



Ganaraska CONSERVATION

Ganaraska Region Monitoring Report

2018

Executive Summary

The Ganaraska Region Conservation Authority (GRCA)'s Monitoring report is to present a summary on the interactions and interdependencies of land use and water resources within the GRCA watershed. Traditional practices look at ecological and socio- economic pressures in isolation thereby reducing environmental systems to their constituent elements. This report will provide readers with a more comprehensive understanding of the linkages between water, land and human activity within the GRCA watershed.

In order to assess or conceptualize potential issues within a watershed enough information must be available to define vulnerabilities and risks. Monitoring is an important characterization procedure for this purpose. The use of indicators within a hydrologically-bounded system, such as a watershed, provides a logical entity to determine baseline conditions, trends and changes and are applied here to describe the present conditions within the GRCA watershed.

The GRCA carries out several monitoring activities, including terrestrial, aquatic, climatological, ground, and surface water quantity and quality measurements. This report provides a snapshot of the current conditions with respect to quality and quantity of water; land use and land cover patterns and fisheries.

Ecological Land Classification (ELC) classifies ecologically distinct areas that describes various systems to indicate natural regions based on ecological factors and is applied in order to assess the various land usages within the jurisdiction of the GRCA. The assessment determines the classification as follows: Forest cover 34.1%, which is slightly higher than the suggested target of 30% advocated as minimum coverage for watershed health (Environment Canada 2013). Further classification reveals that the current wetland cover is approximately 1.4%, water covers about 0.3%, beaches and bluffs about 0.1%, urban surfaces about 11% and meadows about 8%, where only a small fraction is comprised of native tallgrass prairie, which is an exceedingly rare ecosystem. The land usage most prominent within the GRCA is agricultural land with about 45%.

Climate variables within the GRCA watershed are measured for air temperature and precipitation, including rain and snow. The data collected quantifies daily weather conditions and is used to determine long-term averages and trends of temperature and precipitation, annual and seasonal changes and extremes. Average annual precipitation ranges around 850 mm, however during dry years such as 2016 approximately 300 millimetre (mm) less rainfall occurred which resulted in severe drought conditions and shallow aquifer depletion.

Groundwater level and quality measurements are carried out in partnership with the Ministry of Environment, Conservation and Parks. The water quality index of groundwater scores mainly in the range of excellent to good. Although some wells show an increasing trend in chloride and nitrate, their measured concentrations remained well below the threshold values suggested by Ontario Drinking Water Standard (ODWS). The indicators, nitrogen and chloride, provide, even if only very minor, a view into anthropogenic alterations to this resource. Higher chloride concentration in groundwater are observed mostly near roads or storage of salt for de-icing purposes.

A baseflow index is employed to determine the contributions of annual average baseflow to annual streamflow discharge throughout the year. The BFI is generally used as an indicator to determine the impact of urban cover after development. However, it can also be used to estimate the influence of different geology or land use practices within catchments. The contributions of baseflow vary for Cobourg Creek, Wilmot Creek and the Ganaraska River.

Streamflow of the Ganaraska River can be composed of up to 65% baseflow compared to 61% baseflow contribution for Wilmot Creek and 51% for Cobourg Creek indicating that groundwater is a major contributing resource to streamflow within these basins. Baseflow contributions increase over the time of record and show a statistical significant increase for the winter season within the Ganaraska River basin and is also statistical significant for Wilmot Creek throughout the period of record. These results may point to a change of the freezing – thawing cycle within the two sub-catchments. Cobourg Creek on the other hand exhibits an overall decreasing trend in baseflow contributions, which could be an effect of increased urbanization. However, to determine whether the causes of the trends observed correspond to precipitation increases/decreases, warmer temperature or less storage, a more detailed study is necessary.

Similar to groundwater, surface water is collected in partnership with the Ministry of Environment's Provincial Water Quality Monitoring Network (PWQMN). In addition, the GRCA operates several water quality stations within the watershed that provide additional information on the changes to water quality. A Water Quality Index calculator (WQI; CCME 2001) is employed to summarize water quality within the watershed. The WQI was developed to provide a means to calculate complex water chemistry data into an index using a score system based on Provincial Water Quality Objectives (PWQO; MOE 1994) and Canadian Council of Ministers of the Environment (CCME; CCME 2001) guidelines. Water chemistry results in 2016 show a range from Excellent to Poor. Poorest water quality is measured at the stations in Orono and Foster Creek eluding to agricultural and urban impacts on surface water quality. Similarly, Cobourg, Midtown and Brock Creek outlets exhibit marginal water quality indicating that urbanization has an effect on water quality at the outlets of the creeks. Excellent to Good water quality is observed at Ganaraska River 4, Cobourg Creek at Dale and Upper Gages Creek eluding that at these stations water quality has not been effected by either agricultural practices or urban development.

Analysis of trends in nitrate, chloride and phosphorous shows that nitrate and chloride concentration increase over the course of records and phosphorous is declining.

Fish communities appear to be in good or excellent condition within the GRCA watershed. Fair to Poor conditions are mainly found where urbanization occurs.

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1.0 Ganaraska Region Watershed Monitoring Program

1.1 Introduction

Monitoring programs are fundamental to understanding watershed health in any watershed. Collecting baseline data gathers necessary information in order to provide answers for ecological and hydrological processes within the watershed, quantify various watershed parameters, and assist setting realistic and achievable future program targets to ensure meaningful management actions.

The health of watersheds as well as their features and functions within the GRCA vary; 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.

This report provides a snapshot of the current conditions with respect to quality and quantity of water; land use and land cover patterns, and fisheries. The findings presented are gathered on a coordinated, partnership basis using data and information from various sources including Ganaraska Region Conservation Authority (GRCA) monitoring recordings, provincial and federal data collections, research findings, and Ontario terrestrial and aquatic databases.

1.2 Purpose

The purpose of the Ganaraska Region Monitoring Program 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.

1.3 Goal

The goal of the GRCA watershed monitoring program is to collect scientifically defensible, 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.

1.4 Objectives

In order to implement an effective GRCA watershed monitoring program, the following objectives must be satisfied:

- Analyze and evaluate the past and current trends of watershed features and functions;
- Identify areas and activities (natural or human) that have an impact on watershed features or functions;
- Create a monitoring program that is flexible and adaptable to emerging issues (e.g., invasive species or climate change) as well as 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); and,

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

1.5 Approach

In developing a watershed monitoring program, questions should be posed as to what needs be considered when seeking methods, selecting sites, and identifying indicators and targets. The following are some generalized questions being asked regardless of spatial scale. Some of these questions will attempt to be answered in this report.

- 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?

2.0 Terrestrial Natural Heritage Monitoring

2.1 Introduction

Terrestrial natural heritage includes forest, wetland, grassland, beach and bluff habitats and their associated species. Maintaining terrestrial natural features is important for water retention, soil development, erosion control, local climate regulation, and support of biodiversity. The quantity and quality (or health) of these features is therefore important and monitored within the GRCA watershed. The GRCA considers terrestrial natural heritage at landscape, vegetation community, and species levels all of which, affect one another.

Changes at the landscape scale are measured for the entire GRCA watershed area by calculating difference in the total cover of various types of vegetation and land use each time the data is updated based on more recent air photos. This calculation can look at broad habitat categories like forest, or it can focus on more specific types of vegetation, such a particular forest or wetland types as a means of tracking vegetation communities.

Some conservation authorities have plots in numerous habitat types across their watershed in which they record all species of plant and the presence or absence of indicator species according to set protocols. Changes in these, over time can give some indication of the health of these communities. Currently, this level of effort is beyond the capacity of GRCA staff, and we are restricted to monitoring specific indicator species in several forest and wetland sites as a very rough proxy of terrestrial ecosystem and species health. Further, GRCA has recently used roadside mapping of invasive plants to provide some idea of the extent of this threat to terrestrial ecosystems in its watershed.

2.2 Vegetation and Land Use Cover

2.2.1 Methods

The GRCA has used the Ecological Land Classification System for Southern Ontario to remotely map watershed vegetation to the Community Series level. Additionally, land uses such as agriculture, rural residential and urban have been mapped to provide complete landscape cover mapping (Figure 1). Subsequent updating of this data using up-to-date air photography allows for measurement of changes in these.

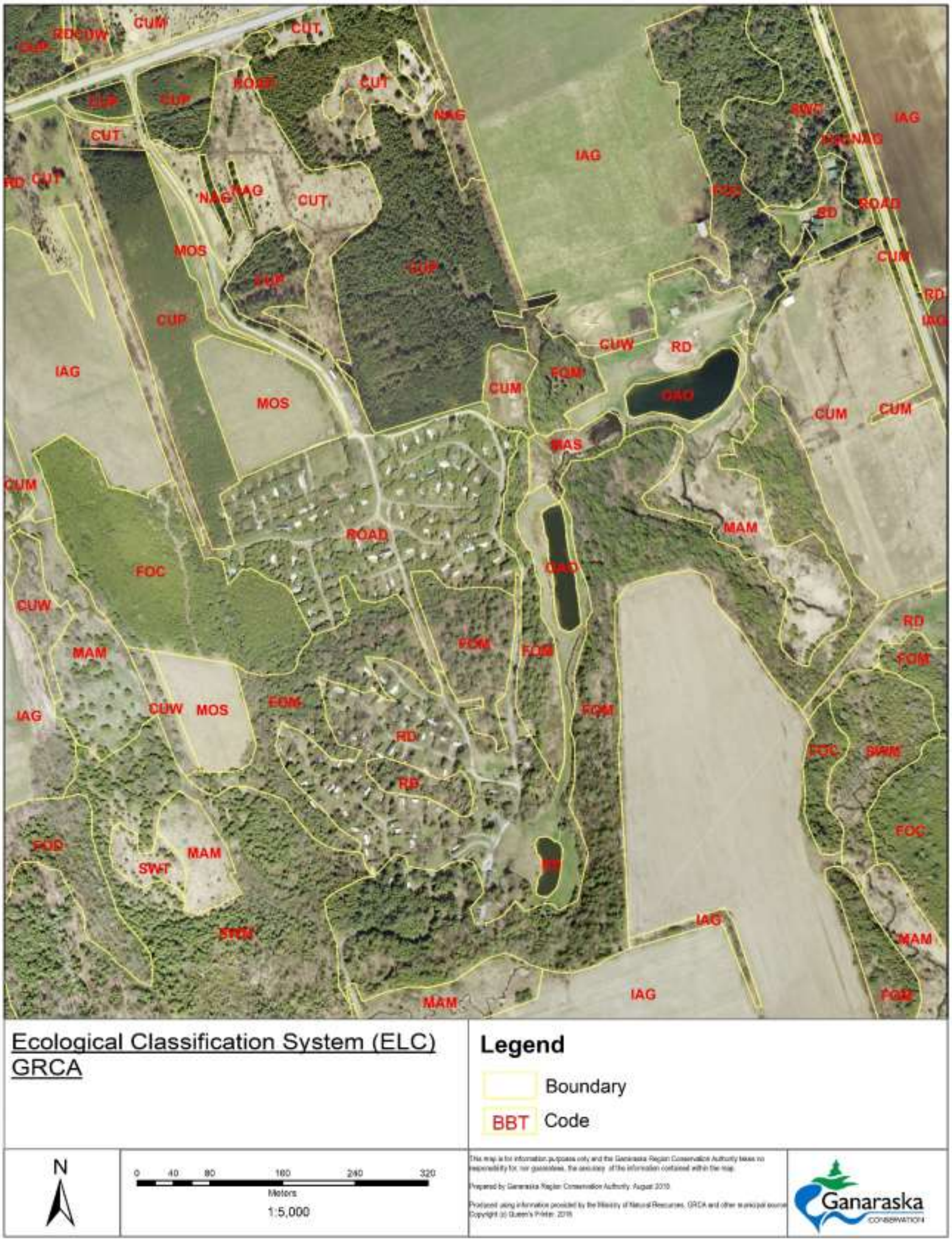


Figure 1: Sample of GRCA's Ecological Land Classification System Mapping

For watershed reporting it is not necessarily important to measure changes in individual vegetation types; general categories suffice. Thus, for example coniferous, deciduous and mixed forest can be combined with cultural plantations to calculate percent cover of a broader category such as forest. Similarly, shallow marsh, meadow marsh, thicket swamp and forest swamp can be combined to calculate percent cover of wetlands.

As the context for every watershed is different and the landscape is naturally dynamic, it is not possible to determine what exact percent coverage of forest or wetland, for example, is healthy for that particular watershed. Historically one watershed may have had less or more cover of these major habitat types than its neighbours. In short, there is no exact figure for the "right" amount of habitat required to make a given watershed healthy. Nevertheless, the federal government has come up with some guidelines for forest and wetland cover, and existing conditions can be compared with these (Environment Canada 2013). Using these guidelines, trends showing an increase in natural cover in the GRCA towards reaching or exceeding these targets would indicate an improvement, whereas continued loss would be detrimental.

Given the size of the entire GRCA watershed, small, incremental changes in habitat cover or land use do not make much noticeable difference. However, if updates to the data set were to occur at five year intervals, trends might be evident. Accuracy becomes diminished with smaller datasets. It is also affected by misinterpretation of land uses or vegetation and subsequent correction of feature labels, as well as changes in skill level of subsequent interpreters.

2.2.2 Results

The Total cover (in Hectares) of major habitat and land use types in the GRCA watershed is as follows:

Forest	39,827
Wetland (non-treed)	1,644
Meadow	9,463
Beach/Bluff	91
Open Water	330
Urban	13,109
Rural/Agriculture	52,245

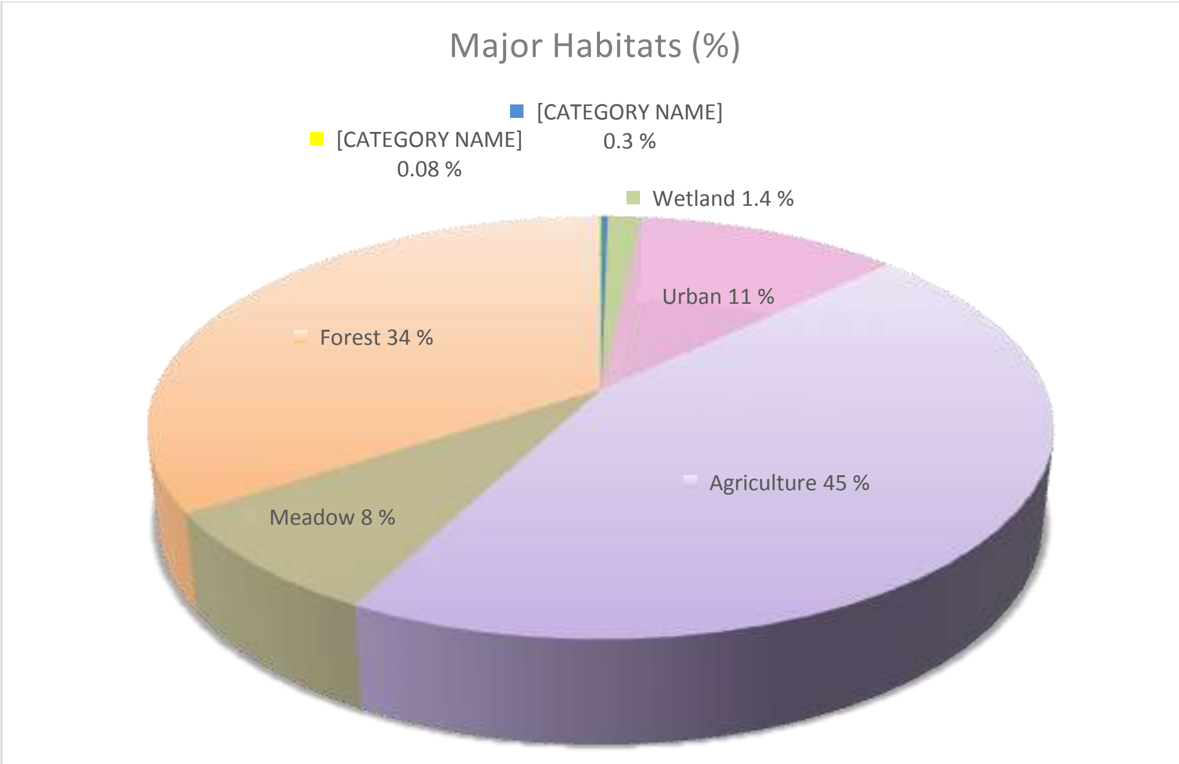


Figure 2: Percent Cover of Total GRCA Watershed Area Made Up of Major Habitat Types and Land Uses

It is important to note that treed wetlands or swamps, can be considered both forest and wetland. In the above statistics they are included under the forest cover to avoid double counting, and as a result the wetland figure includes other wetland types only and is not a full accounting of total wetland area.

The following breakdown of wetland cover includes treed wetlands:

Wetland Cover	*Hectares*
Open Fen (FEO)	0.80
Meadow Marsh (MAM)	513.94
Shallow Marsh (MAS)	300.24
Shallow Floating Aquatic Vegetation (SAF)	23.33
Shallow Aquatic Submergent Vegetation (SAS)	353.37
Coniferous Swamp (SWC)	1247.46
Deciduous Swamp (SWD)	528.66
Mixed Swamp (SWM)	4374.79
Thicket Swamp (SWT)	453.10

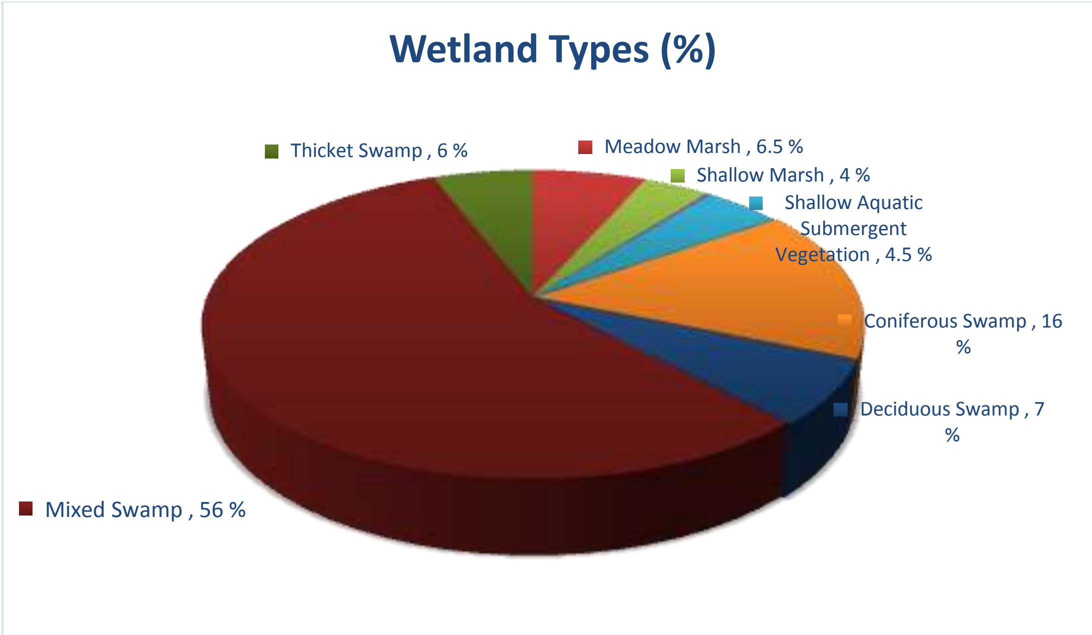


Figure 3: Percent Cover of Individual Wetland Types a Components of Total Wetland Area

An interpretation of these major habitat types is provided in the "Conclusions" section of this report. It is anticipated that new air photo images will become available on a five-year cycle beginning in 2018. Subsequent revisions to the ELC layer as these become available can be used to determine trends in habitat and land use cover.

2.2.3 Recommendations

Changes in Vegetation and Land Use Cover

The current ecological land classification and land use mapping for the GRCA watershed is recent, and therefore no trends can be discerned at this time. Nevertheless, we can attempt to draw some conclusions on the health of the watershed based on existing conditions.

Current forest cover is at 34.12 percent. This is much higher than watersheds in the Greater Toronto Area and southwest Ontario. It is slightly above the target of 30 percent cover that has been widely advocated as minimum for watershed health (Environment Canada 2013). In this respect, the GRCA watershed has good forest cover in comparison to many others. However, considering that forest is the type of vegetation that the landscape naturally reverts to and that a very high percentage of forest is likely the natural state, there is clearly room for improvement. The most recent 'How Much Habitat is Enough?' guidelines suggest that there should be 40 percent forest cover (as a medium risk approach and 50 percent as a low risk approach (Environment Canada 2013)). It is also worth noting that the distribution of this forest cover is skewed towards the stream headwaters and is largely made up of the Ganaraska Forest, while the lower reaches of most watersheds have a much lower percentage of forest cover. Therefore, the upper watersheds could be said to have excellent forest cover, while the lower watersheds have only poor to good conditions.

It can be difficult to determine what is a good versus a poor percentage of wetland cover given that different soil conditions can support different degrees of drainage. Therefore, some landscapes or watersheds historically and naturally have had more wetland than others would. According to the ELC mapping, the GRCA watershed currently has 0.28 percent wetland cover.

In 2010, Ducks Unlimited published a report on wetland loss by county in Ontario. This report is based on a rough estimate of the original wetland cover (Ducks Unlimited 2002). For Durham Region, it is estimated that 12,520 ha of wetland has been lost between the 1800's and 2002, representing 38.2 percent. In Northumberland, the figures are 12,256 ha representing 43 percent of the estimated original cover. These are substantial amounts, and it is likely that most of this area was comprised of forest and thicket swamp, which are difficult to restore. At any rate, the figures suggest that there was once much more wetland than there are currently and that increasing wetland cover would be beneficial to watershed health.

"Meadow" is defined here as a major habitat typically refers to old field or fallow field, which might be argued, are not entirely ecosystems. Only a very small fraction of the mapped meadow habitation is made up of native tallgrass prairie, which is an exceedingly rare ecosystem. Nevertheless, many species of insects and birds, including species at risk such as Monarch, Eastern Meadowlark and Bobolink, rely on meadow habitat to survive. Therefore, as it is not entirely natural, yet it can be important for the conservation of some species, it is difficult to suggest what is an appropriate amount of meadow cover within a watershed.

The land cover data can also over time give us a sense of how much "urban" development is occurring and the degree to which it is displacing natural environments. We know urban and rural development cover is increasing, but so may be natural cover. Only long-term, detailed, on-site, species surveys would determine the quality of this natural cover

To Apply remote sensing for biodiversity conservation as it is a useful tool to determine land use change. This will involve linking remote sensing capabilities to practical and strategic environmental and conservation applications to better address the state of and change of managed natural systems.

2.3 Terrestrial Invasive Plants

Invasive plants can pose a serious threat to the biodiversity of terrestrial and aquatic ecosystems, and the presence of large infestations of them within the ecosystem certainly is an indicator of poor health. If the GRCA had forest monitoring plots, the appearance and spread of these would indicate degradation. However, at the same time, there would be a temptation to simply remove them from the plot rather than allowing them to take over. At any rate, their presence in one or several plots would not indicate that they are present in other similar habitats across the watershed.

In order to get a rough idea of what major invasive plants are located in the watershed, GRCA initiated roadside mapping to look at existing conditions and to set a baseline for looking at the introduction and spread of these over time, ideally on a five-year basis. This involves driving every road in the watershed at peak season (mid-summer), with a person trained in plant identification as a spotter and recorder. Not all invasive plants are recorded. European Buckthorn is not as it is ubiquitous in the landscape. Garlic mustard, on the other hand, is often too difficult to see from a passing vehicle. Therefore, only species that are easily spotted are targeted. Sightings are recorded initially on hard copy maps and later transferred to the Early Detection & Distribution Mapping System (EDDMapS) provincial database and to GIS.

2.3.1 Methods

Invasive Plants – Indicator of Quality

Figure 4 shows a sample of the baseline mapping of major invasive plants along roadsides in Clarington. The watershed results portion of the survey indicate that dog-strangling vine is already well established throughout the GRCA watershed, with larger infestations toward the northwest. Phragmites is also widespread, with significant infestations along busiest roads. Japanese knotweed is appearing sporadically throughout the watershed, with higher concentrations appearing in and around Cobourg. Himalayan balsam and giant hogweed appear to be moving from the west into the GRCA watershed while wild parsnip is appearing sporadically not far from the Highway 401 corridor and appears to be moving from east to west. Future surveys should demonstrate the rate of spread and additional locations of these species.

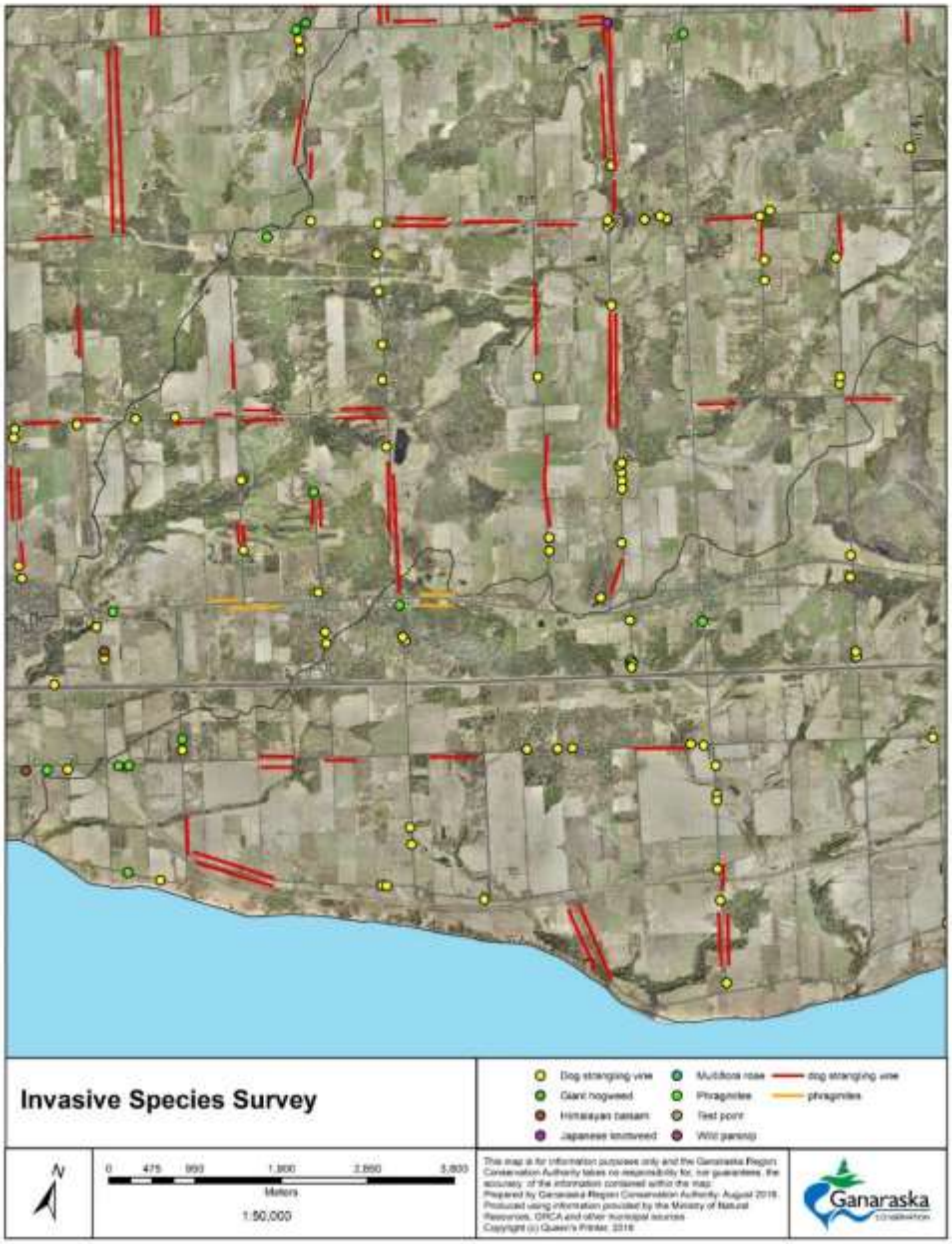


Figure 4: Sample of Invasive Plant Roadside Mapping

2.3.2 Results

Invasive plants can displace sensitive native plants and affect the structure and productivity of ecosystems. In this respect, their presence in large numbers has a negative impact on watershed health. The invasive plant monitoring is done on roadsides only. Therefore, it cannot measure the impact of these plants on ecosystems. However, their presence and abundance can suggest the degree to which they can be present in nearby natural areas. The goal of the monitoring is to get an idea of which species are most abundant and where. The initial survey showed that a number of the major invasive plant species are widely spread within the GRCA watershed. From the records made it would appear that dog-strangling vine is spreading from west to east and wild parsnip from east to west, however given that is a baseline study it is not possible to determine the rate of spread at this point. Ideally, the roadside surveys would be repeated at five year intervals, which would mean

Clarington in 2020, Port Hope in 2021 and 2022. All survey data should be entered on the EDDmapS website.

2.3.3 Recommendations

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 invasive species monitoring system.

2.4 Forest Bird Monitoring

GRCA has actively participated in the Forest Bird Monitoring Program (FBMP) since 2003. The program is administered by Canadian Wildlife Service (CWS) Ontario Region in partnership with the Ontario Ministry of Natural Resources and Forestry and Parks Canada. The goal is to identify trends in Ontario's forest songbird populations and to relate these to landscape change.

2.4.1 Methods

Bird surveys for the FBMP involve 10-minute point counts at locations a minimum of 250 m apart during peak breeding season (June and early July). All birds seen and heard during the count are recorded on field data sheets and later on data summary forms which are sent to CWS.

Due to staff and time constraints GRCA has undertaken counts at only two locations: Thurne Parks Conservation Area and one location in the Ganaraska Forest. The latter site surveys were abandoned in 2011 as a result of difficulties in site access and rough terrain.

Results from only two survey locations cannot be realistically extrapolated to the entire GRCA watershed and it also has to be recognized that during any given year a bird might be present, but did not vocalize during the count. Nevertheless, by using indicator species we can at least have some idea of whether or not the quality of forests is consistent enough to support these sensitive birds over time.
The following is a list of species used and the conditions for which they have been selected as indicators:

> **Eastern Wood Pewee** (EAWP) Special Concern Species. "Although it is not a species that requires large areas of woods (Freemark and Collins 1992), it occurs less frequently in woodlots with surrounding development than in those without nearby houses (Friesen et al. 1995) – Breeding Bird Atlas. EAWP used as indicator of urban intolerance, need for mature enough trees to provide nesting cavities, and is tracked because it is a Species at Risk (SAR) species
>
> **Veery** (VEER). According to Kaufman (1996) prefers damp deciduous woods. "Surrounding habitat usually deciduous woods, sometimes mixed or coniferous woods, or open country on northern Great Plains." According to 2005 Ontario

Breeding Bird Atlas (2007) “the veery is area sensitive, and occupies a variety of woodland types.” VEER is used as indicator of woodland large enough for forest interior and forest interior conditions.

Black-throated Blue Warbler (BTBW). Habitat is “interior of hardwood and mixed deciduous-coniferous forest” (Kaufman 1996). According to the atlas it “has been identified as a forest interior and an area-sensitive species (Robbins et al. 1989).

Ovenbird (OVEN). According to Kaufman it “needs large tracts of mature deciduous or mixed forest for breeding.” Significant decline in population according to the atlas.

Winter Wren (WIWR). According to atlas “breeding habitat is coniferous woodland, especially wetter woodlands, swampy areas and streamside forests. The presence of fallen logs appears to correlate with high population density.

Wood Thrush (WOTH). Ontario Breeding Bird Atlas says area sensitive according to Roth et al. 1996. Significant population declines (BBA) and now a species at risk.

2.4.2 Results

The following graphs show the overall numbers and rough trends in the presence of the selected indicator species at both the Ganaraska Forest and Thurne Parks locations. It is important to note that accuracy of any apparent trend is based on only a small sample over a limited number of years.

Ganaraska Forest:

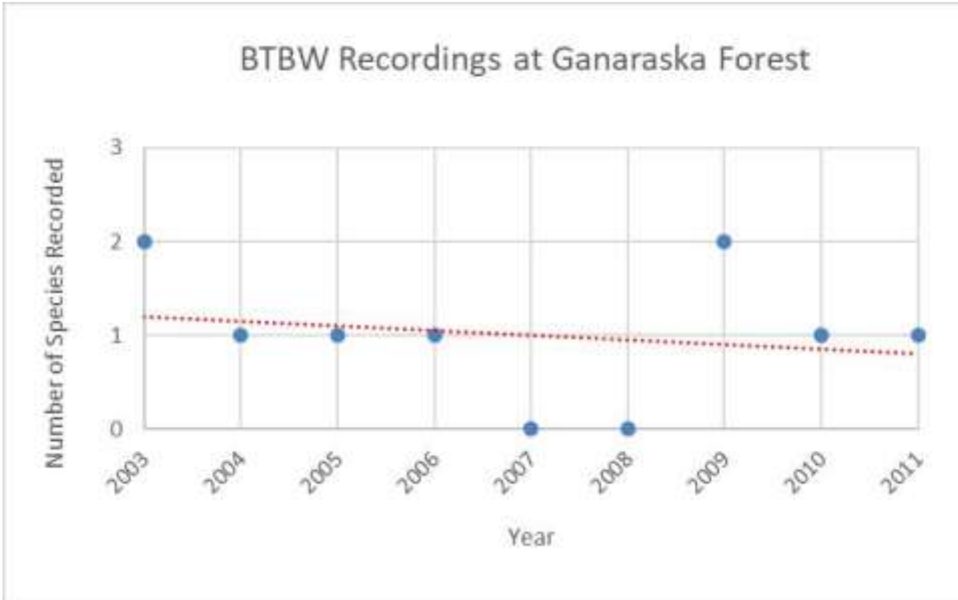


Figure 5: Black-Throated Blue Warbler

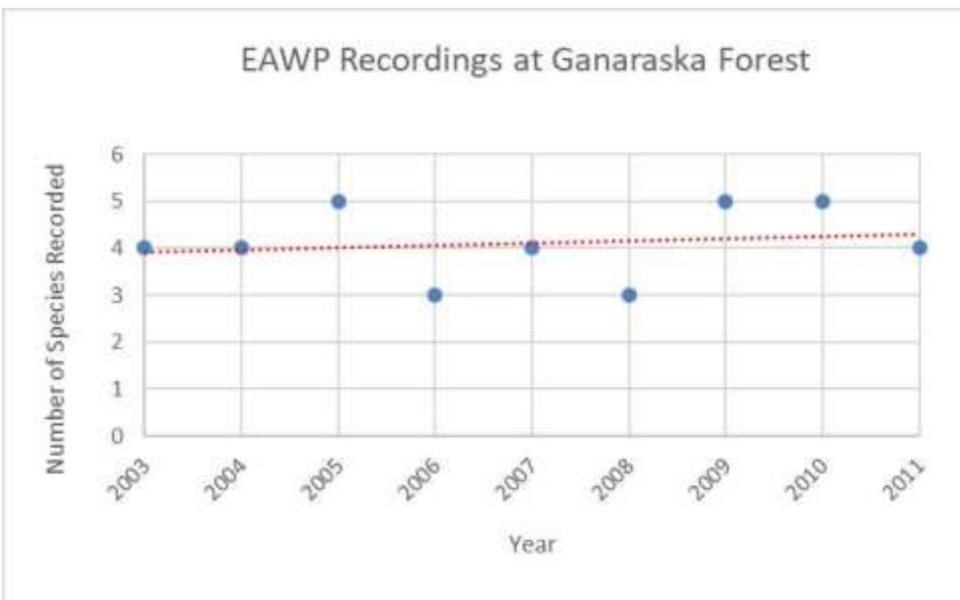


Figure 6: Eastern Wood Pewee

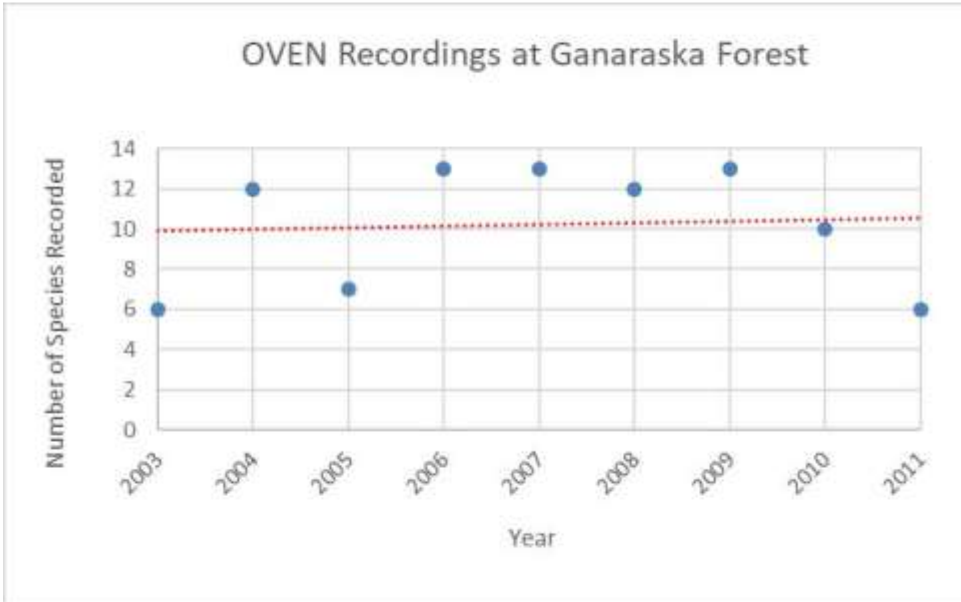


Figure 7: Ovenbird

Figure 8: Wood Thrush

Thurne Parks Conservation Area:

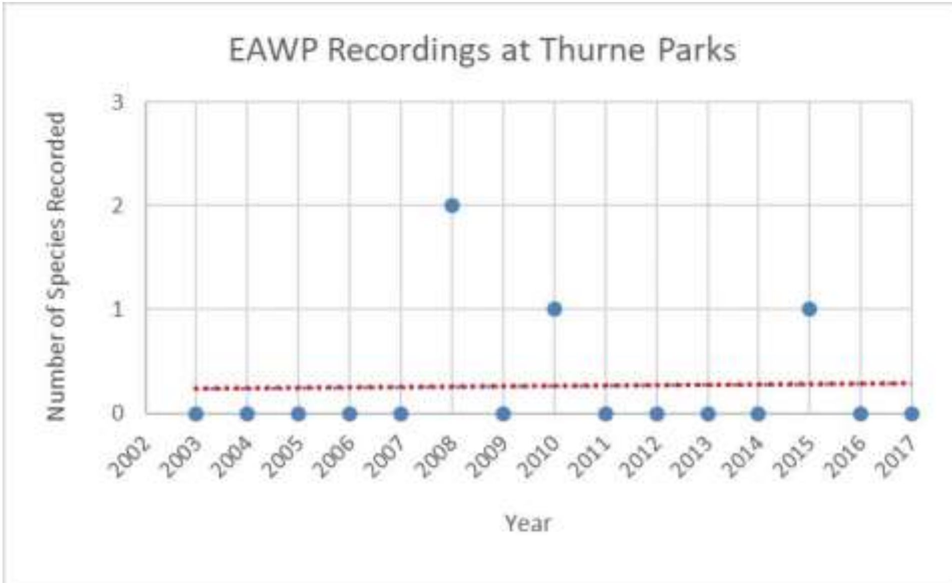


Figure 9: Eastern Wood Pewee

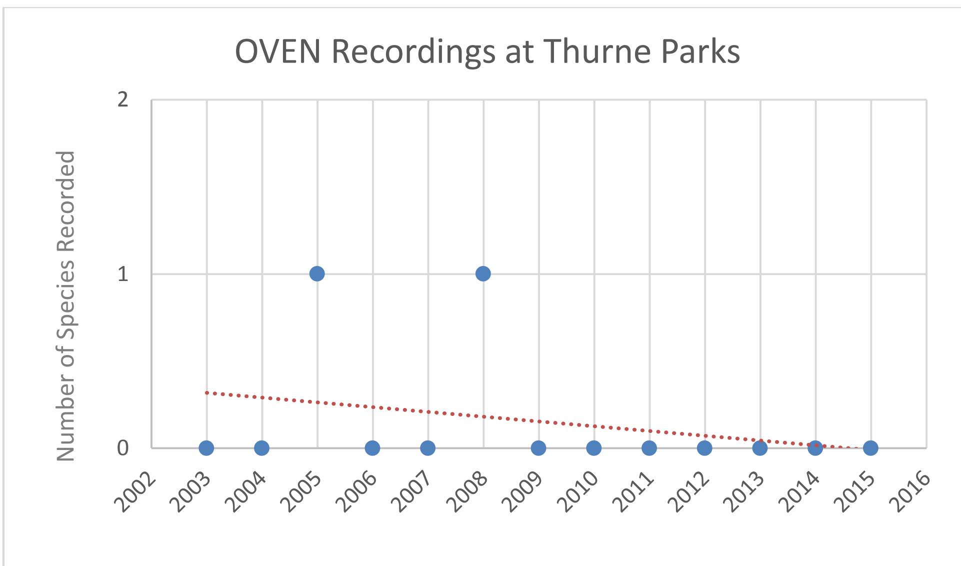


Figure 10: Ovenbird

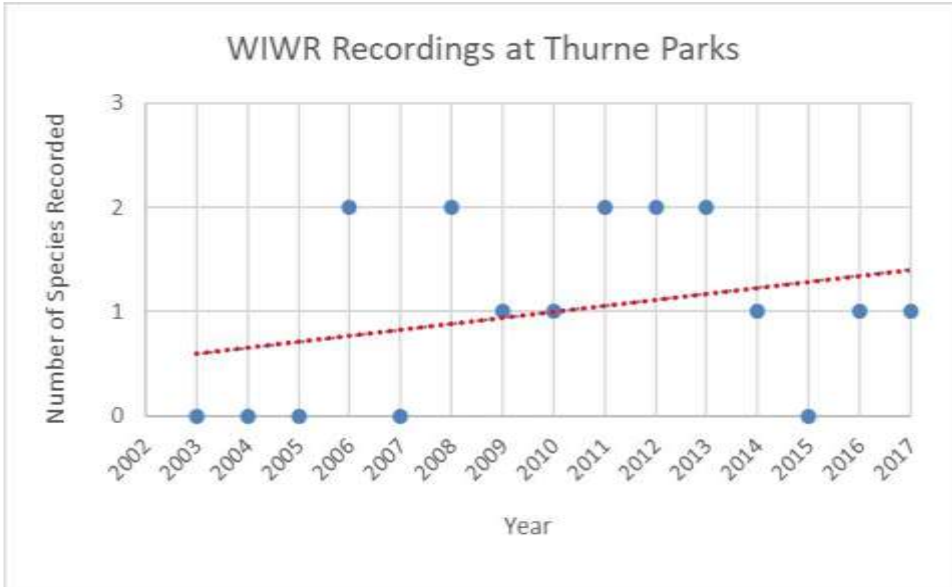


Figure 11: Winter Wren

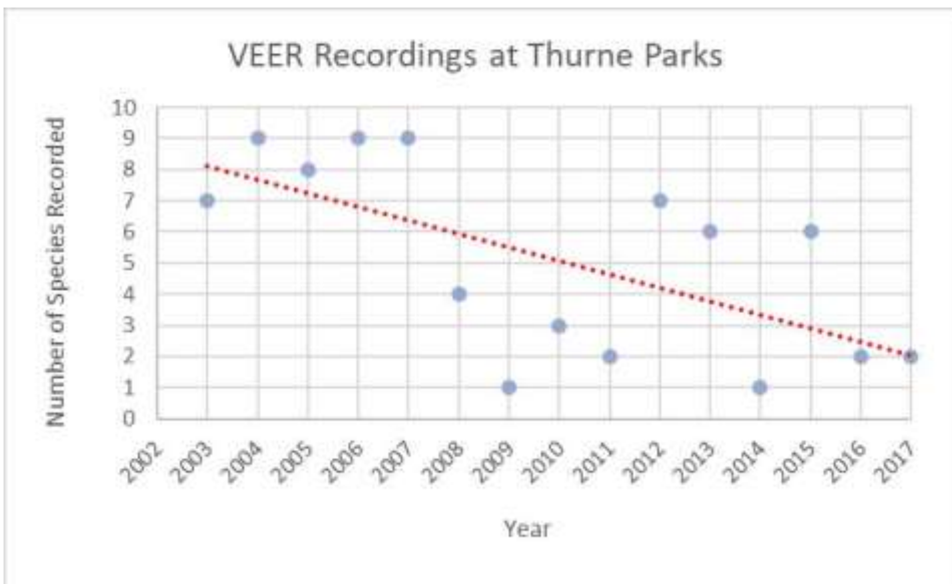


Figure 12: Veery

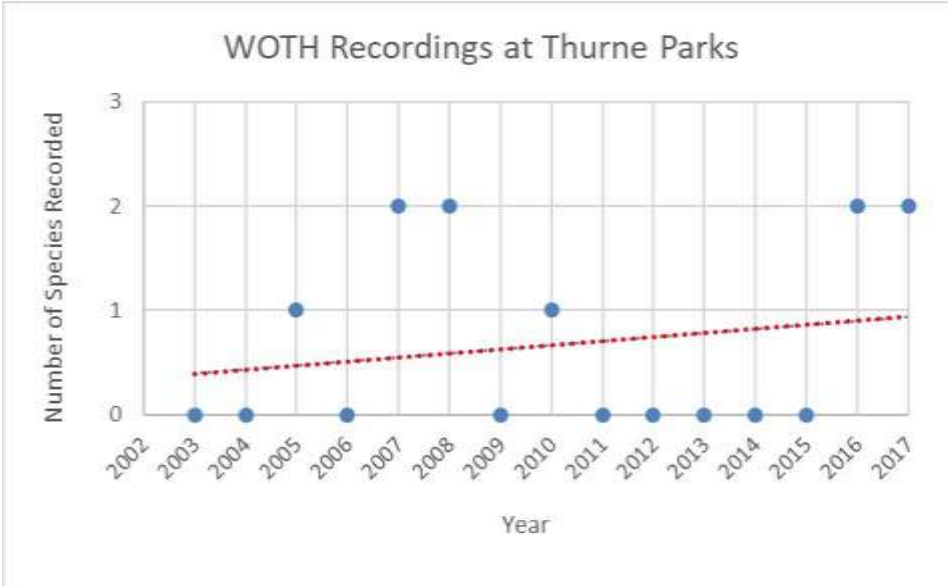


Figure 13: Wood Thrush

2.4.3 Recommendations

Results indicate that for the duration of the survey years, the numbers recorded for most species showed little fluctuation. Therefore, conditions for size and quality of the surveyed forest areas probably changed little, at least in terms of supporting breeding populations of these sensitive bird species. The one exception appears to be the number of Veery recorded at Thurne Parks Conservation Area, which appears to be declining. This should be tracked carefully in subsequent years.

All of these indicator birds are rare or entirely lacking from urban areas and landscapes with little forest cover thus, the presence (and apparently stable populations of these birds) suggests that good quality forest is being maintained. Additional surveys and site assessments in other parts of the watershed have demonstrated that these species are widespread, showing the forest quality over much of the GRCA watershed is good.

The Forest Bird Monitoring program, as is stands provides very limited understanding of population trends of sensitive bird species within our watershed. The data collected is designed to serve a larger continental monitoring system. GRCA should have additional sites throughout the watershed to provide more robust data on the status of birds as indicators of ecosystem and watershed health.

2.5 Wetland Monitoring

The GRCA does not formally monitor wetland health at a watershed scale for two main reasons. The first is a simple issue of time constraints and the second is that there is no protocol in place to monitor for the health of all types of wetland, including shallow marsh, meadow marsh, forest swamp, and thicket swamp, the types most commonly represented in our watershed. Several wetlands that are known to have good populations of sensitive frog species are visited semi-annually to track their continued presence. However, the number of frogs calling at any one time is affected by the amount of water available and weather conditions, particularly temperature. Past attempts at surveys have shown that it is very easy to miss the peak breeding period in any given year, therefore it is challenging to get a clear picture of actual populations. It is even possible to not hear a species for enough years to assume it is no longer present, only to find a full chorus in the same location on a subsequent visit. Thus, a frog that is sensitive to environmental change might appear to be a good indicator, but the inconsistency of their annual activity can lead to false conclusions.

For birds and amphibians, the protocol used is the Marsh Monitoring Program (MMP), which is a bi-national long term monitoring program for the Great Lakes area administered by Bird Studies Canada. All data on these species is sent to BSC and stored in their database. Birds are monitored through 10-minute point counts, and at the same locations, frogs are recorded through 3 minute point counts. Timing of surveys is dictated by the protocol and is designed to coincide with peak bird and amphibian breeding seasons.

GRCA applies the MMP protocol through another program, the Durham Region Coastal Wetland Monitoring Project (DRCWMP), which monitors the health of major Lake Ontario Coastal Marshes found in Durham Region. In the GRCA watershed these include the marsh at the mouth of Wilmot Creek and the Port Newcastle Marsh at the mouth of Graham Creek. The DRCWMP applies indices of biotic integrity to the bird and amphibian data collected for each of the wetlands as one of the measures of wetland condition (Central Lake Ontario Conservation 2009), and it is these results that GRCA makes use of for reporting.

Monitoring of the Lake Ontario coastal marshes is valuable in and of itself to track positive or negative trends in the health of these. However, the condition of these wetlands cannot be extrapolated to an entire watershed for several reasons: 1) it is too small a sample to be statistically valid; 2) the coastal wetlands do not represent all wetland types found in the region; and, 3) the geophysical and hydrological context of a coastal marsh is very different from smaller inland marshes.

2.5.1 Methods

The GRCA wetland monitoring using the Marsh Monitoring Program protocol is limited to two sites in Newcastle. Therefore, as with the forest bird monitoring it provides only a limited understanding of marsh health within our watershed although it does contribute to a larger, continental monitoring effort. As with forest birds, the ideal would be to have similar monitoring occur in inland marshes throughout the watershed. Using LiDAR and Arial photos comparisons can be drawn and it is recommended that this be completed every 5 years.
The wetland monitoring program should be with respect to adding species such as Marsh Wren, extending the monitoring period to insure breeding periods are captured as both date and weather conditions affect success of capturing data.

Changes, recommendations and conclusions of the Bird Studies Canada Marsh Monitoring Programs needs to be reviewed for suggested changes to the GRCA monitoring.

The GRCA should continue to work with Ducks Unlimited and the Ontario Association of Anglers and Hunters in developing programs for the creation, protection and restauration of wetlands.

2.5.2 Results

The Durham Region Coastal Wetland Monitoring Project published a report summarizing health of the monitored wetlands based on indicators used (CLOCA 2009). For bird and amphibian communities indices of biotic integrity were applied and condition grades of poor to excellent provided. For birds, Wilmot Creek Marsh was considered to be in Fair condition and the Port Newcastle Marsh considered to be in Poor condition. For amphibian communities, the respective results were rated Good and Poor. A later publication (Central Lake Ontario Conservation Authority 2011) concluded that there were no significant trends in wetland condition based on either the bird or the amphibian data.

The Marsh Monitoring Program is designed to track birds and frogs not as indicators, but rather to determine population trends in the Great Lakes region for these species. Several marsh birds are of particular concern because of general declines in their populations. These are considered to be “focal species” in the program. Of them, the Virginia Rail (*Rallus limicola*) has been recorded twice only, both occasions at the Wilmot Creek Marsh, while the Least Bittern (*Ixobrychus exilis*) - a species listed as “Threatened” in the province - has been heard once only, at the Port Newcastle Wetland. In both cases these birds were recorded only in the first of the two surveys that take place annually during breeding season, suggesting that they may not have remained on site to breed. This may mean that the habitat is unsuitable for breeding. If so, it may be indicative of poor wetland quality. However, the lack of breeding populations may also be due to lack of suitable food, or to disturbance by humans; both of which might result in unsuitable habitat. This may not reflect the actual health of the wetland.

No other birds that can be considered rare or sensitive, have been recorded during the surveys. The lack of species such as Marsh Wren (*Cistothorus palustris*), which is typical of large cattail marshes, could suggest overuse by people. However, it may also simply be that this marsh is not large enough to support a population of this areas-sensitive species.

Only a few frog species have been recorded in the two coastal wetlands being monitored. Green Frog (*Lithobates clamitans*) appears to be the most common, however, it is not a sensitive species, therefore it cannot be considered a reflection of wetland quality.

The Leopard Frog (*Lithobates pipiens*) has been heard only occasionally and in small numbers at the Wilmot Creek marsh and in the stormwater pond at Port Newcastle. This might be because this species tends to call more during the day than the evening, when the surveys are undertaken. It could also be due to the urbanization of the upland habitat surrounding these wetlands that the frogs require outside of breeding season.

Wood Frogs (*Lithobates sylvaticus*) are perhaps the most sensitive species recorded during the surveys. These frogs breed in swampy areas and spend the remainder of the year in forests, therefore require sufficient quantity of both habitats in close proximity. A small number of Wood Frogs have been recorded consistently in the Wilmot Creek marsh.

Spring Peepers (*Pseudacris crucifer*) have been heard only occasionally at both monitored wetlands. These frogs tend to be sensitive to urbanization as they are rare or absent in cities. Strangely, during one spring only, hundreds of these frogs were heard during the point count while in previous and subsequent years few, and occasionally none are heard. This suggests that timing is critical for these surveys, and that being at the site during peak breeding can be a hit or miss affair.

Figure 14 is a graph released by Bird Studies Canada to show a cross-section of bird species whose populations have increased, remained stable, or decreased in the Great Lakes region from the time of the Marsh Monitoring Program's inception in 1995 to 2014.

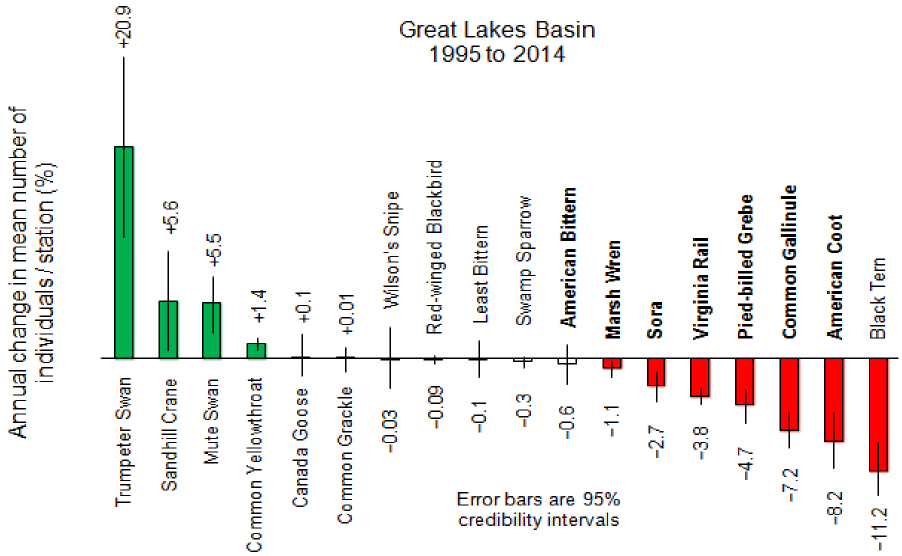


Figure 14: Cross-Section of Bird Species Populations

2.5.3 Recommendations

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.

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.

2.6 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 GIS to develop a landscape resistance model based on the approach by Gunson et al. (2012), when a

Habitat Suitability Index was employed to identify potentially significant wildlife corridors and habitat linkage zones bisected by roads.

Another new program being considered is to work with the Ministry of Natural Resources and the Ministry of Agriculture and Food to share 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.

3.0 Weather Monitoring

3.1 Introduction

Weather variables are the major drivers within a watershed determining the character of an ecosystem and provide healthy, clean water to human beings. Deviations from the norm, such as extreme precipitation or lack thereof, hot temperatures in summer or warmer temperature during winter can cause drought or flooding and may result in a shift of flora and fauna communities within the watershed that adversely affect humans.

3.2 Methods

The weather variables measured within the GRCA watershed include: precipitation, air and water temperature, wind speed and direction, soil moisture, solar radiation, snow depth, barometric pressure, and relative humidity. The data collected quantifies daily weather conditions and is used to determine long-term averages and trends of temperature and precipitation, annual and seasonal changes and extremes. The GRCA operates a number of weather stations with varying levels of instrumentation. This network is created to provide real-time data to the Flood Forecasting and Warning program, but also provides valuable data for the Low Water Response and other watershed monitoring programs.

3.2.1 Precipitation

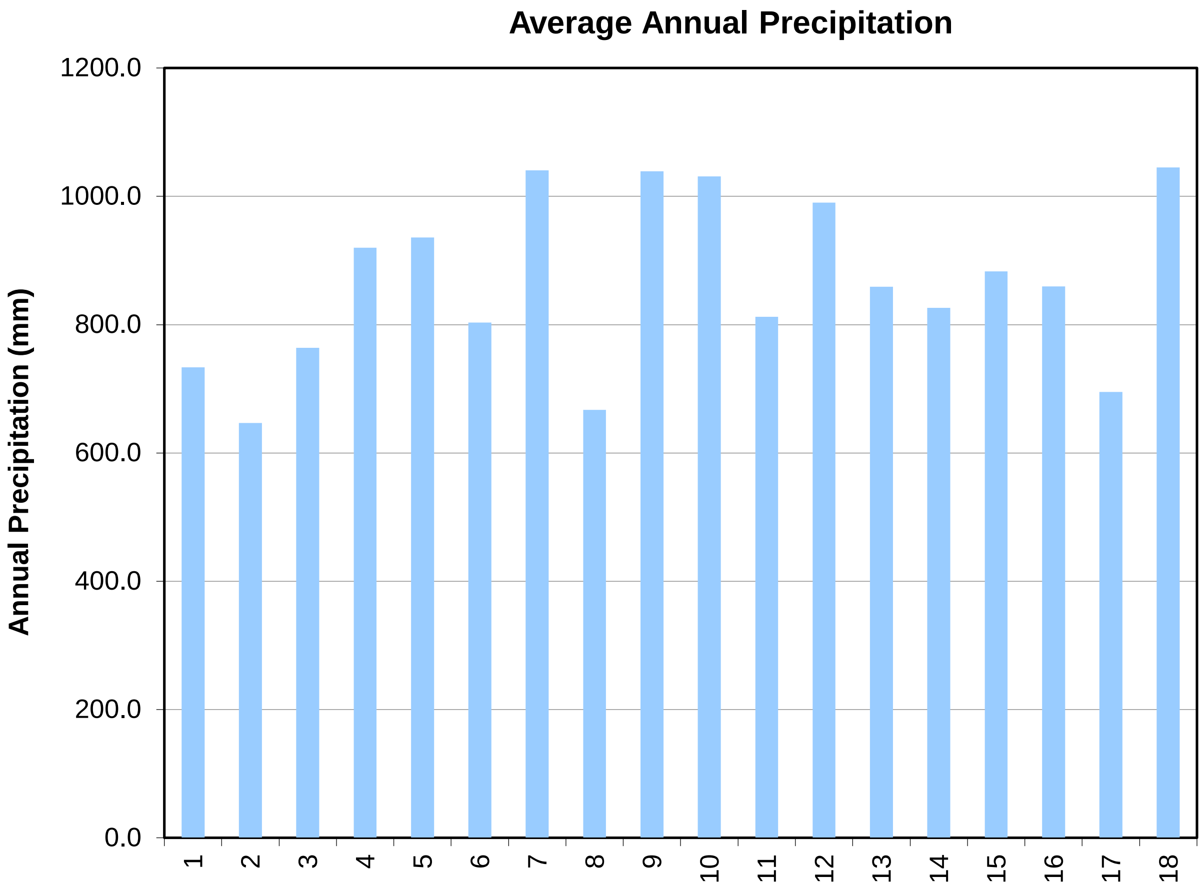
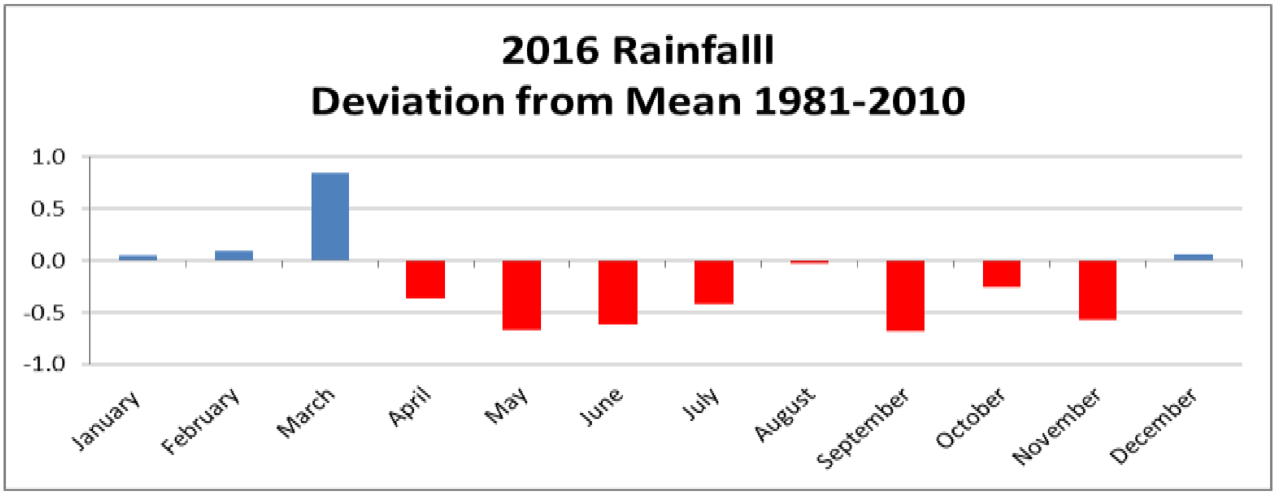


Figure 15: Annual Precipitation Since 2000

Precipitation values are summarized and averaged over the GRCA watershed, as shown in Figure 15. Average annual precipitation ranges around 850 mm. However, during dry years such as 2001, 2007 and 2016, approximately 300 millimetre (mm) less rainfall occurred resulting in drought conditions within the watershed.



	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Precipitation (mm) **2016**	69.8	58.80	104.80	48.2	27.2	31	37.6	69.3	29.6	56.5	40	80.4
EC Normals (mm)	66.7	54.11	56.84	76.2	81.2	80.5	64.8	71.7	93.2	76.3	93.2	75.78
Difference	3.08	4.69	47.96	-28.0	-54.0	-49.5	-27.2	-2.4	-63.6	-19.8	-53.2	4.62
Deviation +/-	0.0	0.1	0.8	-0.4	-0.7	-0.6	-0.4	0.0	-0.7	-0.3	-0.6	0.1

Figure 16: Results and Graphical Illustration for Long-Term Mean Deviation of Precipitation Within the GRCA

3.2.2 Air Temperature

Annual air temperatures have increased up to 1.4°C over the last 50 years in Ontario (Environment Canada, 2006). Climate Conditions for the GRCA watershed have been prepared by SENES Consulting for the area that covers Durham Region until a full assessment can be carried out using GRCA weather stations. The SENES study is based on data collected from 2000-2009 and provides projections of both climate averages and weather extremes such as air temperature, precipitation, wind etc. for the future conditions until 2049. (Senes Consulting: Durham Region's Future Climate – 2040 -2049, Summary, 2014))

Climate Parameter	Detailed Parameter	2000-2009	2040-2049
Extreme Heat	Average max daily (°C)	24	27
	Extreme max. (°C)	32	40
	# days/year > 30(°C)	1	9
Extreme Cold	Average min Daily (°C)	-7	-1
	Extreme min. (°C)	-25	-11
	# days/year < -10(°C)	25	0
	# days/year with min. <0 (frost days)	126	71
Wind Chill	Extreme Daily (°C)	-36	-17
	# days/year <-20 (°C)	14	0
	# days/year > 24 (°C) (AC req'd)	5	32
Humidex	Max (°C)	45	48
	Average # days/year >40(°C)	2	13
Extreme Wind	Max hourly speed (km/hr)	70	56
	Max. gust speed (km/hr)	113	77

Climate Parameter	Detailed Parameter	2000-2009	2040-2049
	# days/year with wind speed > 52 km/hr	3	0.1
	# days/year with wind speed > 63 km/hr	1	0

From: Senes Consulting: Durham Region's Future Climate – 2040 -2049, Summary, 2014

3.3 Recommendations

To combine with existing program and participate with the GTA Flood Forecasting Working Group looking into improved methods.

4.0 Groundwater Quantity and Quality

4.1 Introduction

Groundwater is a vital natural resource within the GRCA. Groundwater levels in wells can be an indicator of the amount of groundwater in aquifers that are the source of water for many people within the Ganaraska watershed. Most groundwater originates as meteoric water from precipitation in the form of rain or snow. Once precipitation reaches the ground it percolates vertically through the earth surface downwards through the various soil horizons until it reaches the underlying groundwater reservoir.

Groundwater use within the GRCA watershed includes private drinking water supplies, as well as agricultural and industrial uses. Further, many plants and aquatic organisms depend on groundwater or groundwater discharge for survival and to maintain good health. During drought conditions, when surface water flows are minimal and precipitation is low, groundwater contributions to streamflow are critical to people and the aquatic ecosystem.

4.2 Provincial Groundwater Monitoring Network (PGMN) Wells Within the GRCA

In 2001 through a partnership with the Ontario Ministry of the Environment and Climate Change, the Provincial Groundwater Monitoring Network (PGMN) was established. GRCA, on behalf of the Ministry of the Environment and Climate Change, monitors groundwater levels in 17 wells at 12 locations throughout the GRCA. These monitoring wells are located in different sediment layers at various depths (Figure 17, Table 1). The wells are mainly distributed to monitor three aquifers that supply water for agricultural, domestic, industrial, and municipal uses.

The Geological Survey of Canada has created a stratigraphic framework for the area with six major elements: Halton till; Oak Ridges Moraine; channel fill; Newmarket till; lower sediments; and bedrock (Figure 17).

The topography as well as geological strata influence the distribution and flow of groundwater within the GRCA. Groundwater drains southward from north east (340 mASL) towards Lake Ontario (40 mASL) in the south (Figure 18). The geologic strata generally consist of sediments deposited during the last few ice advances and retreats over the last 135,000 years resulting a sequence of glacial and interglacial units overlying limestone bedrock which builds the platform strata in this area. North-southerly and north-southeasterly tunnel systems were carved into the existing deposits due to interglacial periods where meltwater eroded the existing materials. These glacial river beds were subsequently filled with sand, gravel, and silt building a complex system of aquifers (Figure 19).

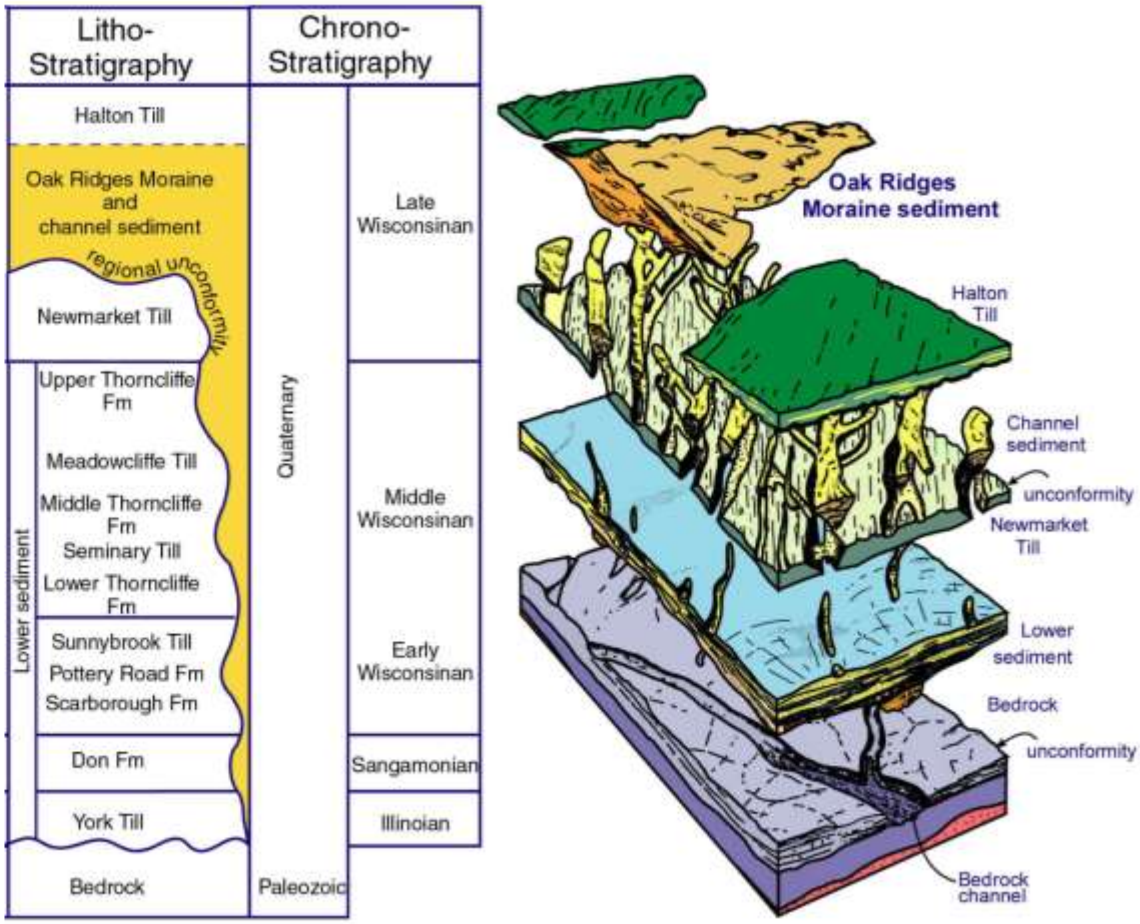


Figure 17: General Geological Stratigraphy GRCA

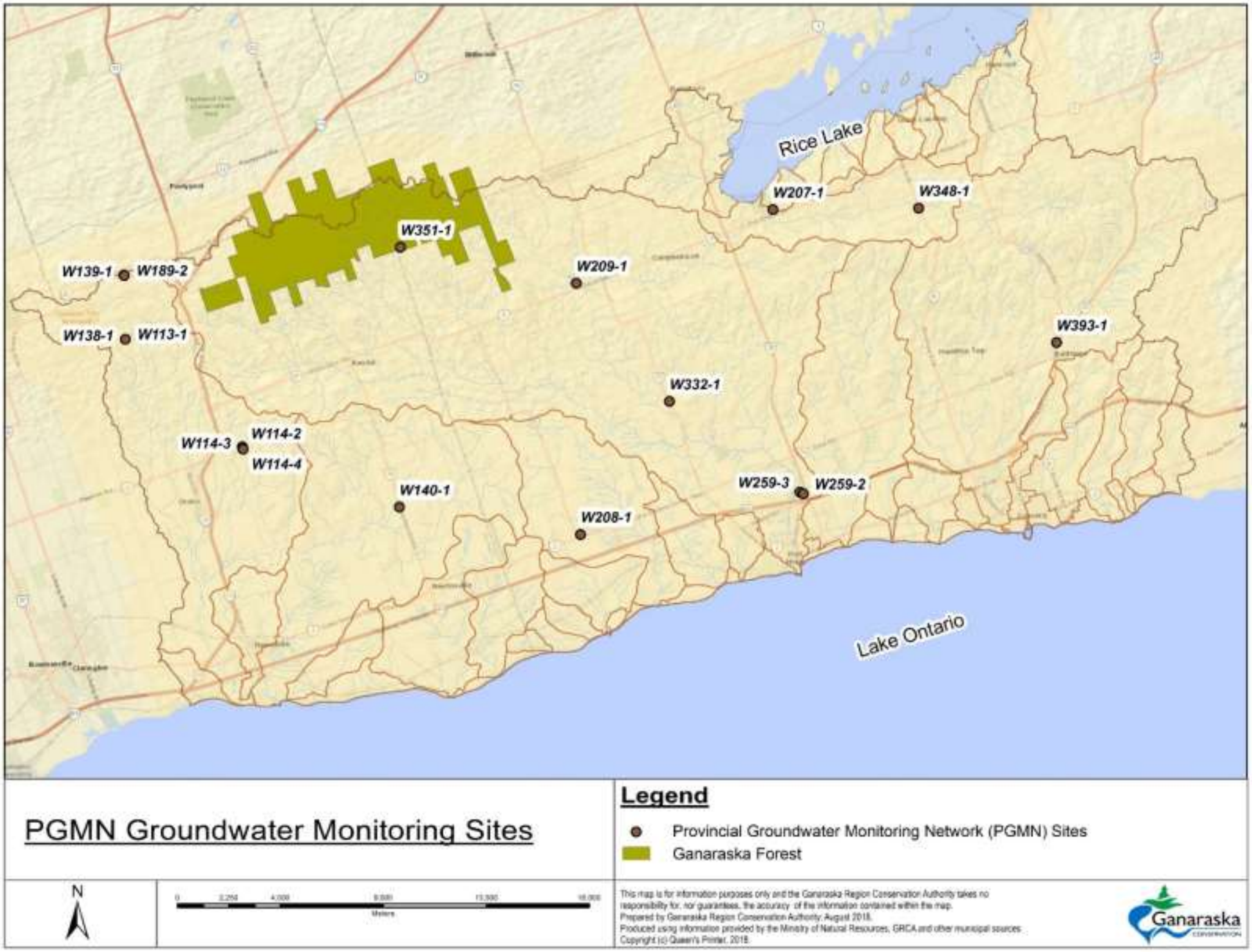


Figure 18: PGMN Wells Distribution Within the GRCA Watershed

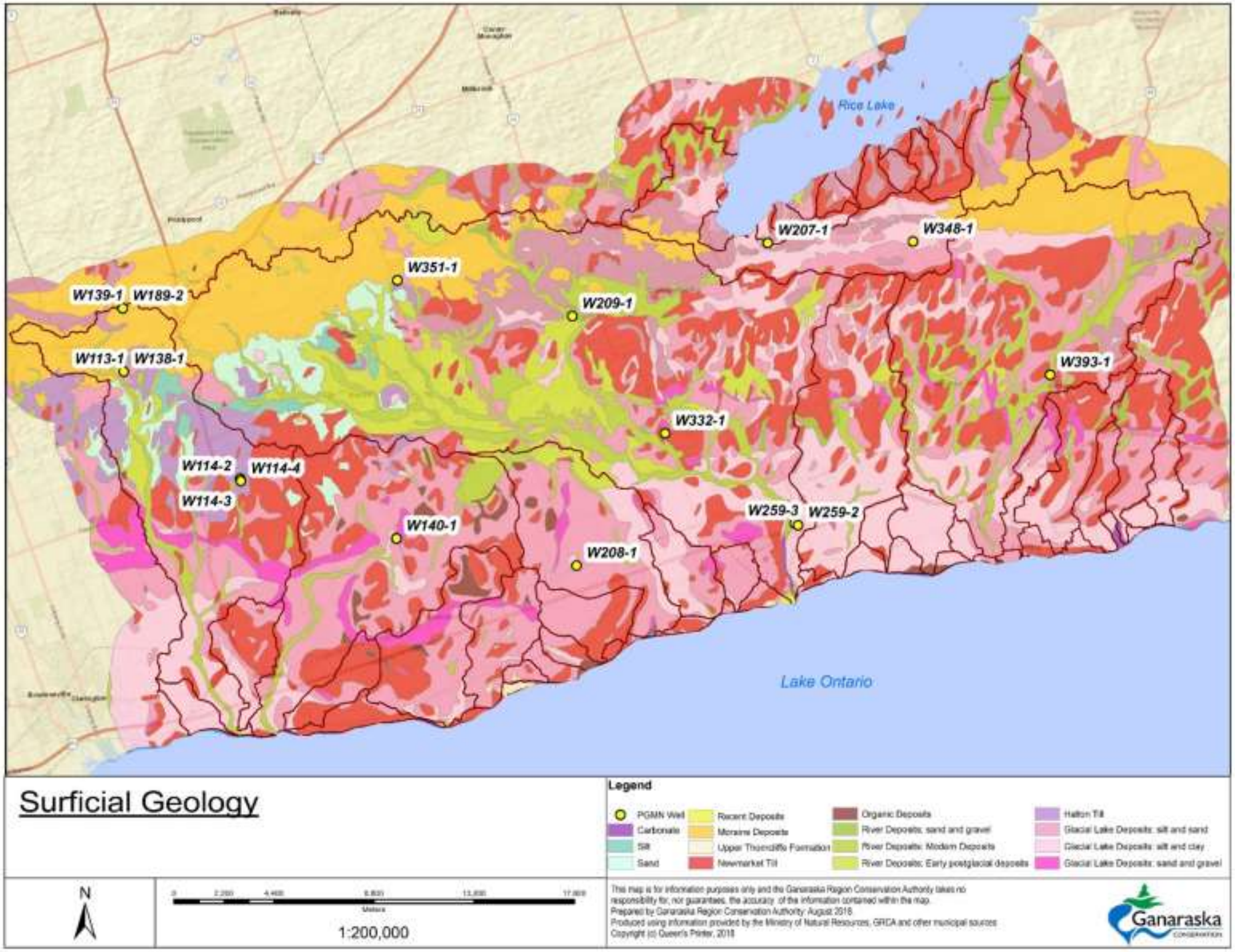


Figure 19: Geological Strata and PGMN Well Distribution Within the GRCA

4.2.1 Hydrology Setting

The Oak Ridges Moraine forms the dominant aquifer complex in the Ganaraska Region consisting of an upper till complex (Halton till) and a glaciolacustrine sequence of silt, sand and clay that are up to 260 m thick. Freshwater within these unconsolidated recent, complex aquifers that locally vary in extent is the principle source of groundwater within the GRCA.

The Newmarket till acts as an aquitard and indicates the beginning of the middle aquifer system within the Thorncliffe formation followed by the lower aquifer system within the Scarborough formation. Both, Thorncliffe and Scarborough formations, are part of the lower sediment complex.

The deepest aquifer system within the GRCA forms at the interface between the porous and permeable surficial sediments of at the base of the lower sediments and the uppermost few metres of the limestone bedrock that is porous, weathered and fractured.

An overview of the distribution of the different PGMN wells within the GRCA to monitor groundwater in the various freshwater sediments is listed in Table 1.

Well Number	Well Name	Screened or Open Interval (m)	Aquifer Material	Formation	Confined/ Unconfined
W393-1	Baltimore CA	3.0-6.1	sand/gravel	river deposits: modern	Unconfined
W208-1	Private PGMN Well	6.9	sand/gravel	filled channel in Newmarket till	Unconfined
W114-2	Jungle Cat – South Well Tall	7.0-8.5	till	Newmarket till	Confined
W259-2	GRCA Office – shallow	7.6-10.7	till	Newmarket till	Unconfined
W140-1	Private PGMN Well	11.3	sand/gravel	glacial lake deposits overlain by Newmarket till	Confined
W114-3	Jungle Cat – North Well	11-13.7	sand/gravel	Newmarket till	Confined
W114-4	Jungle Cat – South Well Medium	12.5-14	sand/gravel	Newmarket till	Confined
W348-1	Plainville Works Yard	14-15.4	silt/gravel	Newmarket till and/or upper lower sediments	Confined
W351-1	Ganaraska Forest Center	17.4-20.4	sand/gravel	Oak Ridges Moraine (glacial river deposits)	Unconfined
W207-1	Rice Lake CA	17.7-18.9	sand/gravel	Oak Ridges Moraine	Confined
W259-3	GRCA Office – deep	18.3-21.3	sand/bedrock	glacial lake deposits – upper lower sediments (Thorncliffe)/limestone	Confined
W259-2	GRCA Office – shallow	7.6-10.7	clay/silt/sand	glacial lake deposits – upper lower sediments (Thorncliffe)	Confined
W209-1	Garden Hill CA	18.8	sand/gravel	upper lower sediment	Confined
W332-1	Canton Works Yard	23.2-26.2	clay	upper lower sediments (Thorncliffe)	Confined
W113-1	Leskard I	35.7-39.6	sand	upper lower sediment	Confined
W189-2	Best South	116.4-117.6	sand/gravel	Oak Ridges Moraine sediments interspersed with Newmarket till at its base	Confined
W138-1	Leskard II	153.0-154.6	limestone	bedrock	Confined

W139-1	Best North	214.8-215.8	limestone	bedrock	Confined

Table 1: PGMN Depth and Aquifer Distribution Within the GRCA

4.2.2 Results Groundwater Quantity

In general, there is no evidence in a long-term drop of groundwater level. As observed at most monitoring wells, groundwater levels during the monitoring period show natural seasonal cyclic conditions with water levels increasing during spring melt and reaching their lowest levels in fall and early winter (Figure 20).

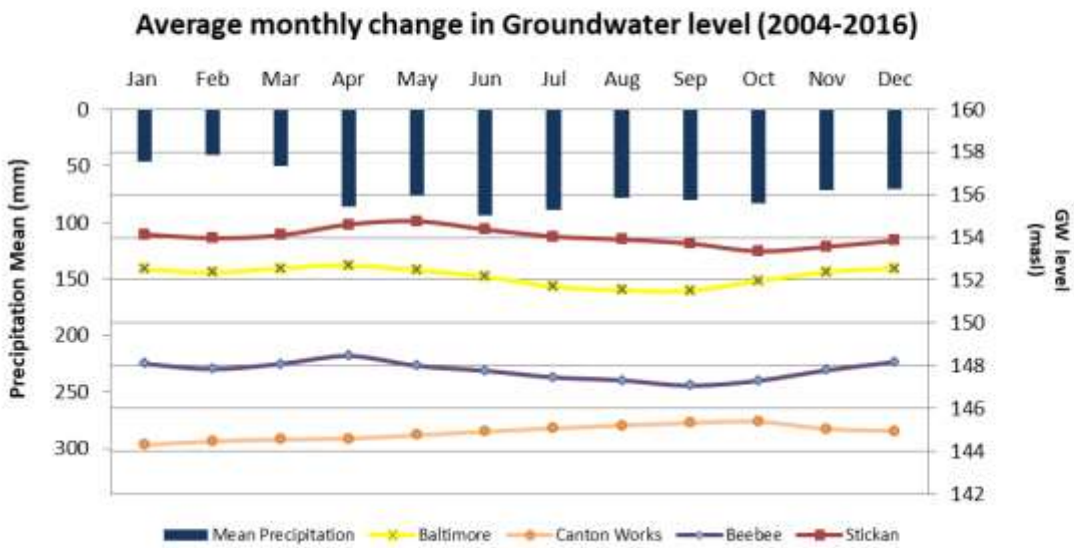


Figure 20: Groundwater Hydrographs for Select PGMN Wells Within the GRCA

The degree of change in groundwater level in response to climatic variability is impacted by the physical make-up of the aquifer including depth and the porosity of its material. In most wells the data recorded to date suggests that current land and water use are having minimal impact on groundwater quantity. However, since climate variation is the main driver of recharge and hydrogeological response it should be noted that shallow wells average annual groundwater levels fell by approximately 3 m during the monitoring period of 2016, indicating a decrease in groundwater quantity at these locations.

Figure 16 previous section illustrates the deviation relationship of precipitation in 2016 compared to the long-term record measured at Cobourg Environment Canada station.
Precipitation records in 2016 differ greatly from the long-term set of values expressed in deviation from the mean.

Over the course of a year groundwater levels fluctuate seasonally about one meter, however during dry years such as 2016 where approximately 300 millimetre (mm) less rainfall occurred water levels in shallow wells dropped about 2 m to 3 m from its usual late summer level compared to the long-term record

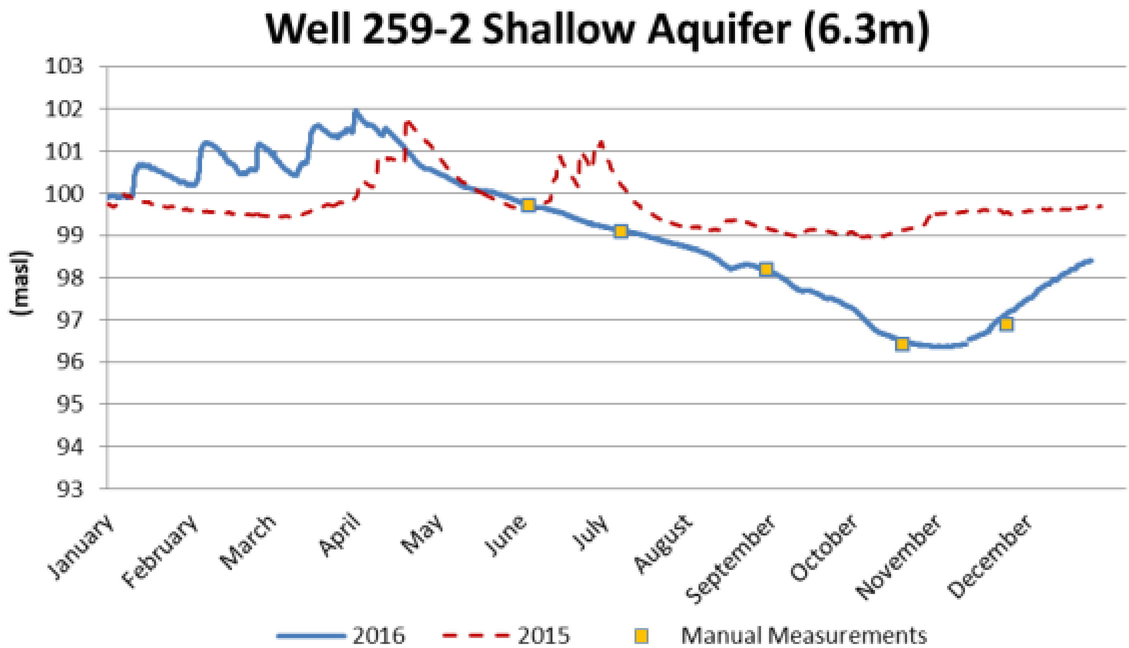


Figure 21: Groundwater Hydrographs of PGMN Wells 259-2 Ending in a Shallow Aquifer

For example, while 2015 was an average year in respect to precipitation input within the GRCA the lack of rain in 2016 caused many shallow private wells to dry up and water needs by some residents were not met. In some cases, water needed to be hauled from water treatment plants to the well owner. Often however, water conservation and/or improvement of wells could aid the situation.

Deeper aquifers seem not have been effected by the lower recharge rates in 2016 (example Figure 22) indicating that those aquifers are interconnected with cross boundary water supplies. It is therefore likely that baseflow downstream of the major rivers within the GRCA are sustained while many tributaries upstream become dry.

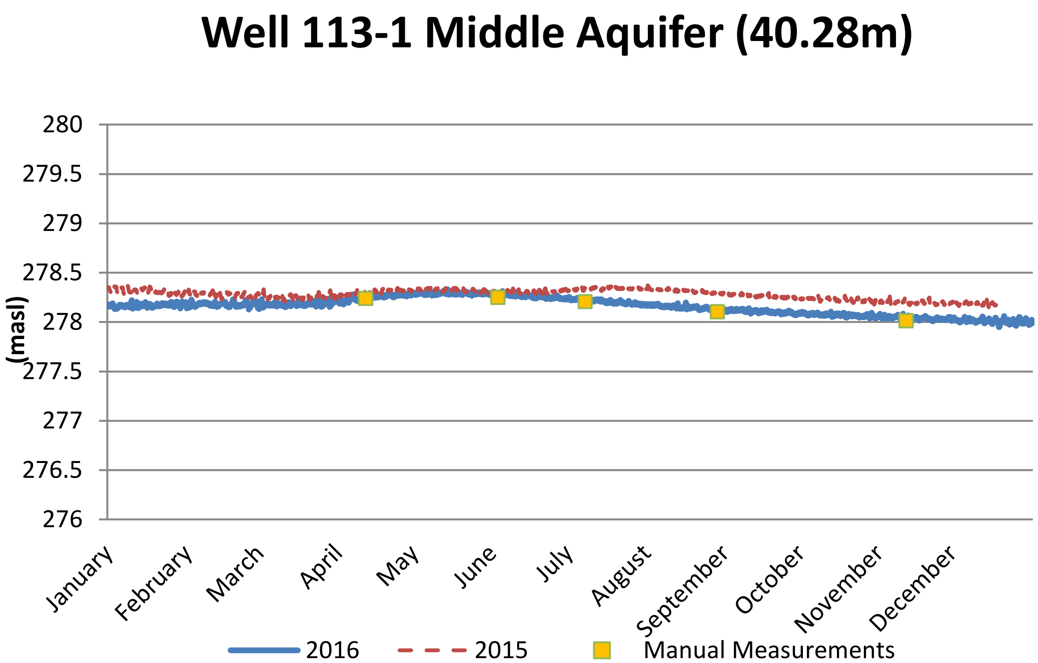


Figure 22: Groundwater Hydrographs of PGMN Well 113-1 Ending in a Medium Aquifer

4.2.3 Introduction and Methods of Groundwater Quality

A variety of factors determine the general chemical composition and quality of groundwater. Soil properties within the vadose and groundwater saturated zone, and the regional hydrological and hydrodynamic conditions driven by weather factors are some of the major natural factors. Due to varying acidity, redox status, and salinity depending on the local geographical setting the resilience of groundwater to contamination differs. In addition, the residence time of pollutants in groundwater will favour either persistence or dilution of a contaminant. The longer the residence time the higher the risk of contamination. Anthropogenic influences, in particular land use, including the storage of fuel, landfills, leaks from septic tanks, the application of road salt and fertilizer impact the quality of the groundwater resource.

Groundwater quality objectives assist in the interpretation of the chemical status of the aquifer. If a representative monitoring point exceeds the threshold, risk is indicated that one or more of the conditions for potable groundwater is not being met.

The sampling methodology for groundwater quality follows the PGMN Long-term Groundwater Quality Sampling Program (MOE 2009) and is collected from 17 PGMN wells within the GRCA. Two indicators are suggested for use in assessing groundwater quality: nitrogen and chloride.

The chloride ion is naturally occurring within the environment, and does not necessarily imply an anthropogenic source. However, anthropogenic sources of chloride constituents entering aquatic ecosystems can occur via waste water effluents due to use of water softener or road runoff (Evans and Frick 2001) among other sources. Within the GRCA elevated chloride concentrations can be observed close to areas with pavement and storage locations for road salt for snow and ice control in the winter season. The Ontario

Drinking Water Standard (aesthetics guideline) for chloride is 250mg/L. The application and storage of road salt can cause an increase of concentrations of chloride in groundwater associated with de-icing practices and have been recorded in groundwater adjacent to snow dumps and salt-storage areas (Figure 23).

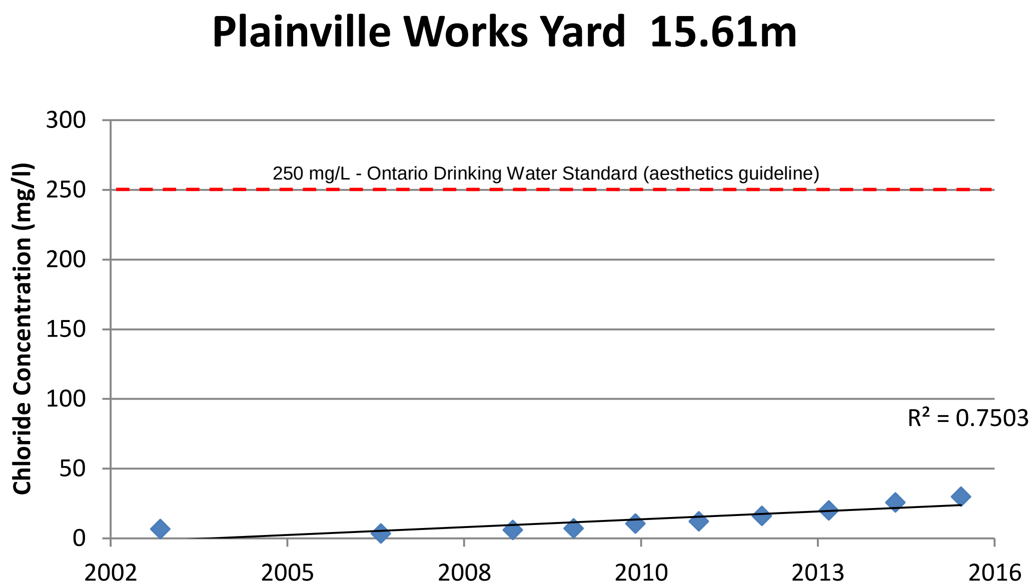


Figure 23: Chloride Concentration Increase Observed at Plainville Works Yard Well

Nitrogen is found in the cells of all living things and is a major component of proteins. The decomposition of organic nitrogen in soils releases ammonia. This ammonia oxidizes to form nitrate and nitrite and act as nutrients in streams. Nitrate compounds in the soil are generally water soluble and readily migrate with groundwater. Human activities such as fertilizer application and loading from sewage systems and treatment plants can artificially elevate nitrogen concentrations. High nitrogen concentrations can have serious adverse effects in aquatic organisms and humans. The Ontario Drinking Water Standard for nitrogen is 10 mg/L. An index combining chloride and nitrogen concentrations into an indicator score (Table 2) can be used to characterize water quality.

Table 2: Groundwater Quality Indicator Scoring and Grading for Monitoring Wells Throughout the GRCA

Chloride (mg/L)	Nitrogen (mg/L)	Score	
0 – 62.5	0 – 2.5	5	Excellent
62.6 – 125.0	2.6 – 5.0	4	↓
125.1 – 187.5	5.1 – 7.5	3	↓
187.6 – 250.0	7.6 – 10.0	2	↓
> 250.0	> 10.0	1	Poor

The scoring ranging from 1 to 5 is based on the aesthetic objective for chloride of 250 mg/L and a maximum acceptable concentration for nitrogen of 10 mg/L.

4.2.4 Groundwater Quality Results (2004 - 2016)

4.2.4.1 Chloride

Generally, groundwater quality within the monitored aquifers is excellent. 80% of water quality samples recorded from 2004 to 2016 for chloride show concentrations less than 125 mg/L (indicator scores 4 and 5) as illustrated in Figure 24. About 16% of sampling sites however indicated high chloride concentrations. This is especially the case for wells in the shallow and upper aquifer, receiving the lowest scores (1 or 2) for chloride (Figure 25) indicating groundwater quality concerns. These sites are located close to roads and salt storage and therefore suggest that chloride ions come into solution and percolate into aquifers.

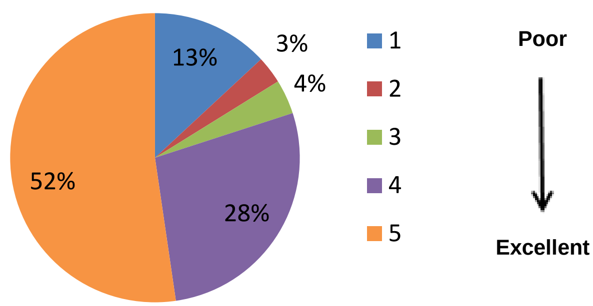


Figure 24: Groundwater Score for Chloride Samples Between 2004 and 2006

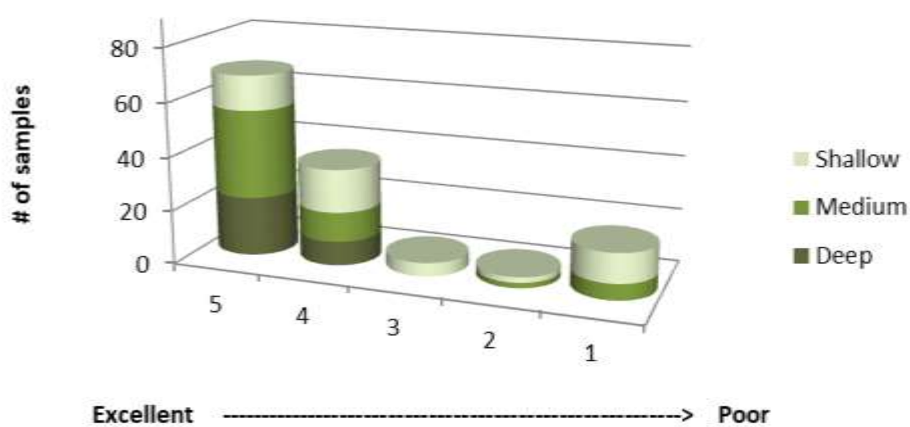


Figure 25: Chloride Score Count in Differing Aquifer Depths

4.2.4.2 Nitrate-Nitrogen

The industrial sector with the highest nitrogen use is agriculture through the application of fertilizers to grow crops that feed people and livestock. Groundwater nitrate concentrations primarily reflect the relative proportion and intensity of agricultural activity. Nitrate-nitrogen concentrations in the GRCA groundwater monitoring showed consistently good results. Only 3% of samples were assigned a score of 3 (Figure 26). Similarly, to chloride, those scores are observed from measurements in the shallow aquifer (Figure 27). Concern however is given to the shallow aquifer where concentrations are elevated ranging from approximately 1.5 to 5.0 mg/L; however not enough data points are available to determine if this is a statistically significant trend.

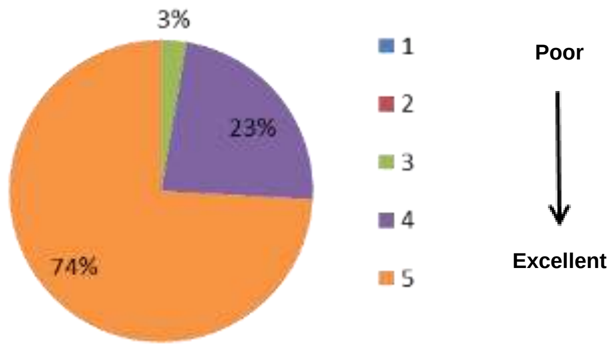


Figure 26: Groundwater Score for Nitrate-Nitrogen Samples Between 2004 and 2016

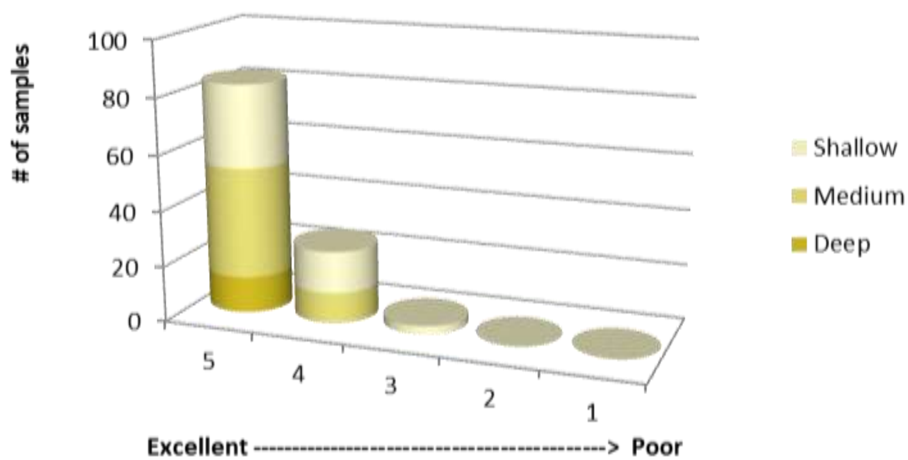


Figure 27: Nitrate-Nitrogen Score Count in Differing Aquifer Depths

During the sampling period none of the sampled aquifers show results above the threshold Groundwater Quality Standard of 10 (mg/L) as defined the ODWS. The criteria of the ODWS are set to provide groundwater for human consumption. However, groundwater also plays an important role in a healthy ecosystem. The results indicate that groundwater has not been polluted with nitrate-nitrogen at present. However, over the long-term data record an increase of nitrate-nitrogen concentration have been observed (Figure 28), especially within the shallow aquifers. Actions to reduce nitrogen levels should be taken in order to prevent the resource from contamination to avoid exceedance of the ODWS threshold to ensure healthy water for consumption. Feedback loops in a crop-soil aquifer system with shallow groundwater have been studied and it should be understood that nitrates might significantly impair the ability of the groundwater body to support human uses.

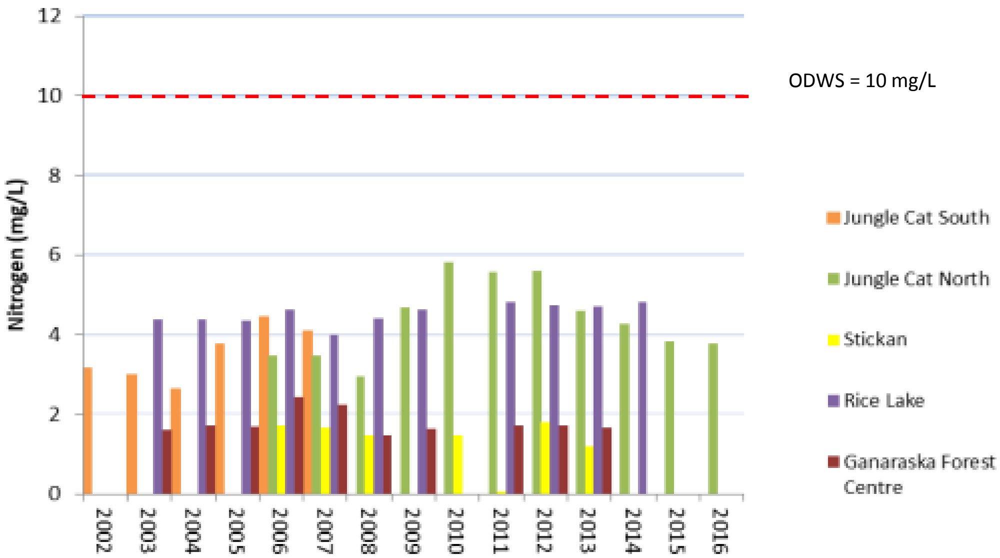


Figure 28: Long-Term Groundwater Nitrate-Nitrogen Concentration at Selected Sites Within the GRCA

4.2.5 PGMN Groundwater Summary

Groundwater aquifers are facing intense pressure from water extraction and pollution. In many regions groundwater tables may decline as they are increasingly faced by a changing climate with less precipitation and more heat days. This condition was seen locally in 2016. Climate change parameters on groundwater recharge and renewal rates must be assessed. Aquifers also may become polluted by various pollutants such as nitrates and chloride. The changes observed in groundwater quantity and quality potentially pose a threat to the crucial ecosystems services groundwater provides, including drinking and irrigation water provision, storage functions and habitats, and groundwater dependent ecosystems such as springs, rivers, wetlands, and lakes. In order to protect this resource, solutions are needed in groundwater management where groundwater systems are seen in a more integrated way.

Integrated management of groundwater has not yet received much attention compared to the integrated management of surface water systems. However, many surface water features rely on groundwater to supply some of that water. Especially sustained streamflow is dependent on baseflow contributions, which is also an important parameter in potential dilution or increased concentrations of constituents. However, at present, data are limited and more monitoring is needed to fully assess groundwater quantity and quality within the GRCA for future generations. The indicators, nitrogen and chloride, provide, even if only very minor, a view into anthropogenic alterations to this resource. Given these results with the limited data set on hand consideration should be given to acquire a broad set of water quality data in order to assess the status of our groundwater resource and to establish natural background levels.

Further, for a future regulatory framework it is essential to consider hydraulic links to surface water and groundwater dependent ecosystems. Groundwater consumption and recharge are key impacts to groundwater quantity. Abstraction impact for human water use should be assessed in more detail to reduce possible negative impacts on this freshwater resource. Socioeconomic issues that relate to land use and food production should also be included into management. Further investigation is needed to clarify whether elevated concentrations are due to anthropogenic activities is likely to impact the freshwater resource significantly.

4.2.6 PGMN Groundwater Recommendations

Groundwater consumption and recharge are key impacts to groundwater quantity. Abstraction impact for human water use should be assessed in more detail to reduce possible negative impacts on this freshwater resource. Socioeconomic issues that relate to land use and infrastructure should also be included into management. Further investigation is needed to clarify whether elevated concentrations are due to anthropogenic activities is likely to impact the freshwater resource significantly.

A future regulatory framework is recommended, as it is essential to consider hydraulic links to surface water and groundwater dependent ecosystems.

Continue to monitor, manage and evaluate the health of groundwater resources and implement management actions where and when necessary.

Identify and implement management actions arising from monitoring, where appropriate.

Develop and adopt an integrated monitoring program for surface- and groundwater connections.

Acquire a water balance model application to proactively promote innovative green infrastructure and Low Impact Development (LID) techniques through infrastructure, development review, planning policy and regulations.

5.0 Surface Water Quantity

5.1 Introduction

The Ganaraska Watershed is made up of several thousands kilometers of flowing water and numerous lakes. These waters have their own characteristics and environmental issues. The climatic conditions influence the water flow and chemical, biological and mineral content of the water. Human activity affects surface water through afforestation, land drainage, agriculture, urbanisation and flow regulation. The environmental assessment of surface waters is crucial for water management and for maintaining and improving water quantity.

Naturally, the streamflow patterns closely follow rainfall patterns and snowmelt contributions. In southeast Ontario, generally winter frontal storms result in heavy snowfall; spring storm events result in heavy rainfall over multiple days; summer produces brief but sometimes extreme thunderstorms; while autumn storm events are generally a result of convectional storms that can last over a few days.

Resulting flows of those storm events govern streamflow and play a major role for biological diversity and productivity of the riverine ecosystem (OMNR 1994; Nilsson and Berggren 2000; Nilsson and Svedmark 2002; Tiegs et al. 2005). Natural variability of streams are dynamic and a function of prevailing climate conditions. Within this dynamic stability of the natural variation, native biota and riverine communities have evolved with, and adapted to (Poff et al. 1997; Stanford et al. 1996) the given conditions, which provides ecosystems the resilience to adjust to changes within this natural range. Therefore, the integrity of flowing

water systems depends largely on this natural dynamic character (Poff et al. 1997) to maintain diverse, resilient, productive and healthy ecosystems (Swanson et al. 1993).
Freshwater and the integrity of riverine systems are therefore critically important to the well-being and economic resources for humans. Hydrological processes, such as peak flow, baseflow, total flow, subsurface and/or surface water runoff interact in a variety of ways within a watershed and influence human and ecosystem wellbeing in different ways. The establishment of a hydrological regime of a riverine system is as such helpful to determine the natural variability of a river or lake in order to make informed decisions if and when alterations occur and to detect and mitigate changes early on. In addition, understanding the ecological functions provided by the natural flow components is necessary for assessing any change to ensure safe guarding water needs for human health and ecological condition.

5.2 Streamflow and Water Level Gauges

The GRCA monitors stream flow data from a network of gauge stations operated by the Water Survey of Canada, and assists in maintaining these streamflow gauges. Data collected are important to predict potential flooding or drought episodes, the impact of development potentially modifying the natural flow regime (magnitude, duration, frequency, timing, and rate of change) downstream of the project, and ecosystem health**.**

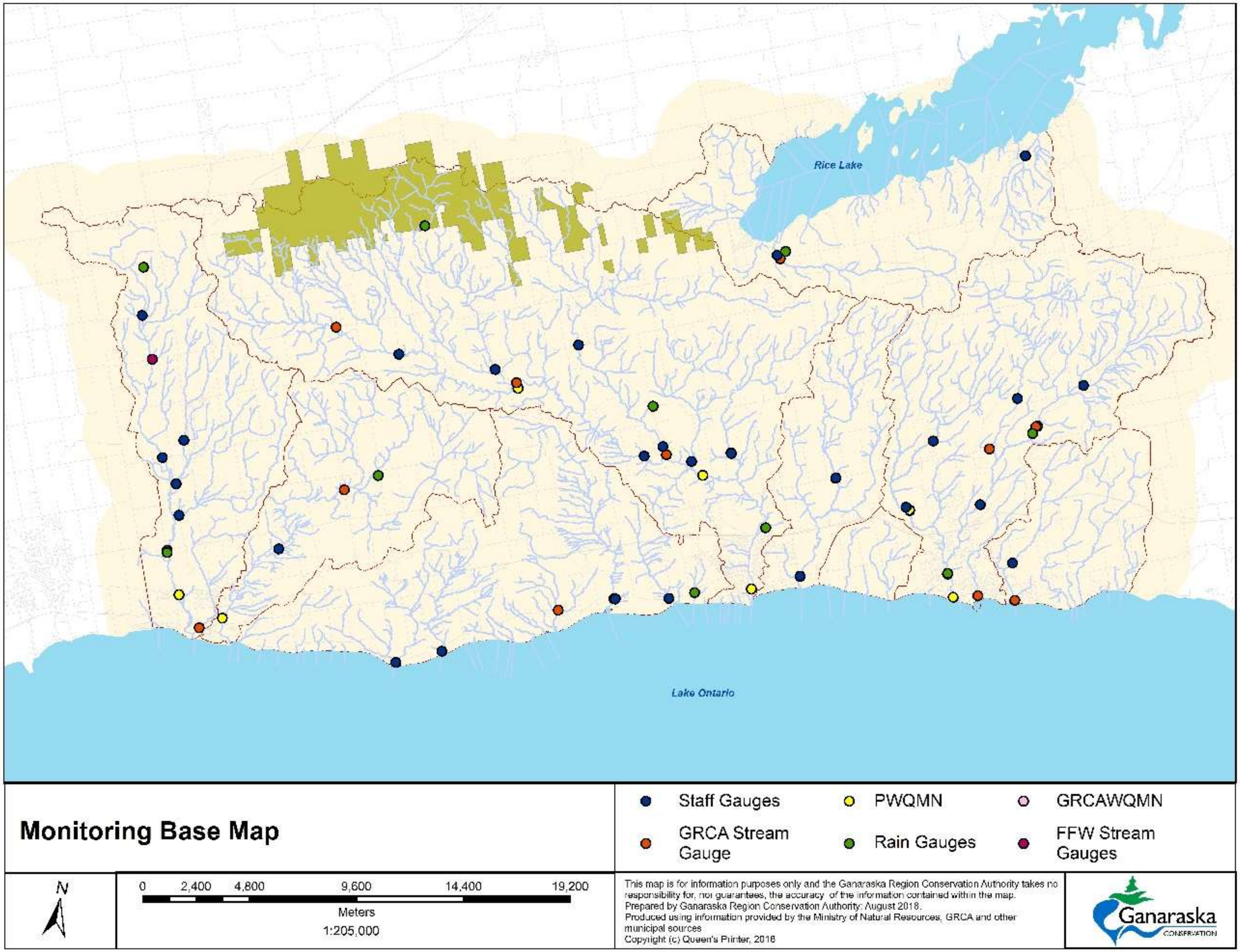


Figure 29: Streamflow and Water Level Monitoring Stations GRCA

Stream Flow Record Period
Stream flow records vary within the GRCA jurisdiction. Stations maintained operate since differing time scales. Data records range from less than 10 years to over 30 years. Since data records are longest for stations Wilmot Creek, Ganaraska River, and Cobourg Creek the focus of this request will be on these stream flow records.

Annual Stream Flow and Runoff Characteristics
Annual average river flows are one of the elements that affect freshwater availability in a river basin, in addition to groundwater sources, lakes or artificial water storage facilities. Variations in river flows are determined mainly by the seasonality of precipitation and temperature, as well as by catchment characteristics such as geology, soil and land cover. Streamflow patterns are best described using hydrological indicators that portray flow quantity, timing, and variability as observed over any time scale using many years of data (Poff et al. 1997) (Figure 30).

5.3 Methods for Streamflow & Water Level Monitoring

Stream flow assessments are carried out using a diagnostic tool (Streamflow Analysis and Assessment Software (SAAS 4.1) - Metcalfe) used in Ontario to support environmental flow assessments. Compared to commonly used indices such as Index of Hydrologic Alteration (IHA) and Range of Variability Approach (RVA) SAAS is suitable to assess changes in flow regimes over very short temporal scales (i.e. hourly). The Ministry of Environment Conservation and Parks (MOECP) is currently testing this tool in several parts of Canada including Ontario, Quebec and the Atlantic (Metcalfe, R.A. and Schmidt, B., 2016).

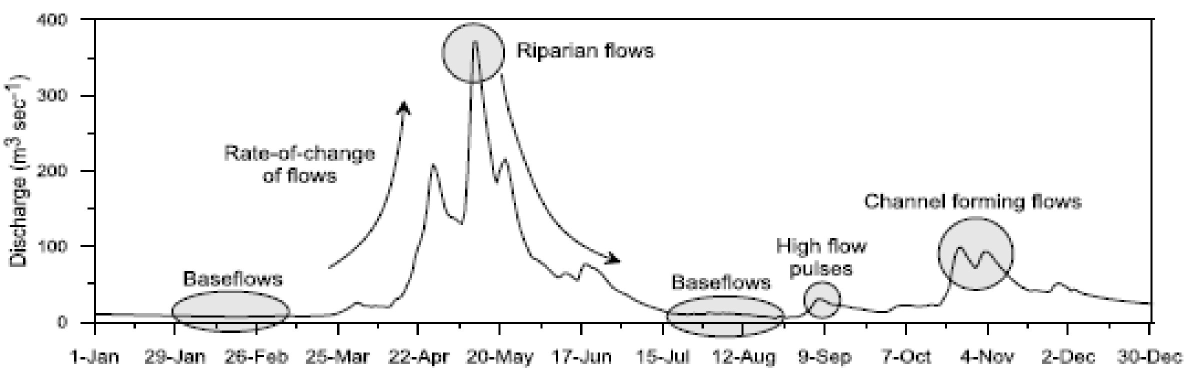


Figure 30: Components of Flow

In order to describe a river's natural system it is helpful to characterize the entire range of flows that occur throughout a year, such as high and low flows, riparian, bankfull, overbank, subsistence flows and baseflow as well as the timing of these flows, the duration and frequency. The different components assist in establishing a baseline reference to assess the hydrologic significance for ecological functions and to determine the resilience of the system to anthropogenic changes (Swanson et al. 1993, Metcalfe et al. 2013). Figure 30 illustrates the components of flow and Figure 31 shows that the Ganaraska River responds accordingly.

5.4 Results for Stream Flow and Water Level Monitoring

Ganaraska River – 1977 to 2016

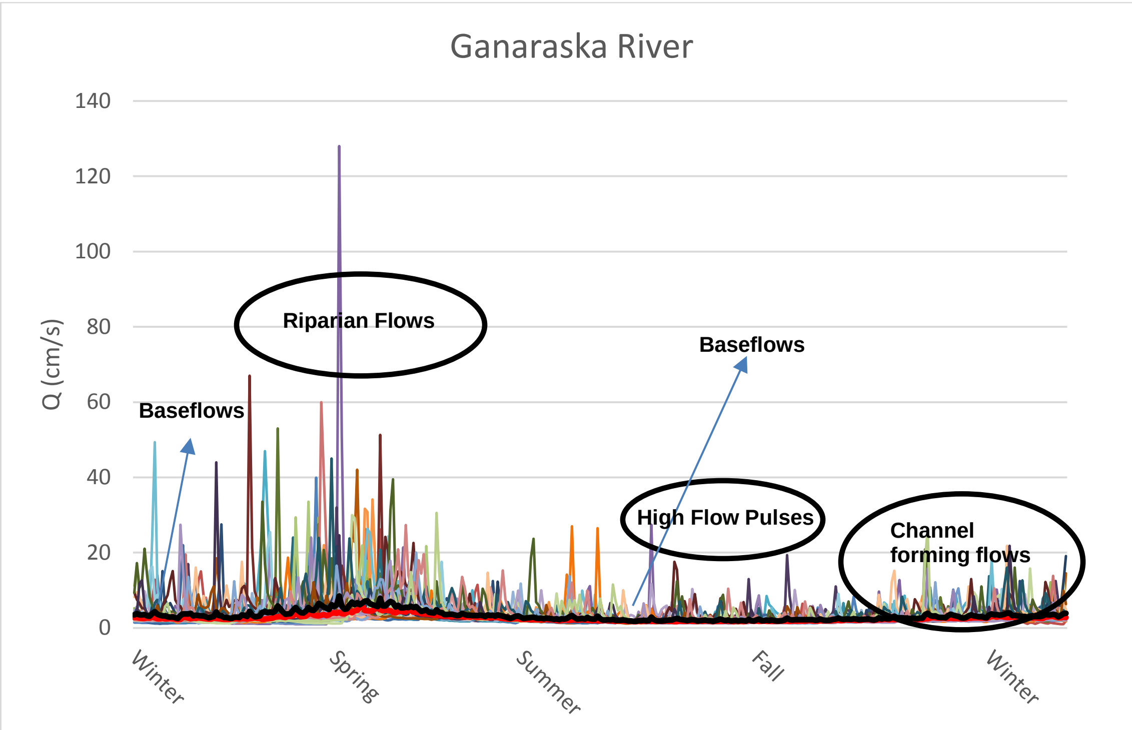


Figure 31: Unaltered Variability of Flow of the Ganaraska River

Each of the flow components are critical to regulate ecological in Ganaraska River and creeks. Riparian and overbank events inundate the areas adjacent to the stream, thus depositing sediments and nutrients ensuring biological diversity. Their reoccurrence interval ranges from 2 to 20 years.

Channel-forming flows are defined as flow that surpass the threshold of sediment erosion and movement (Metcalfe et al. 2013) and are associated with a recurrence interval of 1.5 to 1.7 years (bankfull flow).

High flow pulses are identified that are higher compared to the baseflow at present but less than the bankfull flow magnitude. They are smaller events resulting from short burst rainfall events, short winter or spring thaws, or precipitation events that occur during dry conditions. High flow pulses are critical, especially during the summer to flush out poor quality water, decrease stream temperature, and can mobilize and sort gravels contributing to the stream health (King *et al.* 2003).

Monthly Runoff Characteristics

Figure 32 shows the mean of monthly streamflow at Ganaraska River, Wilmot and Cobourg Creek, respectively for each month over the long term period. Streamflow varies by month and season since each stream exhibits its own unique patterns, due to different to weather conditions, such as precipitation input, snow storage, soil storage and evapotranspiration. However, all streams show lowest flows during July and August when rainfall is sparse and streams are mostly sustained by groundwater. Highest flows occur during the spring with the onset of snowmelt.

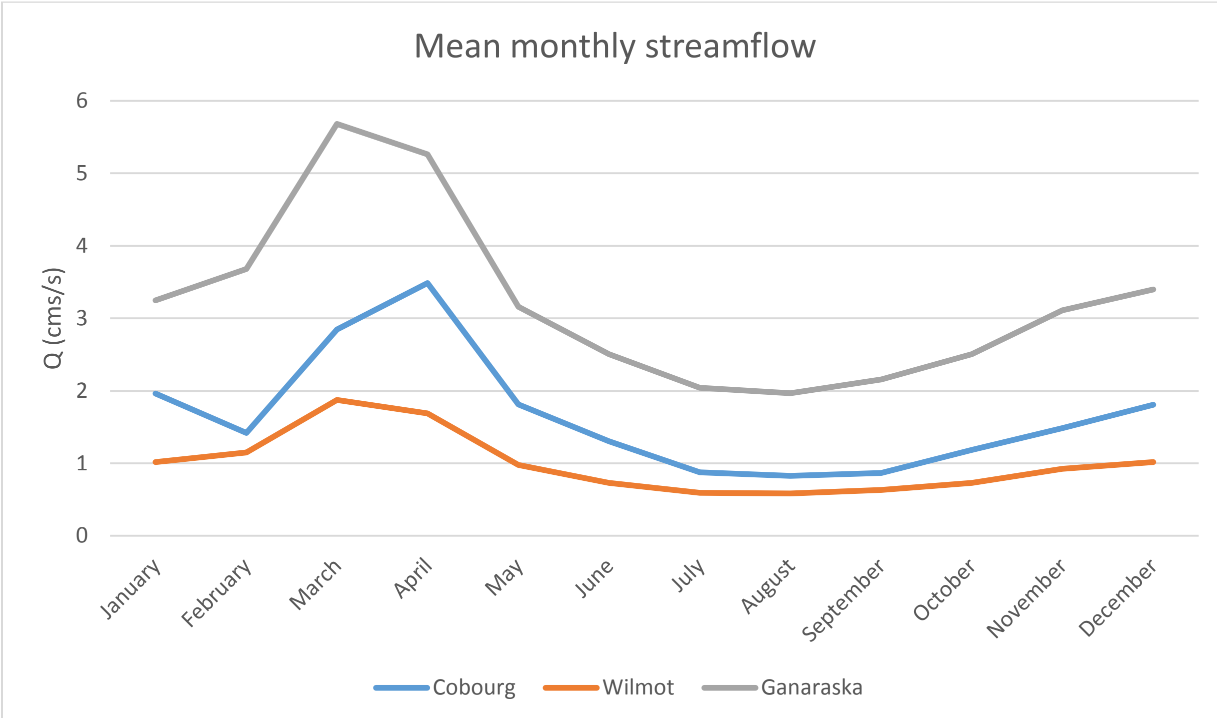


Figure 32: Average Monthly Flow – Period of Record for Each Watercourse Indicated

Ganaraska River

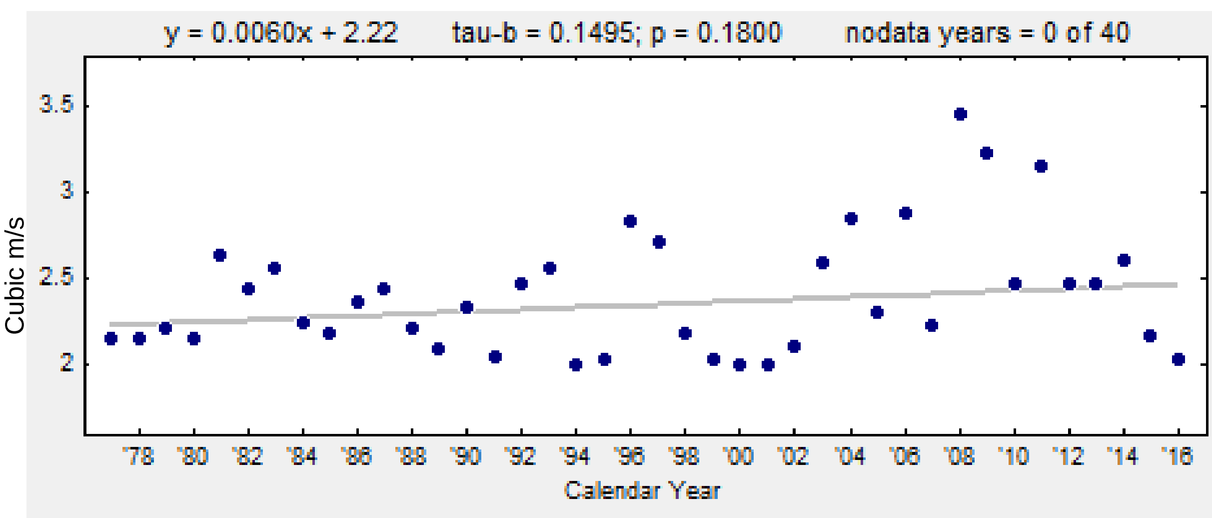


Figure 33: Median Annual Streamflow Trends Ganaraska River Over the Period of Record

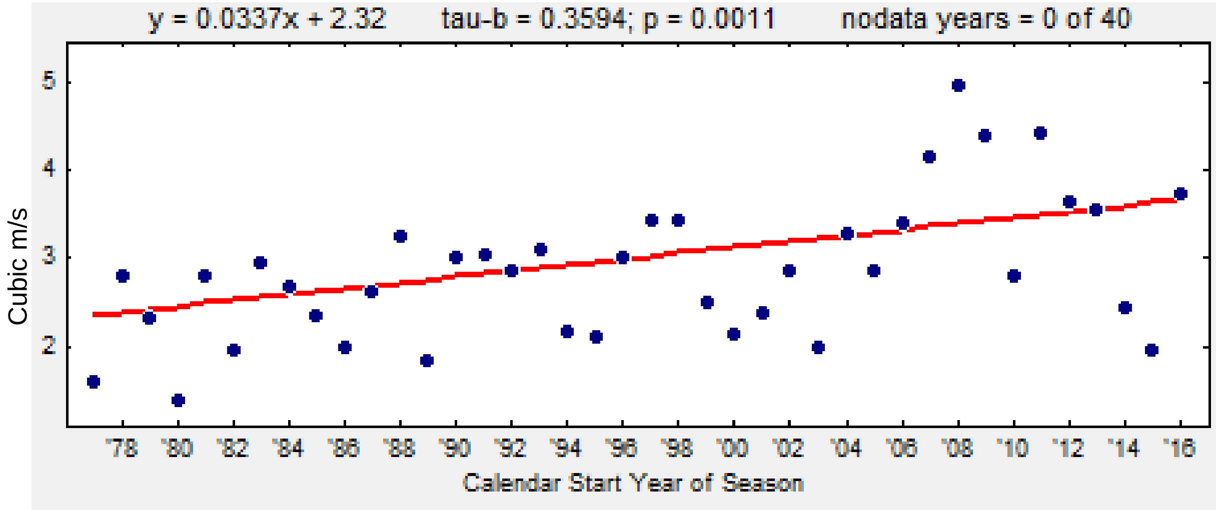


Figure 34: Median Winter Season Streamflow Trends Ganaraska River Over the Period of Record

The Ganaraska Riverine system exhibits an increase in median streamflow magnitudes during the period of record. This trend however is not statistical significant. Further analysis on a seasonal level determines that winter streamflow show a statistical significant increase pointing to a change of flow during the winter months. Both, spring and summer flows show an increasing trend over the course of record while fall flows decrease.

Wilmot Creek

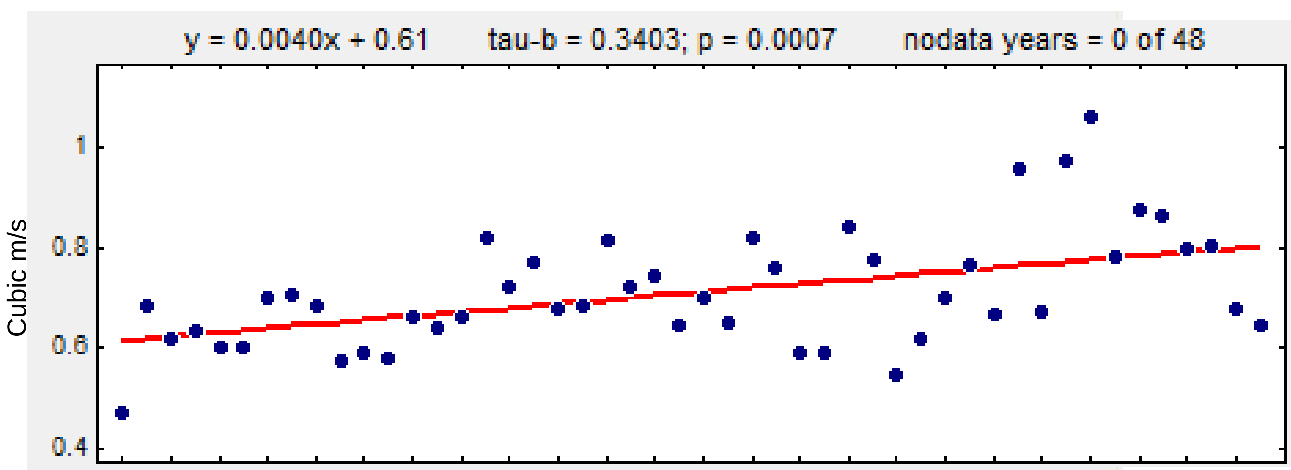


Figure 35: Wilmot Creek Annual Streamflow Values – Increasing Trend Over the Course of the Record

The Wilmot Creek system exhibits an increase in median streamflow magnitudes during the period of record. This trend is statistical significant at $p<0.05$, pointing to both increased rainfall and regular circulation of soil and event water.

Cobourg Creek

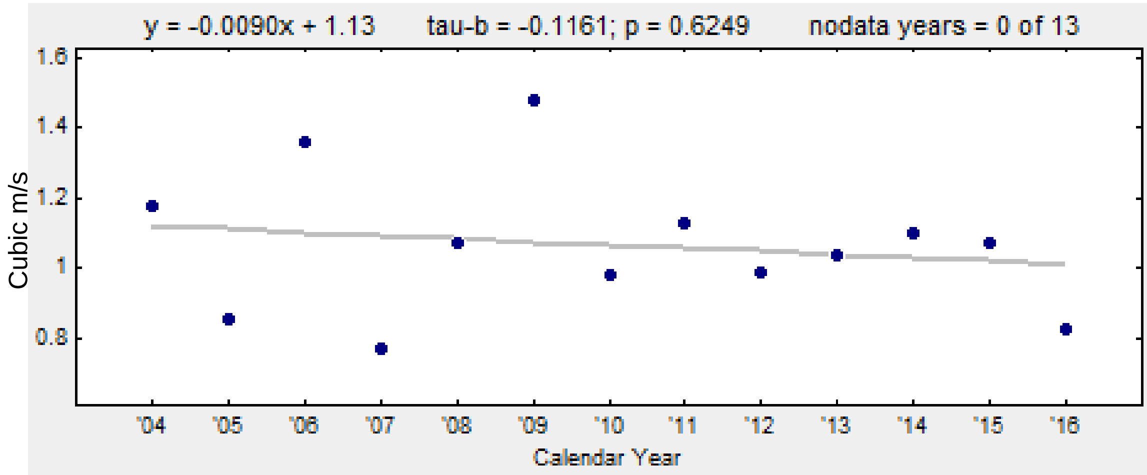


Figure 36: Cobourg Creek Annual Streamflow Values Decreasing Trend But Not Significant

Median streamflow magnitudes within the Cobourg Creek subcatchment show a decrease trend during the period of record, indicating less water discharging over the range of record.

Table 3 lists characteristics related to the magnitude of flow events.

Table 3: Streamflow Return Periods

Watercourse	Ganaraska River	Wilmot Creek	Cobourg Creek
Recurrence Interval (yrs)	Magnitude (cm/s) (40 yrs) of record	Magnitude (cm/s) (56yrs) of record	Magnitude (cm/s (13yrs) of record
1.5	2.00	0.58	0.82
1.7	2.16	0.63	0.93
2	2.38	0.71	1.07
5	3.84	1.20	2.07
10	5.35	1.70	3.11
20	7.36	2.37	4.53
30	8.85	2.87	5.58
50	11.10	3.63	7.20
75	13.40	4.37	8.77
100	15.20	4.97	10.10

Magnitudes determined from the long-term record for the varying return periods differ among the streams. Alterations in the future due to human alterations or climate change can be compared against this assessment.

6.0 Baseflow

6.1 Introduction

Cold water fisheries such as Wilmot Creek rely on an abundance of baseflow to maintain high quality fisheries habitat. The study and understanding of baseflow in a watershed is important in watershed management since water demand during these low flow periods can cause stress on aquatic ecology and many other watershed funtion. Baseflow, for the purpose of this document, is defined as stream discharge during periods when storm flow has ceased (3 days after the end of rainfall) and stream flow consists entirely of delayed sources of flow. However, baseflow or low flow can also be interpreted more narrowly as the flow during a defined period of prolonged dry weather (Hinton, 2005).

Baseflow is a result of groundwater discharge to a stream, and it is controlled by topography and the geological and hydrogeological characteristics of the watershed. Baseflow provides the majority of the flow to streams during dry periods and therefore has a significant effect on the quantity and quality of surface waters. In the Ganaraska Region Conservation Authority, streams are under baseflow conditions approximately 70% of the time. Areas where groundwater discharges to streams (upwelling areas) provide cooler water temperatures, which create attractive refuges and suitable habitats for aquatic species. Fish tend to take advantage of these locations as refuge from warm stream temperatures in the middle of summer (Power et al. 1999).

During baseflow conditions in the Ganaraska Region watersheds, surface water quantity is principally generated by groundwater discharge due to minimal influence or absence of delayed flows from ponds or storm water outfalls. Surface water quality is also affected by the quantity and quality of groundwater entering the system as baseflow.

6.2 Baseflow Survey Methods

From 2006 to 2013, spot baseflow data was collected from approximately 700 sites during the driest conditions each summer. Approximately 300 of the sites identified had no summer baseflow, but likely flowed temporarily during periods of runoff following rain or snowmelt. The remaining sites with baseflow that is sustained through the summer were used in the study to determine the contributions from groundwater and the locations of these baseflow sources.

Pygmy flow meters were used with the Area-Velocity method in open channels, while volumetric gauging was used at perched culverts as defined by Hinton (2005). A nested sampling approach was used to standardize the baseflow dataset to one measurement day each summer, thereby correcting for minor daily fluctuations in baseflows.

Standardized baseflow discharge from each sample site was used to determine the gain or loss observed between sites by subtracting the discharge observed upstream. This data was then used to show gains and losses per unit area of subcatchments and per unit length of flowing channels within subcatchments.

Subcatchment areas were delineated using the Ministry of Natural Resources version one flow direction grid in combination with the geo-referenced locations of baseflow sampling sites. The lengths of all channel segments with observable flow were measured from sample site to sample site immediately upstream. If there was no site upstream of a site, it was recorded as a headwater site and the stream channel was measured to the known or estimated source of flow. Decisions were made based on known geological and hydrogeological characteristics of the watershed to determine the exact locations of sources and changes in baseflow contributions.

6.3 Baseflow Monitoring Results

6.3.1 Oak Ridges Moraine

A high concentration of springs in streams on or near the Oak Ridges Moraine provide a disproportionally high volume of baseflow to the headwaters of Wilmot and Cobourg Creeks, the Ganaraska River and some smaller streams in the GRCA. Tributaries above the Garden Hill pond (5% of the Ganaraska watershed) contribute 284 litres per second (L/s) or 20% of the total baseflow in the Ganaraska River. In Wilmot Creek, four headwater streams near Leskard produce a combined total of 306 L/s or 42% of the total baseflow in Wilmot Creek from an area that represents less than 15% of the watershed. In Baltimore (Cobourg) Creek, springs in the Oak Ridges Moraine produce 238 L/s to one tributary as measured at Bull Rd. This represents 42% of the total baseflow and 18% of the total watershed area.

Some groundwater discharges on the North slope of the moraine into the smaller Rice Lake watersheds. Several small streams appear out of the steep hill sides and valleys that have cut into the moraine near Bewdley, Gore’s Landing and Harwood. The largest stream is Plainville Creek that flows West through the farmland on the south side of County Rd 9 from Burnham St. to Sackville Bridge. As the creek turns North toward Rice Lake, it gains over 60 L/s or 75% of the total baseflow in the final downstream reach (1km) before entering the lake. Similarly, Harwood Creek gains 31.5 L/s or 58% of its total baseflow from groundwater discharges located in the downstream reaches. The high groundwater conditions in the village of Harwood can be seen not only in the streams but by the constant flow of cold water coming from a publicly accessible spring setup at the community hall for residents to fill their jugs.

While there are isolated areas of high groundwater discharge on the moraine, much of the rainfall and snowmelt infiltrates the surface which is dominated by sandy soils. This results in very few surface water features on the moraine and those that are not in contact with the saturated subsurface environment tend to become dry channels each summer. A tributary of the Ganaraska watershed that would flow from the moraine at Featherstone Rd. was dry during the baseflow survey, even though it drains 2.3% of the watershed area. Grey dashed lines on Figure 37 show how most of the first order and some second and third order stream channels can cease to flow under summer low flow conditions.

6.3.2 Other Groundwater Discharge Locations

There are several areas of local groundwater recharge and discharge in the region that act similarly to the surface aquifers of the Moraine, contributing further baseflow to the local streams. There is a small area in the Ganaraska River watershed considered part of the Peterborough Drumlin Field that contains sand and gravel river deposits of recent or glacial origins. This area in the northeast headwaters contains less than 2% of the flowing channels in the Ganaraska watershed but it contributes 151 L/s or 11% of the total baseflow to the river.

In Port Hope's Ward 1, an area of higher topography (locally known as Monkey Mountain) allows enough infiltration to recharge a local aquifer. Three stream channels have cut into this hill, picking up baseflow from the aquifer's discharge areas and contributing 28 L/s to the lower reaches of the Ganaraska River.

West of the urban area of Port Hope, Wesleyville Creek drains a small watershed between Highway 401 and Lake Ontario. This creek has two main tributaries that provide a combined total of 57 L/s or 81% of the total baseflow. The contributing watersheds of the two tributaries cover only 48% of the overall Wesleyville Creek watershed.

6.4 Discussion

Analysis of field sampling indicates that the majority of the baseflow in the Ganaraska Region is gained or lost from specific locations, attributable to their geological and hydrogeological features. The Oak Ridges Moraine and other geologic features have a dramatic effect on baseflow occurrences and distribution due to their coarse surficial sediments and dramatic elevation changes. Underlying geologic features control both the rate and direction of groundwater flow as it moves toward stream channels. The most important geologic features are the Bowmanville Till (equivalent to Newmarket Till), which acts as an aquitard that slows groundwater flow downward, and the sandy aquifers that allow water to move upward, downward and laterally toward surface water at lower elevation areas.

The topography and coarse surficial sediments associated with the Moraine deposits in the northern part of the GRCA watersheds generally have high infiltration capacities, which allow for significant groundwater recharge during wet periods. In the summer, as evapo-transpiration rates increase due to temperature and vegetative activity, the groundwater level drops and the first order streams in the Moraine sediments tend to become dry (Figure XX).

At the lowest elevations of the Moraine where coarse sediments are thin, there is significant groundwater discharge from the upper aquifer. Underlying geology at the margins of the Moraine is of a finer material such as ancient glacial lake deposits of silty sand, the Bowmanville Till or the Halton Till. This is especially evident in many of the upper reaches of the Ganaraska River north of Regional/County Road 9.

These reaches and others within a relatively small geographical area along the Oak Ridges Moraine boundary are responsible for the majority of the baseflows feeding the Ganaraska River as well as Rice Lake, Cobourg and Wilmot Creeks (Figure 37). The groundwater discharge areas around the Oak Ridges Moraine are a direct result of the high recharge rates caused by highly porous surficial geology, hummocky topography and forested landscapes that are typically found on the Moraine. Protection of these headwater features is very important for maintaining resilient baseflows that help buffer the effects of climate change on aquatic ecosystems. The Ganaraska and Northumberland forests play an essential role in headwater protection and maintain groundwater recharge rates that in turn supply these baseflows.

Some of the surficial sandy deposits extend below the Halton Till (upper aquitard) and can carry water from the recharge areas of the Moraine. One such area is located near the Brimacombe Ski Hill. In this area a silty layer of Halton Till lies over a sandy aquifer, confining it and allowing recharged groundwater from the porous layers of the Moraine to travel laterally southward to be discharged in the deep valley near the ski area. It is important to note that groundwater in the deeper aquifers tends to move from north to south sometimes causing discharges outside of the watershed where it originated. Groundwater that may have originated in the Ganaraska River headwaters or even to the north in the Kawartha Conservation and Otonabee Conservation watersheds may reappear in the Ganaraska River watershed; for example, the Brimacombe Ski Hill or further south in Graham Creek or Port Britain Creek watersheds.

Along deeply incised stream valleys in many of the middle reaches of the Ganaraska River watershed, baseflow gains are also observed. In the South Slope physiographic region, the Bowmanville Till aquitard is the dominant hydrostratigraphic feature. Many streams have cut through overlying sediments creating deep valleys that come into contact with the underlying Bowmanville Till. Above the till layer, groundwater moves laterally within local aquifers due to the low permeability of the till. When the till is exposed, groundwater discharges at the surface and runs into stream channels.

Contrary to other Lake Ontario watersheds in this area, the main branch of the Ganaraska River flows from west to east. This means that the river flows over a longer distance, with a similar elevation drop compared to other watersheds, causing the overall slope to be more gradual. As a result, the river meanders greatly through broad valleys and does not cut as deeply into the aquifer below. In contrast, the Wilmot Creek flows almost straight south with a steeper gradient intersecting more groundwater springs relative to its area and has a large baseflow portion of its total flow.

The porous surficial geology of the Peterborough drumlin field causes locally high infiltration. As water moves vertically through the surficial deposits, it eventually encounters a lower aquitard layer, such as the Bowmanville Till, and is forced to flow more laterally toward valleys due to the low permeability of the till layer. As the sandy layers become thin and the aquitard becomes more exposed, the groundwater reaches the surface at a discharge point and runs into stream channels. Over thousands of years many channels have cut down through the sandy layers to expose more of the aquitard, moving the discharge locations further upstream.

Smaller streams such as Wesleyville Creek, Brook Creek and Little’s Creek also have baseflows that are similarly maintained through groundwater recharge and discharge from local aquifers. In the Wesleyville Creek watershed a broad sand plain allows infiltration and storage of precipitation in an unconfined aquifer. The saturated zone of this sandy layer is intersected by deeply incised valleys with numerous groundwater upwelling areas.

Three small tributaries of the Ganaraska River emerge from the ravines of Port Hope where they have cut valleys into the surficial sediments intercepting locally recharged groundwater that flows toward the larger river valley.

With limited areas providing baseflow in these small watersheds, they are especially vulnerable to the effects of drought and potential development or overuse of water through water takings. During hot summer weather, evaporation from coastal wetlands fed by small streams can be high enough that the inflows are not always sustained over the beach sediments. Small streams often become cut-off from the lake through one or more seasons resulting in a separation of the lake and riverine aquatic ecosystems. Smaller streams are also potentially more vulnerable to deteriorating water quality during low flow periods. There is simply less water to dilute any contamination that enters the surface water.

Areas of the watershed that have little or no infiltration can result in long stretches of stream channels that have no baseflow and are susceptible to drying up during periods of no precipitation and high evapotranspiration rates. Water takings, although highly regulated can have a negative impact on summer baseflows as consumption of water for irrigation is highest during periods without rainfall.

Minor losses were observed in urban areas due to a number of possible natural and anthropogenic influences that may be affecting baseflow quantities. These losses could be explained by anthropogenic water takings that were not observed within the baseflow survey. Likewise, the development in Newcastle has the ability to hide further contributions to baseflow as was observed in the Foster Creek tributary. In urban areas the drainage of shallow groundwater is more efficient due to the use of foundation drains, storm water systems and other drainage infrastructure. Urban surfaces such as roads, roofs and lawns are mostly impermeable and do not allow for groundwater infiltration that would recharge aquifers and contribute to downstream baseflows.

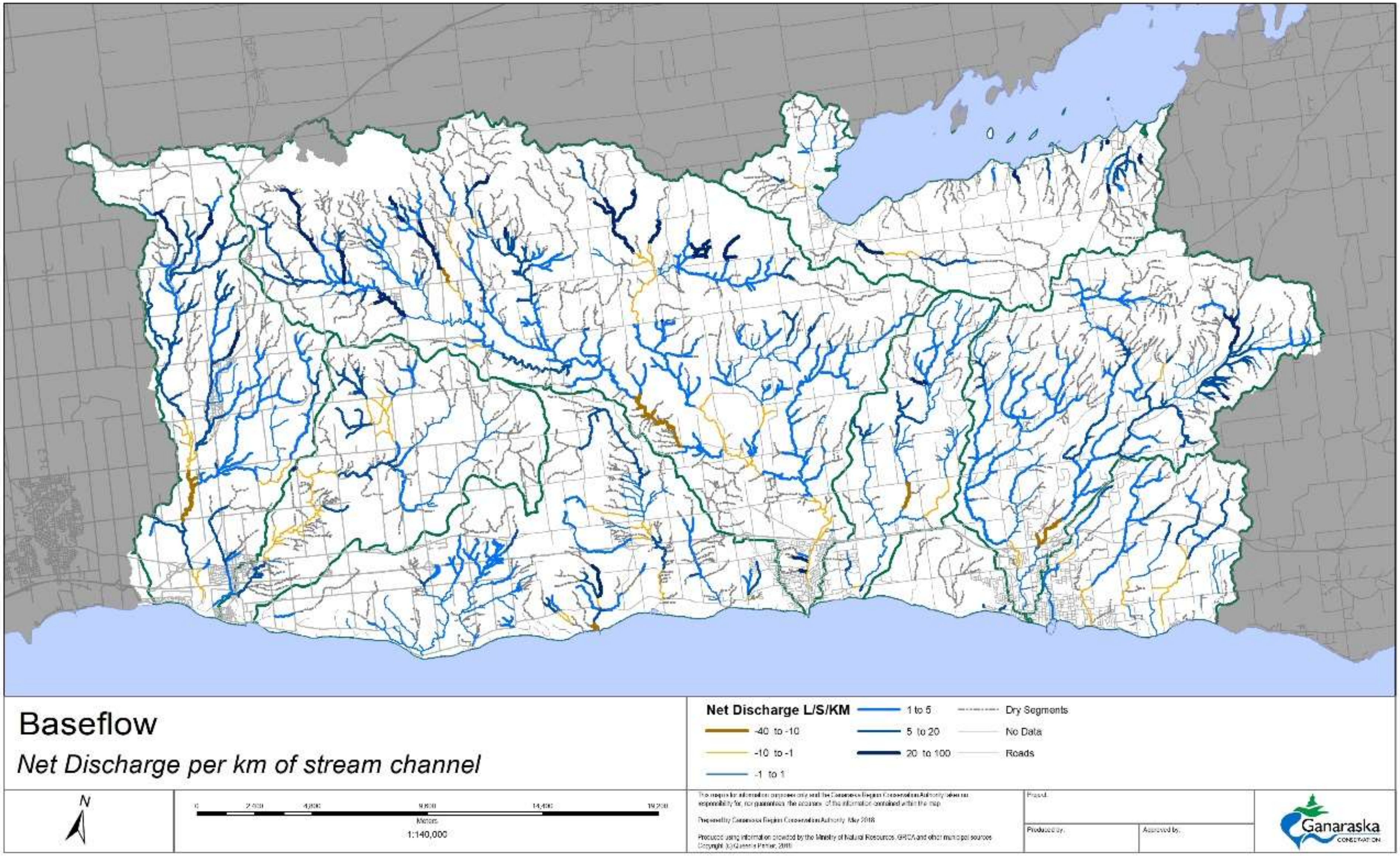


Figure 37: Baseflow Contribution

6.5 Summary Spot Baseflow Measurements

This baseflow analysis reveals the significant and important connection among topography, hydrostratigraphy and the contribution of groundwater to the surface water flows within the Ganaraska Region. The geologic deposits associated with the Oak Ridges Moraine are shown to contribute significant baseflow downstream through groundwater discharge between the divide of the moraine and the South Slope feature. Furthermore, the underlying geologic layers in the South Slope have lower hydraulic conductivity and therefore cause groundwater to flow latterly and discharge to streams rather than percolating deeper.

Localized areas of coarse surficial deposits in the Peterborough Drumlin Field allow groundwater recharge to shallow unconfined aquifers, resulting in discharges downstream that form the source of tributaries in the northeast part of the Ganaraska River watershed. Other areas of coarse surficial geology occur in patches across the GRCA jurisdiction resulting in important groundwater recharge areas that sustain baselfows in the headwaters of small streams such as Wesleyville Creek.

Some lower reaches of streams have cut through the till layers into lower aquifer units. A process taking thousands of years and resulting in the discharge of cold groundwater that likely originated in the Oak Ridges Moraine to the north.

Many streams experience losses of baseflow due to evaporation in wetlands, infiltration to stream beds due to coarse geology or where flowing streams are perched above the groundwater table. Human activities may also have a negative impact on baseflows in development areas due to impermeable surfaces and through water takings.

Future baseflow monitoring initiatives in the GRCA watersheds should focus on determining variations due to precipitation inputs from year to year and identifying any changes in baseflow due to land use changes and development such as the extension of Highway 407 through the watershed.

6.6 Baseflow Index

Baseflows are essential to aquatic life particularly of baseflow influence on river temperatures during the summer. Besides air temperature and solar radiation, the groundwater inflow rate affects stream temperature. Groundwater delivers relative cool water to the stream therefore stabilizing the short term fluctuations caused by air temperature.

The Baseflow Index (BFI) is the ratio of long-term baseflow and total flow. It represents the contribution of deep subsurface flow and groundwater to streamflow. For example, a BFI of 0.65 indicates that 65% of total streamflow can be attributed to baseflow for the respective time period (i.e. period of record).

A baseflow index (BFI) was derived using a hydrograph separation approach were determined using a Stream Analysis and Assessment Software package (SAAS). SAAS separates baseflow from streamflow using a recursive digital filtering as described by Nathan and McMahon (1990) which applies a filter to the streamflow time series to separate total streamflow from baseflow which then is expressed as a ratio in percent.

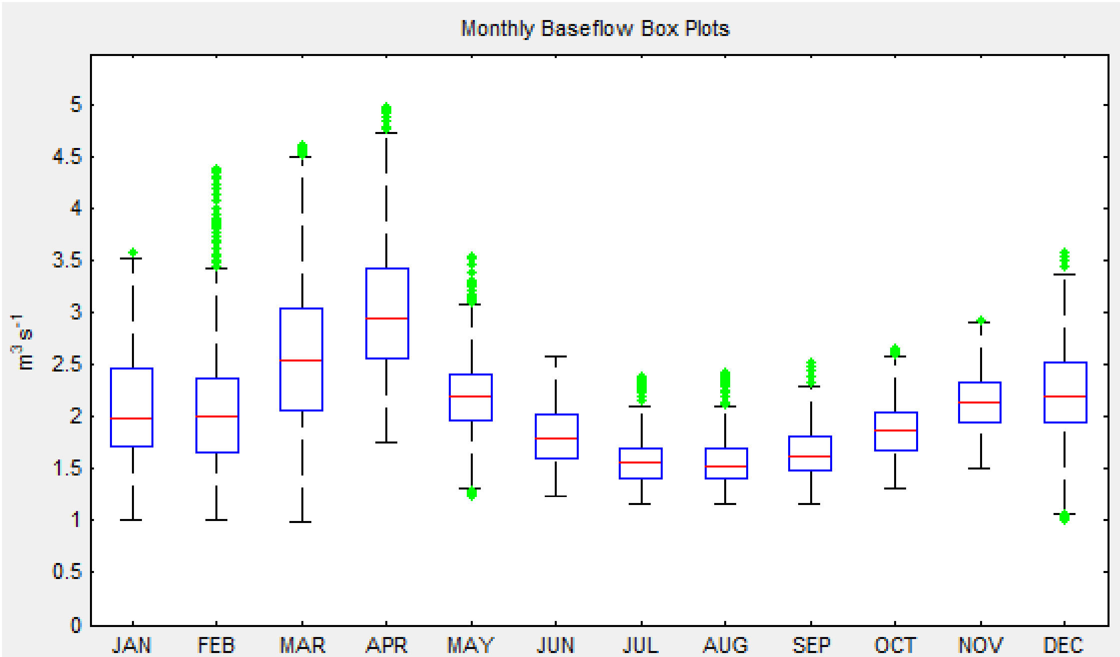


Figure 38: Monthly Baseflow Contribution Derived for the Period of Record for the Ganaraska River

The BFI for the Ganaraska River POR has a value of 0.6378, which means that over the period of record about 64% of streamflow is attributed to baseflow contributions to streamflow.

Wilmot Creek

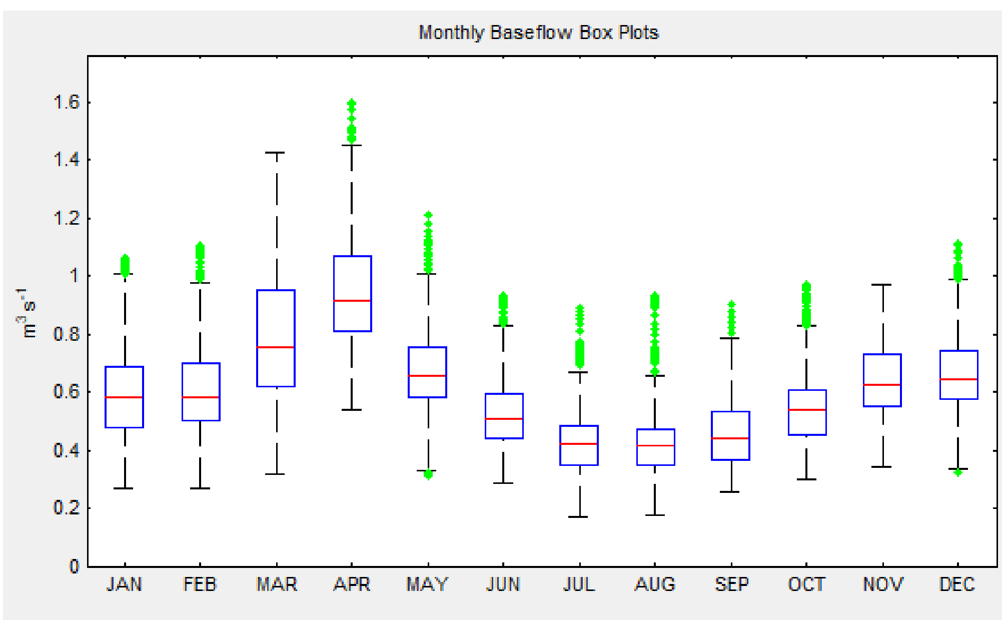


Figure 39: Wilmot Creek Monthly Baseflow Contribution Over the Course of Record

BFI for the Wilmot Creek POR has a value of 0.6081, which means that over the period of record about 61% of streamflow is attributed to baseflow contributions to streamflow

Cobourg Creek

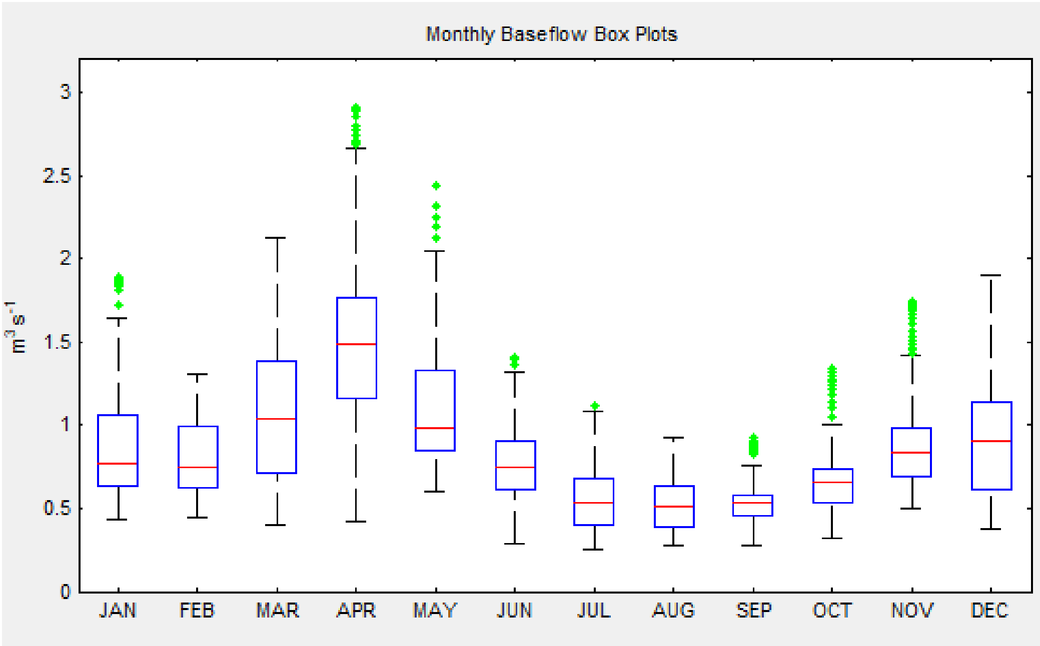


Figure 40: Cobourg Creek – Monthly Baseflow Contribution

BFI for the Cobourg Creek POR has a value of 0.5052, which means that over the period of record about 51% of streamflow is attributed to baseflow contributions to streamflow.

The BFI is an important indicator for baseflow stormflow interactions and changes can have significant effects on the structure and function of aquatic ecosystems.

6.7 Baseflow ***T***rends

The monthly baseflow (cm/s) value is used as indicator to determine monthly trends and changes over time employing the Mann-Kendal statistical test.

Ganaraska River

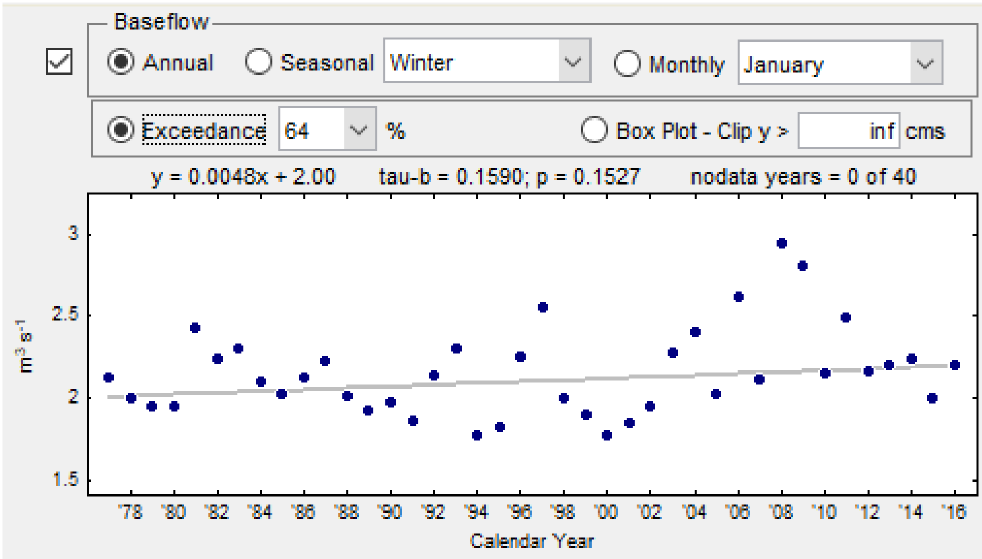


Figure 41: Increase in Baseflow Contribution Over the Course of Record – Ganaraska River

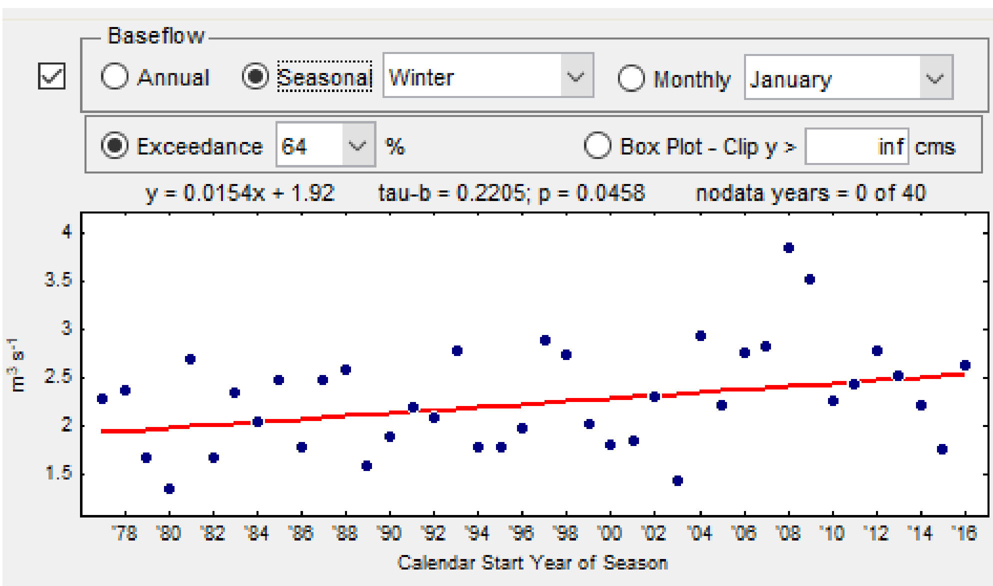


Figure 42: Increase in Baseflow Contribution During the Winter Season Over the Course of Record

While on an annual scale, baseflow shows a slight increase in baseflow contribution during the period or record within the Ganaraska River the trend is not significant. However, further analysis on a seasonal scale revealed that winter baseflow contributions exhibit a significant increase at the $p < 0.05$ level.

Wilmot Creek

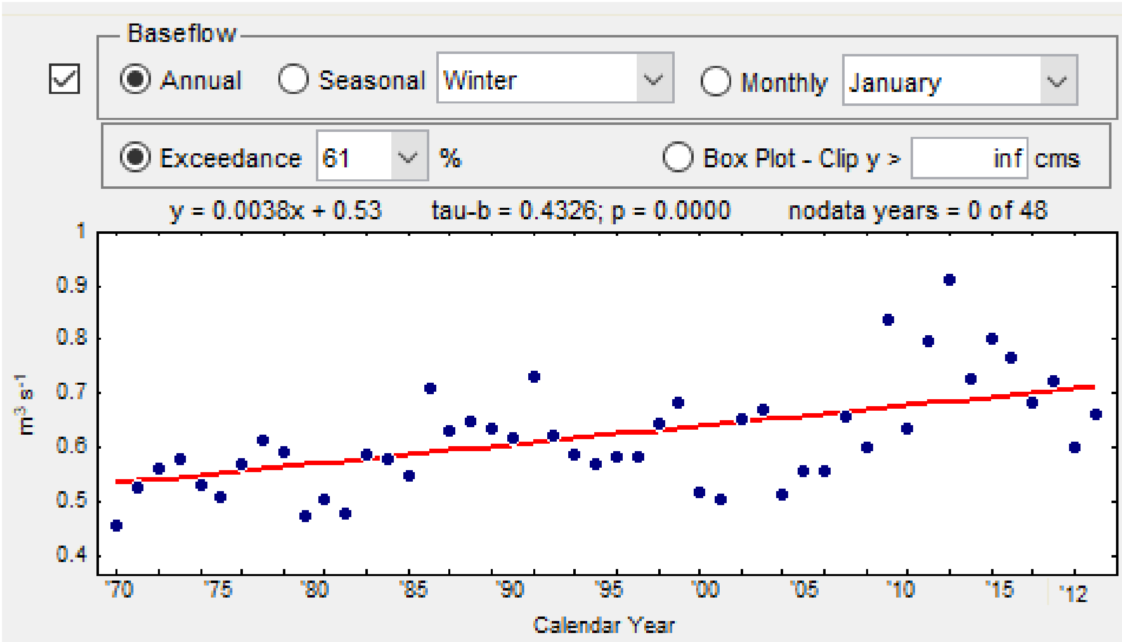


Figure 43: Increase in Baseflow Contribution Over the Course of Record, Wilmot Creek

On an annual scale, baseflow contribution show a significant increase during the period or record within the Wilmot Creek watershed, which is statistically significant at p= 0.0001.

Cobourg Creek

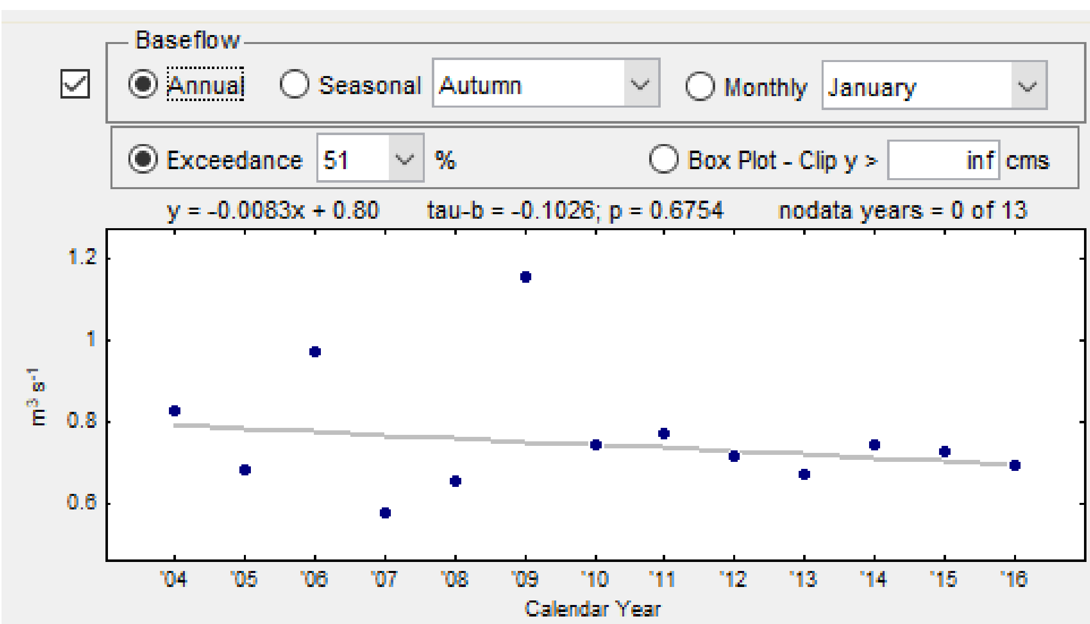


Figure 44: Decreasing Trend in Baseflow Contribution Over the Course of Record – Cobourg Creek

Annual baseflow contribution exhibit decreasing trend within the Cobourg Creek watershed. Due to the short data set a statistical significance test cannot be determined as of today.

6.8 Baseflow Recommendations

The baseflow data presented in this report was collected to map the spatial distribution of baseflows entering the watercourses of the GRCA. In doing so, we have identified and mapped the locations where groundwater and surface water interact. Most of these are groundwater springs or seepages where baseflow is gained in streams, while some areas are considered “sinks” where baseflow is lost from streams and re-enters the groundwater systems. In order to sustain healthy cold water ecosystems area of gain are essential.

Fortunately, in the GRCA watersheds there are far more baseflow gains than loses.

It is recommended that baseflow conditions continue to be monitored each summer during hot and dry weather. By monitoring the lowest annual flows each summer, any changes to the baseflows of the GRCA watersheds can be identified and related to land use or weather conditions. While cause and effect analysis is a complex process, data collection will provide long-range trends in baseflow which may be linked to the changing climate conditions. A subset of the original baseflow sites was selected in 2013 to maximize available staffing and equipment resources to monitoring baseflow in a consistent manner. We currently do not have enough data to report at this time.

The importance of baseflows in the Ganaraska watershed cannot be over-emphasized. The high quality of the cold water fish habitat would not be possible during summer heat waves and droughts if the streams were not flowing with abundant and cold baseflows. It is therefore recommended that groundwater discharge locations continue to be off-limits to development and alterations to these aquatic habitats be prohibited. Further, the groundwater recharge areas that are characterized by high infiltration rates be protected to the highest extent possible. This may include imposing water balance targets for new developments (i.e. 15mm infiltration during rain events before runoff leaves the site via traditional storm sewers.

A decrease or increase of baseflow within a riverine system is in general a long-term process. Short duration droughts are usually shielded by storage of water within the system and therefore do not result in significant water table decrease. Periods of prolonged drought conditions can however result in a water table drop that may result in deficiencies in surface- and groundwater supplies for the months with little precipitation. On the other hand, an increase of winter baseflow could point to increased inputs from snow infiltration, which in turn points to warmer temperatures that intensify the freeze – thaw cycle. An increased BFI points to baseflow that became a larger component of streamflow compared to stormflow over the period of record. A decline in summer or fall baseflow reflect the consequences of reduced precipitation over an extended period of time. It is important to notice the spatial variability of the compared basins. Both, Wilmot Creek and Ganaraska River show increasing trends in baseflow contribution, while Cobourg Creek exhibits a decreasing trend. In order to determine whether the causes of these trends correspond to precipitation increases/decreases, warmer temperature or less storage, a more detailed study is necessary including a storm event analysis and a description of the basin characteristics, such as vegetation, soil depth, slope, and landscape features such as wetlands or lakes.

Monitoring continues at selected sites within the GRCA watershed to further investigate major gains and losses in baseflow that were observed to better understand baseflow dynamics. Monitoring of baseflow temperature to obtain information regarding trends under a changing climate.

The development of a long term plan for the preservation of the significant natural area west of Port Hope in Wesleyville Creek is recommended.

Based on above findings develop priority areas to protect the sustainability of baseflow within the GRCA jurisdiction

Examine current water users to identify potential stressors on the baseflow system in drought prone areas within the GRCA jurisdiction.

7.0 Lake Levels Commentary

There are two lake shorelines within the GRCA jurisdiction (Lake Ontario and Rice Lake), both of which have monitoring stations to record lake level data that are accessible to GRCA staff. GRCA is responsible for providing Flood Forecasting and Warning to the shoreline areas of these lakes as they fall within the Authority's jurisdiction and to communicate these messages to the affected municipalities and their shoreline residents.

Lake Ontario monitoring occurs at a station at Cobourg, which exhibits annual fluctuation due to the seasonal runoff patterns from the upstream Great Lakes watershed. As a result the lake level increases each spring as it receives snowmelt water from the upstream lakes and tributaries. Peak water levels typically occur by early summer, begin to decline through the summer and fall, reaching their lowest elevation over the winter. Total fluctuation is usually in the range of 80 to 100cm and is closely regulated by the International Joint Commission. However, months of heavy rainfall and widespread flooding in 2017 has shown the difficulty in controlling the water levels of Lake Ontario.

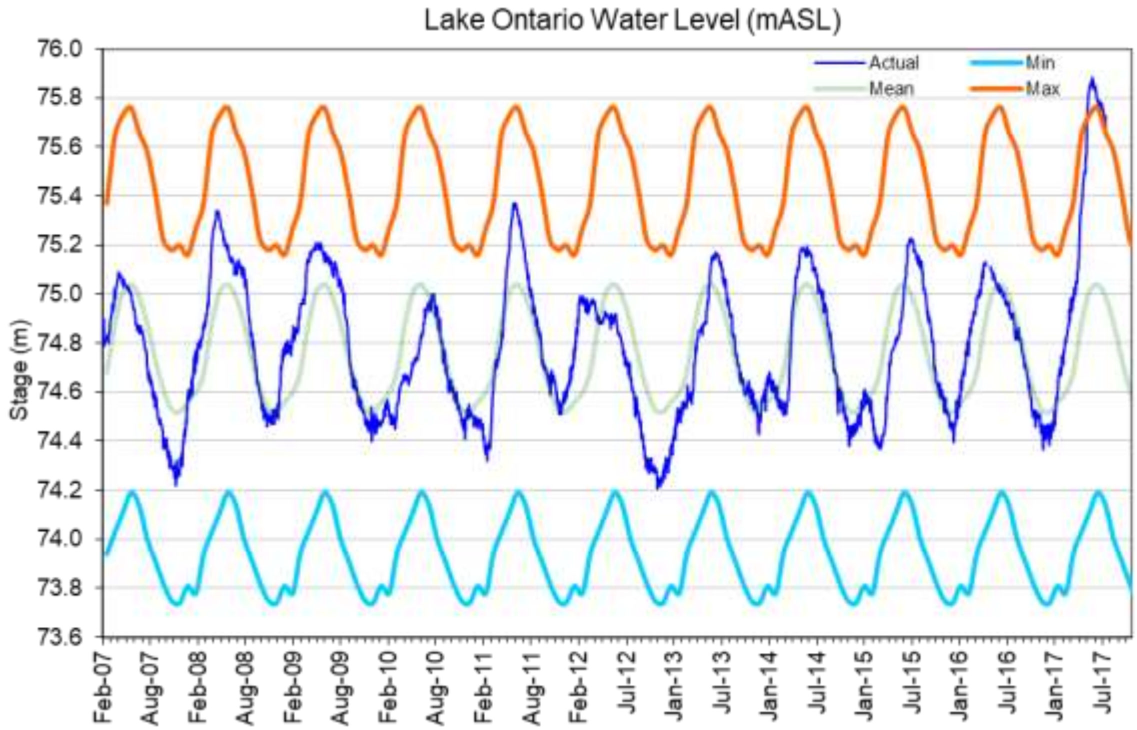


Figure 45: Lake Ontario Water Levels Fluctuate Seasonally

Rice Lake, part of the Trent River watershed is managed by the Trent-Severn Waterway at the Hastings Dam to maintain water levels for recreational boating during the summer and fall. Other management priorities include, mitigating flooding, aquatic habitat protection, maintaining good water quality and ensuring adequate water supply at intake locations. Shoreline flooding does occur from time to time around Rice Lake during the springtime as snowmelt and spring rains make their way from the headwaters down through the Kawartha Lakes, Rice Lake and eventually out to Lake Ontario. There are over 100 dams in the watershed that are managed to mitigate the worst impacts of flooding by reducing risks to personal safety and property damages in flood prone areas.

As recently as April/May of 2014, prolonged flooding occurred along the Rice Lake shoreline, as a result of large amounts of melting snow and spring rainfall that caused high runoff in the headwaters. Flooding occurred throughout the 12,000 square kilometer (km^2) Trent River watershed. On Rice Lake the event caused most of the cottage businesses to delay their season opening as they dealt with water damages and difficult shoreline access to launch docks and water pumps. Figure 45 shows the lake level rising for over three weeks as the large volume of runoff flowing into the lake exceeded the rate of flow out of the lake. At the same time, flooding both upstream and downstream of Rice Lake meant that it would take some time for the water levels to return to normal. The peak water level of 187.43 meter (m) (about 0.7 m above summer recreation levels) remained steady from April 23rd to 25th before a slow decline began when inflows finally started reducing.

GRCA staff issued a Flood Warning for Rice Lake on April 15, 2014 as Trent Severn Waterway staff advised of high runoff volumes in the headwaters. The warning message remained in place until May 8th when levels finally receded below flood threshold. During those three weeks of flooding, GRCA staff documented the event, reported the impacts and communicated forecasts to Hamilton Township staff, distributed sandbags and communicated with many shoreline property owners prior to and during the event.

8.0 Surface Water Quality

8.1 Introduction

The quality of stream surface water is influenced by many factors including inputs from point sources (direct) and non-point sources (indirect), atmospheric deposition (precipitation and dust), transformations (nutrient cycling), and groundwater inputs. Land cover and its uses in a watershed can greatly influence water chemistry and the integrity of the aquatic environment. Within the GRCA watershed, there has been a continued increase of losses of natural landscape that is converted either to urban uses or to agricultural land. The result of these shifts in land use create challenges for water resource management within the jurisdiction. Land use conversion from a natural cover to agricultural or urban purposes are documented to have adverse effects on water quality and quantity. Of particular concern is nutrient rich runoff entering streams and lakes that are known to trigger algal blooms within the Great Lakes causing damage to fish and plants. Agricultural runoff in tributaries discharging into Lake Ontario are recognized as contributing close to 50% of the Total Phosphorous and Nitrogen load that discharges into the lake. Sources associated with community and urban development known to induce stress on water quality include industrial discharge, domestic effluent, septic system wastes, and landfill sites. The water quality is subject to deterioration from these sources that tend to cause heightened concentrations of chloride (Labadia and Buttle, 1996), as well as Escherichia coli, nitrate and phosphorus, (Boyer et al., 2002). Some impacts of increased anthropogenic stress on surface water quality include habitat loss, increased occurrence of algal blooms, and altered stream morphology (Meyer et al., 2005).

The GRCA undertakes a surface water quality monitoring program to help understand the health of local streams. The water chemistry monitoring network consists of 27 stations across the GRCA watershed. Nine of these stations are part of the Provincial Water Quality Network (PWQMN).

High quality water is needed for a healthy aquatic ecosystem that is adapted to the unique initial landscape and as a source of drinking water. Many guidelines exist that set out limits for certain water quality parameters as they relate to the protection of aquatic life, recreational activities, and water use for agricultural purposes and human consumption. In Ontario, the provincial government has set out *Provincial Water Quality Objectives (PWQO)* as target values. In addition, the Federal government has set out *Canadian Environmental Quality Guidelines (CEQG)*.

In order to characterize the surface water quality within the GRCA jurisdiction at present, a subset of water quality parameters were utilized to determine long-term health trends and current conditions. These are chloride, nitrate, phosphorous and E.coli, which are stressors to aquatic life and adversely affect water quality for human consumption or recreational water usage.

8.2 Surface Water Quality Methods

Information detailing the GRCA Surface Water Quality Monitoring Program including the types of programs and sampling methods can be found in *Ganaraska Region Watershed Monitoring Plan: towards an integrated approach, 2014*.

Results from two of the three recommended programs were evaluated: the Provincial Water Quality Monitoring Network (PWQMN), and the Ganaraska Region Water Quality Monitoring Network (GRWQMN). The High Water Event Monitoring Program as recommended in the 2014 *Ganaraska Region Watershed Monitoring Plan* is currently not implemented due to budgetary restraints. At this time a partnership with Trent University is developed that includes research sampling during storm flow events within Wilmot and Gage Creek.

Evaluating status and trends of water quality within the GRCA is based on a sub-set of water quality parameters identified in the 2014 *Ganaraska Region Watershed Monitoring Plan* and are listed in Table 4.

Table 4: Surface Water Quality Indicators and Targets

Indicator	Parameters	Guideline
Ions	Chloride	120 mg/L*
Bacteria	Escherichia coli	100 cfu/100mL
Nutrients	Total Nitrate	2.93 mg/L*
	Total Phosphorus	0.03 mg/L (winter) 0.02 mg/L (summer)
All targets are Provincial Water Quality Objectives (PWQO) unless otherwise indicated. *Canadian Environmental Quality Guidelines (CEQG)		

A Water Quality Index (WQI) is applied employing the methodology published by the Canadian Council of Ministers of the Environment (CCME) in 2001 for assessing water quality conditions relative to water quality objectives. The calculator is a guideline driven tool, providing means for the user to analyze large amounts of data into a single, easy to understand score.

The WQI derives a value between 0 and 100, which indicates the water quality of the sampling site ranging from Poor (0) to Excellent (100) (Table 5).

The GRCA used the CCMEs WQI calculator version 2.0 to generate a water quality index for each sampling station in 2016.

Further statistical analyses is carried out using Microsoft Excel.

Table 5: WQI Indices for Each WQI Category

WQI Index	**WQI Category**	**Description**
95-100	**Excellent**	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels
80-94	**Good**	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels

65-79	**Fair**	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels
45-64	**Marginal**	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels
0-44	**Poor**	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels

8.3 Results

Water Quality status in 2016 within the GRCA watershed ranged from excellent to poor (Figure 46)

Following data sets ranges are used to describe PWQMN trends.

- Current conditions are defined by the year December 2015 to November 2016.
- Long-term trends are defined by the start of the data set to 2016 inclusive.

Following data ranges are used to describe GRWQMN trends

- Year 2016
- Short-term trends are defined by the range July 2013 to 2016 inclusive.

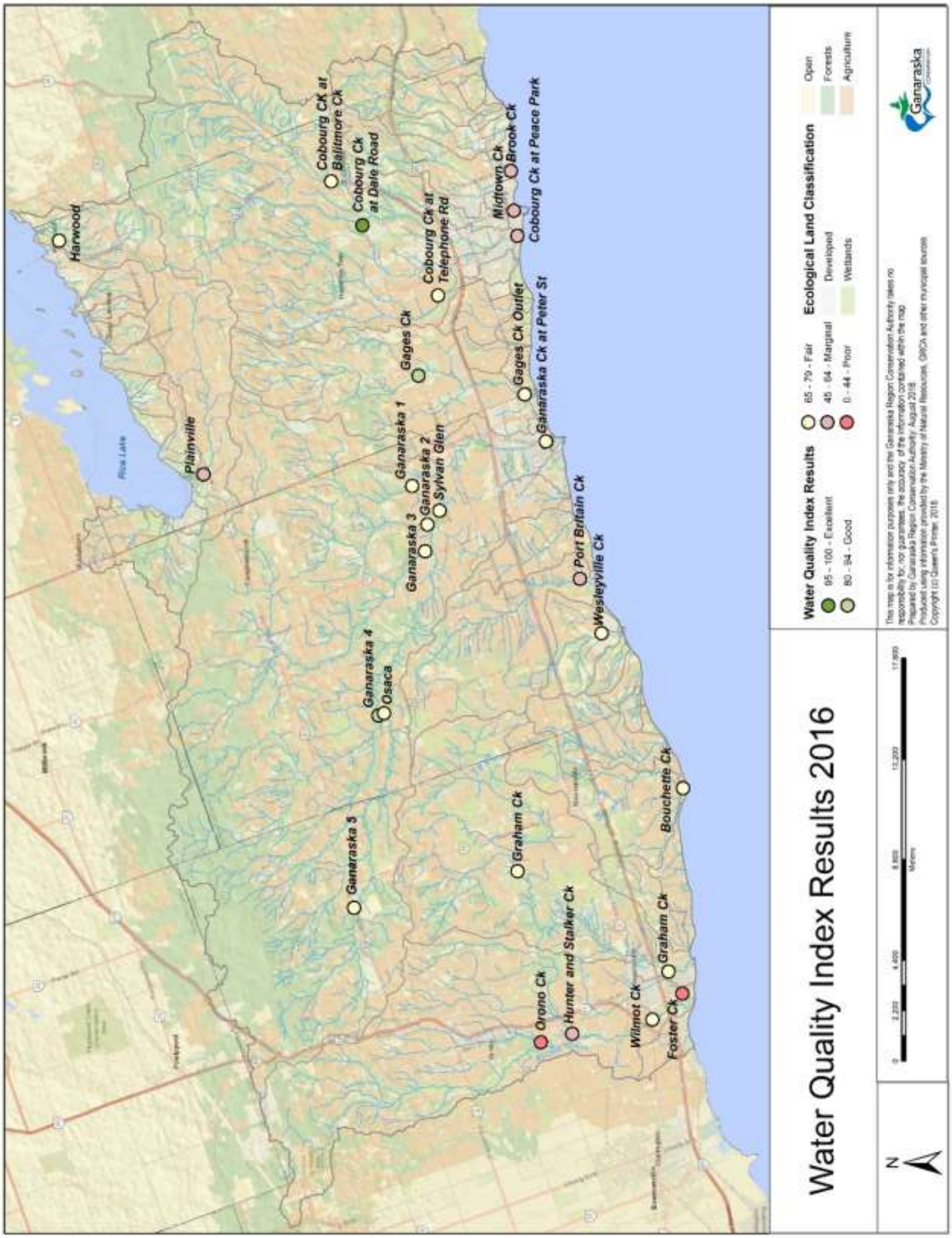


Figure 46: Water Quality Index Results 2016

8.3.1 Chloride

Chloride concentrations sampled at GRWQMN sites vary throughout the watershed. Urban streams such as Foster Creek and Midtown Creek show highest median concentrations near or above CEQG (Figure 47).

Canadian Environmental Quality Guidelines

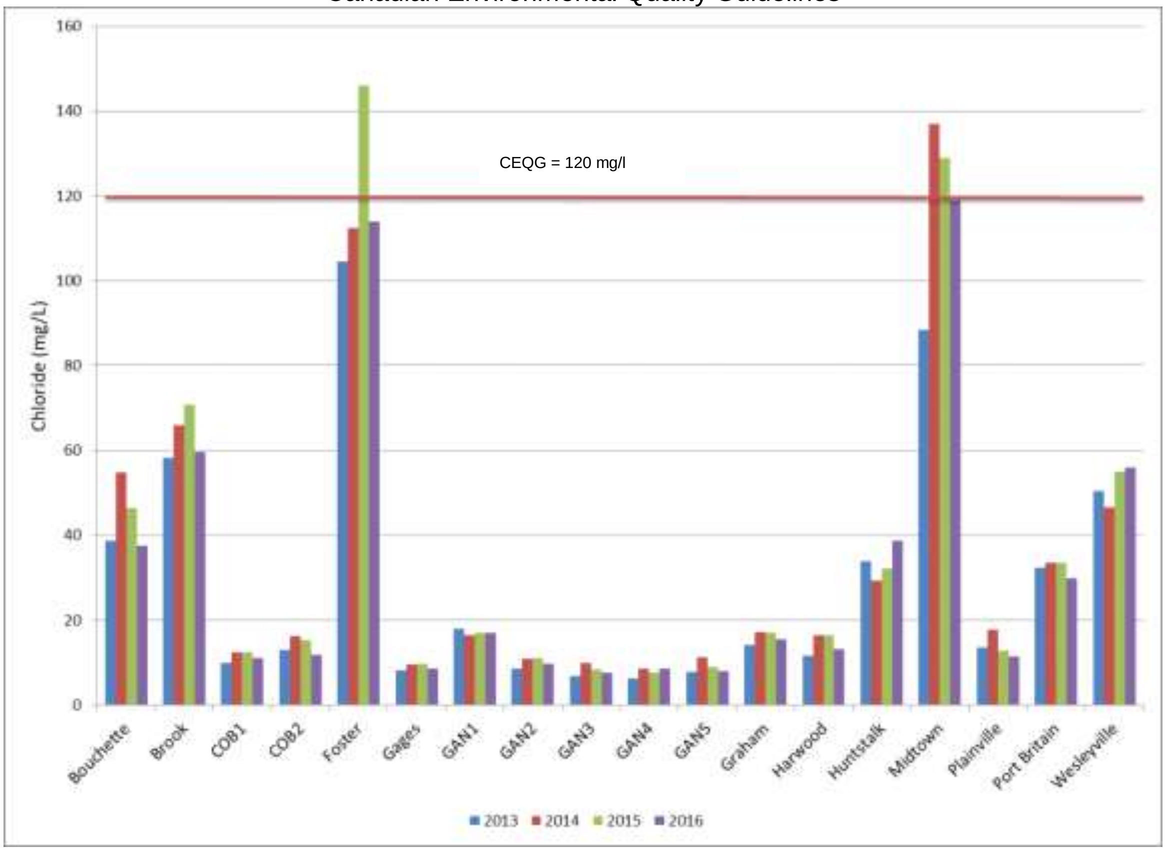


Figure 47: Median Annual Chloride Concentrations at GRWQMN Sites

8.3.2 Total Phosphorus

Total phosphorus concentrations within the GRCA watershed have exceed the PWQO of 0.03 mg/L at Graham Creek, Cobourg Creek and the Ganaraska River at Peter Street, however median concentrations remain below the threshold (Figure 48).

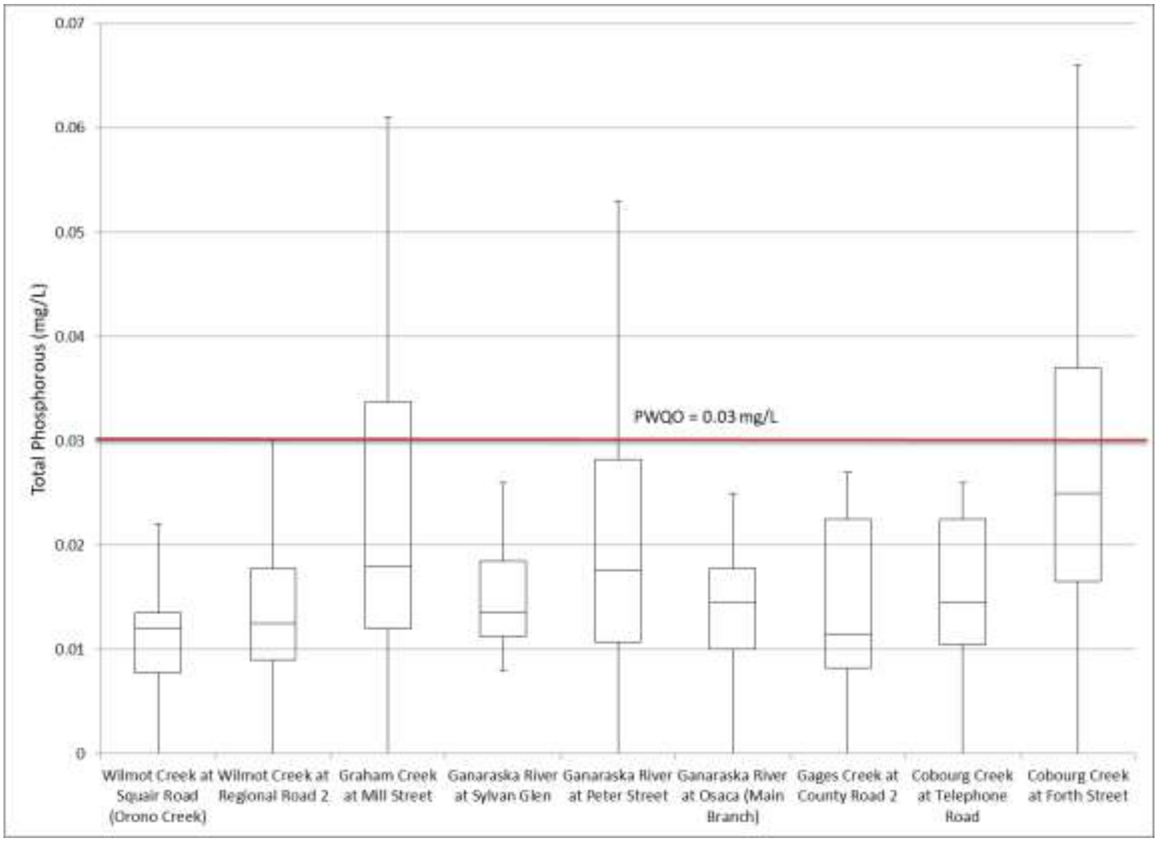


Figure 48: Total Phosphorus Concentration at PWQMN Stations in 2016

Long-term trends at PWQMN stations show a decrease in median annual concentration since the 1970s (Figure 49) and remain below the PWQO benchmark since the millennium, which is most noticeable Cobourg Creek at Fourth Street.

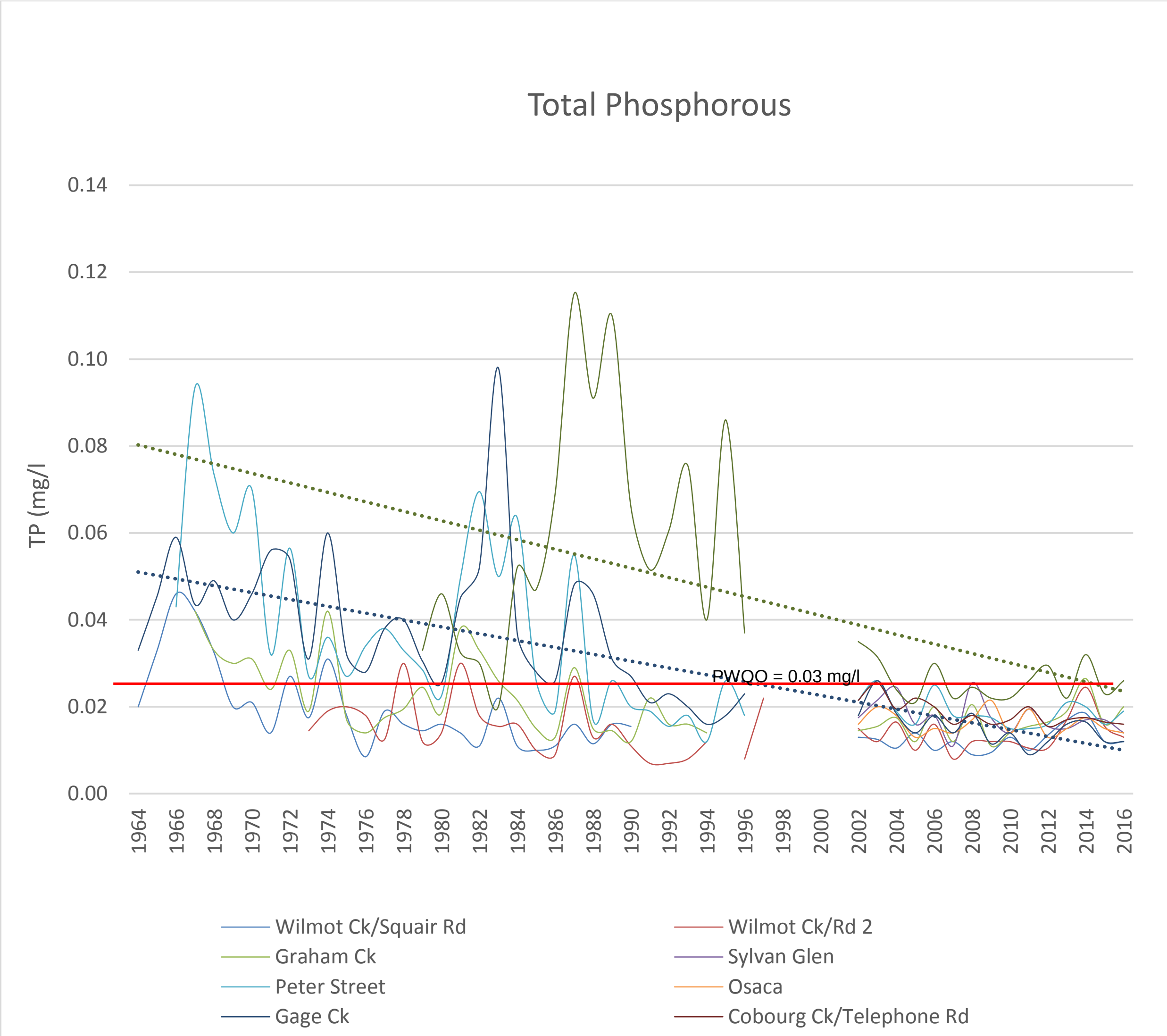


Figure 49: Total Phosphorus Long-Term Trend, Median Concentration at PWQMN Stations – Decreasing Trend

Total phosphorous concentrations sampled at GRWQMN sites show median annual concentrations exceed the PWQO especially in 2014 (Figure 49). Median concentration for Foster Creek are 4 times higher than the recommended objective during that time. Exceedances are also observed for Graham, Midtown, Hunter and Stalker Creek.

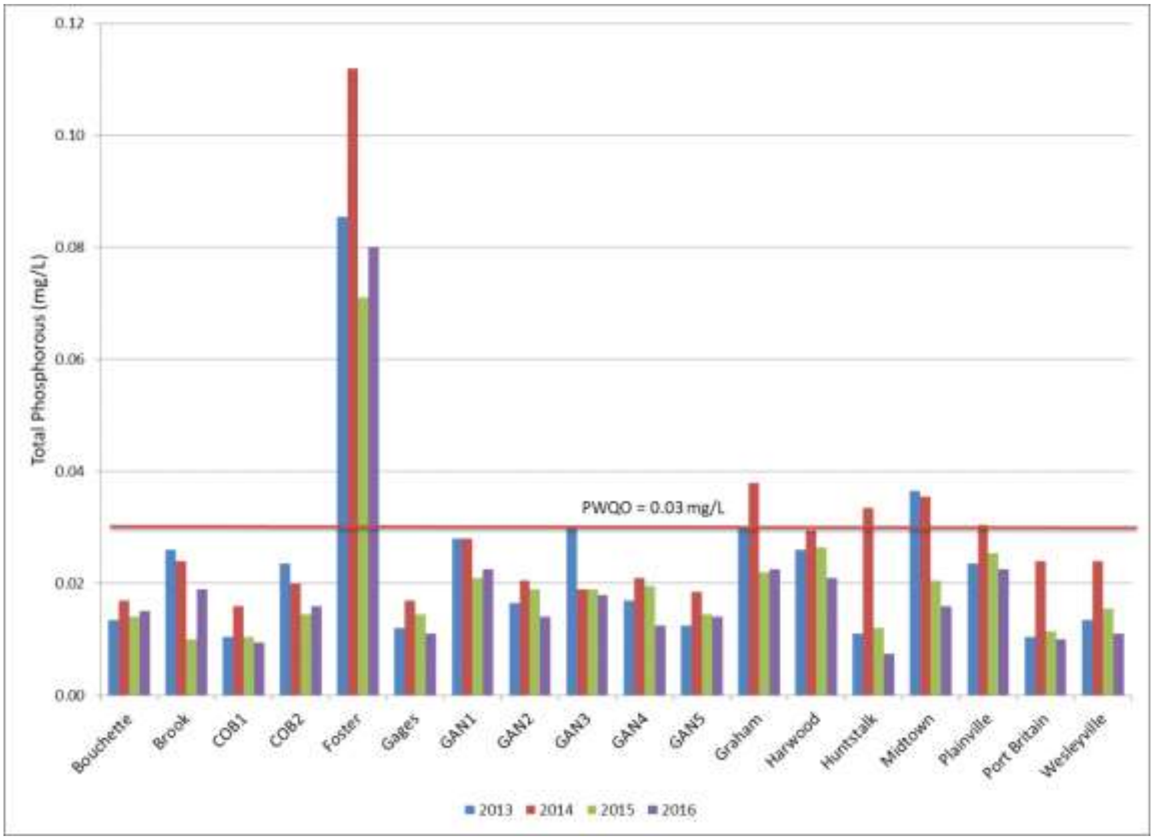


Figure 50: Median Annual Total Phosphorus Concentrations at GRWQMN Sites

8.3.3 Nitrate

Nitrate concentrations vary across PWQMN stations, however median concentrations remain below the CEQG of 2.9 mg/L, with the exception of Orono Creek (Figure 51).

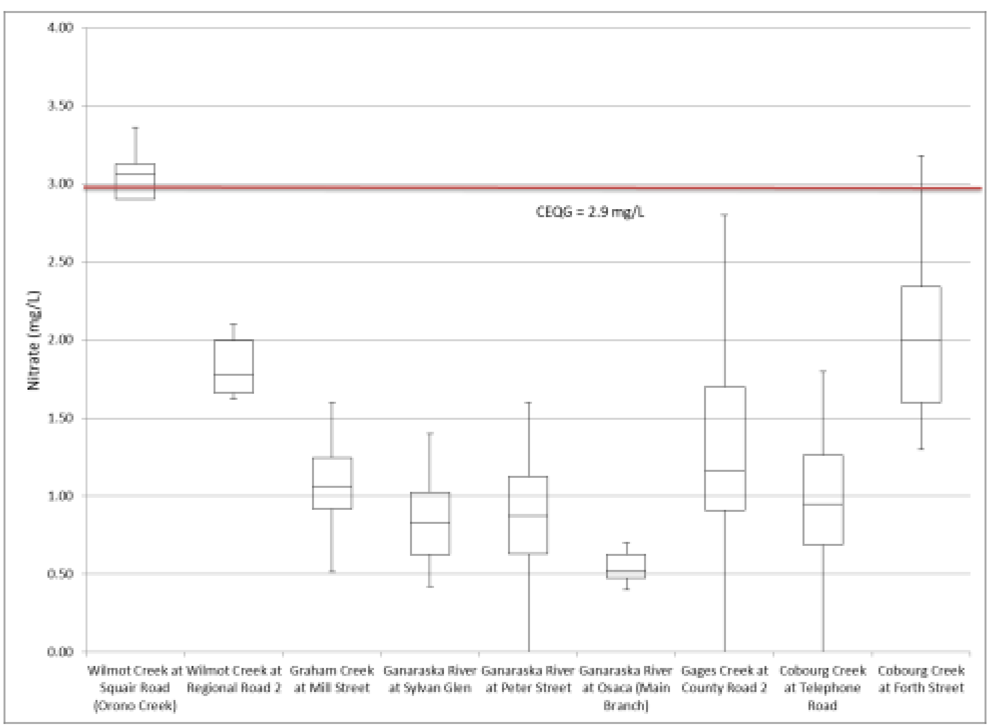
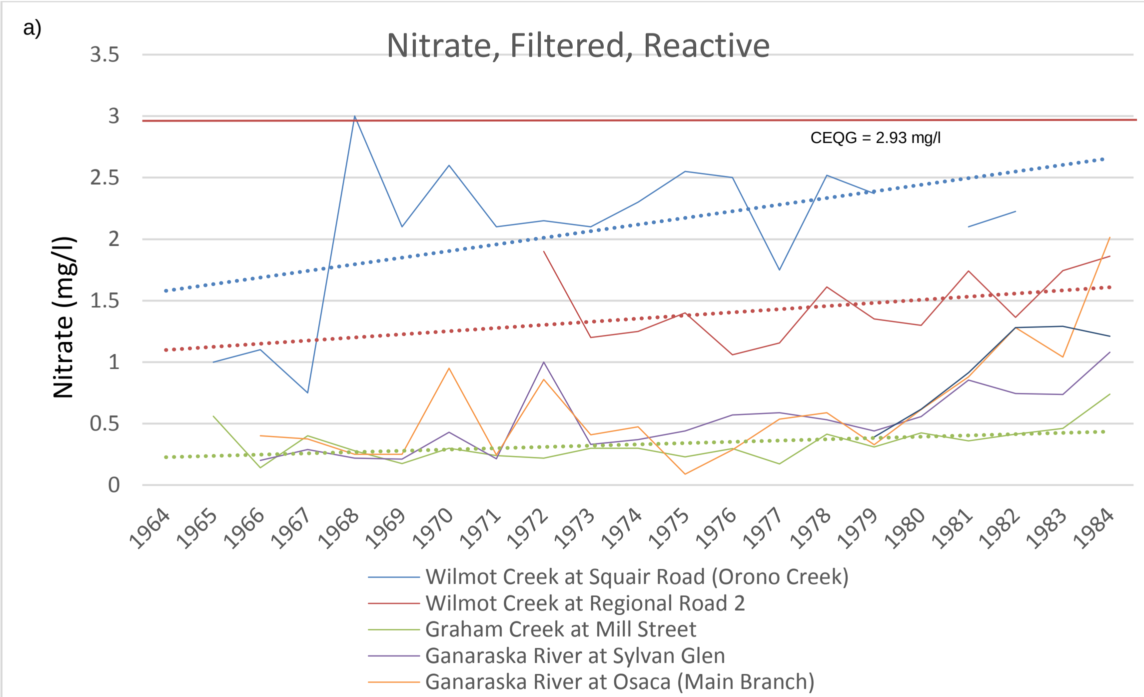
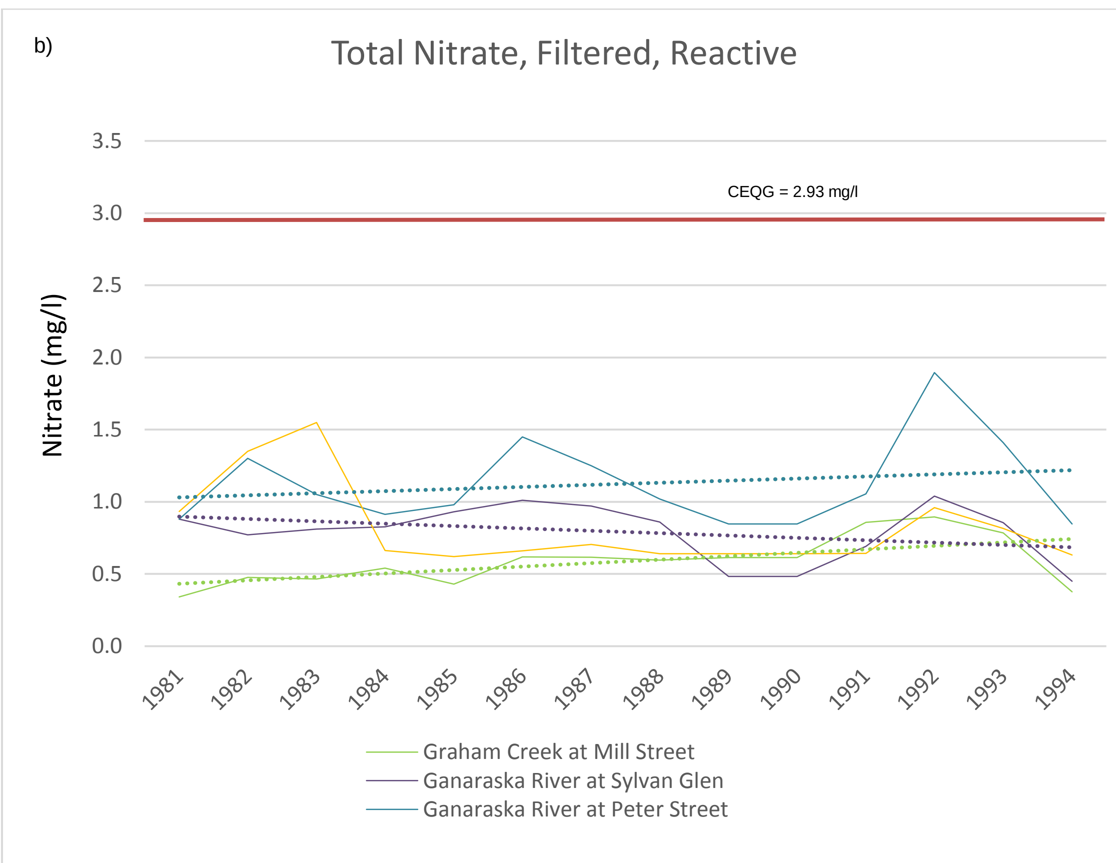


Figure 51: Nitrate Concentration at PWQMN Stations in 2016


a)
Nitrate, Filtered, Reactive
CEQG = 2.93 mg/l
Nitrate (mg/l)
3.5
3
2.5
2
1.5
1
0.5
0
1964 1965 1966 1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984
Wilmot Creek at Squair Road (Orono Creek)
Wilmot Creek at Regional Road 2
Graham Creek at Mill Street
Ganaraska River at Sylvan Glen
Ganaraska River at Osaca (Main Branch)


b)
Total Nitrate, Filtered, Reactive
CEQG = 2.93 mg/l
Nitrate (mg/l)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994
Graham Creek at Mill Street
Ganaraska River at Sylvan Glen
Ganaraska River at Peter Street

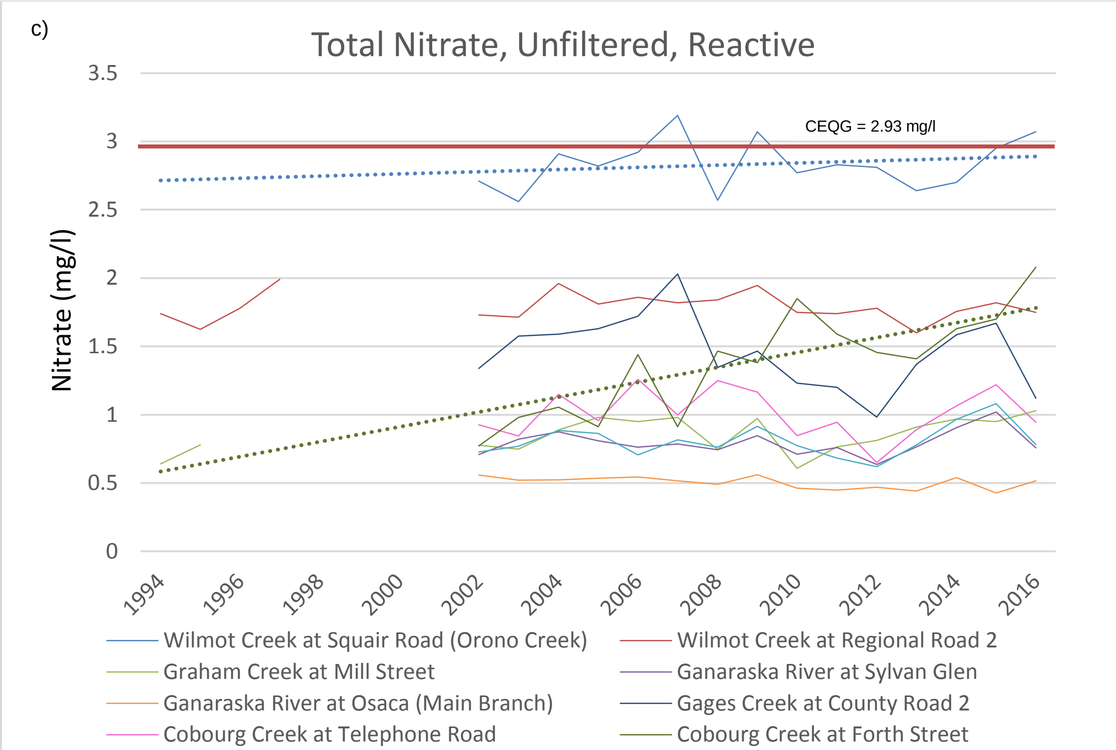


Figure 52: a-c Long-Term Trend, Median Annual Nitrate Concentrations, a) Filtered, Reactive (1964 – 1984); b) Total Nitrate, Filtered, Reactive (1981 – 1994), and c) Total Nitrate, Unfiltered Reactive (1994 – 2016) at PWQMN Stations

Nitrate concentrations indicate that median annual concentrations stay below the CEQG among the GRWQMN sites with the exception of Foster Creek, Hunter and Stalker Creek, and Plainville Creek (Figure 53).

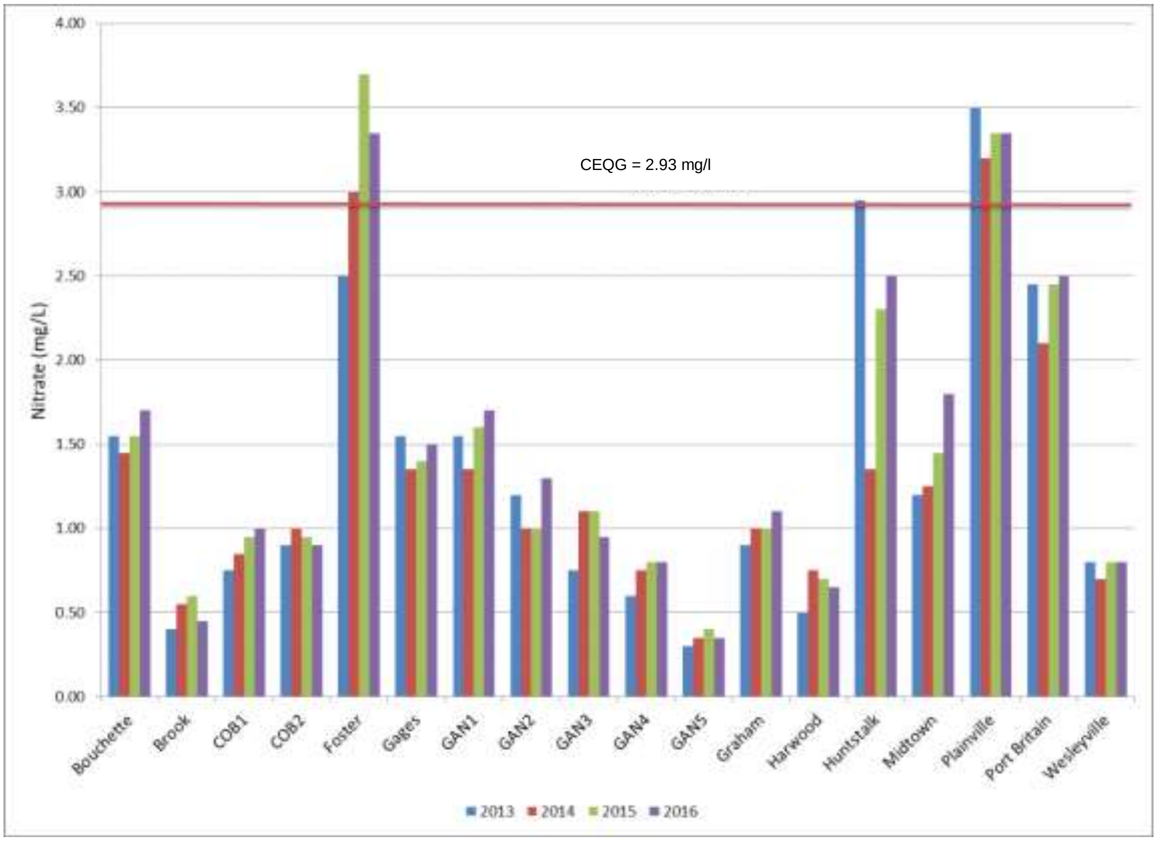


Figure 53: Median Annual Nitrate Concentrations at GRWQMN Sites

8.4 Summary

This initial look at surface water quality across the GRCA jurisdiction indicates that chloride concentrations are highest and are showing an increasing trend in the Orono Creek tributary to Wilmot Creek. Additionally, urban tributaries such as Foster Creek and Midtown Creek exceed the CEQG and show great variability throughout the year. Degraded water quality is seen in relation to chloride concentrations in Wilmot Creek (especially Orono Creek) and urban watersheds such as Foster Creek (tributary to Wilmot Creek) and Midtown Creek in the Town of Cobourg. Ongoing implementation of municipal salt management plans and public education is required to mitigate chloride impacts on local watersheds. Further investigation should be carried out in the Wilmot Creek watershed to understand the increasing trend of chloride, which may be related to provincial, regional and municipal roadways as well as historical salt storage sites. These further investigations may lead to the identification of remediation sites or enhanced salt management areas.

Total phosphorous concentrations vary across PWQMN stations, and short-term trends (median annual concentration) are below PWQO with the exception of Cobourg Creek at Forth Street, which nears or exceeds the PWQO from time to time. Long-term trends (median annual concentration) at PWQMN stations have been reducing in variability since the 1960s and 1970s, specifically at downstream site within Cobourg Creek, Ganaraska River and Gages Creek. The overall decreasing trend in phosphorus concentrations over time may be the result of land conversions from agricultural to residential and commercial uses. It may also reflect the application of best management practices in agricultural lands, including but not limited to the application of slow release fertilizers. Continued monitoring of potential sources of this nutrient should provide a better understanding of the causes of phosphorus enrichment and decline.

Over the time of record, significant changes in the methods for testing nitrate took place. These changes resulted in analysis of laboratory results using different methods at different sampling durations. Therefore, a statistical analysis is not feasible at this time. This includes the recent and more widely accepted method of analyzing unfiltered samples.

Nitrate concentrations vary across PWQMN stations; however, concentrations (median annual concentration) are well below the CEQG of 2.9 mg/L. Although land uses and cover in the immediate vicinity of the monitoring stations have a direct influence on its water quality, upstream land uses and cover are also important contributors to the overall composition of the water sample collected in each station. Long-term trends (median annual concentration) indicate a slight increase of nitrate concentrations sampled at GRWQMN sites, which is most visible at Wilmot Creek at Squair Road (Orono Creek) and Gages Creek.

Continued monitoring is needed to provide a better understanding of the seasonal and annual fluctuations in this nutrient and its current and future potential to affect human consumption and aquatic resources. Ongoing stewardship and public education is required to mitigate increasing trends.

8.5 Recommendations

Provincial Water Quality Monitoring Network

High Water Event Monitoring
Four automated ISCO samplers have been used since 2010 to monitor high flow events for indicators listed in 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. Sampling occurs when rainfall or snowmelt 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. For this *reason,* additional sites are needed to understand the impact of human activities within the GRCA watershed.

- Distribution between catchments representing urban, agricultural and natural land cover as the dominant feature.
- Distribution among subwatershed across the jurisdiction to assess impact of tile drainage on water quantity.
- Distributed between the major physiographic regions across the jurisdiction.
- Representation of major sub-catchments within Wilmot Creek, Ganaraska River and Gages 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 across the GRCA. Chloride is now monitored monthly throughout the year at all the PWQMN and GRWQMN sites.

It is recommended to continue monitoring for the indicated parameters and stations.

9.0 Monitoring Aquatic Resources

9.1 Introduction

Fishes are one of Ontario's most valued natural resources from an ecological, biological, economic, and social perspective. Protecting and restoring the aquatic ecosystem results in healthy fisheries and environments. Any changes to surrounding land-use practices could lead to changes in local watersheds and the health of their aquatic ecosystems. For example, loss of wetlands could result in decreased water quality, water quantity or alteration to stream channel morphology. These changes could then result in a change in the fish community and/or its productivity. The need for active protection and management of the fisheries resource stems from the importance of fish as environmental indicators of the health and condition of the watershed. As defined in Karr (1981), fish are excellent environmental indicators for a number of reasons:

- extensive life-history information is available;
- fish occupy a variety of trophic levels, utilize foods of both aquatic and terrestrial origin and occupy 'apex' aquatic predator positions;
- species are relatively easy to identify;
- fish are typically present in all waters;
- the general public can relate to statements of fish community conditions and the results of the studies can be directly related to the recreational programs of a fishery.

An Index of Biotic Integrity (IBI) is a tool that measures fish community associations and is used to identify the general health of the stream ecosystem/watershed (Steedman 1988). Integrative measures of stream condition, including IBIs and percent similarity measures, are particularly useful for assessing overall stream health because they integrate multiple influences. However, species traits, feeding and reproductive guilds, taxa of known tolerance to particular stressors, and other less-aggregated measures are likely to prove more useful in evaluating the health and status of fish communities and their environments (Poff 1997).

The GRCA has adopted the use of the Central Lake Ontario Conservation Authority (CLOCA) IBI for stream fish communities in wadebale portions of Northern Lake Ontario Tributaries (CLOCA 2013). This IBI has continuous scoring criteria that were developed based on Minns et al. (1994) and Hughes et al. (1998) that allows for increased IBI accuracy and precision. Four metrics are utilized to determine the IBI score, which are shown in Table 6. Sites are classified into poor (0-25), fair (26-50), good (51-75), and excellent (76-100) health based on their IBI score.

Table 6: Metrics Used to Determine the Index of Biotic Integrity

IBI Metric	Metric Characteristic
Intolerant Species	This metric is composed of two parts: percent of total species that are intolerant and percent of total individuals that are intolerant. There is a hierarchy of intolerance, based on (1) high intolerance, e.g., Brook Trout, (2) medium intolerance, e.g., Mottled Sculpin, and (3) low intolerance, e.g., Johnny Darter.
Tolerant Species	The tolerant metric is classed similarly to the intolerant metric, based on (1) high tolerance, e.g., Blacknose Dace, (2) medium tolerance, e.g., Bluntnose Minnow, and (3) low tolerance, e.g., Longnose Dace.
Top Trophic Level Species	Species included in this metric are species that hold the top trophic position, and are not necessarily top carnivores, or over a predetermined size threshold.
Stenothermal Species	This metric includes fish that are unable to tolerate temperature fluctuations and require consistent temperatures (e.g., coldwater species).

9.2 Data Analysis Methods

All backpack electrofishing sites are sampled once per year, usually late summer, and follow a single pass method outlined within the Ontario Stream Assessment Protocol (Stanfield 2013). All sites were a minimum of 40 meters long, or if longer, one complete stream crossover in order to sample all habitat types within that section of stream. Effort is targeted at 5-10 electrofishing seconds per meter^2 of stream habitat. All captured fish are identified to species, counted, and length and weights are collected. From these, density and biomass estimates are created for each species per site, for each year.

Wilmot Creek has five sites on the mainstem, distributed longitudinally along the watershed, and one site on the lower portion of its largest tributary, Orono Creek (Figure 54). Wesleyville Creek has four sites on the mainstem distributed longitudinally along the watershed (Figure 61).

9.3 Preliminary Results

Wilmot Creek

All sites on Wilmot Creek over the whole data series are considered to be in excellent health based on the fish IBI scores, with the exception being the lowest site in the watershed (BM01), which is in fair health (Figure 54). The ecological condition increases longitudinally, from the lowest health downstream (BM01) to the best health at the upstream site (BM05). Orono Creek has only one site (OR01), and it is in excellent health. Site BM01 has had an increasing health trend over time, primarily driven by a decline in cyprinid and catastomid species, and increase in salmonids (Figure 60). Sites BM02, BM03, BM04, and BM05 have also increased in ecological health over time, likely due to the abundance of salmonids and sculpin species dominating the fish community (Figure 55-59). Site OR01 has remained stable with an excellent health score, although the number of sampling events is much smaller for this site (Figure 60). Similar to most sites on Wilmot Creek, salmonid species and sculpin dominate the fish community.

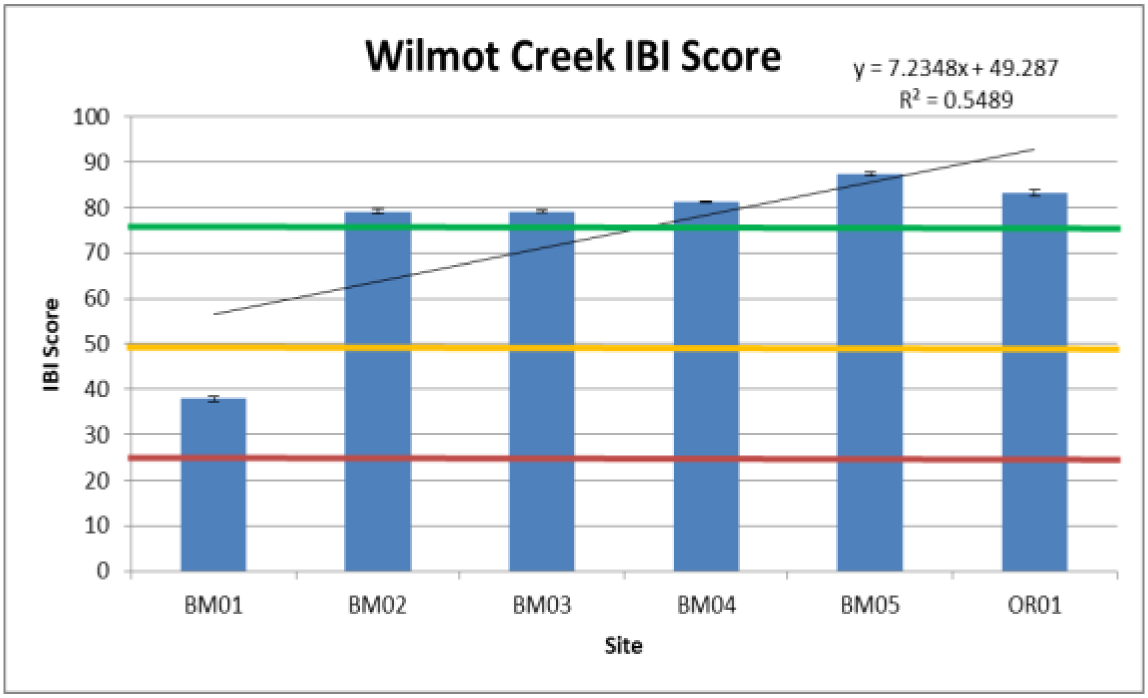


Figure 54: Wilmot Creek Average IBI Scores At All Sites

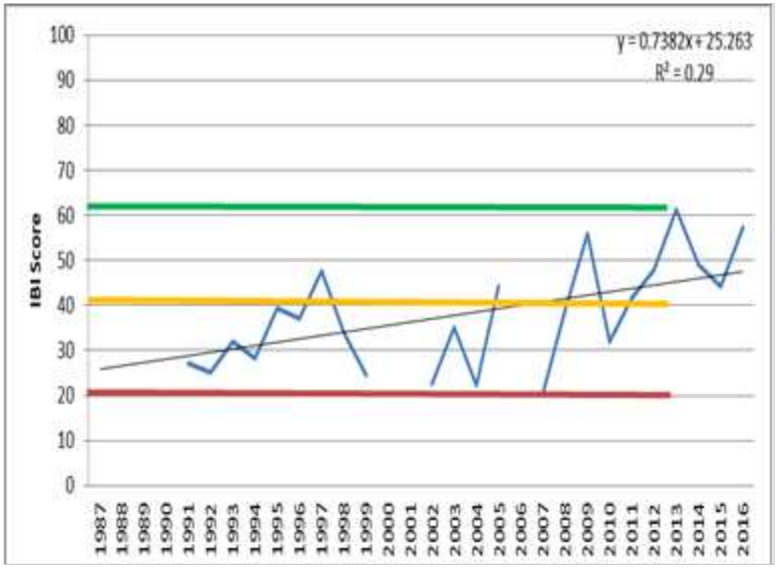


Figure 55: IBI Score Over Time At Site BM01

Figure 56: IBI Score Over Time at Site BM02

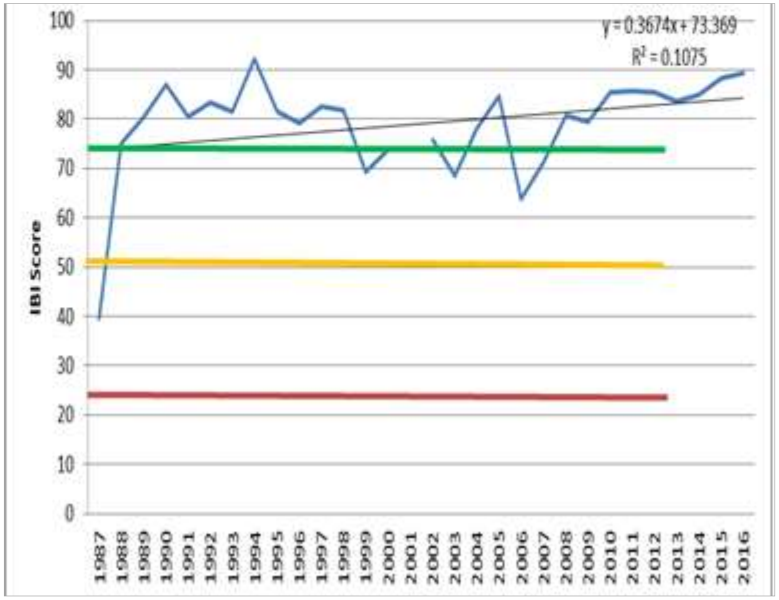


Figure 57: IBI Score Over Time At Site BM03

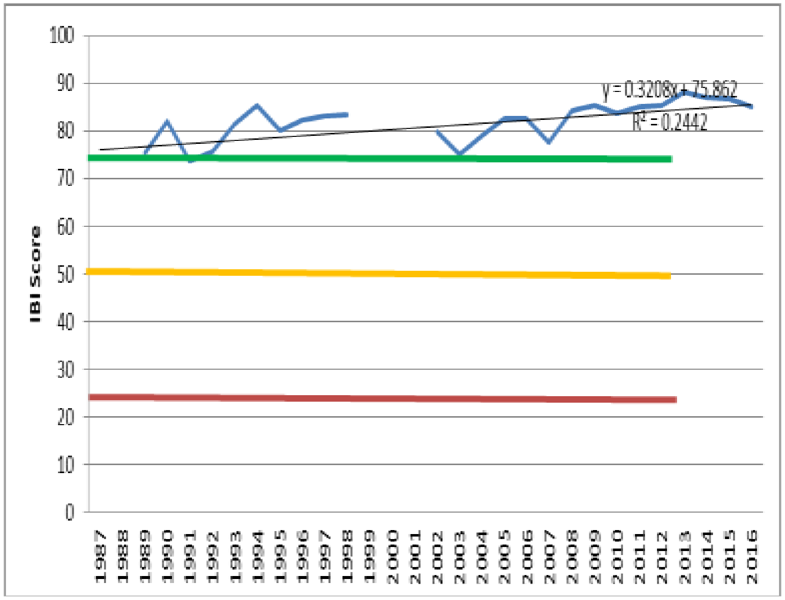


Figure 58: IBI Score Over Time At Site BM04

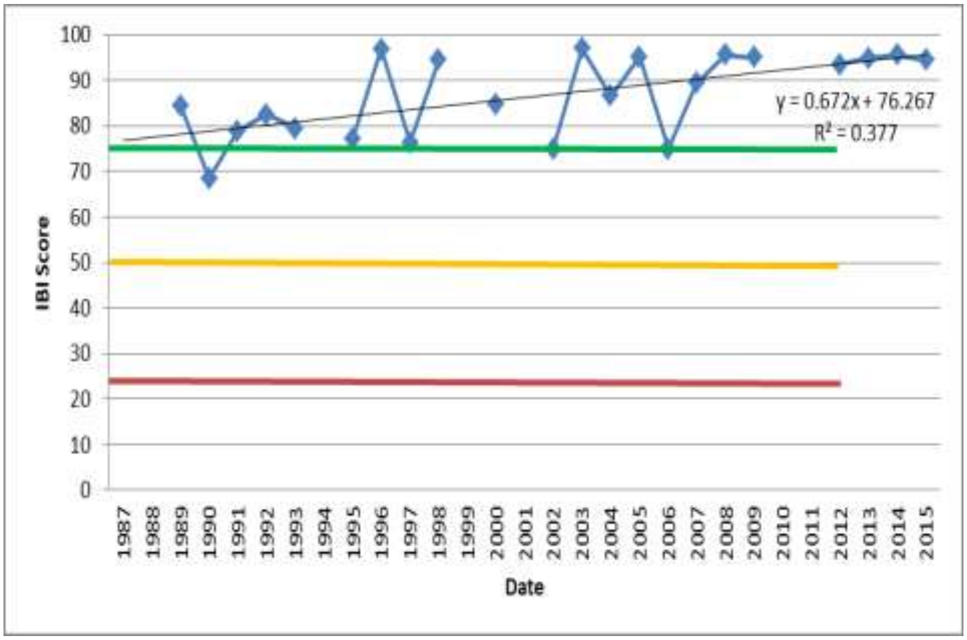


Figure 59: IBI Score Over Time At Site BM05

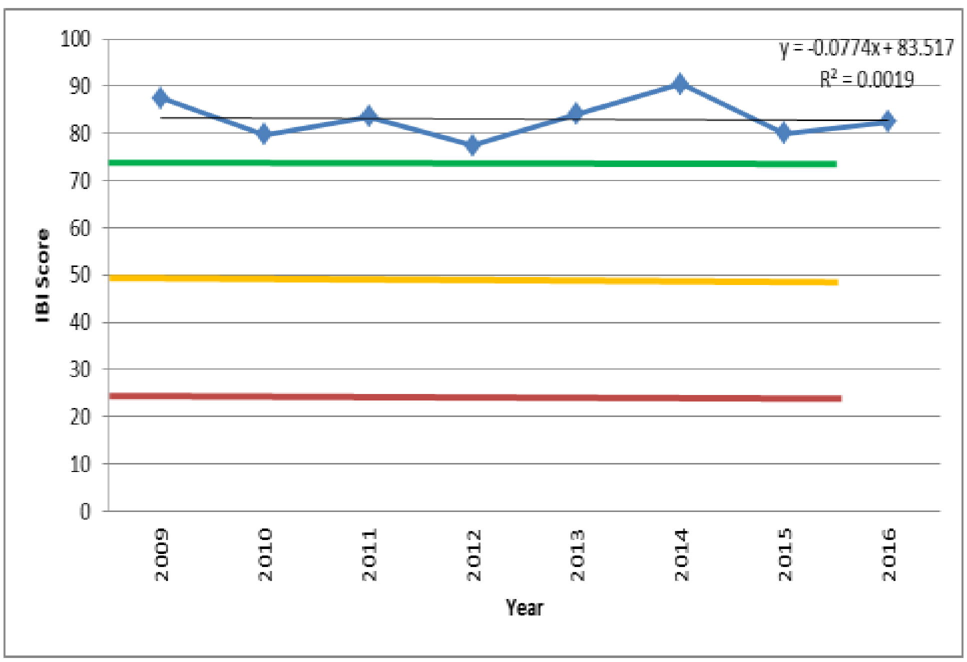


Figure 60: IBI Score Over Time At Site OR01

Wesleyville Creek

Four fisheries sites are monitored annually on Wesleyville Creek utilizing the OSAP protocol. Two sites on Wesleyville Creek over the whole data series are considered to be in excellent health, with one site in good health, and one is in fair health (Figure 60). The ecological health increases longitudinally, from the lowest health downstream (WSL0103) to the best health at the upstream site (WSL0403).

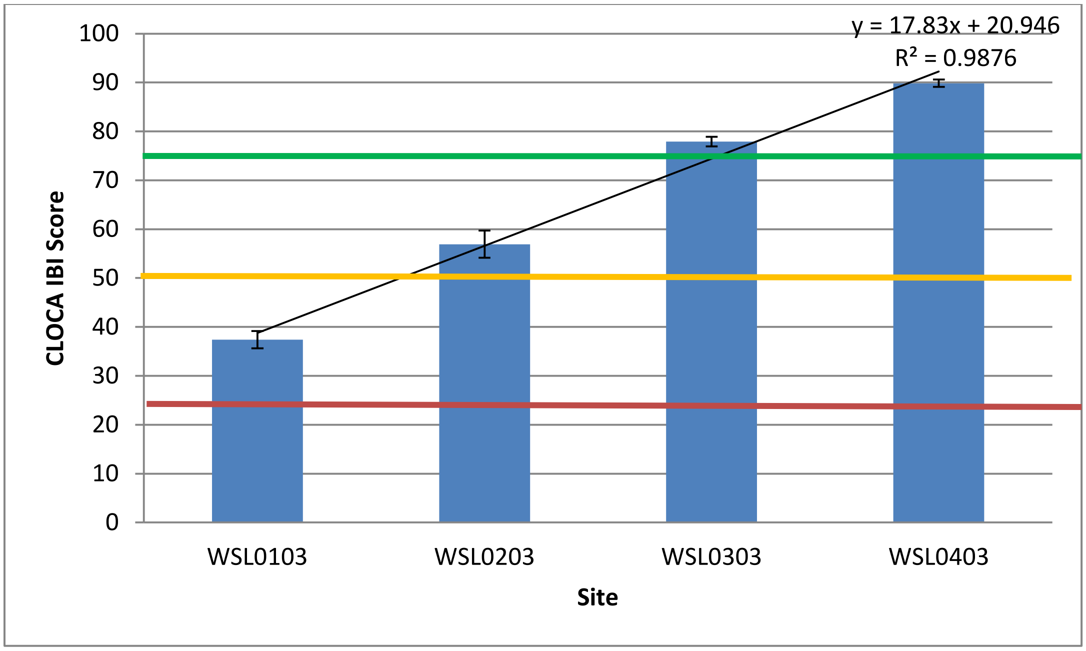


Figure 61: Wesleyville Creek Average IBI Scores At All Sites

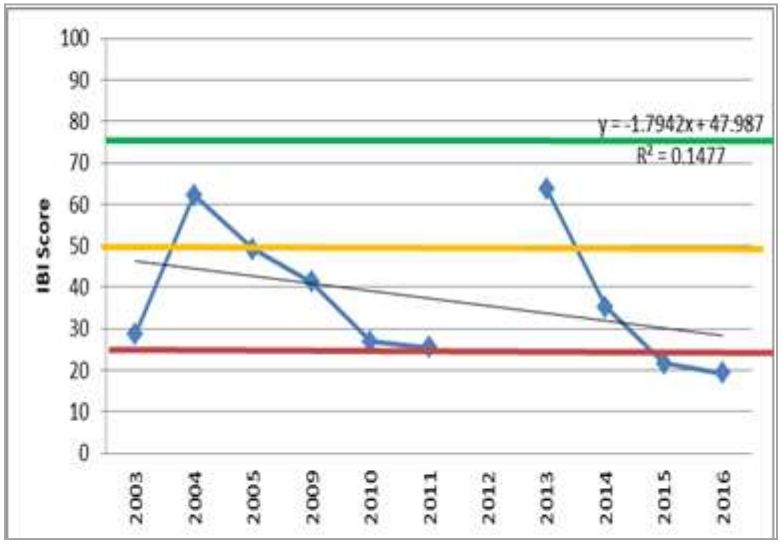


Figure 62: IBI Score Over Time At Site WSL0103

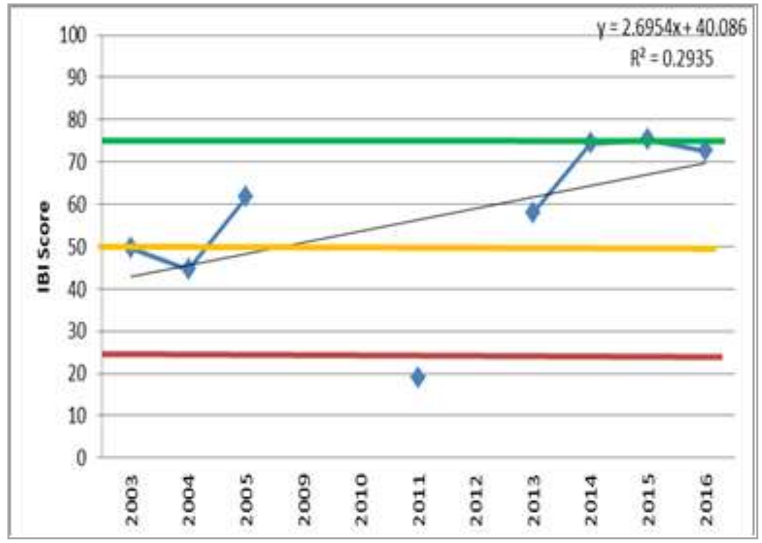


Figure 63: IBI Score Over Time At Site WSL0203

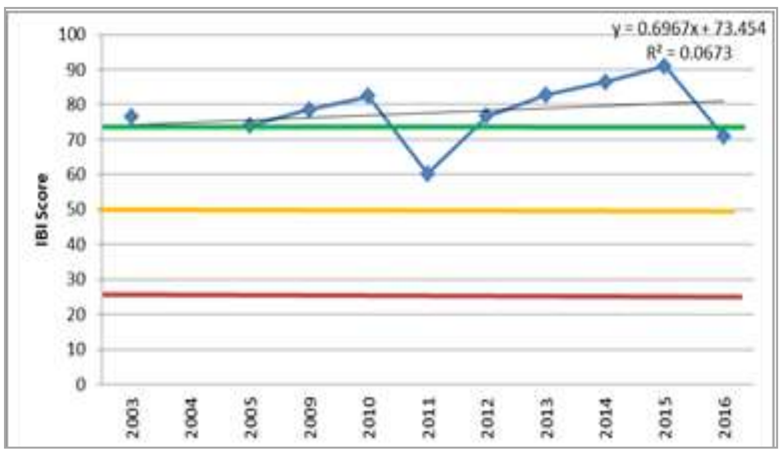


Figure 64: IBI Score Over Time At Site WSL0303

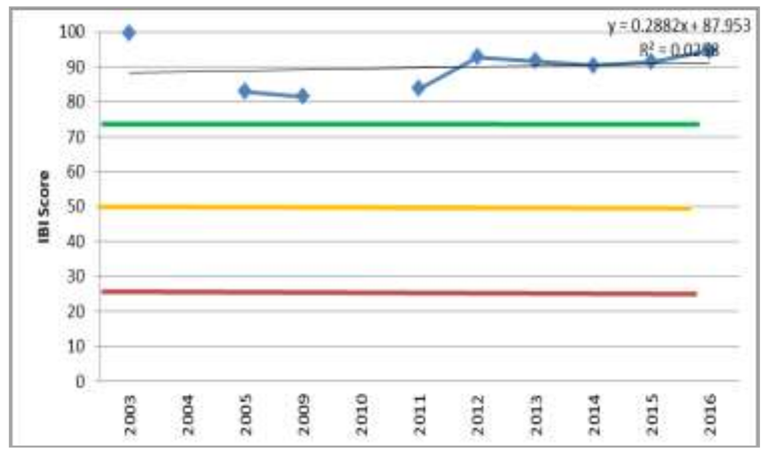


Figure 65: IBI Score Over Time At Site WSL0403

9.4 Cobourg Lamprey Barrier

The Sea Lamprey weir was monitored once every day, starting in late March/early April. Monitoring is conducted for at least 14 weeks, usually until late June or early July. The Sea Lamprey weir contains a trap and sort structure on the east side of the weir. Fish are only able to access the trap from the downstream side of the weir, with all desirable captured fish released upstream of the weir alive.

Across all years, Cobourg Creek has an average IBI score of 31, which is a fair health rating, ranging from 11.5 (poor) to 52 (good). IBI scores have ranged widely across the monitoring period, and show a slight increase over time (Figure 66).

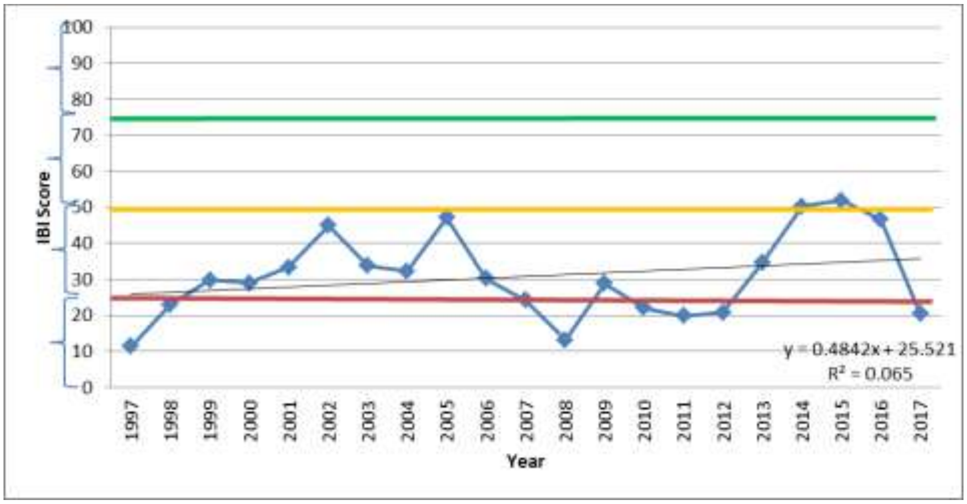


Figure 66: IBI Score At the Sea Lampre Barrier

An increase in documented species richness has occurred since 2008 (Figure 67), which is likely a result of increased efforts to identify every species captured through the monitoring period each year.

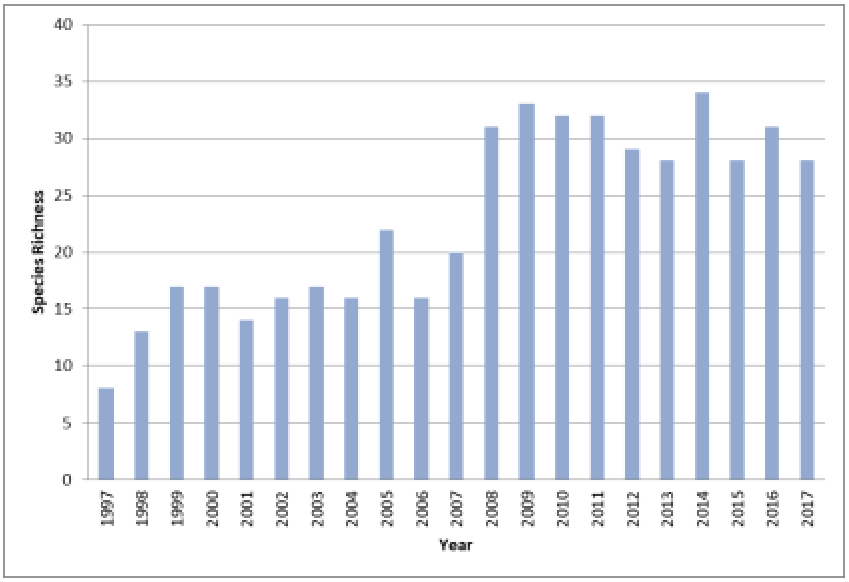


Figure 67: Fish Species Diversity Captured At the Sea Lamprey Barrier, Cobourg Creek

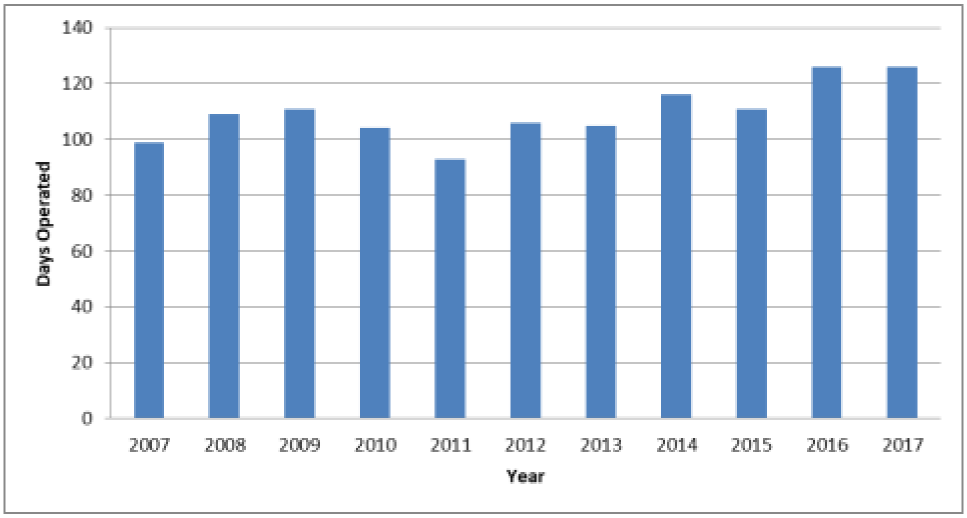
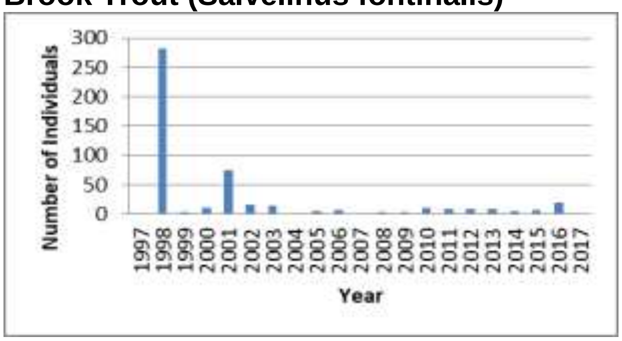


Figure 68: Effort At the Sea Lamprey Barrier

Cobourg Lamprey Barrier Species Summary

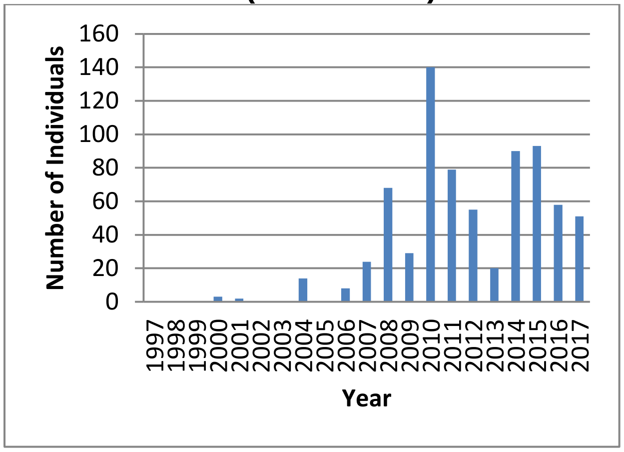
The following section describes some of the species caught at the Cobourg Lamprey Barrier.

Brook Trout (Salvelinus fontinalis)



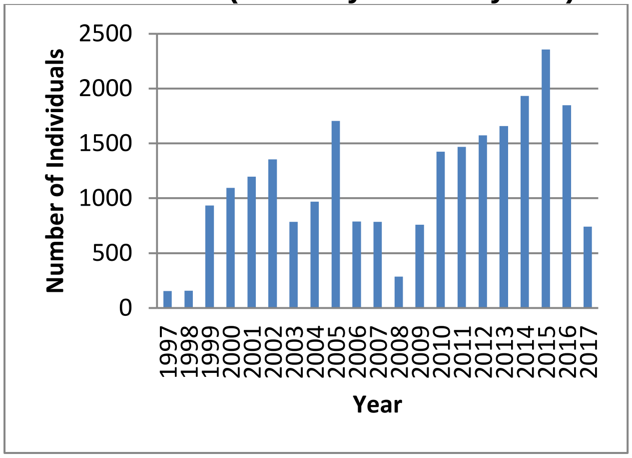
Brook Trout in southern Ontario are generally limited to the upper reaches of coldwater tributaries and are capable of living in coldwater lakes, streams and marine environments. Brook Trout are regularly captured at the Cobourg lamprey barrier. Catches ranged from none to 281 individuals per year, with the latter catch suspect to identification error. If the outlier high catches are removed, there is an annual average catch of ten individuals each year. Various life stages of Brook Trout have been captured, ranging from young-of-the-year to adults as old as age four (GRCA unpublished data).

Atlantic Salmon (*Salmo salar*)



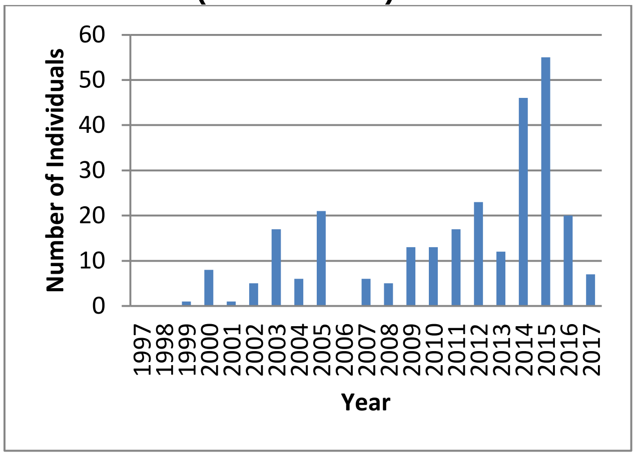
Atlantic Salmon live in cool water streams and lakes, where they exhibit an adfluvial life history. Atlantic Salmon are native to Lake Ontario and tributaries, but were extirpated in the late 1800's. A reintroduction program is currently underway, where Cobourg Creek is stocked with various life stages of juvenile fish. Atlantic Salmon were first stocked in Cobourg Creek in 2007, and stocking has continued until present. Catches ranged from 24 individuals to 144 individuals. There is an annual average catch of 35 individuals each year. Only juvenile Atlantic Salmon have been captured, up to 256mm fork length (GRCA unpublished data).

Rainbow Trout (Oncorhynchus mykiss)



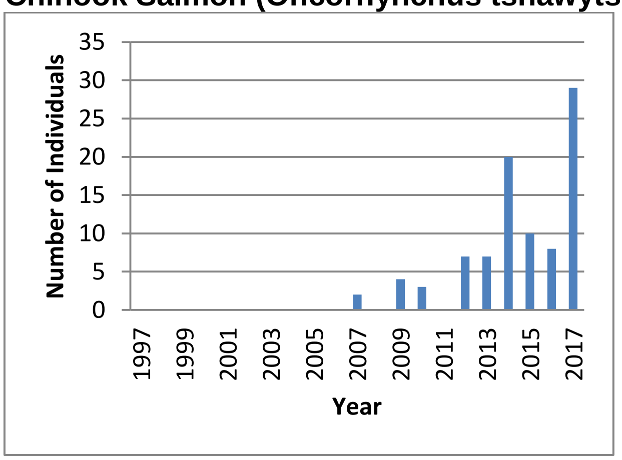
Rainbow Trout live in cool water streams and lakes, where they exhibit both riverine and adfluvial life histories. Juveniles will spend anywhere from one to three years in the streams prior to migrating to Lake Ontario. Adults will spend 1 to 3 years in Lake Ontario prior to maturing, and returning to natal tributaries to spawn. Rainbow Trout have been introduced into Lake Ontario and tributaries, where they are now naturalized. They have been established for at least 50 years. Catches ranged from 155 individuals to 2,355 individuals. There is an annual average catch of 1,141 individuals each year. Various life stages of Rainbow Trout have been captured, ranging from young-of-the-year to adults as old as age eight (GRCA unpublished data).

Brown Trout (*Salmo trutta*)



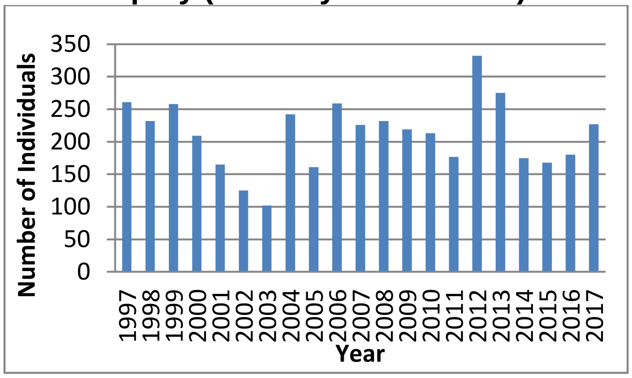
Brown Trout live in cool water streams and lakes, where they exhibit both riverine and adfluvial life histories. Juveniles will spend anywhere from one to four years in the streams prior to migrating to Lake Ontario. Adults will spend 1 to 3 years in Lake Ontario prior to maturing, and returning to natal tributaries to spawn. Brown Trout have been introduced into Lake Ontario and tributaries, where they are now naturalized. They have been established for at least 50 years. Catches ranged from 1 individual to 55 individuals. There is an annual average catch of 13 individuals each year. Various life stages of Brown Trout have been captured, ranging from juveniles to adults.

Chinook Salmon (Oncorhynchus tshawytscha)



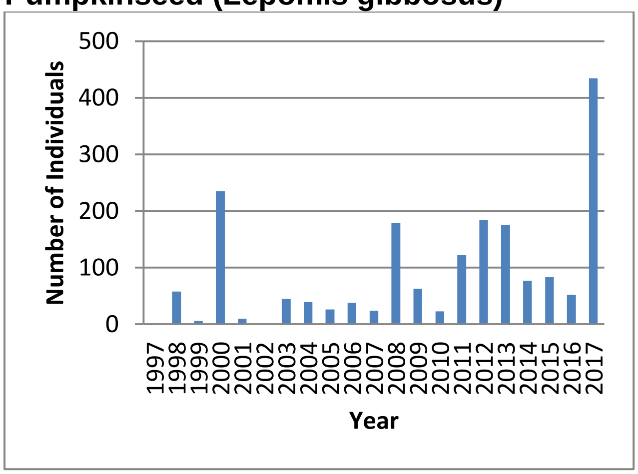
Chinook Salmon live in cool water streams and lakes, where they exhibit an adfluvial life history. Juveniles will spend anywhere from a few weeks to a year in the streams prior to migrating to Lake Ontario. Adults will spend 1 to 4 years in Lake Ontario prior to maturing, and returning to natal tributaries to spawn. Chinook Salmon have been introduced into Lake Ontario and tributaries, where they are now naturalized. They have been established for at least 25 years. Catches ranged from zero individuals to 29 individuals. There is an annual average catch of four individuals each year. Only juvenile Chinook Salmon are captured.

Sea Lamprey (Petromyzon marinus)



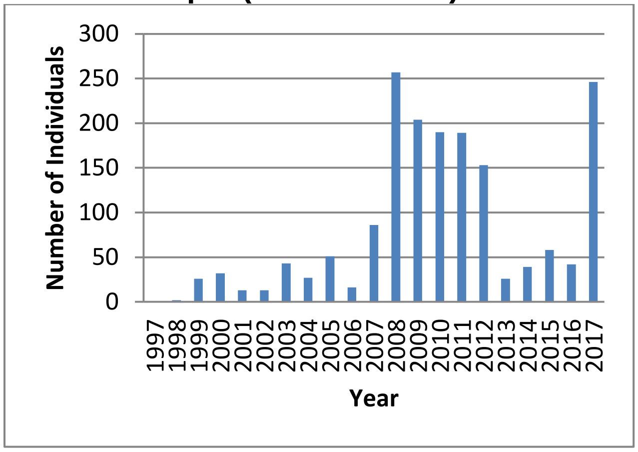
Sea Lamprey ammocoetes burrow into soft substrates of streams to filter feed from 3 to 7 years before they metamorphose into adults that move downstream into Lake Ontario. After approximately 18 months, parasitic adults migrate upstream to spawn, when they are captured through GRCA monitoring. Sea Lamprey are managed as an invasive species within Cobourg Creek, and the Great Lakes. Catches ranged from 102 individuals to 332 individuals. There is an annual average catch of 211 individuals each year. Only adult Sea Lamprey are captured as part of this monitoring.

Pumpkinseed (Lepomis gibbosus)



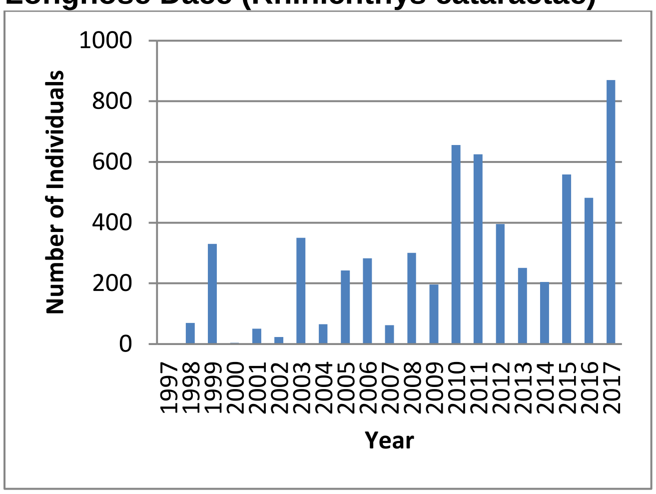
Pumpkinseed generally occur in proximity to vegetation in slow flowing rivers, ponds and lakes, but are often caught in the lower portions of GRCA tributaries. Pumpkinseed catches ranged from no catch individuals to 434 individuals. There is an annual average catch of 89 individuals each year. Different life stages are captured.

Mottled Sculpin (*Cottus bairdii*)



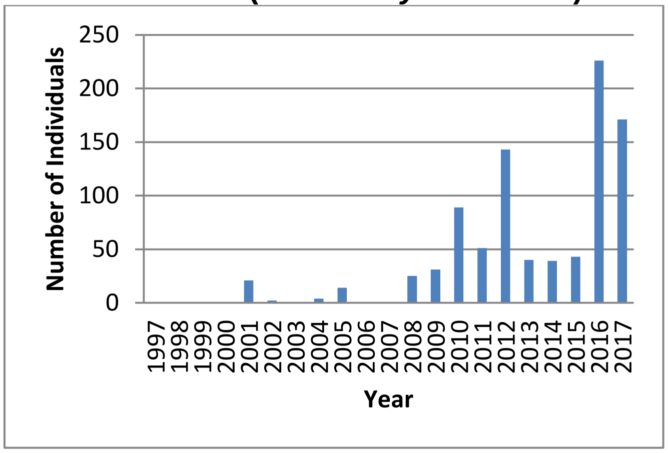
Mottled Sculpin are typically found in cold water shorelines of lakes and in gravel riffles of streams. Mottled Sculpin catches ranged from no catch individuals to 257 individuals. There is an annual average catch of 82 individuals each year. Primarily adult Mottled Sculpin are captured.

Longnose Dace (Rhinichthys cataractae)



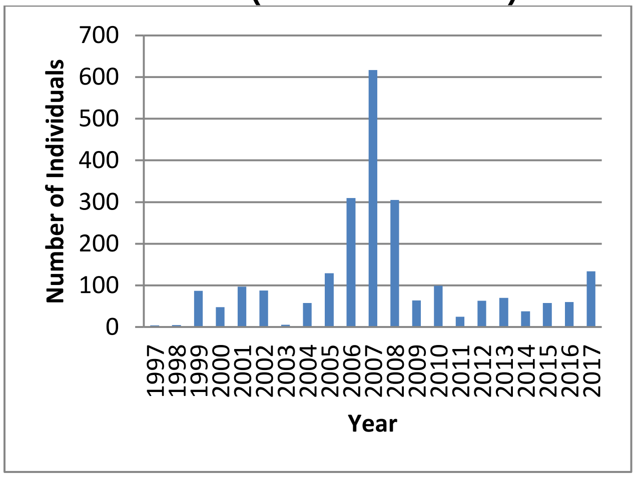
Longnose Dace prefer cool, fast-flowing waters of streams with rocky bottoms. It is also occasionally found along the shoreline of Lake Ontario. Longnose Dace catches ranged from no catch individuals to 870 individuals. There is an annual average catch of 286 individuals each year. Primarily adult Longnose Dace are captured.

Blacknose Dace (*Rhinichthys atratulus*)



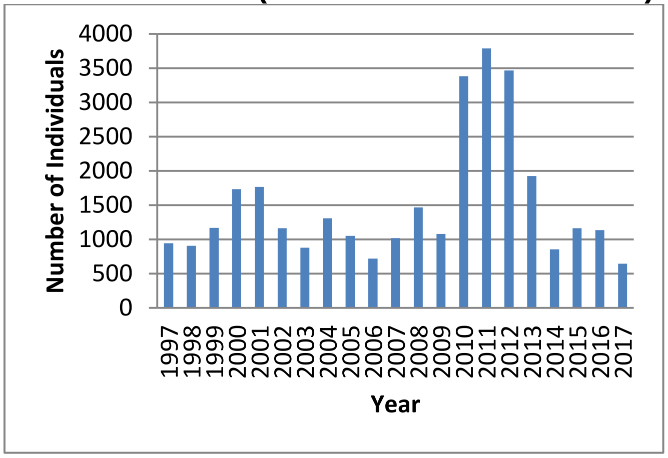
Blacknose Dace prefer small, shallow, cool streams, but are tolerant to environmental degradation. Blacknose Dace catches ranged from no catch individuals to 226 individuals. There is an annual average catch of 43 individuals each year. Primarily adult Blacknose Dace are captured.

Common Shiner (*Luxilus cornutus*)



Common Shiner occur in streams more often than lakes, and generally prefer clear waters. Common Shiner catches ranged from four individuals to 617 individuals. There is an annual average catch of 112 individuals each year. Primarily adult Common Shiner are captured.

Common Sucker (*Catostomus commersonii*)



Common Sucker prefers cool waters, but can be found in a wide range of habitats across Ontario. Common Sucker catches ranged from 719 individuals to 3788 individuals. There is an annual average catch of 1,502 individuals each year. Both adult and juvenile Common Sucker are captured (Figure 69).

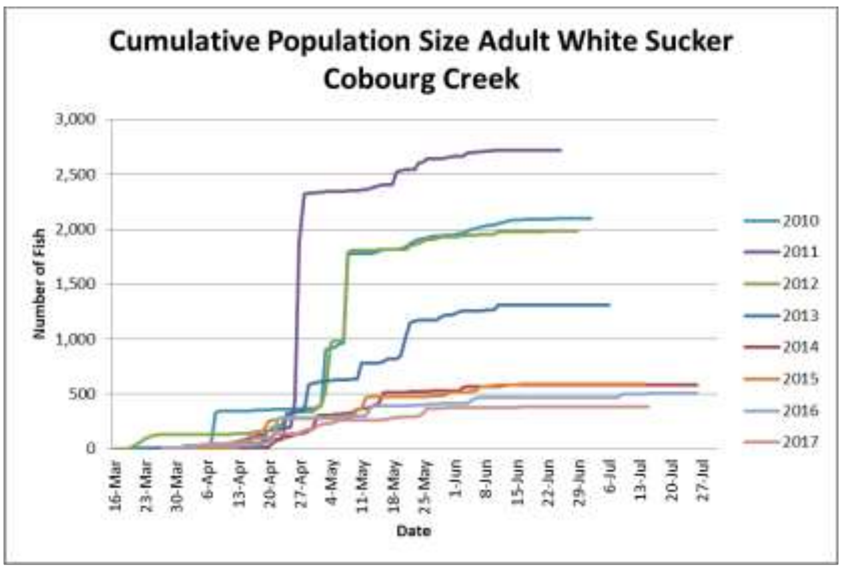
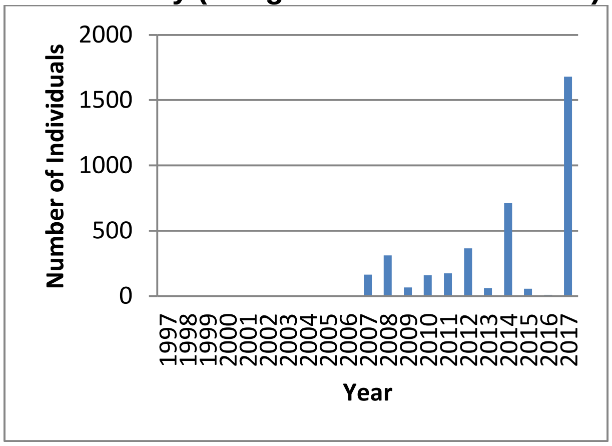


Figure 69: Cumulative Population Size Adult White Sucker Cobourg Creek

Round Goby (Neogobius melanostomus)



Round Goby can be found in a wide variety of habitats, ranging from cool to warm lake habitats and slow moving rocky streams. Round Goby are an invasive fish from central Europe introduced into the Great Lakes in 1990. Round Goby were first caught in 2007 in Cobourg Creek. Catches ranged from 56 individuals to 1,680 individuals. There is an annual average catch of 179 individuals each year. Both adult and juvenile Round Goby are captured.

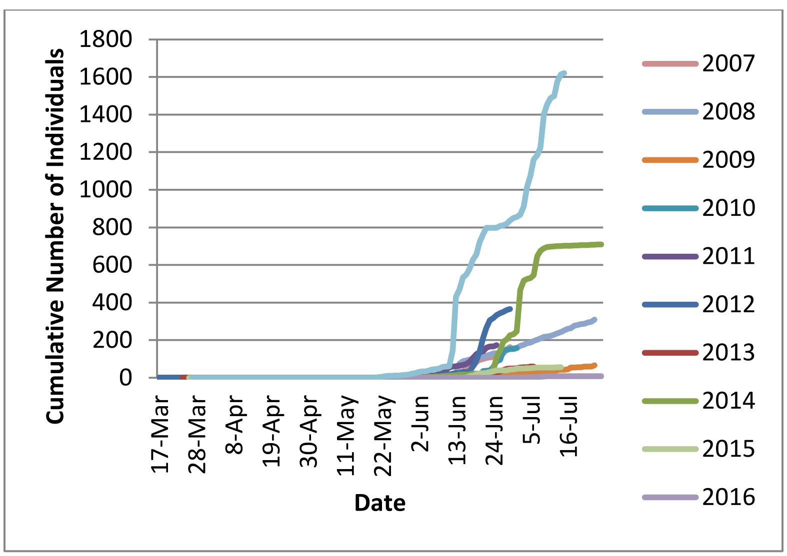
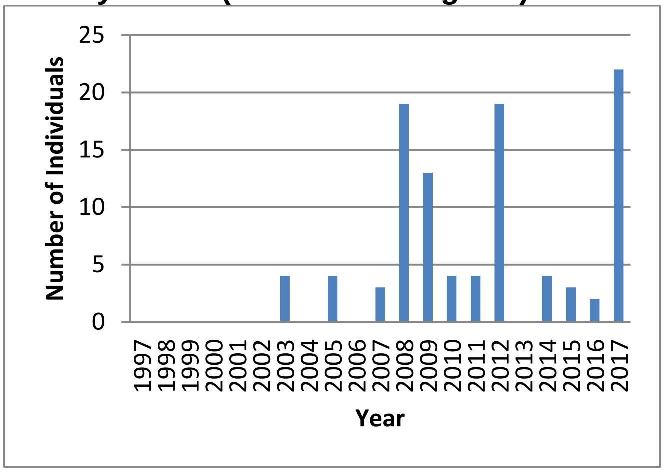


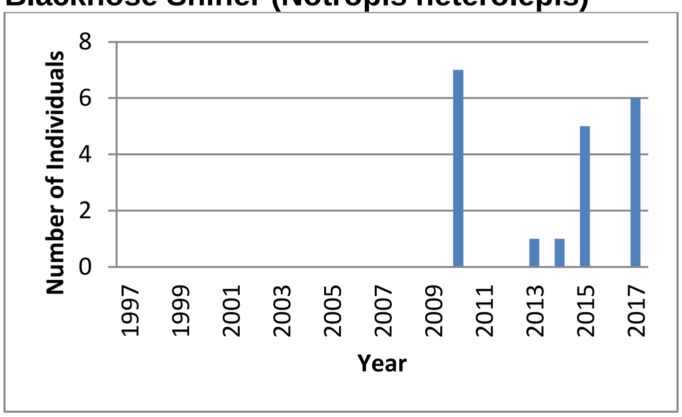
Figure 70: Cumulative Number of Individuals

Johnny Darter (*Etheostoma nigrum*)



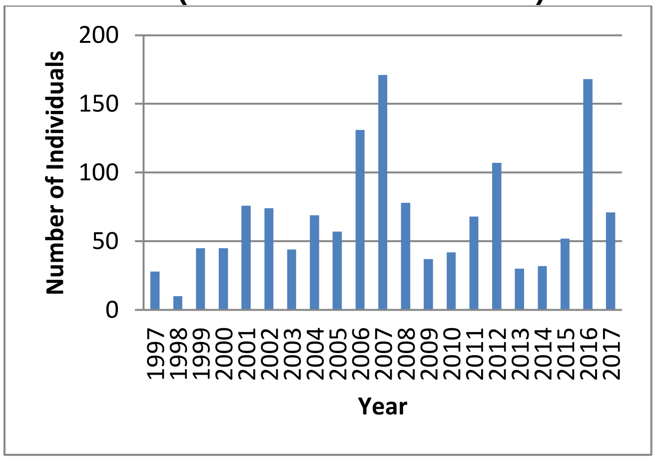
Johnny Darter can be found in a wide variety of bottom habitats in both streams and lakes. Johnny Darter catches ranged from zero individuals to 22 individuals. There is an annual average catch of four individuals each year. Only adult Johnny Darter are captured.

Blacknose Shiner (Notropis heterolepis)



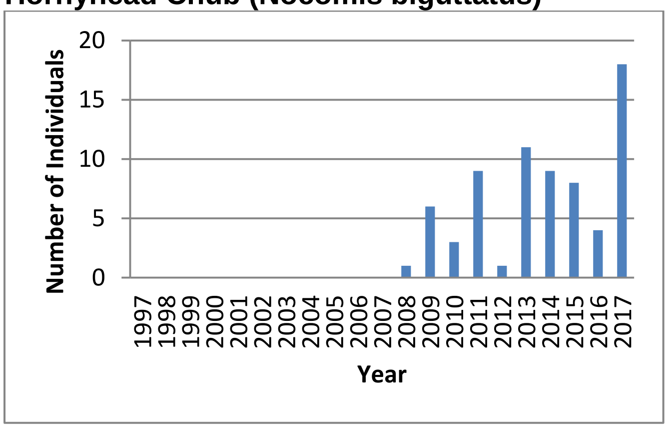
Blacknose Shiner prefer clear weedy waters with sandy bottoms. They cannot tolerate turbid water condition, making them a good warmwater indicator species. Blacknose Shiner catches ranged from zero individuals to seven individuals. There is an annual average catch of one individual each year. Primarily only adult Blacknose Shiner are captured.

Creek Chub (Semotilus atromaculatus)



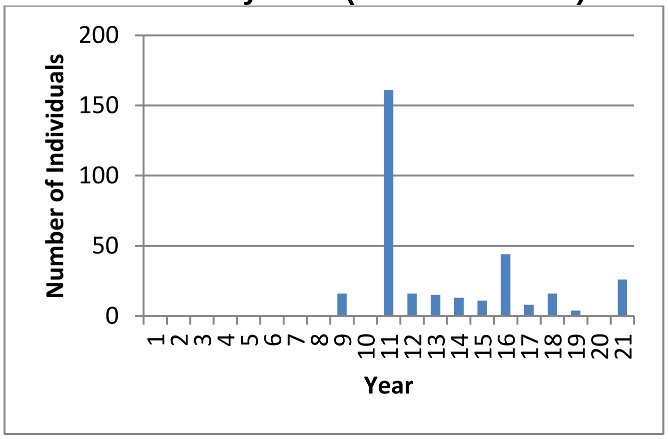
Creek Chub prefer pools in clear streams, but can also be found in lakes. Creek Chub are generally considered to be tolerant to environmental degradation. Creek Chub catches ranged from ten individuals to 171 individuals. There is an annual average catch of 68 individuals each year. Primarily only adult Creek Chub are captured.

Hornyhead Chub (Nocomis biguttatus)



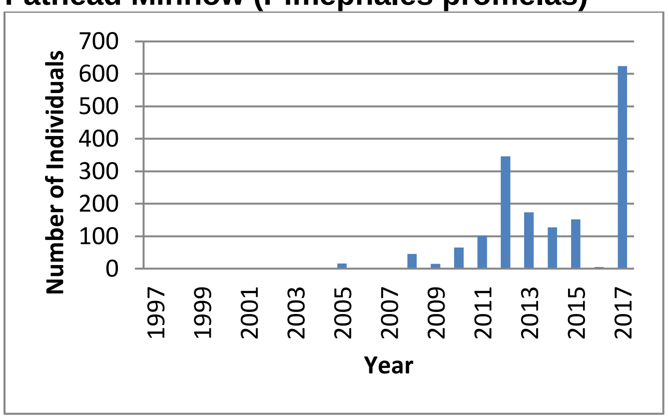
Hornyhead Chub live in clear creeks with gravel and moderate to sluggish flows, while juveniles will occupy weedy areas. Hornyhead Chub catches ranged from zero individuals to 18 individuals. There is an annual average catch of 3 individuals each year. Primarily only adult Hornyhead Chub are captured.

Northern Redbelly Dace (*Chrosomus eos*)



Northern Redbelly Dace prefers cool, heavily vegetated, shallow waters of lakes and slow moving streams with bottoms of silt and detritus. Northern Redbelly Dace catches ranged from zero individuals to 161 individuals. There is an annual average catch of 16 individuals each year. Primarily only adult Northern Redbelly Dace are captured.

Fathead Minnow (Pimephales promelas)



Fathead Minnow is generally found in a wide range of habitats ranging from shallow wetlands to streams. They are considered tolerant to environmental degradation. Fathead Minnow catches ranged from zero individuals to 624 individuals. There is an annual average catch of 80 individuals each year. Primarily only adult Fathead Minnow are captured.

9.5 Summary

The Index of Biotic Integrity (IBI) scores are showing stable numbers, with most of the fish community sites indicating good or excellent condition. The sites that ranked as fair or poor showed the greatest variance in IBI score (e.g., Cobourg Creek), and are located the furthest downstream, closest to Lake Ontario, and had the highest proportion of tolerant fish species captured. Additionally, these sites likely show decreased condition due to cumulative impacts from the upstream catchments (e.g., landuse), with a decrease in the proportion of intolerant fish species (e.g., trout, salmon, sculpin) relative to other species captured.

There are some species specific issues, with declines in migratory adult White Sucker documented in both Cobourg Creek and Wesleyville Creek. While the cause is unknown, it may be linked to shifts in the Lake Ontario ecosystem due to dreissenid mussels, and Round Goby colonization, and resulting shift in productivity from the water column to the lake bed.

The sites annually monitored by GRCA are limited across the landscape, with many watersheds not captured as part of this monitoring (e.g., Rice Lake and tributaries). It is recommended that more sites are incorporated into the stream monitoring program to allow for a broader analysis of watershed health. Additionally, the fish community monitoring program allows for the detection of invasive species, species at risk, rare species, and shifts in the fish community associated with changes within watersheds (e.g., land use or climate change).

10.0 Summary of Watershed Health

Good quality water in sufficient quantity is essential for all stakeholders and living organisms within the GRCA watershed.

The majority of southern Ontario watersheds are experiencing urban growth. Urban trends raise concerns over the fate of Ganaraska watershed surface and groundwater quality, where the Ganaraska watershed may be vulnerable to land use shifts that favour agriculture or urban development.

With the growing population, urban areas will increase at the expense of removing natural and agricultural areas. Removal of these areas can create more intensive farming due to smaller areas of agriculture and increased population.

Increases in crop production will need higher amounts of fertilizers to be applied to fields to maintain supplies for the growing population. Nitrogen fertilizer sales have increased slightly from 1981 - 2011, along with 28.6% increase of corn production in Ontario, which require more nitrogen fertilizers for growth (Smith, 2015).

Increases in impervious surfaces are to be expected with higher populations, which in turn will increase salting and de-icing application during the winter months. An increase of chloride has been evident in water resources. Some of the effects of salt are less fertile soils, more surface runoff, contamination of sodium and chloride in groundwater, and stimulates algae growth (Ramakrishna & Viraraghavan, 2005).

Phosphorus concentrations have declined steadily over the past decade. This may be a result of best management practices and policies aiming to reduce the application of phosphorous in many products. This can be due to the decline in sales of phosphorus fertilizers in Ontario (Smith, 2015). While increasing phosphorus is not an issue at the present, careful monitoring should still be applied considering that it is often the nutrient limiting in an ecosystem and can lead to increased algae blooms.

Current projections of climatic change strongly support the expectation that during the next few decades, temperatures will continue to increase locally and globally. In addition, a shift in spatial and temporal patterns of temperature and precipitation is expected. The consequences of such a change are manifold. Environmental processes which are influenced by thermal and soil moisture conditions may experience a shift in the timing of nutrient export and availability for plants.

Improved data gathering would support better forecasting of both droughts and floods and the impacts on agricultural ecosystems. For example, to ensure food safety, decreasing soil moisture content due to higher evapotranspiration rates could be enhanced by practices such as zero and minimum tillage, which improve soil structure and organic matter contents.

Changing patterns of rainfall may be a serious problem in Southern Ontario. Increased temperatures, variability and seasonality, and extreme events, heatwaves, droughts, storms and floods across southern Ontario will affect farming practices first line. Although projecting how changed precipitation patterns will affect runoff is not yet a precise science, past discharge records denote that for each 1°C rise in temperature, runoff will possibly increase by 4% (Oki and Kanae 2006). Thus, a region that experiences higher annual precipitation and more runoff increases the likelihood for flooding resulting in higher erosion and nutrient loss. The Ganaraska Region Watershed has experienced a change of land use over the past decades and has significant expertise and data collected to help answer questions regarding different agricultural practices that may influence the water quality and quantity of this area.

Monitoring results of this report will help to build adaptive capacity by awareness raising and provides relevant information on advice for best farming practices and management. In addition, adaptive measures can include solutions to adjustments in agricultural management such as using water more efficiently by reducing water losses, improving irrigation practices by increasing water retention to conserve soil moisture, and landscape management, such as maintaining landscape features that naturally store water.

Crop patterns can be adjusted to allow earlier or later planting, to reduce water use, and to minimize or optimize irrigation or supplementary irrigation supplies. Yield and water productivity can be enhanced by adopting better soil moisture conservation practices and better management, as well as by increasing provision of other factor inputs. The options for different mixes of rain fed and irrigated land will vary for each situation according to the relative priorities and benefits to farmers, impacts on ecosystems and costs. Perspectives in urban food security will dominate in some cases, but in others, a rural focus will prevail. Land use changes can result in declining soil organic matter and loss of fertility. The soil in croplands can potentially store massive quantities of nutrients. The impact of a shift in ratios concerning the N:P balance due to increased temperatures and tillage on aquatic ecosystems (rivers and lakes) is not clear. Therefore, further research can address the impacts of changed rainfall patterns and consequently flow regimes on non-point source pollution from agriculture, and give answers on how to best establish drainage management since these have not been sufficiently explored. Each situation will require individual assessment.

Solutions could include the reduction of water demand and to do more with less. Driven by population growth, nutrition needs agricultural practices; in particular water management needs to be made more effectively. Water savings, however, are dependent on soil characteristics, such as soil texture and structure, which determine the soil's ability to store and absorb water, carry out bio-chemical processes and in turn affect water quality in aquatic systems in lakes and rivers as well as groundwater conditions.

In order to make meaningful decisions research is needed to improve knowledge regarding the impact of a changing climate on agricultural, terrestrial and aquatic ecosystems. Increased annual recharge from higher rainfall volumes and runoff, and changes in timing and volume of peak flows are anticipated to result in greater proportions of runoff that will occur as flood flow. Small tillage has the potential to buffer agricultural efforts against increased variability in rainfall and higher crop water requirements. However, nutrient and soil loss may be a consequence from such implementations and may counteract these adaptations for water management. In general, farming practices should be assessed locally to assess their capability to cope with current and future climate variability to reduce vulnerability to a changing climate.

Building resilience today is central to being prepared for future changes. The notion of resilience directly supports the examining of various domains – biophysical (ecosystems), economic and social. It is crucial to identify and evaluate vulnerability within the landscape and to find different adaptation measures. Vulnerability is place-based and context driven. It encompasses searching for options with low economic and environmental consequences, and taking into account farmers considerations and the resources available. An assessment of GRCAs vulnerability to climate change can help to identify particularly vulnerable regions and agricultural practices. This in turn could result in recommendations of specific adaptation measures and help to prioritize resource allocation for adaptation. In addition, long-term benefits may enhance the communication between affected land users and other stakeholders. Findings of this report may help to combine efforts for other adaptation measures to ensure compatibility and increase strategic planning with respect to robust resilient water management. Collaboration with municipalities, provincial agencies, academic researchers and other stakeholders would be seamless and of great mutual benefit.

11.0 Recommendations

Groundwater consumption and recharge are key impacts to groundwater quantity. Abstraction impact for human water use should be assessed in more detail to reduce possible negative impacts on this freshwater resource. Socioeconomic issues that relate to land use and infrastructure should also be included into management. Further investigation is needed to clarify whether elevated concentrations are due to anthropogenic activities is likely to impact the freshwater resource significantly.

A future regulatory framework is recommended, as it is essential to consider hydraulic links to surface water and groundwater dependent ecosystems.

Continue to monitor, manage and evaluate the health of groundwater resources and implement management actions where and when necessary.

Identify and implement management actions arising from monitoring, where appropriate.

Develop and adopt an integrated monitoring program for surface and groundwater connections.

Acquire a water balance model application to proactively promote innovative green infrastructure and Low Impact Development (LID) techniques through infrastructure, development review, planning policy and regulations.

Monitoring continues at selected sites within the GRCA watershed to further investigate major gains and losses in baseflow that were observed to better understand baseflow dynamics. Monitoring of baseflow temperature to obtain information regarding trends under a changing climate.

Based on above findings, develop priority areas to protect the sustainability of baseflow within the GRCA jurisdiction

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