

Beaver River Watershed Report



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for the
Grey Sauble Conservation Authority

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Preface

This study was undertaken by Meghan Allerton for the Grey Sauble Conservation Authority (GSCA) in fulfillment of the requirements of the Master of Environmental Science degree program at the University of Toronto Scarborough. Funding for the project was generously provided by the Beaver River Watershed Initiative, whose mandate is “to co-ordinate actions by environmentally concerned community members aimed at improving and conserving the overall water quality of the Beaver River Watershed”. Thanks to John Bittorf, Water Resources Coordinator at the GSCA, for his guidance and supervision, Gloria Dangerfield for GIS assistance, Anna Beckett, Tim Lanthier, and everyone at Grey Sauble Conservation for their constant support.

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Note Regarding all Maps:

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Glossary of Terms

Areas of Natural and Scientific Interest (ANSIs) - areas recognized by the government of Ontario as having unique geological or natural features.

Aquifer - a geologic formation of porous rock or loose material that can hold and transmit significant quantities of water.

Bankfull width - the width of a watercourse when at its maximum flow before it tops its banks.

Base flow - the portion of flow in a watercourse that comes from groundwater.

Benthic invertebrates - invertebrates such as insects, crustaceans, and molluscs that live at the bottom of lakes, rivers, streams, and creeks.

Family Biotic Index (FBI) - an index used to assess water quality in streams based on the sensitivity of benthic (arthropod) families to nutrient and organic pollution.

Forest interior - the core area of a forest, usually measured as the area that is greater than 100 meters from the forest edge.

Geometric mean - the n^{th} root of the product of all data points, where n is the number of data points. The geometric mean is less affected by extreme values than the mean.

Karst - refers to landscape features formed by the dissolution of soluble rocks.

Provincial Water Quality Objectives (PWQO) - water quality objectives set by the province of Ontario at levels which protect human health and aquatic life.

Re-entrant valley - a valley that forms perpendicular to a ridgeline and slopes downward noticeably away from the ridge.

Riparian zone - the land directly adjacent to a watercourse or waterbody.

Sinkhole - a depression in the land surface, usually caused by the dissolution of underlying rock, and often providing a passage for surface water to quickly enter the ground.

Till - unsorted material deposited by a glacier.

Total phosphorus - a measure of the total amount of all forms of phosphorus in a water sample, including organic and inorganic phosphorus, both dissolved and suspended.

Watershed - an area of land that drains into a particular river, stream, or body of water.

Executive Summary

Following Conservation Ontario watershed reporting guidelines, this report provides an assessment of the health of the Beaver River watershed based on surface water quality and forest conditions. Surface water quality was evaluated based on benthic invertebrate samples, total phosphorus, and *E. coli* bacteria concentrations measured between 2011 and 2015. In addition, water temperatures were monitored during the summer of 2015 and analyzed by comparison with air temperatures, following the protocol developed by Stoneman and Jones (1996). Forest conditions were assessed based on GIS calculations of forest cover, forest interior area, and riparian zone forest cover. These indicators were used to assess the health of the entire watershed and of smaller subwatersheds.

Results indicate generally healthy conditions across the watershed. Forest conditions are excellent for southern Ontario, although forest interior area and riparian zone forest cover are low in some areas. Surface water quality, based on benthic invertebrates, phosphorus, and *E. coli* concentrations is good in the lower watershed and excellent in the headwaters. Slightly elevated levels of total phosphorus were observed at the mouth of the river and at Wodehouse Creek, likely a result of nutrient inputs from agricultural land. Water temperature results indicate that high water temperatures in summer likely pose the greatest threat to aquatic ecosystem health in the watershed. Maximum water temperatures were high at a number of locations, both in the main river and its tributaries. Lack of riparian cover and dams on the river are likely contributing to these high temperatures. Protecting and enhancing the existing forest cover, improving riparian buffers, and reducing ponding of the river where possible will help to improve the health of the watershed. Watershed monitoring and reporting should continue in order to better assess local impacts, track changes, and address environmental issues.

1.0 Introduction

A watershed, or drainage basin, is defined by the flow patterns of surface water. It is an area of land that drains into a particular river, stream, or body of water (Conservation Ontario 2013). Watersheds occur at many different scales, and large watersheds often can be divided into many smaller ‘subwatersheds’.

Within a watershed, land use and water quality and quantity are closely connected. As our understanding of this connection has improved, the importance of watershed-based environmental management has become increasingly evident (Griffiths 1999). In Ontario, many Conservation Authorities report on watershed health through standardized watershed report cards that are updated every five years (Conservation Ontario 2011). These report cards use a set of environmental indicators to measure key components of watershed health based on guidelines developed by Conservation Ontario (Conservation Ontario 2011). The purpose of the report cards is to evaluate local conditions, track changes, and communicate this information to decision-makers, the public, and other stakeholders so that it can be used to effectively address environmental issues (Conservation Ontario 2011).

The most recent report card for the watersheds in the Grey Sauble Conservation Authority (GSCA) jurisdiction was issued in 2013 and will be updated in 2018. This interim report focuses on the Beaver River Watershed, providing an assessment of the health of the watershed as a whole, and of individual subwatersheds. The subwatershed-level results are used to identify how local differences in land use and other activities impact watershed health. This information is then used to provide rehabilitative strategies and recommended actions to improve and protect water quality and wildlife habitat in the watershed.

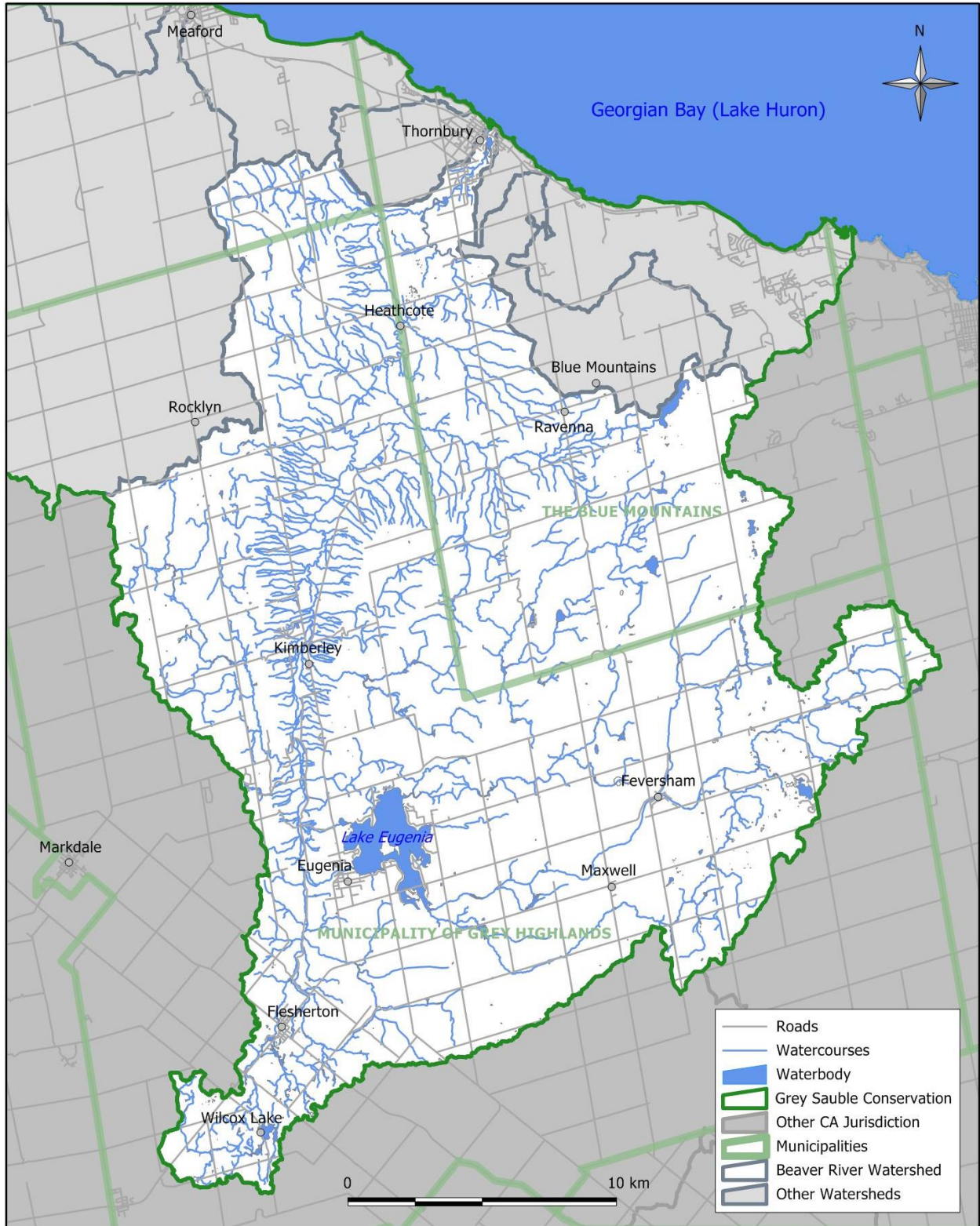


Figure 1. Municipalities in the Beaver River watershed.

1.1 Background

The Beaver River watershed covers an area of 617 square kilometers and outlets into Georgian Bay at Thornbury (Saugeen Conservation et al. 2015). The river originates in a wetland complex east of Feversham and first flows south-west to Lake Eugenia, which was created in 1915 when a dam was built by the Hydro-Electric Power Commission of Ontario (D'Amelio and Imhof 2010; Ontario Power Generation 2014). From here, most of the flow is diverted from its original path over Eugenia Falls and descends into the Beaver Valley through penstocks to the Eugenia hydroelectric generating station (D'Amelio and Imhof 2010; Ontario Power Generation 2014). After being discharged from the power station, the Beaver River is joined by its largest tributary, the Boyne River, which originates southwest of Flesherton. The main stem of the river then continues northward through the valley to Georgian Bay. From its source to its mouth the Beaver River runs 76 kilometers and undergoes a change in elevation of 334 meters (Saugeen Conservation et al. 2015).

The watershed is predominantly rural, the largest centre being Thornbury with a population of 2,253 (Statistics Canada 2012). Other small centres include Clarksburg, Heathcote, Kimberly, Ravenna, Eugenia, Feversham, Maxwell, and Flesherton. Agriculture is a major land use, and the Beaver Valley and surrounding area is especially well known for its apple orchards, which produce about 25% of Ontario's apples (Saugeen Conservation et al. 2015). Grain and hay crops, corn, and livestock are also produced. Outdoor recreation and tourism is another major industry and popular activities include: downhill and cross-country skiing, fishing, swimming, boating, hiking, and snowmobiling (Ontario Ministry of the Environment 1983). Cottage communities exist in a number of locations, such as at Lake Eugenia, bringing many seasonal residents to the area (Saugeen Conservation et al. 2015).

The Niagara Escarpment is a dominant feature of the watershed and a significant portion of the watershed falls under the land use designations of the Niagara Escarpment Plan¹. The Beaver Valley is a re-entrant valley that cuts deep into the escarpment (Saugeen Conservation et al. 2015). Its slopes rise steeply and, in many locations, are capped by white-grey dolostone cliffs (D'Amelio and Imhof 2010). This permeable dolostone of the Amabel Formation forms the bedrock of the upper watershed and is an important regional aquifer (D'Amelio and Imhof 2010). In some locations along the valley, dissolution of the dolostone has caused sinkholes and other karst features to form, resulting in complex patterns of groundwater flow (Saugeen Conservation et al. 2015). Both above and below the escarpment, glacial till deposits cover much of the watershed and these deposits, along with the eroded and exposed dolostone, discharge groundwater to many of the tributaries of the Beaver River, resulting in relatively high base flows (Saugeen Conservation et al. 2015; D'Amelio and Imhof 2010). This helps to stabilize water levels and temperatures and sustain healthy stream ecosystems.

The maintenance of forested areas and wetlands has also helped to protect the river system. Figure 3 shows the woodland and wetland areas of the watershed. While much of the original forest cover was cleared for agriculture and other purposes, significant wooded areas remain, especially within the Niagara Escarpment Plan area. In addition, the system is unique in southern Ontario in that most of the main stem of the river is still forested (Ontario Ministry of the Environment 1983). A number of important wetlands are also found in the watershed, such as the Eugenia Lake Wetland (2.9 km² marsh and 10.2 km² swamp) and the Beaver Valley Lowlands Wetland (7.2 km² swamp) (Saugeen Conservation et al. 2015). In total, wetlands cover 52 square kilometers (8.4%) of the watershed (Saugeen Conservation et al. 2015). These natural areas

¹ The Niagara Escarpment Plan (2005) is a land use plan that establishes land use designations with different levels of protection. See <http://www.escarpment.org/home/index.php> for more information.

provide habitat for a diversity of species and play a critical role in protecting and improving water quality. Forested riparian areas prevent excess sediment, nutrients, and other contaminants from entering streams, provide food for aquatic organisms, and help to keep water temperatures low during the summer by providing shade (Ontario Ministry of the Environment 1983).

Wetlands also improve water quality by removing sediments and contaminants from the water.

All of these factors have helped to maintain the Beaver River watershed as a relatively healthy system². The creeks and streams in the watershed are generally cool, clear, and free of excess algae. Many support cold-water species such as the native Brook Trout (*Salvelinus fontinalis*), and also provide spawning habitat for Rainbow Trout (*Oncorhynchus mykiss*), and a variety of other species (D'Amelio and Imhof 2010). Even so, human activities have altered the watershed significantly, and pose considerable challenges to the conservation of these species and others. The removal of riparian vegetation in many areas has increased the amount of runoff entering streams from agricultural land. Ponds and dams have also been constructed at many locations throughout the watershed, altering stream flow characteristics and increasing water temperatures (Ontario Ministry of the Environment 1983). Lake Eugenia also causes a marked warming of the river (D'Amelio and Imhof 2010). Increasing water temperatures in the lower part of the main river are an issue in the watershed, and will likely continue to be a concern in the future due to climate change. Such changes have complex effects on the physical and biological characteristics of the system, making regular monitoring and reporting essential to the sustainable management of the watershed.

² See the 2013 Watershed Report Card from Grey Sauble Conservation, available at http://www.greysauble.on.ca/publications/reportcard/watershed_reportcard.html.

2.0 Methods

In 2009 Conservation Ontario conducted a review of the watershed report cards produced by Conservation Authorities in Ontario (Conservation Ontario 2011). This brought to light some inconsistencies and led to the development of new guidelines, released in 2011, that standardized many aspects of watershed reporting including: scale, frequency, resource categories, indicators, and grading (Conservation Ontario 2011). The design of this study is based on these guidelines. Standard procedures were followed, where appropriate, and some modifications were made. The methodology employed is explained in the following sections.

2.1 Scale and Frequency

In order to provide locally relevant information, watershed reporting in Ontario is done at the subwatershed scale (Conservation Ontario 2011). For this report, the Beaver River watershed was divided into six major subwatersheds: the Main Beaver River, Grier Creek, Mill Creek, Wodehouse Creek, Lake Eugenia, and Boyne River. The Mill Creek, Lake Eugenia, and Boyne River subwatersheds were further divided to produce seven minor subwatersheds (see Figure 2), which overlap with the major subwatersheds but provide finer-scale results. Subwatersheds were chosen that correspond to tributaries or sections of the river that are identifiable to residents and community members, and capture local impacts on the landscape.

The number of subwatersheds was determined mainly by the water quality monitoring resources available at the GSCA. A total of 14 water quality monitoring sites were selected³ (one site per subwatershed and one for the entire watershed) and water quality data was collected at

³ See Appendix 1 for a list of water quality monitoring sites.

these sites during the summer of 2015. Since the water quality at any particular location reflects

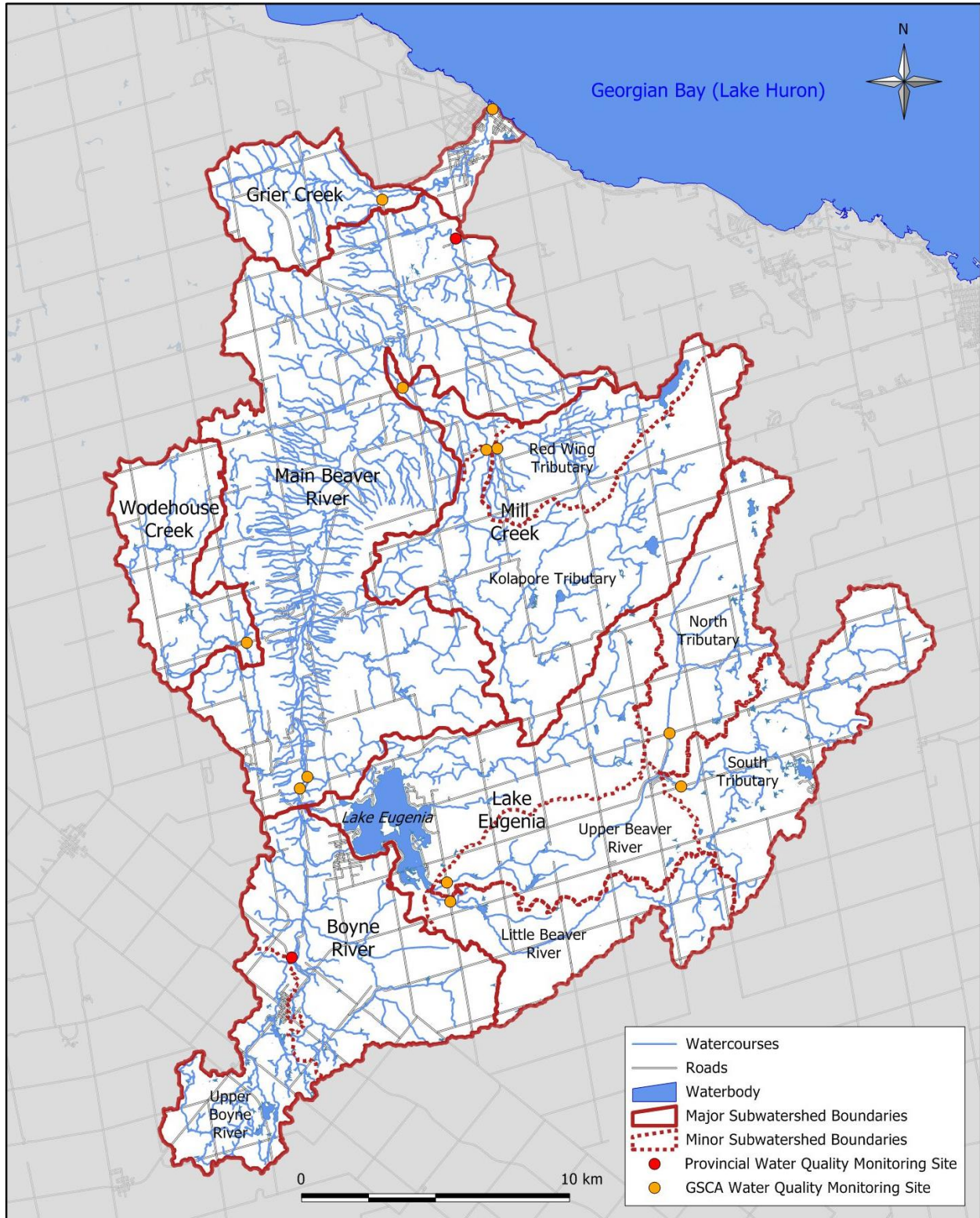


Figure 2. Subwatersheds and water quality monitoring sites in the Beaver River watershed.

the “cumulative impact” of upstream activities and watershed features (Conservation Ontario 2003), each monitoring site was located as close as possible to the subwatershed/watershed outlet. Site selection was also based on accessibility, and the quality and quantity of historical data available for each location. Sites that are regularly monitored by the GSCA or the Ontario Ministry of the Environment and Climate Change (MOECC) were preferred, since watershed report card assessments are normally based on five years of data and updated every five years (Conservation Ontario 2011). As this is the first detailed report completed for the Beaver River watershed, water quality assessments for many sites are based on limited data and reflect only 2015 conditions. However, where historical data was available, the standard five-year time step was used, and water quality assessments were based on data collected between 2011 and 2015.

2.2 Resource Categories, Indicators and Grading

Under the guidelines for watershed reporting developed by Conservation Ontario (2011), watershed health is assessed based on three “resource categories”: surface water quality, forest conditions, and groundwater quality. This report considers only surface water quality and forest conditions, as the number of groundwater monitoring sites in the watershed is not sufficient to provide an accurate picture of watershed health. Standard environmental “indicators” are used to assess the condition of each resource category (Conservation Ontario 2011). The indicators for surface water quality are (Conservation Ontario 2011):

- total phosphorus
- *E. coli* bacteria
- benthic invertebrates

The indicators for forest conditions are (Conservation Ontario 2011):

- % forest cover
- % forest interior
- % riparian zone forested

The health of the Beaver River watershed and each of the subwatersheds is evaluated and graded using these indicators. Water temperature information is also provided, but not included in the surface water quality grades because a grading system has not yet been developed for water temperature. The methodology and grading systems for each indicator are presented in the remaining sections of this chapter. Grades are defined as follows (Conservation Ontario 2011):

A - Excellent

B - Good

C - Fair

D - Poor

F - Very Poor

2.3 Total phosphorus and *E. coli* bacteria

Phosphorus is a nutrient that occurs naturally in aquatic systems, but high concentrations due to human sources, such as fertilizers and municipal waste, can lead to harmful algal blooms (Conservation Ontario 2011). Ontario has a provincial water quality objective (PWQO) for total phosphorus levels of no more than 0.03 mg/l to avoid excess algal growth in rivers and streams (Ministry of Environment and Energy 1994). Levels of *E. coli* bacteria, measured in number of colony forming units (cfu) per 100 ml, are an indicator of fecal contamination in lakes and rivers. The PWQO for *E. coli* bacteria concentrations is no more than 100 cfu/100 ml to be suitable for swimming (Ministry of Environment and Energy 1994).

Total phosphorus levels were monitored by the GSCA at 12 of the 14 monitoring sites, following the MOECC sampling protocol. Water chemistry at four of these sites has been monitored by the GSCA since 2012. The remaining eight sites were monitored only during the spring and summer of 2015 (May 27, June 17, July 15, and July 29)⁴. The other two sites included in this study belong to the Provincial Water Quality Monitoring Network (PWQMN) (see Figure 2) and total phosphorus concentrations have been monitored by the MOECC at these sites since 2011. *E. coli* bacteria concentrations were monitored by the GSCA at all sites⁵.

Total phosphorus and *E. coli* results for each subwatershed were determined following the 2011 Conservation Ontario guidelines. The 75th percentile was calculated for all 2011-2015 total phosphorus data for each monitoring site⁶. Results for *E. coli* bacteria were calculated as the geometric mean of the 2011-2015 data. Point scores and grades for total phosphorus and *E. coli* bacteria were assigned using Table 1. The average of the point scores for all three water quality indicators was used to produce a final surface water quality grade for each subwatershed and for the entire Beaver River watershed (see Table 1).

Table 1. Phosphorus and *E. coli* bacteria grading system. Source: Conservation Ontario 2011.

Phosphorus (mg/l)	<i>E. coli</i> (cfu/100 ml)	Point Score	Grade	Average Point Score	Final Grade
<0.020	0 - 30	5	A	>4.4	A
0.020 - 0.030	31 - 100	4	B	3.5 - 4.4	B
0.031 - 0.060	101 - 300	3	C	2.5 - 3.4	C
0.061 - 0.180	301 - 1000	2	D	1.5 - 2.4	D
>0.180	>1000	1	F	<1.5	F

⁴ Data from these sites was limited and was used with caution; no extreme values were reported.

⁵ See Appendix 2 for information on the number of samples collected at each site.

⁶ The 75th percentile is used to account for the tendency for total phosphorus data to be collected during dry weather when concentrations are typically lower (Conservation Ontario 2011).

2.4 Benthic invertebrates

Benthic invertebrates are invertebrates such as insects, crustaceans, and molluscs that live at the bottom of rivers and streams and are widely used as an indicator of water quality (Griffiths 1999). Benthic invertebrate data was not collected in the summer of 2015 prior to the completion of this study. However, data from the 2011-2015 period was available from the GSCA for six sites and was used to assess water quality at those sites⁷. For monitoring sites with no benthic data, surface water quality grades are based on only total phosphorus and *E. coli* concentrations. The benthic sampling information for each site is displayed in Table 2. It is important to note that all of the benthic invertebrate grades presented in this report are based on only one sample collected on a single day.

Table 2. Benthic sampling information for each water quality monitoring site.

Monitoring Site	Sampling Date (2011-2015)	Number of Samples
26 Upper Boyne River	2012-08-31	1
324 Slabtown	2011-11-25	1
3208 Lake Eugenia Outlet	2012-10-01	1
3210 Mill Creek	2012-10-19	1
3224 Upper Beaver River	2012-08-31	1
6479 Beaver/Boyne River	2012-10-01	1

The grading system for benthic invertebrates developed by Conservation Ontario (2011) is based on the Hilsenhoff (1988) Family Biotic Index (FBI). The FBI is an adaptation of the Hilsenhoff Biotic Index (HBI), which provides a means of assessing water quality in streams by assigning “tolerance values” to benthic (arthropod) species based on their sensitivity to nutrient

⁷ Benthic fauna were monitored by the GSCA following BioMAP protocols for quantitative and qualitative samples (see Griffiths 1999).

and organic pollution (Hilsenhoff 1987). The weighted average of the tolerance values of all arthropod species in a sample produces a biotic index value that can be used to assess water quality (Hilsenhoff 1987). The FBI was developed to enable “rapid, but less critical” assessments that can be carried out in the field (Hilsenhoff 1988). Tolerance values are assigned to arthropod families, rather than species, and averaged for all families in a sample to produce the FBI value (Hilsenhoff 1988). The 2011 Conservation Ontario guidelines score benthic invertebrates using a modified version of the FBI, with an expanded taxa list and recalibrated tolerance values from New York State (Smith et al. 2009).

It was determined that the modified FBI is not the most appropriate index for scoring and grading benthic samples from the Beaver River watershed. A significant degree of accuracy is lost through the higher-level taxonomic resolution of the FBI, which is why it was not meant to be a substitute for the HBI (Hilsenhoff 1988). The FBI tends to overestimate the amount of pollution in unpolluted streams and underestimate the amount of pollution in polluted streams (Hilsenhoff 1988). In addition, it is unclear how the accuracy of water quality scores is affected by the inclusion of non-arthropod families in the modified FBI.

The Biological Monitoring and Assessment Program (BioMAP) developed by Griffiths (1999) provides an alternative method for using benthic invertebrates to assess water quality. BioMAP was designed for the “typical” watercourses of southern Ontario that originate in seeps or springs from till deposits (Griffiths 1999). This groundwater discharge maintains relatively stable conditions (i.e. water temperature, flow rate, turbidity, nutrient levels etc.) in headwater creeks compared to the lower reaches of rivers, which exhibit greater extremes (Griffiths 1999). Since benthic invertebrates are adapted to the conditions of their normal habitat, BioMAP assigns “sensitivity values” to taxa based on where they normally occur in a watershed (Griffiths

1999). These values range from 0 (most tolerant of changing conditions) to 4 (most sensitive to changing conditions), and are assigned mainly at the species and genus levels, though some family-level designations are also included (Griffiths 1999). This system provides more holistic evaluations of aquatic health by taking into account not only organic pollution, but all types of environmental disturbance. The lower-level taxonomic resolution also offers greater accuracy. The BioMAP protocol for sampling and assessing benthic invertebrates is preferred by the GSCA and, for the reasons stated above, was selected as an appropriate water quality assessment system for the Beaver River watershed. All taxa were identified by GSCA staff to the lowest practical taxonomic level.

A grading system based on the BioMAP(q) water quality index⁸ was developed by the GSCA and was used to score water quality at each monitoring site. This index uses qualitative data to measure water quality, i.e. assessments are based on the presence of taxa at a site, not the abundance of each taxon. To calculate the index value, the sensitivity values of all taxa collected at a site are ordered from highest to lowest and the top 25% are averaged (Griffiths 1999). Index values and associated grades are presented in Table 3. Note that grades are dependent on watercourse size (bankfull width), such that conditions that would score a “C” for a creek would be considered a “B” for a stream and an “A” for a river, and so on.

Table 3. BioMAP(q) index values and grades, adapted from Griffiths (1999) by the GSCA.

Watercourse (bankfull width)	A	B	C	D	F
Creek (<4 m)	4.0	>3.4	3.4 – 3.2	<3.2	<2.6
Stream (4-16 m)	>3.4	>3.0	3.0 – 2.6	<2.6	<2.0
River (16-64 m)	>3.0	>2.4	2.4 – 2.0	<2.0	<1.5

⁸ See Griffiths (1999) for a full explanation of this index.

2.5 Water Temperature

Water temperature is a basic physical characteristic of aquatic systems and an important indicator of aquatic health. Water temperatures in the Beaver River watershed were analyzed following the protocol developed by Stoneman and Jones (1996). Hobo data loggers were placed at all water quality monitoring sites from July 10 to August 3, 2015, providing water temperature measurements every half hour during this period. Additional loggers were deployed at the outlets of two headwater creeks in the Boyne River subwatershed (local names: Rock Mills Creek and Flesherton Creek) and at one site on the Beaver River 600 m downstream of the confluence of the Beaver and Boyne rivers.

The protocol by Stoneman and Jones (1996) is used to assess the thermal stability of a site by comparing maximum air and water temperatures on a single day in summer when the peak air temperature exceeds 24.5°C. Watercourses that remain cold are considered thermally stable, while those that heat quickly are considered thermally unstable (Stoneman and Jones 1996). Temperatures measured on July 29 were used to classify sites as “coldwater”, “coolwater”, or “warmwater” based on the temperature preferences of trout, where coldwater sites are ideal for Brook Trout and Brown Trout, coolwater sites are ideal for Rainbow Trout, and warmwater sites are normally avoided by trout (Stoneman and Jones 1996). Thresholds for these classifications were created based on air temperatures and are displayed graphically for each site (thresholds only apply when maximum air temperatures exceed 24.5°C). Air temperature measurements for the watershed were recorded at an Environment Canada weather station located on Mill Creek.

2.6 Forest conditions

Calculations of % forest cover, % forest interior, and % riparian zone forested were made using GIS (Manifold) software. The percentage of the watershed under forest cover was derived from Southern Ontario Land Resources Information System (SOLRIS) mapping data. Under this system, woodland is defined as areas with at least 60% tree cover greater than 2 m in height. (Conservation Ontario 2011). The % riparian zone forested was determined by classifying the land use within a 30 m buffer zone on both sides of all watercourses in the watershed. This was done using GIS technology and satellite images. The “forested” classification was based on the SOLRIS definition of woodland.

Forest interior is the portion of a forest that is greater than 100 meters from the forest edge (Conservation Ontario 2011). It is dependent on the size and shape of a woodland. Clearing of forests in the past has fragmented the natural forest cover of southern Ontario and greatly reduced the amount of forest interior. The patches of forest interior that remain provide habitat for many species and are an important component of watershed health. Point scores for % forest cover, % forest interior, and % riparian zone forested were assigned using Table 4. The average of these point scores was used to produce a final grade for forest conditions for each subwatershed and for the entire Beaver River watershed (see Table 4).

Table 4. Forest conditions grading system. Source: Conservation Ontario 2011.

% Forest Cover	% Forest Interior	% Riparian Zone Forested	Point Score	Grade	Average Point Score	Final Grade
>35.0	>11.5	>57.5	5	A	>4.4	A
25.1 - 35.0	8.6 - 11.5	42.6 - 57.5	4	B	3.5 - 4.4	B
15.1 - 25.0	5.6 - 8.5	27.6 - 42.5	3	C	2.5 - 3.4	C
5.0 - 15.0	2.5 - 5.5	12.5 - 27.5	2	D	1.5 - 2.4	D
<5.0	<2.5	<12.5	1	F	<1.5	F

3.0 Results and Discussion

This section presents the results of watershed monitoring and provides an assessment of environmental health for the Beaver River watershed and each of its subwatersheds. Results are organized into watershed/subwatershed ‘report cards’ that offer a snapshot of conditions during the 2011-2015 period.

3.1 Beaver River Watershed

Watershed Features:	
Area	617.5 km ²
Municipalities	Municipality of Meaford, The Blue Mountains, Municipality of Grey Highlands, Township of Clearview
Fishes	24 species noted in the last 10 years, including Brook Trout, Rainbow Trout, bass, and perch.
Dams	There are four major dams on the lower part of the Beaver River: the Slabtown Dam, the Haines Dam, the Clendenan Dam at Clarksburg, and the Thornbury Dam. There is another large dam at Lake Eugenia and many smaller dams throughout the watershed.
ANSIs	Beaver Valley Lowlands, Wodehouse Creek Sinkholes and Karst, Kimberly Creek, Kolapore Swamp, Kolapore Escarpment, Banks Moraine, Gibraltar Moraine, Eugenia Lake Drumlins, Upper Beaver Valley, Pretty River Valley

Figure 3 is an illustration of the Beaver River watershed, showing woodland and wetland areas, subwatershed boundaries, and water quality monitoring sites used for this study. Results and grades for surface water quality and forest conditions for the entire watershed are presented in Table 5. Results for surface water quality are based only on data collected from site 318 (Beaver River mouth), since water quality at this site reflects the total impact of the watershed.

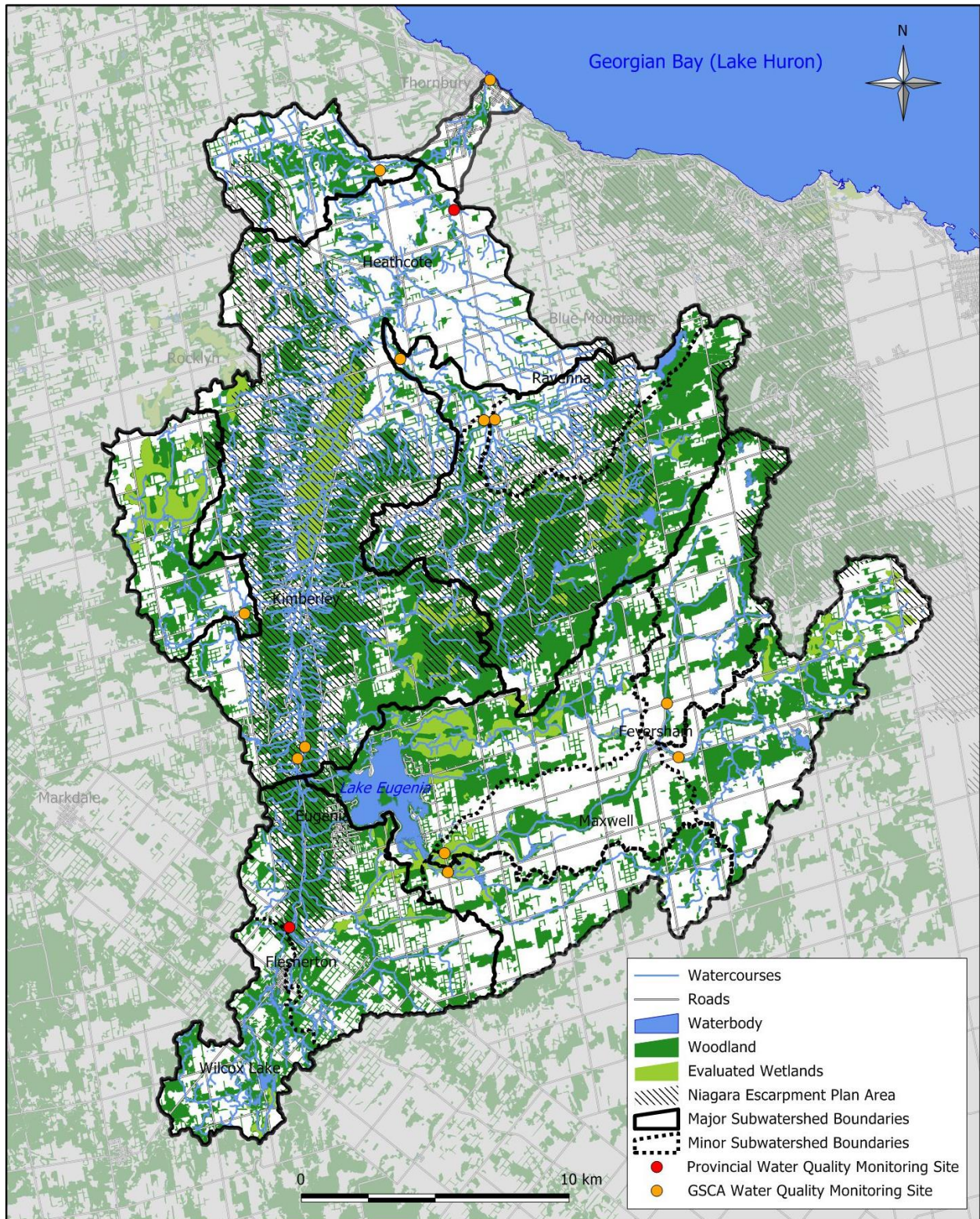


Figure 3. Beaver River Watershed.

Table 5. Surface water quality and forest conditions for the entire Beaver River watershed.
 * indicates result based on fewer than 5 samples.

Indicator	Result	Grade
Total phosphorus (mg/l)	0.031*	C
<i>E. coli</i> bacteria (cfu/100 ml)	43.49*	B
Benthic invertebrates	---	---
Surface water quality	---	B
% forest cover	39.5	A
% forest interior	11.9	A
% riparian zone forested	46.3	B
Forest conditions	---	A

The Beaver River watershed scores a “B” overall for surface water quality and an “A” for forest conditions, reflecting generally healthy ecosystem conditions. A significant percentage of the watershed is forested, and the amount of forest interior area is also relatively high due to a number of large patches of continuous forest. These forested areas provide habitat for a diversity of species and play an important role in watershed hydrology by allowing water to infiltrate into the ground, helping to maintain groundwater levels and base flows in creeks and streams. While a good percentage of the riparian area of the watershed is forested, this indicator does not score as well as overall forest conditions.

The surface water quality grade for the watershed is based on total phosphorus and *E. coli* bacteria concentrations. A closer look at these indicators shows that the total phosphorus result slightly exceeds the PWQO of 0.03 mg/l – a level above which harmful algal blooms can impair water quality. This result may reflect impacts associated with the town of Thornbury, as well as upstream nutrient inputs from agricultural runoff. The *E. coli* result, however, is well below the PWQO and does not indicate water quality impairment.

Water Temperature:

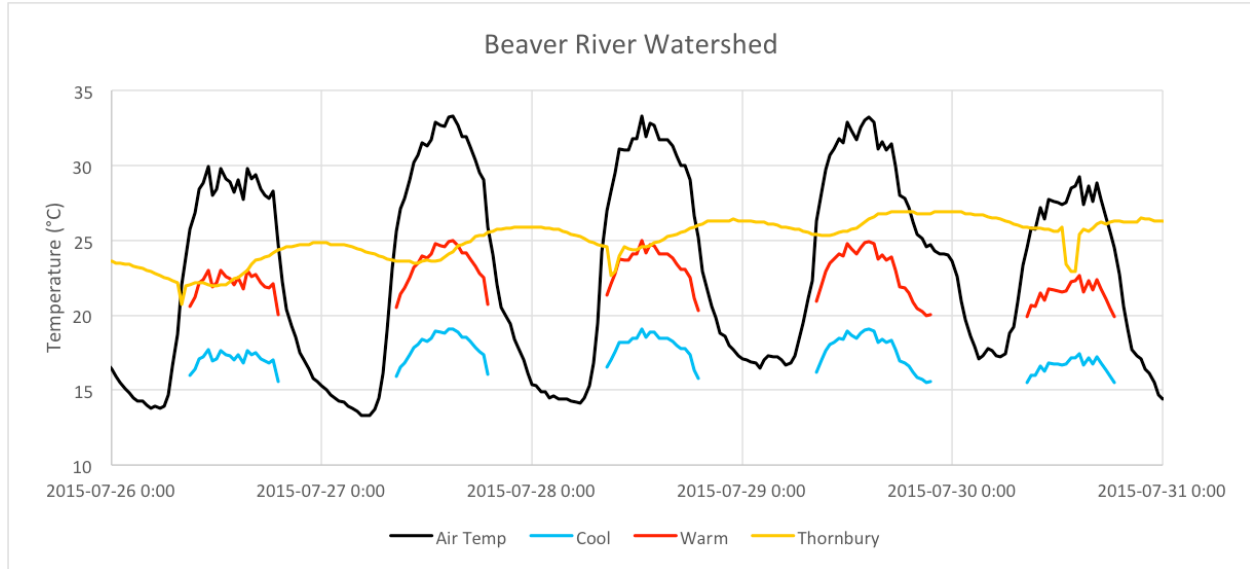


Figure 4. Water temperature measured at site 318 (Beaver River mouth at Thornbury) compared to air temperature and cool and warm water thresholds.

Figure 4 compares water temperatures measured at the mouth of the Beaver River to air temperatures over a five-day period at the end of July 2015. Note that daily water temperatures peak several hours later than daily air temperatures – a result of the high specific heat of water and the relatively large volume of water at this location. The red and blue lines represent the lower thresholds for warm and cool water, respectively, based on the classifications developed by Stoneman and Jones (1996). Water temperatures that peak above the red line are classified as “warmwater”, temperatures peaking between the red and blue lines are classified as “coolwater”, and temperatures that peak below the blue line are classified as “coldwater” (Stoneman and Jones 1996). Estimates of water temperature regimes should be based on a day that was preceded by 2-3 days with similar maximum air temperatures (Stoneman and Jones 1996). As seen in Figure 4, daily air temperatures peaked above 30°C on three consecutive days in July (July 27 to July 29). Thus, temperatures on July 29 were used to classify the thermal regime of the river. Since the maximum water temperature on this day exceeded the warmwater threshold, the

Beaver River mouth is classified as warmwater. This result is typical for the lower reaches of a river. As water flows downstream in summer it gradually warms from the temperature of the groundwater source (normally 8-9°C in southern Ontario) to temperatures closer to that of the air (Nottawasaga Valley Conservation Authority et al. 2015; Griffiths 1999). However, even the minimum water temperature on July 29 exceeded the warmwater threshold, and daily maximum and minimum temperatures differed by only a few degrees. With no nighttime recovery of cool temperatures, daily maximum water temperatures increased each day, reflecting the thermal instability of the site. These results are discussed further in the following section.

3.2 Main Beaver River Subwatershed

Watershed Features:	
Area	585.9 km ² , 95% of Beaver River watershed
Municipalities	Grey Highlands, Blue Mountains
Fishes	Rainbow Trout, Brook Stickleback, Rock Bass
Dams	Slabtown Dam, Haines Dam, Clendenan Dam, and Thornbury Dam.
ANSIs	Beaver Valley Lowlands, Kimberly Creek

Figure 5 shows the Main Beaver River subwatershed, which includes all of the area that drains to the location of the provincial water quality monitoring site at Slabtown Road (northern most red point on the map). As this site is upstream of the town of Thornbury, comparison with results from the Beaver River mouth may provide information about the effects of urban development on water quality. Results and grades for surface water quality and forest conditions for the Main Beaver River subwatershed are presented in Table 6.

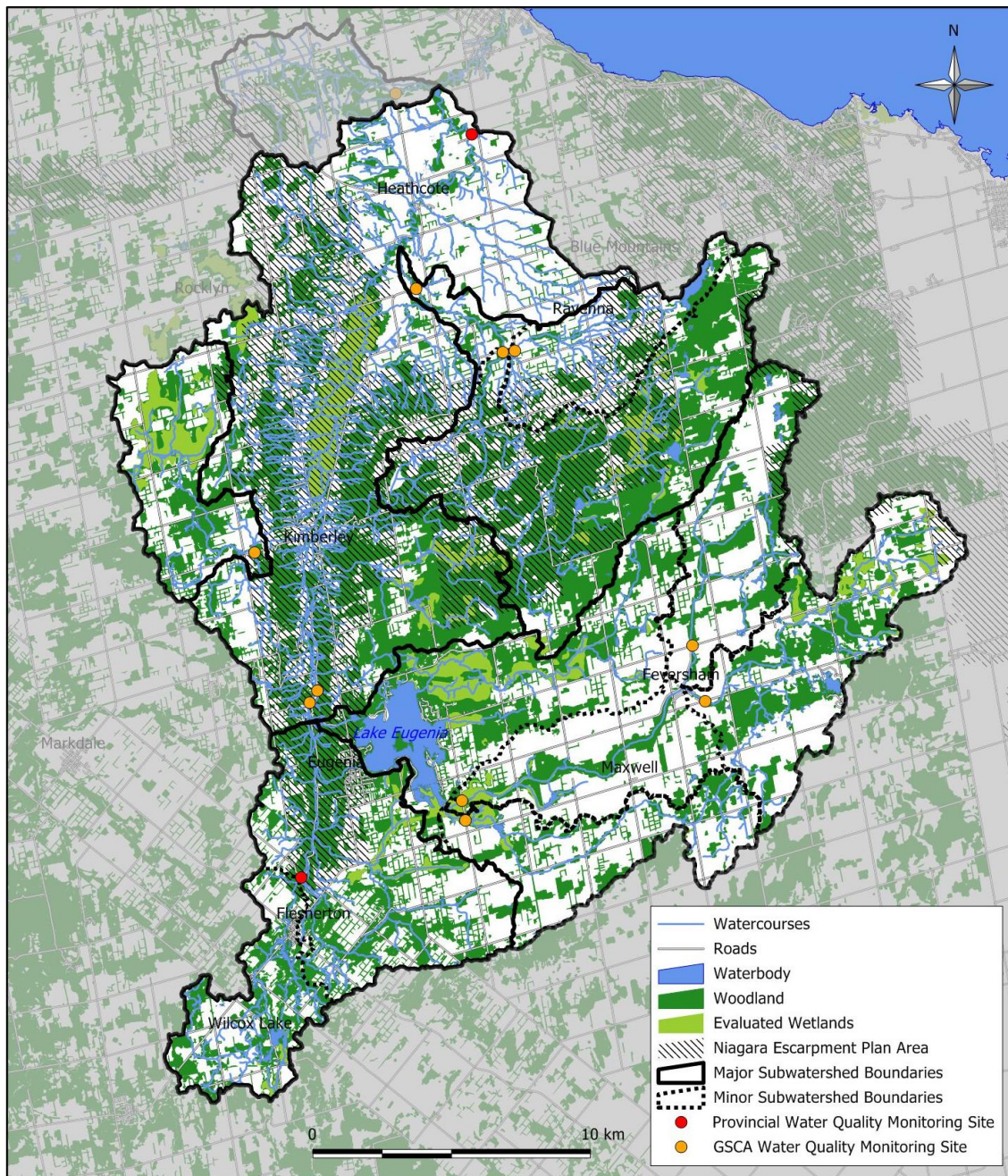


Figure 5. Main Beaver River Subwatershed.

Table 6. Surface water quality and forest conditions for the Main Beaver River subwatershed.
 * indicates result based on fewer than 5 samples.

Indicator	Result	Grade
Total phosphorus (mg/l)	0.023	B
<i>E. coli</i> bacteria (cfu/100 ml)	63.47	B
Benthic invertebrates	3.13*	A
Surface water quality	---	B
% forest cover	41.2	A
% forest interior	12.9	A
% riparian zone forested	48.8	B
Forest conditions	---	A

Surface water quality for the Main Beaver River scores a “B” overall, and forest conditions score an “A”, again reflecting generally healthy conditions. The amount of forest cover and forest interior is high, especially in the Niagara Escarpment Plan Area. The percentage of riparian area that is forested is also relatively high at nearly 50%, and fortunately, much of the main stem of the river is forested. However, as seen in Figure 5, riparian cover in the northern portion of the subwatershed is low.

The benthic invertebrate score suggests that aquatic health is better than would be expected based on the size of the river. Total phosphorus also scores better at this location than at the river mouth, indicating that phosphorus inputs between the Slabtown site and the river mouth have a noticeable impact. *E. coli* bacteria concentrations, on the other hand, are slightly higher at this location than at the river mouth, although still below the PWQO of 100 cfu/100 ml. Together, the surface water quality indicators suggest that the main river is not impaired.

Water Temperature:

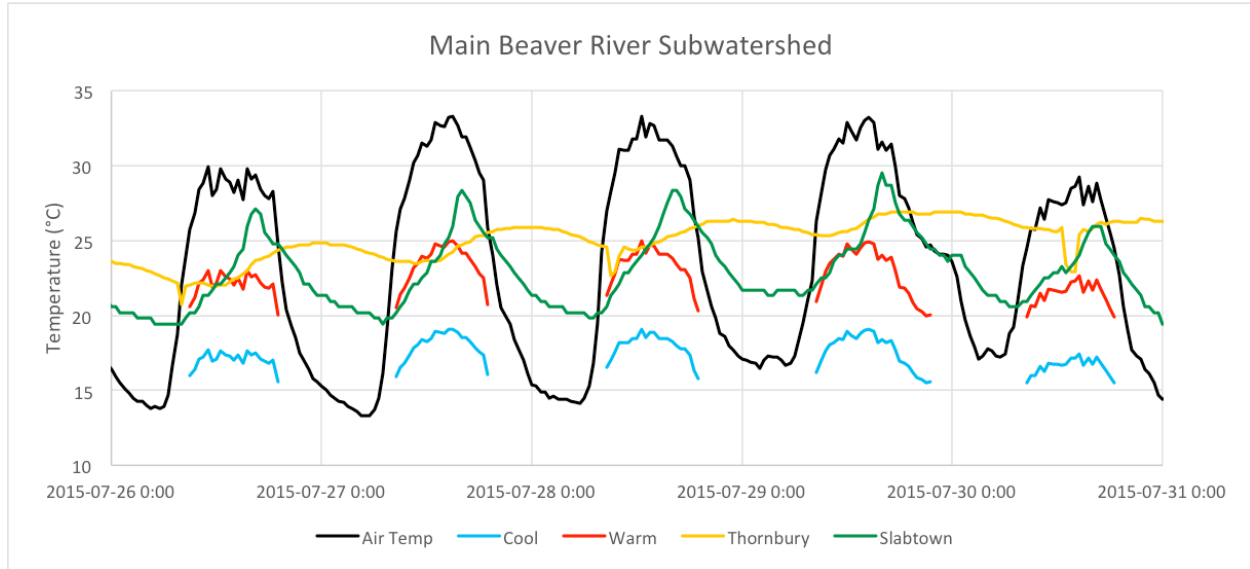


Figure 6. Water temperature measured at site 324 (Slabtown) and site 318 (Beaver River mouth at Thornbury) compared to air temperature and cool and warm water thresholds.

Despite good riparian cover in the subwatershed, there is concern about rising temperatures in the main stem of the river. Figure 6 shows the temperature at both the Slabtown monitoring site and the monitoring site in Thornbury in order to evaluate the effect of development between these two locations on water temperature. Since maximum water temperatures at both sites exceeded the warmwater threshold on July 29, the river is classified as warmwater (thermally unstable) at both locations. However, as seen in Figure 6, daily water temperatures behave quite differently at the two sites. Water temperatures at the Slabtown site exhibit much greater daily fluctuations than at the river mouth, and peak earlier in the



day, following the air temperature more closely. There may be several reasons for this.

Temperatures at the river mouth may be buffered by the larger volume of water flowing past this point. Inputs of warm water from urban runoff also could be contributing to consistently high water temperatures at the river mouth. Perhaps more significantly, the temperature at the mouth may be reflecting the impact of several large dams located between sites 324 and 318.

Site 324 is a provincial water quality monitoring site located just below the Slabtown Dam. There are three other large dams on the river between this site and the outlet: the Clendenan Dam, the Haines Dam, and the Thornbury Dam. The Haines Dam is unlikely to have an impact on water temperatures since there is no significant ponding of the river above the dam. The Clendenan Dam and the dam at Thornbury, however, may be altering downstream temperature regimes. Both dams cause significant upstream ponding of the river. These ponds reduce the flow rate of the river, which reduces mixing, causing the water to heat more quickly. Since warmer water is less dense, it 'floats' on the top of the water column, forming a warm surface layer. Water from the surface of the Mill Pond above the Thornbury Dam flows over the top of the dam (top draw), most likely causing the downstream water temperature to be warmer and show less daily fluctuation than it otherwise would. The Clendenan Dam may have a similar effect. The Slabtown Dam causes minimal ponding of the river. The flow rate at this location is higher, allowing greater mixing of the water such that the water temperature more closely follows the air temperature.

3.3 Grier Creek Subwatershed

Watershed Features:

Area	23.0 km ² , 4% of Beaver River watershed
Municipalities	Meaford, Grey Highlands, Blue Mountains
Fishes	Bluntnose Minnow, Common Shiner, Creek Chub, Longnose Dace, Rainbow Trout
Dams	None recorded
ANSIs	None

The Grier Creek subwatershed covers a relatively small area of 23 square kilometers and outlets to the main stem of the Beaver River between the Slabtown and Clendenan dams, roughly four kilometers from the mouth of the river. The subwatershed is illustrated in Figure 7 and results and grades for surface water quality and forest conditions are displayed in Table 7.

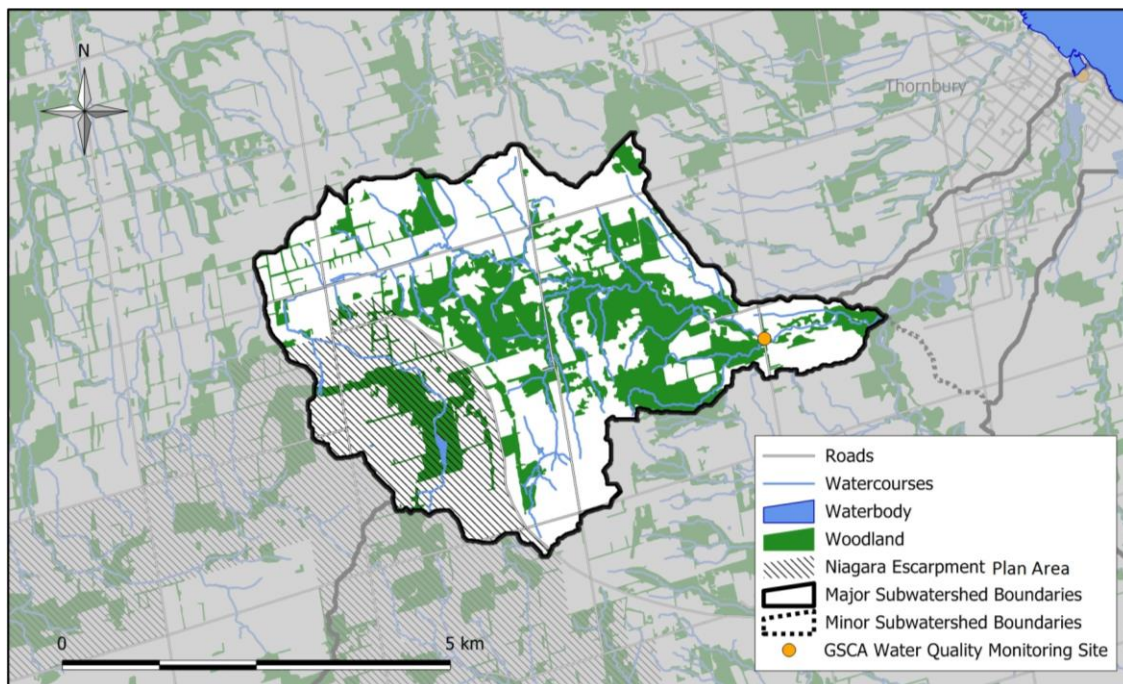


Figure 7. Grier Creek Subwatershed.

Table 7. Surface water quality and forest conditions for the Grier Creek subwatershed.
 * indicates result based on fewer than 5 samples.

Indicator	Result	Grade
Total phosphorus (mg/l)	0.027*	B
<i>E. coli</i> bacteria (cfu/100 ml)	8.05*	A
Benthic invertebrates	---	---
Surface water quality	---	A
% forest cover	30.0	B
% forest interior	3.2	D
% riparian zone forested	45.1	B
Forest conditions	---	C

Surface water quality scores well for the Grier Creek subwatershed, with an overall grade of “A”. This result, however, is based only on levels of total phosphorus and *E. coli* bacteria, both of which are relatively low. Water temperature results are discussed below. Forest conditions score a “C” overall. While a good percentage of the subwatershed is forested, forest patches are small and fragmented, resulting in a poor grade for forest interior. Riparian zones are relatively well forested, but lack of vegetative cover in some areas likely has a negative impact on the creek ecosystem.

Water Temperature:

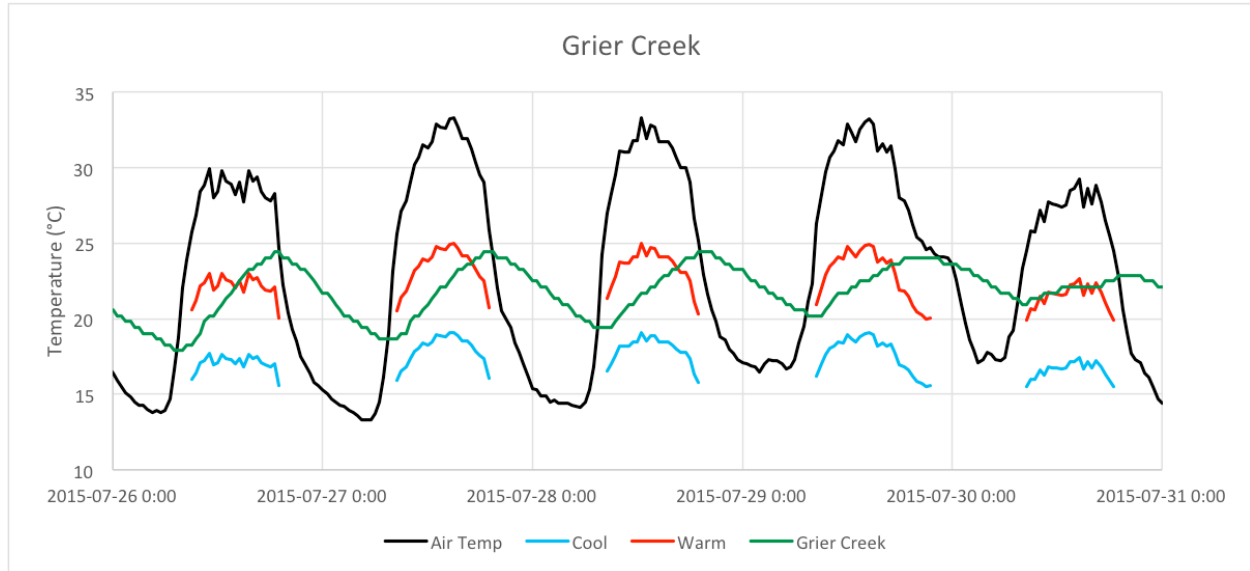


Figure 8. Water temperature measured at site 544 (Grier Creek) compared to air temperature and cool and warm water thresholds.

As seen in Figure 8, July 29 water temperatures at the Grier Creek monitoring site peaked just below the warmwater threshold, suggesting that the site provides marginal coolwater habitat. Daily maximum water temperatures were higher than would be expected for a small creek, and daily minimum temperatures were also relatively high, indicating that water temperatures did not recover significantly at night. These results suggest that groundwater inputs do not occur in the vicinity of the monitoring site and the creek temperature likely increases quickly with distance downstream from the groundwater source. Lack of riparian cover shading the creek is likely a contributing factor. The creek flows over rocks that quickly heat under the direct sun, further heating the water. The low water levels observed at the site would also exacerbate heating of the creek since a smaller volume of water heats more quickly. While the creek may still support some coolwater species, rising water temperatures and low water levels are issues to watch in this subwatershed.

3.4 Mill Creek Subwatershed

Watershed Features:

Area	Mill Creek: 105.9 km ² , 17% of Beaver River watershed Red Wing Tributary: 23.4 km ² , 4% of Beaver River watershed Kolapore Creek: 75.9 km ² , 12% of Beaver River watershed
Municipalities	Grey Highlands, Blue Mountains
Fishes	Blacknose Dace, Longnose Dace, Rainbow Trout, Brook Trout, Creek Chub
Dams	4 small dams recorded
ANSIs	Kolapore Swamp, Kolapore Escarpment, Banks Moraine, Gibraltar Moraine

The Mill Creek subwatershed is illustrated in Figure 9, and outlets to the main Beaver River just south of Heathcote, approximately 10 kilometers upstream from the mouth of the river. The subwatershed is divided into two minor subwatersheds corresponding to two branches of the creek: the Red Wing tributary and Kolapore Creek. Data collected from site 3210, located near the outlet of Mill Creek, was used to assess surface water quality for the entire subwatershed. Water quality was also monitored at the outlets of both minor subwatersheds.



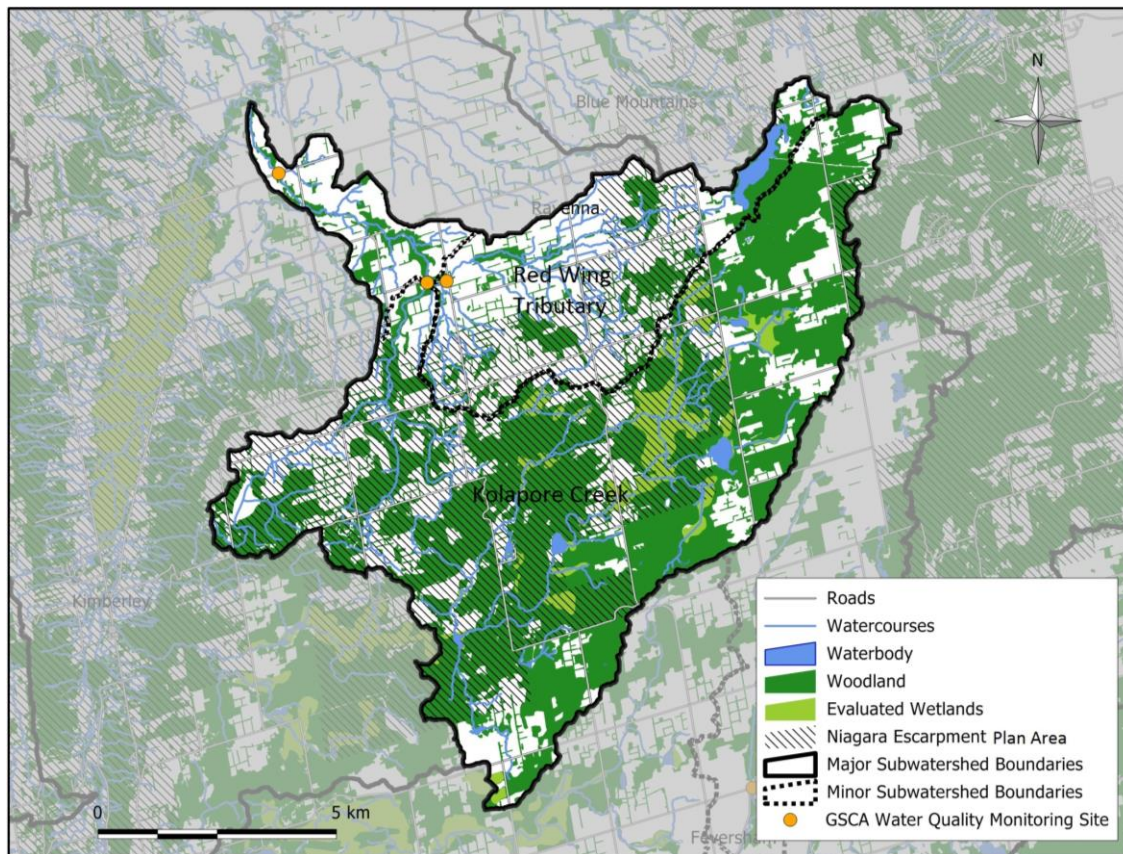


Figure 9. Mill Creek Subwatershed.

Table 8. Surface water quality and forest conditions for the Mill Creek subwatershed.

* indicates result based on fewer than 5 samples.

Indicator	Red Wing Tributary		Kolapore Creek		Mill Creek	
	Result	Grade	Result	Grade	Result	Grade
Total phosphorus (mg/l)	0.016*	A	0.028*	B	0.019	A
<i>E. coli</i> bacteria (cfu/100 ml)	48.73*	B	41.13*	B	52.29	B
Benthic invertebrates	---	---	---	---	3.17*	B
Surface water quality	---	A	---	B	---	B
% forest cover	26.9	B	67.1	A	55.3	A
% forest interior	3.9	D	31.1	A	23.6	A
% riparian zone forested	31.0	C	61.7	A	49.1	B
Forest conditions	---	C	---	A	---	A

Results and grades for surface water quality and forest conditions for the Mill Creek subwatershed and its two minor subwatersheds are displayed in Table 8. Overall forest conditions in the subwatershed are excellent. This is mainly a reflection of the exceptionally high forest cover in the Kolapore Creek subwatershed. Forest cover in the Red Wing tributary subwatershed is much lower, and forest patches are small and fragmented, resulting in very little forest interior area. The percentage of riparian areas that are forested is also low – only half of the percentage in the Kolapore Creek subwatershed.

Surface water quality might be expected to reflect these results and score more poorly in the Red Wing tributary compared to Kolapore Creek, however, the results show little difference between the two sites. Total phosphorus levels are slightly lower at the outlet of the Red Wing tributary, resulting in a higher overall grade. The generally healthy conditions in the Mill Creek subwatershed may be a reflection of the large portion of the subwatershed that is protected to some degree under the designations of the Niagara Escarpment Plan.

Water Temperature:

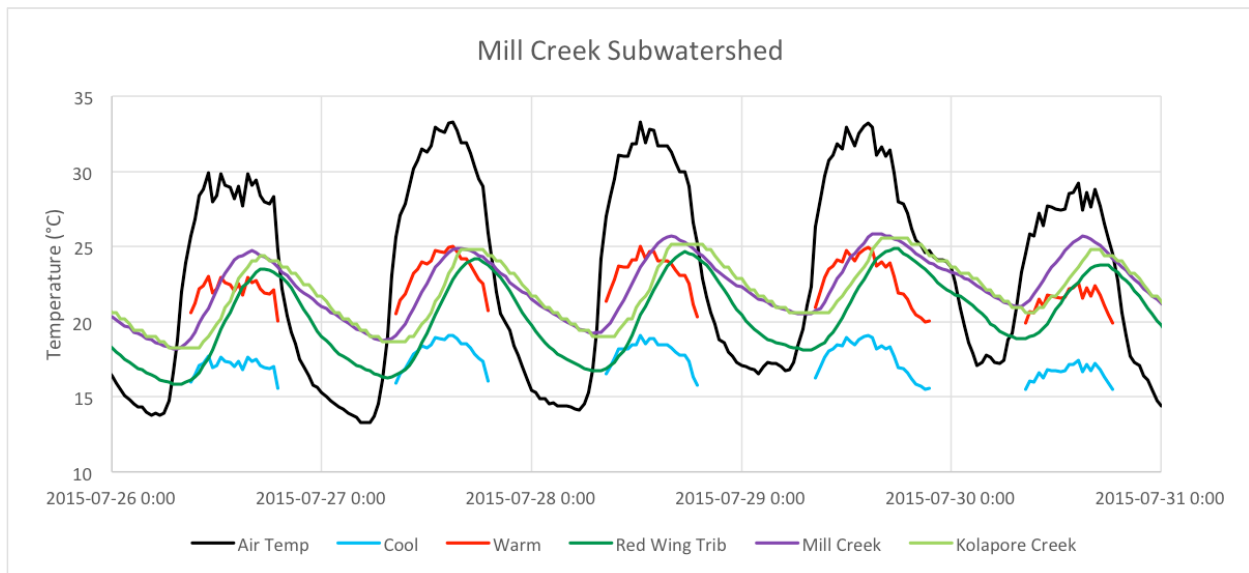


Figure 10. Water temperatures measured at sites 3210 (Mill Creek), 3214 (Red Wing tributary), and 3215 (Kolapore Creek) compared to air temperature and cool and warm water thresholds.

As seen in Figure 10, the maximum water temperature at both the Mill Creek and Kolapore Creek monitoring sites slightly exceeded the lower warmwater threshold on July 29, suggesting that both sites may be classified as warmwater, or thermally unstable. The water temperature at the Red Wing tributary site peaked just at the warmwater threshold, indicating that this site may be marginal coolwater. Daily maximum water temperatures were high, considering the size of the creek at all sites. The temperature at Kolapore Creek is particularly unusual given the high riparian forest cover in the subwatershed. The graph shows that there is some nighttime recovery of cool temperatures at the Red Wing site, but less so at the other two, suggesting that the Red Wing site is located closer to groundwater inputs than the other sites.



3.5 Wodehouse Creek Subwatershed

Watershed Features:	
Area	32.9 km ² , 5% of Beaver River watershed
Municipalities	Grey Highlands
Fishes	No data available
Dams	3 small dams recorded
ANSIs	Wodehouse Creek Sinkholes and Karst

Wodehouse Creek drains an area of about 33 square kilometers, most of which is located above the Niagara Escarpment on the west side of the Beaver Valley. Figure 11 shows the water quality monitoring site for the subwatershed and depicts the creek continuing southward from this point. This is not an accurate representation as these are actually two separate systems, both of which disappear above the escarpment due to the presence of large sinkholes that receive to the upper reaches of the watershed (J. Bittorf, personal communication, August 25, 2015).

Wodehouse Creek disappears just downstream from the indicated monitoring site. It is uncertain where the creek outlets below the escarpment (J. Bittorf, personal communication, August 25, 2015).

Results of analyses of surface water quality and forest conditions are presented in Table 9.



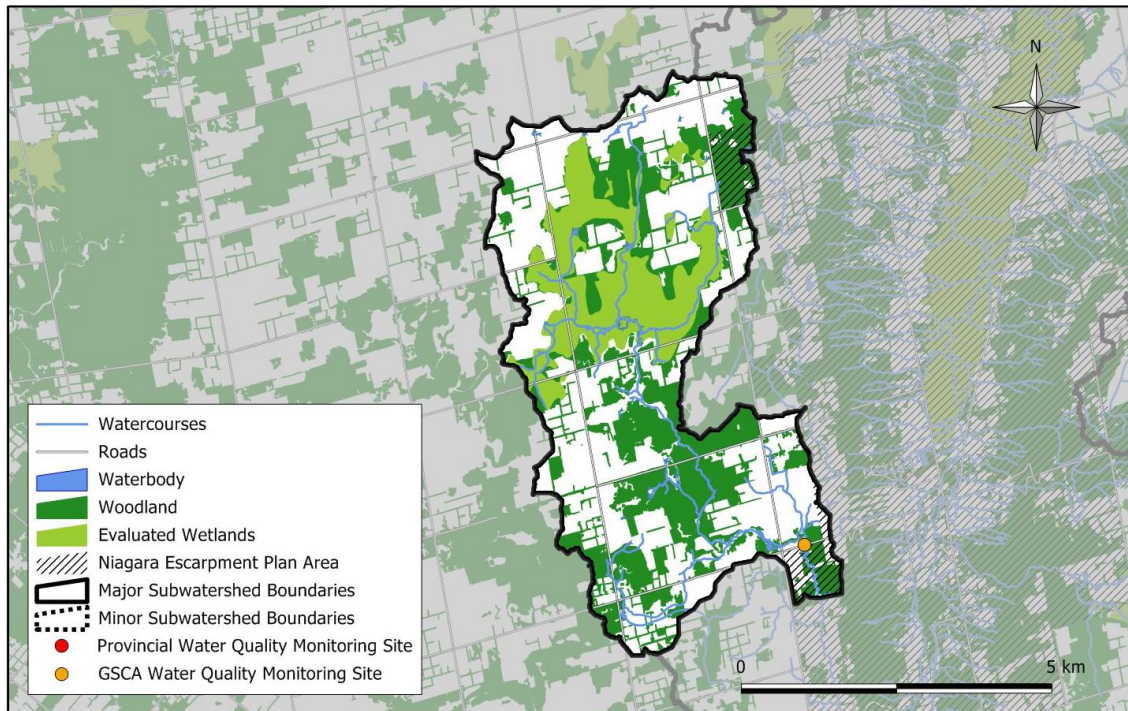


Figure 11. Wodehouse Creek Subwatershed.

Table 9. Surface water quality and forest conditions for the Wodehouse Creek subwatershed.
* indicates result based on fewer than 5 samples.

Indicator	Result	Grade
Total phosphorus (mg/l)	0.033*	C
<i>E. coli</i> bacteria (cfu/100 ml)	91.11*	B
Benthic invertebrates	---	---
Surface water quality	---	B
% forest cover	42.9	A
% forest interior	11.8	A
% riparian zone forested	39.2	C
Forest conditions	---	B

Concentrations of both total phosphorus and *E. coli* bacteria at the Wodehouse Creek site were the highest observed in the watershed. The *E. coli* bacteria result is still below the PWQO of 100 cfu/100 ml and does not indicate water quality impairment. The total phosphorus result,

however, slightly exceeds the PWQO. As this result is based on only a small number of samples, it is difficult to assess the potential risk of water quality impairment due to elevated phosphorus levels. Based on these two indicators, overall surface water quality scores a “B”. The relatively high phosphorus levels may be a reflection of the relatively low percentage of forest cover in the riparian areas of the subwatershed, potentially causing excess nutrient and sediment loading from agricultural runoff. Higher than usual *E. coli* levels are likely due to cattle entering the creek upstream from the monitoring site. While forest cover in riparian areas is low, total forest cover in the subwatershed is high, resulting in an overall “B” grade for forest conditions.

Water Temperature:



Figure 12. Water temperature measured at site 4041 (Wodehouse Creek) compared to air temperature and cool and warm water thresholds.

Temperature records for July 29 show that a maximum water temperature of about 25°C was reached at the Wodehouse Creek monitoring site, matching the lower warmwater threshold. The creek could be classified as marginal coolwater at this site. Similar to the Grier Creek site, daily maximum water temperatures were high given the size of the watercourse, most likely a

result of poor riparian cover and exposure to direct sun, as well as a small upstream dam. The relatively high daily minimum water temperatures recorded from July 26 to July 30 indicate that the site is some distance from the groundwater source of the creek and, as a result, nighttime recovery of cool temperatures did not occur. Wodehouse Creek may provide marginal habitat for coolwater species, but thermal stress is likely an issue during summer.

3.6 Lake Eugenia Subwatershed

Watershed Features:	
Area	Lake Eugenia subwatershed: 190.3 km ² , 31% of Beaver River watershed Little Beaver River: 30.9 km ² , 5% of Beaver River watershed Upper Beaver River: 108.4 km ² , 18% of Beaver River watershed Upper Beaver N Tributary: 34.8 km ² , 6% of Beaver River watershed Upper Beaver S Tributary: 45.1 km ² , 7% of Beaver River watershed
Municipalities	Grey Highlands, Blue Mountains, Clearview
Fishes	Brook Trout, Rainbow Trout, Brown Trout, Common Carp, Largemouth Bass, Rock Bass, Smallmouth Bass, Pumpkinseed, White Sucker, Yellow Perch, Black Crappie, Brook Stickleback, Central Mudminnow, Mottled Sculpin, Northern Redbelly Dace, Golden Shiner
Dams	Lake Eugenia dam and 4+ small dams
ANSIs	Eugenia Lake Drumlins, Gibraltar Moraine, Pretty River Valley



Lake Eugenia is an artificial lake that was created in 1915 when the upper Beaver River (above the escarpment) was dammed to create a reservoir for the Eugenia hydroelectric generating station (Ontario Power Generation 2014). Approximately 190 square kilometers of the Beaver River watershed drain into Lake Eugenia, making the Lake Eugenia subwatershed the largest considered in this report. In order to provide more detailed results, the subwatershed was divided into the Little Beaver River and Upper Beaver River subwatersheds, and the Upper Beaver River subwatershed was further divided based on the catchment areas of its north and south tributaries (see Figure 13). Water quality monitoring site locations are shown in Figure 13.



Note that the monitoring site located at the outlet of Lake Eugenia (3208) does not appear within the subwatershed boundary. This is because the boundary reflects the original course of the Beaver River. Most of the flow is now diverted

through penstocks to the hydroelectric generating station in the valley below the escarpment.

As a result, the main confluence of the Beaver and Boyne rivers occurs about a kilometer north of its original location. The Lake Eugenia Outlet monitoring site is located at the outfall of the hydroelectric station.



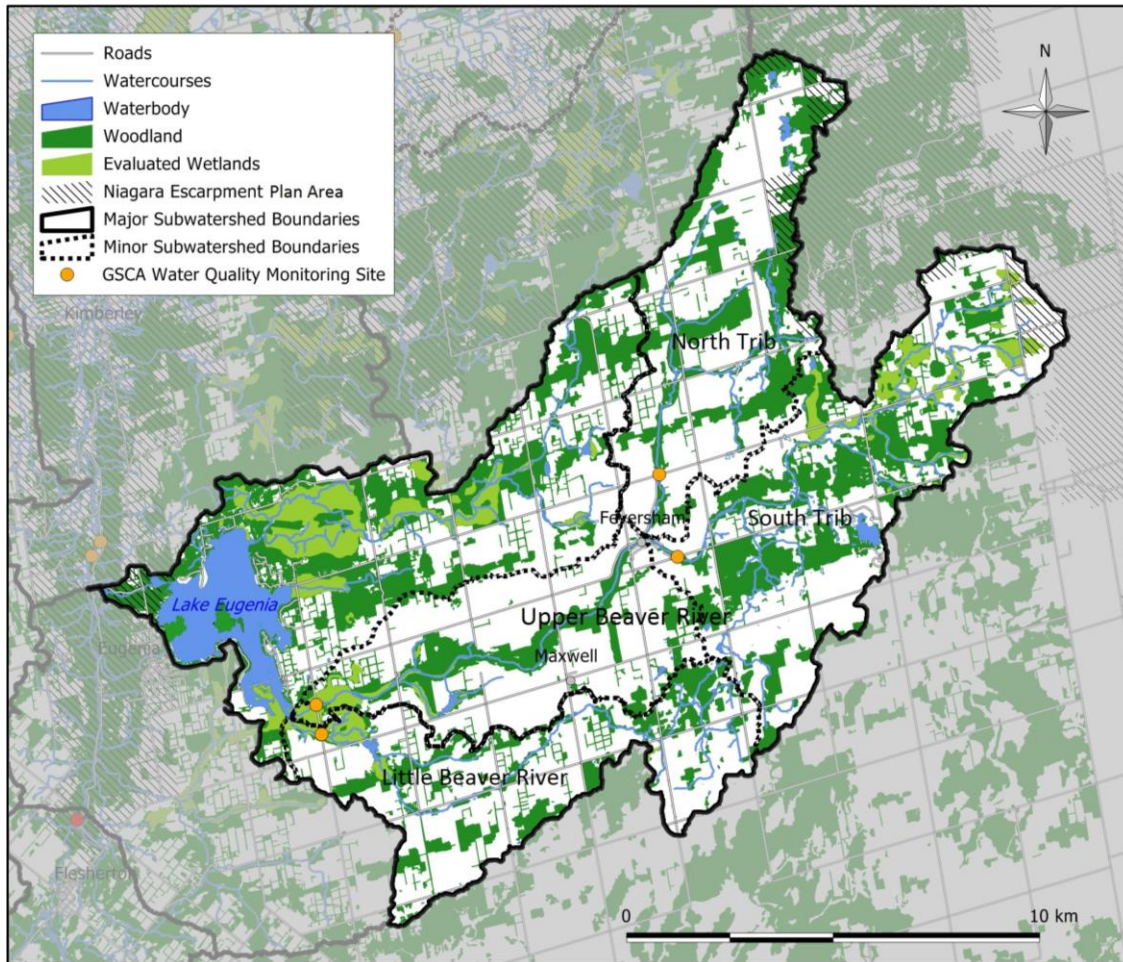


Figure 13. Lake Eugenia Subwatershed.

Results and grades for surface water quality and forest conditions for the Lake Eugenia subwatershed and each of its minor subwatersheds are presented in Tables 10 and 11. The results indicate that overall surface water quality is excellent across the entire subwatershed. Total phosphorus concentrations were low at all monitoring sites and all *E. coli* bacteria results met the PWQO of 100 cfu/100 ml, though levels were slightly higher at the Upper Beaver River North Tributary monitoring site than in the rest of the subwatershed. The *E. coli* bacteria result for the Lake Eugenia Outlet monitoring site is exceptionally low, and *E. coli* concentrations have been consistently near zero at this location. There may be several factors contributing to this result. The water intake for the hydro station penstocks is located on a shallow inlet on Lake Eugenia, at

a depth of 1-2 meters. Thus, water is taken essentially from the surface of the lake where *E. coli* concentrations would be low due to exposure to UV radiation and settling of sediment-bound



bacteria. Zebra mussels observed at the hydro station outfall may also be contributing to the low *E. coli* levels by filtering out the bacteria. Zebra mussels are an invasive species that were likely introduced to the

Beaver River by boats on Lake Eugenia. The mussels cover the substrate at the Lake Eugenia Outlet site, currently preventing collection of benthic invertebrate samples.

As seen in Tables 10 and 11, overall forest conditions are good across most of the Lake Eugenia subwatershed. However, forest interior results are relatively low, especially in the Little Beaver River subwatershed, and riparian forest cover is also lacking in a number of places.

Table 10. Surface water quality and forest conditions for the Little Beaver River, Upper Beaver River, and Lake Eugenia subwatersheds.

* indicates result based on fewer than 5 samples.

Indicator	Little Beaver River		Upper Beaver River		Lake Eugenia	
	Result	Grade	Result	Grade	Result	Grade
Total phosphorus (mg/l)	0.016*	A	0.011	A	0.014	A
<i>E. coli</i> bacteria (cfu/100 ml)	37.41*	B	31.25	B	3.83	A
Benthic invertebrates	---	---	3.15*	A	3.00*	B
Surface water quality	---	A	---	A	---	A
% forest cover	25.4	B	31.8	B	34.1	B
% forest interior	2.8	D	7.4	C	8.5	C
% riparian zone forested	41.0	C	47.2	B	46.6	B
Forest conditions	---	C	---	B	---	B

Table 11. Surface water quality and forest conditions for the Upper Beaver River North Tributary and South Tributary subwatersheds.

* indicates result based on fewer than 5 samples.

Indicator	Upper Beaver North Tributary		Upper Beaver South Tributary	
	Result	Grade	Result	Grade
Total phosphorus (mg/l)	0.012*	A	0.018*	A
<i>E. coli</i> bacteria (cfu/100 ml)	75.88*	B	28.51*	A
Benthic invertebrates	---	---	---	---
Surface water quality	---	A	---	A
% forest cover	33.7	B	35.3	A
% forest interior	8.3	C	8.8	B
% riparian zone forested	63.1	A	38.9	C
Forest conditions	---	B	---	B

Water Temperature:

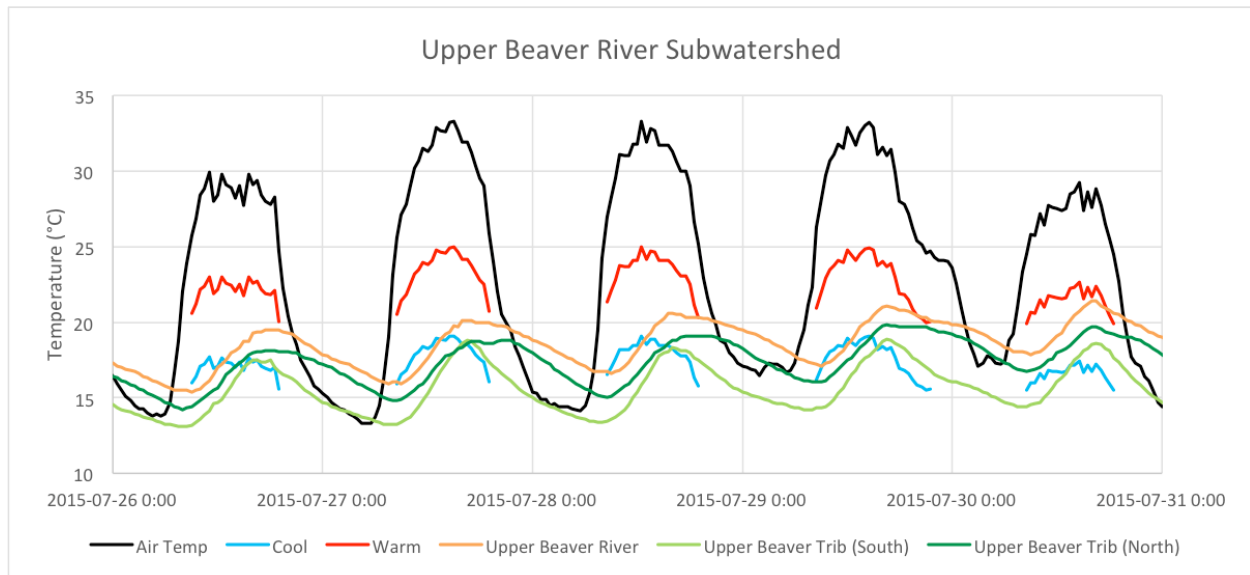


Figure 14. Daily water temperatures measured at sites 3224 (Upper Beaver River), 4170 (Upper Beaver South Tributary), and 4186 (Upper Beaver North Tributary) compared to air temperature and cool and warm water thresholds.

Daily water temperatures for the Upper Beaver River and its two tributaries are shown in Figure 14. Maximum water temperatures on July 29 indicate that both the Upper Beaver River and the North Tributary sites are coolwater. The July 29 maximum temperature at the South Tributary site matches the lower coolwater threshold, indicating that this site may be considered marginal coldwater. As expected, water temperatures at the downstream (Upper Beaver River) site are slightly higher, since the site is further from the groundwater source and is also located downstream from a small dam. Low temperatures at all three sites indicate that the Upper Beaver River is well buffered by groundwater inputs.

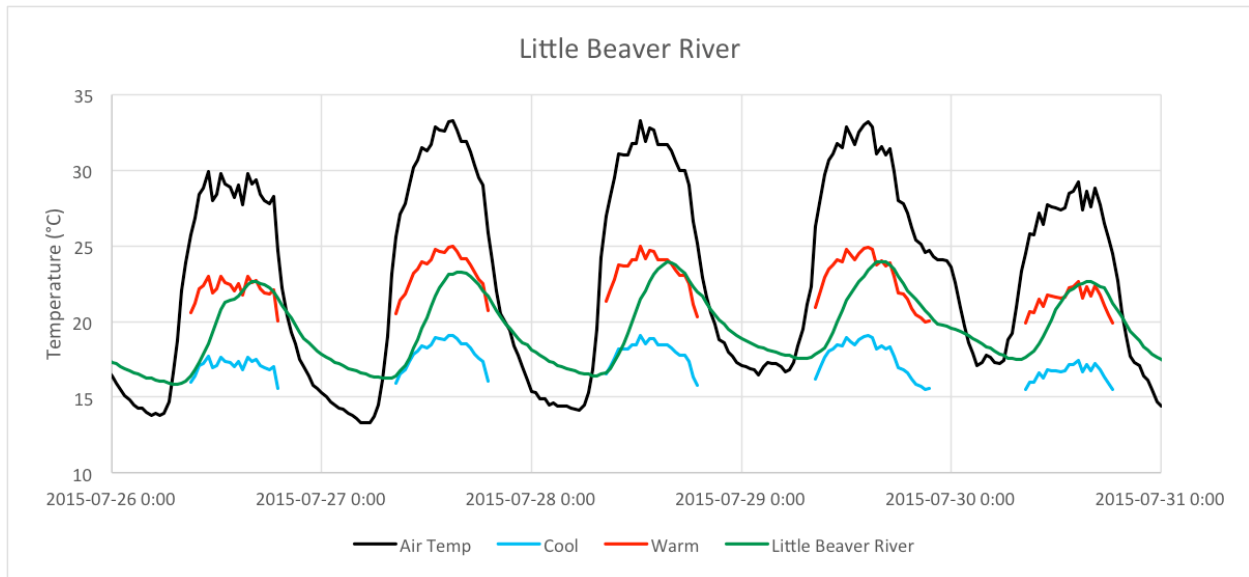


Figure 15. Water temperature measured at site 3222 (Little Beaver River) compared to air temperature and cool and warm water thresholds.

Daily water temperatures measured at the Little Beaver River monitoring site are shown in Figure 15. The July 29 maximum temperature is just within the coolwater zone. Daily maximum water temperatures are higher than expected for a small headwater creek. Nighttime recovery of cold temperatures suggests that the site is cooled by upstream groundwater inputs. Thus, the high water temperatures reached during the day are likely a reflection of relatively low forest cover in

the riparian areas of the subwatershed, compounded by the effects of another upstream dam.

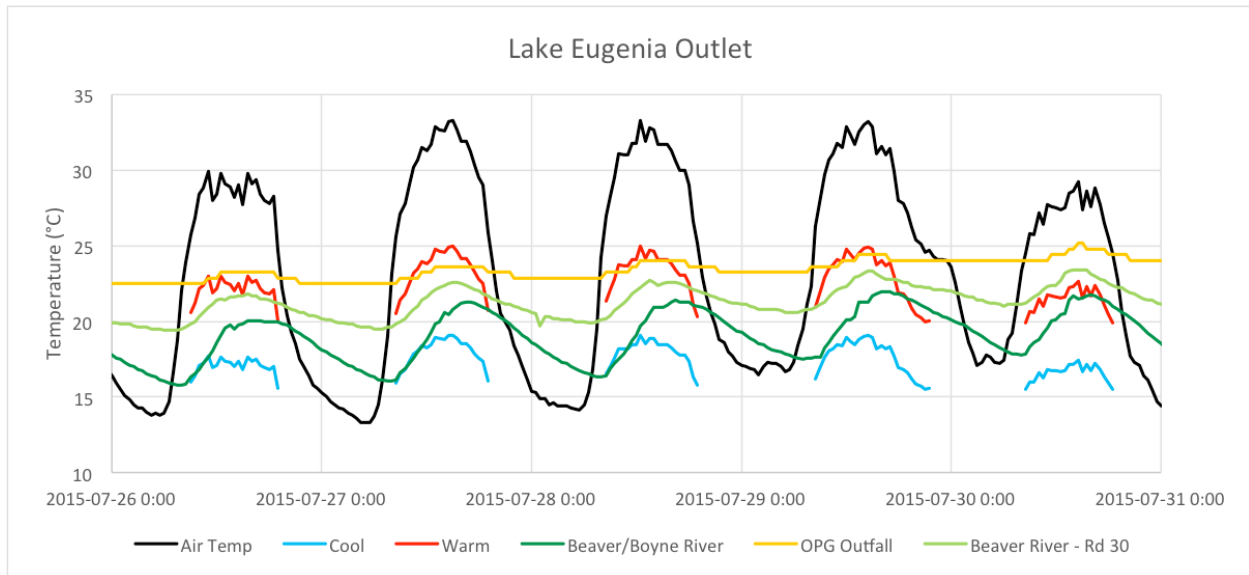


Figure 16. Daily water temperatures measured at sites 3208 (Lake Eugenia Outlet/OPG Outfall), 6479 (Beaver/Boyne River), and at a downstream location (Beaver River - Rd. 30) compared to air temperature and cool and warm water thresholds.

Figure 16 shows daily water temperatures recorded at the Ontario Power Generation (OPG) hydro station outfall. Daily water temperatures at the outlet of the Boyne River and at a site about 600 meters downstream are also shown to illustrate the effect of the hydro station on the thermal regime of the river. The July 29 maximum temperature at the hydro station outfall is at the lower threshold for warmwater. Temperatures at this site reflect those near the surface of Lake Eugenia, at the intake for the penstocks, and show almost no daily fluctuation. The Boyne River outlet is a coolwater site that exhibits a normal daily fluctuation in response to the air temperature. The temperatures recorded at the downstream site illustrate the effect of the hydro station. As the water from the hydro station outfall flows downstream and mixes with the Boyne, it causes daily maximum temperatures to increase and significantly reduces nighttime cooling.

3.7 Boyne River Subwatershed

Watershed Features:

Area	Boyne River: 79.1 km ² , 13% of Beaver River watershed Upper Boyne River: 32.6 km ² , 5% of Beaver River watershed
Municipalities	Grey Highlands
Fishes	Brook Stickleback, Brook Trout, Fathead Minnow, Rock Bass, Smallmouth Bass, Sunfish, Yellow Perch
Dams	Flesherton Dam and 3+ other small dams
ANSIs	Eugenia Lake Drumlins, Upper Beaver Valley

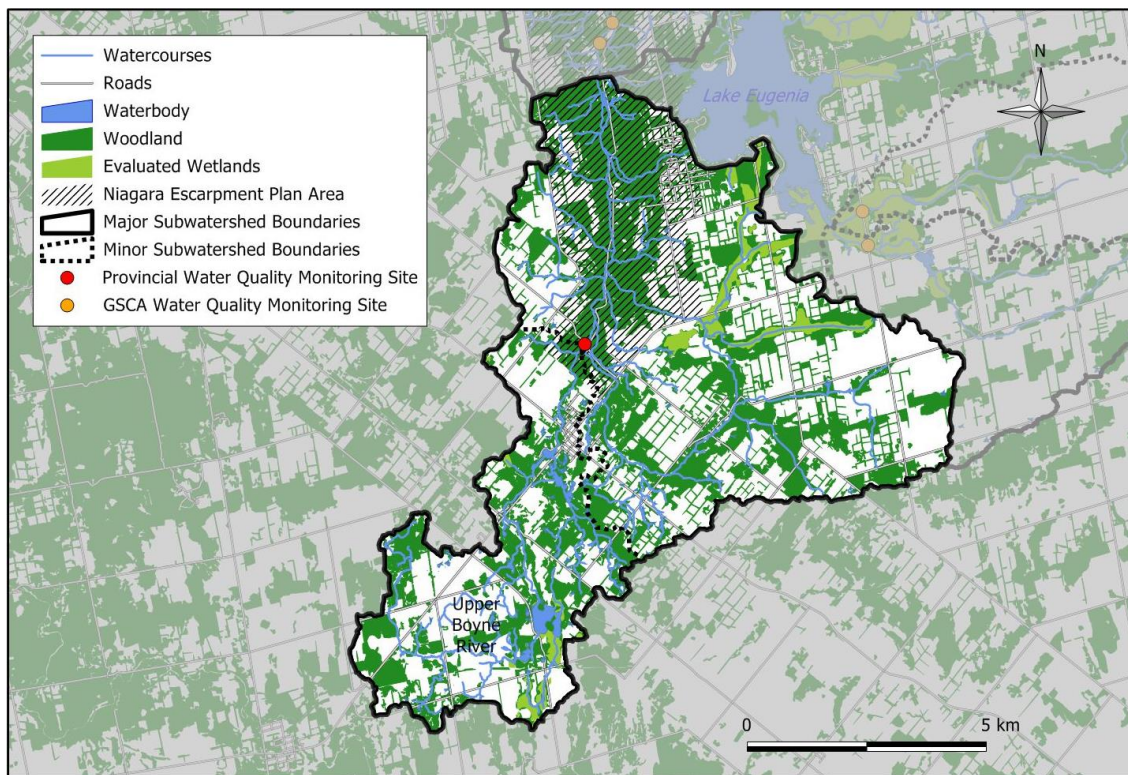


Figure 17. Boyne River Subwatershed.

The Boyne River subwatershed and Upper Boyne River minor subwatershed are illustrated in Figure 17. As with the Lake Eugenia Outlet site, the monitoring site at the outlet of the Boyne River does not appear within the subwatershed boundary since the confluence of the Boyne and

the Beaver has been shifted northward by the diversion of the Beaver River for hydropower generation. Surface water quality in the Upper Boyne subwatershed was measured at the provincial water quality monitoring site indicated in Figure 17. Results of analyses of forest conditions and surface water quality in the subwatershed are presented in Table 12.

Table 12. Surface water quality and forest conditions for the Boyne River subwatershed.
* indicates result based on fewer than 5 samples.

Indicator	Upper Boyne River		Boyne River	
	Result	Grade	Result	Grade
Total phosphorus (mg/l)	0.012	A	0.014	A
<i>E. coli</i> bacteria (cfu/100 ml)	46.33	B	23.90	A
Benthic invertebrates	3.33*	B	3.33*	B
Surface water quality	---	B	---	A
% forest cover	38.1	A	41.9	A
% forest interior	2.7	D	7.0	C
% riparian zone forested	49.2	B	59.9	A
Forest conditions	---	B	---	B

Overall surface water quality in the Boyne River subwatershed is excellent. Concentrations of both total phosphorus and *E. coli* bacteria at the outlet of the subwatershed are low, and the benthic invertebrate score indicates healthy conditions. These results likely reflect the high forest cover and riparian forest cover across the subwatershed. Despite these excellent conditions, overall forest conditions score a “B” due to the low amount of forest interior area, especially in the Upper Boyne subwatershed. Surface water quality in the Upper Boyne subwatershed received a slightly lower score due to higher *E. coli* bacteria concentrations. The *E. coli* bacteria result, however, is still well below the PWQO and does not indicate impairment. It is somewhat unusual that *E. coli* concentrations are lower at the downstream site. This result may be due to

inputs of clean water from small tributaries that outlet to the Boyne River between the two sites.

Water Temperature:

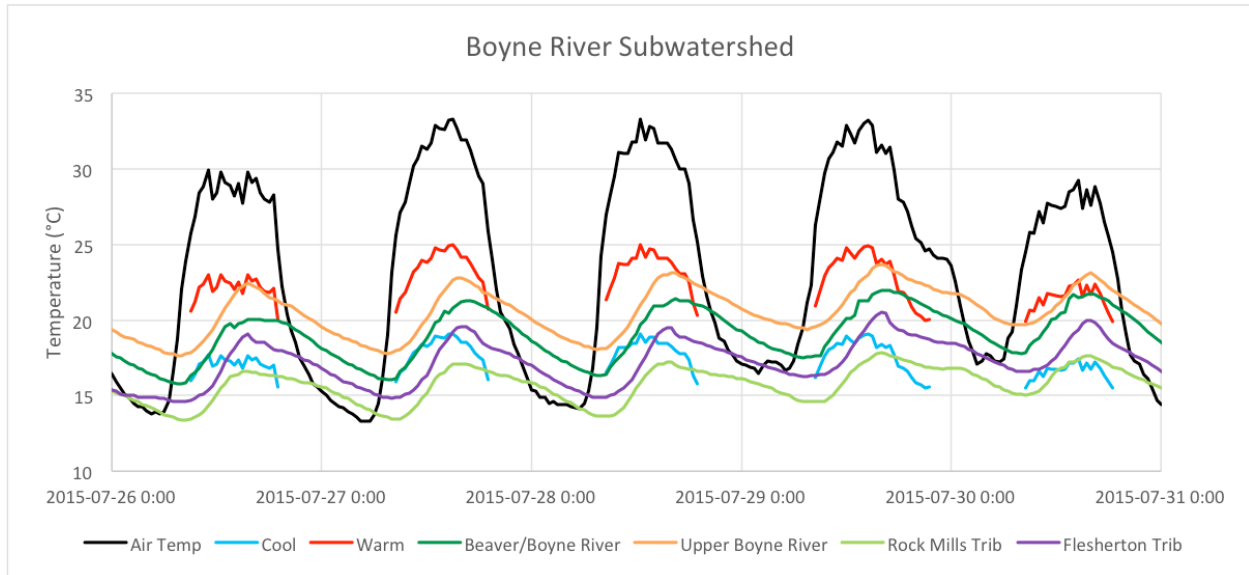


Figure 18. Daily water temperatures measured at sites 6479 (Beaver/Boyne River), 26 (Upper Boyne River), and at the outlets of two headwater creeks (Rock Mills Tributary and Flesherton Tributary) compared to air temperature and cool and warm water thresholds.

Temperature records for the Boyne River outlet (Beaver/Boyne River) and Upper Boyne River monitoring sites are shown in Figure 18, along with records from the outlets of two small creeks that flow into the Boyne River. Results from the Boyne River outlet and the Upper Boyne sites are unusual in that they show water temperatures actually decreasing downstream. The higher temperatures observed at the Upper Boyne site may be partly a result of upstream ponding of the river above the dam in Flesherton, and partly due to heating in areas where riparian cover is lacking. As suggested by Figure 18, the cool temperatures observed downstream may have been recovered due to inputs of cold water from small tributaries, such as Rock Mills Creek, that flow into the Boyne River between the two monitoring sites.

4.0 Conclusions and Next Steps

Results of water quality monitoring from 2011 to 2015 and analyses of forest conditions indicate that conditions in the Beaver River watershed are generally healthy. Overall forest conditions in the watershed are excellent for southern Ontario, though riparian forest cover and forest interior cover are low in some subwatersheds. *E. coli* bacteria results for all 14 monitoring sites in the watershed met the PWQO of 100 cfu/100 ml, and total phosphorus results met the PWQO of 0.03 mg/l in all but two locations: the Beaver River mouth and Wodehouse Creek, where total phosphorus levels slightly exceeded the provincial objective. Comparison with the results from the Slabtown monitoring site indicates that the slightly elevated phosphorus levels at the Beaver River mouth may be due to nutrient inputs downstream of this site, possibly from Grier Creek or the town of Thornbury. Higher than usual phosphorus levels at both the Beaver River mouth and Wodehouse Creek, as well as slightly elevated *E. coli* levels at Wodehouse Creek, are likely due to the impacts of agriculture (runoff from fields where riparian buffers are lacking and livestock entering watercourses). Overall surface water quality results for the upper watershed (Lake Eugenia and Boyne River subwatersheds) were excellent.

Water temperature measurements provided important water quality information that often was not reflected in the grades, especially where benthic invertebrate data was not available, and monitoring water temperatures proved to be a simple way to improve water quality assessments. Water temperature measurements from the end of July 2015 showed that daily maximum water temperatures in lower Beaver River were high (nearly 30°C at the Slabtown site and 27°C at the river mouth). Many of the small tributaries of the Beaver River also showed daily maximum water temperatures that were higher than expected given the size of the watercourses. A number of factors may be contributing to these results. Poor riparian cover and shading in some areas is

very likely contributing to warm water temperatures, especially in small creeks and streams that would otherwise be kept cool by groundwater inputs. Dams that cause upstream ponding of the river are also likely causing downstream water temperatures to increase, and temperature records from the Lake Eugenia Outlet site show that the man-made lake has a significant impact on water temperature.

High water temperatures in the Beaver River watershed will likely continue to be an issue in the future as the climate changes. While the observed increase in average annual temperatures in the region since 1950 has been relatively slight, the number of days of temperatures below 0°C has decreased significantly (Saugeen Conservation et al. 2015). This implies a shorter frozen period and reduced snow storage, which will likely result in reduced groundwater recharge in spring, and consequently, reduced groundwater discharge to creeks and streams in summer (Saugeen Conservation et al. 2015). The region has also experienced an increase in the number of days with maximum temperatures exceeding 30°C (Saugeen Conservation et al. 2015). The high rates of groundwater discharge currently observed in the Beaver River watershed help to make the watershed less sensitive to the impacts of these high air temperatures (Chu et al. 2008). However, reduced groundwater discharge in the future could make the area more vulnerable to the impacts of climate change. Therefore, conserving groundwater resources will continue to be very important to maintaining healthy conditions in the watershed.

Protecting and enhancing the existing forest cover in the watershed will help to maintain groundwater levels, as well as provide habitat for woodland species. Improving riparian forest cover in many areas of the watershed will also help to maintain cool water temperatures and improve aquatic health by providing shade, reducing nutrient and sediment loading, and adding organic matter and woody debris to watercourses that becomes food and habitat for aquatic

organisms and reduces erosion. The impacts of dams and other engineered structures are more difficult to address. However, reducing ponding of the river, where possible, will also help to keep water temperatures down.

The results of this study indicate that local features and differences in land use across the watershed have a measurable impact on water quality and aquatic health. Results and grades for surface water quality and forest conditions provide a snapshot of conditions during the 2011-2015 period. Continued monitoring of water chemistry, *E. coli* bacteria, benthic invertebrate communities, and water temperatures in the Beaver River watershed is needed in order to track constantly changing conditions. Regular monitoring is particularly important at sites where results may indicate a threat of impairment due to high water temperatures or elevated nutrient levels. GIS data for forest cover, forest interior cover, and riparian forest cover also should be updated on a regular basis to reflect changing conditions and evaluate the effects of rehabilitation efforts. Further on-the-ground investigation is needed in order to better identify local impacts and target rehabilitation projects within each subwatershed. Finally, it is recommended that reporting of results continue at regular intervals in order to provide environmental managers and decision makers with information essential to the sustainable management of the watershed.

References

- Chu, C., Jones, N.E., Mandrak, N.E., Minns, C.K., and Piggott, A.R. 2008. The influence of air temperature, groundwater discharge, and climate change on the thermal diversity of stream fishes in southern Ontario watersheds. *Canadian Journal of Fisheries and Aquatic Sciences*. 65(2): 297-308.
- Conservation Ontario. 2013. What is a watershed? [online]. Available from <http://www.conservation-ontario.on.ca/what-is-a-watershed> [cited 9 July 2015].
- Conservation Ontario. 2011. Guide to developing Conservation Authority watershed report cards. Available from Conservation Ontario, Newmarket, ON.
- Conservation Ontario. 2003. Watershed reporting: improving public access to information. Available from Conservation Ontario, Newmarket, ON.
- D'Amelio, S., and Imhof, J. 2010. 2010 Temperature report for the Beaver River. Trout Unlimited Canada Technical Report No. ON-079 [online]. Available from <http://www.tucanada.org/files/1/ON-079%20Beaver%20River%20Temperature%20Report%202010.pdf> [cited 13 July 2015].
- Griffiths, R.W. 1999. BioMAP: bioassessment of water quality. The Centre for Environmental Training, Niagara College, Niagara-on-the-Lake, ON.
- Hilsenhoff, W.L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. *Journal of the North American Benthological Society*, 7(1): 65-68.
- Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. *The Great Lakes Entomologist*, 20(1): 31-39.
- Ministry of Environment and Energy. 1994. Water management: policies, guidelines, provincial water quality objectives [online]. Available from <http://www.ontario.ca/document/water-management-policies-guidelines-provincial-water-quality-objectives> [cited 18 August 2015].
- Nottawasaga Valley Conservation Authority, Blue Mountain Watershed Trust Foundation, and Grey Sauble Conservation Authority. 2015. Townline Creek 2014 assessment report.
- Ontario Ministry of the Environment. 1983. Water quality and hydrology of the Beaver River, Grey County. Water Resources Assessment Unit, Technical Support, Southwestern Region.
- Ontario Power Generation. 2014. Eugenia Generating Station [online]. Available from <http://www.opg.com/generating-power/hydro/central-ontario/Pages/eugenia-station.aspx> [cited 13 July 2015].

Saugeen Conservation, Grey Sauble Conservation, and Municipality of Northern Bruce Peninsula. 2015. Revised assessment report for the Grey Sauble Source Protection Area [online]. Available from http://www.waterprotection.ca/RAR/GSSPA/gsspa-rar_2015_new.html [cited 9 July 2015].

Smith, A.J., Heitzman, D.L., and Duffy, B.T. 2009. Standard operating procedure: biological monitoring of surface waters in New York State. New York State Department of Environmental Conservation, Division of Water.

Statistics Canada. 2012. Thornbury, Ontario (Code 0932) and Ontario (Code 35) (table). Census Profile. 2011 Census. Statistics Canada Catalogue no. 98-316-XWE. Ottawa. Released October 24, 2012. Available from <http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/index.cfm?Lang=E> [cited 21 July 2015].

Stoneman, C.L., and Jones, M.L. 1996. A simple method to classify stream thermal stability with single observations of daily maximum water and air temperatures. *North American Journal of Fisheries Management*, **16**(4): 728-737.

Appendices

Appendix 1. Surface water quality monitoring sites.

GSCA Station ID	Station Name	Watershed	UTM Coordinates (NAD83)
318	Beaver River Mouth (Thornbury)	Beaver River	543730, 4934651
324	Slabtown	Main Beaver River	542378, 4929800
544	Grier Creek	Grier Creek	539631, 4931268
3210	Mill Creek	Mill Creek	540390, 4924240
3214	Red Wing Tributary	Red Wing Tributary	543536, 4921954
3215	Kolapore Creek	Kolapore Creek	543512, 4921950
4041	Wodehouse Creek	Wodehouse Creek	534559, 4914740
3208	Lake Eugenia Outlet (OPG Outfall)	Lake Eugenia	536818, 4909754
6479	Beaver/Boyne River	Boyne River	536776, 4909713
26	Upper Boyne River	Upper Boyne River	536239, 4903027
3224	Upper Beaver River	Upper Beaver River	542036, 4905801
3222	Little Beaver River	Little Beaver River	542155, 4905093
4170	Upper Beaver Tributary (South)	Upper Beaver South Tributary	550780, 4909384
4186	Upper Beaver Tributary (North)	Upper Beaver North Tributary	550336, 4911376

Appendix 2. Total phosphorus and *E. coli* bacteria sampling information.

GSCA Station ID	Years of Water Chemistry Data	Number of Total Phosphorus Samples	Number of <i>E. coli</i> Samples
318	2015	4	4
324	2011 - 2015	33	34
544	2015	4	4
3208	2012 - 2015	29	29
3224	2012 - 2015	29	29
4170	2015	4	4
6479	2012 - 2015	29	29
26	2011 - 2015	33	34
3215	2015	4	4
3222	2015	4	4
3210	2012 - 2015	29	29
4186	2015	4	4
3214	2015	4	4
4041	2015	4	4