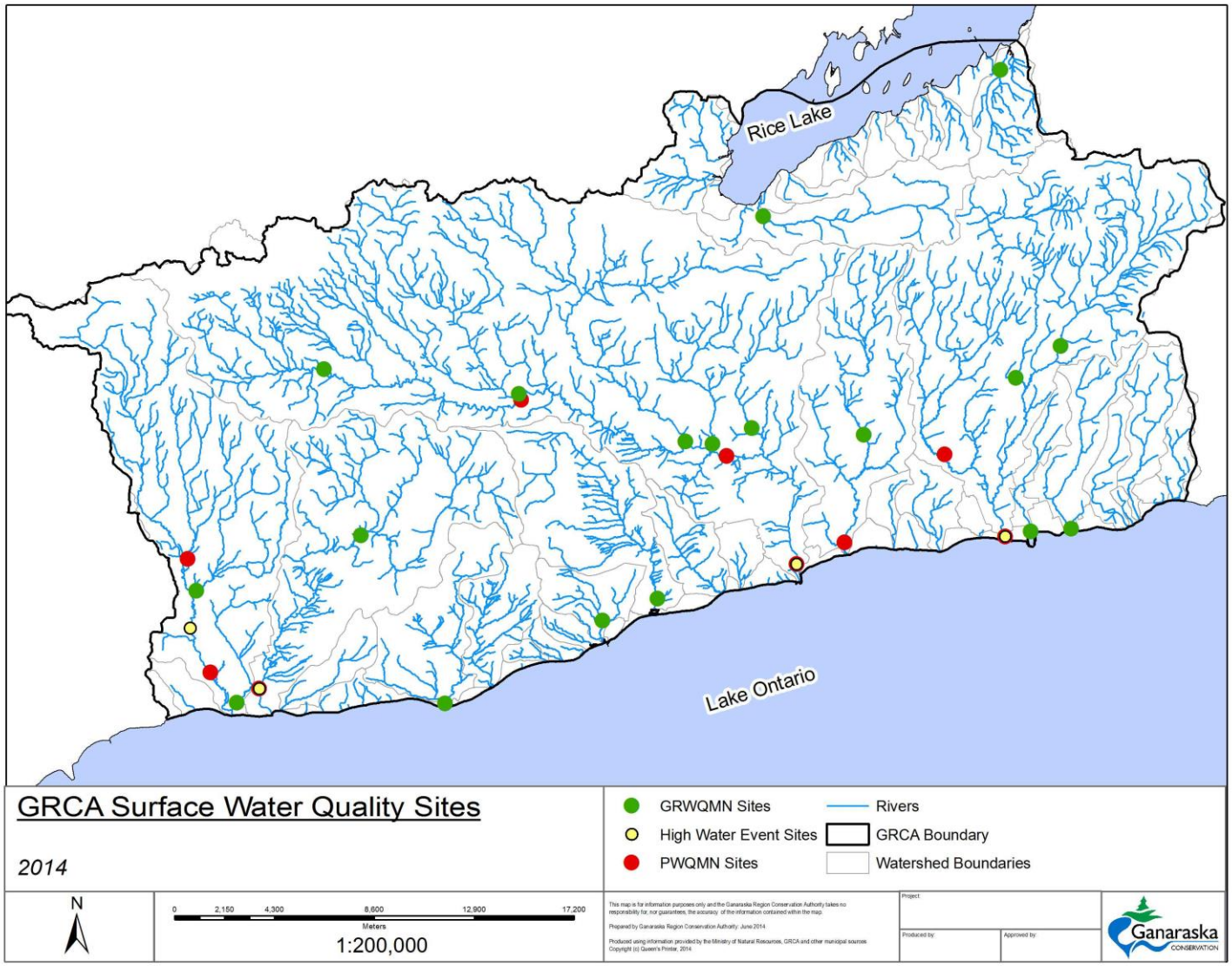


Figure 6: Surface water quality monitoring sites

8.5 Monitoring Aquatic Resources

8.5.1 Background

Aquatic resource monitoring has occurred within the GRCA area since the 1940's, with the commencement of characterizing the aquatic biota (fish and benthic macroinvertebrates) for the development of *The Ganaraska Watershed: a Study in Land Use with Recommendations for the Rehabilitation of the Area in the Post-war Period*[6]. Over the past decade, the following programs have been implemented by the GRCA either independently or in partnership with other agencies.

- Benthic macroinvertebrate monitoring: utilizing benthic macroinvertebrate species and assemblages/communities to evaluate surface water quality and aquatic habitat attributes to understand general water quality and habitat conditions.
- Fish community monitoring: utilizing fish species and assemblages/communities to evaluate surface water quality and aquatic habitat attributes to understand general water quality and habitat conditions.

8.5.2 Purpose of Monitoring

Benthic Macroinvertebrate Monitoring

Benthic macroinvertebrates have been collected within the GRCA by a variety of agencies through a range of monitoring approaches, protocols and levels of taxonomic resolution. Historical data is used as a baseline to characterize shifts in benthic macroinvertebrate communities, or loss of sensitive taxa from specific locations/reaches within a watercourse/watershed. This provides and understanding of long-term trends in water and habitat quality.

Fish Community Monitoring

Fisheries monitoring has been widely conducted throughout the GRCA by a number of agencies for a wide variety of monitoring and research purposes. Certain annual fish community monitoring sites/projects have been maintained by the GRCA to assess fish community health, individual species/population health, and changes to community and populations over time.

[6] Richardson, A.H. 1944. The Ganaraska Watershed: A study in land use with recommendations for the rehabilitation of the area in the post-war period. Ontario Department of Planning and Development, Toronto, Ontario.

8.5.3 Recommended Aquatic Resource Program

The following benthic macroinvertebrate and fish community monitoring programs should continue to occur annually. No new monitoring programs are being recommended at this time.

Benthic Macroinvertebrate Monitoring

Past benthic macroinvertebrate monitoring has been conducted utilizing either the Ontario Stream Assessment Protocol (OSAP) or Ontario Benthos Biomonitoring Network (OBBN) protocols, with a taxonomic resolution of either Order or Family level. These protocols would continue to be used as required, and the past data collected using these protocols are useful in understanding historical aquatic resource conditions.

Currently, the GRCA provides support for the MOE's regional biocriteria project, which characterizes reference condition sites (assumed minimally disturbed from historical conditions), and uses statistical tools to determine whether test sites are considered reference, or fall outside of reference condition and are considered altered or degraded. Sampling is conducted during May, utilizing the OBBN methodology. Taxa are identified to at least the Family level.

The GRCA has partnered with the Royal Ontario Museum (ROM) to develop a rapid bioassessment tool to characterize the health of watersheds by examining sites for a suite of sensitive taxa, which have published sensitivity values, and which have a diverse range of ecological attributes (e.g., functional feeding type, life history, and habitat use).

Using this tool, the GRCA collects excuviae (remains of an exoskeleton) from recently emergent stonefly species to characterize a stream site's ecological health, as well as an opportunity to determine abundance on any given year. The stonefly species of most interest is *Isogenoides frontalis*, and has only been identified within two watersheds. Annual sampling locations (Figure 7) on Wilmot Creek include (Taunton Road, 5th Concession, 4th Concession and 3rd Concession), and Cobourg Creek (Hickerson Road, Dale Road). No other GRCA watersheds have been documented to contain this species (as of April 2014). Sampling is conducted during the last two weeks of May, with total number of excuviae counted on each bridge abutment wall. Voucher specimens are annually collected and sent to Henry Frania of the ROM.

Fish Community Monitoring

Fish community monitoring surveys follow the methods outlined in the Ontario Stream Assessment Protocol[7]. Fish community changes are examined by looking at species richness, community evenness, and assessed using an Index of Biotic Integrity (IBI). The IBI score is a multivariate measure of stream quality that uses fish

[7] Stanfield L. (editor). 2010. Ontario Stream Assessment Protocol. Version 8.0. Fisheries Policy Section. Ontario Ministry of Natural Resources. Peterborough, Ontario.

fauna as a biological indicator. Nine measures, or metrics, of fish community composition, grouped into four categories (species richness, local indicator species, trophic composition and fish abundance), are used to derive the IBI score. The IBI score is used to rate the overall health of the stream (site) on a scale of 9 (poor) to 45 (very good). For more information on this metric please refer to Steedman, 1988[8].

The GRCA currently monitors ten electrofishing sites annually, with six sites on Wilmot Creek and four sites on Welseyville Creek (Figure 7).

Other fish community monitoring activities include:

- Sea Lamprey Barrier: 14 to 18 week monitoring of fish community migrations during the spring on Cobourg Creek, which have been ongoing since 1997 (Figure 7).
- Durham Region Coastal Wetland Monitoring Program: boat electrofishing at two coastal wetlands, Port of Newcastle and Wilmot Creek, conducted during the summer (Figure 7).

Continued monitoring of aquatic biota "health" provides an efficient and representative mechanism in which to assess the quality and quantity of surface waters, and the physical quality of aquatic habitats. These monitoring activities should be considered as components of an integrated aquatic monitoring program for the GRCA.

8.5.4 Methods

Benthic Macroinvertebrate Monitoring

Specimens are collected by kick and sweep method, or picking up substrate and gently shaking it in a washtub with water, allowing the organisms to fall off into the washtub. All specimens are identified within the field to the lowest taxomonic resolution possible, with target species identified to at least the Genus level. This data is utilized in conjunction with historical benthic data to characterize changes through time. Sensitive species that are looked for specifically include those identified in Table 3.

[8] Steedman, R.J. 1986. Comparative analysis of stream degradation and rehabilitation in the Toronto area. PhD. Dissertation. University of Toronto.

Table 3: GRCA/ROM rapid benthic biosampling target species

Family	Genus	Species	Family	Genus	Species
Baetidae			Perlodidae		
	Baetis			*Isogenoides*	*frontalis*
Ephemerellidae			Perlidae		
	Ephemerella	*subvaria*		*Acroneuria*	
	Drunella			*Agnetina*	
Ephemeridae				*Pragnetina*	
	Ephemera	*guttulata*	Pteronarcyidae		
	Ephemera	*simulans*		*Pteronarcys*	*dorsata*
	Hexagenia		Rhyacophilidae		
Heptageniidae				*Rhyacophila*	
	Epeorus	*pleuralis*	Hydropsychidae		
	Epeorus	*vitreus*	Brachycentridae		
	Rhithogena		Uenoidae		
Isonychiidae				*Neophylax*	
	Isonychia	*bicolour*			

Fish Community Monitoring

Fish communities are sampled using OSAP with a backpack electrofisher using a single pass approach. Electrofishing is a non-lethal sampling technique that uses electric currents and electric fields to immobilize fish, allowing capture. Captured fish are identified to species, weighed and measured and then released back into the water. Quality Assurance/Quality Control (QA/QC) of identified samples is carried out by certified GRCA staff and where the identification of a specimen is uncertain it is sent out for verification by a qualified fish taxonomist.

Under OSAP, all sample sites are set-up following a standardized geomorphic unit which was a minimum of two crossovers or 40 metre in length. Electrofishing effort is undertaken at 7 to 15 seconds per square meter.

8.5.5 Integration

Aquatic biological monitoring data synthesis, analysis, and reporting can be integrated with:

- upstream catchment land use/cover identified through Ecological Land Classification, water control structure database, or other land use designation tools;
- stream flow and temperature;
- groundwater discharge/springs/baseflow conditions;
- implementation of stewardship projects aimed at protecting surface water quality and quantity;
- new development/changing land use, point source stressors (e.g. stormwater discharge locations); and
- Regionally collected biological data.

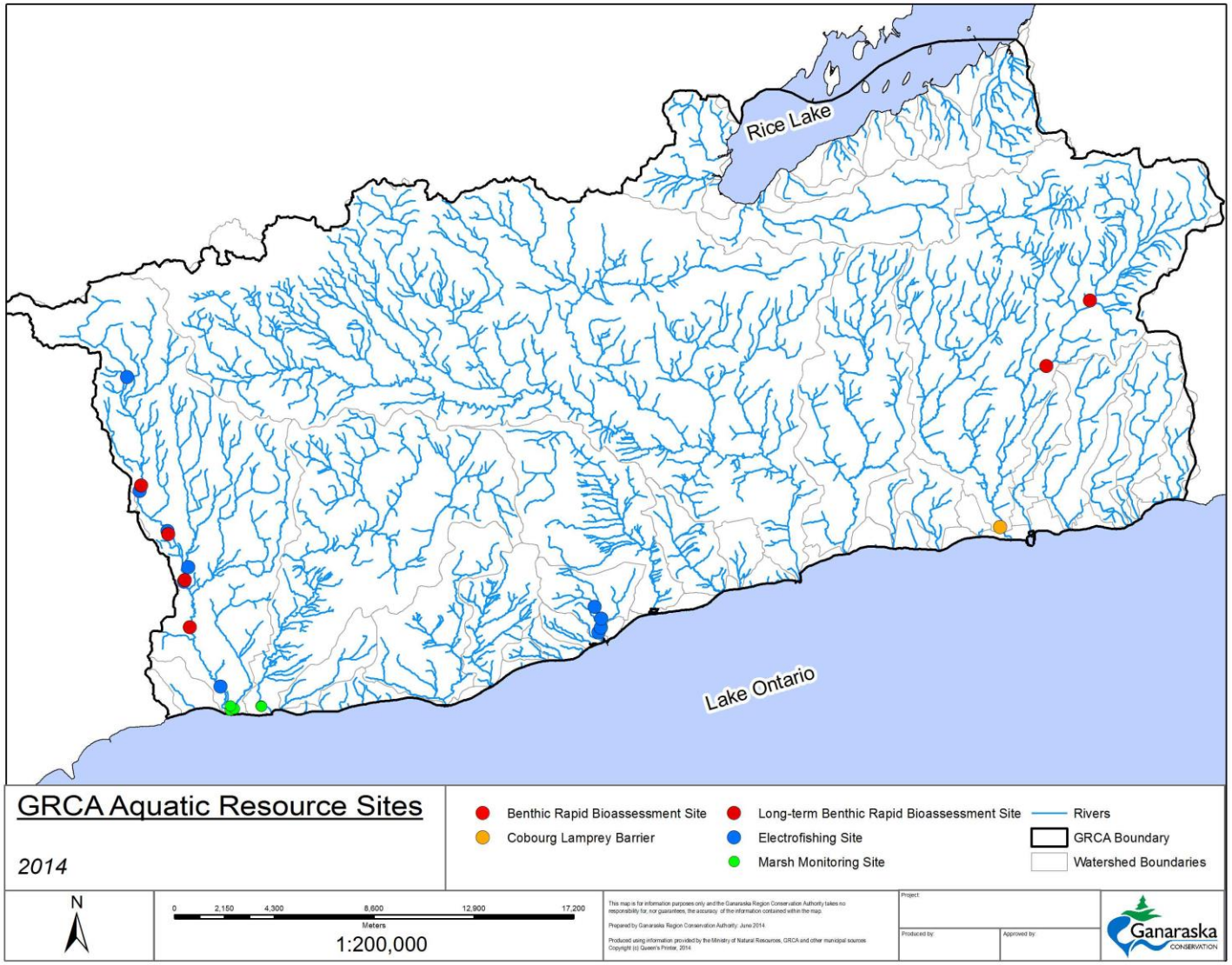


Figure7: Aquatic resource monitoring sites

8.6 Monitoring Terrestrial Natural Heritage

8.6.1 Background

Monitoring of terrestrial natural heritage features and functions has occurred annually since the early 2000s, but was begun in the 1940s. Initially the focus of the recent terrestrial natural heritage monitoring program was completing Ecological Land Classification (ELC) across the GRCA using air photos from 2002. Since this time, ELC has been refined based on updated air photos (2008 or 2010 depending on availability).

A current focus of terrestrial natural heritage monitoring includes Durham Coastal Wetland monitoring, distribution and populations of amphibians and forest birds, and terrestrial invasive plant presence. Emerging monitoring topics include road effects on wildlife populations and movement, and the benefits of culverts and road underpasses to wildlife movement. The latter two topics relate to the functional connectivity within the natural heritage system.

8.6.2 Purpose of Monitoring

Monitoring of terrestrial natural heritage is shifting focus from individual species or population of species to understanding the functional capacity and connectivity within a natural heritage system. Natural heritage includes geological features and landforms; associated terrestrial and aquatic ecosystems; plant species, populations and communities; and all native animal species, their habitats and sustaining environment. The natural heritage system is made up of natural heritage features and areas, linked by natural corridors which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species and ecosystems.

8.6.3 Recommended Terrestrial Natural Heritage Program

Coastal Wetland Monitoring

The Durham Coastal Wetlands Monitoring program should continue within the Wilmot Creek wetland and Port of Newcastle wetland. The program is surveillance based and follows the Environment Canada Marsh Monitoring Program protocol. The program uses breeding birds and frogs as indicators of ecological health. Further, this program should be expanded to Northumberland County coastal wetlands where appropriate.

Amphibian Surveys

Amphibians, specifically frogs, are an indicator of habitat quality. The population and distribution of frogs will help to answer what wetlands support what frog species and in what population densities. Currently, amphibian surveys occur annually, using sensitive frog species as indicators. This program should be continued.

Bird Surveys

Birds, specifically forest birds and their communities are an indicator of forest habitat quality. The population and distribution of sensitive breeding bird species will help to answer what forest patch types, sizes, shapes and landscape matrices support what sensitive species and in what population densities. Currently, forest bird community surveys occur at Thurne Parks Conservation Area in partnership with Canadian Wildlife Survey and Bird Studies Canada. This program should continue, in addition to roadside point counts throughout the GRCA. In doing so, changes in sensitive bird species populations can be documented and understood as natural heritage system targets are achieved and land use changes.

Terrestrial Invasive Plants

Beginning in 2014, focus is being given to inventory terrestrial invasive plants on public lands (conservation area, Ganaraska Forest, crown lands, nature reserves). The properties and specific areas selected for inventorying are based on the quality of habitat found within the properties as define by the Natural Heritage System model. In doing so a better understanding will be gained in regards to the types of terrestrial invasive plants found on high quality public lands, as well as their distribution, and extent. The benefit of this program will be in determining the extent of the threat and to prioritise control activities. In addition, this program will feed into the provincial based EDDMapS[9] invasive species monitoring system.

Road Impacts and the Natural Heritage System

One of the biggest threats to fauna species is the effects of roads on their actual survival. Roads can cause direct mortality and fragment species habitat. Two questions can be asked when investigating the impacts of roads within a natural heritage system. In doing so the functional connectivity within the natural heritage system can be better understood.

1. To what extent are roads affecting wildlife populations and impeding wildlife movement?
2. What species are present in the Natural Heritage System and to what extent are culverts and road underpasses allowing for wildlife movement?

In answering these questions, a new program is being considered using the following general steps.

- Undertake road mortality surveys in areas where major wildlife corridors in the natural heritage system are traversed by roads and where wetlands occur adjacent to roads.

[9] http://www.eddmaps.org/ontario/

- Collect photo documentation of all culverts and underpasses in major wildlife corridors in the natural heritage system.

8.6.4 Methods

The major type of monitoring within a terrestrial natural heritage context is surveillance. This requires the person engaged in the monitoring activity to have a high skill level in species identification by sight and sound. Monitoring of species also needs to be temporally flexible given that many species are best monitored in the spring, and in the early morning or around dusk. Other aspects of monitoring (e.g., road wildlife movement) will require digital assistance (e.g., game cameras).

8.6.5 Integration

Terrestrial natural heritage data synthesis will evaluate species presence/absence and trends from the above noted programs in association with the following watershed features and functions when data availability and model/software permits. Terrestrial natural heritage results will be integrated with:

- land use/cover identified through Ecological Land Classification;
- changes in regional and national climate;
- groundwater discharge/springs/wetlands;
- implementation of stewardship projects aimed enhancing the natural heritage system; and
- new development/changing land use.

9.0 Reporting

Next to the scientific steps, reporting is the second most important step within a watershed monitoring program. Reporting should tell a story to a variety of audiences regarding the current state of the watershed or an area of science, as well as trends (historical and potential future), and potential relationships or drivers.

Information can be reported in the form of a written report, as raw data, or anywhere in between. When providing data, the following principals should be adhered to:

- The landowner who allowed sampling to occur on his/her property should be provided with the results.
- All data should be provided to those requesting it, while properly considering the *Municipal Freedom of Information and Protection to Privacy Act*.
- If data is collected outside of a formal monitoring protocol (e.g. data collected through educational or public information programs) the limitations of use of the data must be clearly defined.
- Metadata must be provided with all data disseminated.

Reporting should occur at each step of the monitoring program.

9.1 Reporting at the Data Collection and Evaluation Step

The GRCA currently reports information during the data collection/evaluation step. The information will continue to be provided, and will include basic data collection information such as the number of sample sites, sample frequency and parameters collected. The reporting format varies, and generally includes the GRCA annual report, questionnaires and surveys provided by other agencies and as content within presentations. Generally, the intended audience for the reporting format includes municipalities, the public, Conservation Ontario, and partners/stakeholders. In addition, the GRCA provides raw data to many stakeholders for their own use (e.g., municipalities, academia, and consultants).

9.2 Reporting at the Data Analysis Step

The GRCA currently reports information during the data analysis step and generally as a result of a project or program deliverable. The information provided includes basic data analysis and evaluation, as well as data collection methods. Generally, the intended audience includes the GRCA Full Authority Board, staff, academia, consultants, partners/stakeholders, a particular proponent, municipality, or funder. The format generally includes a topic/project specific and/or presentation.

9.3 Reporting at the Data Synthesis Step

The GRCA, as part of this watershed monitoring program will create an annual *Watershed Monitoring Report* which will include results from data synthesis. This report allows staff to investigate individual data sets, in relation to other watershed data sets, to understand potential cause and effects. This step brings other

disciplines together to gain greater insight. It is understood that this step requires greater staff time, staff participation, sharing of data sets, and additional tools (software, models, GIS). The content of the report will include data collection methods, basic data analysis results and data synthesis. The report will also contain, as required, recommendations for improving the watershed monitoring program, and integrating watershed areas of science during monitoring, data analysis or synthesis. Generally, the intended audience includes the GRCA Full Authority Board, staff, academia, consultants, partners/stakeholders, and municipality.

The timeline for the *Watershed Monitoring Report* will be as follows.

Task	Deadline
Data collection	Year prior
Description of methods, sample site location, sampling frequency and basic data analysis.	January 31
Data synthesis results	February 28
Recommendations	February 28
Distribution and presentation to GRCA Full Authority Board	March
Distribution to target audience	April
Implementation of recommendations	As required

10.0 Implementation

Implementation of the GRCA watershed monitoring program will occur through various steps. These steps include those described in Section 7 (data collection and evaluation, analysis, synthesis and reporting). In addition, implementation will include the identification of specific questions that must be asked to support the actual collection of data; as well as the selection monitoring stations/sites, methods and laboratory analysis, if required.

Implementation also includes the consideration of data management structures that are required to store, site information (e.g., site coordinates), raw data, corrected data, and manipulated/analyzed data. GRCA staff are currently considering different programs that may be useful in storing data (e.g., CUAHSI). It is acknowledged that basic software program (e.g., Microsoft Excel or Access), program specific software (e.g., HABPROGS for OSAP data), or GIS platforms (e.g., ArcView) may be useful in storing data. Further, different structures may be required when storing abiotic data versus biotic data. The GRCA will continue to work cooperative with partners using their data storage systems when this use expands the quality of the data synthesis and ultimate recommendations. Additionally, when data is stored, all data must have comprehensive metadata attached to it. Metadata is an additional set of data that describes and gives information about the monitoring data.

The bulk of implementation considerations which will include new program development, program specific budget requirements, prioritization of monitoring programs and reporting activities will be determined during the annual GRCA budgeting process. As technology continues to improve, it is recommended that a

portion of the budget be allocated to improve telemetry systems, replace aging equipment and upgrade sensors. Details regarding these considerations are outlined in the *GRCA Water Resources Monitoring Networks – Maintenance Plan*. Budget and staff capacity will ultimately dictate what watershed monitoring programs are undertaken within a given year. However, it is acknowledged that some programs must be undertaken regardless of budgetary or staffing constraints given the GRCA mandate (e.g. monitoring related to flood forecasting).

The importance of partnering cannot be understated in implementation of the GRCA Watershed Monitoring Plan. The GRCA, in implementing any of its resource management programs, always looks to partner to expand the impact of available resources. Monitoring is no different. It is recommended that the GRCA continue to actively look for partnerships and that monitoring programs continue to be based on a partnership foundation.

11.0 Plan Cycle

The GRCA watershed monitoring program is to be implemented adaptively and a comprehensive update should occur every five years in order to address any gaps or changes in science, and issues and opportunities the activity of monitoring, management plan recommendations and implementation, and watershed health.

12.0 Conclusions

The purpose of monitoring is to support the conservation, enhancement and management of local watersheds and resources for current and future generations through data collection, evaluation, synthesis and reporting.

The goal of the GRCA watershed monitoring program is to collect scientifically defensible and locally relevant data and information on abiotic and biotic features and functions in an effective and efficient manner. The data and information collected is to be the basis for understanding current watershed conditions, predicting trends, evaluating local regulations, programs and management plans, predicting effects from climate change, and reporting.

Given this purpose and goal, it is vital that the GRCA continues to implement an effective watershed monitoring program that considers various watershed areas of study and the integration and linkages between these areas. Without continued long-term financial support, adequate staff capacity, and the ability to improve equipment and software, the required data (current conditions and trends), and holistic understanding needed to run the many GRCA programs and ultimately deliver meaningful watershed conservation will falter.

Appendix A: Summary of GRCA Monitoring Programs up to 2014

Acronyms:

BSC	Bird Studies Canada
CAMC	Conservation Authorities Moraine Coalition
CLOCA	Central Lake Ontario Conservation Authority
CWS	Canadian Wildlife Service
DFO	Department of Fisheries and Oceans
EC	Environment Canada
GRCA	Ganaraska Region Conservation Authority
MNR	Ministry of Natural Resources
MOE	Ministry of the Environment
OFAH	Ontario Federation of Anglers and Hunters
OIPC	Ontario Invasive Plant Council
ROM	Royal Ontario Museum

Meteorology			
Area of Interest: Climate			
Tool: Climate stations			
Purpose: Measure climatic parameters such as air temperature, relative humidity, wind speed and direction, and precipitation.			
Data Collection Methods: Different instruments measure the respective climatic condition; loggers store the information to be downloaded.			
Monitoring Locations: See Table 2			
✓	**Monitoring Standards Established**		
Partner(s): MNR, EC, MOE	✓	**Memorandum of Understanding Present**	
Roles: GRCA maintains stations and can add additional stations			
Training: On the job, literature and safety			
Scale: Regional, however consider topography		**Station State:** Permanent	
Frequency: 15 minute continuous readings		**QA/QC:** annual calibration of precipitation instruments (TBRG)	
Target: none, surveillance		**Indicator:** historic data normals	
Data Limitations: Data does drift so continual calibration is required along with regular maintenance.			
References: Siting standards for meteorological observing sites (Environment Canada)			

Table 2: Climate monitoring station information

Station	Station Type	TBRG	WPG	AT	WS/WD	RH	BP	SM	SR
Baltimore	Hydrometric	✓		✓	✓				
Forest Centre	Weather	✓	✓	✓	✓				
Main Office	Weather	✓		✓	✓	✓			
Wilmot	Hydrometric	✓							
Cobourg	Hydrometric	✓		✓					
Osaca NW	Hydrometric			✓					
Leskard	PGMN	✓							
Rice Lake	PGMN	✓							
Stickan	PGMN	✓							
Canton	Weather	✓		✓	✓	✓	✓	✓	✓

TBRG= Tipping Bucket Rain Gauge, WPG= Weighing Precipitation Gauge, AT= Air Temperature, WS/WD= Wind Speed and Direction, RH= Relative Humidity, PGMN = Provincial Groundwater Monitoring Network

Groundwater Quantity			
Area of Interest: Groundwater Level			
Tool: Provincial Groundwater Monitoring Network (PGMN)			
Purpose: Monitor ambient groundwater levels to set baseline conditions and assess how groundwater is affected by land use and water use[1].			
Data Collection Methods: Water levels are recorded using pressure sensors. Please refer to Ministry of the Environment, 2010 for details.			
✓	**Monitoring Standards Established**		
Partner(s): MOE	✓	**Memorandum of Understanding Present**	
Tasks: MOE established the PGMN and PGMIS, responsible for coordination, data analysis and reporting on a provincial scale, and maintaining information system, technology transfer and training. GRCA responsible for field operations including maintaining field equipment, collecting data and reporting on a local level.			
Training: on the job, literature, MOE/Conservation Ontario training, Eastern Conservation Authority working group.			
Scale: Regional aquifers in Ontario and site specific within the GRCA on a geological scale		**Station State:** permanent	
Frequency: Hourly and continuous		**QA/QC:** Manual measurements every two months	
Target: long-term average water level		**Indicator:** water level (meters above sea level)	
Data Limitations: Data cannot be inferred to all scales. Lack quantity of data (number of years). Efficiency of wells vary therefore data may be compromised. Not all data allowed to be used (Well 140-1).			
References: [1]Ministry of the Environment. 2006. PGMN Fact Sheet Ministry of the Environment. 2010. PGMN Sampling Protocol.			

Groundwater Quantity			
Area of Interest: Groundwater and Surface Water Interactions			
Tool: Streambed piezometer			
Purpose: Characterize groundwater discharge areas.			
Data Collection Methods: Please refer to Widaatalla and Peacock, 2007 for details.			
	Monitoring Standards Established		
Partners: None		**Memorandum of Understanding Present**	
Tasks: GRCA conducts all aspects of the streambed piezometer program			
Training: on the job and literature.			
Scale: Watershed, site and reach		**Station State:** permanent	
Frequency: Weekly in the summer, bi-weekly in spring and fall. Occurs from April to November. Continuous.		**QA/QC:** None	
Target: Positive hydraulic gradient, but variable on area, develop into a long-term average.		**Indicator:** hydraulic gradient and hydraulic head (pressure)	
Data Limitations: new program, evolving, few stations			
References: Widaatalla and Peacock. 2007. Using streambed piezometers as a tool in the assessment of different catchment response to precipitation and verification of mapping outputs.			

Groundwater Quantity			
Area of Interest: Groundwater Level			
Tool: Ganaraska Region Groundwater Monitoring Network (GRGMN)			
Purpose: Monitor ambient groundwater levels to set baseline conditions and assess how groundwater is affected by land use and water use.			
Data Collection Methods: same as PGMN in the Ganaraska Forest (CAMC wells), Midtown Creek and Massey Creek.			
	Monitoring Standards Established		
Partners: None			**Memorandum of Understanding Present**
Tasks: GRCA conducts all aspects of the GRGMN			
Training: on the job and literature.			
Scale: Regional aquifers in Ontario and site specific within the GRCA on a geological scale			**Station State:** permanent Many available sites within our jurisdiction.
Frequency: hourly			**QA/QC:** manual measurements
Target: long-term average water level			**Indicator:** water level (meters above sea level)
Data Limitations: Data cannot be inferred to all scales. Lack quantity of data (number of years). Efficiency of wells vary therefore data may be compromised. Additional wells exist that have no measuring instruments (GRCA main office and Newcastle).			
References: None			

Groundwater Quality			
Area of Interest: Ambient Groundwater Water Quality			
Tool: Provincial Groundwater Monitoring Network			
Purpose: Monitor ambient groundwater quality to set baseline conditions and assess how groundwater is affected by land use and water use[1].			
Data Collection Methods: According to the MOE protocol. Please refer to Ministry of the Environment, 2010 for details.			
✓	**Monitoring Standards Established**		
Partner(s): MOE		✓	**Memorandum of Understanding Present**
Tasks: MOE established the PGMN and PGMIS, responsible for coordination, data analysis and reporting on a provincial scale, and maintaining information system, technology transfer and training. GRCA responsible for field operations including maintaining field equipment, collecting data and reporting on a local level.			
Training: on the job, literature, MOE/Conservation Ontario training, Eastern Conservation Authority working group.			
Scale: Regional aquifers in Ontario and site specific within the GRCA on a geological scale			**Station State:** permanent
Frequency: Annual in fall and continuous (year step)			**QA/QC:** Laboratory methods
Target: Ontario Drinking Water Standards (others have suggested parameter defined at site)			**Indicator:** nutrients, chemicals, ions, temperature
Data Limitations: Data cannot be inferred to all scales. Potential lack of quantity of data (number of years). Efficiency of wells vary therefore data may be compromised. Not all data allowed to be used (Well 140-1). Certain wells are not sampled for water chemistry.			
References: [1]Ministry of the Environment. 2006. PGMN Fact Sheet Ministry of the Environment. 2010. PGMN Sampling Protocol.			

Groundwater Quality		
Area of Interest: Ambient Groundwater Water Quality		
Tool: Private well inventory		
Purpose: Monitor ambient groundwater quality to set baseline conditions and assess how groundwater is affected by land use and water use.		
Data Collection Methods: With well owner permission, sample private wells. Samples sent to accredited lab, and data shared with well owner.		
✓ **Monitoring Standards Established**		
Partner(s): well owner		**Memorandum of Understanding Present**
Tasks: GRCA program, conducts well owner contacts and water sampling. Samples sent to an accredited lab.		
Training: on the job.		
Scale: Local aquifers		**Station State:** permanent sites (well), unless decommissioned by owner.
Frequency: Annual, circulating through different watersheds (e.g., 2013 Wesleyville Creek, 2014 Gages Creek).		**QA/QC:** Laboratory methods
Target: Ontario Drinking Water Standards		**Indicator:** Cl, F, NO_3, NO_2, S
Data Limitations: Data cannot be inferred to all scales. Potential lack of quantity of data (number of years).		
References:		

Surface Water Quantity		
Area of Interest: Stream flow and stage		
Tool: Hydrometric Stations: 8 EC stations; 8 GRCA stations		
Purpose: Monitor stream flow and stage for the primary purpose of flood forecasting and warning and hydrology modeling.		
Data Collection Methods: Sensors measure water level; data to a logger for downloading. Data applied to a rating curve to convert to discharge/flow. There is also a water level gauge in Harwood on Rice Lake used by Trent Severn Waterway. There is also a gauge in Lake Ontario at Cobourg Harbour operated by Environment Canada to assist the GRCA in coastal flood forecasting and warning. These are asked from the MNR WISKI website.		
✓ **Monitoring Standards Established**		
Partner(s): EC, MNR		**Memorandum of Understanding Present**
Tasks: GRCA maintains stations, downloads data and analyzes. EC adjusts for ice conditions, owns and maintains stations. MNR collects data for use in Whisky Soda.		
Training: On the job, literature		
Scale: Watershed, sub-watershed and site.		**Station State:** Permanent. Some can be temporary.
Frequency: 15 minutes. Temporary stations set depending on required need.		**QA/QC:**
Target: none, surveillance.		**Indicator:** stream flow and rating curve
Data Limitations: limited by quality of rating curve quality		
References: manuals		

Surface Water Quantity		
Area of Interest: Baseflow / Low-flow		
Tool: Baseflow surveys		
Purpose: Measure and understand stream flow during a period of prolonged dry weather and evaluate the distribution and magnitude of groundwater discharge.		
Data Collection Methods: Adapted from Hinton (2005)		
✓ **Monitoring Standards Established**		
Partner(s):		**Memorandum of Understanding Present**
Tasks: GRCA implements the entire baseflow monitoring program		
Training: On the job, literature		
Scale: Watershed, sub-watershed and site.		**Station State:** Reference Sites and 150 long-term sites.
Frequency: Once per season (intermittent)		**QA/QC:** Use of reference sites
Target: none, surveillance		**Indicator:** Discharge
Data Limitations: Access to better sites is challenging given to use of road allowance. Limitation in methodology for very low-flow.		
References: Hinton. 2005. Methodology for measuring the spatial distribution of low stream flow within watersheds.		

Surface Water Quantity		
Area of Interest: Stream flow		
Tool: Staff gauges		
Purpose: measure stream level/discharge to rainfall or snowmelt event to understand conditions of the stream/river.		
Data Collection Methods: Attach staff gauge (ruler) to a solid structure at waters edge. Additionally use flow meters to determine a rating curve.		
Monitoring Standards Established		
Partner(s):		**Memorandum of Understanding Present**
Tasks: GRCA implements the entire staff gauge program		
Training: On the job and literature		
Scale: site specific – above and below flood damage centres.		**Station State:** Permanent
Frequency: as required during flood events.		**QA/QC:** Rating curve
Target: none, surveillance.		**Indicator:** stage
Data Limitations: This is a crude analysis given the number of observations and rating curve accuracy.		
References:		

Surface Water Quantity		
Area of Interest: Condition of snow		
Tool: Snow Courses: 6 stations		
Purpose: Measure snow pack and potential water content for spring melt predictions.		
Data Collection Methods: Described in snow survey manual[1]		
✓ **Monitoring Standards Established**		
Partner(s): MNR		**Memorandum of Understanding Present**
Tasks: GRCA does the monitoring, MNR publishes the data and puts into a provincial context		
Training: On the job, literature		
Scale: Watershed		**Station State:** Permanent
Frequency: 1st and 15th of each month from November to May inclusive		**QA/QC:**
Target: historical data and statistical comparison		**Indicator:** water equivalent, soil conditions, crust characteristics
Data Limitations: Limited number of site (more could be used). Lack of documentation on how sites have changed over time and how these changes could affect the data.		
References: [1]MNR. 1985. Snow Survey Manual		

Surface Water Quantity		
Area of Interest: Condition of River Ice		
Tool: Visual Ice Inspection		
Purpose: Measure and visually examine ice conditions in the Ganaraska River (harbour, Sylvan Glen and Corbetts Dam) to understand ice movement and jam potential. This is used to advise the municipality.		
Data Collection Methods: visual inspection and measure ice thickness.		
✓ **Monitoring Standards Established**		
Partner(s): Municipality		**Memorandum of Understanding Present**
Tasks: GRCA does the monitoring, Municipality implements recommended actions		
Training: On the job		
Scale: Sub-watershed		**Station State:** Permanent
Frequency: as needed		**QA/QC:**
Target: none, surveillance		**Indicator:** ice thickness and condition
Data Limitations:		
References:		

Surface Water Quantity		
Area of Interest: Flood forecasting and warning		
Tool: Flood Debris/Damage Inventory		
Purpose: document and understand the extent of flooding events.		
Data Collection Methods: visual, measurement and picture documentation. Also includes landowner surveys and discussions/documentation, and consultation with municipal staff who deal with flooding issues. In some cases involves surveys (total station) to delineate flood limits. A protocol needs to be written.		
	Monitoring Standards Established	
Partner(s):		**Memorandum of Understanding Present**
Tasks: GRCA documents flood events		
Training: On the job, literature		
Scale: Watershed		**Station State:** no station
Frequency: as needed		**QA/QC:**
Target: none, surveillance		**Indicator:**
Data Limitations: This program needs to be formalized.		
References:		

Surface Water Quality		
Area of Interest: Ambient Surface Water Quality		
Tool: Provincial Water Quality Monitoring Network (PWQMN)		
Purpose: Evaluation and trending background surface water quality to understand general location and cause of water quality problems.		
Data Collection Methods: Please refer to Ministry of the Environment, 2003 for details.		
✓	**Monitoring Standards Established**	
Partner(s): MOE		**Memorandum of Understanding Present**
Tasks: MOE established the PWQMN, is responsible for coordination, data analysis and reporting on a provincial scale, and maintaining information system, technology transfer and training. GRCA responsible for field operations including maintaining field equipment, collecting data and reporting on a local level.		
Training: on the job, literature, MOE/Conservation Ontario training.		
Scale: Watershed, reach and site		**Station State:** permanent
Frequency: monthly/continuously for 8 months per year		**QA/QC:** Laboratory methods
Target: Provincial Water Quality Objectives (PWQO) and Canadian Environmental Quality Guidelines (CEQG)		**Indicator:** nutrients, chemicals, ions, temperature
Data Limitations: Need large data set for reliable assessment.		
References: [1]Ministry of the Environment. 2003. Water Sampling and Data Analysis Manual.		

Surface Water Quality		
Area of Interest: High Flow Ambient Surface Water Quality		
Tool: High Water Event Monitoring		
Purpose: Understand surface water quality related to high flows caused by rainfall or snowmelt.		
Data Collection Methods: Please refer to the Wet Weather Water Quality Monitoring Protocol		
✓ **Monitoring Standards Established**		
Partner(s): MOE		**Memorandum of Understanding Present**
Tasks: GRCA conducts all aspects of the program. In some cases samples are sent to the MOE lab for analysis depending on the needs of other studies.		
Training: on the job, literature, MOE/Conservation Ontario training.		
Scale: Watershed, reach and site		**Station State:** permanent
Frequency: yearly (April/May to October/November)		**QA/QC:** Laboratory methods
Target: PWQO and CEQG		**Indicator:** nutrients, chemicals, ions, temperature
Data Limitations: Need large data set for reliable assessment		
References: GRCA. 2009. Wet Weather Water Quality Monitoring Protocol		

Surface Water Quality		
Area of Interest: Overall Ambient Surface Water Quality in a Watershed		
Tool: Ganaraska Region Water Quality Monitoring Network (GRWQMN)		
Purpose: Evaluation and trending background surface water quality to understand general location and cause of water quality problems throughout a watershed.		
Data Collection Methods: Please refer to Ministry of the Environment, 2003[1] for details.		
✓ **Monitoring Standards Established**		
Partner(s): None		**Memorandum of Understanding Present**
Tasks: GRCA conducts all aspects of the GRWQMN		
Training: on the job, literature, MOE/Conservation Ontario training.		
Scale: Watershed, reach and site		**Station State:** movable
Frequency: four months a year, rotated		**QA/QC:** Laboratory methods
Target: PWQO and CEQG		**Indicator:** nutrients, chemicals, ions, temperature
Data Limitations: Need large data set for reliable assessment. This program morphed into the Baseflow Water Quality Program in 2007.		
References: [1]Ministry of the Environment. 2003. Water Sampling and Data Analysis Manual.		

Surface Water Quality		
Area of Interest: Ambient Surface Water Quality During Baseflow		
Tool: Baseflow Water Quality Program		
Purpose: Evaluation of background surface water quality to understand general location and cause of water quality problems during baseflow conditions.		
Data Collection Methods: Please refer to Ministry of the Environment, 2003[1] for details.		
✓	**Monitoring Standards Established**	
Partner(s): None		**Memorandum of Understanding Present**
Tasks: GRCA conducts all aspects of the Baseflow Water Quality program		
Training: on the job, literature, MOE/Conservation Ontario training.		
Scale: Watershed, reach and site		**Station State:** movable
Frequency: once a year during baseflow conditions on a rotation		**QA/QC:** Laboratory methods
Target: PWQO and CEQG		**Indicator:** nutrients, chemicals, ions, temperature
Data Limitations: Need large data set for reliable assessment.		
References: [1]Ministry of the Environment. 2003. Water Sampling and Data Analysis Manual.		

Surface Water Quality		
Area of Interest: Ambient Chloride Surface Water Quality		
Tool: Chloride Monitoring Program and Provincial Water Quality Monitoring Network (PWQMN)		
Purpose: Evaluation and trending background chloride concentrations to understand general location and concentrations of chloride through the GRCA.		
Data Collection Methods: Please refer to Ministry of the Environment, 2003 for details.		
✓	**Monitoring Standards Established**	
Partner(s): MOE (PWQMN) Municipalities (chloride monitoring)		**Memorandum of Understanding Present**
Tasks: GRCA conducts all aspects of the Chloride Monitoring Program		
Training: on the job, literature, MOE/Conservation Ontario training.		
Scale: Watershed, reach and site		**Station State:** permanent
Frequency: monthly in summer through PWQMN, bi-weekly, November to April for chloride monitoring program		**QA/QC:** Laboratory methods
Target: 250 mg/L		**Indicator:** chloride concentrations
Data Limitations: Need large data set for reliable assessment.		
References: [1]Ministry of the Environment. 2003. Water Sampling and Data Analysis Manual.		

Aquatic Habitat and Species		
Area of Interest: Evaluation of physical habitat and water quality		
Tool: Benthic Macroinvertebrate Surveys		
Purpose: Understand benthic community in relation to physical habitat characteristics and water quality		
Data Collection Methods: Please refer to Jones et al., 2007 for details. In addition informal surveys may occur based on partnerships with the Royal Ontario Museum.		
✓ **Monitoring Standards Established**		
Partner(s): MOE and ROM		**Memorandum of Understanding Present**
Tasks: MOE provides training, maintains a database, helps selects reference sites on a regional scale and provides regional evaluation on reference sites. GRCA collects samples, identifies samples to family, enumerates samples and does data analysis.		
Training: on the job, literature, MOE/Conservation Ontario training.		
Scale: Regional, watershed, reach and site		**Station State:** reference site are permanent, test sites are repeatable.
Frequency: reference sites, once per year in May, test sites sampled in May and rotated		**QA/QC:** Picked samples are saved for future verification
Target: none, surveillance. Future sites can be evaluated against reference sites. Can also use Hilsenhoff, % EPT, BioMAP etc., to characterize site.		**Indicator:** Reference site criteria, benthic community and rare species.
Data Limitations:		
References: Jones et al., 2007		

Aquatic Habitat and Species		
Area of Interest: Fish Community Characterization		
Tool: Ontario Stream Assessment Protocol		
Purpose: Sample fish communities to characterize and understand effects from physical habitat and land use.		
Data Collection Methods: Please refer to Section 3 in Stanfield (editor), 2010[1] for details.		
✓ **Monitoring Standards Established**		
Partner(s): Other agencies (e.g., OFAH) as opportunities occur.		**Memorandum of Understanding Present**
Tasks: GRCA conducts all aspect of the program with assistance from other agencies as required.		
Training: Ontario Stream Assessment Protocol training, on the job, literature		
Scale: Regional, watershed, reach and site		**Station State:** Some stations are permanent (e.g., long-term historic record) while other are on a rotational basis.
Frequency: Once per year		**QA/QC:**
Target: none, surveillance. Future sites can be evaluated against reference sites. Can also use IBI, biomass and density to characterize site.		**Indicator:** Reference site criteria, fish community and rare/sensitive species.
Data Limitations: Sampling needs to occur during appropriate time of year.		
References: [1]Stanfield L. (editor). 2010. Ontario Stream Assessment Protocol. Version 8.0. Fisheries Policy Section. Ontario Ministry of Natural Resources. Peterborough, Ontario.		

Aquatic Habitat and Species			
Area of Interest: Fish Community Characterization			
Tool: DFO Lamprey Barrier			
Purpose: Manage for Sea Lamprey, and characterize and understand fish community at and downstream of the lamprey barrier.			
Data Collection Methods: DFO protocol for managing Sea Lamprey. Enumerate fish species found in lamprey barrier trap			
✓	**Monitoring Standards Established**		
Partner(s): DFO and contractors	✓	**Memorandum of Understanding Present**	
Tasks: DFO originally established the barriers and contracts out work at the lamprey barrier. GRCA conducts all aspect of the program on Cobourg Creek. Contractors conduct the program on Graham Creek.			
Training: On the job			
Scale: reach and site and infer to watershed.		**Station State:** permanent	
Frequency: Daily from March to July 30 (14 weeks)		**QA/QC:**	
Target: none, surveillance. Future sites can be evaluated against reference sites. Can also use population size, species richness and community stability to characterize site.		**Indicator:** Fish community and rare/sensitive species.	
Data Limitations: Utilizing a site/program not designed to truly characterize fish communities, unskilled contractors in relation to robust identification skills, 100% of the community not captured.			
References: DFO Protocol			

Aquatic Habitat and Species			
Area of Interest: Estimation of Spawning Population			
Tool: Spawning Surveys			
Purpose: Understand relative abundance of spawning sites for indicator species to estimate size of spawning population and spawning habitat conditions.			
Data Collection Methods: Walk streams and document spawning locations (need to write protocol).			
	Monitoring Standards Established		
Partner(s): volunteers		**Memorandum of Understanding Present**	
Tasks: GRCA conducts all aspect of the program			
Training: On the job			
Scale: reach and site and infer to watershed.		**Station State:** repeatable	
Frequency: once per year per species		**QA/QC:**	
Target: none, surveillance		**Indicator:** Rainbow Trout, Brook Trout, salmon, bass, cyprinids (selected as required)	
Data Limitations: Obtaining general information			
References: Gallagher, S.P., P.K.J. Hahn, and D.H. Johnson. No date. Redd Counts, in Salmonid Field Protocols Handbook: techniques for assessing state and trends in salmon and trout populations (D.H. Johnson, B.M. Shrier, J.S. O'Neal, J.A. Knutzen, X. Augerot, T.A. O'Neil, T.N. Pearsons eds). American Fisheries Society. Bethesda, Maryland. http://www.statusofthesalmon.org/fieldprotocols/			

Aquatic Habitat and Species		
Area of Interest: Habitat Structure and Healthy		
Tool: Ontario Stream Assessment Protocol		
Purpose: Understand channel structure (e.g., cover, substrate), channel processes (e.g., hydrology, sediment transport), and the stream's suitability for biota[1].		
Data Collection Methods: Please refer to Section 4, M1 and 2 in Stanfield (editor), 2010[1] for details.		
✓	**Monitoring Standards Established**	
Partner(s): Other agencies (e.g., OFAH) as opportunities occur.		**Memorandum of Understanding Present**
Tasks: GRCA conducts all aspect of the program with assistance from other agencies as required.		
Training: On the job, literature		
Scale: reach and site and infer to watershed.		**Station State:** As required; background sites present/available.
Frequency: as needed		**QA/QC:**
Target: none, surveillance		**Indicator:**
Data Limitations:		
References: [1]Stanfield L. (editor). 2010. Ontario Stream Assessment Protocol. Version 8.0. Fisheries Policy Section. Ontario Ministry of Natural Resources. Peterborough, ON.		

Aquatic Habitat and Species		
Area of Interest: Stream temperature regime		
Tool: Water temperature probe or thermometer		
Purpose: Understand thermal regime in streams		
Data Collection Methods: various methods are used. Some hydrometric stations have stream temperature monitors; staff deploy water temperature sensors/probes; staff take point in time stream temperatures using thermometers or other instruments.		
✓	**Monitoring Standards Established**	
Partner(s):		**Memorandum of Understanding Present**
Tasks: GRCA conducts all aspect of the program with assistance from other agencies as required.		
Training: On the job, literature		
Scale: reach and site and infer to watershed.		**Station State:** As required; background sites present/available.
Frequency: as needed in the summer months		**QA/QC:**
Target: cold, cool and warm stream temperature thresholds		**Indicator:** Stream temperature
Data Limitations:		
References:		

Terrestrial Natural Heritage		
Area of Interest: Forest health and state		
Tool: Roadside Bird Surveys		
Purpose: To demonstrate changes in sensitive birds as the natural heritage system targets are achieved and as land use changes.		
Data Collection Methods: Modified Forest Bird Monitoring protocol[1]: 10 minute count from point facing one direction into forested area from a road.		
✓	**Monitoring Standards Established**	
Partner(s): None		**Memorandum of Understanding Present**
Tasks: GRCA carries out the roadside bird surveys in the early morning.		
Training: On the job, literature, must know all forest and wetland birds by sight and sound.		
Scale: Landscape		**Station State:** permanent
Frequency: Every five years.		**QA/QC:**
Target: none, surveillance		**Indicator:** Sensitive breeding birds
Data Limitations: need skilled/trained people to identify birds visually and auditory, ability to monitor at dawn.		
References: [1]http://www.bsc-eoc.org/nabm/index.jsp?lang=EN&proj=77		

Terrestrial Natural Heritage		
Area of Interest: Forest health and state		
Tool: Forest Bird Surveys		
Purpose: Monitor and understand forest health based on species presence and absence, and trends. Contribute to national monitoring programs		
Data Collection Methods: Forest Bird Monitoring protocol[1]		
✓	**Monitoring Standards Established**	
Partner(s): CWS, BSC		**Memorandum of Understanding Present**
Tasks: GRCA conducts all aspects of the forest bird monitoring program		
Training: On the job, literature, must know all forest birds by sight and sound.		
Scale: Forest patch, habitat (Thurne Parks Conservation Area). Ganaraska Forest has been historically monitored.		**Station State:** Permanent (1 site, 5 stations)
Frequency: annually in spring		**QA/QC:**
Target: none, surveillance		**Indicator:** forest birds
Data Limitations: need skilled/trained people to identify birds visually and auditory, ability to monitor at dawn.		
References: [1]http://www.bsc-eoc.org/nabm/index.jsp?lang=EN&proj=77		

Terrestrial Natural Heritage		
Area of Interest: Marsh health and state		
Tool: Marsh Monitoring Protocol – Durham Coastal Wetland		
Purpose: To provide information about wetland turbidity and water levels as well as population trends for calling frogs and toads and birds as indicators of marsh health, and to contribute to understanding their habitat needs[1].		
Data Collection Methods: Described in the Durham Region Coastal Wetland Monitoring Program[2]		
✓ **Monitoring Standards Established**		
Partner(s): CWS, Regional Municipality of Durham		**Memorandum of Understanding Present**
Tasks: GRCA carries out sampling in partnership with CLOCA as needed. CWS helps guide the program. Other partners exist within the program.		
Training: On the job, literature – specialized in identifying species visually and auditory. Marsh Monitoring Protocol training.		
Scale: Regional to habitat; coastal marshes (Port of Newcastle Marsh and Wilmot Marsh).		**Station State:** Permanent, 5 stations.
Frequency: Spring, sample 3 times for frogs and 2 times for birds. Wetland water levels and turbidity sampling occurs 4 times a year (once a month) in the summer.		**QA/QC:**
Target: none, surveillance		**Indicator:** breeding birds and frogs. Water levels and turbidity.
Data Limitations: Timing and weather can cause problems with data. Ensuring adequate coverage is an issue.		
References: [1]http://www.on.ec.gc.ca/wildlife/wildspace/project.cfm?HoldID=I62&Lang=e [2]Durham Region Coastal Wetland Monitoring Project: 6-Year Technical Report Module 1 – Introduction and Assessment Methods		

Terrestrial Natural Heritage		
Area of Interest: Wetland health and state		
Tool: Roadside frog surveys		
Purpose: Understand wetland health, population state and distribution of amphibian species.		
Data Collection Methods: Modified methods from the Durham Region Coastal Wetland Monitoring Program[1]		
✓ **Monitoring Standards Established**		
Partner(s): None		**Memorandum of Understanding Present**
Tasks: GRCA conducts all aspects of the forest frog monitoring program.		
Training: On the job, literature, must know all frog species by sight and call.		
Scale: Landscape		**Station State:** permanent
Frequency: Annual		**QA/QC:**
Target: none, surveillance		**Indicator:** sensitive frog species
Data Limitations: need skilled people to identify frogs auditory. Difficult to get survey during peak breeding for all species.		
References: [1]Durham Region Coastal Wetland Monitoring Project: 6-Year Technical Report Module 1 – Introduction and Assessment Methods		

Terrestrial Natural Heritage		
Area of Interest: Terrestrial invasive plants		
Tool: Terrestrial invasive plant survey		
Purpose: Determine the extent of invasive terrestrial plant species and set control priorities.		
Data Collection Methods: Roadside and trail side surveys and active searching.		
✓ **Monitoring Standards Established**		
Partner(s): OIPC, OFAH, other conservation authorities		**Memorandum of Understanding Present**
Tasks: GRCA collects/records speices, quantity and location data as plants are encountered.		
Training: On the job, literature, identification skills of major species.		
Scale: Landscape		**Station State:** n/a
Frequency: Continuous		**QA/QC:** verification of plant identification
Target: none, surveillance		**Indicator:** specific plants and vegetation community health.
Data Limitations:		
References: Ganaraska Region Conservation Authority Priority Invasive Species Inventory Methods, June 2014. EDDMapS Ontario website.		

Terrestrial Natural Heritage		
Area of Interest: Land Cover Characteristics		
Tool: Ecological Land Classification		
Purpose: Delineate landscape by different characteristics		
Data Collection Methods: Defined in Lee et al. 2001[1]		
✓ **Monitoring Standards Established**		
Partner(s): None		**Memorandum of Understanding Present**
Tasks: GRCA conducts all aspects of ELC		
Training: On the job, literature, ELC course		
Scale: Regional		**Station State:** n/a
Frequency: As updated air photos become available or as field visits need to be conducted.		**QA/QC:** field visits can occur to verify desk top exercises
Target: none, surveillance.		**Indicator:** n/a
Data Limitations: based on individual interpretation.		
References: [1]Lee, H.T. et. al. 2001. Ecological Land Classification for Southern Ontario: Training Manual. Ontario Ministry of Natural Resources, SCSIS Training Manual TM-01.		

Lake Ontario Shoreline		
Area of Interest: Costal Geomorphology		
Tool: Shoreline erosion monitoring Stations and lake level gauges		
Purpose: Monitor shoreline erosion and understand lake high water events. Future forecasting and warning element may be integrated.		
Data Collection Methods: Survey shoreline and access lake level gauges. Should incorporate photo interpretation.		
✓ **Monitoring Standards Established**		
Partner(s): EC		**Memorandum of Understanding Present**
Tasks: GRCA conducts surveys; Environment Canada operated lake level gauges.		
Training: On the job, literature		
Scale: defined reach and site		**Station State:** Permanent
Frequency: Survey once every five years. Lake level data collected hourly.		**QA/QC:**
Target: surveillance to determine bets erosion offset limit/hazard line		**Indicator:** recession rate
Data Limitations: The Sandwell report needs updating (base data). Limited stations, not all shoreline reaches covered. Delta S needs to be defined (extent and removal of dynamic beach).		
References: Sandwell Swan Wooster Incorporated. 1990. Lake Ontario Shoreline Management Study. In association with Beak Consultants Limited and EDA Collaborative. Submitted to the Central Lake Ontario Conservation Authority, Ganaraska Region Conservation Authority and Lower Trent Region Conservation Authority.		