Blackstock Creek Watershed

Characterization Report

2012

KAWARTHA CONSERVATION

About Kawartha Conservation

A plentiful supply of clean water is a key component of our natural infrastructure. Our surface and groundwater resources supply our drinking water, maintain property values, sustain an agricultural industry and support tourism.

Kawartha Conservation is the local environmental agency through which we can protect our water and other natural resources. Our mandate is to ensure the conservation, restoration and responsible management of water, land and natural habitats through programs and services that balance human, environmental and economic needs.

We are a non-profit environmental organization, established in 1979 under the Ontario *Conservation Authorities Act* (1946). We are governed by the six municipalities that overlap the natural boundaries of our watershed and voted to form the Kawartha Region Conservation Authority. These municipalities include the City of Kawartha Lakes, Township of Scugog (Region of Durham), Township of Brock (Region of Durham), the Municipality of Clarington (Region of Durham), Cavan Monaghan, and Galway-Cavendish & Harvey.

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1.0 Introduction

Blackstock Creek, north of Beacock Road

1.1 Project Background

In 2007, Kawartha Conservation and the Regional Municipality of Durham initiated a watershed planning process for watersheds located within the Oak Ridges Moraine and within the jurisdictions of both agencies. These watersheds include: Nonquon River, Southern Lake Scugog Tributaries, Blackstock Creek and East Cross Creek. The watershed (i.e., the surface water drainage boundaries of a specific stream, river or lake) is widely recognized as an appropriate unit for managing human activities and water-related resources. This is because the health of rivers and streams is both influenced by, and illustrative of, the health of the lands through which they flow.

The need for a watershed management plan is usually brought upon by some type of trigger, such as public concern about environmental conditions. In this instance, it was the introduction of the *Oak Ridges Moraine Conservation Act* by the province of Ontario in 2001.

The Blackstock Creek Watershed Characterization Report is intended to be a complementary document to the Blackstock Creek Watershed Plan, providing much of the background information with respect to existing watershed resources, functions and linkages and information gaps. Summarizing this information into one comprehensive document will ultimately help inform management decisions throughout the development of the Blackstock Creek Watershed Plan, and provide detailed supporting background information.

1.2 Oak Ridges Moraine Conservation Plan

The Oak Ridges Moraine has a unique concentration of environmental, geological and hydrological features that make its ecosystem vital to south-central Ontario, including: clean and abundant water resources; healthy and diverse plant and animal habitat; an attractive and distinct landscape; prime agricultural areas; and, sand and gravel resources. In response to the increasing development pressures facing this significant landform, the province of Ontario introduced the *Oak Ridges Moraine Conservation Act* in 2001 which provided the legal basis for establishing the Oak Ridges Moraine Conservation Plan in 2002. The purpose of the Oak Ridges Moraine Conservation Plan is to provide land use and resource management direction on how to protect the Moraine's ecological and hydrological features and functions.

A key requirement of this plan is the integration of watershed management planning with municipal land use planning. It also provides direction on the content within these plans.

Section **24** of the Oak Ridges Moraine Conservation Plan (OMMAH 2002) states:

> **24.**(1) Every upper-tier municipality and single-tier municipality shall, on or before April 22, 2003, begin preparing a watershed plan, in accordance with subsection (3), for every watershed whose streams originate within the municipality's area of jurisdiction.
>
> (2) The objectives and requirements of each watershed plan shall be incorporated into the municipality's official plan.
>
> (3) A watershed plan shall include, as a minimum,
>
> (a) a water budget and conservation plan as set out in section **25**;

(b) land and water use and management strategies;

(c) a framework for implementation, which may include more detailed implementation plans for smaller geographic areas, such as subwatershed plans, or for specific subject matter, such as environmental management plans;

(d) an environmental monitoring plan;

(e) provisions requiring the use of environmental management practices and programs, such as programs to prevent pollution, reduce the use of pesticides and manage the use of road salt; and,

(f) criteria for evaluating the protection and water quality and quantity, hydrological features and hydrological functions.

Since the Oak Ridges Moraine Conservation Plan planning boundary exists within the Blackstock Creek watershed, the legislative requirements listed above need to be addressed within the Blackstock Creek Watershed Plan. Technically, these provisions only apply to the portions of the Blackstock Creek watershed that exist within the Oak Ridges Moraine Conservation Plan boundaries. However, in taking a watershed management approach, the entire Blackstock Creek watershed has been included in the planning area.

1.3 Blackstock Creek Watershed Plan

The scope of watershed management has changed significantly within the past 50 years, from a single-issue driven focus (e.g., flooding and drainage) to an integrated ecosystem-based approach. The current watershed management process aims to protect and manage natural resources (including their functions and linkages) for current and future generations; reflects the local environmental and social context; uses an integrated, interdisciplinary approach; considers the environment, the economy and communities; uses a partnership approach to plan and manage; and, uses adaptive environmental management approaches that aim for continuous improvement (Conservation Ontario 2003).

To ensure that the Blackstock Creek Watershed Plan is consistent with the provisions within the Oak Ridges Moraine Conservation Plan, the approach in formulating the Blackstock Creek Watershed Plan is based on guidance provided in the Oak Ridges Moraine Conservation Plan Technical Paper 9: Watershed Plans (Province of Ontario 2007). This document is part of series of technical reports that were developed to assist upper-tier and single-tier municipalities in preparing watershed plans that conform to the requirements of the Oak Ridges Moraine Conservation Plan. Much of the information contained within this technical report builds upon proven best management practices and lessons learned from similar watershed management projects in Ontario (Conservation Ontario 2003).

Figure 1.1 illustrates the four main phases in the watershed management process: plan, implement, monitor and report, and review and evaluate. Within the planning phase, there are eight key steps: (1) scoping; (2) characterizing the watershed system; (3) set goals, objectives and working targets; (4) develop management alternatives; (5) evaluate management alternatives; (6) select preferred management alternatives; (7) finalize targets; and, (8) develop implementation and monitoring plan.

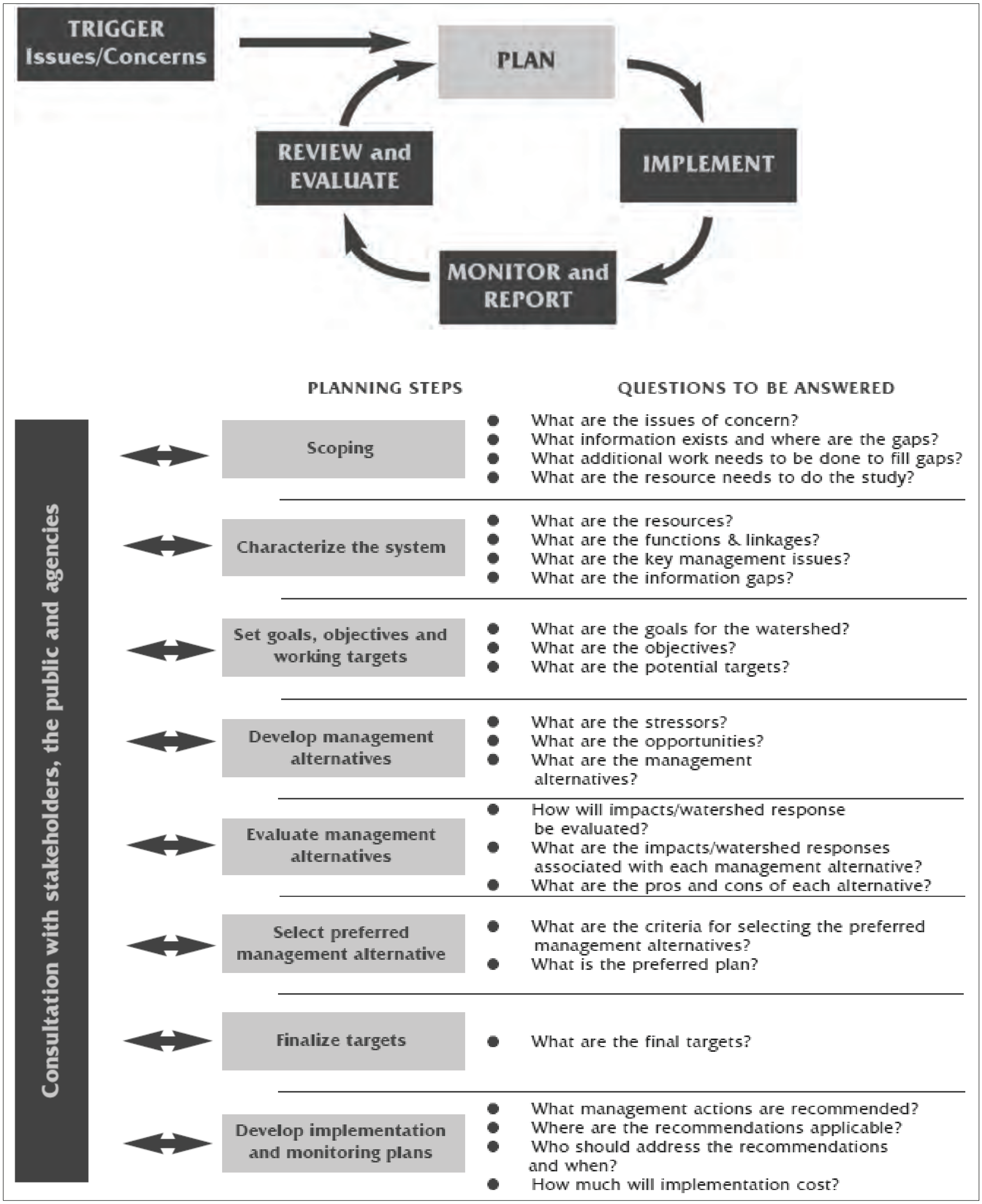
Step 1 (scoping), is outlined in the project terms of reference (Kawartha Conservation 2010a). The Blackstock Creek Watershed Characterization Report addresses step 2 (characterization). The purpose of this step in preparing the watershed plan is to identify, analyze, and evaluate watershed-specific constraints and opportunities in land-use. In particular, this document presents all available and relevant information with respect to watershed resources, functions and linkages, key management issues and information gaps. In characterizing the Blackstock Creek watershed, Kawartha Conservation has drawn upon all available data, studies and sampling results and combined this information into up-to-date report that can be reviewed and updated as required. This “background” information will ultimately help inform management decisions and recommendations that will be developed through steps 3 to 8.

Blackstock Creek is a watercourse that flows into Lake Scugog, thus, maintaining the health of the Blackstock Creek watershed is also crucial for maintaining the ecological integrity of the larger Lake Scugog watershed. Lake Scugog is an extremely significant resource within the area, in terms of its natural values (e.g., important habitat for wildlife), social values (e.g., vibrant history), and economic values (e.g., tourism).

1.4 Planning Area Boundaries

The Blackstock Creek watershed is identified in the Oak Ridges Moraine Technical Papers as existing within the Oak Ridges Moraine Planning area. The extent of the study area that is characterized within this report is shown in **Figure 1.2**, and includes all lands that exist within the Blackstock Creek watershed. The watershed boundaries and watercourse network were delineated using the ArcHydro tool, which is based on digital elevation mapping.

The Blackstock Creek watershed is located immediately south-east of Lake Scugog near Port Perry, which is approximately 50km north-east of Toronto, Ontario. The watershed drains 37.9km^2 of land into the Blackstock Creek and outlets into the south-eastern section of Lake Scugog, which in turn flows north through the Scugog River and into the chain of lakes known as the Kawartha Lakes. The Blackstock Creek watershed is bounded by Lake Scugog to the north, Southern Lake Scugog Tributaries watershed to the west, Bowmanville Creek watershed to the south, and East Cross Creek watershed to the east. The Oak Ridges Moraine Conservation Plan planning area exists within the south-western portion of the Blackstock Creek watershed, encompassing approximately 11.9km^2, or 31.5% of the watershed.



From Conservation Ontario (2003)

Figure 1.1: Key steps in the watershed management planning process.

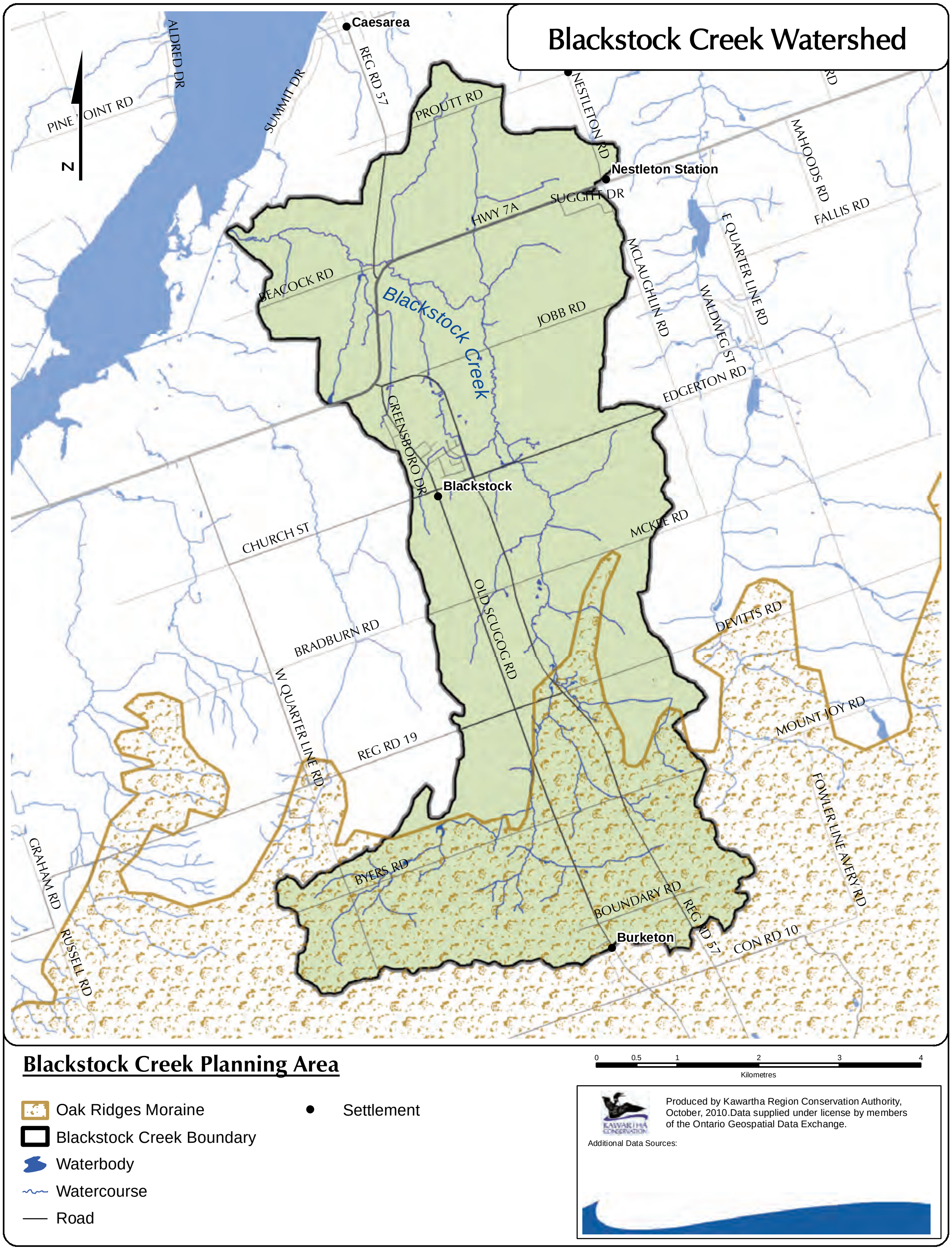


Figure 1.2: Blackstock Creek Watershed planning area.

2.0 Physical Landscape

Blackstock Creek, south of Regional Road 19

2.1 Introduction

The physical features of the landscape are key determinants of watershed resources, influencing the fundamental properties of the drainage network and watershed ecosystems. The landform features that currently dominate the landscape are a relic of the most recent period of glacial activity. The movement and melt waters of these large ice masses carved and deposited large amounts of earthen material, ultimately forming the Blackstock Creek watershed as it exists at present. In this chapter, the physical characteristics of the landscape are summarized in terms of its geologic setting, physiography, soils and topography.

2.2 Geologic Setting

The information presented in this section is summarized from a report by GENIVAR (2011), that was recently completed for Kawartha Conservation to characterize groundwater resources within the Blackstock Creek watershed, as well as three other watersheds (Southern Lake Scugog Tributaries, Nonquon River and East Cross Creek). This section describes the geologic setting in the Blackstock Creek watershed from the oldest deposits (i.e., bedrock) to youngest deposits (i.e., recent sediments in stream valleys). The study area consists of varying thicknesses of unconsolidated sediments that have been shaped and altered by glacial and post-glacial activities. The overburden is deposited on top of the shale and limestone bedrock.

Bedrock Geology

Bedrock across the watersheds consists of a thick sequence of Middle to Late Ordovician shale and limestone that unconformably overlies the Precambrian basement at depth. The Precambrian rock found in this area consists of metamorphic rocks of the Grenville Province. This bedrock is typically described as pink to grey, medium-grained granitic gneiss. The Precambrian rock is known from deep borehole and geophysical information and is not known to be exposed in outcrops within this study area.

Overlying this Precambrian rock are the Ordovician sedimentary rocks of the Blue Mountain and Lindsay Formations (**Figure 2.1**). These formations are relatively un-deformed and dip gently to the south or southwest. The Blue Mountain Formation is found in southern portions of the watershed. The Blue Mountain Formation is the youngest of the Ordovician age rock units found in this area. The formation is characterized by rocks that are blue-grey, poorly fossiliferous, noncalcareous shale, with minor limestone. The Lindsay Formation underlies the Blue Mountain Formation and a sharp contact has been observed between the two formations. The Lindsay Formation has been subdivided into two member units. The lower member unit is characterized by argillaceous, fine to coarse-grained limestone with a nodular appearance and is very fossiliferous. The upper member, called the Collingwood Member, consists of high fossil content and thick interbeds of black organic-rich limestone and shale.

Overburden Geology

The unconsolidated sediments that overly the bedrock have been deposited by glacial, fluvial, and lacustrine processes associated with glacial advance and retreat over the past 135,000 years. Thick, laterally extensive deposits of till often represent the periods of glacial advance. Granular sediments, ranging from silts to coarse sands and gravels, are deposited by glacial melt waters. In the latter stages of glaciations, the deposits are typically observed as thick sequences of fine grained sediments.

The basic geological sequence is illustrated in **Figure 2.2** as derived from studies by the Geologic Survey of Canada and Earthfx (2006). This geological sequence represents up to six periods of glacial advance. The most recent, extensive glacial advance is represented by the Newmarket Till between 25,000 and 15,000 years ago. The majority of the sediments observed at surface were either deposited during or after this glacial advance. In general, earlier deposits are known only from exposure on incised stream valleys and shore bluffs along Lake Ontario. In general, the hydrostratigraphy is better defined for the more recent sediments associated with the last glaciations. The earlier sediments have been collectively referred to as the Lower Sediments.

The Lower Sediments reflect several cycles of glacial advance and retreat and can contain deposits from the York, Don, Scarborough, Sunnybrook, and Thorncliffe Formations. The older York and Don formations are considered to be of limited lateral extent. The Scarborough, Sunnybrook, and Thorncliffe Formations are more widely observed and stratigraphic interpretations have extended into the study area.

The Scarborough Formation is a coarsening upward sequence of sediment deposited by glacial runoff in a delta. Soil textures range from clay/silt rhythmites (fine) to channelized cross-bedded sands (coarse). The Scarborough Formation Sediments tend to be observed in bedrock valleys and are not always continuous.

The Sunnybrook Drift consists of fine grained material deposited in glacial and proglacial lacustrine depositional environments. The Sunnybrook Drift is considered to represent a deep lacustrine environment with deposits including varied silt and clay.

The Thorncliffe Formation is composed of stratified sand, silt, and clay of glaciolacustrine and glaciofluvial origin. These deposits are considered to have been deposited by drainage along the southern margin of an extensive ice sheet in the Hudson Bay Lowlands. The depositional environment of the Thorncliffe Formation is highly variable and is best described as fine grained, with interbedded coarse grained material. Areas of the Thorncliffe Formation that contain coarse grained sediment are productive regional aquifers.

The Newmarket Till is a distinct, dense glacial deposit with a fine grained matrix and up to 15% stones, deposited by the Simcoe lobe of the Wisconsinan glacier. In the field, the Newmarket Till is readily recognized by its relative hardness. The Newmarket Till is considered to be a regionally significant marker horizon and provides protection to the groundwater resources beneath it. Since the interpretation presented in 2006 (Earthfx 2006), the CAMC has conducted further work and have subsequently subdivided the Newmarket Till into three units: The Lower Newmarket Till; Inter-Newmarket Sediments; and the Upper Newmarket Till. The Lower Newmarket Till is considered to be regionally extensive. The Inter-Newmarket Sediments are typically fine to medium grained sediments deposited by meltwaters between two stages of active glaciation. At this time the CAMC has not provided more detailed descriptions of the subunits of the Newmarket Till.

The top of the Newmarket Till is recognized as a regional erosional unconformity. This unconformity provided an opportunity for removal of parts of the Newmarket Till, either in conjunction with later glacial processes (tunnel channels) or by subaerial exposure. The upper surface of the Newmarket Till exhibits large-scale erosion by channels that have subsequently been infilled by a fining upward sediment sequence. The erosion of these channels is considered to have developed beneath the glacial ice and hence are referred to as tunnel channels. An initial surge of glacial meltwater beneath the ice is considered to have cut these channels. As flow waned in these channels, they were partly infilled with water-borne sediments, which typically fine upwards from a cobble or boulder lag. The tunnel channels deeply dissected the Newmarket Till plain, leaving the discrete till upland areas mentioned above. Tunnel channel erosion and sedimentation was followed by or was formed at a similar time to the deposition of the east-west trending Oak Ridges Moraine, which is an important regional physiographic and hydrogeologic feature. Many tunnel channels created low-lying areas and several rivers in southern Ontario, including the Nonquon River and East Cross

Creek, currently flow through these former tunnel channels, which have been filled in with recent organic deposits.

The Oak Ridges Moraine Sediments are a complex package of dominantly coarse grained proximal glaciofluvial and terminal outwash material. These deposits generally become finer, and typically become thinner and eventually pinch out away from the original outlets of meltwater. The Oak Ridges Moraine sediments were deposited by meltwater flowing between two glacial lobes, with ice blocking the Lake Ontario basin and another ice sheet in the Simcoe basin.

The Halton Till is a dense glacial deposit with a fine-grained matrix and fewer stones compared to the Newmarket Till. The Halton Till was deposited in the late stages of the last glaciation by a minor advance of the Lake Ontario lobe after the sedimentation cycle that deposited the Oak Ridges Moraine Sediments. The Halton Till unit overlaps and caps portions of the Oak Ridges Moraine. The Halton Till typically is not observed north of the Oak Ridges Moraine.

As the glaciers retreated, large lakes formed in regional basins. Thick sequences of lacustrine sediment were deposited in these lakes above the glacial units. These lacustrine deposits are observed extensively in the Lake Scugog basin. After these meltwaters retreated, erosion has been the dominant force with some sedimentation associated with river channels, and accumulations of organic material in poorly drained areas as deposits of peat and muck.

Further information that outlines water movement through these geologic materials (i.e., hydrostratigraphy), is summarized in Section 6.5: Groundwater Characterization.

2.3 Physiography

The physiography within the Blackstock Creek watershed has been characterized by Chapman and Putnam (1984). Regions of similar physiography are shown in **Figure 2.3** and distinct physiographic features that exist on the landscape are shown in **Figure 2.4**.

The Oak Ridges Moraine physiographic region is located in the south of the watershed, occupying approximately 2.6km^2 of the total watershed area. It is part of a continuous range of rolling hills extending from the Niagara Escarpment to Trenton. As mentioned earlier, the Oak Ridges Moraine consists mainly of permeable sands and gravels with some impermeable deposits of till, silt and clay. These sediments are of optimal configuration to retain and store precipitation, which is slowly released as cold, flowing surface waters into the southern parts of the Blackstock Creek watershed. Within this physiographic region, there tends to be a lack of streams because the permeable sand and gravel that makes up the Moraine, allows water to drain vertically into the moraine, rather than along the surface. Water infiltrating the moraine is forced to move horizontally when it reaches less permeable geologic layers. Springs and headwaters for many of the watercourses flowing off the moraine can be found.

The Peterborough Drumlin Field physiographic region occupies the majority (33.2km^2) of the watershed and extends north from the Oak Ridges Moraine. It is part of a rolling till plain extending from Hastings County in the east to Simcoe County in the west. Drumlins typical to this area are elongated, low-lying hills composed of highly calcareous glacial till consisting of sands and gravels. This physiographic region is notable for its drumlins, but also for it eskers.

The Schomberg Clay Plain physiographic region occupies 2.1km^2 of the watershed and includes the north-eastern portion of the watershed. These materials consist of stratified clay and silt deposits that overlays a drumlinized till plain. Some large drumlins have escaped complete burial by these sediments and hence, many still exist within this region. The majority of the deposits throughout this physiographic region measure an average depth of 5m in thickness; in some locations the thickness of the sediment layers reaches a depth of up to 8m.

2.4 Soils

The uppermost sediment layer within the Blackstock Creek watershed is described by soil type. Soils are classified based on their structure, texture, permeability, material composition, and topography. A number of physical factors including: local topography, vegetation, parent material, climate, chemical weathering and bedrock materials affect soil formation. This complex interplay of factors over time has created soil structures as we know them today.

The naming and distribution of soils within the watershed is complex. For the purposes of this report, soils are classified into four hydrologic soil groups based on their infiltration and runoff potential: A, B, C, and D (USDA 1986) as described in **Table 1.1**. Hydrological soil groups within the study area are shown in **Figure 2.5**.

Soils with a high infiltration rate (Group A) are most common in the southern portion of the Blackstock Creek watershed, especially on the Oak Ridges Moraine. Soils with moderate infiltration rates (Group B) occur throughout the majority of the Blackstock Creek watershed whereas only small pockets of soils with low infiltration rates (Group C) are evident. Soils with very low infiltration rates (Group D) exist along the valleys and low-lying areas in the central portion of the watershed.

Table 1.1: Hydrologic soil groups.

Soil Group	Infiltration Rate	Description	Water Transmissivity	Soil Types
A	High infiltration rates and low runoff potential even when thoroughly wet	Chiefly deep, well to excessively drained sands or gravels	High rate of water transmission (>0.75cm/hr)	Sand, loamy sand, sandy loam
B	Moderate infiltration rates when thoroughly wetted	Chiefly moderately deep to moderately well drained soils with moderately fine to moderately coarse textures	Moderate rate of water transmission (0.40-0.75cm/hr)	Silt loam, loam
C	Low infiltration rates when thoroughly wetted	Chiefly soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures	Low rate of water transmission (0.15-0.40cm/hr)	Sandy clay loam
D	Very low infiltration rates and high runoff potential when thoroughly wetted	Chiefly clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface or shallow soils over nearly impervious material	Very low rate of water transmission (0-0.15cm/hr)	Clay loam, silty clay loam, sandy clay, silty clay, clay

From USDA (1986)

2.5 Topography

The ground-surface elevations within the watershed generally slope from south to north and east to west. The highest elevations in the Blackstock Creek watershed occur in the southern section of the watershed as a result of the Oak Ridges Moraine feature that creates a regional surface water divide. Based on a $10m^2$ digital elevation grid, elevations range from approximately 346.1 metres above sea level in the south-western portion of the watershed and declines to a minimum elevation of approximately 250.4 metres above sea level at the watershed outlet into Lake Scugog (**Figure 2.6**). The average slope of the terrain is approximately 3.8%

Areas of topographic lows are located in the central portion of the watershed, associated with the valley of the main channel of the creek, and at the watershed outlet near Lake Scugog. Slopes are significantly higher along the southern flanks of the watershed than in the low-lying central and eastern portions.

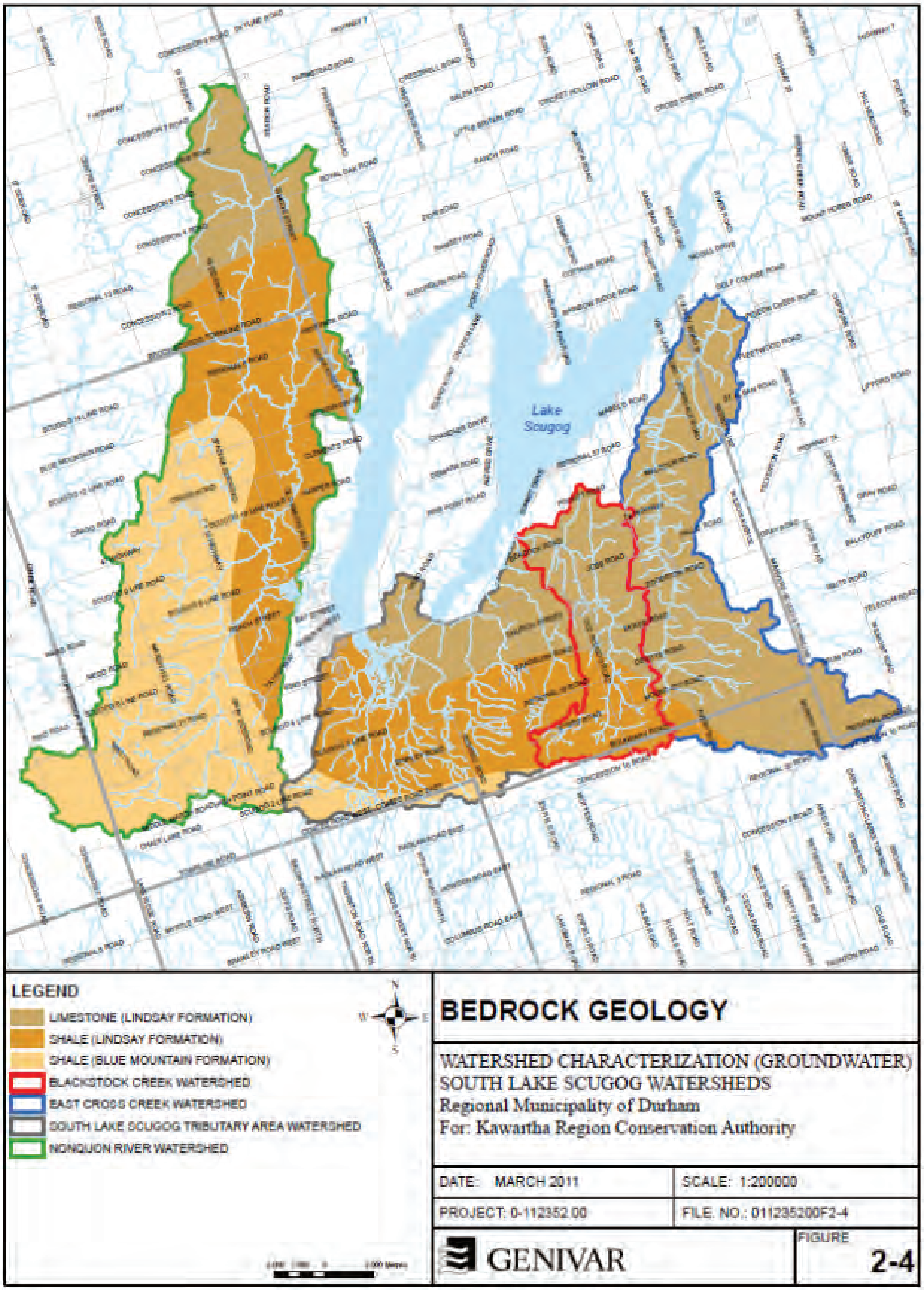
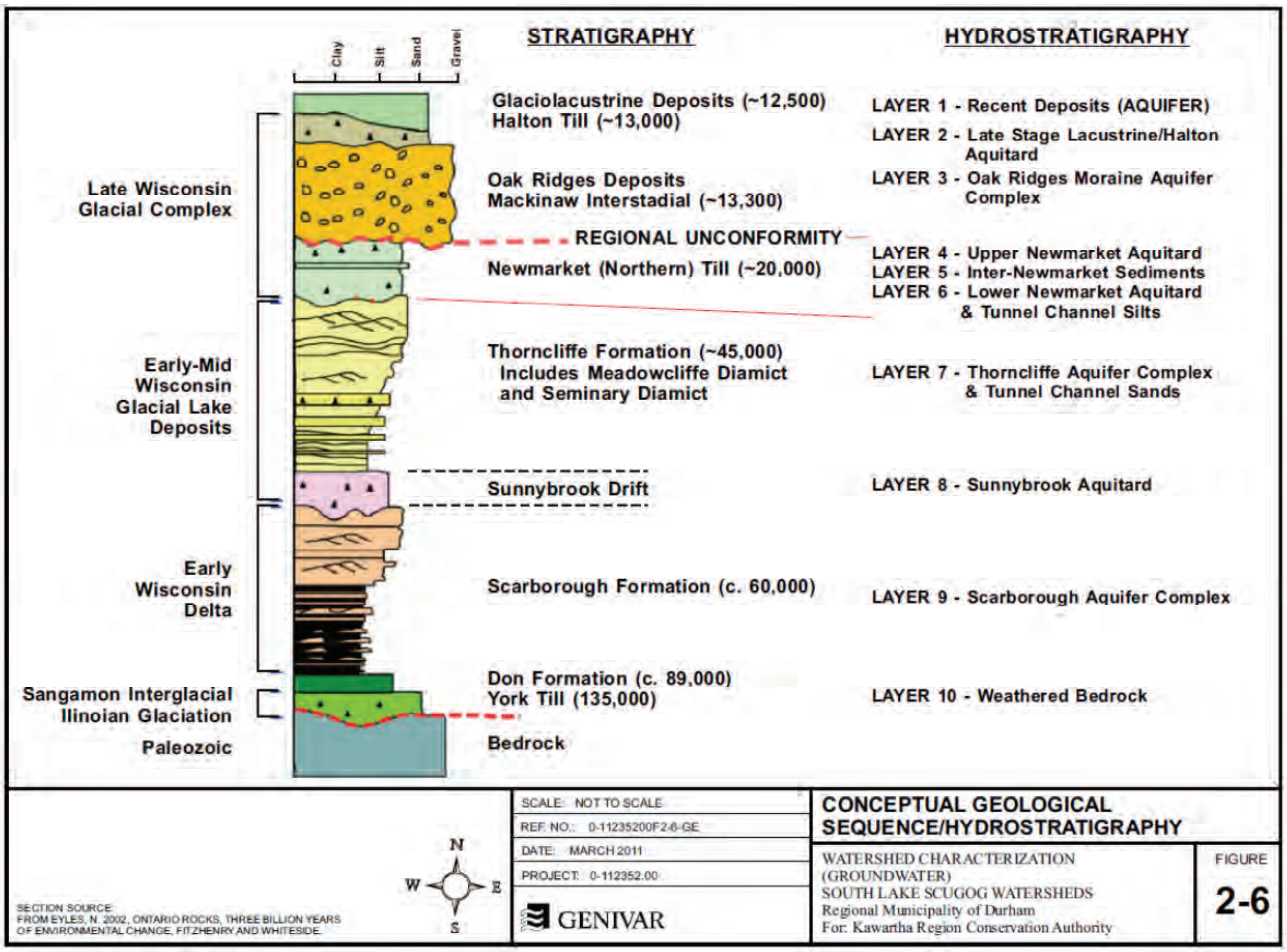


Figure 2.1: Bedrock geology.



From GENIVAR (2011)

Figure 2.2: Geological profile of Pleistocene sediments.

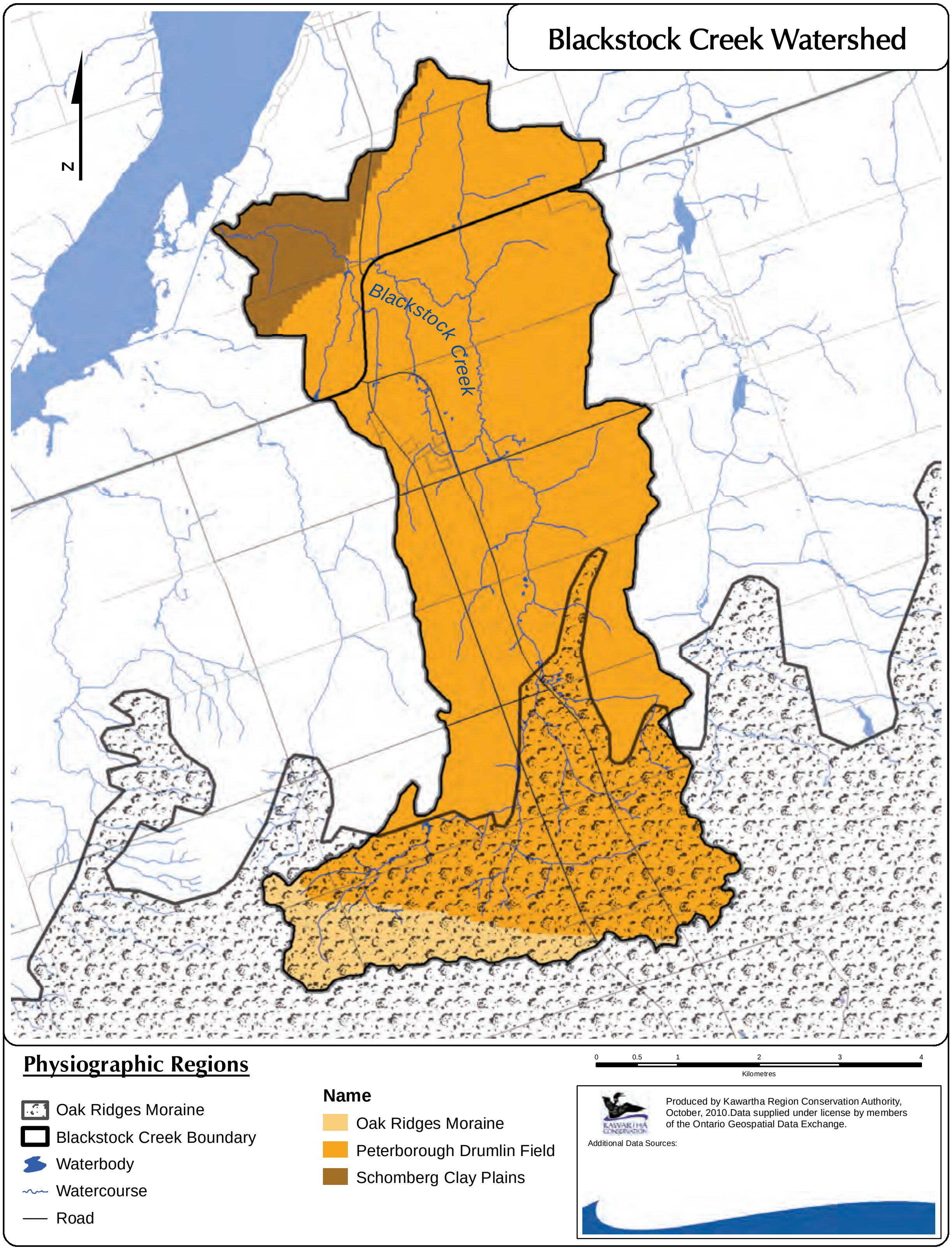


Figure 2.3: Physiographic regions.

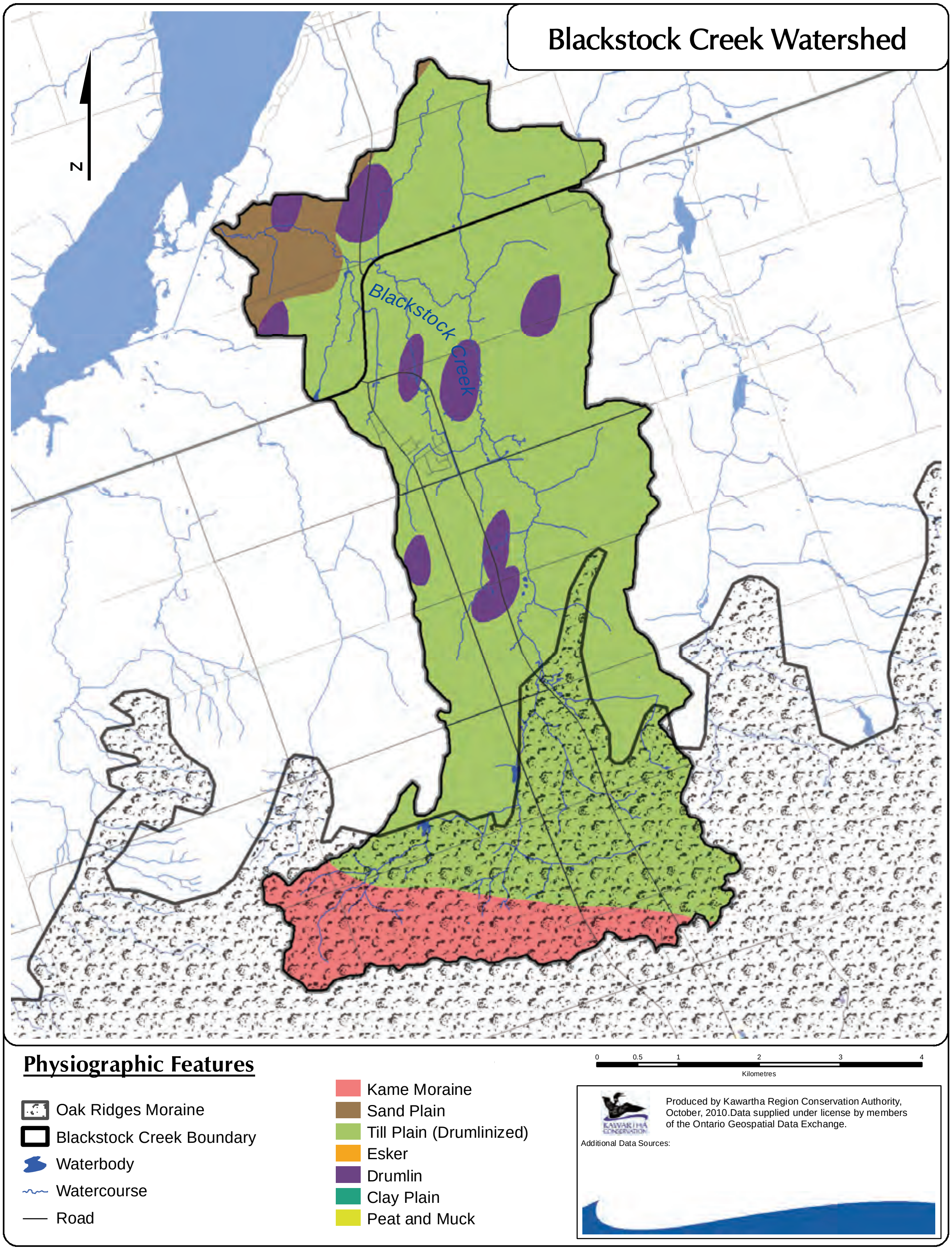


Figure 2.4: Physiographic features.

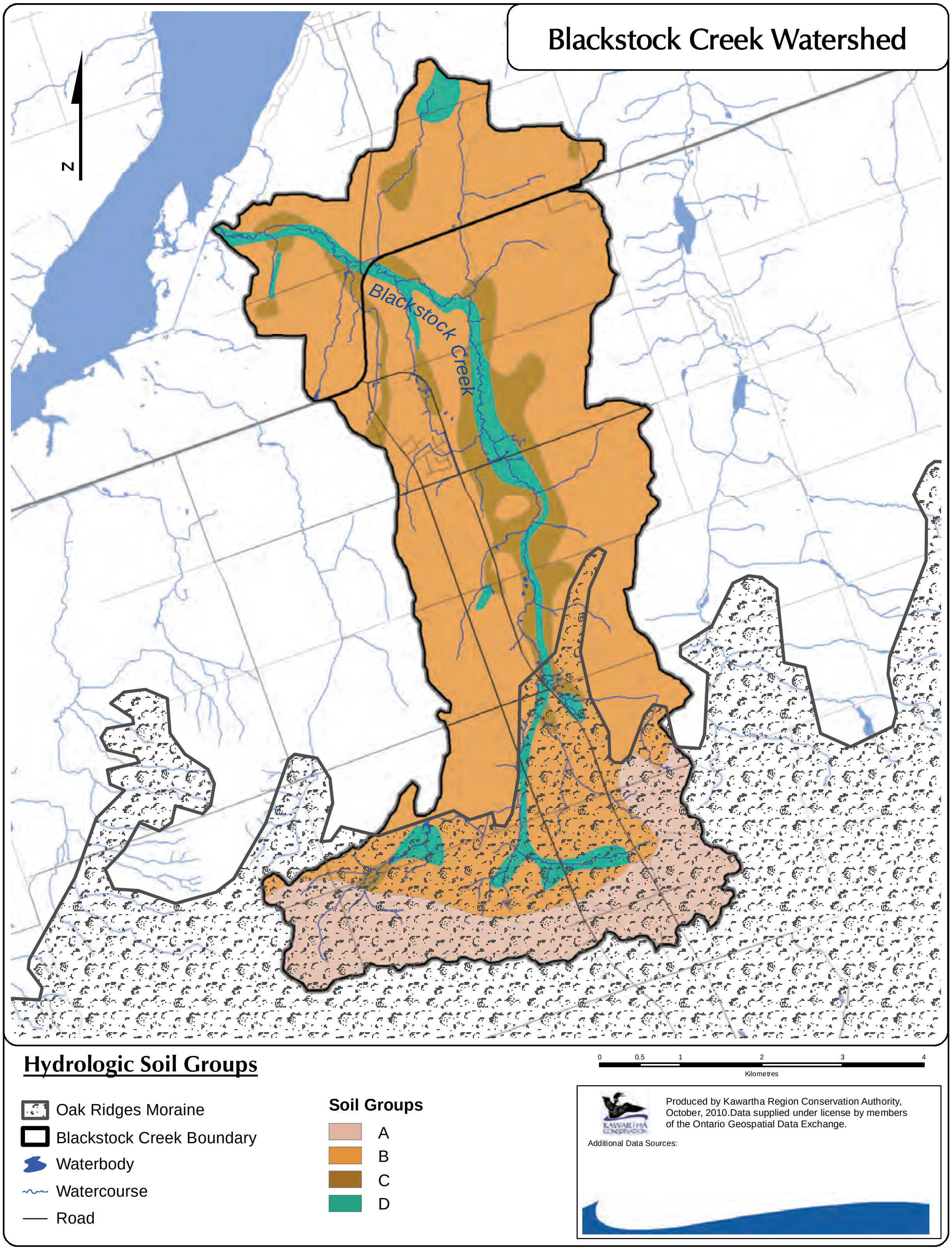


Figure 2.5: Hydrologic soil groups.

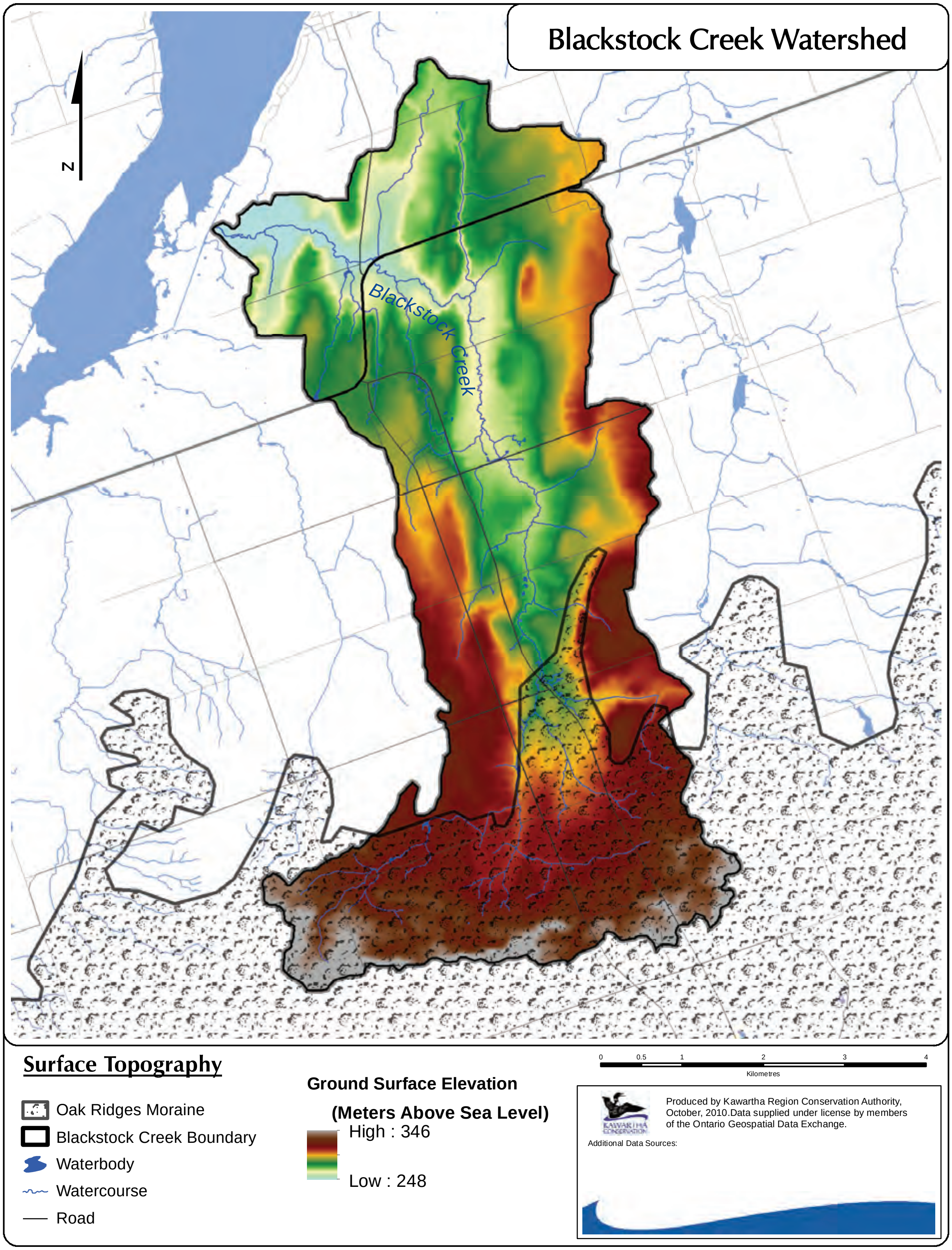


Figure 2.6: Surface topography.

3.0 Regional Climate

Blackstock Creek, south of Regional Road 57

3.1 Introduction

Regional climate can be defined as the expected weather conditions within a region determined from averaging site-specific weather data. Characterizing climatic conditions is key to developing water budgets and understanding the linkages between the hydrological and ecological conditions of the watershed.

The Blackstock Creek watershed is located within a humid-continental climate zone. This zone represents the majority of east-central Ontario, which is characterized by large seasonal temperature differences with hot, often humid summers, and cold winters. The Great Lakes have a significant influence on the climate within southern Ontario; however, the presence of the Oak Ridges Moraine tends to limit their moderating effect within the region. As a result, spring usually begins later (on average about one week later) and fall usually begins earlier (about one week earlier) within the study area than along the shore of Lake Ontario (Adams and Taylor 2009).

To characterize local climatic conditions within the watershed, weather data were summarized from available monitoring stations in-and-around the study area. Data from five of these stations are particularly important for characterizing local climate conditions (**Figure 3.1**). The Janetville, Lindsay Frost, and Burketon McLaughlin climate stations have provided enough long-term weather data between 1971 and 2000 to establish "normal" conditions according to Environment Canada standards. These stations are no longer actively recording data. The remaining two stations, Blackstock and Sonya Sundance Meadows, have a limited period of record but are significant as they are the only active climate stations (recording since 2001). **Table 3.1** describes the period of record and data availability at these stations.

Table 3.1: Climate station information.

Station Name	Station ID	Status	Beginning	End	Elevation (masl)	Station Owner
Burketon McLaughlin	6151042	Inactive	1969	2002	312	Environment Canada
Janetville	6153853	Inactive	1981	2005	297	Environment Canada
Lindsay Frost	6164433	Inactive	1974	2006	262	Environment Canada
Blackstock	6150790	Active	2001	-	291	Environment Canada
Sonya Sundance Meadows	6168100	Active	2001	-	275	Environment Canada

3.2 Air Temperature and Precipitation

Air temperature and precipitation normals (i.e., average values, calculated between 1971 and 2000) for each long-term monitoring station are shown in **Table 3.2** with monthly summaries provided in **Figure 3.2**, **Figure 3.3**, and **Figure 3.4**.

Among the three climate stations, average daily air temperatures range from 6.3 to 6.6ºC. January is the coldest month, with average daily temperatures ranging from -7.7 to -8.9ºC. Average monthly temperatures rise above freezing in April and reach a peak of about 20ºC in July, the warmest month. Temperatures tend to fall below freezing again in December. In general, there is little variability in average air temperatures between monitoring stations; the difference in average values never exceeds 1.2ºC.

In contrast to air temperatures, precipitation is quite variable between monitoring stations. Average annual precipitation ranges from 881.6mm at Lindsay Frost station to 926.2mm at Janetville station, the majority of which falls as rain. September is generally the wettest month of the year whereas February is the driest.

Table 3.2: Air temperature and precipitation normals.

	Burketon McLaughlin	Janetville	Lindsay Frost
Air Temperature - daily average (ºC)	6.4	6.6	6.3
Air Temperature - daily maximum (ºC)	10.8	11.9	11.3
Air Temperature - daily minimum (ºC)	2.0	1.2	1.3
Precipitation - yearly total (mm)	909	926.2	881.6
Precipitation - yearly rainfall (mm)	774.1	745.7	718.8
Precipitation - yearly snowfall (mm)	135.0	181.1	162.8

3.3 Evapotranspiration

Evapotranspiration is the combination of two separate processes, evaporation and transpiration, that results in liquid water being lost to the atmosphere. Evaporation is the process by which liquid water in streams and lakes turns into vapour whereas transpiration is the process by which liquid water is absorbed by plant materials and released into the atmosphere. These two processes occur simultaneously and as such, there is no easy way of distinguishing between the two processes.

Evapotranspiration is a key component of the water budget, and is particularly influenced by solar radiation, air temperatures and length of the growing season. More detailed information on evapotranspiration can be found in Section 6.6: Water Budget.

3.4 Climate Change

Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC 2007). Climate change has been researched at a global (IPCC 2007), national (Government of Canada 2006), and provincial-scale (Colombo et al. 2007). Global warming (the increase in average air and ocean temperatures), is regarded as a significant driver of climate change. It is generally accepted that global warming is fueled by increases in greenhouse gas emissions at a global scale. Since climatic processes are key drivers of hydrological and ecological properties of watersheds, it is important to understand the implications of a changing climate in terms of watershed management.

The Expert Panel on Climate Change Adaptation (2009) has summarized recent modeling projections for Ontario in 2050. Some of the key predictions include:

- middle-of-the-road reductions in greenhouse gas emissions show an increase in the annual average air temperature of 2.5ºC to 3.7ºC compared to 1961-1990 average values;

- the range of the projections, from minimum change to maximum change, is from 2.3ºC to 3.0ºC in the south of the province, to 3.2ºC to 4.0ºC in the Far North;
- total precipitation shows little change in the south of the province but an increase of about 5-15% in the Far North;
- southern Ontario, like the Far North, is also projected to see the greatest seasonal increase in precipitation in winter, much of it likely to fall as rain;
- the combination of increased evaporation with little change in precipitation raises the likelihood of more intense dry periods with low run-off water and low soil moisture; and,
- more frequent and possibly more intense extreme events (e.g., droughts, severe rainstorms, etc.).

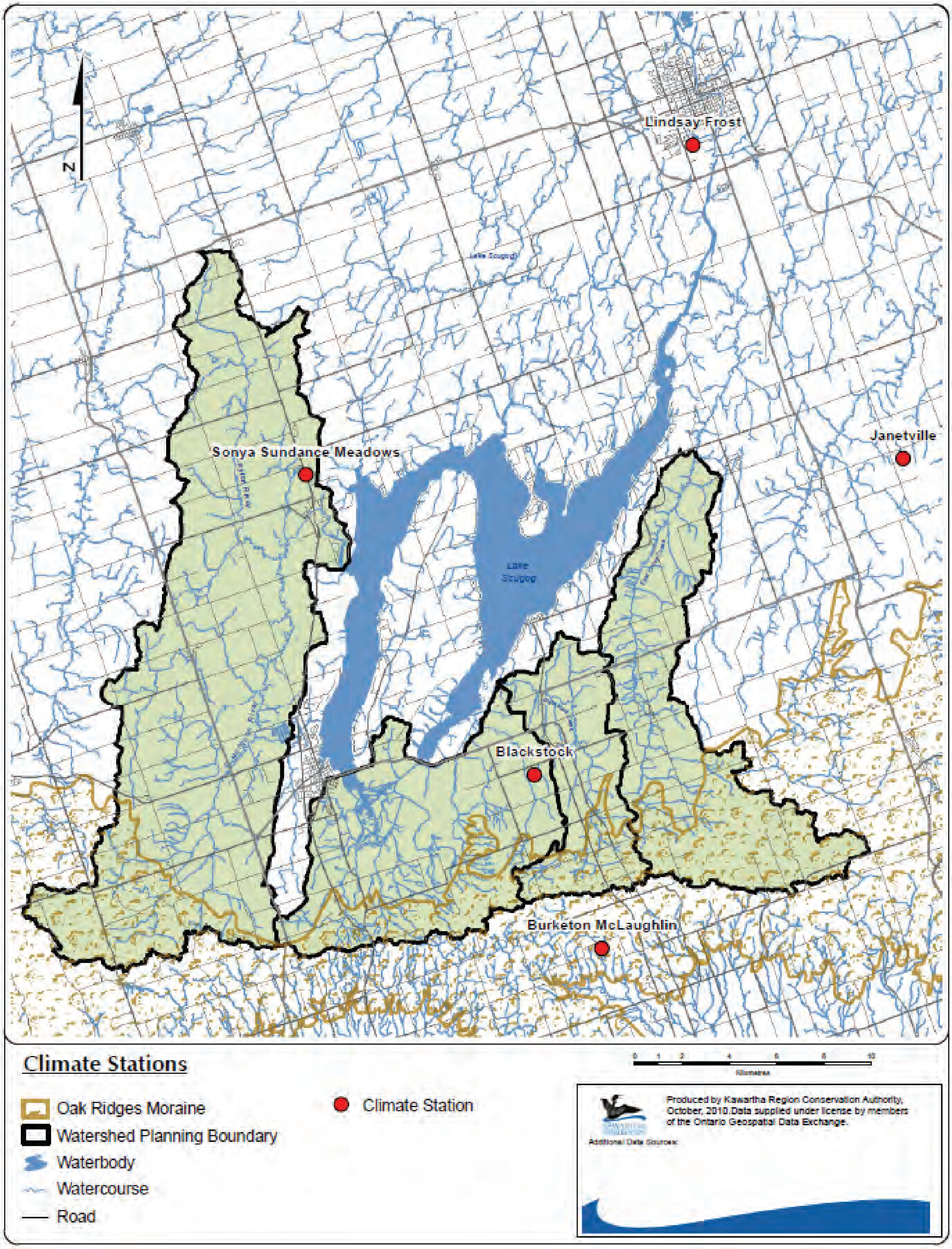
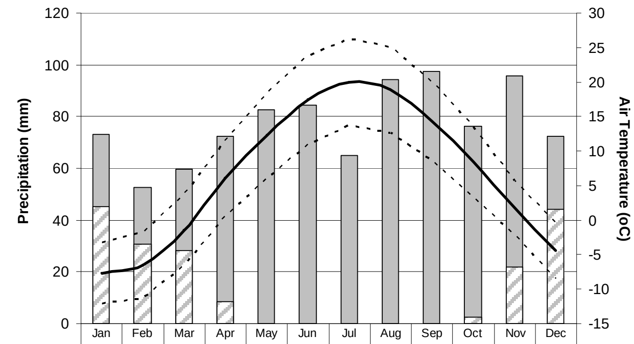
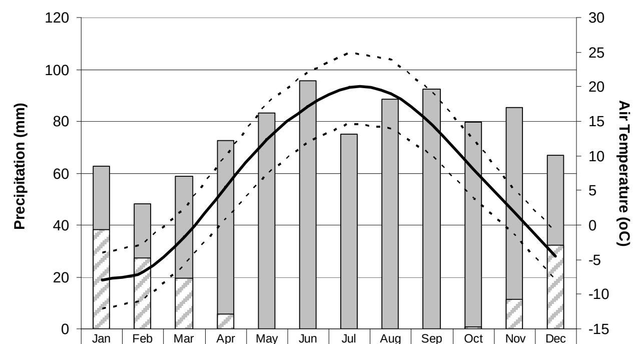


Figure 3.1: Climate stations.



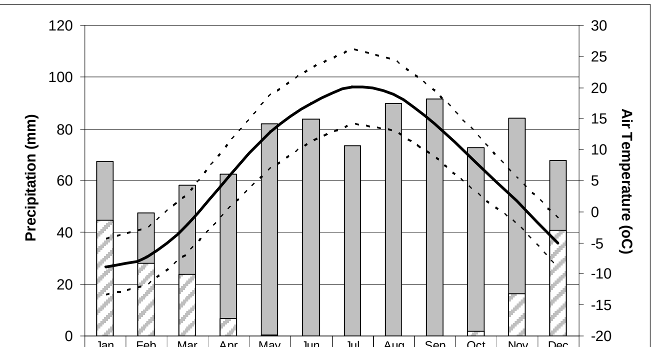
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation - total	73.2	52.7	59.7	72.3	82.7	84.3	64.9	94.4	97.4	76.4	95.7	72.5
Precipitation - snowfall	45.3	30.8	28.2	8.5	0.0	0.0	0.0	0.0	0.0	2.4	21.8	44.1
Air Temperature - daily max	-3.2	-1.7	3.6	11.5	18.3	23.8	26.3	25.1	19.9	13.5	5.7	-0.4
Air Temperature - daily average	-7.7	-6.5	-1.5	6.0	12.2	17.4	20.0	18.9	14.2	8.4	1.8	-4.4
Air Temperature - daily min	-12.1	-11.3	-6.7	0.5	6.1	11.0	13.7	12.7	8.5	3.2	-2.1	-8.5

Figure 3.2: Janetville climate station normals.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation - total	62.7	48.3	58.6	72.5	83.3	95.7	74.9	88.5	92.4	79.8	85.4	67.0
Precipitation - snowfall	38.2	27.2	19.5	5.8	0.1	0.0	0.0	0.0	0.0	0.6	11.5	32.1
Air Temperature - daily max	-4.0	-2.8	2.4	10.0	17.5	22.1	24.9	23.9	19.1	12.3	5.1	-1.0
Air Temperature - daily average	-8.0	-6.8	-1.7	5.4	12.4	17.1	19.9	19.0	14.5	8.1	1.8	-4.5
Air Temperature - daily min	-12.1	-10.9	-5.8	0.8	7.3	12.0	14.8	14.0	9.9	3.9	-1.5	-8.1

Figure 3.3: Burketon McLaughlin climate stations normals.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Precipitation - total	67.6	47.5	58.4	62.5	81.9	83.9	73.4	89.7	91.7	72.9	84.1	67.9
Precipitation - snowfall	44.6	28.2	23.8	6.7	0.3	0.0	0.0	0.0	0.0	1.9	16.3	41.0
Air Temperature - daily max	-4.3	-2.7	2.9	11.0	18.7	23.2	26.1	24.5	19.5	12.6	5.4	-1.1
Air Temperature - daily average	-8.9	-7.3	-1.9	5.8	12.8	17.4	20.1	18.9	14.2	7.9	1.8	-5.1
Air Temperature - daily min	-13.3	-11.9	-6.7	0.5	6.9	11.4	14.1	13.1	8.9	3.1	-2.0	-9.1

Figure 3.4: Lindsay Frost climate station normals.

4.0 Land Use

Blackstock Creek watershed landscape, photo by Lou Wise

4.1 Introduction

The major connecting link in a watershed ecosystem is the flow of water. As water travels through the watershed it flows above and below land in the form of surface water and groundwater. Therefore, the way humans influence the landscape often directly relates to changes in the hydrological and ecological integrity of the watershed. This chapter outlines past land use activities, current land uses and key elements of the planning framework that is currently is place.

4.2 Human Settlement and Growth

Following the last period of glacial activity, the landscape in-and-around the Blackstock Creek watershed remained large tracts of natural unbroken forest and wetlands. The landscape changed dramatically with the onslaught of European settlement in the early 19th century, which revolved around two main activities: agriculture and forestry. By the early 20th century the settled landscape in-and-around the watershed began to resemble what we see today; agricultural lands surrounding small communities that support a variety of industry.

Settlement History

The European history of the area surrounding Lake Scugog dates back to 1809, when Major Wilmot surveyed Reach Township to the west of the lake. Wilmot was also responsible for surveying Cartwright Township, to the east of Lake Scugog. Prior to this time, Mississauga First Nations, who made use of the wild rice growing in Lake Scugog, inhabited the area around the lake.

The formation of hamlets was often a function of proximity to water and the milling power it provided. Gristmills and sawmills played an important role in the development of communities throughout the Lake Scugog watershed. Sawmills were the first industrial enterprises in the area. In Reach Township the first sawmills were constructed in 1831 and in Cartwright Township in 1851.

The most consequential mill construction was the Lindsay gristmill. Constructed in approximately 1837 by William Purdy, the dam significantly changed the landscape around Lake Scugog. Prior to the mill's construction, Lake Scugog was described as merely a "mass of marsh and grass" (Weir 1927). The dam caused a four-foot rise in water levels and made Lake Scugog a navigable waterway. This rise in water levels benefited the more isolated townships of Cartwright and Mariposa, making transportation to the "front" (Oshawa and Whitby) much easier.

In the mid-1800s, the towns of Manchester, Port Perry and Prince Albert, all within a 5km distance of each other, were competing to become major trade centre in Reach Township. The Town of Manchester was positioned further away from Simcoe Street (present-day Old Simcoe), the main corridor to Whitby, and did not thrive to the same extent as Port Perry or Prince Albert. Still, the mid-1800s was a time of extensive population growth. The 11 years between 1840 and 1851 saw the population of Reach Township grow by over 400%, from 771 to 3,897 residents (Johnson 1973). **Table 4.1** list the various hamlets that were formed during these periods. **Figure 4.1** shows a historical map of the former Cartwright Township.

Following European settlement, large areas on the Oak Ridges Moraine were discovered to be unsuitable for long-term farming due to topography or poor soil types. With faster snowmelt, downstream flooding, erosion and dust storms, thousands of acres of cleared land were subsequently abandoned. Large areas of wasteland on the Oak Ridges Moraine became common with deep, eroded gullies and sand dunes. Once-productive forest soils were depleted of nutrient rich soils that had blown or washed away.

Forests were once abundant throughout the Lake Scugog watershed, blanketing most of the area. However, other than scattered remnants of the original forest, contemporary woodlands are the result of human settlement activities since the first quarter of the 1800s. The original forest was viewed mostly as an impediment to settlement and travel, something to be conquered or exploited for any kind of value, rather than managed. In fact, the volume of product was so enormous that there was no market for much of it during the intensive period of land clearing. The dominant land use throughout the Lake Scugog watershed has since become agriculture, with only small areas of forest remaining.

Table 4.1: Areas of settlement and approximate year formed.

Hamlet/Community	Approximate Year Formed
Blackstock	1898
Nestleton Station	1904
Burketon	1885

Current Demographics

The Blackstock Creek watershed is not densely populated. Most residents live either in small hamlets or scattered across the rural portions of the watershed. The Durham Regional Official Plan Amendment No. 128 (2009) estimates a population growth for the Township of Scugog of approximately 3,950 persons between 2006 and 2031, comprising a total population of 25,390 in 2031.

Currently the Township of Scugog has a total population of 21,439 persons (Statistics Canada 2007), with 45% living in the urban area of Port Perry (Township of Scugog 2009). The Township of Scugog Official Plan estimates that in the future, population growth will occur mainly in urban areas (60% of the total population increase), while the surrounding rural and shoreline areas will accommodate 40% of the total increase.

In the foreseeable future, land use within the Blackstock Creek watershed will stay rural and agriculture-based. As the Township of Scugog continues to promote tourism in the area, it is evident that recreational activities will also play a significant role in the economy of this watershed.

4.3 Current Land Cover

Current land cover with the Blackstock Creek watershed was interpreted using 2008 aerial photography of the landscape. Natural vegetative cover (e.g., forests, wetlands, etc.) were classified according to Ecological Land Classification methodology (Lee et al. 1998). The remaining land cover were classified into Urban and Rural Development, Manicured Open Space, Intensive Agriculture, and Non-intensive Agriculture following methods developed by Credit Valley Conservation (1998). **Figure 4.2** depicts the total amount and relative percentages of these land cover types. **Figure 4.3** shows the distribution of these land cover types across the watershed.

Natural Cover

Natural Cover exists within 10.8 km^2 or 28.4% of the watershed. These areas mainly consist of natural forests, wetlands and cultural plantations that are concentrated within the central, low-lying areas of the watershed. Areas of natural cover also exist in the southern portion of the watershed on the Oak Ridges Moraine. These natural areas on the landscape are considered natural heritage features, and are extremely important for contributing to the hydrological integrity (e.g., permitting groundwater recharge, reducing peak flows, etc.) and ecological integrity (e.g., providing fish and wildlife habitat, stabilizing stream banks, etc.) of the watershed. Please refer to Chapter 9.0 Terrestrial Natural Heritage for more detailed information on the locations and significance of specific natural cover types.

Urban Development

Areas considered urban development exist within 1.9km^2 or 5.2% of the watershed and include the hamlets of Blackstock, Nestleton Station and the north portion of Burketon. These are small urban communities that consist of dense residential lots.

Rural Development

Areas considered rural development account for 2.0km^2 or 5.2% of the watershed and generally include single or small groups of rural lots (i.e., rural-residential) or other small-scale developments that dot the landscape.

Agriculture - Intensive

Intensive agriculture refers to lands that are annually cultivated and planted with row crops. These areas account for 21.8km^2 or 57.7% of the land area, which is the dominant land cover type within the watershed. Major crop production within the area includes alfalfa and alfalfa mixtures, corn, soybeans, and wheat (Statistics Canada 2007).

Agriculture - Nonintensive

Nonintensive agriculture refers to lands that are currently in use for pasture. These areas account for 1.3km^2 or 3.4% of the total land cover. Livestock production is dominated by cattle in these areas, but there are numerous equine operations as well.

Manicured Open Space

Areas of manicured open space account for 0.1km^2 or 0.2% of the watershed. They consist of "regularly-maintained" open grassy areas that are primarily used for recreational purposes.

Aggregate

This land cover type includes areas defined by recent aggregate extraction activity or where aggregate extraction no longer occurs, but lands continue to be defined by historic aggregate extraction activity. These are heavily disturbed, open quarry areas that account for 0.1 km^2 or 0.2% of the total land cover. Small operations exist in the extreme south-east portion of the watershed within the Oak Ridges Moraine. These areas closely resemble their corresponding "licensed extraction areas", therefore, it is expected that expansion of current aggregate land cover will be minimal.

4.4 Transportation Network

Within the Blackstock Creek watershed there are 51.1 km of roads, with a density of 1.4 km/km^2. These include one provincial road (Highway 7A), several regional and county roads (19, 57), and numerous minor roads. Generally, roads intersect the watershed in a north-south, east-west grid pattern. The provincial and regional roads are all asphalt whereas the minor roads are gravel-sand surfaces.

4.5 Impervious Surfaces

Impervious surfaces refers to hardened areas (e.g., driveways, parking lots, rooftops, etc.) that increase rates of surface water runoff and reduce groundwater infiltration. In developed areas, runoff often carries with it contaminants from roads, lawns and driveways, directly into the tributaries of river systems. Research suggests that significant impacts to fish and benthic macroinvertebrate communities, water temperature, width, depth and stability of banks occur when cumulative impervious surfaces within a watershed exceeds 10 percent (Environment Canada 2004).

To obtain an estimation of the amount of impervious cover within the watershed each rooftop, swimming pool, driveway, accessory building, and paved roads were delineated from aerial photography taken in 2008. These results indicate that total impervious cover of all permanent, hard surfaces within the watershed accounts for 1.1 km^2 or 2.9 % of the total watershed area. The existing road network accounts for the majority of the total. This value is relatively low compared to other watersheds originating on the Oak Ridges Moraine, especially when compared to watersheds draining south to Lake Ontario. This can be attributed to the lack of wide-spread urban development in the Blackstock Creek watershed.

4.6 Waste Disposal Sites

There is one known waste disposal site within the watershed that is currently closed. It is located near Church Street and Regional Road 57. Although leachate from landfill sites can be a significant water quality threat in some areas, this site is not known to be negatively impacting watershed resources.

4.7 Land Use Planning

Land use planning and policy within the Blackstock Creek watershed is guided by various initiatives at the federal, provincial and municipal level. The following are key overarching land use policies that should be considered during the watershed management planning process.

Oak Ridge Moraine Conservation Plan

The Oak Ridges Moraine Conservation Plan was introduced by the province in 2002, with the primary purpose of protecting the hydrological and ecological features and functions of the Oak Ridges Moraine (OMMAH 2002). The land use provisions contained within the plan apply to lands within the Oak Ridges Moraine Planning Area, which extends 1900km^2 across south-central Ontario. Areas within the Oak Ridges Planning Area have been divided into four land use designations that have varying levels of development restrictions and/or permitted land use activities. They include Natural Core Areas, Natural Linkage Areas, Countryside Areas and Settlement Areas. In total, the Oak Ridges Moraine Conservation Plan covers 11.9km^2 or 31.5% of the entire watershed. The Oak Ridges Moraine portion of the watershed includes: Natural

Linkage Areas ($7.5 km^2$) and Countryside Areas ($4.0 km^2$). There are no Natural Core Areas and no Settlement Areas (**Figure 4.4**).

Greenbelt Plan

The Greenbelt Plan was introduced by the province in 2005, with the primary purpose of sustaining productive agricultural lands and preserving natural heritage features that exist in-and-around the Greater Toronto Area (OMMAH 2005a). Although the Plan area includes the Niagara Escarpment and the Oak Ridges Moraine, the land use provisions contained within the Plan apply to the area designated as "Protected Countryside" in the Plan. Protected Countryside land falls into one of the following policy areas: Prime Agricultural Areas, Rural Areas, Towns/Villages, Hamlets, or Shoreline Areas. Lands may also be subject to the policies of a Natural Heritage System, which is an overlay on the Protected Countryside designation. In total the Greenbelt Plan covers $26.1 km^2$ or 68.9% of the entire watershed. Within the Greenbelt lands in the watershed, $9.2 km^2$ is Natural Heritage System, and $16.9 km^2$ is Protected Countryside (**Figure 4.4**).

Provincial Policy Statement

The Provincial Policy Statement was introduced by the province in 2005, with the primary purpose of providing for appropriate development while protecting resources of provincial interest, public health and safety, and the quality of the natural environment (OMMAH 2005b). Ultimately, it sets the general land use policy framework throughout all Ontario. The Provincial Policy Statement identifies various natural heritage features (e.g., fish habitat, significant wetlands, significant valleylands, etc.), that should be protected from incompatible development.

Municipal Official Plans

The Blackstock Creek watershed is located within the jurisdiction of three municipalities (**Figure 4.5**). These include the Regional Municipality of Durham, Scugog Township, and the Municipality of Clarington. The upper tier Regional Municipality of Durham jurisdiction covers $3.9 km^2$ or 100% of the watershed, which includes the lower tier municipalities of Township of Scugog ($36.7 km^2$), and Municipality of Clarington ($1.2 km^2$). Municipal Official Plans and their associated updates (e.g., amendments) and by-laws, contain land use policies that provide direction on development and other activities within that respective municipality. The Official Plan of lower municipalities (e.g., Scugog Township) are consistent with their upper tier municipality (e.g., Durham Region). All Official Plans must conform with provincial planning policies (where they apply), such as the Provincial Policy Statement, Oak Ridges Moraine Conservation Plan, Greenbelt Plan, and the Growth Plan for the Greater Golden Horseshoe.

The Regional Municipality of Durham Official Plan (Region of Durham 2008) designates most of the land throughout the watershed as Major Open Space and Prime Agricultural Areas (**Figure 4.6**). Land designated as Major Open Space is intended for conservation, agriculture and agriculture related activities, and recreation. Any development that occurs within the area must ensure that the disturbed area does not exceed 25% and impervious surface does not exceed 10%. Prime Agricultural Land is intended to encourage continual farming practices and restrict severances that may fragment the farming landscape.

Within the Township of Scugog Official Plan (Township of Scugog 2009), a large portion of land within the watershed is designated as Greenlands System (**Figure 4.7**). Accepted use of these lands include: agriculture, single detached dwellings, recreation that has no adverse affect on the environment, forestry, fisheries and watershed management activities. Other areas are designated Agricultural Reserve, established to maintain prime agricultural lands and General Agriculture. Other areas, not considered prime agricultural, permit more diverse land uses such as commercial development and industry.

Conservation Authority Regulations

The Blackstock Creek watershed is within the jurisdiction of Kawartha Conservation, one of 36 Conservation Authorities in the province. In 2006, the province of Ontario approved the Kawartha Region Conservation Authority: Regulation of Development, Interference and Alteration to Shorelines and Watercourses (O.Reg 182-06) consistent with Ontario Regulation 97/04 of the *Conservation Authorities Act*. The Act gives Kawartha Conservation administrative authority to regulate development and other land use activities within its jurisdiction, including:

- development in river or stream valleys, wetlands, shorelines and hazardous lands and associated allowances;
- the straightening, changing, diverting or interfering in any way with the existing channel of a river, creek, stream, watercourse or for changing or interfering in any way with a wetland; and,
- other areas where, in the opinion of the Minister, development should be prohibited or regulated or should require the permission of the authority.

Kawartha Conservation Watershed Planning Policies (Kawartha Conservation 2012) provide a decision-making framework for the review of applications under the Regulations. Kawartha Conservation has developed Regulation Limit mapping for the purpose of provincial policy and regulations implementation (**Figure 4.8**). The Regulation Limit mapping is a key tool in protecting public and property against natural hazards such as flooding and regulating activities that could impact floodplains, shorelines, wetlands, watercourses, and unstable slopes and soils.

Ontario Drinking Water Source Protection Planning

In 2005, the province of Ontario introduced the *Clean Water Act*. The purpose of this Act is to protect municipal drinking water at the source, which includes surface water and groundwater. A key component of this legislation is the requirement for the development of local and science-based Source Water Protection Plans. The Blackstock Creek watershed exists within the Kawartha-Haliburton Source Protection Area, which is part of the larger Trent Conservation Coalition Source Protection Region. Various studies and reports developed through this planning process provide background information on watershed resources, especially within the context of protecting water quality and quantity of municipal drinking water systems. These data are summarized in the Kawartha Conservation Watershed Characterization Report (Kawartha Conservation 2008) and the Trent Assessment Report (TCCSPC 2011). Source Water Protection Plans are expected to be finalized in 2012.

Lake Scugog Environmental Management Plan

The purpose of the Lake Scugog Environmental Management Plan (Kawartha Conservation 2010b) is to ensure the long-term environmental and social sustainability of Lake Scugog and its resources. This plan provides an overall stewardship strategy for the lake and its watershed for the next ten years, with estimated costs for its implementation. The Implementation Plan actions are designed to cover all aspects of human activities and are grouped under six strategies: Watershed Planning, Regulation and Enforcement Strategy; Communications and Education Strategy; Stewardship Strategy; Agricultural Land Use Strategy; Urban Land Use Strategy; and, Monitoring and Scientific Studies Strategy.

4.8 Key Observations and Issues

- The dominant land use within the watershed is agriculture, which comprises approximately 61% of the total land area. No major urban growth and expansion is expected to occur within the next 25 years, and as such the watershed will remain distinctly rural in nature for the foreseeable future.
- Areas of natural cover still exist within the watershed, comprising approximately 28% of the total land area. These include wetland complexes in the central portion of the watershed and forested areas in the southern portion on the Oak Ridges Moraine.
- The watershed is located within the jurisdiction of 3 municipalities. These include the Region of Durham (100% of the total land area), which includes Scugog Township and Municipality of Clarington.
- The southern portion of the watershed lies within the Oak Ridges Moraine Conservation Plan planning boundary (31% of total watershed area), while the majority of the watershed lies within the Greenbelt Plan planning boundary (69% of total watershed area).

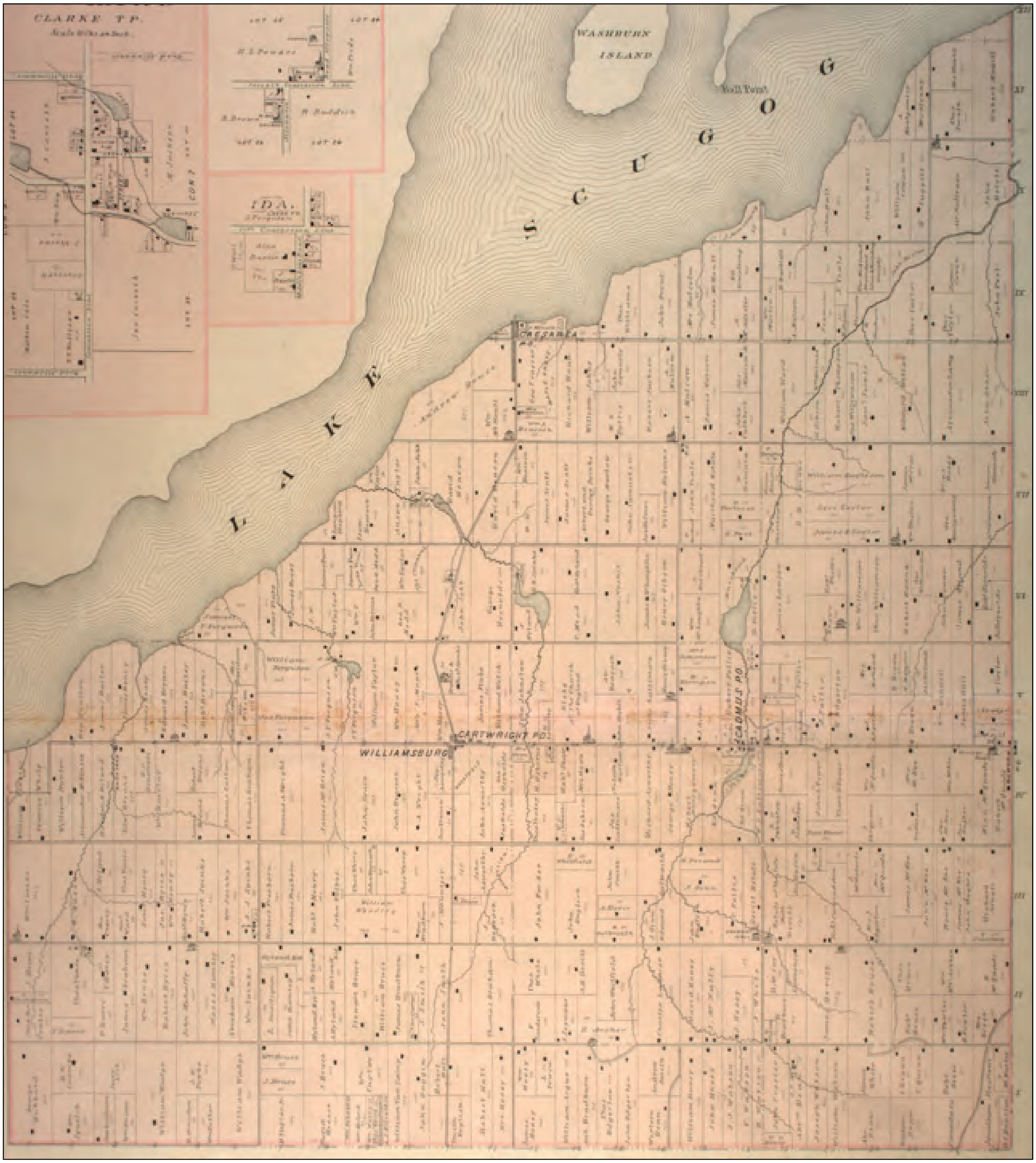


Figure 4.1: Historical map of Cartwight Township (circa 1880).

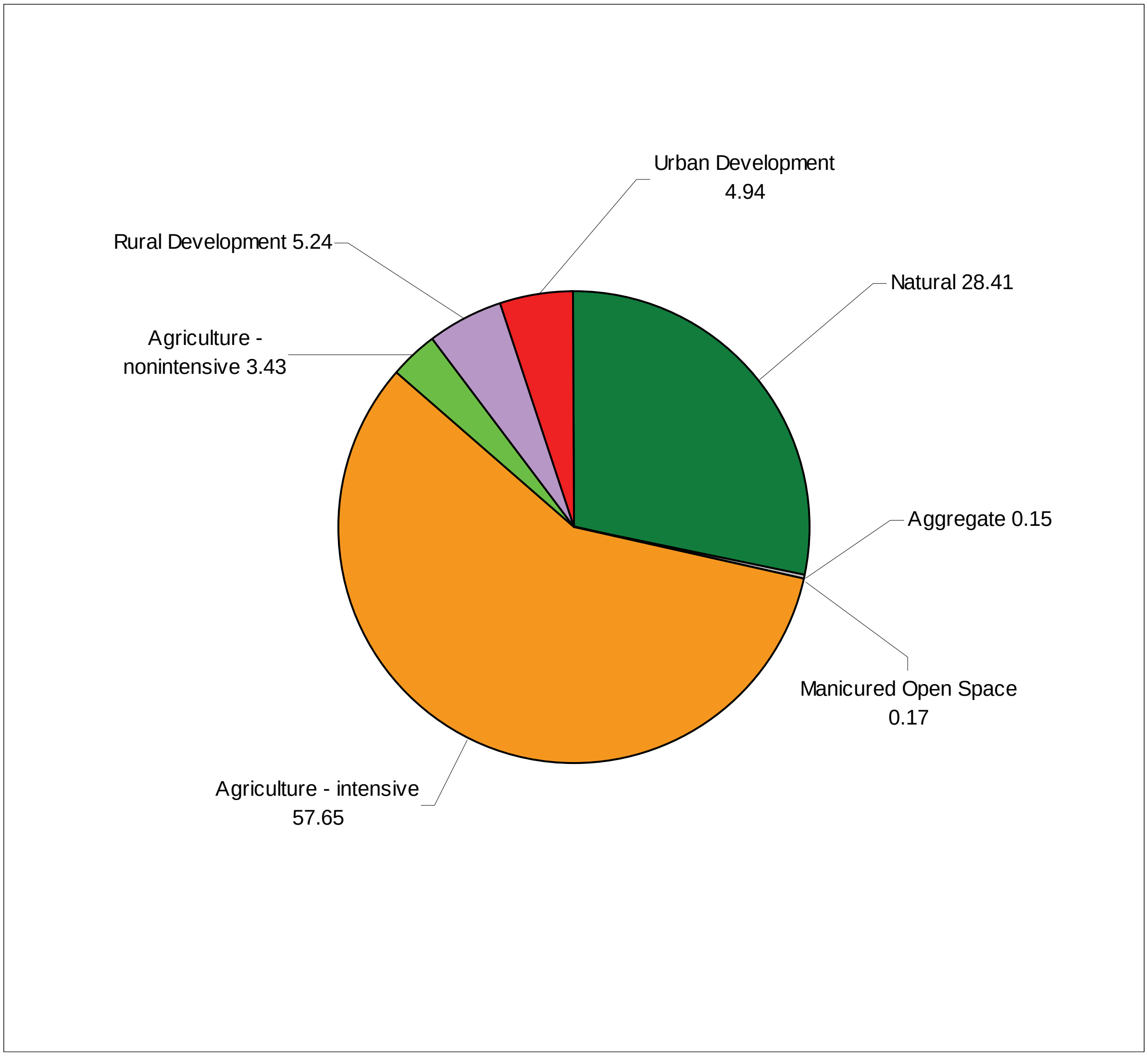


Figure 4.2: Percentage of major land cover types.

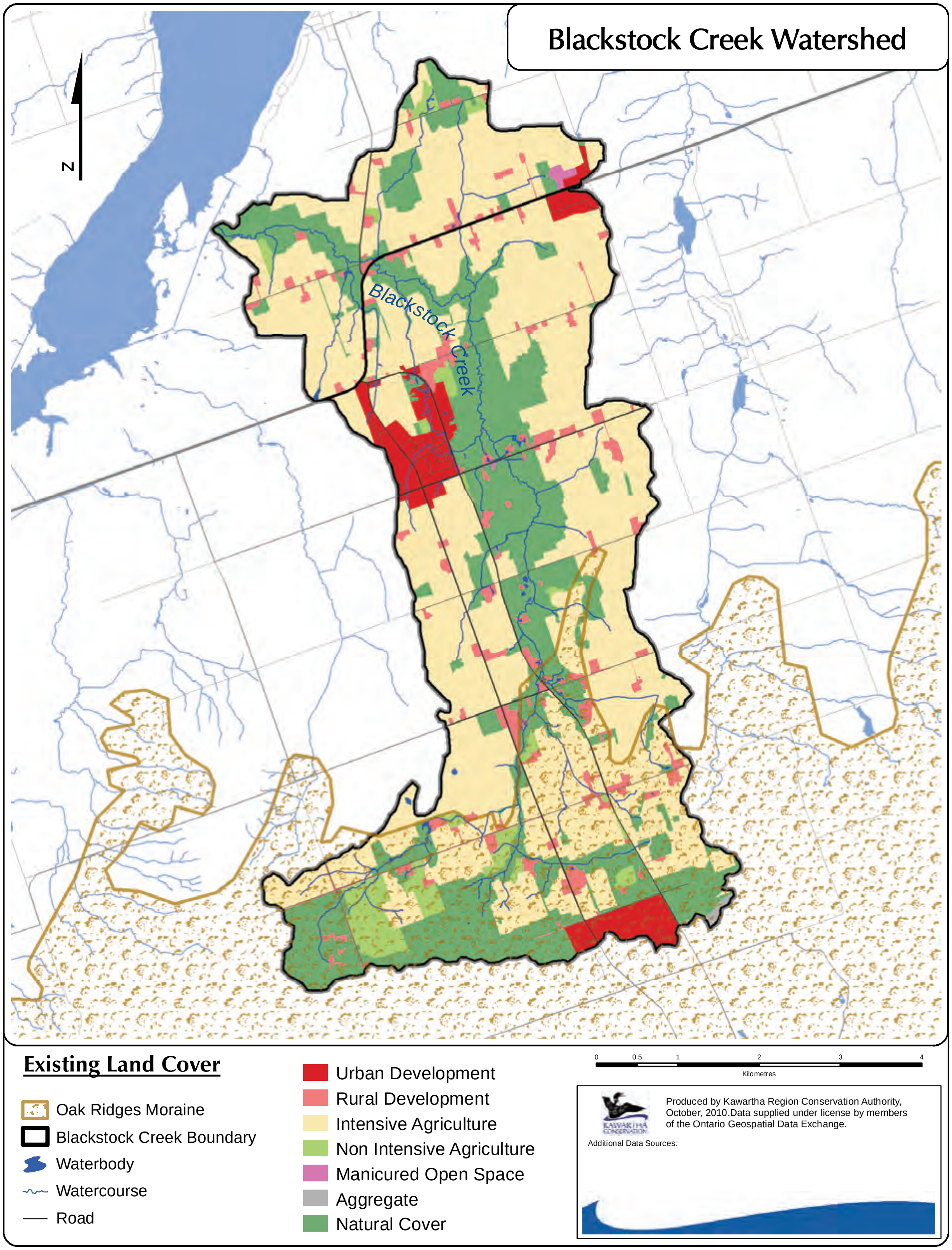


Figure 4.3: Existing land cover.

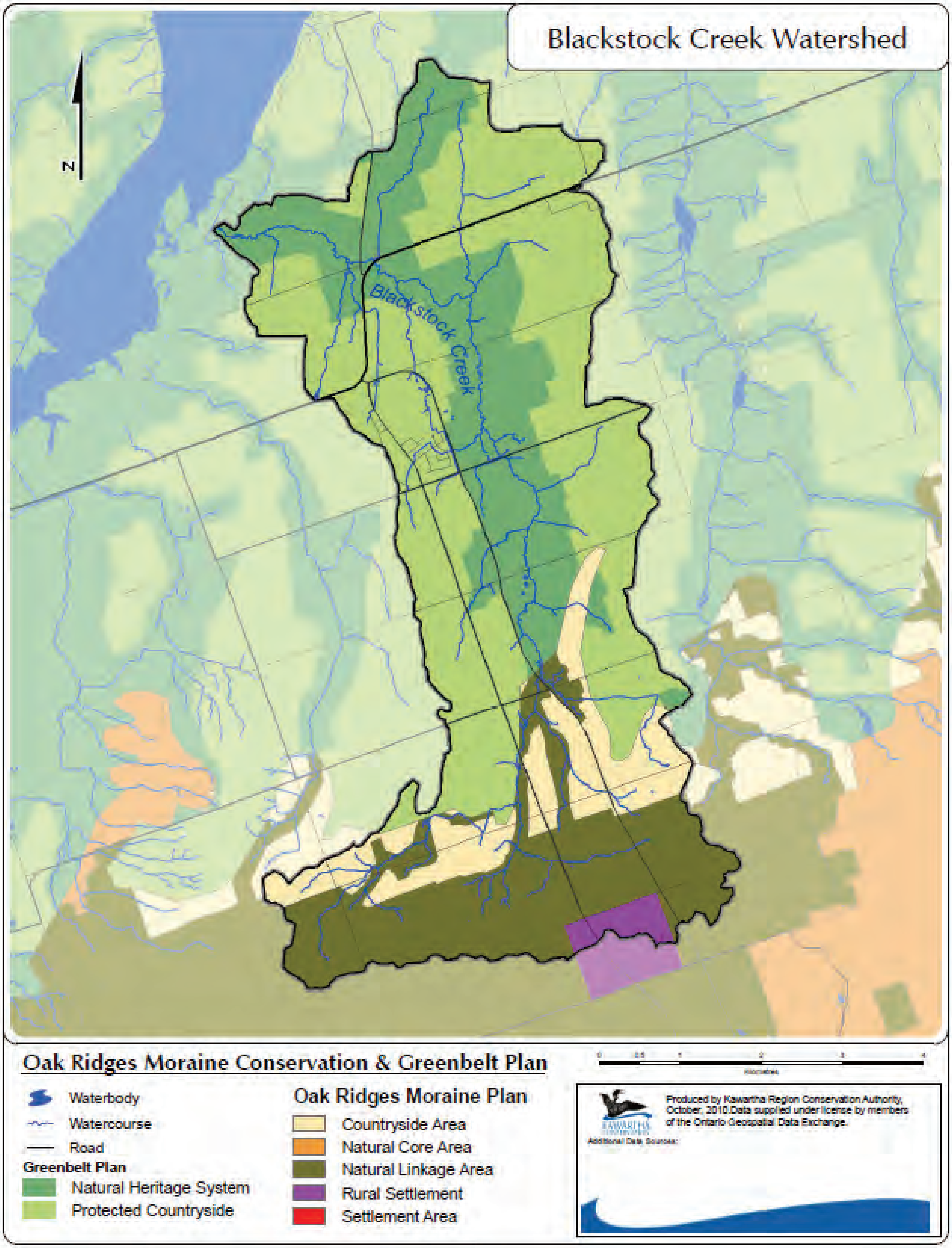


Figure 4.4: Oak Ridges Moraine and Greenbelt land use designations.

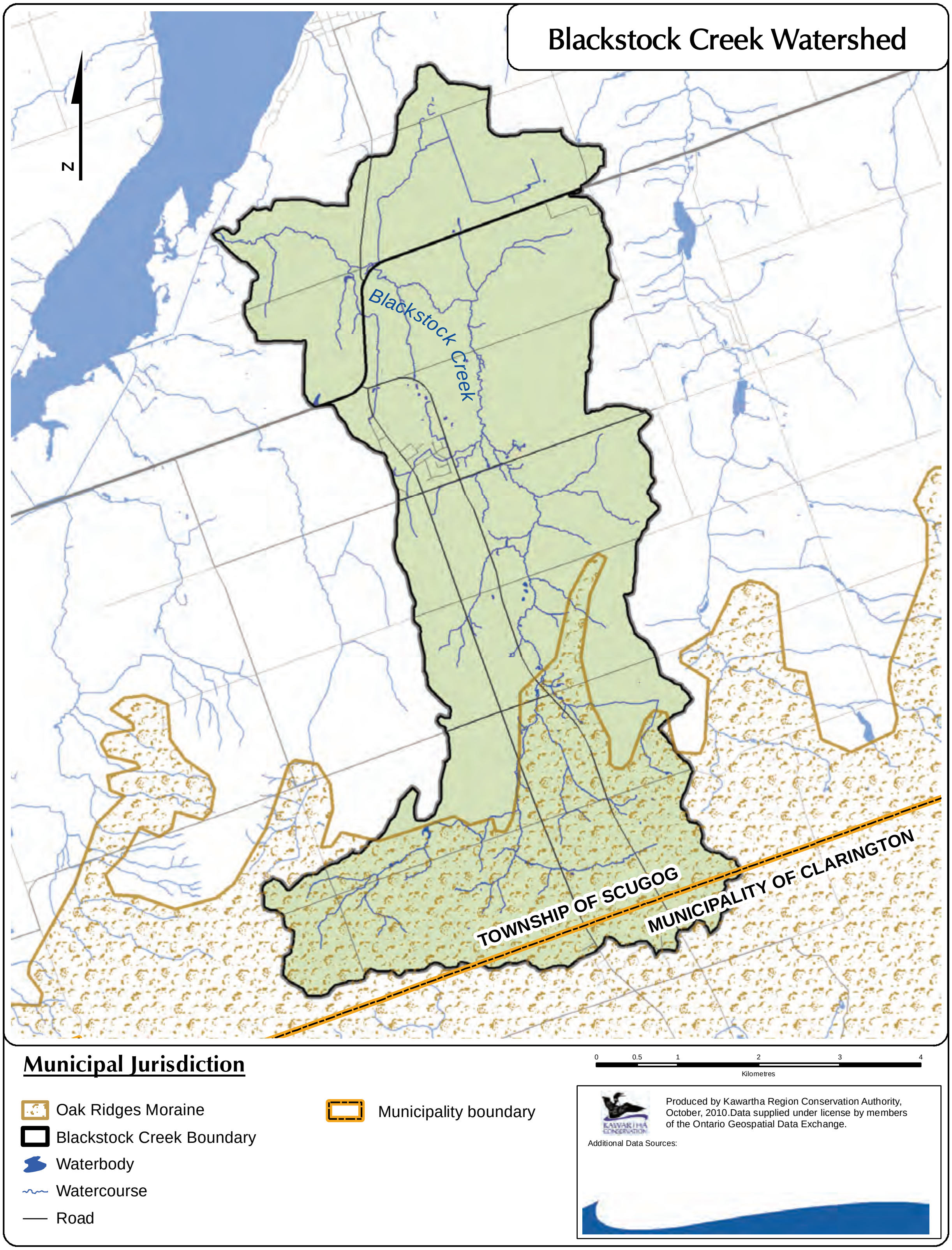


Figure 4.5: Municipal jurisdiction.

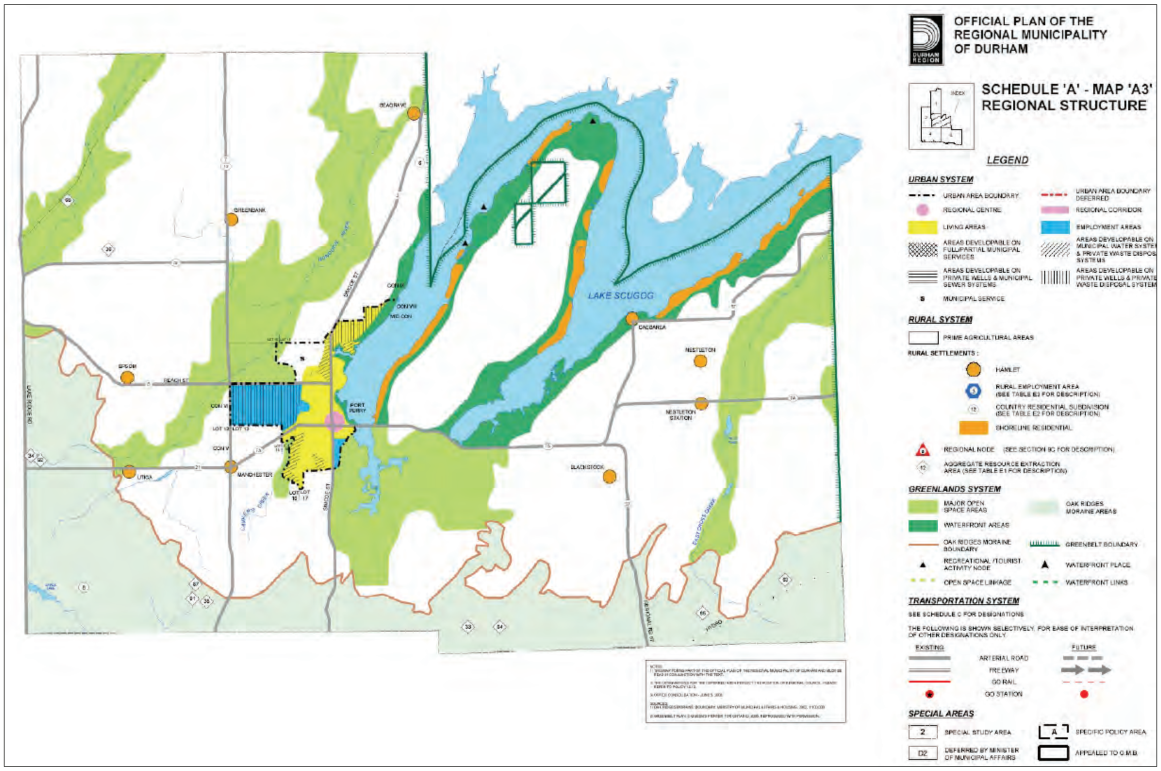


Figure 4.6: Regional Municipality of Durham Official Plan land use designations.

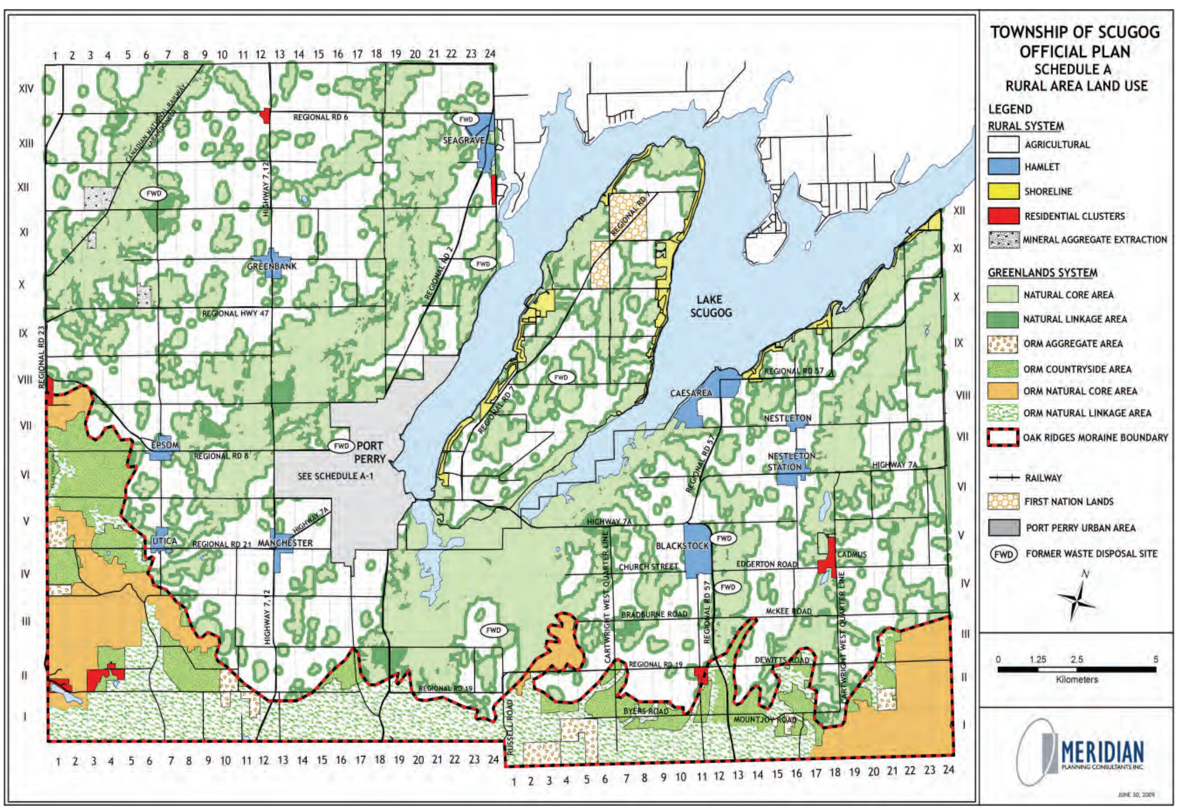


Figure 4.7: Township of Scugog Official Plan land use designations.

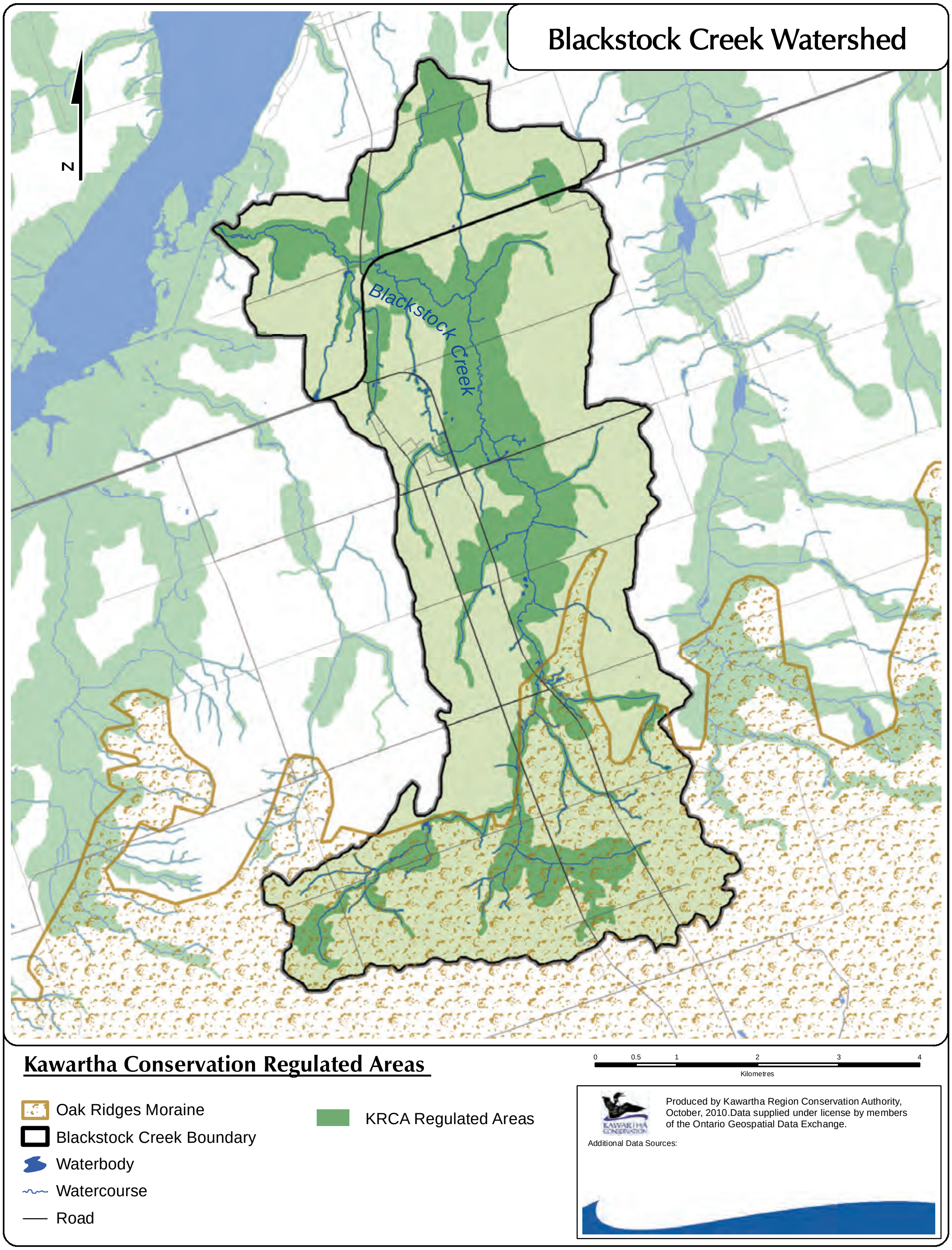


Figure 4.8: Conservation Authority regulated areas.

5.0 Water Use

Blackstock Creek, north of Beacock Road

5.1 Introduction

An abundant water supply is critical to maintaining both the hydrological integrity and ecological integrity of watersheds. Humans are also heavily dependent upon surface water and groundwater for drinking and potable purposes, agricultural use, industrial and recreational use. The intent of this chapter is to provide a summary of estimated use of water resources within the Blackstock Creek watershed.

5.2 Major Water Takings

Water users that withdraw or holdback (e.g., through impoundments) more than 50,000 litres of water per day are considered major water takings. These activities require a Permit to Take Water (PTTW) from the Ontario Ministry of Environment and the amount of water used is documented and reported to the MOE. Water takings for domestic use, agriculture and emergency purposes (e.g., firefighting) do not require a permit. Major water taking information is managed in a provincial dataset, maintained by the Ministry of the Environment, which contains specific information including the name of permit holder, location of withdrawal, permitted purpose, maximum permitted water taking volumes and maximum number of water taking days per year. As of 2008, all major water takers are required to report the total volume of water taken each year.

The Ontario Ministry of Environment was contacted to provide current water taking information within the watershed. The best available data was provided for active permits within the watershed (as of May 2010). Some permits were removed from the analysis in order to give a better representation of water usage (e.g., pumping tests).

There is only one active Permit to Take Water within the Blackstock Creek watershed (**Figure 5.1**, **Table 5.1**). It employs three groundwater monitoring wells for municipal water supply for Hamlet of Blackstock. The total maximum permitted amount of water withdrawal for all three wells is 2,160 m^3/day. It includes provision for use of Well MW7 at 985 m^3/day. However, Well MW7 is not currently connected to the municipal water supply system. Therefore, the current maximum daily taking possible from the existing wells is 1,175 m^3/day.

The permitted capacity for the existing wells in Blackstock is set to allow for planned growth and predicted maximum day usage. Maximum day usage is typically on the order of two times the average usage rate but can vary from system to system. The observed average daily rate for the Blackstock Wells in 2007 was 139 m^3/day. This represents approximately 14% of the quantity allowed under the permit for the lead well (MW8). Well MW1 is used primarily as a back-up and is pumped minimally. The average pumping rates for 2007 are used as this reflects a relatively dry year and therefore relatively high water usage by the community.

Table 5.1: Permits to take water.

Permit number	Surface or Ground Water	Source	Maximum Daily Water Taking (Litres/day)	Category	Purpose	Issue Date	Expire Date
0118-6VDVQX	Ground Water	MW1	190,000.00	Water Supply	Municipal	2/14/2007	3/31/2017
0118-6VDVQX	Ground Water	MW7	985,000.00	Water Supply	Municipal	2/14/2007	3/31/2017

0118-6VDVQX	Ground Water	MW8	985,000.00	Water Supply	Municipal	2/14/2007	3/31/2017

5.3 Private Water Supply

As water usage requiring less than 50,000 litres per day are not required to obtain a Permit to Take Water and thus no data is available on actual usage. Examples of these include: rural and residential domestic wells, non-business irrigation and livestock operations. Although each of these users withdraws relatively little water from the watershed (when compared to the major water takings), the cumulative amount of water taken may be high. However, because rates of use are not reported and thus it is difficult to accurately quantify the total amount extracted, rates are estimated. In addition, many of the private wells in the watershed have not been registered and many are no longer in active use.

Most rural residences within the watershed rely on water supplied by private wells. An estimated 306 private wells are located within the Blackstock Creek watershed (**Figure 5.2**). A typical private household uses approximately of 1,000 litres of water per day (Shrubsole and Draper 2007). This would equate to a total water use in the order of 306,000 litres/day or 306 m^3/day. In rural areas, this water is returned to the groundwater flow system as infiltration from the private sewage disposal system. The net consumption of water is minor. In many areas, the water is withdrawn from a deeper aquifer and returned to a shallow aquifer. A small percentage of these wells are considered communal wells, supplying groundwater to small rural subdivisions and other small-scale users.

Water usage for agricultural operations are usually not covered by the Permit to Take Water database. As the Blackstock Creek watershed is primarily rural in nature, agricultural activities are considered to be one of the major water uses in the study area. The extent to which water is used regionally is dependent on the nature of the agricultural activities (i.e., type of crop, livestock operation), as well as the amount of land cultivated. However, the agricultural operations do not require permits to take water unless water is brought into storage prior to use. As such, additional quantities of water may be used for animal watering and crop irrigation purposes without any record of volumes applied.

5.4 Municipal Drinking Water Supply

There is one municipal drinking water system located within the Blackstock Creek watershed, which relies on groundwater (**Figure 5.3**). The system (Blackstock Municipal Drinking Water System) is operated by the Regional Municipality of Durham. As part of the Drinking Water Source Protection Planning process, detailed water use information for these systems has been summarized in the Trent Assessment Report (TCCSPC 2011). Some of it is presented in **Table 5.2**.

A wellhead protection area (WHPA) is an area of land surrounding a well, from which a well may draw its water. The WHPA is subdivided into four zones: WHPA-A, WHPA-B, WHPA-C, and WHPA-D. Except for WHPA-A zone, the delineation is based on the time it would take water to travel horizontally to the well. Zones WHPA-B, C, and D represent a 2-year time-of-travel, 5-year time-of-travel and 25-year time-of-travel of groundwater, respectively. Zone WHPA-A is assigned as a 100 m radius surrounding the well.

Table 5.2: Municipal groundwater systems.

Municipal Residential Groundwater System	Operating Authority	Safe Drinking Water Act classification	Serviced Population
Blackstock	Durham	Large municipal residential	527

Blackstock Municipal Drinking Water System

The Blackstock Creek municipal drinking water system consists of one primary well (main production well), one secondary well (stand-by production well) and one tertiary well (emergency stand-by well) within the Blackstock Creek watershed. The delineated wellhead protection areas shown on **Figure 5.3**. Depth of wells varies from 40.5 m to 60.82m. Drinking water system provides drinking water to estimated 527 people in Hamlet of Blackstock. The wellhead protection areas for these municipal wells reflect groundwater flow from southeast to northwest to the municipal wells.

5.5 Wastewater Treatment

The watershed is separated into either serviced or non-serviced areas. Serviced areas are those where waste is discharged to municipal wastewater treatment facilities. Within non-services areas, waste is typically discharged to private septic systems. There are no municipal wastewater treatment facilities within the Blackstock Creek watershed.

5.6 Key Observations and Issues

- Groundwater is the dominant source of municipal and private water supply.
- The majority of residents within the watershed obtain their water from private, individual groundwater wells. There are approximately 306 wells within the watershed. The estimated total amount of groundwater being extracted from these sources is 306,000 litres per day.
- The hamlet of Blackstock is serviced by municipal groundwater wells. The estimated total permitted amount of groundwater allocated for withdrawal from these sources is 2,160,000 litres per day.
- There is one active Permit to Take Water in the watershed. This permit is allocated for groundwater extraction for the municipal system.
- The total estimated water taking for the watershed is 445,000 litres per day. This estimate reflects the average municipal water taking for 2007 plus private well taking.
- It is difficult to precisely quantify the amount of water that is being withdrawn from groundwater and surface water sources other than those requiring reporting. Only users requiring Permits to Take Water are required to report the actual amount being extracted.

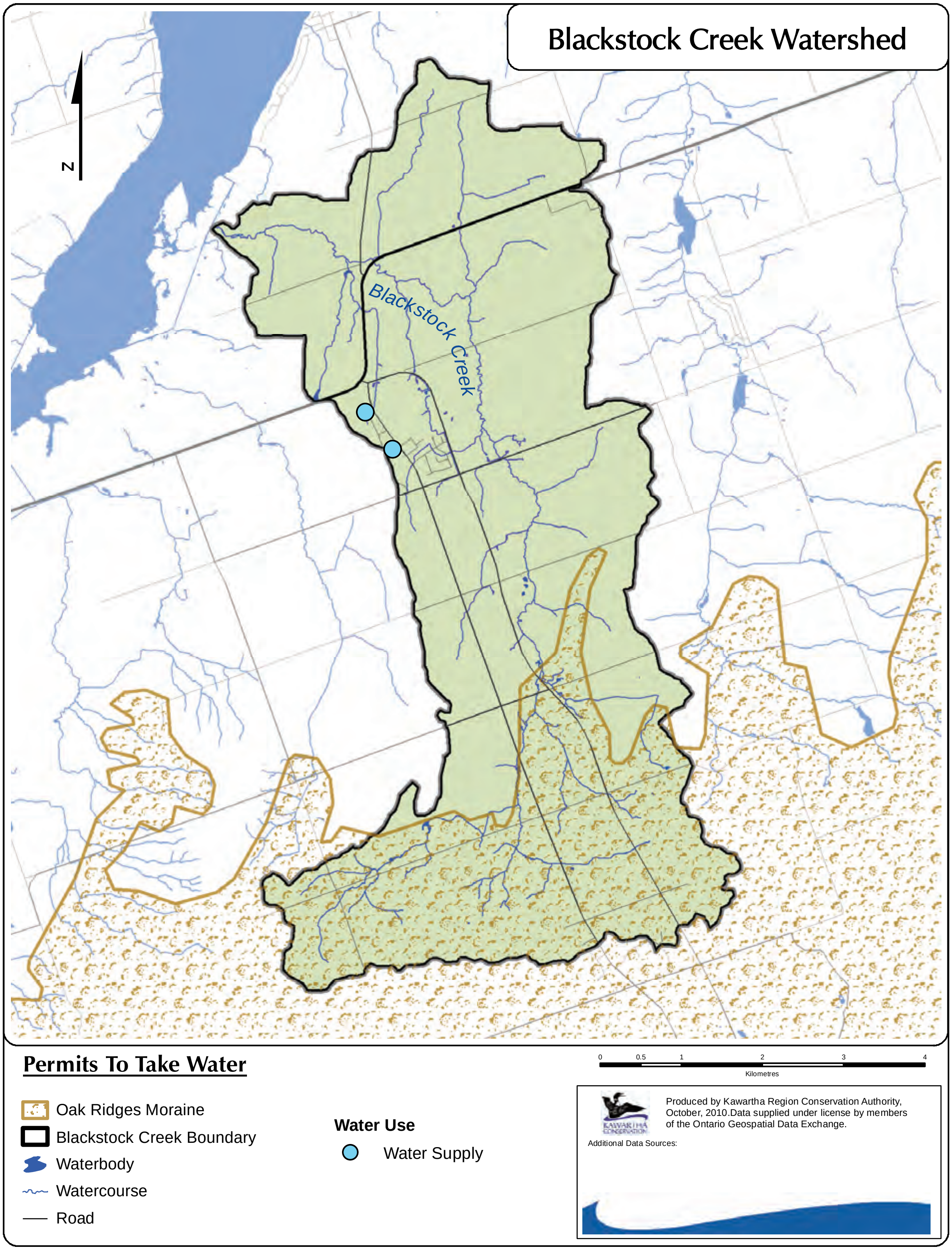


Figure 5.1: Permits to take water.

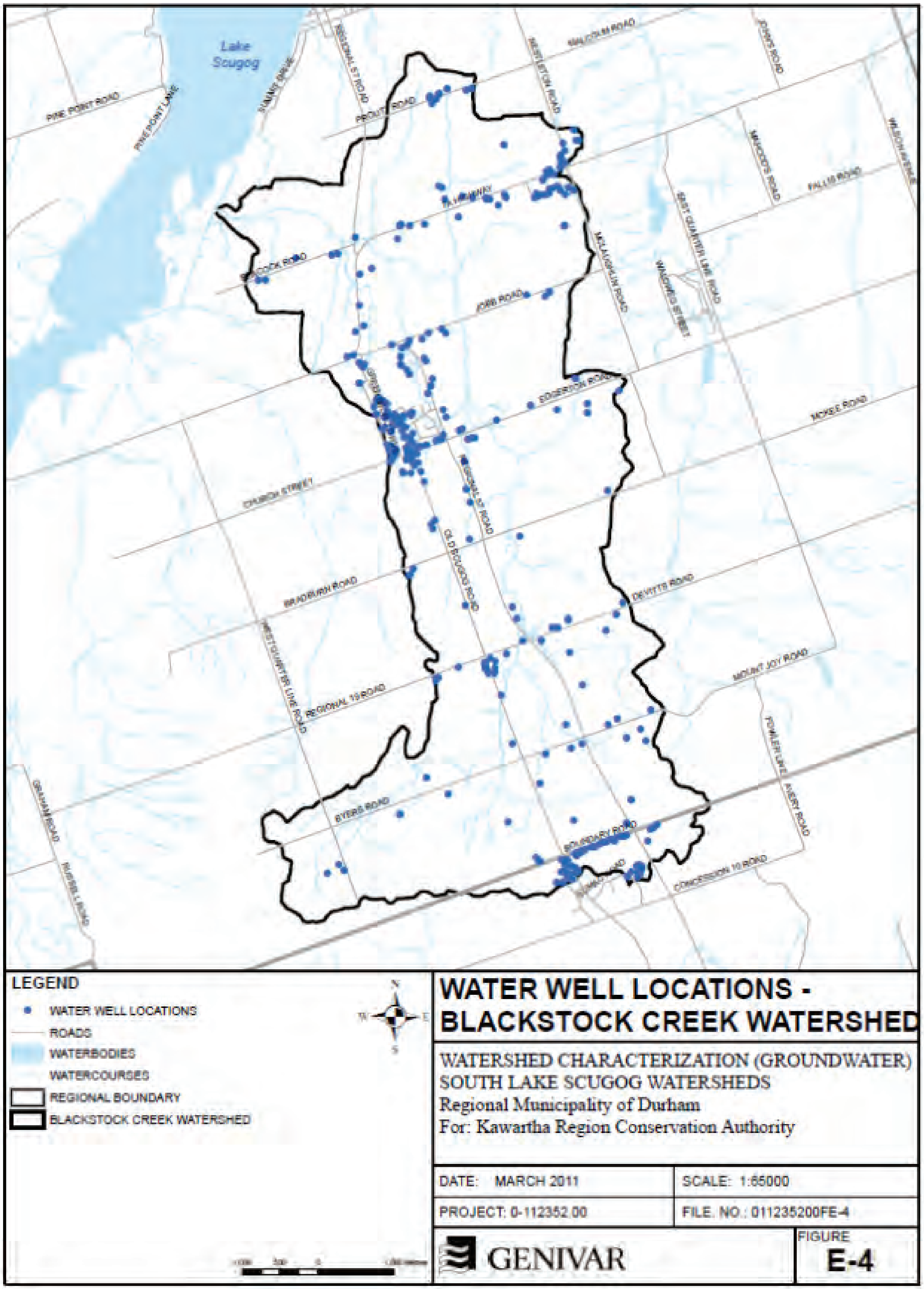


Figure 5.2: Water well locations.

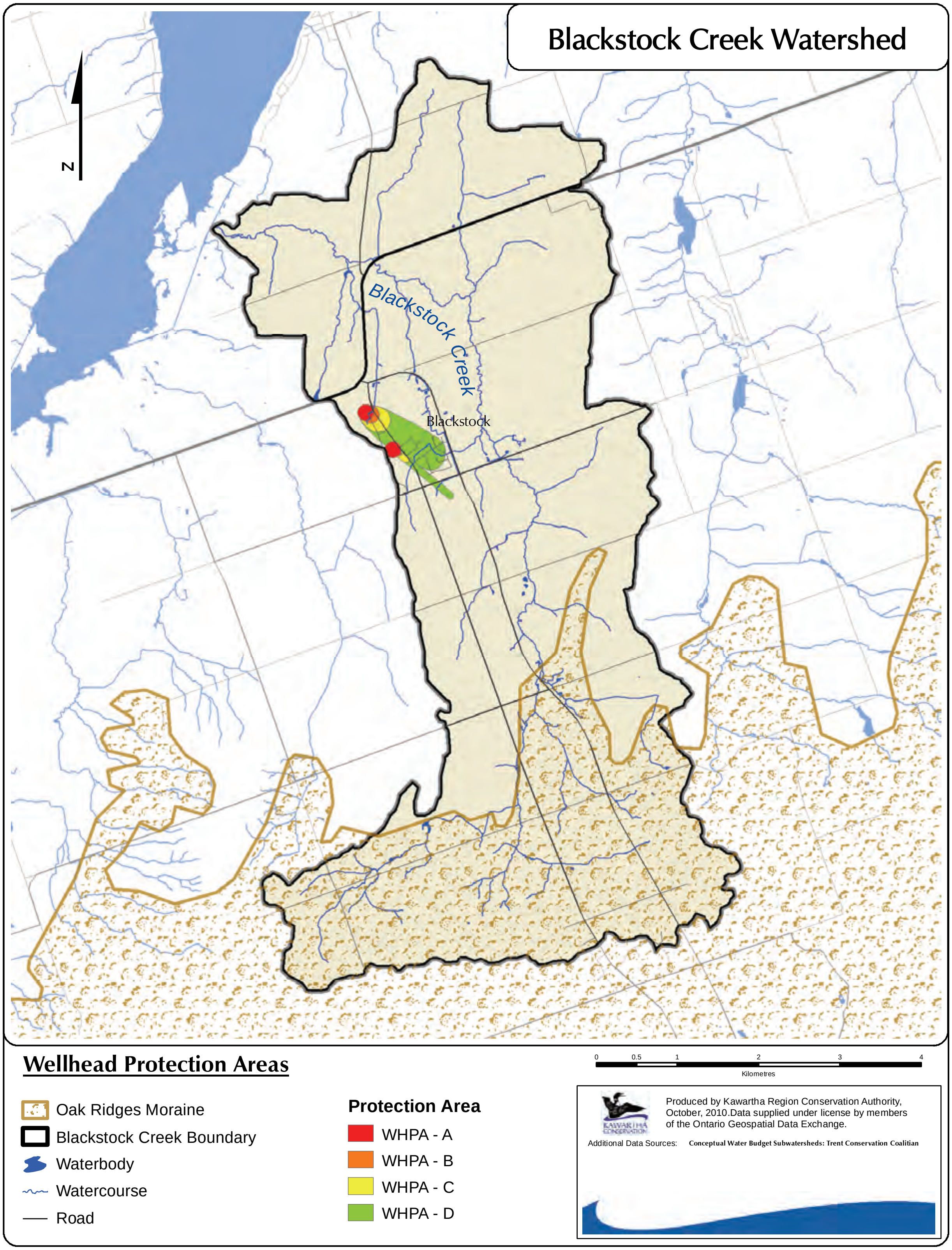


Figure 5.3: Municipal drinking water systems.

6.0 Water Quantity

Blackstock Creek, north of Byers Road

6.1 Introduction

Water quantity refers to components of the hydrological cycle that move overland and within streams, wetlands and lakes (surface water), and that are present below the earth's surface (groundwater). The physical features of the Blackstock Creek watershed, including drainage area, topography, geology, and land and water use, influence the distribution of water and thus the hydrological and ecological processes within the watershed.

6.2 Drainage Network

The Blackstock Creek watershed has a drainage area of 37.9km^2, and contains approximately 60.2km of flowing watercourses. Much of the waters originate in the southern portion of the watershed, where the Oak Ridges Moraine provides constant groundwater inputs into the system. Blackstock Creek generally flow in a northerly direction, turning to the west for the last 3 kilometers before inflowing into one of the dredged channels in the south-east shore of Lake Scugog.

In the upper portion of the watershed, Blackstock Creek and its tributaries are characterized by steep slopes, well-defined channels and narrow floodplains. The average slope of the terrain within this portion is approximately 4.6% and the average gradient of the main channel is 7.3 m/km. In the middle portion of the watershed, Blackstock Creek has a wider floodplain and considerably lower main channel gradient (3.1 m/km). The watershed slopes are not as steep as in upper portion of the watershed, with an average of only 3.14%. The total length of the main channel of Blackstock Creek is approximately 16.5 km, with an average gradient of 5.0m/km.

The Blackstock Creek watershed is highly used for agricultural purposes and as such, many of the watercourses within the watershed flow through, or are drained by, agricultural lands. These have the potential to negatively influence certain aspects of streamflow, such as increasing run-off over tilled soils and altering peak flows. There are small wetland complexes within the centre portion of the watershed, which provide hydrological benefits such as peak flow mitigation and flood storage.

The watershed characteristics of the entire Blackstock Creek watershed, as well as it's portion that lies within the Oak Ridges Moraine, are shown in **Table 6.1**.

Table 6.1: Watercourse and watershed characteristics.

Watershed/ Catchment Name	Drainage Area (km^2)	Stream Network Length (km)	Main Channel Length (km)	Main Channel Gradient (m/km)	Natural Cover (%)	Agriculture (%)	Urban Development (%)
Blackstock Creek	37.9	60.2	16.5	5.0	28.4	61.1	4.9
Blackstock Creek within the ORM	11.9	21.2	-	-	37.0	51.6	0.0

6.3 Surface Water Flow

Surface water quantity (volume of available water in watercourses and water bodies) assessments are usually achieved through flow and water level monitoring. Data that are collected assist in identifying changes that may affect the aquatic health, geomorphic stability and water quality of a watercourse as well as providing invaluable data for modeling of water resources, water budget calculation, and water use. Changes in flow conditions may reflect changes in climate (precipitation, evapotranspiration), water demand, land use or natural cover. Water level monitoring data also provide base information for flood forecasting and warning.

Water quantity information has been collected by means of continuous and spot flow monitoring. Continuous monitoring is performed by two gauge stations along the lengths of Blackstock Creek. Both monitoring gauges consist of a sensor that measures water level on a preset interval (30 min) and a data logger that records measured values (**Figure 6.1, Table 6.2**).

The gauge station at McKee Road provides information on flow regime of the upper portion of the Blackstock Creek catchment basin. Station is located downstream of the Oak Ridges Moraine and monitor flow that is generated by 42.6% of the watershed. The station was installed temporarily and was maintained by Kawartha Conservation.

The monitoring location on Reginald Road 57, near Blackstock, is a part of the Environment Canada streamflow monitoring network. It was established in 2005. It is a permanent, pressure transducer type station, located at the downstream portion of the watershed, where Blackstock Creek crosses Regional Road 57. Gauge captures flow that is produced by almost 90% of the watershed's drainage area. Flow data recorded at this location is available starting November 2005. In addition to water levels, air and water temperature are monitored at this location.

In order to convert water levels, that represent heights of water above the sensor, to flow (amount of water that passes through the given transect in one second), a rating curve is developed. Flow and corresponding water levels are measured numerous times at the monitoring location and graphed to develop a rating curve. A wide range of water levels and flow (from the highest to the lowest) are targeted in order to establish reliable relationship. Once the rating curve and an equation, that describes it, are developed, water level values are converted to discharges that characterize water quantity at the gauging location.

An example of a rating curve is shown in **Figure 6.2**. The dashed line demonstrates how the curve can be used to translate the measured water level into a discharge rating.

Since both gauges have a recording length of no more that four years, their data are not satisfactory for the statistic analysis. As such, the conclusions derived from these data should be treated as strictly preliminary. Quality control and quality assurance of the data for the gauge station at McKee Road are maintained by Kawartha Conservation personnel, while Environment Canada – Water Survey Division (EC-WSD) is responsible for controlling the quality of data for the gauge station near Blackstock (at Regional Road 57).

Table 6.2: Continuous flow monitoring stations.

Location	Data Interval	Data Record	Type	Ownership	Drainage Area (km^2)	Natural Cover (%)	Agriculture (%)	Urban Development (%)
At McKee Road	30 min	2006 - 2009	Temporary, pressure transducer	KRCA	16.1	53.7	37.4	1.1
At RR57	1 hour	2005 - present	Permanent, pressure transducer	EC-WSD 02HG003	33.9	29.0	60.4	4.8

Flow Regime

River flow varies over time and space. Floods and low-flow periods occur, sometimes in a predictable seasonal pattern, and sometimes less predictably. Rivers in variable climates tend to have variable flows, and river flows that are groundwater fed tend to have more constant and predictable flows. Flow regime describes the average seasonal flow variability for a particular river and reflects climatic and physiographic conditions in a watershed.

The best way to explore the flow regime of a watercourse is to study its long-term average flow. However, since there is not enough sufficient data to determine average monthly and yearly discharges, monthly flows for gauging locations on the Blackstock Creek as observed in 2007 and 2008 are used for interpretation. They are graphed at **Figure 6.3** and **Figure 6.4**.

It is seen from the graph that values of monthly flow increase from McKee Road to the gauging site near Blackstock for the most part of the year, for both years. It is a result of increase in drainage area that contributes to the flow. For example, the maximum monthly flow observed at McKee Road monitoring location is 0.348 m^3/sec in April of 2008, for location near Blackstock it is 1.185 m^3/sec.

These data confirm that Blackstock Creek has a well-defined seasonal pattern along its length, reflecting seasonal variations of water inflow. The highest flows were observed in March (2007) and April (2008), caused by a spring freshet. However, during the recent years, increases of water levels and flows as a result of winter thaws that occur in December-February, accompanied by abundant rain, are resulting in a change in the flow regime. High water levels, caused by mid-winter thaw events, have reached values that are comparable to those of the spring freshet on a number of occasions (December 26-28 2008, February 12-14 2009). It is believed, that these anomalies, observed recently, may become more frequent in the future as a result of climate change.

The lowest average monthly flow in 2008 was observed in September for both monitoring locations, when sporadic precipitation and high evapotranspiration rates bring the surface run-off component of stream flow to a minimum. The main source of water supply to the watercourse during that time is groundwater. However, at gauging site near Blackstock, the lowest discharge in 2007 was recorded in February when groundwater is the only source of water to the streams as well.

Water levels start gradually increasing in October and keep rising in November-December, responding to higher precipitation volumes and lower rates of evapotranspiration. During the winter months (December-February), ice cover establishes on the Blackstock Creek and its tributaries. However, it has been observed that the upper reaches of the creek remain open longer than the lower reaches and freeze up only when temperature falls below -10° C. It is a clear evidence that the groundwater component is very significant for Blackstock Creek, especially at the headwaters portion of the watershed. In winter months, groundwater is the only source of water supply to the river system. Abundance of groundwater inflow that is characterized by higher and more steady temperature keeps watercourse open longer.

Climate data demonstrate that precipitation amount in 2007 was below the normal, so 2007 is considered as a 'dry' year; and two consequent years were 'wet' years when recorded amounts of precipitation were above long-term average. The difference in precipitation is clearly reflected by monthly average flow values for both monitoring locations. The values of monthly average discharges in 2007 are considerably lower than they were in 2008 for both monitoring locations. The difference in flow values during the spring freshet (March-April) and low flow summer period, was about 200-250% for both sites.

<u>High and Low Flows</u>

The highest flows on Blackstock Creek typically take place in springtime as a result of the melting of snow that is sometimes accompanied by rain. The spring snowmelt and rain combination frequently results in very high water levels that can cause flooding of low-lying areas, areas with insufficient drainage, or road crossings that can become barriers to flow. Although no significant flood damage has occurred within the Blackstock Creek watershed, there several locations throughout the watershed that can be considered prone for road overtopping and washouts. Areas susceptible to this kind of situation should be monitored closely. Flooding and flood vulnerable areas are discussed further in this chapter.

Table 6.3 contains all available data on highest and lowest instantaneous discharge, and daily discharges for monitoring locations on Blackstock Creek. The data show that eleven high water events out of twelve analyzed (92%) occurred in late March-early April and one (8%), in December. Therefore, all yearly highest water recorded to this date, have resulted from snowmelt, sometimes combined with a rain event. As it was noted earlier, the lowest average monthly flow is generally observed during August-September. However, minimum daily flow occurs as early as July 7th. Sometimes summer storms interrupt the pattern, causing water levels in Blackstock Creek to increase, as it happened in 2008.

Baseflow index was calculated as a part of baseflow separation analysis that was performed for both monitoring locations on Blackstock Creek (**Table 6.4**). The baseflow index indicates proportion of baseflow in the total runoff of a catchment and describes the influence of watershed's geology and soils on river flows. It varies between 0 and 1, indicating the range of conditions from an absence of the groundwater inflow to fully groundwater fed watercourses, respectively.

Results of analysis show that baseflow makes up more than 68 % of the total flow at the gauge at McKee Road, as it was recorded in 2007, 'dry', year. At the gauge station location at Regional Road 57, on average 56% of total flow comes from baseflow, ranging from 59% in 2007 to 53 % in 2009 (2009 is characterized by higher than normal amount of precipitation). Therefore, it demonstrates that proportion of groundwater in streamflow is higher in upper reaches of the watercourse comparing to its lower reaches.

Table 6.3: Maximum and minimum discharge at monitoring locations.

Year	Maximum instantaneous discharge		Maximum daily discharge		Minimum daily discharge	
	m^3/sec	Date	m^3/sec	Date	m^3/sec	Date
Blackstock Creek at McKee Road						
2007	0.967	14/03	0.893	14/03	0.005	23/09
2008	1.283	1/04	1.089	1/04	0.021	7/07
Blackstock Creek at Regional Road 57						
2006	6.23	12/03	3.53	10/03	0.032	13/08
2007	5.23	14/03	3.07	14/03	0.027	17/08
2008	5.74	28/12	6.52	1/04	0.046	19/07
2009	6.61	3/04	4.16	4/04	0.082	22/07

Table 6.4: Baseflow Indexes.

Year	2007	2008	2009	Average
Blackstock Creek at McKee Road	--	0.680	0.61	--
Blackstock Creek at Regional Road 57	0.57	0.59	0.53	0.56

Flow Duration

A flow-duration curve represents the relationship between the magnitude and frequency of daily, weekly, monthly (or some other time interval of) streamflow for a particular watershed. This provides an estimate of the percentage of time a given streamflow was equaled or exceeded over the monitoring period. Applications of flow duration curves include, but are not limited to, water control structure design, hydropower planning, water-quality management, river and reservoir sedimentation studies, habitat suitability, and low-flow augmentation (Vogel and Fennessey 1994). Although flow duration curves have a long and rich history in the field of hydrology, they are sometimes criticized because, traditionally, their interpretation depends on the particular period of record on which they are based.

The shape of a flow duration curve in its upper and lower portions is particularly significant in evaluating watercourse and catchment characteristics. The shape of the curve in the high-flow portion indicates the type of flood regime the basin is likely to have, whereas the shape of the low-flow region characterizes the ability of the basin to sustain low flows during dry seasons. A very steep curve (high flows for short periods) would be expected for rain-caused floods on small watersheds. Snowmelt floods, which last for several days, or regulation of floods with reservoir storage, will generally result in a much flatter curve near the upper limit. In the low-flow portion, an intermittent stream would exhibit periods of no flow, whereas, a very flat curve indicates that flows are sustained throughout the year due to natural or artificial streamflow regulation, or due to a large groundwater capacity which sustains the base flow to the stream.

Some researchers separate flow duration curves into the following zones (Cleland 2003):

- high flows zone includes flow which probability is less than 10%;
- moist conditions are characterized by flow within 10-40 % probability interval;
- mid-range flows zone includes probability of 40-60 %;
- dry conditions zone of flow are described by flows of 60-90 % of probability; and,
- low flow zone includes flows that happen in more than 90 %.

Figure 6.5 shows the semi-log plot of flow duration curves for monitoring locations on Blackstock Creek at McKee Road and Regional Road 57. **Figure 6.6** and **Figure 6.7** show the flow duration curves whereas **Table 6.5** contains the flow values that correspond to the probabilities.

Both monitoring locations have fairly steep high flow portions of the flow duration curves, which suggests that high flows are typically driven by rain or/and quick snow-melting events. The lower portions of the curves are slightly different. Blackstock Creek at Regional Road 57 monitoring location is described by flatter curve that confirms existence of storage within the drainage area that moderates flows. As location at McKee Road describes the headwaters area of Blackstock Creek where the storage capacity is usually limited, the lower portion of the flow duration curve is steeper.

Table 6.5: Flow values as per probability gradation for monitoring locations.

	Discharge of certain probabilities (m^3/sec)				
	High flows <10 %	**Moist conditions 10-40 %**	**Mid-range flows 40-60 %**	**Dry conditions 60-90 %**	**Low flow >90 %**
Blackstock Creek at McKee Road	> 0.260	0.260-0.107	0.107-0.075	0.075-0.028	<0.028
Blackstock Creek at Regional Road 57	>0.740	0.740-0.698	0.698-0.145	0.145-0.058	<0.058

<u>Flood Vulnerable Areas</u>

Extreme weather events such as heavy rainfall and snowmelt can result in dangerous flood conditions, erosion and slope failure. The most common occurrences of flooding within the watershed are during the spring freshet and mid-winter rain events that occur when drainage channels and rivers are blocked by snow and ice. Severe flooding conditions can threaten property and humans. Kawartha Conservation maintains a database of the potential and observed flood prone areas within the watershed as a part of the Flood Forecasting and Warning Program. To this date there are no records of observed flooding sites within the Blackstock Creek subwatershed, but some locations could be considered as potential.

6.4 Baseflow

Baseflow is the portion of flow in a watercourse that comes from groundwater discharge or seepage, rather than direct runoff related to rain or snowmelt events. During most of the year, stream flow is composed of both groundwater discharge and surface runoff. Baseflow conditions are deemed to exist when groundwater provides the entire flow of a stream. When evaluating the health of a watercourse, baseflow is an important characteristic. In terms of aquatic life, one of the most important factors is the amount of sustainable flow in the channel. Streams with adequate baseflow can support fish and aquatic organisms during prolonged dry periods. Furthermore, groundwater temperatures are nearly uniform year-round, so groundwater discharge provides insight into temperature stability in surface water.

Natural land cover plays an important role in recharging aquifers and hence sustaining baseflow. Human activities such as urbanization, wetland drainage, deforestation, and an increase in impervious surfaces within a watershed can significantly affect recharge to groundwater and subsequently, baseflow conditions.

Baseflow monitoring provides baseline data and long-term trends of baseflow rates throughout the watershed. Monitoring also allows for the determination of the spatial distribution of baseflow, including areas and stream reaches of significant groundwater discharge.

Methodology

Baseflow monitoring involves measuring the discharge (volume of water that flows through a cross section of a watercourse in one second) at designated locations during prolonged periods of dry weather. In general, the sample sites were located at every stream-roadside crossing.

Criteria for site selection include:

- Accessibility – preference was given to easily accessible, public sites;
- Hydrological features – it is important to locate sites upstream and downstream of the confluence of tributaries, and suggested groundwater discharge areas etc; and,
- Water use features – upstream and downstream of water taking or discharge locations.

Baseflow sampling was conducted following standardized procedures outlined in Hinton (2005). Two flow measurement techniques were utilized: the area-velocity method and volumetric method. In the area-velocity method, stream velocity and water depth measurements are taken along a transect perpendicular to the stream flow direction. Total discharge is calculated by integrating the stream velocities with the cross sectional area of the stream profile defined by the transect. The volumetric method involves measuring the amount of time taken for a container of known capacity to be filled. This is a simple method for measuring small streams where all of the flow is concentrated and a container can be filled in a reasonable amount of time. Stream discharge is calculated by dividing the total volume of water by the amount of time required to fill the container.

Weather conditions may pose significant limitations to baseflow measurements. In order to collect comparable and reliable data, the measurements were taken under consistent groundwater inflow conditions (i.e., the volume of groundwater storage did not experience significant change). The summers of 2008 and 2009, with abundant precipitation, did not allow for the collection of quality baseflow data.

Findings and conclusions

The best baseflow dataset for the Blackstock Creek watershed was obtained during the summer of 2006. In total, 22 sites throughout the watershed were visited during July 19-20, 2006. No precipitation was recorded over these 2 days, allowing for comparison and analysis of spot measurements to interpret the spatial distribution of baseflow. Eighteen sites were found flowing and measurements were taken. Four sites were found dry or with standing water in the channel, indicating that no groundwater inflow is available upstream of the sampling location (**Table 6.6**). The values of flow and positions of the monitoring sites as well as overall status of the watercourse reach (loosing or gaining) are shown in the flow diagram (**Figure 6.8**). Further data analysis involves the calculation of net discharges at every measuring point and net discharges per a square kilometer (**Figure 6.9**).

Data collected during the baseflow survey have been used to illustrate the magnitude and distribution of baseflow discharge within the Blackstock Creek subwatershed. Baseflow analysis has revealed that:

- The southeastern portion of the watershed (northeast of the intersection of Byers Road and Old Scugog Road) is an important groundwater discharge area for the Blackstock Creek watershed.
- The highest net baseflow value within the Blackstock Creek watershed (over 14 l/sec/km^2) was measured in the Blackstock Tributary at Bradburn Road and was produced by a small area 0.65 km^2.
- The area north of McKee Road/Bradburn Road) is characterized by low groundwater discharge values, less that 2 l/sec/km^2. This portion of the watershed contains considerable wetlands area and natural factors such as evapotranspiration and water storage may be contributing to low measured discharge rates.
- The portion of the Blackstock Creek watershed located at the Oak Ridges Moraine is represented by low discharge rates as well.

Table 6.6: Baseflow monitoring sites 2006.

	Number of baseflow sites			
	Flowing		Dry / Standing Water	Total
	Measured	Unsuitable		
Blackstock Creek	18	0	4	22

6.5 Groundwater Characterization

The information presented in this section is taken from the executive summary from a report by GENIVAR (2011), that was recently completed for Kawartha Conservation to characterize groundwater resources within the Blackstock Creek watershed, as well as the other three watersheds (Southern Lake Scugog Tributaries, Nonquon River and East Cross Creek) that require watershed plans. Surficial geology plays an important role in the regional drainage and recharge patterns of the Blackstock Creek watershed. Normally, higher infiltration rates can be observed in the coarse grained deposits associated with the Moraine, as these deposits exhibit a higher permeability. Additionally, some of the geological units that underlie the watershed are partially or completely saturated with groundwater. The characterization presented herein is based on review of work performed by others with some additional interpretation and analysis using available data and tools.

Hydrostratigraphy

The stratigraphy and hydrostratigraphy presented herein has been based on interpretations provided by the Conservation Authorities Moraine Coalition/York-Peel-Durham-Toronto groundwater studies. This interpretation documents an inter-layered sequence of sedimentary deposits that are considered to be aquifers and silt, clay and till deposits that are considered to be aquitards. Groundwater flow in aquifers tends to be directed horizontally, while groundwater flow through aquitards tends to be directed vertically.

The general distribution and characteristics of each aquifer layer are described by a series of figures and maps for the watershed. **Figure 6.10** shows the locations of two representative cross-sections are provided for each subwatershed to show how the layers interrelate. **Figure 6.11** and **Figure 6.12** show these hydrostratigraphic layers.

The observed hydrostratigraphic layers observed from the surface to the bedrock at depth include:

- Layer 1 - Recent Deposits;
- Layer 2 - Late Stage Lacustrine/Halton Aquitard;
- Layer 3 - Oak Ridges Moraine Aquifer Complex (ORAC);
- Layer 4 - Upper Newmarket Aquitard;
- Layer 5 - Inter-Newmarket Sediments (INS) [Aquifer];
- Layer 6 - Lower Newmarket Aquitard or Tunnel Channel Silts;
- Layer 7 - Thorncliffe Aquifer Complex (TAC) or Tunnel Channel Sands;
- Layer 8 - Sunnybrook Aquitard;
- Layer 9 - Scarborough Aquifer Complex (SAC); and
- Layer 10 – Bedrock [Aquifer].

The *Oak Ridges Moraine Aquifer Complex* (ORAC) is a significant aquifer layer, particularly in the southern parts of each watershed. This layer is typically observed as a wedge that is thickest along the center of the Oak Ridges Moraine and thins north. This layer is not continuous across the watersheds. This layer is important hydrogeologically as it receives much of the groundwater recharge that then either flows to surface water, laterally through the edges of the watershed, or downward to another aquifer layer.

The lower portion of the *Newmarket Aquitard* is laterally extensive and represents the glacial till deposit associated with the main advance of the last glacial period. The upper portion of the Newmarket Aquitard and the layer of interpreted sediments deposited between the two till events are not continuous across the entire area. This may mean that they were either not deposited or removed by erosion prior to deposition of the ORAC deposits.

The Newmarket Aquitard is observed to have been partly removed by a series of channels that have subsequently been filled first with coarse sand and toward the top finer sand and silt. These channels have been interpreted as having formed beneath the ice sheets and are therefore referred to as “tunnel channels”. These tunnel channels can have a significant role in the hydrogeological setting as they provide a conduit for lateral groundwater movement along their predominantly northeast orientation, or for groundwater movement up and down between the surface and deeper aquifer layers.

The *Thorncliffe Aquifer Complex* (TAC) is observed to be an important aquifer layer in the groundwater flow system. The TAC has been interpreted to be laterally extensive in the subsurface beneath the study area. Groundwater recharge from surface is observed to infiltrate downward to the TAC and then move laterally in conjunction with the regional drainage pattern. Groundwater flow then moves from the TAC upwards to surface beneath the observed surface water drainage features (streams, wetlands, etc). Groundwater can also move laterally between the north draining watersheds, and potentially to the south beneath the Oak Ridges Moraine.

The *Scarborough Aquifer Complex* (SAC) and the upper portion of the bedrock are typically considered to behave as one aquifer layer. This layer is also interpreted to be laterally extensive although there is considerably less information available on which to base these interpretations. The work has shown that in general the movement of groundwater in the groundwater flow system generally follows the regional ground surface topography. There is evidence presented that the flow divide within individual aquifer layers may not always correspond to the surface watershed divide. This is observed most notably along the Oak Ridges Moraine where a combination of conditions relating to the soil types and stratigraphic layers appears to result in groundwater flow being directed in a southerly direction from areas north of the surface watershed divide. The current numerical model suggests that the contribution of groundwater flow to the south draining watersheds may be significant. Further work is required to improve the confidence in this interpretation and to quantify the flux of water being directed to the South.

<u>Regional groundwater flow model</u>

A regional groundwater flow model previously constructed for use by Conservation Authorities Conservation Authorities Moraine Coalition/York-Peel-Durham-Toronto groundwater management strategy provided and adapted for use in evaluating the flux of groundwater movement and water budgets within the individual watersheds. Groundwater flow is typically directed in a northerly direction from the Oak Ridges Moraine towards Lake Scugog. The majority of recharge is directed downward to the Thorncliffe Aquifer Complex. Although the groundwater flow tends to be directed downward overall, groundwater moves both up and down between each of the identified hydrostratigraphic/model layers. The upward movement of groundwater tends to occur adjacent to and beneath streams and surface water features. There is a net downward movement of groundwater below the Thorncliffe Aquifer Complex, however the flux is a small proportion of the recharge that moves down to the lower overburden layers and bedrock (<1% of recharge). Additional work will be required to improve the ability of the models to estimate the flux across the north and south boundaries.

<u>Simulated Water Budget – Blackstock Creek Watershed</u>

The findings presented herein reflect interpretations and results of numerical model applications that are based on available data. The distribution, quantity, and quality of the available data to describe geology, hydraulic properties and groundwater elevations is variable. The interpretative studies and models are also being conducted on a regional scale and as such, it is not unusual that model results do not directly correspond with local data. This study has identified several attributes of the conceptual and numerical models that could potentially be improved but considerable effort may be required to balance the effects of changes of competing factors. The results presented herein are considered to be based on the currently best available tools and may change as more data becomes available or the capacity of these tools improves.

The findings of the water budget analysis are summarized in **Table 6.7**. The numerical groundwater flow model as described in GENIVAR (2011) was applied to quantify the components of the water budget equation for the Blackstock Creek watershed. The results of this analysis are summarized in **Figure 6.13**.

Figure 6.13 illustrates the flow into and out of each of the hydrostratigraphic layers considered in the numerical groundwater flow model. Flow in typically occurs through recharge, recharge in the streams, or lateral transfers from adjacent watersheds. Lateral transfers were quantified separately for flow to and from the adjacent South Lake Scugog Tributaries Area and East Cross Creek watersheds. The lateral transfers from watersheds on the north and south sides of the Blackstock Creek watershed are presented as one value.

Some observations drawn from analysis of include:

- Recharge from infiltration is primarily received in the two upper hydrostratigraphic layers (Surficial/Weathered Till/Halton Till). Recharge accounts for 69% of the input to the groundwater flow system. Lateral inflow from adjacent watersheds accounts for 31% of the total inputs.

- Net groundwater flux appears to be downward from surface to the Thorncliffe Aquifer Complex.

- There is minor potential for downward flux of groundwater below the Thorncliffe Aquifer Complex. This flux is observed to be transferred laterally out of the system in the Scarborough Aquifer Complex and weathered bedrock layer.

- The quantity of water transferred downward to each underlying layer decreases with increasing depth.

- The majority of the discharge to streams occurs through the Thorncliffe Formation. Discharge to streams accounts for approximately 6% of the flow out of the groundwater flow system.

- Lateral outflow accounts for approximately 94% of the flow out of the groundwater system. There is a net inflow from the East Cross watershed of 1,853 m^3/day. There is a net outflow of 10,210 m^3/day to the Southern Lake Scugog Tributaries watershed. The net lateral outflow to either the north or the south is 14,119 m^3/day. The lateral transfer is primarily within the Oak Ridges Moraine Aquifer Complex, Thorncliffe Aquifer Complex, and Scarborough Aquifer Complex layers. The majority of the lateral outflow is directed to the south.

- The total permitted groundwater taking is approximately 6% of the estimated recharge to the groundwater system and less than 3% of the total input or output from the groundwater flow system. At this time, this reflects the total potential capacity of the municipal water supply for the Hamlet of Blackstock. The permitted water taking rate for municipal supplies are designed to be higher than observed use yet to provide capacity for future and emergency demand. The removal of groundwater from aquifers as water taking would result in a reduction to either the discharge to streams or lateral outflow. The groundwater from municipal takings will ultimately be returned to the surface water system following treatment.

- The observed groundwater taking from the municipal wells for the Hamlet of Blackstock in 2007 was observed to be less than 0.4% of the estimated recharge to the groundwater system and approximately 0.6% of the total input or output from the groundwater flow system. The groundwater from municipal takings will ultimately be returned to the subsurface or to the surface water system after treatment.

- The total groundwater use for residential purposes by the private water wells is less than 2% of the estimated recharge to the groundwater system and less than 1% of the total input or output from the groundwater flow system. The use of water from private wells is typically non-consumptive and water is returned as recharge to shallow aquifer units.

Table 6.7: Summary of groundwater budget analysis.

Item	Units	Nonquon River Watershed		South Lake Scugog Tributaries Area Watershed		Blackstock Creek Watershed		East Cross Creek Watershed		Total Study Area	
		Value	%	Value	%	Value	%	Value	%	Value	%
Watershed Area	km²	194.43		84.96		37.87		78.85		396.11	
	m²	1.9E+08		8.5E+07		3.8E+07		7.9E+07		4.0E+08	
Oak Ridges Moraine Planning Area	km²	27.85	14.3%	19.32	22.7%	11.93	31.5%	32.25	40.9%	91.35	23.1%
	m²	2.8E+07		1.9E+07		1.2E+07		3.2E+07		9.1E+07	
Water Budget											
Inputs:											
Recharge	m³/day	82,632	74.5%	34,498	60.1%	18,804	52.3%	50,882	62.2%	186,816	65.3%
Stream Recharge	m³/day	761	0.7%	2,447	4.3%	5,964	16.6%	0	0.0%	9,172	3.2%
Lateral Inflow (Adjacent)	m³/day	253	0.2%	15,022	26.2%	9,294	25.8%	3,768	4.6%	28,336	9.9%
Lateral Inflow (Other)	m³/day	27,210	24.5%	5,407	9.4%	1,916	5.3%	27,202	33.2%	61,736	21.6%
Total Input	**m³/day**	**110,856**	**100.0%**	**57,374**	**100.0%**	**35,979**	**100.0%**	**81,852**	**100.0%**	**286,061**	**100.0%**
Outputs:											
Discharge to Stream	m³/day	70,220	63.3%	22,000	38.3%	2,289	6.4%	33,843	41.3%	128,351	44.9%
Discharge to Lake Scugog	m³/day	492	0.4%	3,309	5.8%	0	0.0%	0	0.0%	3,801	1.3%
Lateral Outflow (Adjacent)	m³/day	1,120	1.0%	3,935	6.9%	17,651	49.1%	5,622	6.9%	28,327	9.9%
Lateral Outflow (Other)	m³/day	39,028	35.2%	28,135	49.0%	16,035	44.6%	42,384	51.8%	125,583	43.9%
Total Outflow	**m³/day**	**110,861**	**100.0%**	**57,378**	**100.0%**	**35,975**	**100.0%**	**81,849**	**100.0%**	**286,063**	**100.0%**
Groundwater Use:											
Total Permitted Water Taking	m³/day	1,406	1.3%	9,164	16.0%	2,160	6.0%	2,177	2.7%	14,907	5.2%
Municipal Permitted Water Taking	m³/day	865	0.8%	9,164	16.0%	2,160	6.0%	0	0.0%	12,189	4.3%
Municipal Average Water Taking - Durham Region Wells (2007)	m³/day	131	0.1%	2,667	4.6%	139	0.4%	0	0.0%	2,937	1.0%
Private Well Taking (Estimate)	m³/day	858	0.8%	275	0.5%	306	0.9%	261	0.3%	1,700	0.6%
Total Estimated Groundwater Taking	**m³/day**	**1,312**	**1.2%**	**2,942**	**5.1%**	**445**	**1.2%**	**2,438**	**3.0%**	**7,137**	**2.5%**

Note:
1. Total Permitted Water Taking represents total quantity of groundwater that can be removed on a daily basis under authority of a Permit To Take Water issued by the Ontario Ministry of the Environment.
2. The Total Estimated Water Taking reflects the average municipal water taking for 2007 plus Private Well Taking Except as specified below.
3. The Total Estimated Water Taking for the Nonquon River Watershed considers the Permitted Water Taking rate for municipal residential systems in the City of Kawartha Lakes and Permits issued for non-municipal use plus the average water taking by the Regional Municipality of Durham and the Private Well Taking.
4. The Total Estimated Water Taking for the East Cross Creek Watershed considers the Total Permitted Water Taking rate for private Permits plus the Private Well Taking.

From GENIVAR (2011)

Recharge Flux – Blackstock Creek Watershed

Groundwater recharge is the process by which aquifers are replenished by the downward movement of water. The process occurs as water seeps vertically through unsaturated soils until it reaches a saturated layer or aquifer. Land surface characteristics play an important role in recharging aquifers and hence sustaining baseflow. Human activities such as urbanization, wetland drainage, deforestation and an increase in impervious surfaces can significantly affect this fragile balance and greatly affect groundwater quality and ecosystem health.

The total recharge to groundwater estimated for the Blackstock Creek watershed is 82,632 m^3/day. **Figure 6.14** illustrates the distribution of recharge to the groundwater system as obtained from the numerical groundwater flow model. The recharge was estimated by Earthfx (2009).

The spatial patterns of recharge correlate with the distribution of coarse and fine-grained sediments. The average recharge over much of the area is on the order of 90 mm/year. Recharge flux is higher in areas underlain by coarser sand and gravel deposits and low in areas underlain by low permeability silts and clays or glacial till. The recharge is observed to be highest in the south in association with the Oak Ridges Moraine. The observed recharge can be up to five (5) times the average values. The relative proportion of total groundwater recharge will be higher in the southern areas associated with the Oak Ridges Moraine.

In addition to the analyses provided by GENIVAR, groundwater recharge areas were assessed by a joint project of the Conservation Authorities Moraine Coalition (CAMC) and the municipalities of York, Peel, Durham and Toronto (YPDT) to fulfill the requirements of the *Clean Water Act*. The following is a summary of the CAMC-YPDT (2009) report.

Significant recharge areas were delineated by calculating a threshold rate above which an area would be considered a significant groundwater recharge area and comparing the recharge rates estimated across the Trent Conservation Coalition source protection region to this threshold value. In accordance with the Technical Rules (OMOE 2009a), this threshold value was calculated at 55% of the water budget surplus for each determined climate zone. Also, areas with shallow groundwater (water table less than 2 metres below the ground surface) were removed from the analysis because any recharge occurring within these low-lying areas is expected to would move laterally and discharge into adjacent streams and wetlands. The final delineation of significant groundwater recharge areas is shown in **Figure 6.15**.

Discharge Flux to Surface Water – Blackstock Creek Watershed

The total discharge to surface water within the Blackstock Creek watershed is calculated to 2,289 m^3/day. based on the numerical model outputs. The numerical model is considered to represent the average of observed baseflow measurements reasonably well but locally calculated measurements can be either higher or lower than the observed baseflow values. Baseflow is typically measured during a low flow period and may be less than the annual baseflow rate. There was no flux observed as direct discharge to Lake Scugog. A portion of the lateral transfer of water along the northern boundary of the watershed will likely be transferred directly to Lake Scugog.

Figure 6.16 illustrates the observed distribution of the groundwater discharge to streams within the Blackstock Creek watershed. The grey circles represent locations where the numerical model calculates no flow to the surface water feature under steady-state conditions. Groundwater is observed to discharge to surface water in the down-gradient portions of Blackstock Creek.

Aquifer Vulnerability

As part of the Technical Studies conducted under the *Clean Water Act*, 2006 to protect municipal sources of drinking water, two studies were completed for the Assessment Report to evaluate groundwater vulnerability for the Kawartha Haliburton Source Protection Region, including the Blackstock Creek watershed. The vulnerability assessments were carried out on a well to well basis, within the Wellhead Protection Area delineations to evaluate the immediate risk to contamination that may exist in that area to ensure the protection of the municipal water supply (GENIVAR 2010) and on a regional scale to understand the vulnerability of aquifers outside the delineated areas (AECOM 2009) to address groundwater source protection in areas that are not delineated as municipal Wellhead Protection Areas. The aquifer vulnerability assessment was conducted on a regional scale as part of the science-based Kawartha-Haliburton Assessment Report. The map illustrating the vulnerable areas is shown in **Figure 6.17**.

In addition to the above analyses, GENIVAR prepared vulnerability mapping for each individual aquifer within the Blackstock Creek watershed, as part of the groundwater characterization report (GENIVAR 2011). The regional groundwater vulnerability map, mentioned in the previous paragraph, does not reflect individual aquifer layers and thus is not consistent with the individual maps. Further discussions are ongoing to identify opportunities for consistency and watershed planning applicability.

6.6 Water Budget

A water budget is one of the major tools in describing and quantifying the various components of the hydrological cycle of the watershed. The hydrological cycle describes the constant movement of water above, on, and below the Earth's surface. The cycle operates across all scales, from the smallest stream catchment to a global scale. At all levels the cycle involves the movement of water through evapotranspiration, precipitation, surface runoff, subsurface flow and groundwater pathways (**Figure 6.18**).

Water is evaporated from the land, vegetation and bodies of water such as lakes, seas, and oceans to the atmosphere, using the radiant energy from the sun, and is returned back in the form of rain or snow. When precipitation falls to the ground surface, it becomes subdivided into different interconnected pathways. Precipitation can directly enter surface water or infiltrate into the ground to replenish soil moisture where it can be taken up by plants. Excess water percolates to groundwater aquifers or moves downward to sites of groundwater discharge. The rate of infiltration varies with land use, soil characteristics and the duration and intensity of the rainfall event. If the rate of precipitation exceeds the rate of infiltration the result is overland flow. Water reaching streams, both by surface runoff and groundwater discharge eventually moves to a larger body of water (lake, sea) where it is again evaporated to perpetuate the hydrological cycle.

Water takings from both surface and groundwater sources, as well as water discharges, spatial and temporal alterations of water flow and its regime, and the transfer of water between major watersheds are some of the ways humans influence the hydrological cycle.

<u>Methodology</u>

Since the hydrological cycle is a continuous process, the general water budget may be expressed as an equation, where the sum of water inputs is equal to the sum of water outputs plus changes in storage.

$$\textit{Inputs} = \textit{Outputs} + \textit{Change in storage} \quad (1)$$

When inputs and outputs are separated into components, equation (1) will look as following:

$$P + SWin + GWin + ANTHin = ET + SWout + GWout + ANTHout + \Delta S \quad (2)$$

where:

P = precipitation;
SWin = surface water flow in;
GWin = groundwater flow in;

ANTHin	= human input such as wastewater discharges;
ET	= evaporation and transpiration;
SWout	= surface water flow out;
GWout	= groundwater flow out;
ANTHout	= human removals and abstractions; and,
ΔS	= change in storage.

When only a portion of a watershed is investigated the surface water input (SWin) from upstream sources in the watershed must be measured and accounted for in the water budget. If an entire watershed, subwatershed, or its headwaters portion is investigated, then the surface water input equals zero (SWin =0) and is removed from the calculation. However, groundwater inflow to the watershed still has to be calculated.

The groundwater fluctuation can be expressed as a difference between GWin and GWout (inputs and outputs) and is referred to as GWnet.

Anthropogenic influences such as water use, water removals and discharges can be expressed as ANTHnet, which represents the difference between ANTHin and ANTHout (inputs and outputs). As removals always exceed returning water, the ANTHnet should be placed in the output portion of the equation.

Therefore, equation 2 can be expressed as:

$$P + GWnet = ET + SWout + ANTHnet + \Delta S \quad (3)$$

A long-term water budget requires enough data to statistically determine a mean value, which is typically 25-30 years. For this period of time it is assumed that storage remains the same, thus ΔS will be equal to zero. Over a long period of time in a watershed with no or negligible groundwater pumping, the natural inputs will balance the natural outputs so the change in storage is assumed to be zero (Freeze and Cherry 1979). Soil moisture storage may vary considerably on a daily basis but the net change over an annual cycle and a long-term period will be negligible compared to other water budget components. Similarly, groundwater storage and land surface storage may fluctuate on a monthly or annual basis, but this variation will approach zero over an extended period of time provided other components of the water budget remain essentially constant.

The anthropogenic component (human withdrawals and returns) is considered negligible within the watershed. Therefore, the ANTHnet component of the equation is considered to be zero as well.

Since the area under investigation is the entire Blackstock Creek watershed, SWin is considered to be zero. The SWout component is quantified by discharge values (Q), measured at the Regional Road 57 gauge station. Therefore, the symbol Q will be used further.

Considering the simplifications mentioned above, the water budget equation looks as following:

$$P + GWnet = ET + Q \quad (4)$$

The values for all components cannot be accepted without uncertainty. Hence, as a check on estimated values, it is useful to rearrange the equation to show estimated values and include the term "Residual":

$$P + GWnet - ET - Q = Residual \quad (5)$$

Generally, water budget calculations require the use of long-term data sets. Since not enough data are available to calculate the long-term water budget for the whole watershed, the Canadian Nutrient and Water Evaluation Tool (CANWET) was used to generate the water budget. CANWET is a GIS-based software tool for estimating a water balance and nutrient loading (Greenland 2008).

The model allows consideration of multiple land use categories; each category is assumed to be uniform in distribution and parameters associated with land use. CANWET produces a continuous stream flow simulation using daily weather data and daily water balance. The surface runoff component of streamflow from each land use category is determined based on the Soil Conservation Services curve number approach. The curve number can be adjusted on a monthly basis to reflect variation of runoff characteristics throughout the year. The subsurface component of the streamflow is calculated using linear regression approach and can be adjusted on monthly basis as well.

Using total daily precipitation, daily maximum and minimum temperatures, the model can quantify the following characteristics on a monthly basis for a delineated drainage area: precipitation, evapotranspiration, surface runoff, sub-surface flow, total stream flow, and overall water takings.

Long term, average data for the water budget of the Blackstock Creek were obtained from the following sources:

- Precipitation (P): is the mean annual total precipitation that was obtained from two Environment Canada climate stations in close proximity to the watershed (Blackstock and Burketon McLaughlin) for the period of 1984-2010.

- Net Groundwater value (GWnet): is the difference between lateral groundwater inflow and lateral groundwater outflow to the watershed, as determined by the groundwater modeling exercise by GENIVAR (2011).

- Evapotranspiration (ET): is the mean annual evapotranspiration that was obtained from the output of the Canadian Nutrient and Water Evaluation Tool (CANWET), and reflects physiography, soil type and land use inputs.

- Streamflow (Q): is the mean annual streamflow that was recorded at Regional Road 57, obtained from the Water Survey of Canada database (HYDAT) from 2006-2009.

Findings

All components of the water budget are presented in depth (mm) over the watershed area. The long-term average annual values for the Blackstock Creek watershed are shown in **Table 6.8**.

As data demonstrate, 60% of precipitation that falls on the subwatershed evaporates back to the air from the ground surface or is transpired into the air by vegetation; about 37% of precipitation runs out of the subwatershed as stream flow and approximately 5% leaves the subwatershed as groundwater.

As previous research shows, the groundwater flux is negative for the headwaters of the Oak Ridges Moraines because the groundwater divide, is located further south and does not correspond to the surface water divide. As a result, some groundwater flows out of the Blackstock Creek subwatershed.

Additionally, a long-term monthly water budget was calculated for Blackstock Creek at Regional Road 57 (refer **Table 6.9** and **Figure 6.19**).

Negative values of change in storage (ΔS) in March, April, June, July and August indicate that more water evaporates and flows out of the watershed as streamflow and groundwater than comes into it with precipitation. As a result, there is a deficit in water budget during those months. Alternatively, the rest of the year (May, September through February) is characterized by a surplus of water that accumulates in the watershed. That excess water percolates down the ground surface and replenishes groundwater, and is stored in lakes and wetlands. During months when outputs of water resources to the subwatershed exceed input, the deficit is replenished from water, previously stored.

Table 6.8: Long-term, annual water budget components.

Catchment	Precipitation (mm)	Evapotranspiration (mm)	Groundwater Net (mm)	Surface Water Discharge (mm)	Residual (mm)
Blackstock Creek Watershed	**913**	**544**	**-48**	**339**	**-18**

Table 6.9: Long-term, monthly water budget components.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
P (mm)	67	53	55	75	89	87	81	85	89	76	90	67	**913**
ET (mm)	1	1	13	18	35	95	159	130	68	18	5	1	**544**
GW (mm)	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	-4	**-48**
Q (mm)	30	34	51	61	25	13	16	16	10	25	25	33	**339**
ΔS (mm)	32.3	14.5	-13.9	-7.6	24.6	-24.8	-98.1	-64.8	7.1	28.7	56.2	29.3	**-18**

6.7 Key Observations and Issues

- The watershed exhibits a natural flow regime, with well-defined seasonal flow patterns. High flows typically occur in the spring, associated with snowmelt, and throughout the year following high precipitation events. Low flows are typically observed in the summer and winter months.

- Climate change as it is forecasted has the potential to impact the flow regime of the Blackstock Creek and its tributaries, by reducing duration and intensity of spring runoff and increasing potential for dry conditions and extreme high flow events during the summer.

- Wetlands and forested areas (about 25% of the watershed), mostly located at the ORM portion of the watershed and along the Blackstock Creek valley, provide significant benefits to the surface water, moderating streamflow, providing high and low flow mitigation and assisting in groundwater recharge.

- The watershed contains significant areas where groundwater discharges to the watercourses. Areas of particular significance are located at the middle portion of the watershed. The groundwater discharge supports baseflow and is a main component of the streamflow during the dry periods.

- Significant groundwater recharge areas are located within the Oak Ridges Moraine as well as throughout the watershed. They are extremely important, as groundwater resources are replenished through those areas.

- As regional groundwater model demonstrates, the groundwater divide is likely located to the north of the surface water divide, and as such, portion of groundwater that is recharged in the Oak Ridges Moraine flows south, out of the watershed.

- Groundwater use within the watershed is low, estimated below 2% of total available groundwater resources. Therefore, water withdrawals are not considered a major threat to the resource. Further, groundwater is used for water supply that is considered as non-consumptive usage since it is returned as recharge to shallow aquifers.

- According to the water budget, on the average, Blackstock Creek watershed receives 913 mm of precipitation. Five hundred and forty four millimeters, or 60% of that are returned to the atmosphere through the evaporation and evapotranspiration. Three hundred and thirty nine millimeters (37%) leaves the watershed as stream flow and approximately 48 mm (5%) as groundwater.

- Currently, there are no records of existing flood prone areas within the Blackstock Creek watershed. However, several sites throughout the watershed can be considered potential for adverse effects of high-water situations such as roads overtopping and erosion.

- Some aspects of land use change, such as increasing of impervious surfaces, urban development and agricultural practices can influence the quantity of both surface and groundwater resources.

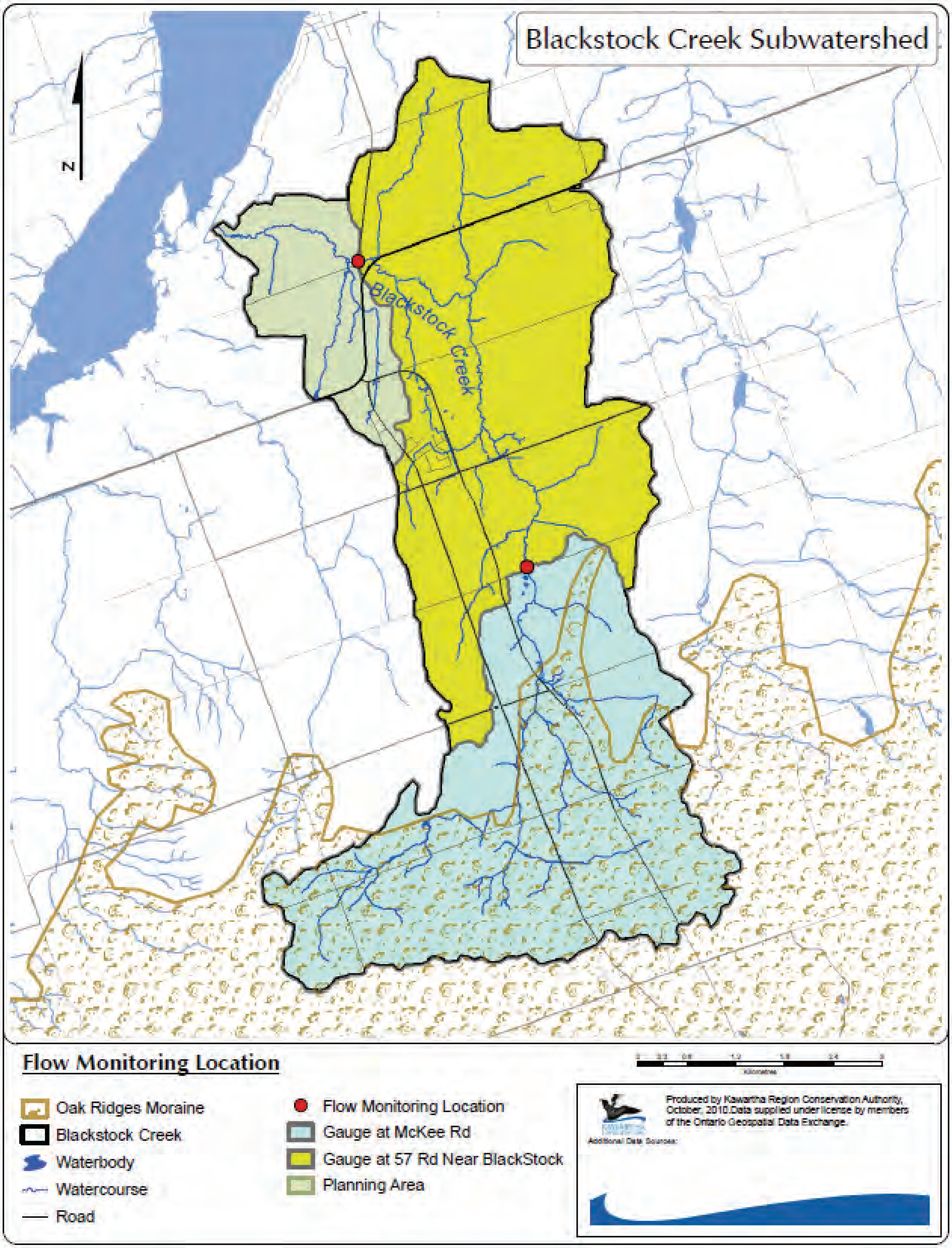


Figure 6.1: Continuous flow monitoring locations.

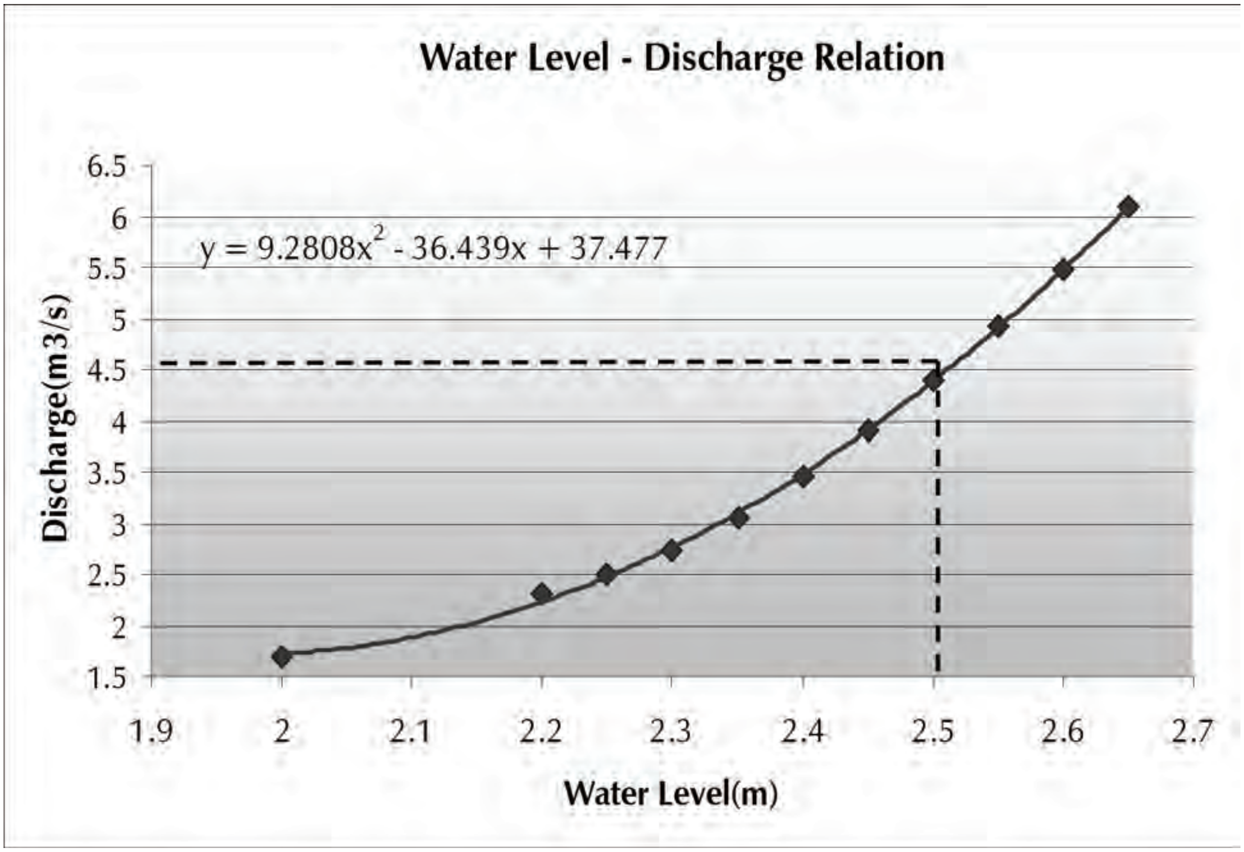


Figure 6.2: Sample rating curve

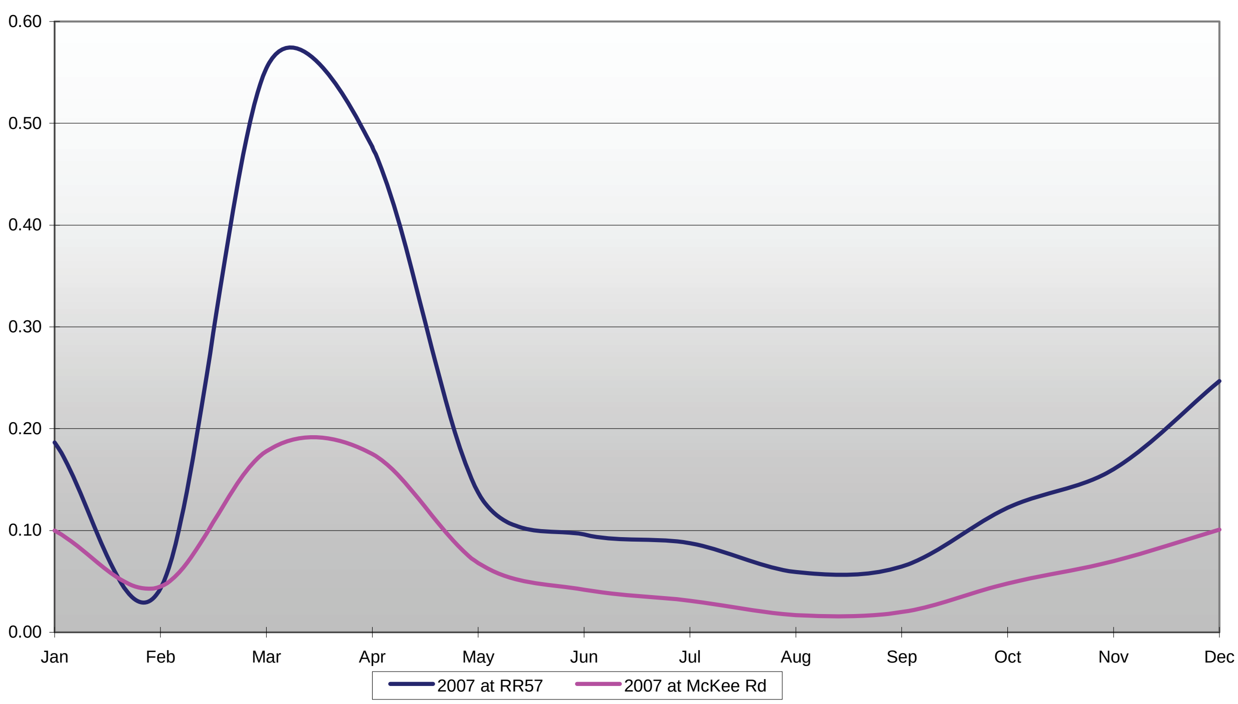


Figure 6.3: Monthly Discharge of Blackstock Creek at McKee Road and near Blackstock monitoring locations, 2007.

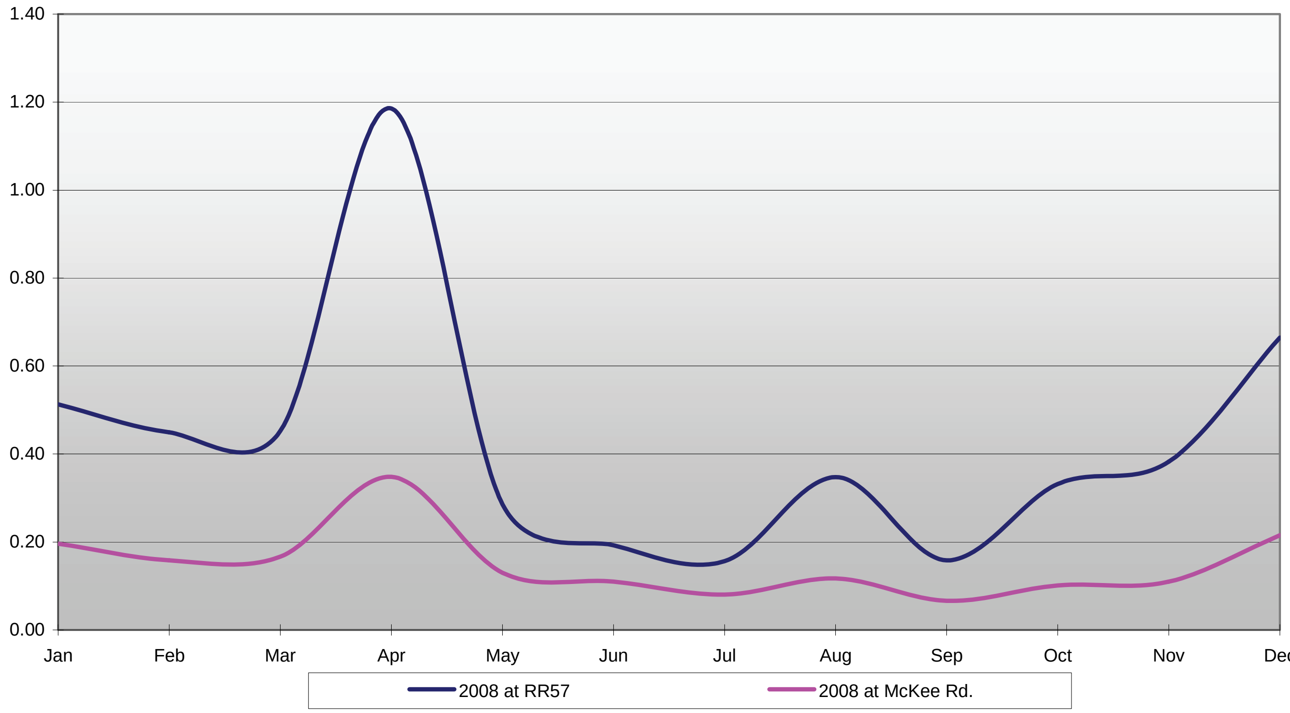


Figure 6.4: Monthly Discharge of Blackstock Creek at McKee Rd and near Blackstock monitoring locations, 2008.

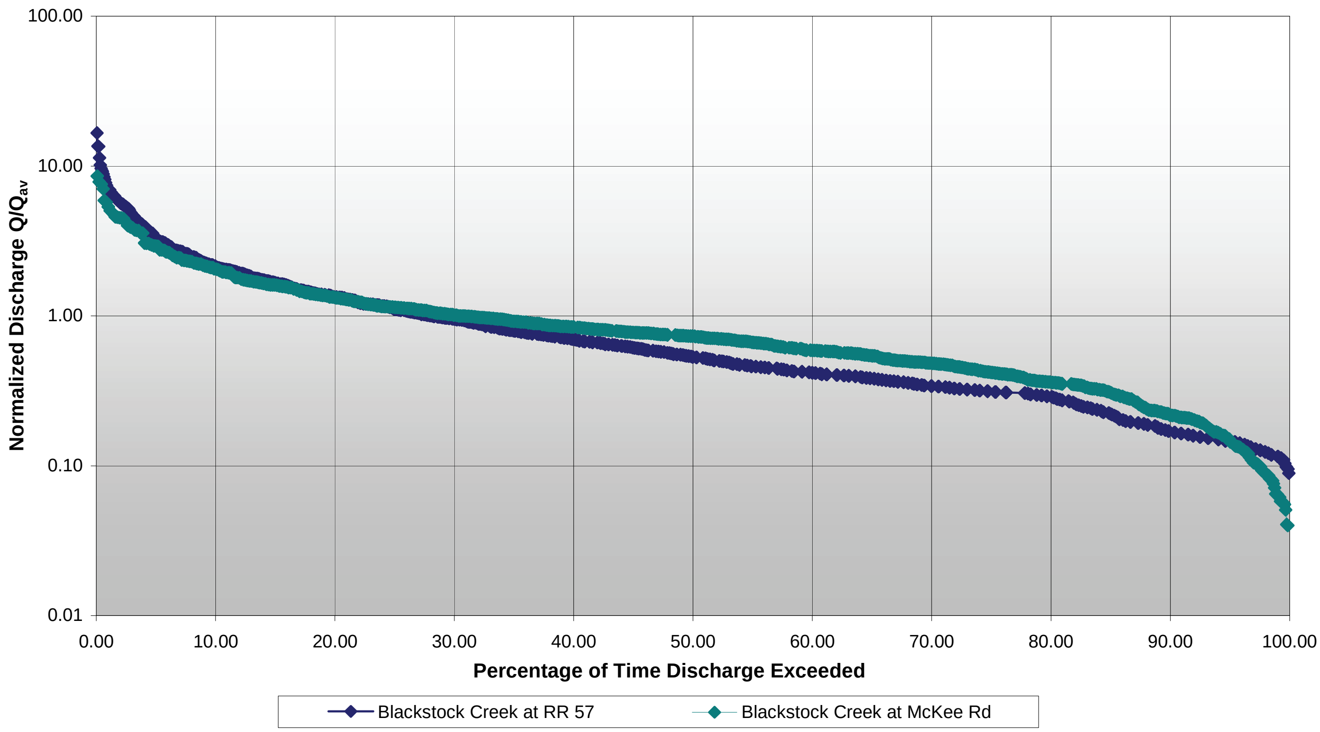


Figure 6.5: Semi-log plot of Flow Duration Curves, Blackstock Creek at McKee Road and Blackstock Creek at Regional Road 57.

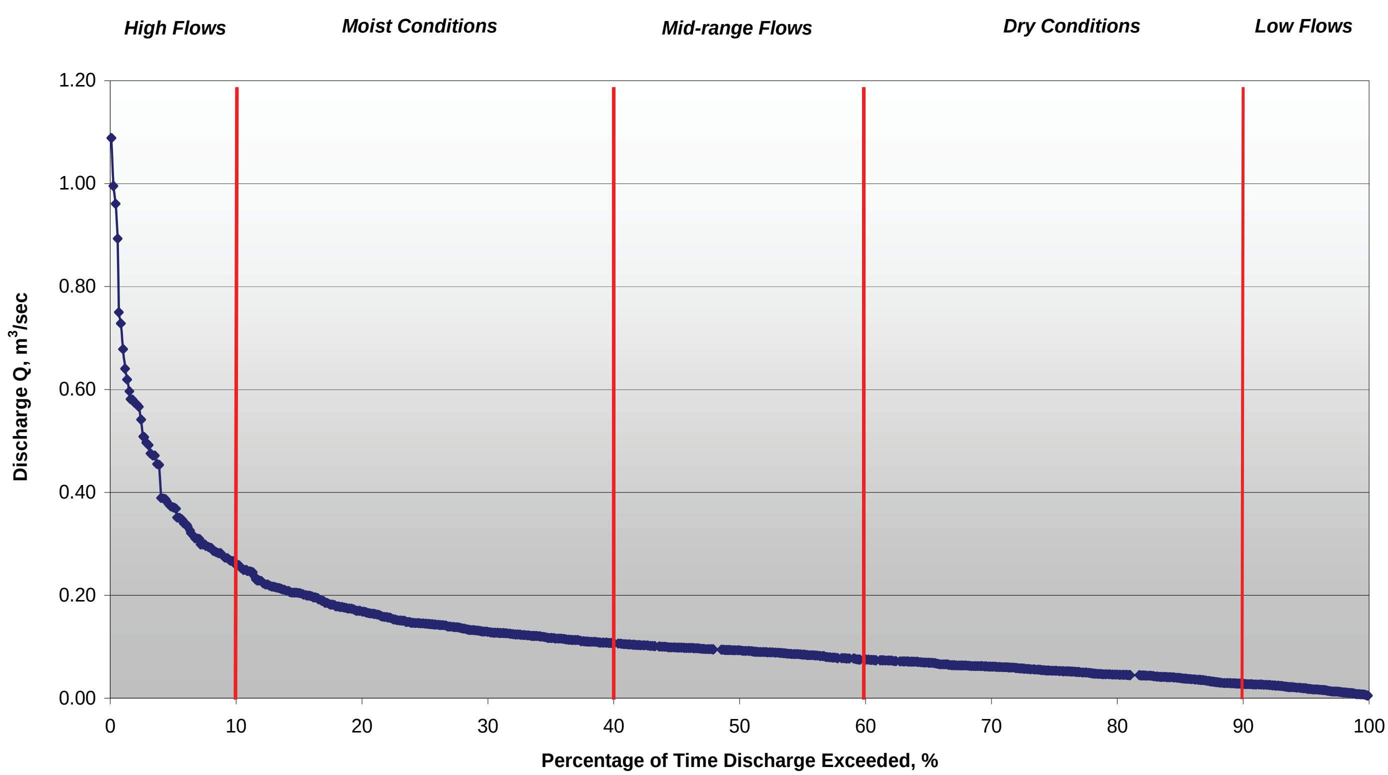


Figure 6.6: Flow Duration Curve, Blackstock Creek at McKee Road.

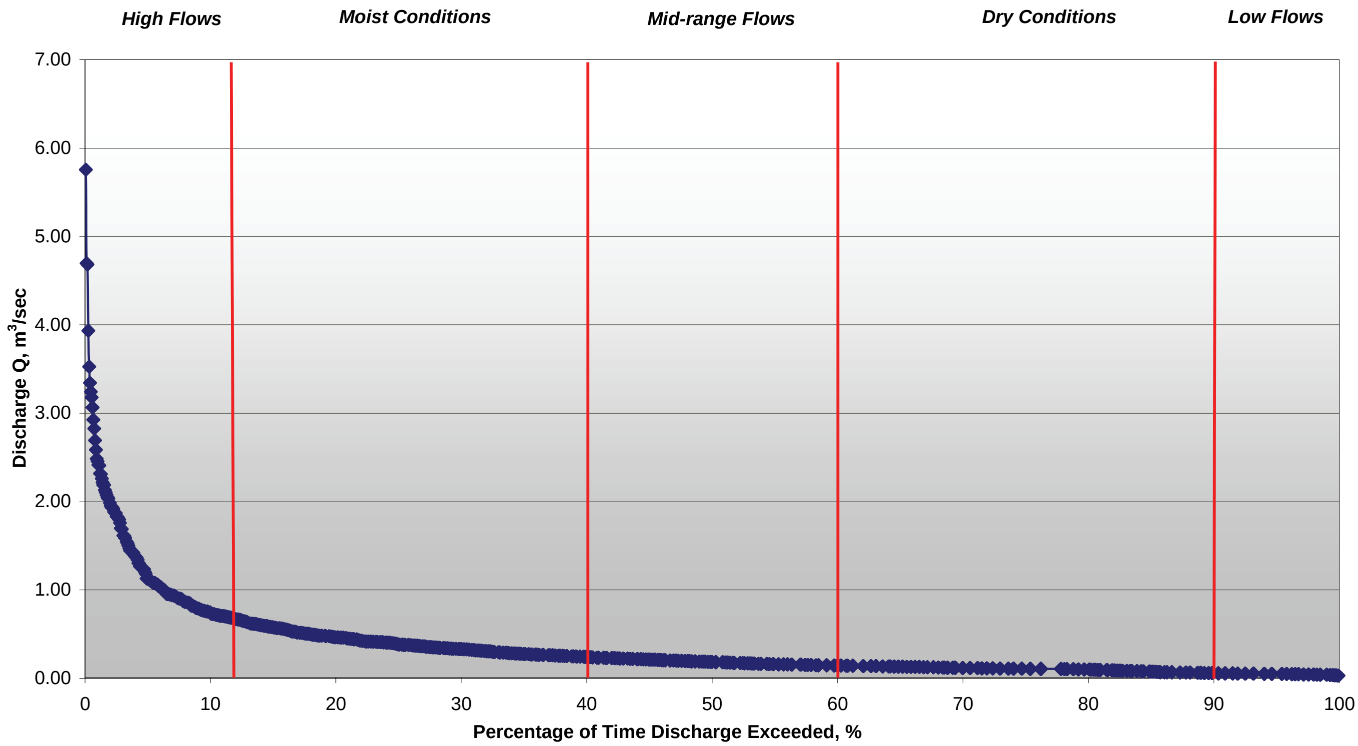


Figure 6.7: Flow Duration Curve, Blackstock Creek near Blackstock.

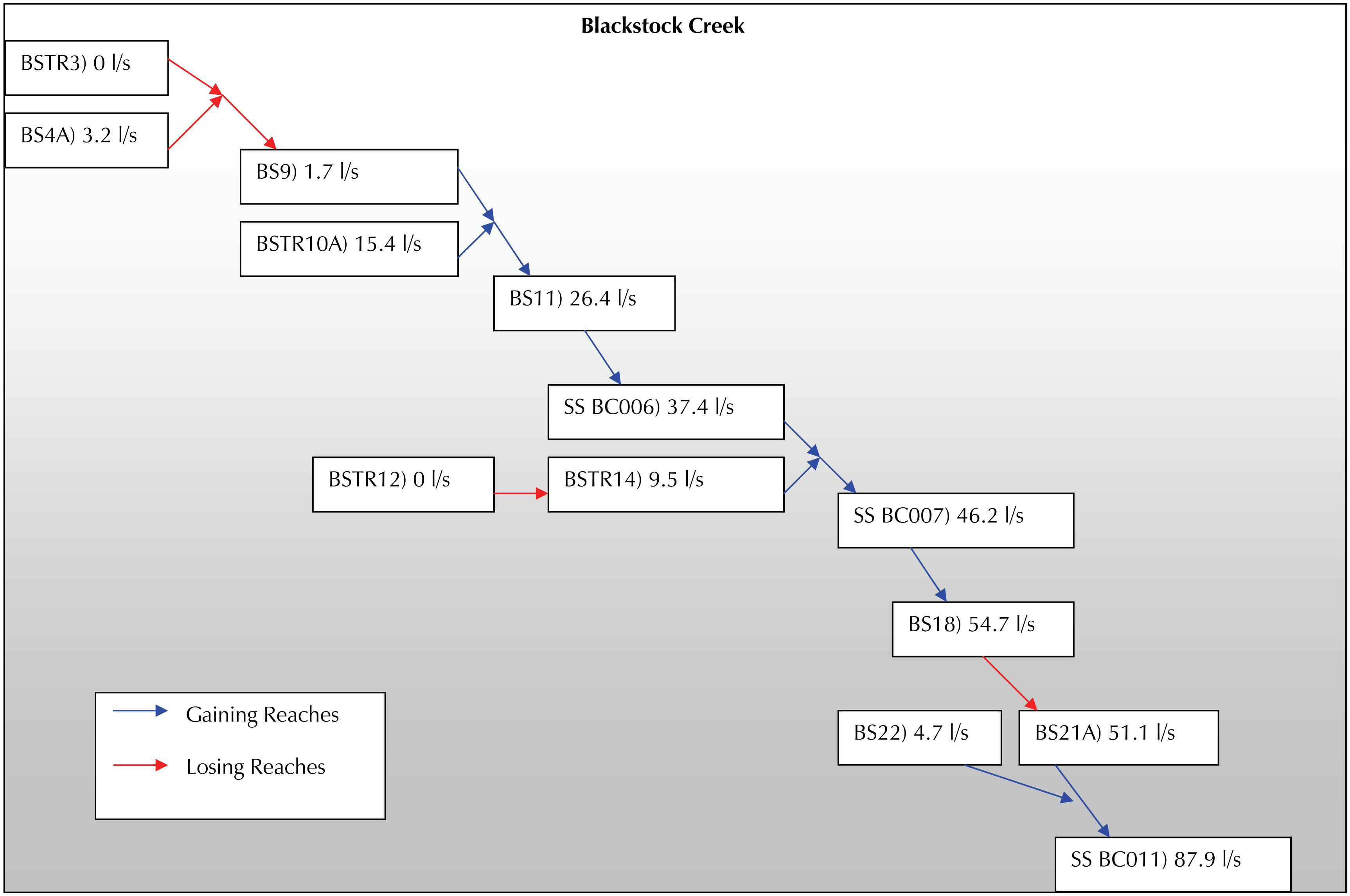


Figure 6.8: Flow Diagram, Blackstock Creek.

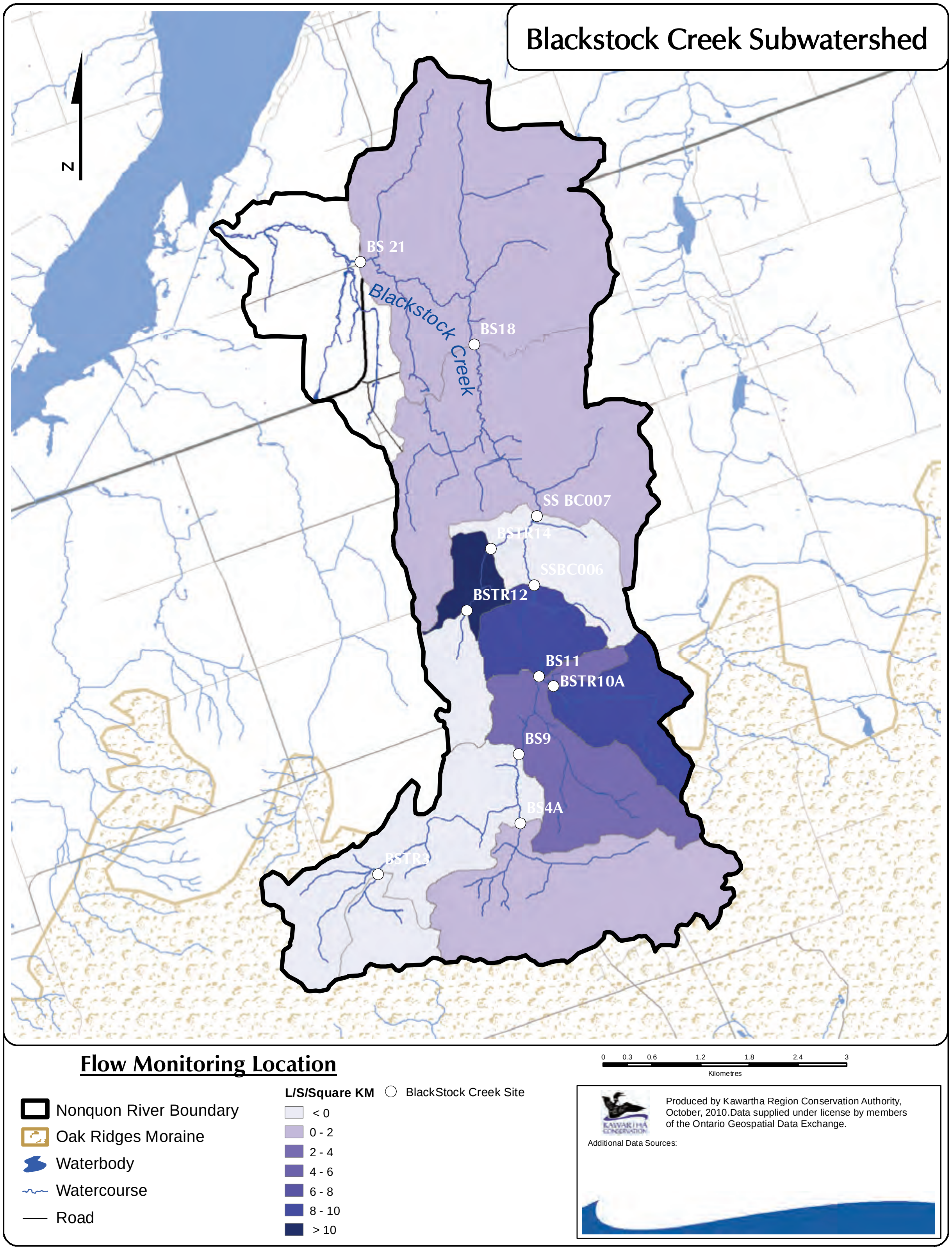


Figure 6.9: Net baseflow discharge per unit area.

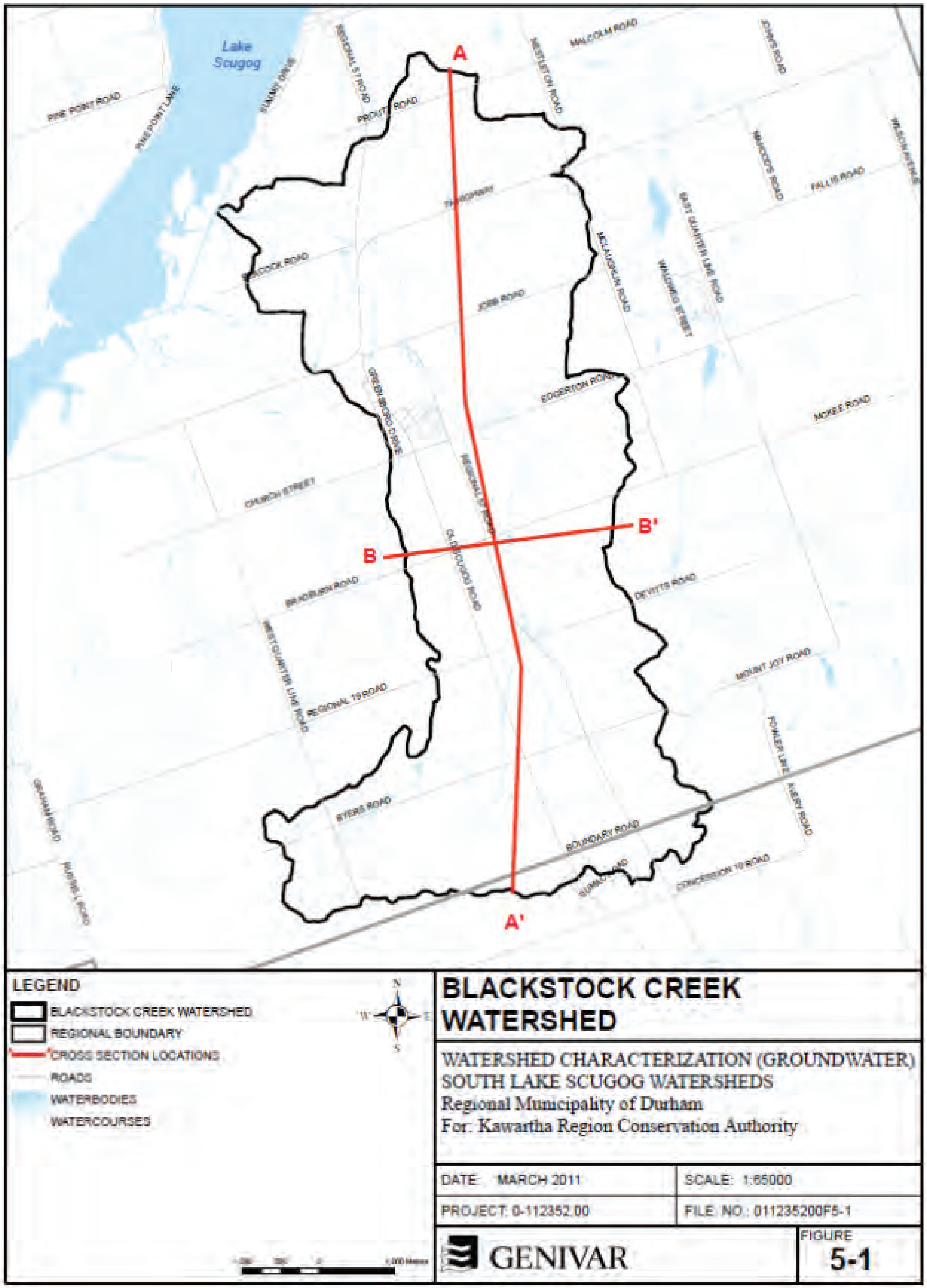


Figure 6.10: Locations of stratigraphic cross sections.

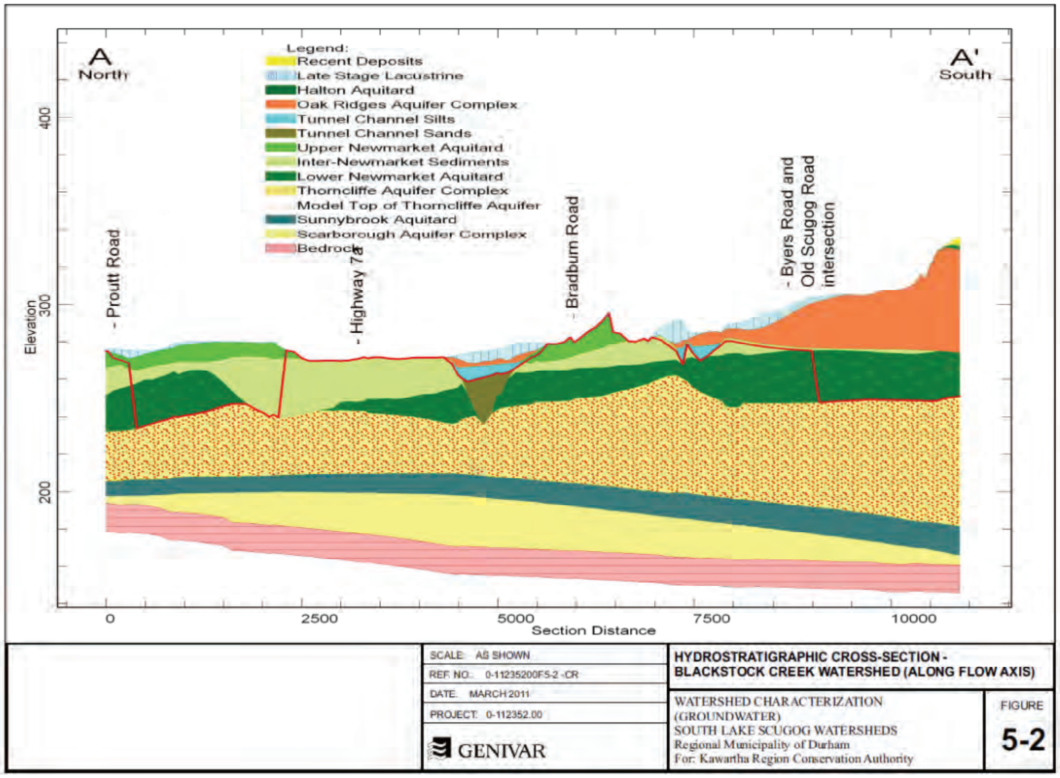


Figure 6.11: Cross section A - A'.

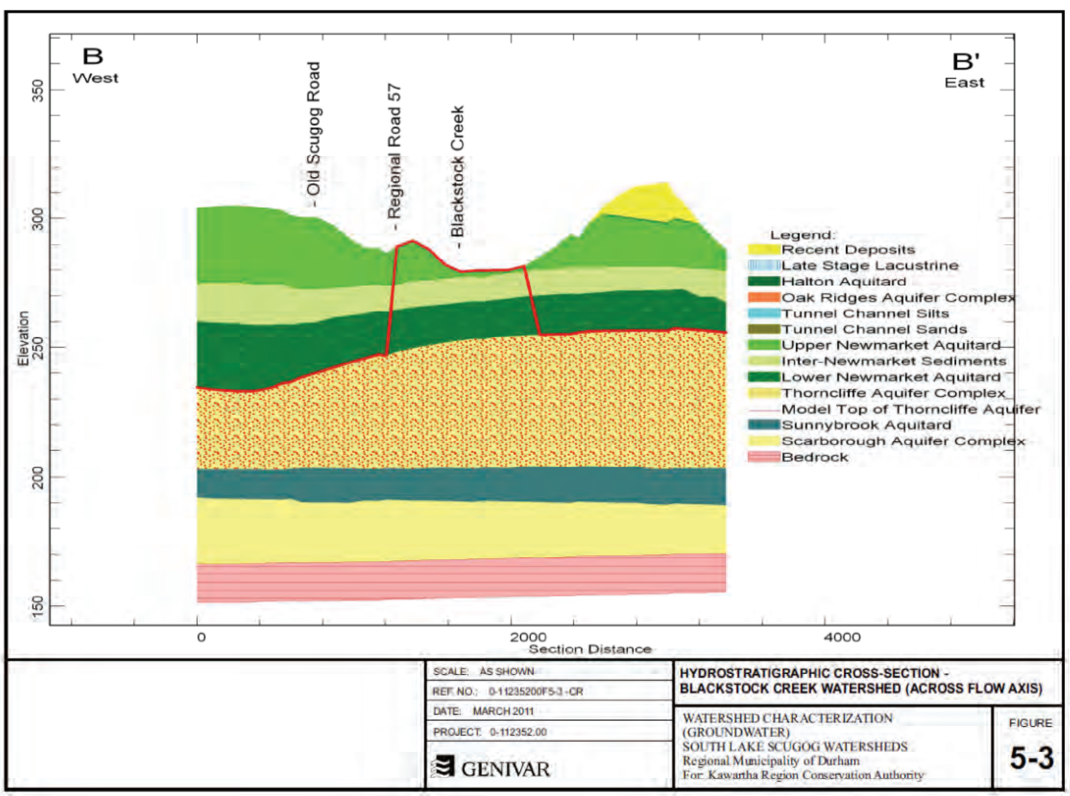
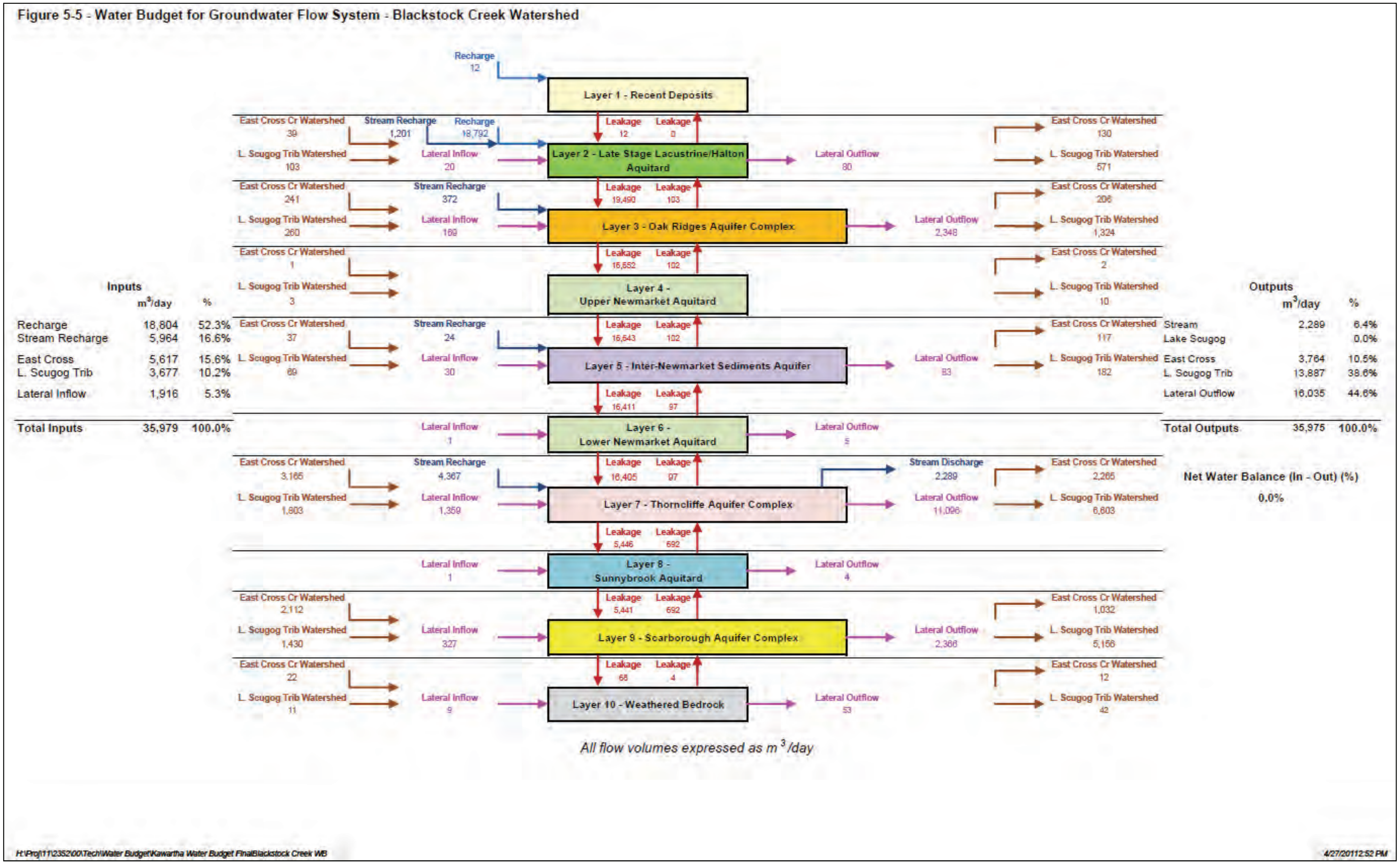


Figure 6.12: Cross section B - B'.



From GENIVAR (2011)

Figure 6.13: Water budget for groundwater flow system

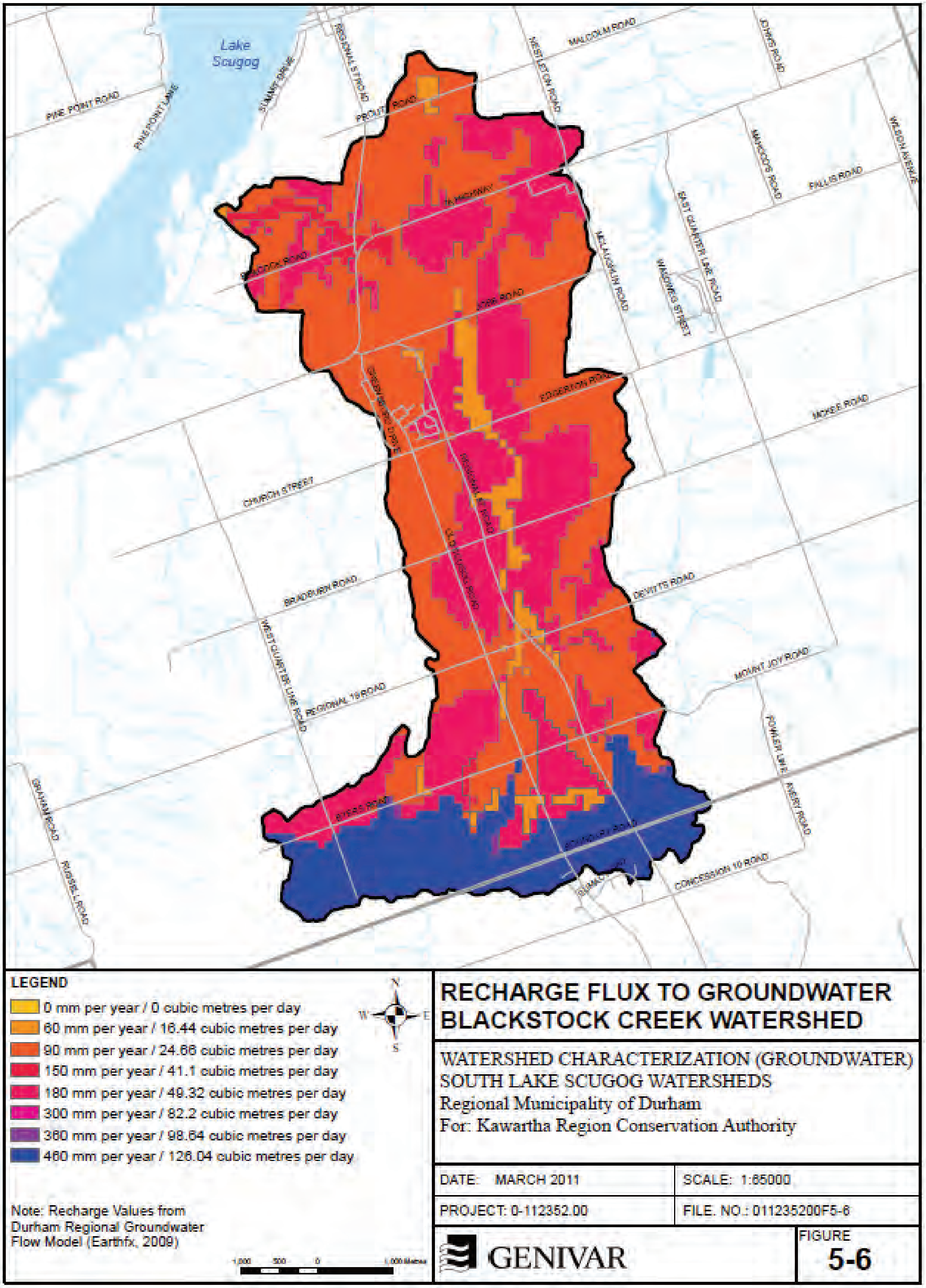


Figure 6.14: Recharge flux to groundwater.

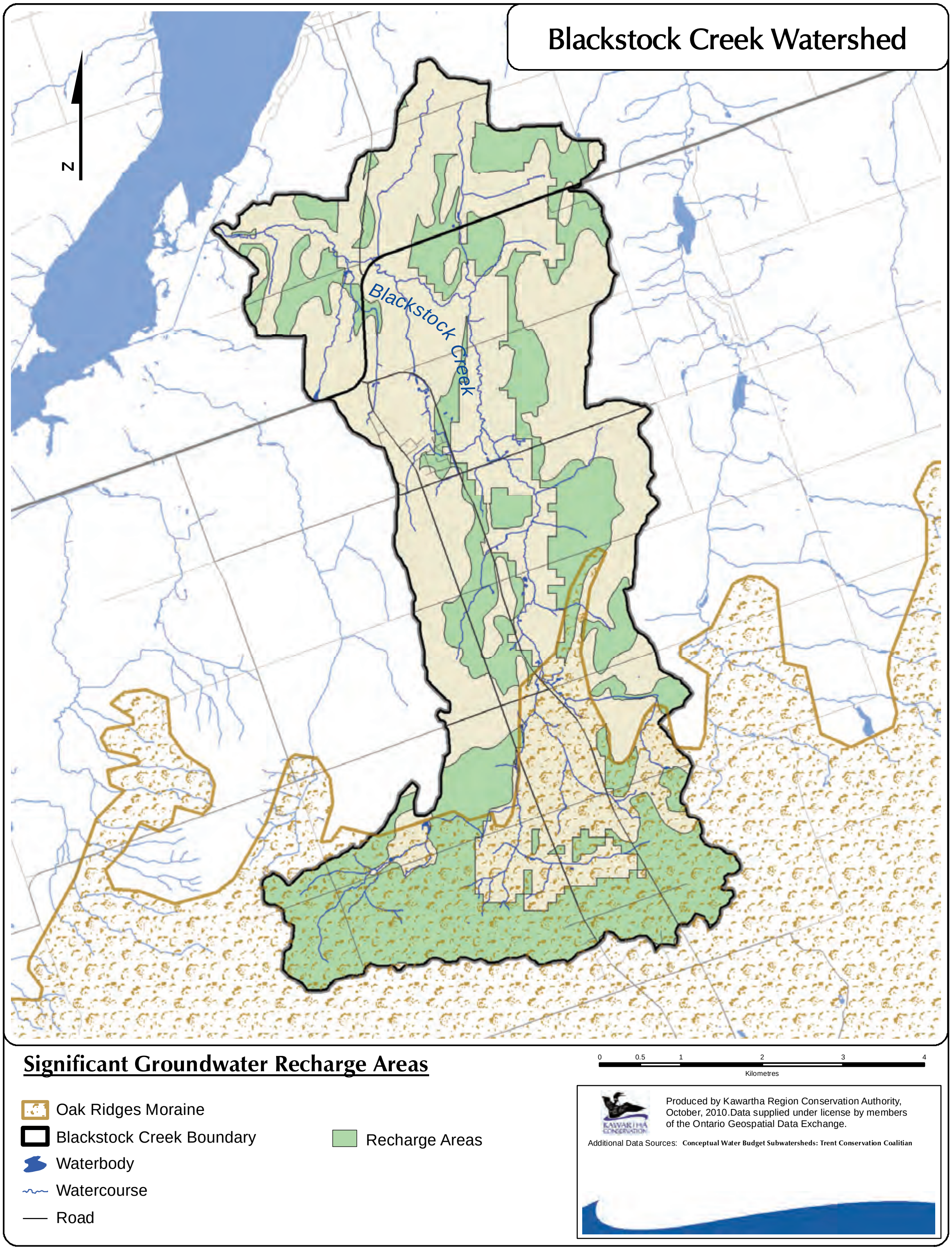


Figure 6.15: Significant groundwater recharge areas.

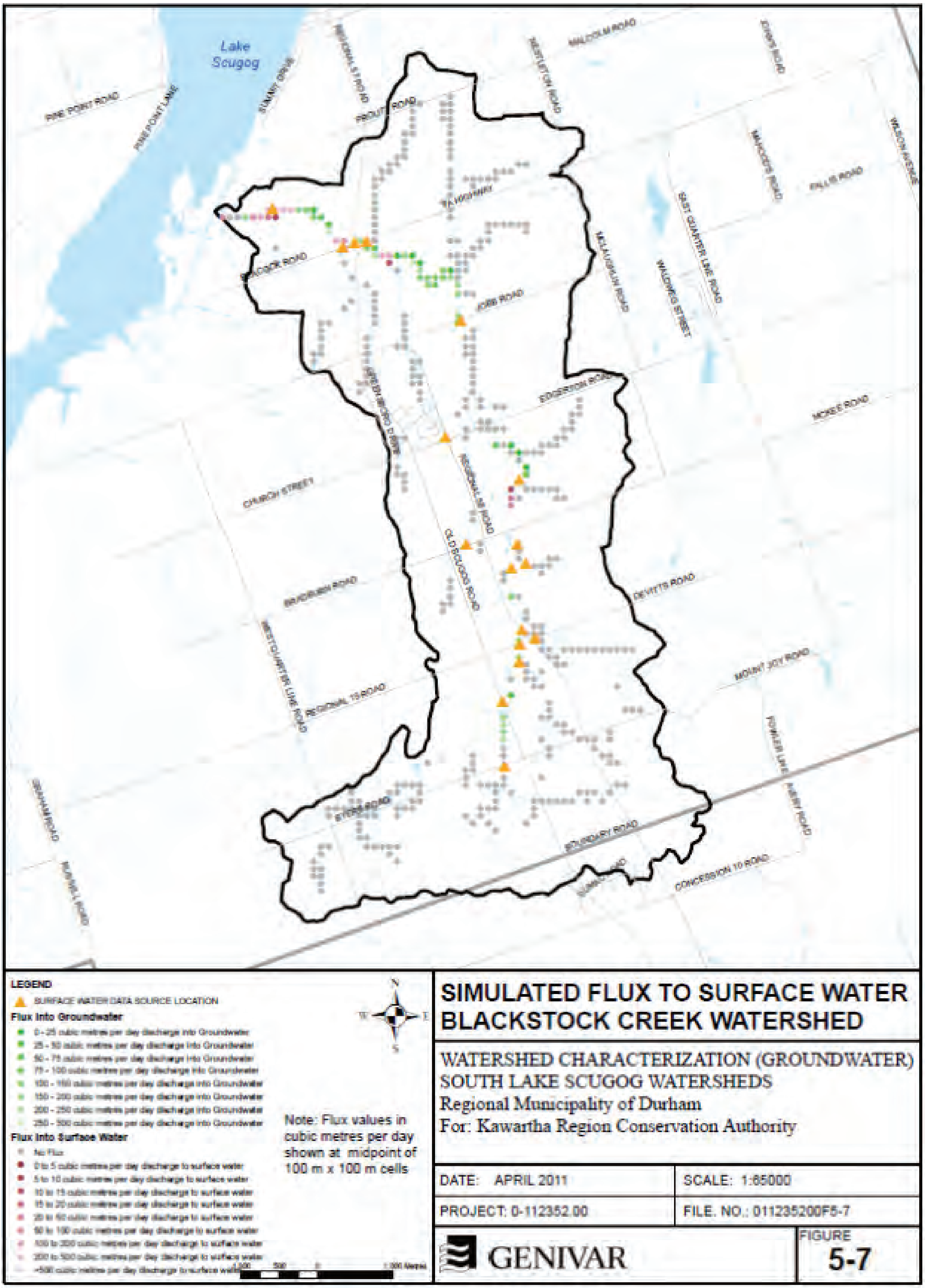


Figure 6.16: Simulated flux to surface water.

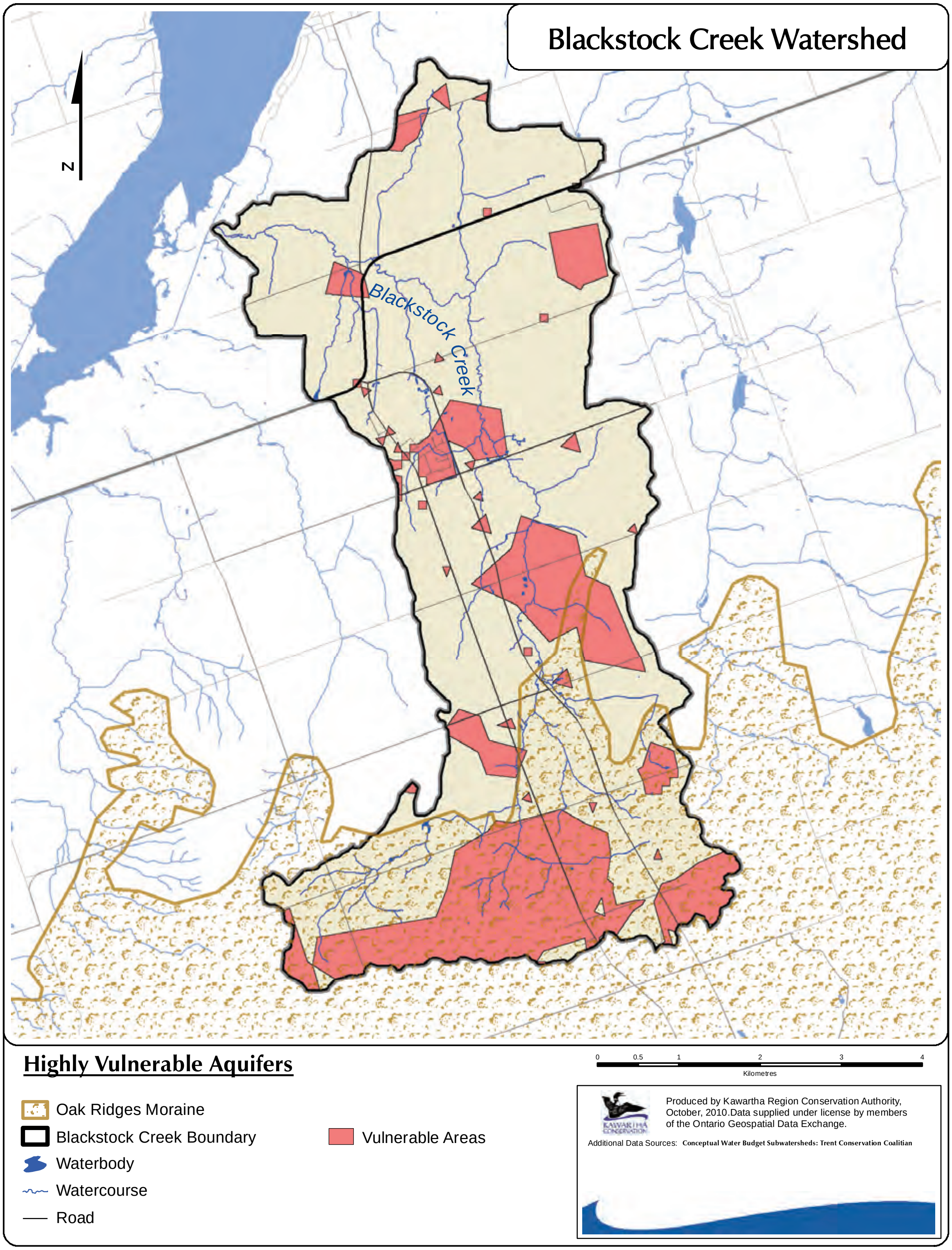


Figure 6.17: Highly vulnerable aquifers.

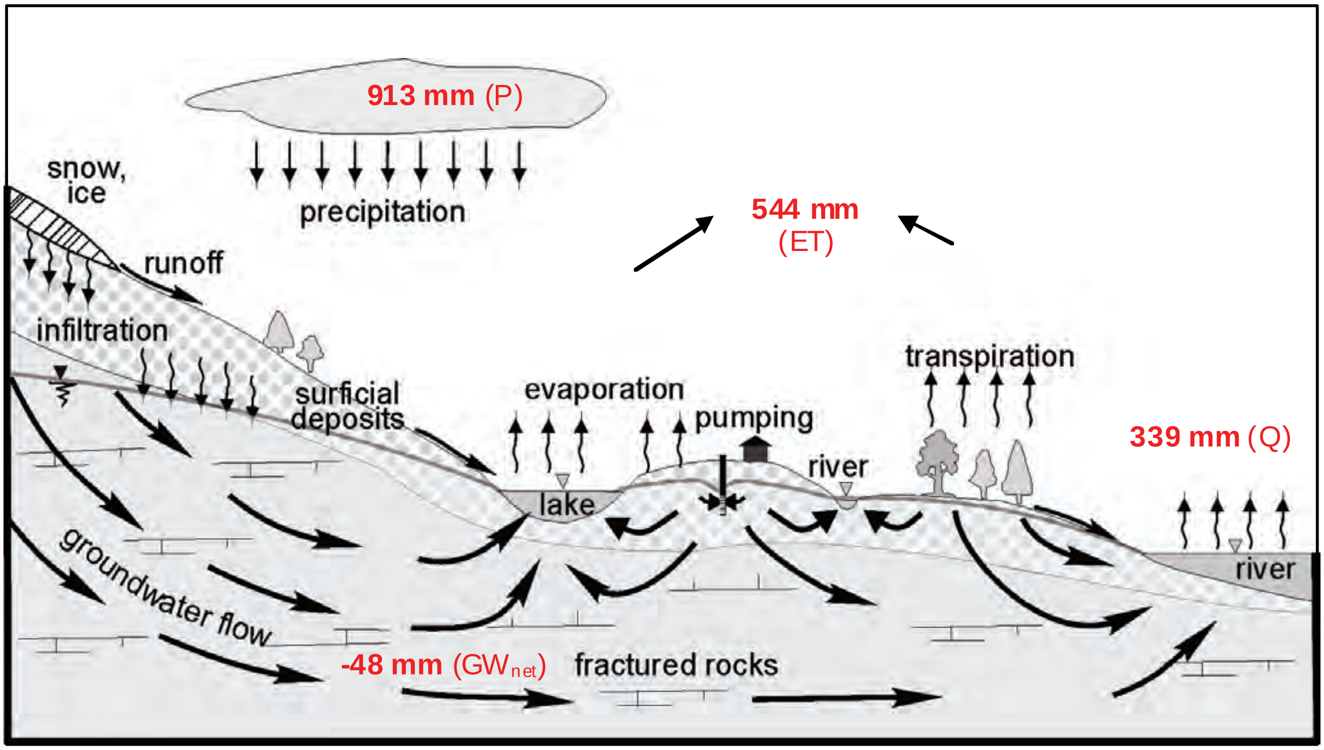


Figure 6.18: Hydrological cycle and water budget components.

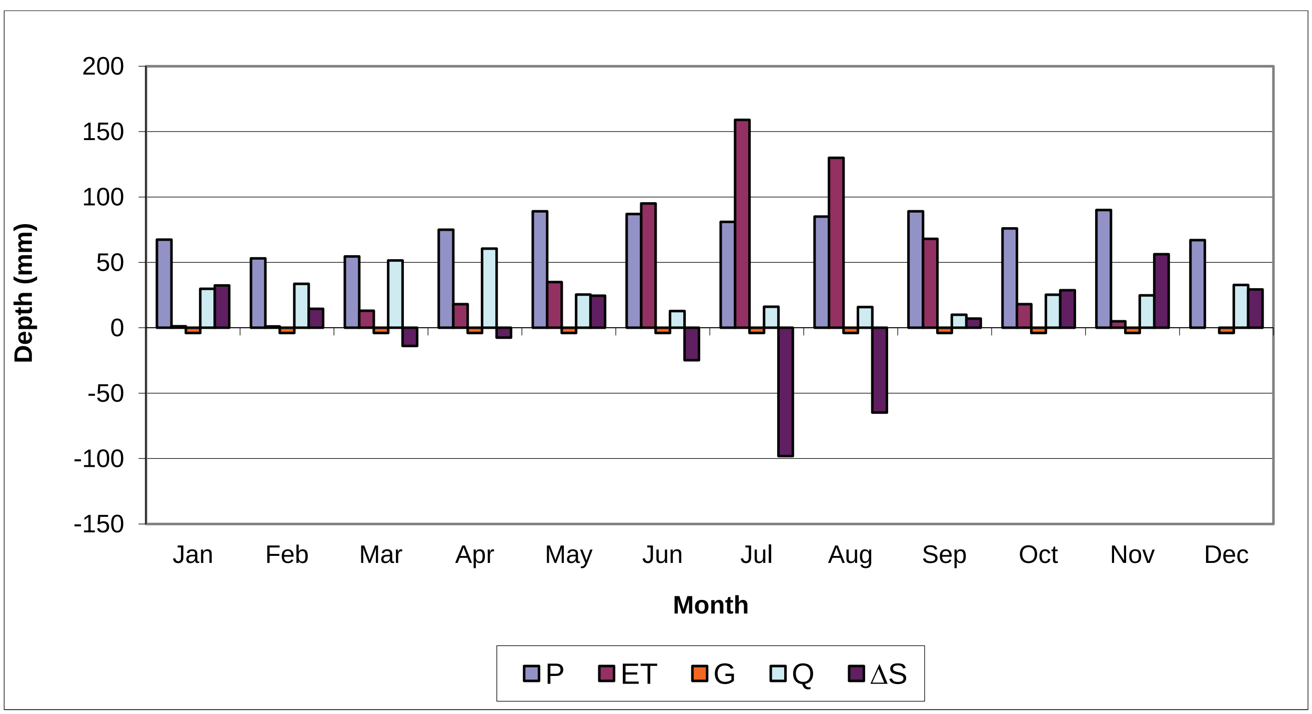


Figure 6.19: Monthly water budget components.

7.0 Water Quality

Blackstock Creek, south of Regional Road 19

7.1 Introduction

Water quality can be defined as an integrated index of chemical, physical and microbiological characteristics of natural water. Water quality is a function of both natural processes and anthropogenic (of human origin) impacts. Natural processes such as weathering of minerals and erosion can affect the quality of ground and surface waters. Factors such as the type of bedrock and soil type can impact water quality as well. For instance, water samples from the central part of Ontario have naturally higher levels of metals than those in the south because of the Canadian Shield bedrock. Usually natural background concentrations of water quality parameters do not pose any threat to the health of aquatic ecosystems or humans.

Anthropogenic sources of pollution are generally classified as either point or non-point source pollution. Point sources may include municipal and industrial wastewater discharges, ruptured underground storage tanks, septic tanks and/or landfills. Point sources of pollution are typically more easily identified and managed. In contrast, non-point sources of pollution reflects land use and refers to diffuse sources such as agricultural drainage areas, urban runoff, land clearing and the application of manure and chemical fertilizers to fields. Non-point sources can be more difficult to identify and manage than point sources because they cover a large geographic area and are difficult to pinpoint to a specific site.

Water quality is a key element in achieving the objectives of any watershed management plan. By sampling a wide variety of parameters it is possible to get an accurate, overall assessment of the water quality at a given point in time. To broaden the perspective, numerous samples are taken at different locations and periods of time providing for variances such as air and water temperature, flow volume, precipitation and land uses that vary throughout the year. Obtained results are compared to the Provincial Water Quality Objectives (PWQOs) (OMOE 1994) and Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) (CCME 2007). Some common water quality parametres and associated standards, are shown in listed in **Table 7.1**.

Table 7.1: Common water quality parametres and standards.

Parameter	Limits	Authority
Aluminum	0.100 mg/L	Canadian Water Quality Guideline for the Protection of Aquatic Life
Chlorides	128.0 mg/L	Canadian Water Quality Guideline for the Protection of Aquatic Life (Draft)
Iron	0.300 mg/L	Provincial Water Quality Objectives
Nitrate	2.930 mg/L	Canadian Water Quality Guideline for the Protection of Aquatic Life
Phosphorus	0.030 mg/L	Provincial Water Quality Objectives
Total Suspended Solids	Background+25.0 mg/L	Canadian Water Quality Guideline for the Protection of Aquatic Life

<u>Methodology</u>

Water quality data are obtained by the collecting water samples at monitoring sites throughout the entire Blackstock Creek watershed. As of 2010, Blackstock Creek has one long-term monitoring site (BR4) sampled since 2004 through the monitoring program of the Lake Scugog Environmental Management Plan (LSEMP).

This station is also an element of the Provincial Water Quality Monitoring Network (PWQMN) and is sampled in the framework of this program since 2004 as well. There are also nine new sites that were established and sampled in 2006-2010 for the purposes of the Blackstock Creek Watershed Plan development (**Figure 7.1**).

The monitoring stations are dispersed across the watershed at ten key locations covering main channel at five locations as well as five larger tributaries. At each site water samples are collected by grab method according to the planned monitoring schedule and then sent to a certified private laboratory or MOE's Laboratory Branch to be analyzed for alkalinity, total metals, hardness, suspended and dissolved solids, anions and nutrients including ammonia, nitrites, nitrates, total Kjeldahl nitrogen and total phosphorous. Furthermore, pH, dissolved oxygen, conductivity and temperature readings are taken at the time of sampling using an YSI hand held multi-meter. Samples for the PWQMN program (station BR4 at R.R. 57) are collected during ice-free period eight times per year. Samples for the LSEMP monitoring program were collected bi-weekly year round. In the framework of the Blackstock Creek Watershed Plan samples were collected three-four times a year during both wet and dry conditions to account for all types of weather and different phases of the hydrograph. A complete list of parameters sampled are found in **Appendix A**.

Statistical analysis of data was completed for sites BR1, BR2, BR3, BR3A, BR4 and BR4A as they have the largest number of samples. **Table 7.2** shows the site ID, location, number of samples and date of the most recent sample. Grey highlights indicate sites with enough samples to warrant statistical analysis.

Table 7.2: Water Quality Monitoring Stations in the Blackstock Creek Watershed.

Station ID	Location	Number of Samples	Most Recent Sample
BR1	Blackstock Creek at Byers Road	14	May-10
BR1A	Blackstock Creek at Regional Road 19	4	Aug-10
BR1B	Blackstock tributary at Devitts Road	6	Aug-10
BR2	Blackstock Creek at McKee Road	19	Aug-10
BR2A	Blackstock tributary at Bradburn Road	5	Aug-10
BR3	Blackstock Creek at Jobb Road	15	Aug-10
BR3A	Blackstock tributary at R.R. 57 north of Edgerton Road	9	Aug-10
BR4	Blackstock at Regional Road 57 north of Hwy 7A	175	Aug-10
BR4A	Blackstock tributary at Hwy 7A	11	Aug-10
BR4B	Blackstock tributary at Beacock Road	6	Aug-10

* Station BR4 is also monitored through the LSEMP and PWQMN monitoring programs. Grey highlights indicate sites with enough samples to warrant statistical analysis.

7.2 Surface Water Quality Assessment

The major water quality concern in the Blackstock Creek watershed is elevated concentrations of nutrients, phosphorus in particular. As well, elevated concentrations of nitrates were quite often observed in wintertime at station BR4. Other parameters of concern at some stations include metals such as aluminum and iron, and total suspended sediments (TSS). High levels of chloride have been detected at station BR3A. All other parameters have very low concentrations far below the corresponding PWQOs or CWQGs and do not present any threat to the aquatic life or human health.

Phosphorus

Since the beginning of monitoring activities in 2004, phosphorus concentrations in Blackstock Creek have always exceeded the PWQO set for total phosphorus (TP) (**Figure 7.2**). Phosphorus is not considered toxic to plants and animals, but elevated levels of this nutrient in water can result in the process of eutrophication and excessive algae and aquatic plant growth. The PWQO for total phosphorus is set at 0.030 mg/L, in order to prevent nuisance algae and aquatic plant growth. Total phosphorus is a measure of both soluble and insoluble phosphorus within a water sample. The insoluble component is primarily decaying plant and animal matter or soil particles, which either settles to the bottom or remains suspended in the water column. This form of phosphorus is not readily available to plants, and does not instantly change biological productivity of a water body. In contrast, soluble phosphorus (e.g., orthophosphates) can be readily taken up by aquatic plants, causing increased biological productivity and plant growth. Soluble phosphorus has primarily anthropogenic origin and poses a greater threat to the ecosystem than insoluble forms.

Monitoring results collected during 2004-2009 don't show any apparent trend in total phosphorus levels in Blackstock Creek. Additional sampling from the new monitoring stations across the watershed in recent years has shown that all sites have average total phosphorus concentrations well over the PWQO of 0.030 mg/L (**Figure 7.3**). Average TP concentrations in Blackstock Creek and its tributaries range from 0.056 to 0.085 mg/L. Phosphorus levels exceeded the PWQO the most often at station BR3A (100%) and the least at station BR2 (44%) (**Table 7.3**). The highest average concentrations of 0.086 and 0.087 mg/L are observed at stations BR3 and BR3A correspondingly. Both stations also have the highest median concentrations (**Table 7.4**). The maximum recorded value of 0.540 mg/L was observed at station BR4 at Regional Road 57 in April of 2008.

It is interesting to compare station BR1 in the Blackstock watershed and station NR1 in the Nonquon River watershed. Both of them are located in the headwater sections of their watersheds within the Oak Ridges Moraine. Nevertheless station NR1 has significantly lower phosphorus levels compared to the station BR1 that can be explained by higher percentage of agricultural lands upstream of BR1. Nevertheless the average phosphorus concentration at BR1 was 0.056 mg/L with a range of 0.016 to 0.262 mg/L that is the lowest in the Blackstock Creek watershed. It is meaningful to mention that very low TP concentrations have been detected in water of a small tributary at Bradburn Road (station BR2A). Phosphorus levels at this station varied from 0.002 to 0.029 mg/L with an average of 0.009 mg/L. Maximum value of 0.029 mg/L was observed in March of 2010 during spring freshet. Despite only four samples collected from this location, it is possible to conclude that so low phosphorus concentration is related to a significant groundwater discharge in forested area immediately upstream of the monitoring station.

On other hand, stations BR3A and BR4A, which are also located on small tributaries, both have shown elevated concentrations of phosphorus, with averages of 0.087 and 0.067 mg/L correspondingly. Station BR3A is situated downstream of urban area of Blackstock and station BR4A is downstream of agricultural fields. As a result, they have a considerable increase in phosphorus concentrations comparing to other stations in the watershed. Average annual TP concentrations at BR4 location fluctuated from 0.058 mg/L (in 2004) to 0.072 mg/L (in 2005) (See **Figure 7.2**). Looking at the results from all four monitoring stations along the main channel one can note that while phosphorus levels generally increase midway down the river, water quality starts to improve downstream of station BR3 and phosphorus concentrations are lower at BR4 location. For example, phosphorus exceeded PWQO in 44% of samples at BR2 location, in 93% of samples at BR3 location and only 66% at station BR4 despite the fact that water quality at this location is influenced by inflow from tributary where station BR4A is located (See **Table 7.3**). At the same time this trend should be interpreted with a caution, as station BR4 was monitored year round during five years and has much more data, while stations BR1, BR2 and BR3 were sampled only 16-18 times mainly in the summer-autumn period (See **Table 7.3**).

Seasonal distribution of total phosphorus in Blackstock Creek is characterized by the highest readings in springtime during intensive snowmelt and corresponding freshet. In summertime phosphorus concentrations are usually quite high as well during both high and low flow conditions. This fact can indicate that phosphorus coming into the watercourse with both stormwater runoff and groundwater discharge. The lowest TP concentrations are usually observed throughout late autumn – early spring.

Taking into consideration data collected at station BR4 for the LSEMP program and flow data from the gauge station at the same location, phosphorus export per unit area of the watershed was calculated for three consecutive hydrologic years. TP export varied from 15.3 kg/km^2/yr in 2005 – 2006 hydrologic year to 24.4 kg/km^2/yr in 2007 – 2008. Total annual phosphorus export from the Blackstock Creek watershed into Lake Scugog varied from 600 to 911 kg. As well, it was calculated that lower portion of the watershed (downstream of station BR2) generates 65% of the total phosphorus load while occupies 57% of the watershed area.

Table 7.3: Average and percent of exceedences of Total Phosphorus, Total Suspended Solids, Aluminum and Iron concentrations in Blackstock Creek during 2004 - 2010.

Monitoring station	TP			TSS			Al			Fe		
	Mean, mg/L	Exceedences, %	Number of Samples	Mean, mg/L	Exceedences, %	Number of Samples	Mean, ug/L	Exceedences, %	Number of Samples	Mean, ug/L	Exceedences, %	Number of Samples
BR1	0.056	**69**	16	5.3	0	14	84	25	12	258	25	12
BR2	0.071	**44**	18	23.1	17	18	228	29	17	414	35	17
BR3	0.086	**93**	15	5.1	0	15	62	8	12	364	**50**	12
BR3A	0.087	**100**	9	4.3	0	9	22	0	9	222	33	9
BR4	0.062	**66**	175	6.6	4	54	66	**9**	54	202	13	54
BR4A	0.070	**73**	11	6.2	0	9	58	**17**	6	213	**17**	6

Table 7.3: Total Phosphorus concentrations at Blackstock Creek water quality monitoring stations during 2004 - 2010.

	BR1	BR2	BR3	BR3A	BR4	BR4A
75-%	0.054	0.069	0.103	0.120	0.084	0.104
max	0.262	0.375	0.257	0.129	0.540	0.143
min	0.016	0.012	0.019	0.052	0.010	0.013
25-%	0.028	0.020	0.053	0.064	0.023	0.033
mean	0.056	0.071	0.086	0.087	0.062	0.070
median	0.044	0.024	0.065	0.068	0.046	0.075

Nitrogen

Nitrogen is present in surface water in several chemical forms such as ammonia, nitrite, nitrate and total Kjeldahl nitrogen (TKN). The nitrite values are usually combined with the nitrate concentrations, as a nitrite-ion is the transitional form of nitrogen from ammonia to nitrate-ion that is present in surface water in very low concentrations. Eventually all nitrites in lake or river water will be transformed into nitrates in a very short time. The combined concentrations of nitrate and nitrite are usually called total nitrate and consist typically of 98.0-99.9% of nitrates and 0.1-2.0% of nitrites. Total Kjeldahl nitrogen is a measure of total organic nitrogen plus total ammonia and in some cases can show presence of fresh organic pollution in a water body or level of the phytoplankton development in the lake water. Usually, TKN concentrations across the watershed are below 1.0 mg/L but occasionally can considerably exceed this value.

Very often in streams nitrates compose most of the total nitrogen amount, which comprises all the above-mentioned chemical forms of nitrogen in water. Nitrates are essential for plant growth in both terrestrial and aquatic ecosystems because they are highly soluble and mobile in water solutions and are the most available for plant consumption. Anthropogenic sources of nitrates include inorganic fertilizers, septic systems and wastewater treatment plants. Concentration of total nitrates in surface water reflects general land use and an anthropogenic pressure within the various parts of the watershed. In the Blackstock Creek watershed nitrates from time to time exceed the limit set by the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) at 2.93 mg/L. At the same time the average nitrate levels in Blackstock Creek and most its tributaries are well below the guideline (**Table 7.4**). On the watershed wide scale the highest nitrate levels are detected in small streams or in the main creek channel close to the groundwater discharge points. For instance, the highest summer nitrate concentration (6.0 mg/L) was detected in water of the small tributary at station BR2A at Bradburn Road, which is heavily influenced by local groundwater discharges. This site has also very high average nitrate concentration of 5.5 mg/L. Among other monitoring stations, site BR4 had the highest maximum concentrations of 6.2 mg/L detected in winter of 2006. Average nitrate concentrations varied from 0.39 mg/L at station BR3 to 1.62 mg/L at site BR2 (**Figure 7.4**).

Seasonal distribution of nitrates in the Blackstock Creek watershed is characterized by high concentrations in wintertime, late autumn and early spring. In general, the highest levels of nitrates in the creek and tributaries were detected in the middle of winter – during January and February, when groundwater contributes the most to the flow in rivers and creeks and natural processes of nitrate assimilation are very slow.

Taking into consideration available monitoring data it is possible to conclude that the main source of inorganic nitrogen in the Blackstock Creek watershed is groundwater discharge. In turn, high levels of nitrates in groundwater are most likely caused by agricultural activities in the watershed.

At the end, looking into phosphorus and nitrogen concentration in water of the creek, it can be concluded that Blackstock Creek can be described as a eutrophic water body that sometimes shows characteristics of hyper-eutrophic category.

Table 7.4: Nitrate concentrations at Blackstock Creek water quality monitoring stations during 2004 - 2010.

	BR1	BR2	BR3	BR3A	BR4	BR4A
75-%	0.912	1.945	0.586	1.000	1.927	1.160
max	1.240	3.700	1.600	1.600	6.206	2.190
min	0.040	0.656	0.008	0.015	0.094	0.159
25-%	0.160	1.209	0.099	0.360	0.378	0.296
mean	0.533	1.615	0.388	0.783	1.315	0.808
median	0.490	1.400	0.200	0.920	0.959	0.480

Aluminum

Aluminum can be toxic to various aquatic organisms, fish in particular, in concentrations above 0.100 mg/L (CCME 2003). Toxicity of aluminum increases in water with a pH below 6.5 and above 8.5 resulting in high mortality of aquatic organisms.

Elevated aluminum concentrations have been observed at several locations across the Blackstock Creek watershed. At one location average aluminum concentration is above the CWQGs limit of 0.100 mg/L. This station, BR2 at McKee Road, has the highest levels of aluminum recorded throughout the observation period: a maximum of 2.02 mg/L and an average of 0.228 mg/L (**Table 7.5**). As well, it has the highest number of exceedences above the CWQG: 29% of all samples (See **Table 7.3**). Another station with quite high aluminum concentrations is BR1 with an average value of 0.084 mg/L and 25% of all samples above the guideline (**Figure 7.5**). Aluminum concentrations exceeded the CWQG in water of five stations out of six but at stations BR3 and BR4A it happened only once. No exceedences were detected in water of station BR3A that can be explained by the fact that samples from this location have been collected only during low flow periods. As a result, this station has the lowest aluminum levels with an average concentration of 0.022 mg/L and the range of 0.006 to 0.079 mg/L (See **Table 7.5**).

It seems that aluminum concentrations in water of Blackstock Creek are higher in headwater sections of the stream that can be explained by more intensive erosion in that portion of the watershed. In addition, elevated levels of aluminum were detected under high flow conditions and can be easily correlated with high TSS concentrations in the water. Usually high aluminum concentrations coincide with increased iron and manganese concentrations after rain events and during snowmelt. Local soils, which are probably rich in aluminum, seems are the major source of this element, as no anthropogenic sources of aluminum contamination are known in the watershed.

Table 7.5: Aluminum concentrations at Blackstock Creek water quality monitoring stations during 2004 - 2010.

	BR1	BR2	BR3	BR3A	BR4	BR4A
75-%	0.089	0.180	0.017	0.024	0.031	0.055
max	0.330	2.020	0.430	0.079	1.260	0.170
min	0.011	0.011	0.003	0.006	0.004	0.022
25-%	0.014	0.015	0.006	0.007	0.012	0.026
mean	0.084	0.228	0.045	0.022	0.066	0.058
median	0.043	0.025	0.008	0.019	0.019	0.035

Iron

A numerical limit for total iron, which is 0.3 mg/L, was set by the Ontario Ministry of the Environment in 1984. Later it was adopted by the CWQGs. Iron in concentrations above 0.3 mg/L can be toxic to invertebrates and aquatic insects (CCME 1999).

Throughout the period of observation the majority of the monitoring stations had average iron concentrations well below the PWQOs and CWQGs limit of 0.30 mg/L, with the exception of stations BR2 and BR3 that had averages of 0.414 and 0.364 mg/L correspondingly (**Figure 7.6**). At station BR3 50% of samples exceeded the PWQO, while at station BR2 35% of samples exceeded the guideline and ranged from 0.05 to 3.18 mg/L. At the same time, it is important to note that average for the station BR2 is skewed by one extremely high reading (3.18 mg/L) from the sample collected after heavy rains while median value is only 0.120 mg/L (**Table 7.6**). All six stations of interest have had at some point iron concentrations above the PWQO. Quite often reoccurrence of elevated iron levels at station BR3 can be result of natural processes in wetland that is located upstream from this station.

For example, elevated levels of iron as well as manganese in stream water can be related to the deficit of dissolved oxygen in combination with low pH values, which can be often observed in marshes, swamps and shallow beaver ponds in summer time. As a result, low DO and pH values create a reducing environment in bottom sediments and at the water-sediment interface that can cause an intensive process of desorption of previously adsorbed metals from sediments. As well, reducing conditions can lead to mineral dissolution of iron-phosphorous, manganese-phosphorous and aluminum-iron-phosphorous minerals present in sediments. High concentrations of iron and manganese as well as phosphorus during summers in river water without known external sources of contamination are usually the indicators of the above-mentioned processes.

The lowest iron levels have been observed at stations BR4 and BR4A with average concentrations of 0.202 and 0.213 mg/L correspondingly and only a few exceedences above the PWQO (See **Table 7.3** and **Table 7.6**).

Table 7.6: Iron concentrations at Blackstock Creek water quality monitoring stations during 2004 - 2010.

	BR1	BR2	BR3	BR3A	BR4	BR4A
75-%	0.288	0.320	0.445	0.310	0.218	0.260
max	0.580	3.180	1.000	0.408	1.860	0.340
min	0.090	0.050	0.040	0.090	0.031	0.120
25-%	0.148	0.090	0.185	0.140	0.087	0.165
mean	0.258	0.414	0.364	0.222	0.202	0.213
median	0.170	0.120	0.300	0.180	0.134	0.190

Total Suspended Sediments

Total suspended sediments may have significant effects on aquatic organisms because of shading, abrasive action, habitat alteration and sedimentation. Suspended sediments have a significant effect on community dynamics when they interfere with light transmission. The role of sediments as a reservoir of toxic chemicals has been widely demonstrated. Most flowing waters have considerable variation in suspended sediments from day to day. Because this natural variation is so great, it is not desirable to establish fixed rigid guideline (CCME 2002). Therefore more flexible guidelines have been established: suspended sediment concentrations in stream water should not be increased by more than 25 mg/L over background levels during any short-term exposure period and no more than 5 mg/L over background levels for longer term exposure (30 days and more) (CCME 2002).

Background concentrations of total suspended sediments in streams of the Blackstock Creek watershed are usually 1-2 mg/L. Occasionally after rain events TSS concentrations increase substantially in water of some monitoring stations (**Table 7.7**). From time to time high TSS levels have been observed in water of station BR2 at McKee Road. Maximum TSS concentration detected at this location was 221 mg/L. As well, 17% of samples from this station had TSS concentrations in excess of 25 mg/L above the background level (See **Table 7.3**). Another station where a few TSS exceedences were detected was station BR4. The other four stations did not have exceedences (See **Table 7.7**). Average TSS concentrations in water of all monitoring stations are well below the CCME guideline (**Figure 7.7**).

Table 7.7: Total Suspended Solids concentrations at Blackstock Creek water quality monitoring stations during 2004 - 2010.

	BR1	BR2	BR3	BR3A	BR4	BR4A
75-%	5.0	16.8	4.5	6.0	4.4	11.0
max	19.0	221.0	26.0	8.0	74.0	17.0
min	1.0	1.0	1.0	2.0	0.5	1.0
25-%	2.3	1.3	3.0	2.0	1.6	2.0
mean	5.3	23.1	5.1	4.3	6.6	6.2
median	3.0	2.0	4.0	4.0	2.2	2.0

Chloride

During the monitoring period chloride concentrations in water of the most water quality monitoring stations in the Blackstock Creek watershed were below the recently developed CWQG for Chloride for the Protection of Aquatic Life, which is set at 128 mg/L (CCME 2010). The only station that shows elevated chloride concentrations is station BR3A located on small watercourse, which collects surface runoff from urban area of hamlet of Blackstock (**Table 7.8**).

This station has the highest chloride concentrations with an average of 171.0 mg/L and a range of 49 to 290 mg/L clearly indicating anthropogenic contamination due to urban stormwater runoff. Water from this urban tributary can have negative effect on water quality in the main channel. Looking at **Figure 6.8** one can see that chloride concentrations increase downstream the creek. Headwater station BR1 has the lowest chloride levels with an average of 19.8 mg/L and a range of 8.0 to 36.0 mg/L, while station BR4 has the highest levels among four main channel stations with an average of 34.8 mg/L and a range of 25.1 to 46 mg/L (See **Table 6.8**). Station BR4A, which is located on small tributary draining agricultural area also shows somewhat elevated chloride concentrations thus influencing water quality in the main channel.

Analyzed data indicate that in future water quality in Blackstock Creek can be significantly affected by the elevated chloride concentrations in excess of the CWQGs limit in water of some small tributaries.

Table 7.8: Chloride concentrations at Blackstock Creek water quality monitoring stations during 2004 - 2010.

	BR1	BR2	BR3	BR3A	BR4	BR4A
75-%	23.0	34.0	32.0	220.0	38.2	51.0
max	36.0	47.0	39.0	290.0	46.0	63.0
min	8.0	13.0	27.0	49.0	25.1	28.0
25-%	15.3	26.0	28.0	100.0	30.8	39.0
mean	19.8	30.8	30.8	171.0	34.8	45.5
median	19.5	31.0	29.5	180.0	34.8	46.5

7.3 Point and Non-point Sources of Contamination

Within the Blackstock Creek watershed there are no point sources of contamination such as wastewater treatment plant effluents or industrial plant effluents.

Non-point sources include runoff from agricultural fields that occupy more than 68% of the river watershed, urban runoff from several hamlets scattered across the watershed (2.4% of the watershed area) and runoff from road network in the watershed. Our previous research data obtained in the framework of the Lake Scugog Environmental Management Plan (LSEMP) show that phosphorus is the major concern in the Blackstock Creek watershed (Kawartha Conservation 2010b). Average phosphorus loading rate from the watershed into Lake Scugog is 740 kg annually. Approximately 63% of this amount is generated from the non-point sources of pollution including urban areas (11.9%), rural road network (11%) and agricultural lands

(40%). Approximately the same proportion of total nitrogen amount in the river flow is coming from non-point sources as well. On average, around 30,110 kg of nitrogen is entering Lake Scugog every year from Blackstock Creek and 64.8% of this amount is from non-point sources such as agriculture (62%) and urban runoff (2.8%).

7.4 Groundwater Quality Assessment

Groundwater is an important component of natural water resources and an essential source of drinking water supply for the rural population in both Ontario and nationwide. Groundwater aquifers of the Oak Ridges Moraine are a source of drinking water for 250,000 people in Southern Ontario. In the Blackstock Creek watershed all drinking water for the municipal water supply system, farms and private rural dwellings is coming from groundwater wells. Therefore, it is very important to have comprehensive information about groundwater quality and quantity as well as clear understanding of problems and issues related to groundwater.

Natural groundwater quality varies from place to place and is determined mainly by the types of sediments and rocks that water moves through. When water from rain or snow moves over the land and infiltrates into the ground, it may dissolve minerals in rocks and soils, percolate through organic material such as roots and leaves, and react with algae, bacteria, and other microscopic organisms. Each of these natural processes changes groundwater chemistry and potentially water use.

The groundwater quality assessment within the study area is based on data obtained from the Blackstock municipal water supply system situated west of hamlet of Blackstock (See **Figure 7.1**) and data from the Provincial Groundwater Monitoring Network (PGMN) well W387 located west of Cartwright West Quarter Line at Byers Road.

Unfortunately, there are quite limited groundwater quality data to allow for the comprehensive analysis on the entire watershed scale. The Blackstock municipal wells have available data, mainly microbiology, since 2003.

The hamlet of Blackstock located in the central portion of the watershed draws water from two municipal wells that range from 40.5 m (well #1) to 53.61 m (well #8) in depth. Well #8 is the main supply well (pump rate is 11.5 L/s) and well #1 is standby well (pump rate is 1.1 L/s). Third well #7 with depth of 60.82 m serves as emergency stand-by well and is not equipped with a pump. Well #1 draws water from the intermediate overburden aquifer within the lower sediment hydrological unit, which consists of sand deposits. Wells #7 and #8 extend into deep overburden aquifer within the same lower sediments (See Hydrogeology section). The system serves population of about 527 people (OMOE 2009b). The hydrogeological studies completed by Jagger Hims Ltd in recent years identified the modest sensitivity of the municipal wells to potential sources of pollution as the recharge areas to these wells and well fields consist of mostly residential lands within the hamlet, some open spaces and agricultural lands to the west and south.

The PGMN well W387 is located in the headwaters of the small-unnamed creek to the west from the Blackstock Creek subwatershed. The well extends 33.79 m into the overburden intermediate aquifer of the lower sediments. According to the Ministry of the Environment protocol, all PGMN monitoring wells are to be sampled at least once a year or, if possible, twice per year. The main purpose of this sampling is to monitor the ambient water quality and chemical composition of groundwater and evaluate long-term trends and changes. Samples collected and analyzed from this monitoring well show very good water quality.

Analysis of water quality data was based on a number of parameters, including general chemistry, metals, nutrients, microbiology, pesticides and other organic artificial compounds. However, number of samples is dissimilar for different parameters. In municipal wells raw water is tested most often for E. coli and total coliform, in compliance with the *Safe Drinking Water Act*, 2002. For other chemical compounds raw water samples analyzed only annually or semi-annually. **Table 7.9** shows the number of samples analyzed for each group of parameters at the various sampling locations. Analytical results were compared with the Ontario Drinking Water Quality Standards (ODWQS). The primary purpose of the ODWQ Standards, Objectives and Guidelines is to protect public health through the provision of safe drinking water. Water intended for human consumption should not contain disease-causing organisms or unsafe concentrations of toxic chemicals or radioactive substances. Water should also be aesthetically acceptable and palatable. Taste, odour, turbidity and colour are parameters that shall be controlled; such that water is clear, colourless, and without objectionable or unpleasant taste or odour. Standards, objectives and guidelines are considered to be the minimum level of drinking-water quality, although it does not preclude a better quality of water be achieved, or that the degradation of a high quality water supply to the specified level or range is acceptable. The standards, objectives and guidelines described in ODWQS have been derived from the best information currently available (OMOE 2003).

Based on the available analytical data it is possible to conclude that both the Blackstock municipal wells and the PGMN well W387 have an excellent water quality. The Blackstock municipal drinking water supply system has good water quality from a chemical perspective. Except iron, no exceedences for any other chemical parameter have been detected in recent years as concluded from the available data. Iron concentrations in water from well #8 exceed drinking water standard on regular basis. In particular, we have information that iron concentration exceeded the ODWQS in water of well #8 in August of 2008 when it was 0.54 mg/L. All other major parameters such as Cu, Na, Pb, F, Mn, NO3, Cl and Zn have concentrations far below the Ontario Drinking Water Quality Standards.

The Blackstock municipal drinking water system has available microbiological data for its two active wells for the period of 2003-2008. During those years, more than 500 samples of raw water from two wells have been tested for E. coli and total coliform. No single sample has revealed the presence of E. coli bacteria in raw groundwater. Only one sample from well #1 was tested positively for total coliform in 2005 when six bacteria colonies were detected. As well, total coliform has been detected in water from well #8 three times in 2003, 2005 and 2006. In all cases, a single colony has been discovered. Based on the extensive set of data it is possible to state that raw water in the Blackstock municipal system has very good water quality from the microbiological point of view.

Although the groundwater monitoring results show good water quality, it is important to recognize that sampled wells represent limited number of aquifers in only two locations of the watershed. In many locations, several aquifers may provide adequate volumes of water. For example, within the Blackstock well field, a deeper aquifer, beneath the municipal intermediate aquifer, is capable of producing high yields of water. However, the quality of water from this lower aquifer is poorer with high concentrations of dissolved minerals.

The greatest immediate concern for drinking water quality is bacteriological contamination. To address this concern municipal drinking water supply wells are frequently tested on a government-regulated schedule to ensure public health.

Table 7.9: Number of Groundwater Samples Since 2003.

Well ID	Metals	Nutrients	Pesticides	E.coli & Total Coliform
Blackstock well # 1	7	24	5	235
Blackstock well # 8	7	24	6	239
PGMN well W387	7	7	2	4

7.5 Key Observations and Issues

- Results indicate that Blackstock Creek and most of its tributaries have elevated total phosphorus levels caused by human activities, which is a major water quality threat across the watershed. Even at the watershed headwaters, phosphorus levels are exceeding the water quality guidelines. High amounts of phosphorus and nitrogen found in the creek have been identified as one of the main causes of eutrophication in Lake Scugog.

- In general, groundwater quality in the watershed is considered good. In many cases, groundwater quality is getting better as the depth of wells increases. Shallow wells tend to draw water from shallow unconfined aquifers, which can exhibit poorer water quality.

- Characterizing groundwater quality is a complex and difficult task because of a number of aquifers are present within the watershed, and there is a wide variety of different geologic features.

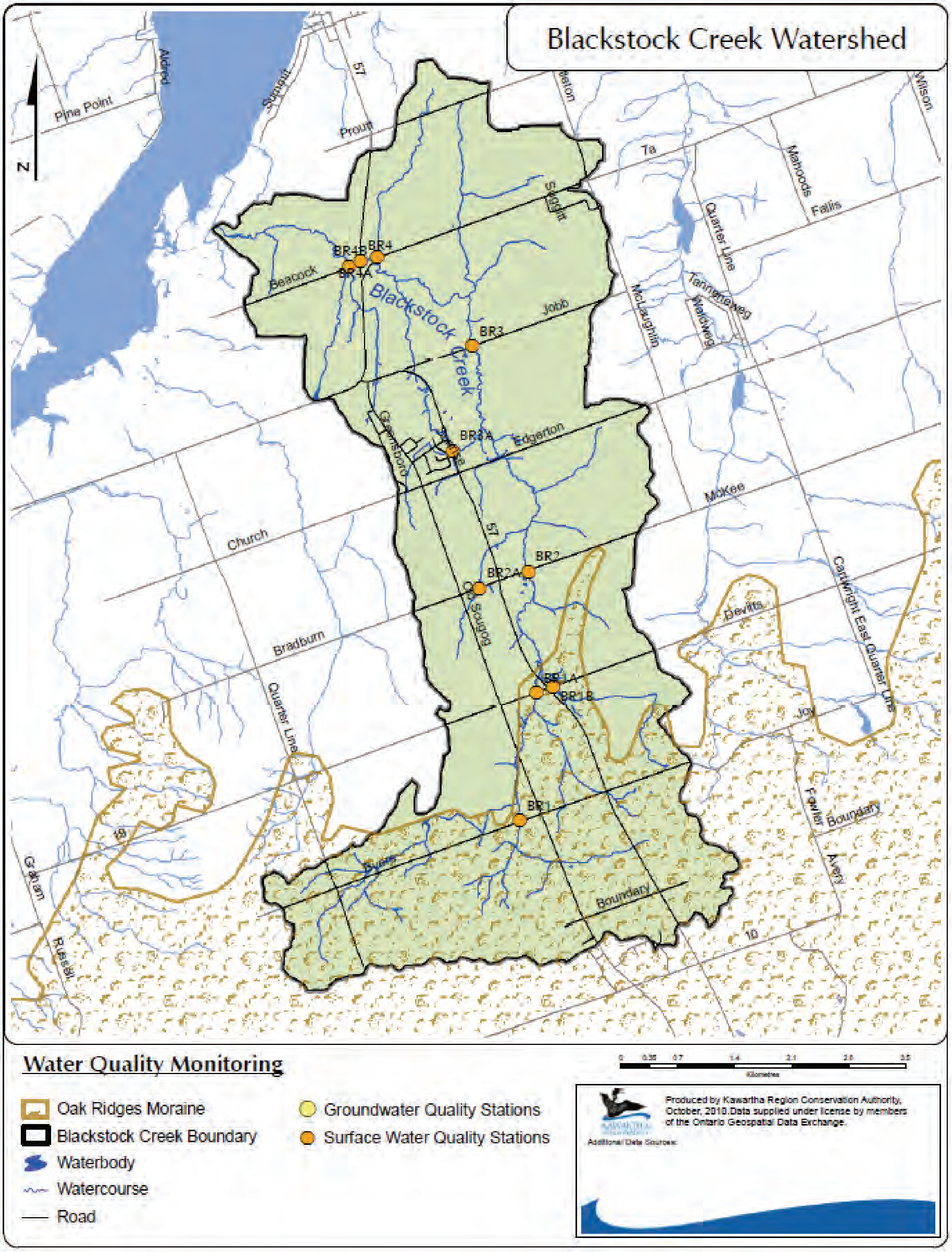


Figure 7.1: Water quality monitoring sites.

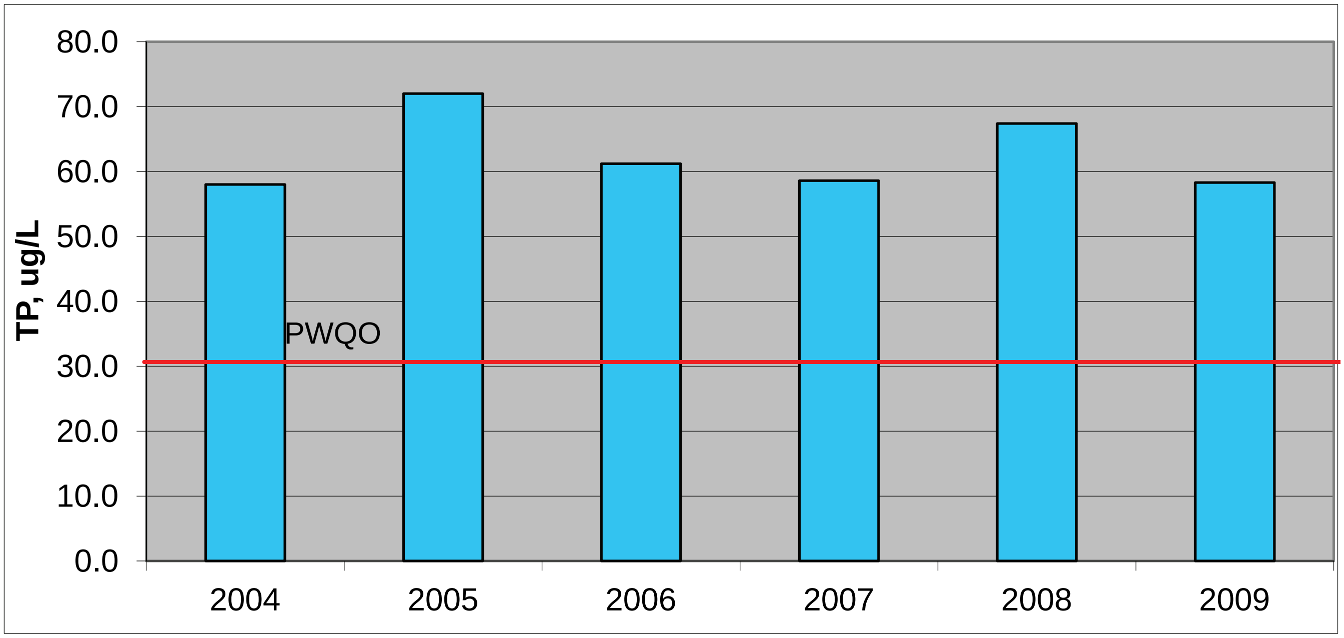


Figure 7.2: Annual Average Phosphorus Concentrations in Water of Blackstock Creek at Long-term Monitoring Station BR4 during 2004 – 2009 period.

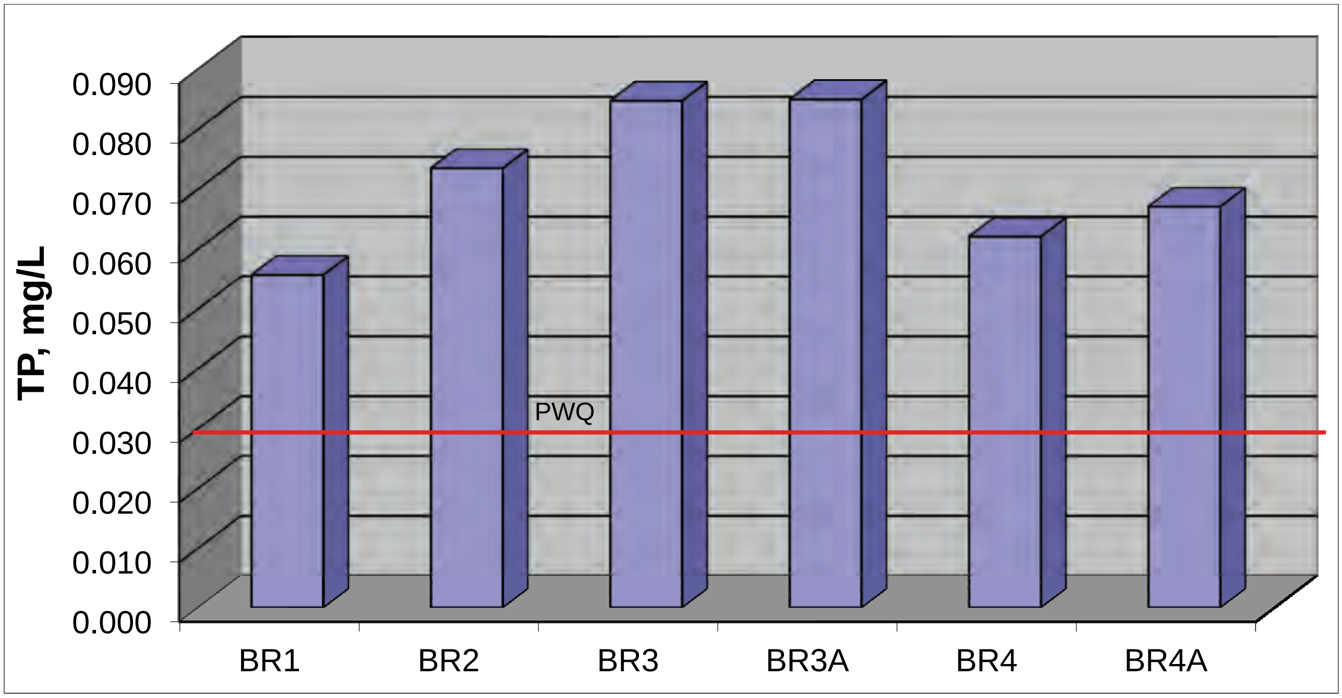


Figure 7.3: Average Phosphorus Concentrations at Blackstock Creek Monitoring Stations in 2004 - 2010.

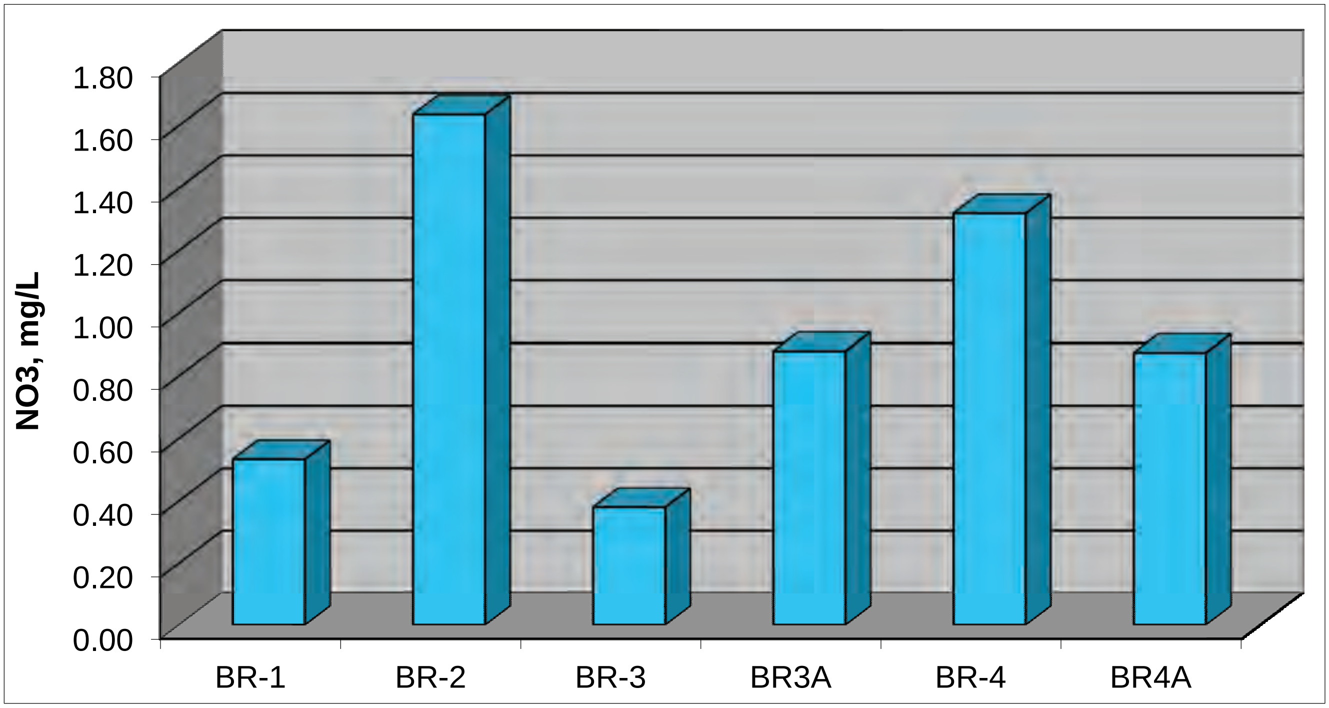


Figure 7.4: Average Nitrate Concentrations at the Blackstock Creek Monitoring Stations in 2004 - 2010.

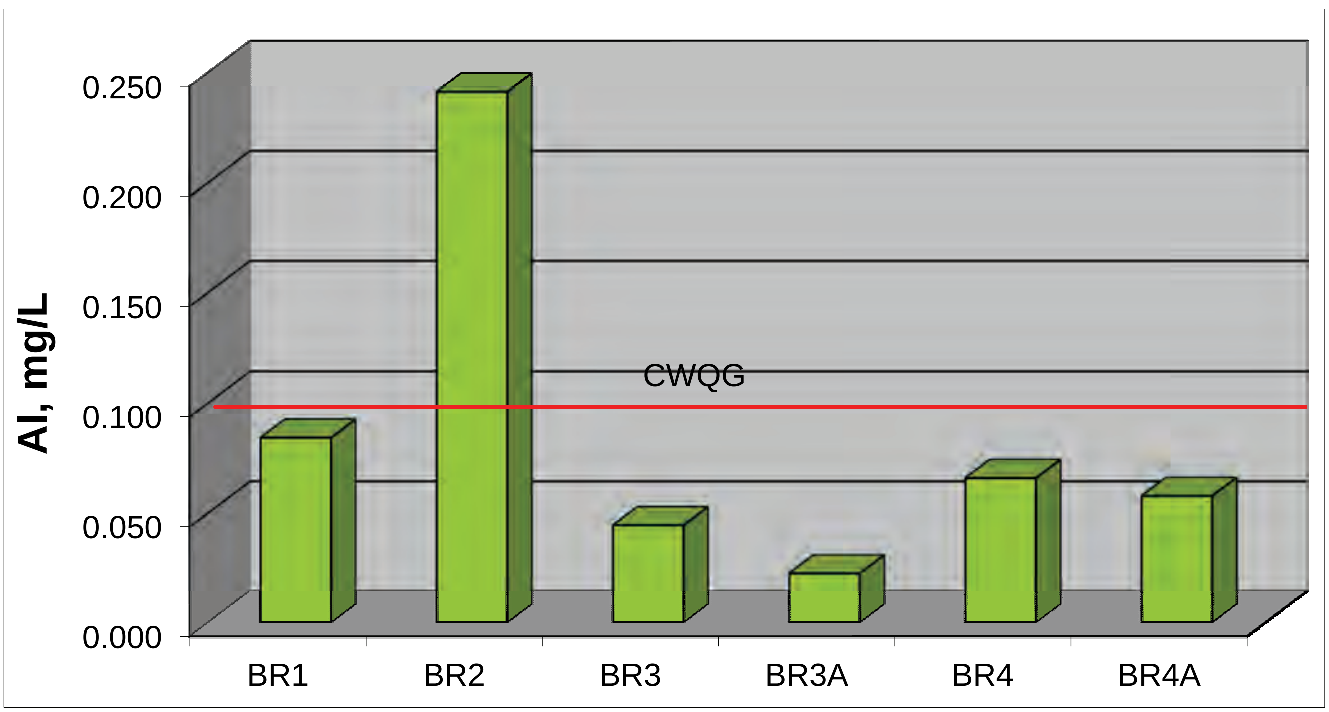


Figure 7.5: Average Aluminum Concentrations at the Blackstock Creek Monitoring Stations in 2006 - 2010.

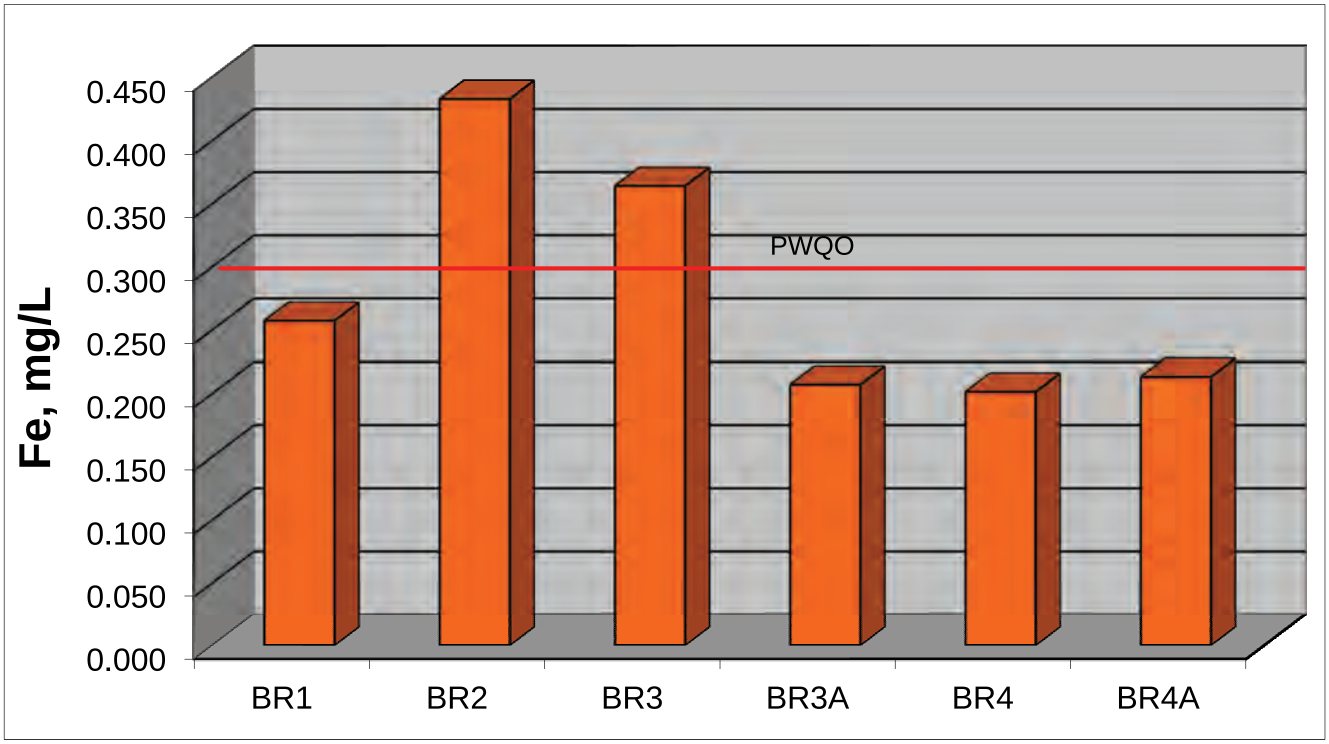


Figure 7.6: Average Iron Concentrations at Blackstock Creek Monitoring Stations in 2006 - 2010.

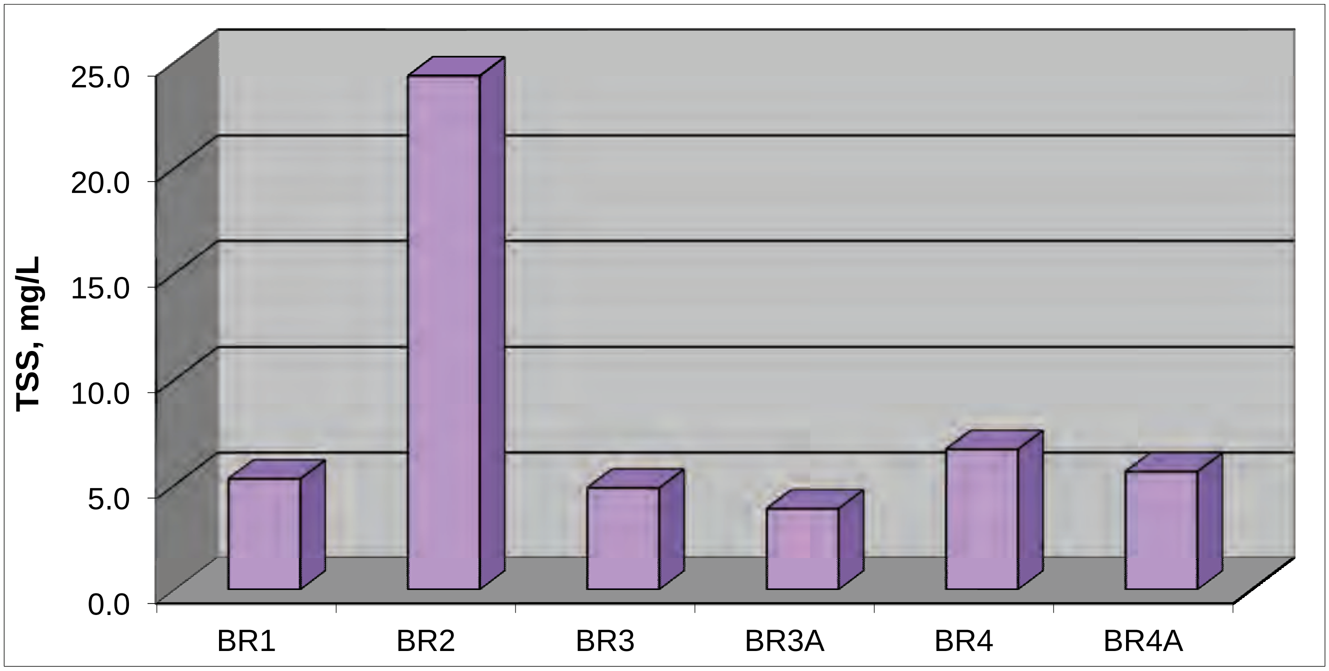


Figure 7.7: Average TSS Concentrations at Blackstock Creek Monitoring Stations in 2004 - 2010.

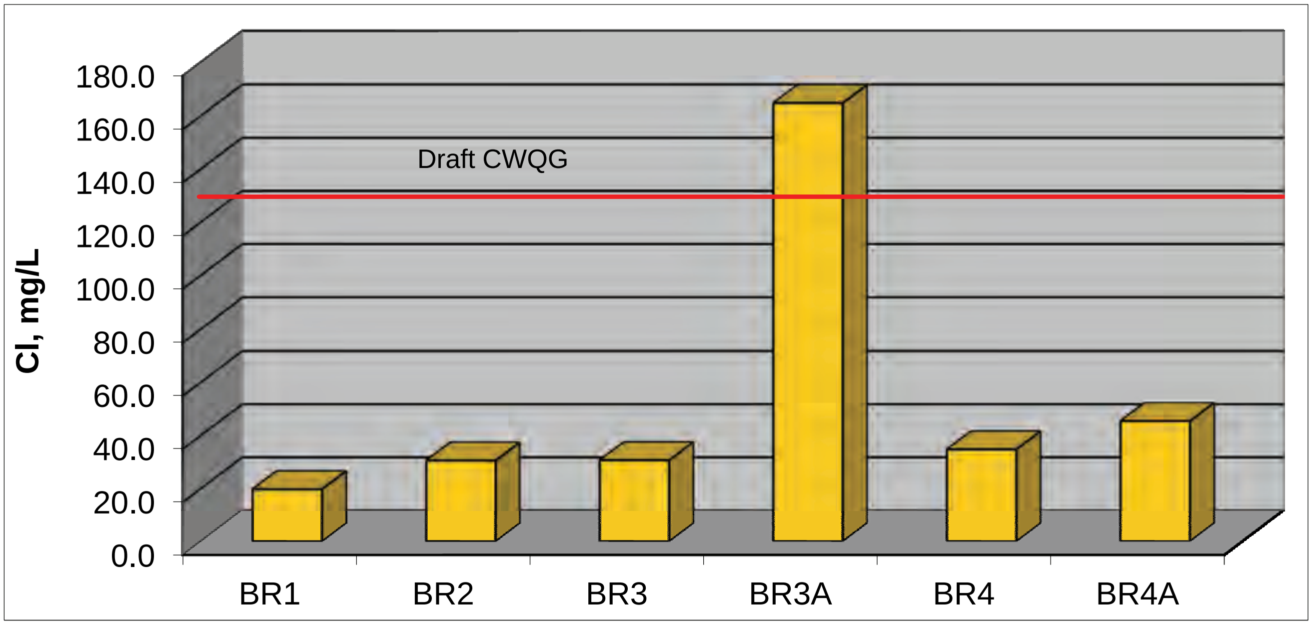


Figure 7.8: Average Chloride Concentrations at the Blackstock Creek Monitoring Stations in 2004 - 2010.

8.0 Aquatic Resources

Blackstock Creek, north of McKee Road

8.1 Introduction

Aquatic resources include the aquatic species that occupy the watercourses flowing through the Blackstock Creek watershed as well as significant in-stream habitat features that support these species. The presence and distribution of these resources is largely a function of watershed geography (e.g., latitude, slope, and geology) and hydrological conditions (e.g., intensity, timing, and duration of flows), and land use (e.g., human influences). Due to these close linkages with the landscape, the presence and distribution of these resources within watercourses is often reflective of the ecological and hydrological conditions within their upstream catchments. This chapter characterizes existing (and historical where available) instream habitat, riparian areas, benthic macroinvertebrates and fish communities.

8.2 Instream Habitat

Instream habitat refers to the various components within the stream corridor that provide habitat for aquatic species such as benthic macroinvertebrates and fishes. Fish habitat, as defined in the *Fisheries Act*, includes spawning grounds and nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly in order to carry out their life processes. This section provides an overview of some key instream habitat features that support aquatic resources within the watershed.

Stream Order

Stream ordering is a method of classifying the branching complexity of the stream network, which is largely influenced by the slope and geological characteristics of the stream valley. This can be a useful approach to assist in identifying watercourse reaches of similar biological, physical and chemical conditions. First-order streams are watercourses with no tributaries; second-order streams begin when two first-order streams meet; third-order streams begin when two third-order streams meet; and so on (Strahler 1957). The term 'headwaters' is commonly used when referring to first-, second-, and third-order stream reaches. The characteristics of these lower-order streams make them much more dependent upon riparian vegetation for protection of natural ecological functions.

The Blackstock Creek watershed supports a fourth-order watercourse before emptying into Lake Scugog (**Figure 8.1**, **Table 8.1**). First-order streams account for the majority of individual stream sections and comprise the majority (55%) of the entire watercourse length. Many more first-order streams exist in the southern half of the watershed than in the northern half, which is likely due to the relatively steep topography and areas of groundwater discharge. Headwater streams account for almost 80% of the entire length.

Table 8.1: Watercourse length by stream order.

	1st order	2nd order	3rd order	4th order
Stream Length (km)	32.7	11.7	3.5	12.0
Stream Length (%)	54.6	19.5	5.8	20.1

Substrate

Substrate refers to materials (gravel, sand, silt, etc.) that exist on the streambed. These features can significantly influence the types of aquatic communities living within the watercourse. In a general sense, substrates tend to be dominated by coarse materials (e.g., gravel, cobble, boulder) in relatively high gradient (steep) stream and where water velocities tend to be high and dominated by fine materials (e.g., silt, sand) in relatively low gradient (flat) stream sections and where water tends to be slow moving (Mackie 2001). The dominant substrate type within a given reach can be indicative of the types of aquatic organisms that live nearby. Stoneflies and caddisflies, for example, prefer stream reaches with coarse substrates, whereas aquatic worms and prefer fine substrates. Certain fish species, such as Walleye and Brook Trout, have an affinity towards coarse substrate during reproduction stages, whereas Largemouth Bass and Yellow Perch tend to spawn amongst aquatic vegetation that are rooted in fine substrates.

To characterize substrate conditions within the Blackstock Creek watershed, methods outlined in the Rapid Assessment Module of the Ontario Stream Assessment Protocol (Stanfield 2007) were applied at sample sites between 2006 and 2007. Average particle size of the substrate materials was determined at each sample site and grouped into three categories: fines (<2 mm), gravel (2mm to 100mm), and cobble (<100 mm). Of the 12 sites sampled, 6 of these have substrates that fall within the gravel category, 5 have substrates that fall within the fines category, and 1 site has substrates within the cobble category (**Figure 8.2**). The northern portion of the watershed exhibits more coarse substrates than the southern portion.

Instream Barriers and Ponds

Instream barriers include any man-made structure (e.g., dams, weirs, perched culverts) within a watercourse that obstructs or isolates aquatic species and habitats in either an upstream or downstream direction. These structures often alter the natural flow regime, and can negatively impact aquatic habitat and species by: fragmenting habitat, reducing the downstream movement of organic matter and habitat structure, impounding water thereby elevating temperatures, and genetic isolation (Bunn and Arthington 2002). In some cases, however, instream barriers have proven to be beneficial in protecting aquatic ecosystems by preventing the natural colonization of non-native species into a particular area within a watershed.

Perched culverts refer to culverts that are elevated from the stream bed. This often results from either improper installation (rare) or from high water velocities scouring the bed of the stream over time. The locations of perched culverts within the watershed were assessed in 2010 by volunteers during low-flow conditions following the Check Your Watershed Day protocol (Stanfield 2007). Of the 30 sites that were visited, 6 perched culverts were identified (**Figure 8.3**).

The locations of potential in-stream (directly connected to a watercourse) ponds were identified by highlighting areas of open water that exist along the watercourses. These are referred to as "potential" instream ponds because there was no detailed verification process. There are 60 potential ponds located within the watershed (**Figure 8.3**).

Water Temperature

Water temperature plays an important role in the overall health of aquatic ecosystems, affecting the rates of productivity, timing of reproduction, molting and movement of aquatic organisms (Caissie 2006). Fishes and other aquatic organisms often have specific temperature preferences, which can ultimately determine their distribution within streams. This 'thermal habitat' is influenced by a number of factors including: air temperature, precipitation, relative humidity, flow, geology, topography, land use, channel morphology, and riparian vegetation (Poole and Berman 2001).

To examine the existing thermal regime throughout the Blackstock Creek watershed, in the summer of 2007, temperature data loggers were installed at road-stream crossings and point-in-time spot-measurements were recorded following the protocols outlined in the Ontario Stream Assessment Protocol (Stanfield 2007). The data from these surveys were used to assigned a thermal regime status (cold, cool, or warm) to each sample site, based on the nonograms in Stoneman and Jones (1996), which were developed from relationships between air temperature and water temperatures observed in streams across southern Ontario (**Figure 8.4**).

Within the Blackstock Creek watershed, the thermal regime at 14 sites was determined. Of these sites, two (14.3%) were classified as warmwater, nine (64.3%) as coolwater, and three (21.4%) as coldwater (**Figure 8.5**). All of the coolwater and coldwater sites are located in the southern portion of the watershed, however, there is one warmwater site in the extreme headwaters. According to Bowlby (2008), all sites within the coolwater and coldwater category are likely capable of supporting a coldwater (i.e., Brook Trout) fish community, whereas warmwater sites are not.

8.3 Riparian Areas

Riparian areas are the transitional zones between aquatic and terrestrial habitats. Natural riparian areas encompass a range of vegetation types (i.e., forest, wetland, meadow), and provide many benefits to the watershed system, including: stabilizing stream banks, reducing erosion, moderating water temperatures, filtering contaminants, providing cover and spawning habitat for fishes, and supplying nutrient and food sources into the watercourse (Gregory et al. 1991).

Various studies have investigated the minimum riparian buffer width that is necessary to maintain the ecological and hydrological integrity of watercourses. These often range from 5 metres to 300 metres depending on the functions they provide (**Figure 8.6**). For example, a larger width may be required in areas adjacent to pristine or highly valued wetlands or streams; in close proximity to high impact land use activities; or with steep bank slopes, highly erodible soils, or sparse vegetation (Fischer and Fischenich 2000). Appropriate lengths of riparian coverage along watercourses have been investigated as well. Studies in southern Ontario suggest that stream degradation occurs when riparian vegetation amounted to less than seventy-five percent of the total stream length (Environment Canada 2004).

To characterize riparian areas within the Blackstock Creek watershed, the extent and type of land cover along the watercourse was interpreted from aerial photography taken in 2008. Natural cover (e.g., forest, wetlands, etc.) within the riparian areas was classified according to Ecological Land Classification methodology (Lee et al. 1998), whereas non-natural land cover (e.g., agricultural lands, urban areas, aggregate pits, etc.) was classified according to methods developed to complement this protocol developed by Credit Valley Conservation (1998).

Table 8.2 shows the percentage of major land cover types that occupy the riparian areas for a variety of widths (5, 30, 50, 100 and 200 metres), along both sides of the watercourse. Natural lands account for the most riparian area coverage among all widths, and tend to decline as width increases. The Blackstock Creek watershed does not meet the minimum recommended length of natural coverage of 75%, which is largely due to the encroachment of agricultural lands. Agricultural lands are the next prominent land cover type within all riparian widths, followed by areas of development. **Figure 8.7** shows the extent of these cover types within the 30 metre riparian area.

Table 8.3 shows the percentage of natural land cover that occupy the same riparian widths, based on stream order. Among all orders and widths, only fourth-order streams have extensive natural riparian coverage. The remaining orders have relatively low natural coverage (rarely over 50%) when compared to the rest.

Table 8.2: Riparian area coverage by land use type.

Land Cover Type	Riparian Area Coverage (%)				
	5 metre	30 metre	50 metre	100 metre	200 metre
Agriculture (intensive and non-intensive)	35.3	37.4	39.8	45.5	53.8
Aggregate	0	0	0	0	0
Natural	56.9	53.6	50.6	44.1	35.7
Development (rural and urban)	7.7	8.9	9.5	10.3	10.4
Manicured Open Space	0.1	0.1	0.1	0.1	0.1

Table 8.3: Natural riparian areas by stream order.

Stream Order	Natural Riparian Area Coverage (%)				
	5 metre	30 metre	50 metre	100 metre	200 metre
1st order	40.2	37.8	36.0	31.5	25.0
2nd order	58.3	50.9	45.4	35.2	23.6
3rd order	64.6	57.8	51.3	39.7	26.7
4th order	98.8	96.8	93.9	86.7	74.7

8.4 Benthic Macroinvertebrates

Benthic macroinvertebrates (benthos) are small, stream-dwelling organisms visible to the naked eye. They include taxa such as: crayfish, worms, spiders, beetles, mussels, snails, fly larvae and other organisms that live within or on the bottom substrates of watercourses for a significant portion of their life cycles.

Benthos have long-been utilized in biological assessments to characterize water quality and watercourse health. Sampling for benthos is advantageous because they are abundant in most streams, serve as primary food source for fishes, respond to ecosystem stress, and are relatively inexpensive to collect (Barbour et al. 1999). Also, an assessment of benthos condition within a watershed can complement traditional water chemistry sampling. A variety of indices are currently being used among conservation authorities to assess benthos data, including: number of taxa (richness); diversity; percent composition; Hilsenhoff Biotic Index; and, functional feeding groups (i.e., filters, grazers, shredders, etc.).

Historical benthos information within the Blackstock Creek watershed is limited; however, there are two known reports of significance. In 1983, IEC Beak Consultants Ltd. conducted a benthos survey at 2 sites, examining their functional feeding groups, diversity and physical habitat conditions. That study found that, in general, water quality and benthic habitat at these sites were of high quality (IEC Beak Consultants Ltd.

1983). Also, the Blackstock Creek watershed ranked 3rd when compared to sites within the Blackstock Creek, Layton River, Pigeon River, Fleetwood Creek, and East Cross Creek.

In 1992, the OMOE conducted a water quality survey of 28 sites in relatively undisturbed headwater streams across the Oak Ridges Moraine using benthos. From these regional data, a proposed set of reference values was derived for indicators of minimally-impacted benthos community composition: benthic taxa richness, >=20; EPT taxa richness >=8; and Hilsenhoff's Biotic Index, <=4.40 (Maude and Di Maio 1996). In addition, the authors utilized these data to develop a preliminary model of benthos community composition expected in minimally impacted sites across the Oak Ridges Moraine (**Figure 8.8**).

To examine the existing benthos community compositions within the Blackstock Creek watershed, Kawartha Conservation collected benthos at 24 sites, between 2006 and 2009, following methodology outlined in the Ontario Benthos Biomonitoring Network protocol (Jones et al. 2007). Benthos were identified to a 27-taxa level, made up of classes, orders, and families. To characterize biological water quality at each site, benthos data are summarized using two indices: a modified version of Hilsenhoff Biotic Index and percent EPT.

Hilsenhoff's Biotic Index is commonly used to assess the degree of organic pollution at the site level. In this approach, taxa identified down to the species-level (Hilsenhoff 1982) or family-level (Hilsenhoff 1988) are rated on a scale of 0 (least tolerant to nutrient enrichment) to 10 (most tolerant). An index value is calculated by summarizing the number of benthos in a given taxa, multiplied by tolerance value, and divided by the number of total organisms in the sample. This value is then compared to a range of values that specify the degree of organic pollution. Since benthos collections within the Blackstock Creek watershed were not identified consistently to species or family level, a modified Hilsenhoff Biotic Index approach was utilized, that averages tolerance values found in Mandaville (2002) for the 27 course-taxonomic level. Kilgour (1998) applied a similar approach on southern Ontario streams, demonstrating that a modified biotic index can be used to distinguish nutrient-poor and nutrient-rich streams with about 70% accuracy.

Using this modified Hilsenhoff Biotic Index approach to determine water quality, the majority of sites (78%) are classified as having "fairly poor" water quality. All sites were found to exhibit "fair" water quality or poorer. (**Table 8.3**, **Figure 8.9**).

Another commonly used index is Percent EPT. This index refers to the total percentage of taxa within the orders of Ephemeroptera (mayflies), Plecoptera (stone flies) and Tricoptera (caddis flies) within the sample. This index is considered one of many "best candidate benthos metrics" because taxa percentages have been shown to decrease in response to increasing perturbation (Barbour et al. 1999). **Figure 8.10** shows the relative benthos composition at each site, using the same seven taxa (EPT are lumped together) as used by Maude and Di Maio (1996) in the development of their benthos community composition model. Among all sample sites, percent EPT ranges from 1.3% to 41.9%. Within-and-around the Oak Ridges Moraine planning area, none of the sites matched the "reference composition" of 55% EPT. There is no apparent pattern in the distribution of sites within the watershed.

Table 8.3: Hilsenhoff index values.

Index Value	Water Quality	Degree of Organic Pollution	Number and (%) of Samples Sites
0.00-3.75	Excellent	Organic pollution unlikely	0 (0)
3.76-4.25	Very Good	Possible slight organic pollution	0 (0)
4.26-5.00	Good	Some organic pollution probable	0 (0)
5.01-5.75	Fair	Fairly substantial organic pollution likely	1 (11)
5.76-6.50	Fairly Poor	Substantial organic pollution likely	7 (78)
6.51-7.25	Poor	Very substantial organic pollution likely	1 (11)
7.26 - 10.00	Very Poor	Severe organic pollution likely	0 (0)

8.5 Fisheries

Fish species are an important ecological link in the food web and are also important indicators of water quality and ecosystem health. In addition, they serve as food for other fish, birds, reptiles and mammals, including humans. Understanding the status of fisheries resources within a watercourse often provides insight into the ecological status of the entire watershed in which the watercourse flows. Fish, as do all aquatic life forms, serve as "sentinel" species, alerting people that water quality is changing.

No known historical data on fish communities exist within the Blackstock Creek watershed. To examine the existing fisheries communities within the Blackstock Creek watershed, Kawartha Conservation sampled 12 sites between 2006 and 2007 (**Figure 8.11**). Sites and sampling techniques were selected to reflect the influence of landscape features that are known to influence aquatic community composition, and other variables such as: physiographic regions, land use, above-and-below significant barriers, site accessibility, depth and substrate, and above all, geographic coverage. All stream sections were wadeable, thus, the single-pass electrofishing method as outlined in the Ontario Stream Assessment Protocol (Stanfield 2007), was used to determine fish species composition.

A total of 19 fish species, represented 8 families, were captured during these recent sampling efforts (**Table 8.4**). Species richness per site ranged from 1 to 12 (average of 5.8) among these sites. Most of these fishes are common throughout watercourses within south-central Ontario; there are no species of conservation concern. Goldfish are considered the only non-native (not naturally occurring) species within the watershed. These species are not native to the Great Lakes Basin, but are found throughout many watersheds in Ontario as a result of unintentional introductions (aquarium release).

The Blackstock Creek watershed contains both warmwater and coldwater fish communities. **Figure 8.12** shows the sites where coldwater fishes (Brook Trout and/or Mottled Sculpin) and where warmwater fishes (all other species) were captured. The distribution of warmwater fishes is widespread throughout the watershed, however, coldwater fishes were caught at the majority of sites. Brook Trout were only found in sites south of Edgerton Road. Brook Trout naturally occurs in cold, well-oxygenated waters with nearby groundwater-upwelling areas. They are particularly sensitive to ecosystem disturbance, thus their presence and continuing natural reproduction within a watercourse indicates healthy aquatic habitat conditions.

The ability for Brook Trout to persist within the middle and upper reaches of Blackstock Creek is largely due to continuous groundwater inputs, cold water temperatures, lack of development in the area, and absence of known competitors (i.e., Rainbow Trout and Brown Trout). The fact that Rainbow Trout were not documented within the headwaters of the Blackstock Creek is extremely significant, as they have been introduced to many Oak Ridges Moraine tributaries.

Table 8.4: List of fish species.

Common Name	Scientific Name
Rock Bass	*Ambloplites rupestris*
White Sucker	*Catostomus commersonii*
Brook Stickleback	*Culaea inconstans*
Iowa Darter	*Etheostoma exile*
Brassy Minnow	*Hybognathus hankinsoni*
Pumpkinseed	*Lepomis gibbosus*
Common Shiner	*Luxilus cornutus*
Northern Pearl Dace	*Margariscus nachtriebi*
Largemouth Bass	*Micropterus salmoides*
Yellow Perch	*Perca flavescens*
Logperch	*Percina caprodes*
Northern Redbelly Dace	*Chrosomus eos*
Blacknose Dace	*Rhinichthys atratulus*
Longnose Dace	*Rhinichthys cataractae*
Brook Trout	*Salvelinus fontinalis*
Creek Chub	*Semotilus atromaculatus*
Central Mudminnow	*Umbra limi*
Mottled Sculpin	*Cottus bairdii*
Goldfish	*Carassius auratus*
Total number of documented species	**19**

8.6 Key Observations and Issues

- The watershed supports diverse fish communities that are dominated by native species. Nineteen species of fish have been documented within the watershed.
- No aquatic species of conservation concern (e.g., Species at Risk) have been documented.
- One aquatic invasive species, Goldfish, has been documented within the watershed.
- Brook Trout, a sensitive coldwater species, exist within the southern and central sections of the watershed. However, elevated water temperatures caused by on-line ponds and lack of riparian areas are likely limiting suitable habitat for this and other coldwater species. Climate change has the potential to exasperate the effects of stream temperature warming.

- Small headwater streams (i.e., 1st, 2nd and 3rd order streams) account for over 80% of the total watercourse length within the watershed.

- The watercourses have natural vegetation along their length, at approximately 54%. However, this amount does not meet minimum ecological requirements with respect to total riparian area coverage (i.e., 75% of the total watercourse length being naturally vegetated to a width of 30 metres on both sides). Riparian areas are particularly lacking along the smaller tributaries (e.g., 1st and 2nd order streams).

- Benthic macroinvertebrate communities tend to be dominated by pollution tolerant organisms. Community composition indicates that there is likely substantial organic pollution occurring throughout the watershed.

- The fragmentation of aquatic habitat, caused by in-stream barriers, has the potential to negatively impact the integrity of existing populations of fishes.

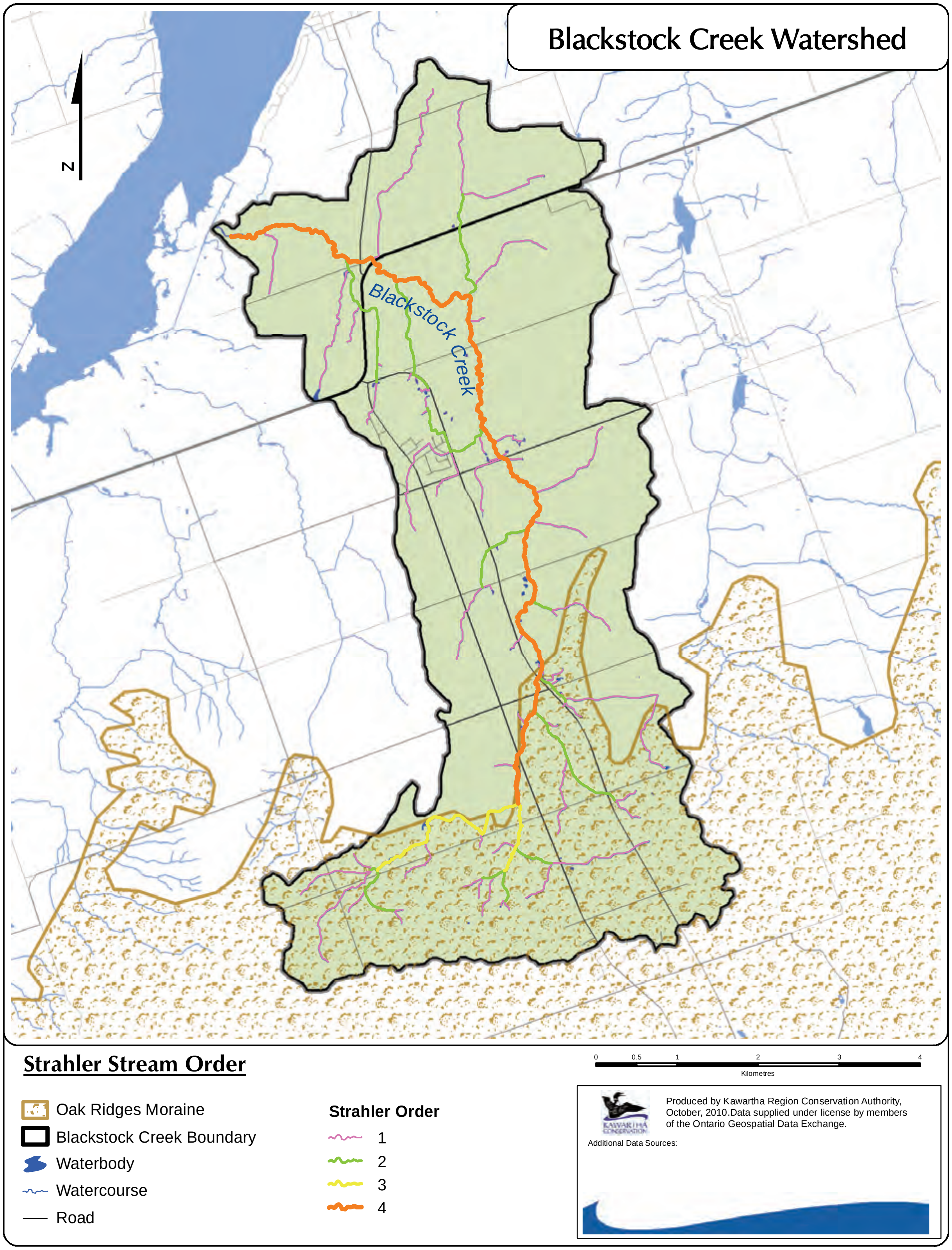


Figure 8.1: Stream order.

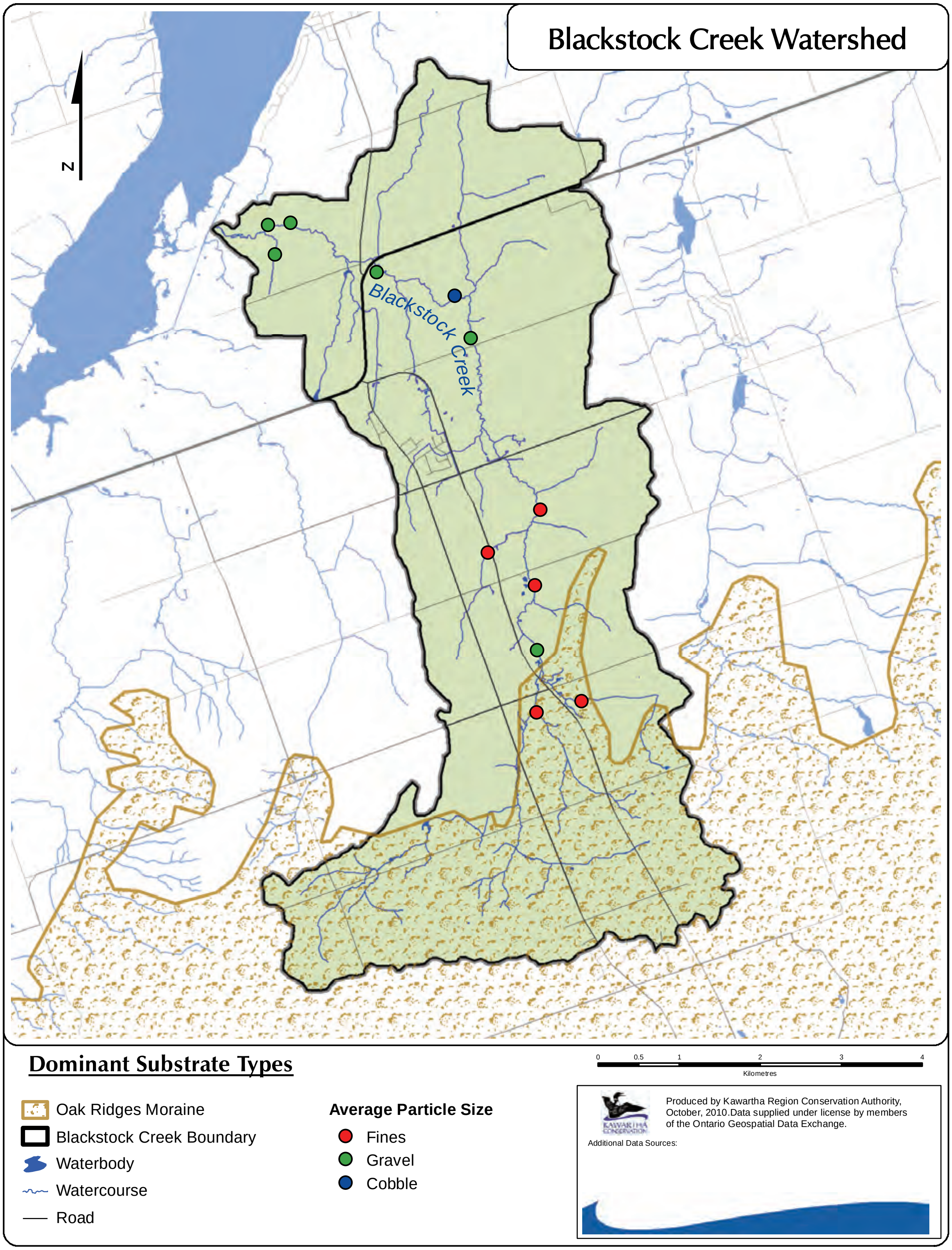


Figure 8.2: Dominant substrate types.

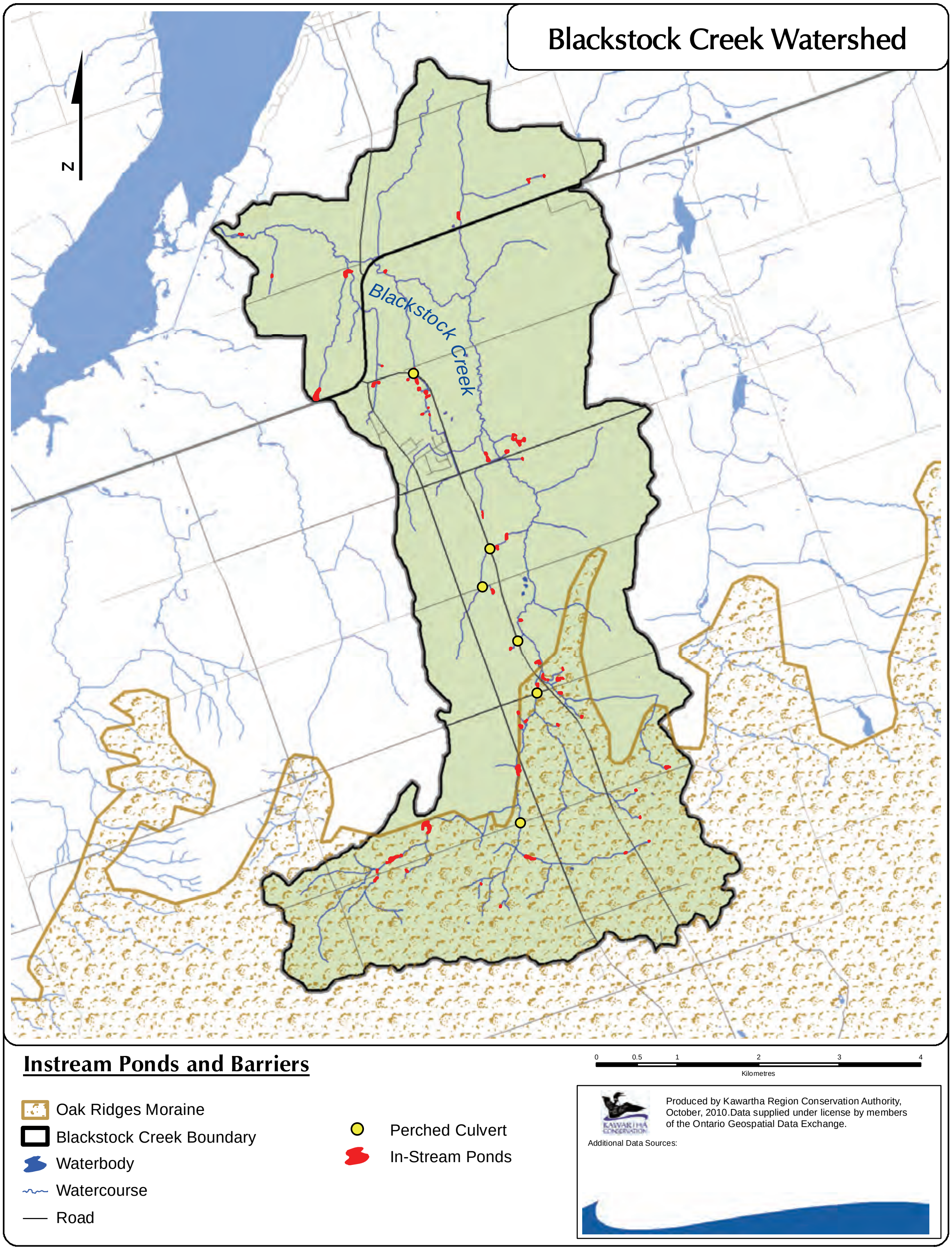
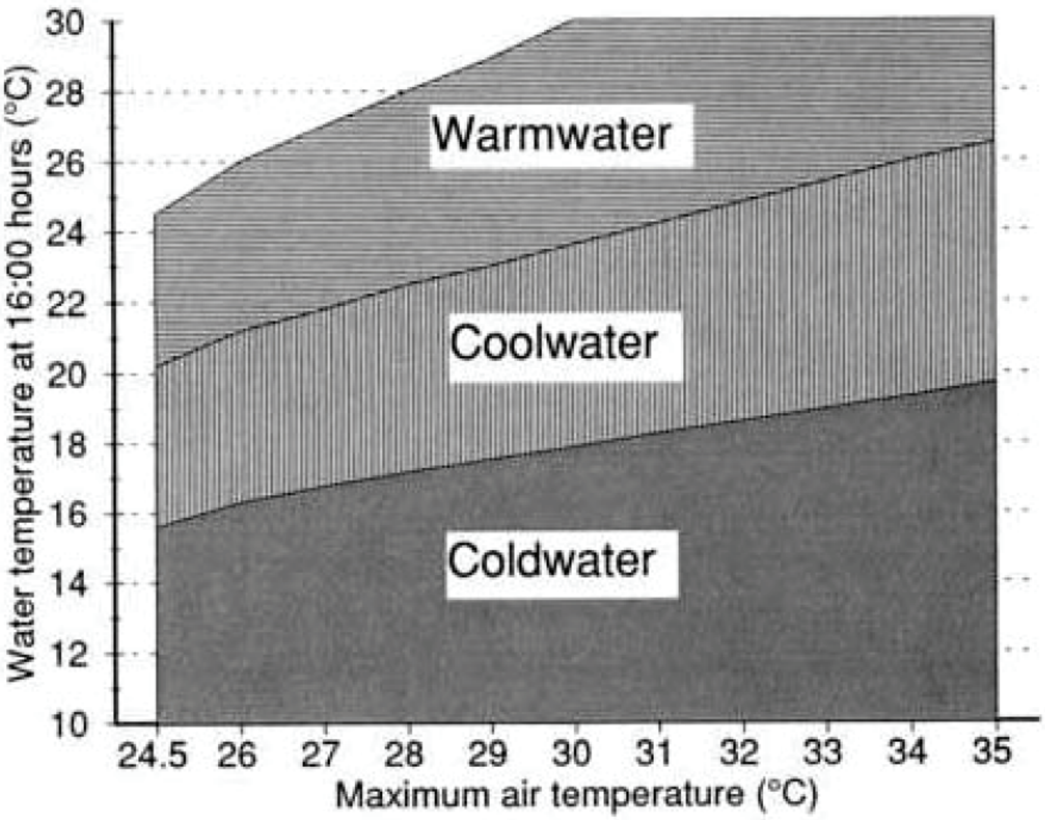


Figure 8.3: Instream barriers and ponds.



From Stoneman and Jones (1996)

Figure 8.4: Thermal regime classification based on relationships between maximum air temperatures and water temperatures.

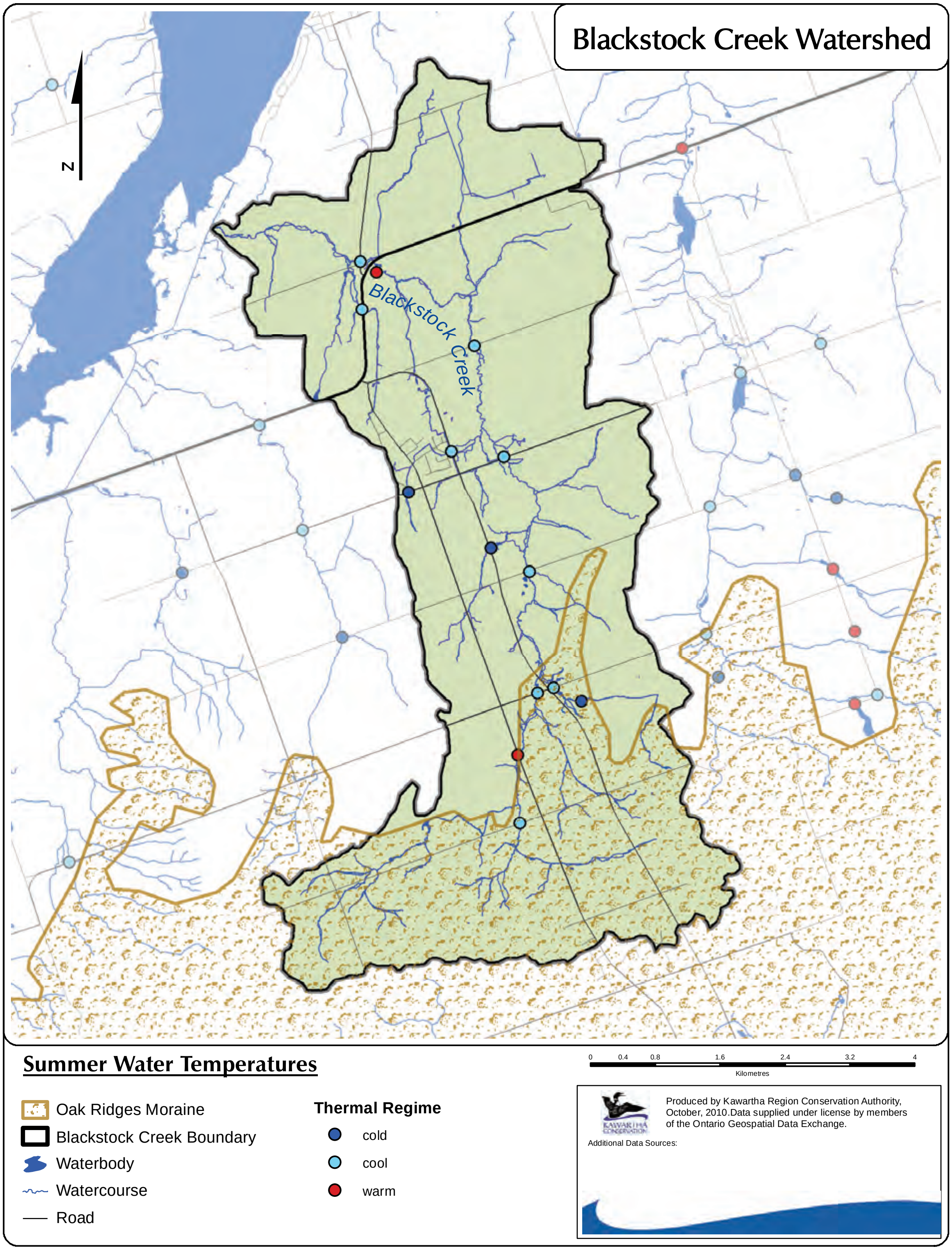
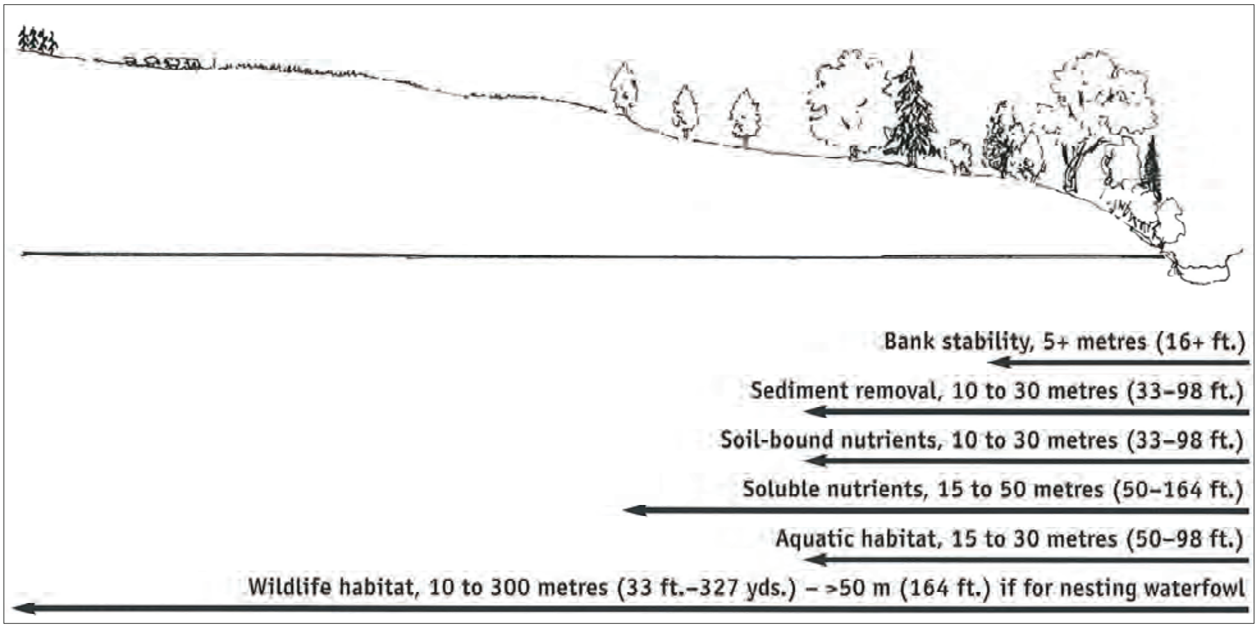


Figure 8.5: Thermal regime based on summer water temperatures.



From OMAFRA (2003)

Figure 8.6: Length of naturally vegetated buffers necessary to maintain functions.

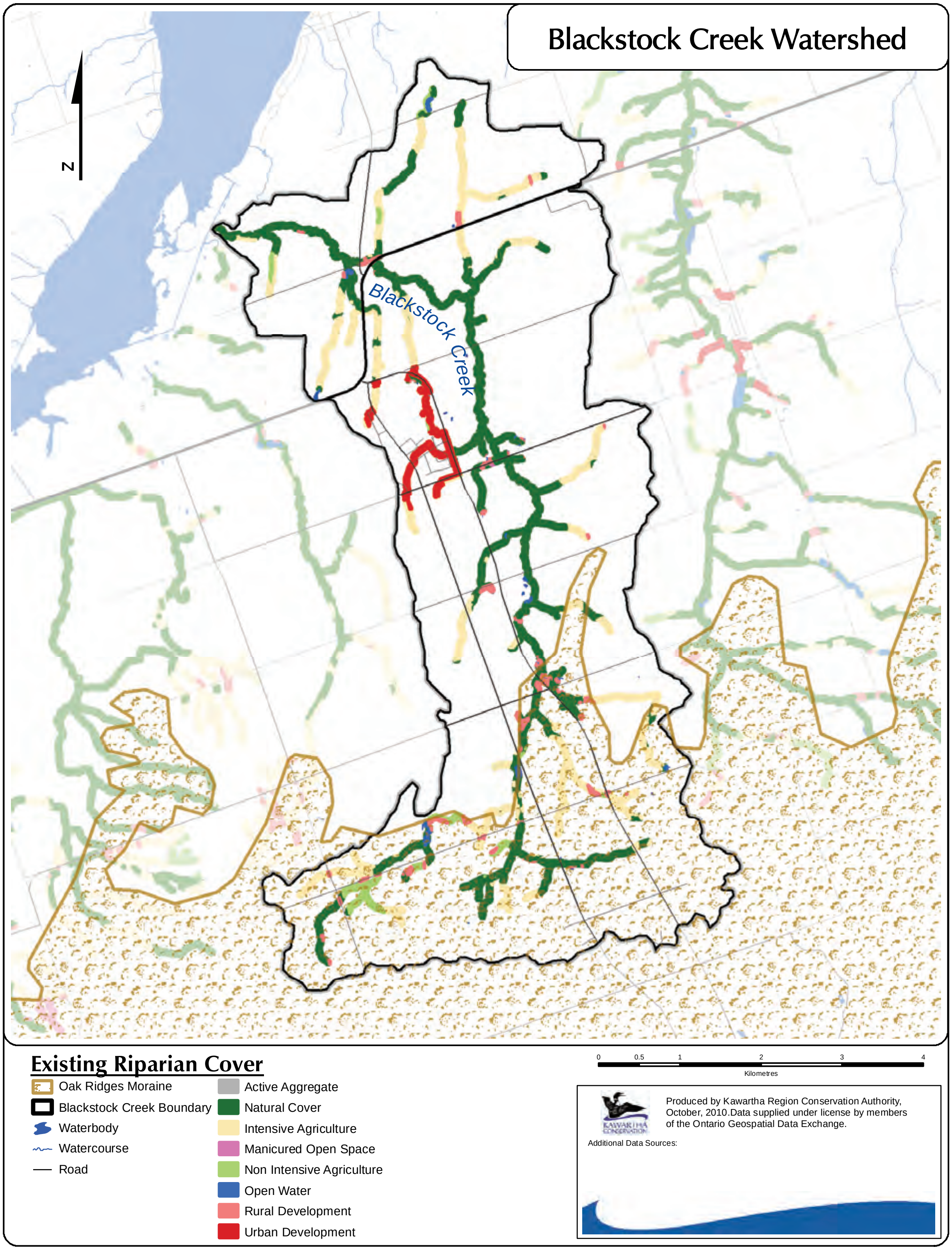
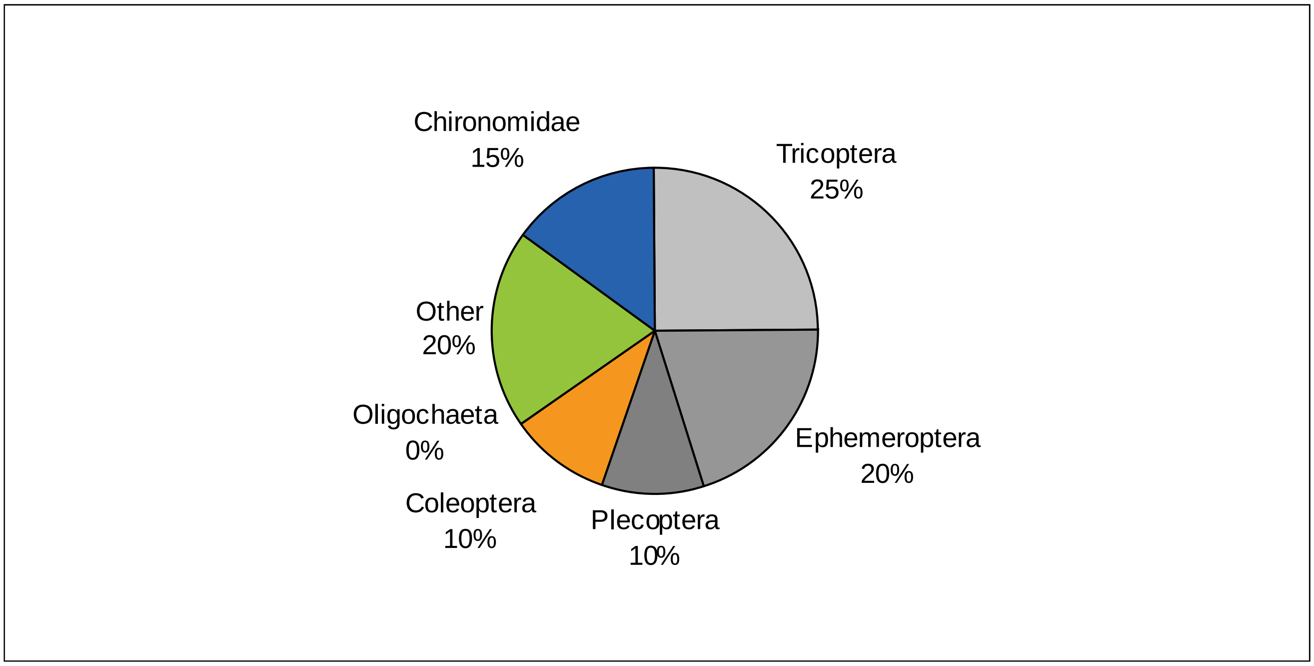


Figure 8.7: Existing riparian cover.



From Maude and Di Maio (1996)

Figure 8.8: Benthos community composition model.

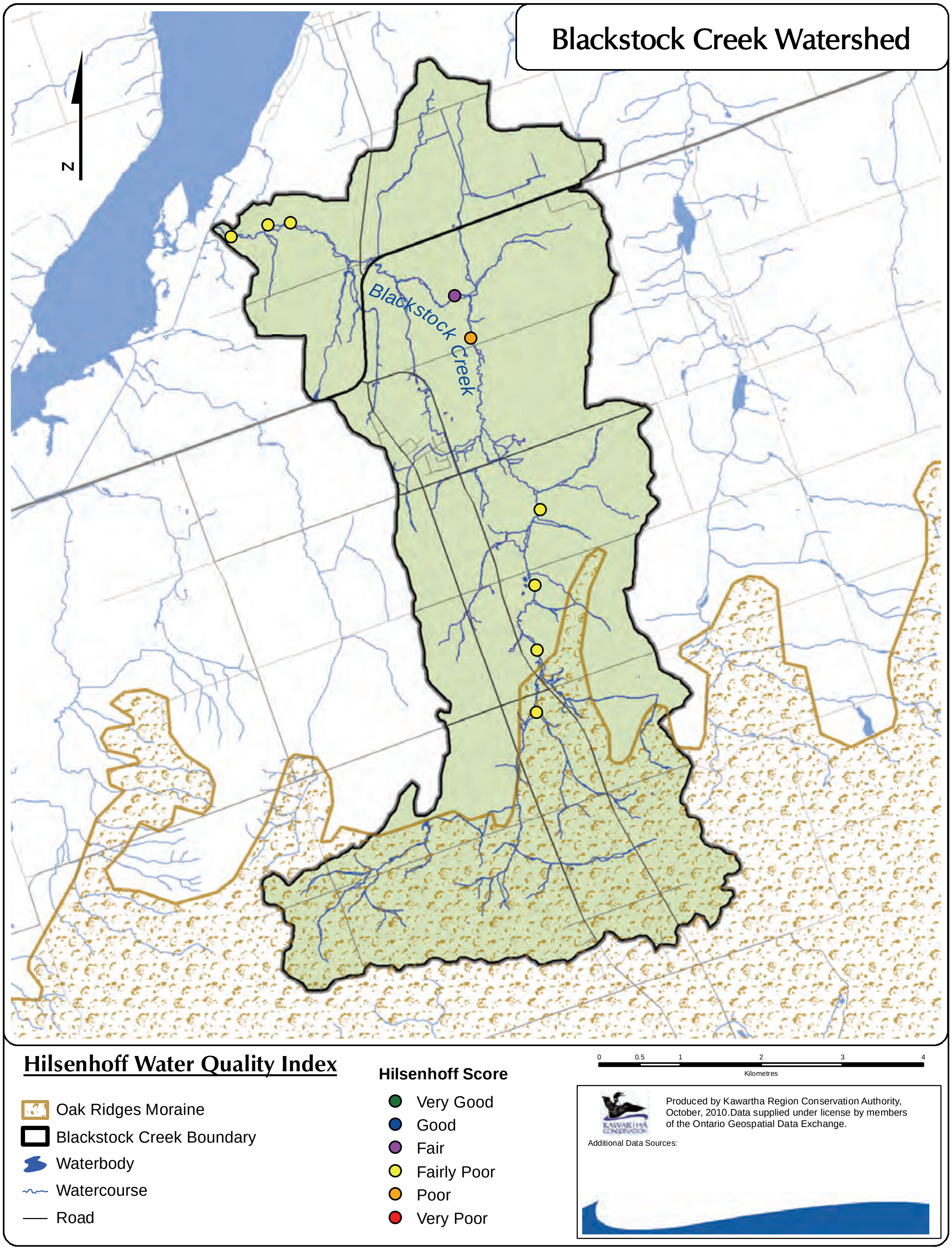


Figure 8.9: Hilsenhoff Index values.

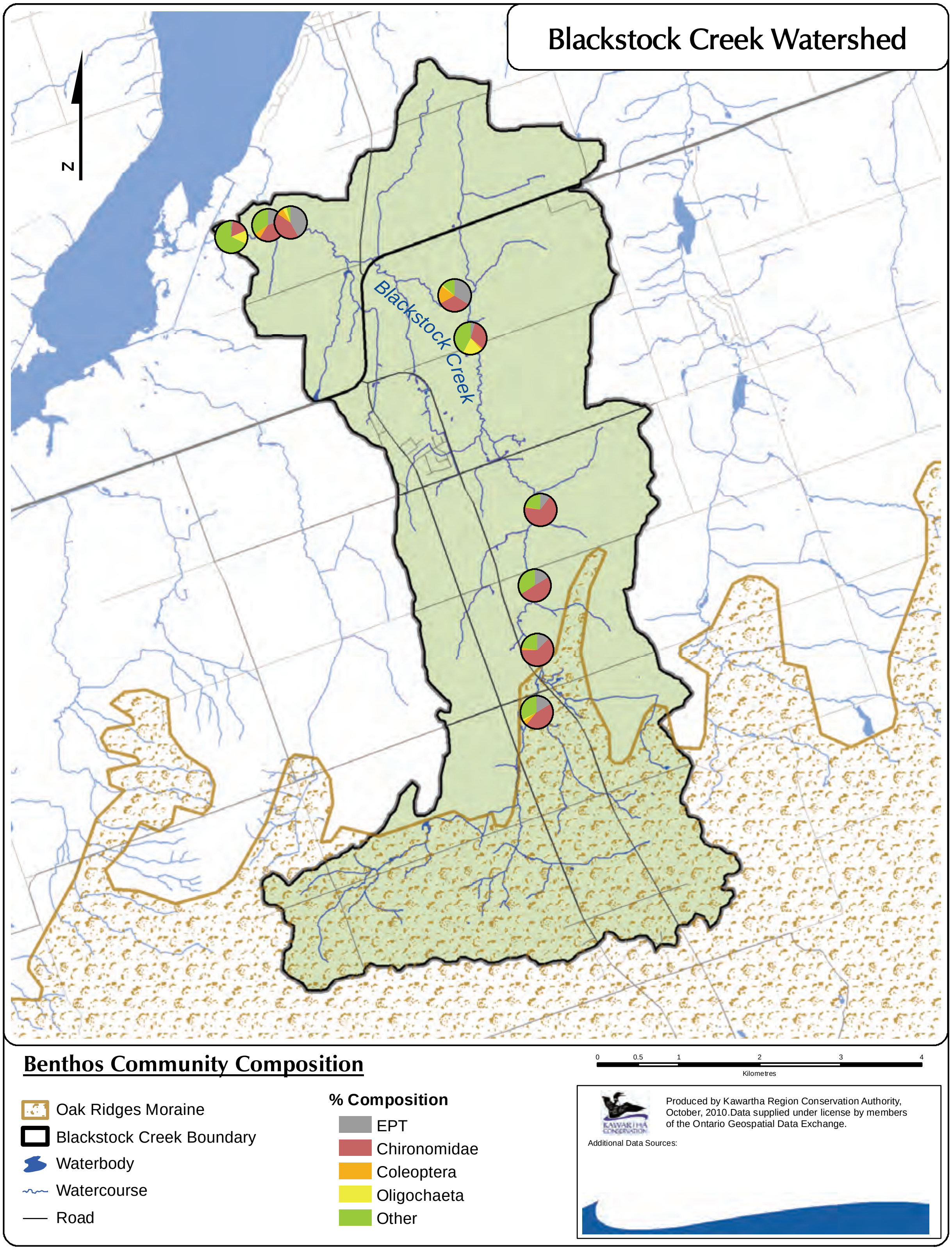


Figure 8.10: Benthos community composition.

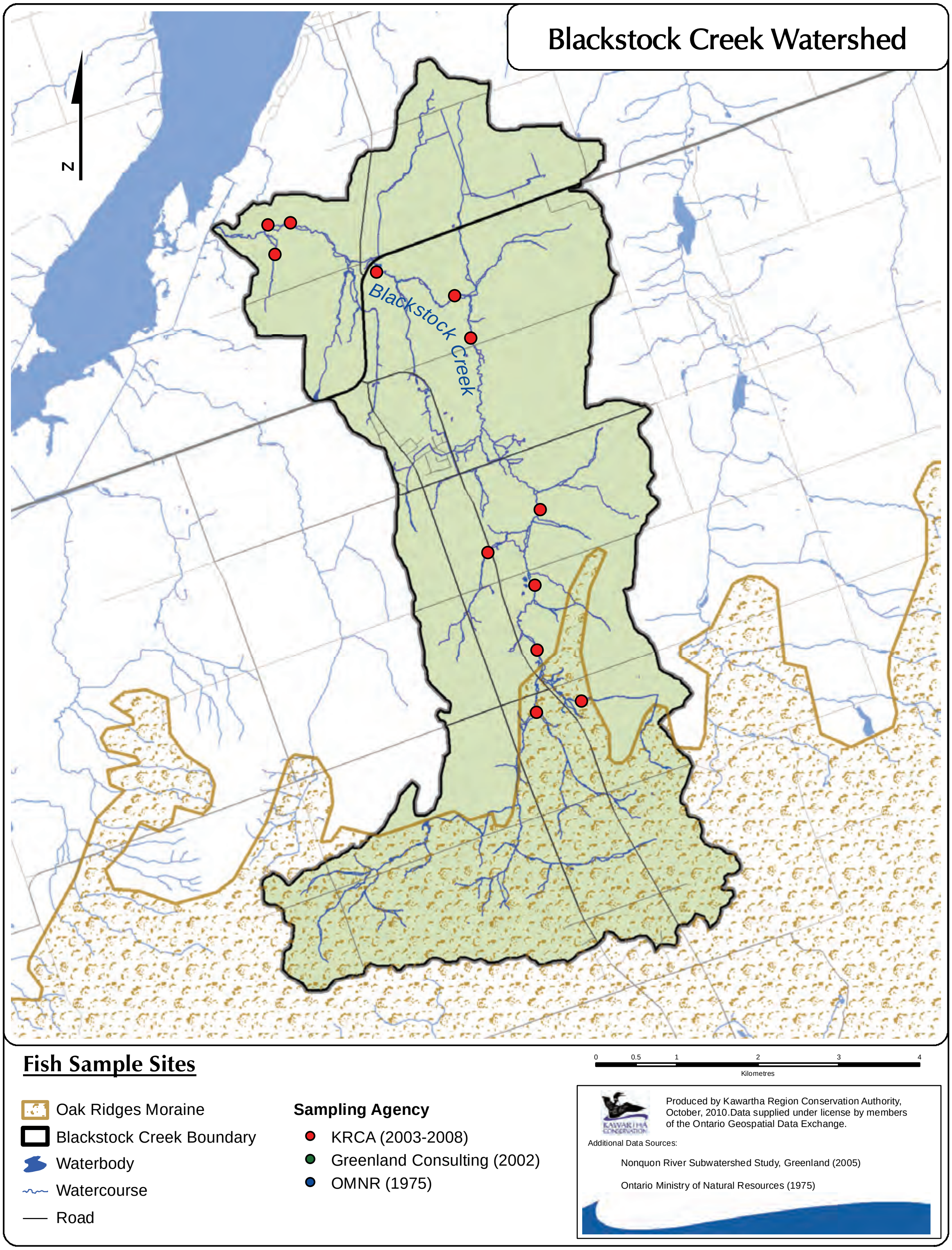


Figure 8.11: Fish samples sites.

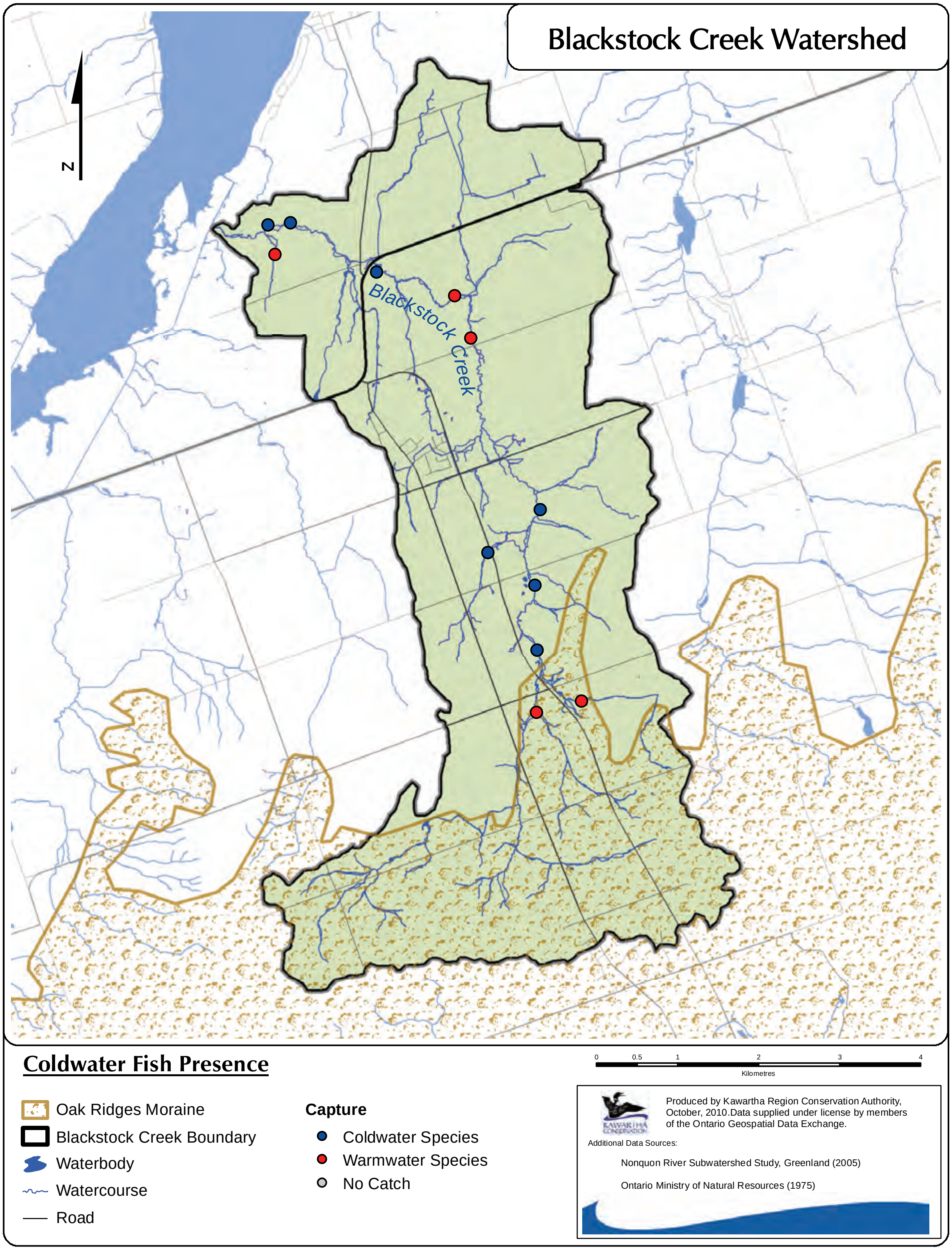


Figure 8.12: Coldwater fish captures.

9.0 Terrestrial Natural Heritage

Blackstock Creek, north of Jobb Road

9.1 Introduction

This section reports on the terrestrial natural heritage system within the Blackstock Creek watershed through an analysis of natural cover, vegetation communities, wildlife habitat, biodiversity, significant natural heritage features and forest cover. Principles of conservation biology and landscape ecology are used to evaluate terrestrial natural heritage resources and to predict the impact of alterations to natural cover, vegetation communities, wildlife habitat, biodiversity or significant natural heritage features.

9.2 The Watershed within the Surrounding Landscape

The Blackstock Creek watershed lies within the Huron-Ontario section of the Great-Lakes St. Lawrence Forest Region. This region is characterized by its glacial-derived irregular topography that is often plain-like. The area is well-settled with few extensive forest tracts. The dominant forest canopy species of the region include Sugar Maple, American Beech, Basswood, Ash, Birch, Oak and occasionally Eastern Hemlock, White Pine and Balsam Fir. The species composition of the Blackstock Creek watershed forests are typical of this forest region, with primarily mixed forest, some deciduous and pockets of coniferous forest.

The watershed is located within the Scugog Tertiary watershed, 2HG (Phair et al. 2005). 2HG is an inland watershed wherein the land use is predominantly agriculture with some relatively small residential communities. 12.6% of the 2HG watershed consists of lands under conservation protection, the majority of these being provincially significant wetlands. Natural cover in 2HG consists of mixed forest, coniferous and deciduous forest; deciduous and coniferous swamp; and marsh.

The Blackstock Creek watershed is situated over two ecodistricts including the Peterborough Ecodistrict (6E-8) and the Uxbridge Ecodistrict (6E-7).

The northern portion of the Blackstock Creek watershed is located within ecodistrict 6E-8. This ecodistrict is underlain for the most part by a drumlinized till plain referred to as the Peterborough Drumlin Field but its southern portion, to the west of the watershed, is situated over scattered sands and the Schomberg Clay Plains, to the west of the watershed. Within the watershed, the physiography is mainly sand plain with one area of clay plain and scattered drumlins. 1% of ecodistrict 6E-8 is residential settlement and approximately 60% of the lands are agriculture related. The ecodistrict contains over 49 000 ha of provincially significant wetland, and 96% of the target conservation areas for the ecodistrict are provincially-significant wetlands.

The southern portion of the Blackstock Creek watershed is located in ecodistrict 6E-7. Ecodistrict 6E-7 encompasses the majority of the Oak Ridges Moraine and features kame moraines, drumlinized till plains and sand plains. Over half of the ecodistrict is currently in agriculture including crops, pasture and abandoned fields. Approximately 30% of the ecodistrict remains in natural cover and is primarily deciduous forest with some wetland. 7% of the ecodistrict is conservation land, with one-third of this being owned by Conservation Authorities.

Wetlands in these ecodistricts are primarily swamp with some marsh with small amounts of fen and bog. Significant remnants of globally rare vegetation communities including tallgrass prairie, savanna and alvar have been identified as high priority conservation targets for ecodistricts 6E-7 and 6E-8. There is potential for such remnants to exist within the southern portion of this watershed on the Oak Ridges Moraine, however none have yet been confirmed.

The Oak Ridges Moraine, extending along the southern portion of this watershed, is an environmentally-sensitive geological feature that extends across the landscape of south central Ontario. Due to the high natural and cultural significance of this feature, activity on the Oak Ridges Moraine is subject to the Oak Ridges Moraine Conservation Plan. The deep deposits of sand and gravel substrates that make up the Oak Ridges Moraine support an ecological system that is unique within the surrounding landscape. The high porosity of the substrates on the Oak Ridges Moraine make much of the moraine an area of high aquifer vulnerability. Due to its complex hydrogeologic functions, the terrestrial system of the Oak Ridges Moraine has great influence on water systems within the Blackstock Creek watershed and all of south central Ontario.

9.3 Natural Cover

An area of natural cover refers generally to land that has not been significantly influenced by anthropogenic activity. Areas of natural cover provide many benefits and perform a variety of functions that are essential to overall watershed health including:

- filtering nutrients, sediments and pollutants from surface water run off;
- improving air quality through filtration and oxygen release;
- improving the natural aesthetic of communities thus contributing to the well being of local citizens;
- maintaining aquatic and terrestrial wildlife habitat;
- performing flood attenuation;
- providing opportunities for recreation and for people to connect with the natural world through activities such as hiking, nature viewing, biking, fishing, and hunting;
- providing wildlife habitat & preserving biodiversity;
- reducing shoreline erosion by slowing and reducing surface water run off;
- sequestering carbon to reduce atmospheric carbon dioxide levels, thus contributing to the mitigation of the effects of climate change; and,
- moderating summer temperature extremes through transpiration.

Alteration of natural cover within the watershed, particularly within riparian buffer areas, may affect any or all of the above functions.

The watershed contains 10.8km^2 of natural cover, representing 28.4% of the total watershed area. This includes all areas classified as forest, wetland or meadow. **Figure 9.1** details the areas of each of these natural cover types existing within the watershed and **Table 9.1** illustrates the percentage of each land use type within the watershed.

The watershed, with 28% natural cover, falls short of targets set by the Great Lakes Conservation Blueprint for Biodiversity for Ecodistrict 6E-8, however it exceeds the target for Ecodistrict 6E7: 30% natural cover for Ecodistrict 6E-8, and 22% natural cover for Ecodistrict 6E-7.

A subset of natural cover, forest cover, was also assessed in relation to percent cover targets. To determine the total forest cover area, forested wetlands (swamps) are included in the total forest area. Forested wetlands are also included in the total wetland area. When determining the total natural cover for the watershed, forested wetlands cannot be double counted as part of both forests and wetlands, therefore forests, forested wetlands and wetlands are counted separately to determine the total natural cover area. The watershed contains 23% forest cover, falling below target levels including: 30% forest cover for the Region of Durham, 25% - 35% forest cover for watersheds in Ontario, and 30% forest cover for area of concern watersheds within the great lakes basin.

Comparison of the amount of forest cover with target levels suggests that restoration efforts to increase forest cover would be beneficial for overall watershed health. The areas of the watershed available for forest restoration include all those areas not already under natural cover. This includes lands currently being used for agriculture, dump sites, manicured open space, urban areas, aggregate extraction areas, and rural development. Areas that are inappropriate for forest restoration include roads, active dump sites and active aggregate extraction areas. If forest restoration was completed in urban areas and rural development areas it would be possible only in small patches and would not increase percent forest cover to meet target levels. Thus meeting targets for percent forest cover would require restoration efforts in areas that are currently in agriculture, manicured open space, or inactive aggregate extraction areas. Additionally, restoration efforts will have the highest benefit if they are focused on areas where habitat connectivity can be simultaneously improved. Additionally, restoration efforts will have the highest benefit if they are focused in areas where habitat connectivity can be simultaneously improved.

Table 9.1: Percentage of natural cover.

Land Use	Watershed Area (km^2)	Watershed Area (%)
Forest	6.5	17.1
Forested Wetland	2.2	5.7
Non-Forested Wetland	0.6	1.6
Meadow	1.4	3.7

9.4 Ecological Land Classification

Ecological Land Classification (ELC) is a method to further classify natural cover types into vegetation community types within the watershed. Vegetation communities for the watershed were classified and mapped in 2008-2010 based on the ELC System for Southern Ontario (Lee et al. 1998). All areas of the watershed were classified through interpretation of 2008 aerial photography. Eleven types of cultural areas and 12 types of natural areas (ELC community series) were identified for the watershed. Vegetation community types are described in **Table 9.2** and community types are mapped in **Figure 9.2**.

The ELC assessment shows that 5% of the watershed contains cultural vegetation community types, and 23.4% natural vegetation community types. Mixed forests encompass the greatest area of the natural forest community types, accounting for 7.2% and coniferous (5.7%) and deciduous (2.9%) make up the remainder of the forest cover in the watershed.. Seven different wetland types have been determined within the watershed with coniferous swamp (3.9%) and mixed swamp (1.3%) making up the majority of wetland area.

Table 9.2: Community series description.

Community Series (Code -Descriptive Name) [1]	Description of Community Series	Watershed Area (km^2)	Watershed Area (%)
Cultural Areas			
CUM – Cultural Meadow	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by a tree and shrub cover each of less than 25%.	0.7	1.9
CUP – Cultural Plantation	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by tree cover > 60%.	0.5	1.2
CUS – Cultural Savanna	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by 25%< tree cover ≤ 35%.	<0.1	0.1
CUT – Cultural Thicket	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by tree cover ≤ 25%; shrub cover >25%	0.7	1.7
CUW – Cultural Woodland	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by tree cover between 35% and 60%.	<0.1	0.1
Natural Areas			
FOC – Coniferous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% coniferous tree species	2.2	5.7
FOD – Deciduous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% deciduous tree species	1.1	2.9
FOM – Mixed Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 25% deciduous tree species and greater than 25% coniferous tree species.	2.7	7.2

[1] Community series' refer to those described in the Ecological Land Classification for Southern Ontario manual, first approximation (Lee et. al. 1998), unless marked with a * which indicates a land use code that has been created by practitioners and accepted by the South Central Ontario Conservation Authorities terrestrial natural heritage discussion group (SCOCA), but which are not explicitly included in Lee et. al. (1998).

Community Series (Code -Descriptive Name) [1]	Description of Community Series	Watershed Area (km^2)	Watershed Area (%)
MAM – Meadow	Areas with <2m of water over substrates. Often seasonally flooded with soils drying out by mid-summer. Tree and shrub cover is less than or equal to 25% and area is dominated by emergent hydrophytic macrophytes. Represents the wetland-terrestrial interface.	0.3	0.7
MAS – Shallow Marsh	Areas with <2m of water over substrates. Often with standing or flowing water for much or all of the growing season. Tree and shrub cover is less than or equal to 25% and cover of emergent hydrophytic macrophytes is greater than or equal to 25%.	<0.1	0.2
OAO – Open Aquatic	Areas with water >2m deep. Plankton dominated with no macrophyte vegetation and no tree or shrub cover.	<0.1	0.2
SAF – Floating-leaved Shallow Aquatic	Area with standing water <2m deep. No tree or shrub cover, and if emergent vegetation is present is not dominant. Greater than 25% cover of floating-leaved macrophytes. Often influenced by shoreline energy.	0.0	0.0
SAM – Mixed Shallow Aquatic	Area with standing water <2m deep. No tree or shrub cover, and if emergent vegetation is present is not dominant. Greater than 25% cover of submerged and floating-leaved macrophytes. Often influenced by shoreline energy.	<0.1	<0.1
SAS – Submerged Shallow Aquatic	Area with standing water <2m deep. No tree or shrub cover, and if emergent vegetation is present is not dominant. Greater than 25% cover of submerged and floating-leaved macrophytes. Often influenced by shoreline energy.	0.0	0.0
SWC – Coniferous Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is >25%, canopy height is greater than 5m, and conifer tree species make up >75% of the canopy. Hydrophytic shrubs and herbs present.	1.5	4.0
SWD – Deciduous Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is >25%, canopy height is greater than 5m, and deciduous tree species make up >75% of the canopy. Hydrophytic shrubs and herbs present.	0.2	0.5
SWM – Mixed Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is >25%, canopy height is greater than 5m, deciduous tree species	0.5	1.3

Community Series (Code -Descriptive Name) [1]	Description of Community Series	Watershed Area (km^2)	Watershed Area (%)
	make up >25% of the canopy, and coniferous tree species make up >25% of the canopy. Hydrophytic shrubs and herbs present.		
SWT – Thicket Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is less than or equal to 25% and hydrophytic shrub cover is >25%.	0.3	0.8
Cultural Areas		**1.9**	**5.0**
Natural Areas		**8.9**	**23.4**
Total Natural Cover		**10.8**	**28.4**

9.5 Terrestrial Biodiversity

The diversity of vegetation communities as well as the flora and fauna species that they support can provide an insight into the overall ecological health and condition of the watershed, and assist with prioritization of conservation work within the watershed.

Full flora and fauna lists have not been compiled for the watershed, however significant species existing in the watershed or with high potential to exist within the watershed have been determined (**Table 9.3** and **Table 9.4**). The existence of significant species, such as designated species at risk or species populations known to be in decline, can assist with prioritization of conservation work within the watershed.

Table 9.3: Significant Fauna Species with High Potential to Exist within the Watershed.

Scientific Name	Common Name	Species Target for Ecodistrict 6E-7	Species Target for Ecodistrict 6E-8	Species Target for Tertiary Watershed 2HG	EO[2] in Blackstock Creek Watershed	Comments
Aeshna verticalis	Green-striped Darner				√	
Buteo lineatus	Red-shouldered Hawk	√				Requires relatively large undisturbed forests. Observations relatively close to the watershed in forests similar to those existing in the watershed.
Childonias niger	Black Tern		√	√		

[2] EO (Element Occurrence): species observation recorded in the Natural Heritage Information Center (NHIC) database

Scientific Name	Common Name	Species Target for Ecodistrict 6E-7	Species Target for Ecodistrict 6E-8	Species Target for Tertiary Watershed 2HG	EO[2] in Blackstock Creek Watershed	Comments
Dendroica cerulea	Cerulean Warbler	√	√			This migratory species has been observed elsewhere in the Regional Municipality of Durham. It is more likely to pass through the watershed than to breed there.
Ixobrychus exilis	Least Bittern	√	√	√	√	
Lanius ludovicianus	Loggerhead Shrike		√			Found in only 6 core locations in Ontario including the Carden Plain north of the watershed.
Rallus elegans	King Rail		√	√		Observed in wetlands just east of the watershed. Suitable habitat available in the watershed.

Table 9.4: Significant Flora Species with High Potential to Exist Within the Watershed.

Scientific Name	Common Name	Species Target for Ecodistrict 6E-7	Species Target for Ecodistrict 6E-8	Species Target for Tertiary Watershed 2HG	EO in Blackstock Creek Watershed	Comments
Juglans cinerea	Butternut	√	√			Mature deciduous forests. Species common, but Ontario populations undergoing rapid decline due to Butternut canker.
Panax quinquefolius	American Ginseng	√				Observed in relatively close proximity to the watershed.

<u>Forests</u>

Woodlands in the Oak Ridges Moraine have been impacted by nearly 200 years of human settlement activities. When Europeans first settled the Oak Ridges Moraine the value of timber was not recognized and the forest was viewed as an impediment to settlement and travel. Woodlands that were not cleared for settlement were used to meet the demand for rapid growth and construction of towns.

All of this has resulted in a landscape very different than the one encountered by the first settlers. Most southern Ontario woodlands are now small, fragmented forests. These forests include: plantations on private land and Conservation Areas or large municipal properties (e.g., the Durham Regional Forest); abandoned Christmas tree plantations (often referred to as Scots pine jungles); immature mixed forests that are regenerating abandoned agricultural lands; or the fairly extensive lowland woodlands along the middle and lower reaches of Blackstock Creek.

Woodlands and the Hydrological Cycle

The hydrological cycle is a complex web of interacting events and features that move water within our atmosphere and on or under the land. The cycle includes processes such as evaporation, transpiration, rainfall, and features such as streams, rivers, geology and the water table.

Woodlands affect the hydrology of watersheds in many ways, including: retaining snow melt and storm runoff (thereby increasing infiltration and groundwater recharge); reducing the nutrient load of runoff; and, providing balanced groundwater discharge during periods of drought. Excessive forest clearing leads to erosion, increased sedimentation in streams, warming of surface waters, and seasonal extremes in high and low stream flow.

Tree cover creates and maintains a mat of decomposing leaf and twig litter which protects the soil surface, slows runoff, reduces erosion, and increases infiltration. The older, most decomposed materials near the bottom of this layer become the organic matter in the soil, tending to be rich in nutrients, with improved soil structure. Infiltration may also be improved by the development of root channels as trees grow.

Woodland Streams

Woodlands play an important role in stream health and hydrology. By retaining and discharging ground water throughout the year, forests help maintain the base flow of the smaller headwater tributaries that often originate in woodlands or small wetlands. Overhead shade helps to maintain cool water temperatures. These small streams can provide essential habitat for the native Brook Trout; as they require excellent water quality, cool water temperatures and high oxygen levels. The presence of Brook Trout is considered an indicator of healthy streams and watersheds.

Forest Types

The forests within the Oak Ridges Moraine and south-central Ontario are considered to be part of the Great Lakes – St. Lawrence Forest Region, located north of the Deciduous Forest Region (generally running along and south of the 401) and south of the Boreal Forest Region. Some forest types are unique to this area but others resemble forests in the Regions to the north and south (Farrar 1995).

The primary forest types of the Oak Ridges Moraine and area are variations of upland woodlands, lowland woodlands, and early successional forests (commonly referred to as pioneer forests). One other major southern Ontario woodland type is the plantation, with various species and many planting arrangements, which are generally established on eroded valleylands, riparian areas, and abandoned or marginal farmlands.

Pioneer Forests

Pioneer forests are the first stage in succession, naturally regenerating after a significant disturbance, e.g. fire, wind damage, clear cutting, large scale mortality from insects or diseases, or abandonment from agricultural use. These forests are usually comprised of fast growing, relatively short-lived hardwoods requiring full sunlight for germination and growth. Within several decades, many of these pioneer species die off, having created the more suitable conditions (cooler, moister, greater organic materials) for natural 'succession' to longer-lived species that grow more successfully in shade. Pioneer species vary from site to site, most commonly including:

- Trembling (Populus tremuloides) and large toothed aspens (Populus grandidentata), balsam poplar (Populus balsamifera), silver (Acer saccharinum) and red maples (Acer rubrum), white ash (Fraxinus americana), red (Prunus) and black (serotina) cherries, and white birch (Betula papyrifera).

- With the appropriate soil and a ready seed source, red oak (Quercus rubra), white pine (Pinus strobus), spruce (Picea spp.) and white cedar (Thuja occidentalis) can occasionally be considered pioneer species.

- Pioneer conifers include white pine, white cedar, balsam fir (Abies balsamea), and white spruce (Picea glauca). However, these species can usually tolerate slightly more shade and follow a few years after the pioneer hardwoods.

- Shrub species include hawthorn (Crataegus spp.), beaked hazel, dogwood (Cornus spp.), elderberry (Sambucus spp.), choke cherry (Prunus virginiana) and wild raspberries (Rubus ideaus).

- Exotic species such as Scots pine (Pinus sylvestris) and the very invasive European buckthorn (Rhamnus cathartica), also thrive in these conditions. These two species are becoming increasingly common in many areas of the Blackstock Creek watershed, replacing native trees and shrubs as pioneer species.

<u>Upland Forests</u>

There are basically two types of upland forests in the Blackstock Creek watershed, depending on soil types, drainage patterns, stages of succession, and land-use history. These forest types and their variations can be found growing side by side, often signaling a change in the site or stand history. These woodlands, once the most common in the Blackstock Creek watershed uplands, now exist only as remnant features.

Upland Oak-Pine Forests are found on drier sites, with red oak and occasionally white oak being the major hardwood species, in conjunction with white pine, hemlock, white spruce, and occasionally red pine. They can grow on shallow or drought prone soils, e.g. the higher slope, coarse sandy – gravel soils of the Oak Ridges Moraine. Oaks are not extremely tolerant of shade, and usually follow shortly after the pioneer forests that become established after major disturbances - fire, heavy logging, or perhaps clearing for agriculture – or may in fact be elements of pioneer forests. Associated species include: Red maple (Acer rubrum), Sugar maple (Acer saccharum), White Ash (Fraxinus americana), American beech (Fagus grandifolia),and Basswood (Tilia Americana).

Upland Hardwood Forests are comprised primarily of deciduous trees with high tolerance to shade, and growing most successfully in deep soils which are moister and typical of the mid-range slopes and well drained flat lands. Hard (sugar) maple (Acer saccharum), American beech (Fagus grandifolia), Ironwood (Ostrya virginiana), hemlock (Tsuga canadensis), and occasionally balsam fir are all very tolerant of shady conditions and tend to dominate this forest type. These species can successfully regenerate in small openings (i.e. where 1-2 mature trees die or blow over). This forest type is the final step of the “succession” process, and is often referred to as the climax forest (i.e., it will sustain itself for centuries until there is a major forest disturbance).

<u>Lowland Forests</u>

Lowland forests can be very different in species composition and history, with distinct types often growing side by side, in mixtures, or in adjacent pockets. These woodlands are the most common of all forest types growing in the watershed, especially in the middle and lower reaches of the river, as it meanders to Lake Scugog.

Cedar swamps are dense woodlands in low areas, higher moisture soils, and valley lands adjacent to streams and small rivers. White cedar can also quickly colonize abandoned fields adjacent to established cedar woodlands, and could then be referred to as a 'pioneer forest'. Other species commonly associated with white cedar include white spruce, white pine, balsam fir, hemlock, poplar, yellow and white birch, black ash, white elm (Ulmus americana) and poplar. Tamarack (Larix laricina) frequently grows on sites with higher water levels, where wetland shrubs such as red osier dogwood, alder, willow (Salix spp.) shrubs become more common. Black spruce is a common lowland conifer species in the boreal forest, but is very rare this far south.

Plantations

With the extensive land clearing following settlement in the 1800's, large areas became unsuitable for farming in the long term due to poor soils or topography. With faster snowmelt and downstream flooding, erosion, dust storms and the subsequent abandonment of thousands of acres of cleared land resulted. Tree planting was the most obvious option to effectively reduce further site degradation. Plantations have become a major southern Ontario forest type. These "man-made" woodlands now provide the same benefits as natural woodlands, usually much quicker than natural regeneration. This cultural forest, primarily red pine and other conifers, now the most common forest type on the Oak Ridges Moraine portion of the Blackstock Creek watershed. Reforestation was accomplished in several ways, as summarized below.

Much of the most severely degraded land was taken over by municipalities or Conservation Authorities, then reforested and managed by the Provincial Government until the late 1990's. Local examples include the Ganaraska, the Northumberland, the York and Durham Regional Forests. Some of the finest examples of reforestation in North America are exhibited within these forests.

The Ontario Ministry of Natural Resources and conservation authorities undertook an ambitious private land tree planting program from the late 1960's. Although much reduced at the present time, several thousand acres were planted annually throughout Ontario to the early 1990's.

Private landowners undertook reforestation on their own properties, largely through the purchase and planting of trees from the Provincial Nurseries in Orono and Midhurst, now closed. These projects were generally one of two types:

i.) Large areas of unsuitable farm land were planted to Christmas trees, with the main species being Scots pine. Other species include white and blue spruce or western fir. The Scots pine planted for Christmas trees often were left unharvested as the market collapsed with the appearance of artificial trees. This species tends to regenerate easily, perpetuating itself and invading into adjacent fields as they become abandoned to agriculture.

ii.) Small areas were reforested by the landowner, friends and family, often only a few hundred trees each spring. Thousands of acres have been reforested over the decades, including field corners, stream banks, windbreaks and pockets of wildlife habitat.

Forest Conservation By-Laws

Commercial forest operations in many southern Ontario municipalities are now regulated by Forest Conservation By-Laws. These municipal acts of legislation are enacted for the purpose of achieving the objectives of the Official Plans by sustaining a healthy natural environment, while regulating forest harvests so they comply with good forestry practices. They encourage sustainable forest harvest and provide a certain measure of protection to the landowner.

The current Durham Region Forest Conservation By-Law applies to all Woodlands one (1) hectare or more in size. Individuals who are considering the harvest or removal of trees in any way are strongly encouraged to contact the Regional Planning Department. They may be required to submit a Good Forestry Practices Permit Application form, or be within one of a number of exemptions which may be applicable to individual circumstances.

Forest Health

Over the last century, forest pests (insects and diseases) imported from other continents have resulted in the decimation of several significant tree species – American chestnut (Castanea dentate), American (or white) elm, American beech, and butternut. All ashes are now at risk from the Emerald Ash Borer at the time this report is being produced. The impact of these species all but disappearing is incredibly significant.

For example, American beech, one of the three most common and important species within the upland hardwood forest, has over the last 12-15 years become a remnant species, the result affects the entire eco-system. Not only was this tree excellent at self regenerating after any disturbance, but it had the potential to provide high quality lumber. In addition, it was formerly a valuable nut producing species for a wide range of forest wildlife, while almost certainly providing less obvious roles within the forest eco-system.

The ash family seems to be the next species threatened as the Emerald Ash Borer has expanded its territory into North America. In the last 4-5 years, the Ash Borer's range has rapidly expanded from the Windsor – eastern Michigan area (its point of first discovery) well into the central states, to Sault Ste. Marie in the north and the Regional Municipality of Durham at the time of this report (spring of 2009). Significantly, white ash is the second of the three most common species within the upland hardwood forest.

At this very time, over the last several years, federal, provincial and municipal governments are working to contain the Asian Long-Horned Beetle in the Vaughan – Black Creek area. This insect is fatally destructive of several species, including sugar maple – the most common species within our upland hardwood forest. Fortunately, this insect is slow moving, reasonably detectible, and seemingly possible to be contained.

Invasive Plants and Shrubs

In our southern Ontario forest ecosystems and natural areas, invasive plants are now well established and altering our natural ecosystem communities. An invasive species is one that has been moved from its native habitat – usually from another continent - to a new area, often for a landscaping or other domestic use. Occasionally, a plant escapes and reproduces so aggressively in its new environment (without the natural controls of its native environment) that it displaces species within our native communities. Some very common species we have all become familiar include: starlings, zebra mussels, purple loosestrife and gypsy moth.

Some particularly persistent plant species now well established in Ontario woodlands, to varying degrees, include common and glossy buckthorn, swallow wort / dog-strangling vine (Cynanchum louiseae, nigrum; Vincetoxicum nigrum), garlic mustard (Alliara petiolata), and Norway maple (Acer plantaoides) and its many cultivars. These plants are capable of displacing native plants such as Trilliums and ferns, as well as smothering the natural regeneration of forest trees. Some of these plants also have the alleliopathic qualities, i.e. capable of discouraging other plants from growing nearby. Garlic mustard, for example, is thought to produce chemicals that may interfere with the function of the soil fungi / plant root relationship necessary for the long-term survival and health of our native plants.

Woodlands and Bio-Diversity

Forests were the dominant terrestrial vegetation community throughout Ontario prior to European settlement. In today's southern and central Ontario landscape, our remaining forest cover is mostly small, fragmented woodlands separated by agricultural land, urban / residential areas, and expansive transportation networks. These 'island' woodlands provide habitat for species that benefit from both the forest and the adjacent land uses – e.g. deer, wild turkeys, raccoons, squirrels - however larger woodlands, or woodlands connected by corridors of natural vegetation are healthier and provide the varied habitat required by many native woodland species.

Large woodlands contain an increasingly rare, high quality wildlife habitat referred to as the "forest interior". As a rule, forest interior habitat is that portion of a woodland greater than 100 metres from any edge – a field, road or hydro corridor. To put this into perspective, a square 4 hectare (10 acre) woodlot measures 200 metres by 200 metres, and will contain only a fraction of 1 hectare of forest interior habitat. Some bird species require up to 2 ha of home range, and will not tolerate other nesting pairs of that same species within their range. In fact, some species require an area of interior habitat sufficiently large for social interaction of several nesting pairs. **Table 9.5** lists the general response of species to varying sizes of forest patches.

Like many natural heritage features, guidelines for the minimum amount of forest interior have been developed. Environment Canada recommends that the proportion of the sub-watershed that is forest cover 100 meters or further from the forest edge should be greater than 10 %. The proportion of the sub-watershed that is forest cover 200 meters or further from the forest edge should be greater than 5%. The Blackstock Creek watershed has 3.7% forest coverage that is >100 meter from edge and 0.8% forest coverage that is > 200 meter form edge. Therefore the Blackstock Creek watershed is well below the federal guidelines for interior forest and deep interior forest. **Figure 9.3** shows the distribution of interior forest areas within the watershed.

Table 9.5: Anticipated response by forest birds to size of largest forest patch.

Size of Largest Forest Patch (hectares)	Response by Forest Associated Birds
200	Will support 80 percent of edge-intolerant species including most area-sensitive species.
100	Will support approximately 60 percent of edge-intolerant species including most area-sensitive species.
50 – 75	Will support some edge-intolerant species, but several will be absent and edge-tolerant species will dominate.
20 – 50	May support a few area-sensitive species but few that are intolerant of edge habitat.
<20	Dominated by edge-tolerant species only.

From Environment Canada (2004)

9.6 Significant Natural Heritage Features

The assessment of significant natural heritage features for the watershed is primarily based on key natural heritage features (KNHFs) as defined by Section 22 of the Oak Ridges Moraine Conservation Plan, but also includes other features determined to have particular ecological importance at any scale within the watershed.

Identifying significant natural heritage features provides an understanding of the unique conservation values associated with the watershed. This understanding allows watershed management efforts to be focused on areas where they are most needed and can be most effective. Significant natural heritage features applicable to the terrestrial ecology of the watershed are discussed in the following sections.

The Oak Ridges Moraine Conservation Plan has developed a natural heritage system that identifies key natural heritage features and linkages and provides a template for sustainable use of the moraine into the future. In addition, the Greenbelt Plan has also identified a Natural Heritage system that is based on the same principles, that is the identification of key natural heritage features and linkages supported by maps showing these areas. These land use designations are show in Chapter 4: Land Use.

Areas of Natural and Scientific Interest

Areas of Natural and Scientific Interest (ANSI) are areas that have been identified by the Ontario Ministry of Natural Resources as having provincially or regionally significant representative ecological or geological features. Life Science ANSIs (ANSI-ls) are designated based on ecological significance, and Earth Science ANSIs (ANSI-es) are designated based on geological significance. Only a very small portion of the Scugog Marsh Life Science ANSI is found in the north-western area of the Blackstock Creek watershed.

Endangered, rare and threatened species

Significant portions of the habitat of endangered, rare and threatened species exist within the watershed. Current Ontario Ministry of Natural Resources mapping, based on a one kilometer grid size, highlights the entire watershed as habitat of rare and threatened species. In order to effectively inform watershed management, a greater level of detail and prioritization of these areas is necessary.

Priority areas of habitat of endangered, rare and threatened species were identified by Kawartha Conservation staff as areas where: (1) there has been a documented observation of an endangered, rare or threatened species, and (2) the general habitat requirements of the observed species can reasonably be assumed to be met by the habitat available in that area.

Priority areas of habitat of endangered, rare and threatened species exclude any areas classified as Active Aggregate (AA), Inactive Aggregate (AI), Intensive Agriculture (IAG), Manicured Open Space (MOS), Urban Development (URB), and in some cases Rural Development (RD). **Figure 9.4** includes areas of significant woodland that have the greatest probability of supporting species at risk in this subwatershed.

Significant Wildlife Habitat

The identification of Significant Wildlife Habitat (SWH) areas for the watershed was guided primarily by the Oak Ridges Moraine Technical Paper #2 (Province of Ontario 2007), the Significant Wildlife Habitat Technical Guide (OMNR 2000), and mapping provided by the Ontario Ministry of Natural Resources. Field assessments to identify significant wildlife habitat included breeding amphibian surveys in collaboration with the Great Lakes Marsh Monitoring Program administered by Bird Studies Canada.

Significant wildlife habitat (SWH) is defined by the Oak Ridges Moraine Conservation Plan as: an area where plants, animals and other organisms live or have the potential to live and find adequate amounts of food, water, shelter and space to sustain their population, including an area where a species concentrates at a vulnerable point in its annual or life cycle and an area that is important to a migratory or non-migratory species.

Seasonal Concentration Areas

Seasonal concentration areas include areas where a particular wildlife species congregates or relies on during a certain time of year such as deer wintering yards, migratory bird stop-over, or reptile hibernation areas.

Amphibian breeding surveys have been completed once within the watershed. These surveys were completed in partnership with the Great Lake Marsh Monitoring Program administered by Bird Studies Canada. These long-term surveys will determine changes in amphibian populations in watershed over time. Ecological Land Classification vegetation community mapping was used to determine areas of the watershed containing marsh habitat suitable for amphibian breeding. The majority of these areas are very small pockets of marsh and inadequate for surveying.

The survey stations established in the watershed include:

- Lake Scugog #37 Provincially Significant Wetland at Jobb Rd.
- A wetland along the north side of Hwy 7A just east of the intersection with Regional Road 57.

Breeding evidence of Spring Peepers and Boreal Chorus Frogs were recorded at both of the above locations.

Rare Vegetation Communities

Rare vegetation communities, identified as Key Natural Heritage Features, in the Oak Ridges Moraine Conservation Plan include sand barrens, savannahs and tallgrass prairies. None of these vegetation communities are known to exist within the watershed, however there is potential for them to exist in this area due to the presence of appropriate substrate types, climates, and their documented presence in adjacent watersheds.

Animal Movement Corridors

Animal Movement Corridors are typically long, narrow areas used by wildlife to move from one habitat to another. Such corridors facilitate seasonal migration; allow animals to move throughout a larger home range; and improve genetic diversity in species populations. To effectively serve their purpose, animal movement corridors must meet the needs of the species using the corridor. This includes consideration of corridor width, length, % natural vegetation cover, and species composition.

The Oak Ridges Moraine, extending through the southern portion of this watershed, is a wildlife corridor that functions on a landscape scale. The areas of the Oak Ridges Moraine designated as Natural Core and Natural Linkage form a corridor that supports the movement of flora and fauna across the Oak Ridges Moraine and to natural areas north and south of the Oak Ridges Moraine.

Areas of natural cover within this watershed are minimal and exist primarily as isolated pockets across the landscape. This lack of habitat connectivity highlights the need for increased and improved animal movement corridors within the watershed. The largest and best connected area with potential to function as an animal movement corridor within the watershed includes a mosaic of swamp, marsh and forest extending roughly north-south along the Blackstock Creek riparian corridor beginning between Hwy 7a and Jobb Rd. and ending between Shirley Rd. and Byers Rd.

Within the watershed there are areas of natural cover with the potential to function as wildlife corridors. These areas of natural cover are clustered primarily along the route of the Blackstock Creek and within the Oak Ridges Moraine boundary.

Significant Woodlands

Significant woodlands are identified for conservation protection because of the features and functions that they provide. They may include areas that have supported a treed community for more than 100 years; contain significant species; contain or support other significant natural heritage features (such as significant wildlife habitat); provide supporting habitat for another Key Natural Heritage Features; or act as an ecological linkage between them.

There are 6.0km^2 of significant woodlands within the watershed in total. These areas are primarily clustered along the riparian corridor of Blackstock Creek. There are also several areas of significant woodland in the southern-most part of the watershed on the Oak Ridges Moraine. Significant woodlands within the Blackstock Creek watershed have been mapped by the Ontario Ministry of Natural Resources. Significant woodland locations are illustrated on **Figure 9.4**.

Wetlands

Wetlands are identified as Key Natural Heritage Features and hydrologically sensitive features in the Oak Ridges Moraine Conservation Plan. **Figure 9.1** illustrates the location of wetlands within the watershed. **Figure 9.2** also illustrates wetland location but provides a greater level of detail about each wetland by indicating the vegetation community series. Wetlands occur on the landscape as single vegetation communities, or as complexes made up of a grouping of several small wetlands. Wetland complexes may be under-represented on this figure due to the minimum classification unit sizes used in the Ecological Land Classification system.

Although all wetlands have high ecological value, and are of significance to the management of the watershed, the classification of provincially significant wetlands assists with prioritizing wetlands for conservation protection. There is one provincially significant wetland within the Blackstock Creek watershed, Lake Scugog #37 Wetland. Lake Scugog #37 Wetland is 1.9km^2 consisting of 95% swamp and 5% marsh. The wetland is 100% riverine on Blackstock Creek, with 60% clays, loams or silts and 40% organic soils. Lake Scugog #37 wetland scores 211 points in the biological component of the Ministry of Natural Resources Evaluation (200 or more in biological or special features results in provincially significant status).

Environment Canada's guidelines on wildlife habitat recommends that approximately 10% of each watershed, and 6% of each subwatershed in the Great Lakes basin should be wetland. This guideline is based on evidence that occurrences of high flows and floods decrease significantly as the amount of wetland in a watershed increases. This inversely proportional relationship holds true until the amount of wetland reaches 10% of the watershed, at which point the decrease in flood occurrence begin to level off.

The watershed contains approximately 2.8km^2 of wetland in total which represents 7.4% of the total watershed area. Of those wetlands, 1.9km^2 have been designated as provincially significant. All Ontario Ministry of Natural Resources evaluated wetlands including provincially significant wetlands (PSWs) are illustrated on **Figure 9.5**. The Blackstock Creek watershed contains less wetland coverage than Environment Canada's recommended 10% wetland area for a watershed and therefore would benefit from wetland restoration efforts.

Forested wetlands, including headwater wetlands, are full of life and home to a complex food web that includes various microbes, bacteria, invertebrates and larger life forms. These include mammals, birds, reptiles, amphibians, fish, insects and other invertebrates that use wetlands as habitat for all or part of their life cycle, including for breeding and nesting seasons, migratory stopovers, resting and shelter, and food. In addition, wetlands perform these valuable functions within a watershed:

- Wetlands play a significant role as a water filter, having the capacity to remove great amounts of harmful impurities, bacteria and excess nutrients. In fact wetlands are so good at this process that constructed wetlands have been used to treat urban stormwater runoff in Europe (and now in Ontario) for several decades.

- Wetland plants are effective for stabilizing shoreline areas, trapping sediments and lessening the effects of erosion.

- Wetlands store water, reduce flood events, and help to replenish groundwater. Excess water is stored after storms or spring snow melt and is gradually released after it is filtered and purified.

- Wetlands release purified water into streams and rivers, and can be critical at maintaining stream flow during periods of drought.

9.7 Key Observations and Issues

- The watershed contains some areas of natural cover, which accounts for approximately 28% of the total watershed area. Natural cover is comprised of forests, wetlands and meadows.

- Forested areas account for approximately 23% of the total watershed area, and are comprised of cultural plantations (1%), cultural woodlands (<1%), coniferous forest (6%), deciduous forest (3%), mixed forest (7%) and forested wetlands (6%). Forested areas do not meet the minimum ecological requirements with respect to total watershed coverage (i.e., 30% of total watershed area).

- The amount of interior forest habitat (i.e., at least 100 metres from the forest edge) accounts for approximately 4%, which does not meet the minimum ecological requirements of 10%. The amount of deep interior forest habitat (i.e., at least 200 metres from the forest edge) accounts for approximately 1%, which also does not meet the minimum ecological requirements of 5%.

- Wetland areas account for approximately 7% of the total watershed area, and are comprised of marshes (<1%), shallow open waters (<1%), and swamp (7%). Wetland areas do not meet the minimum ecological requirements with respect to total watershed coverage (i.e., 10% of total watershed area). The majority of these wetlands (approximately 75%) are considered provincially significant.

- A long history of agriculture and forestry-related activities have resulted in fragmentation of natural cover across the landscape. This results in a loss of habitat linkages, movement corridors, and quality habitat patches.

- Two terrestrial species of conservation concern (i.e., species at risk) have been documented within the watershed. These include the Least Bittern and Green-striped Darner. Nine additional terrestrial species of conservation concern have a high potential to exist within the watershed.

- Invasive species including insects, diseases and plants, are considered one of the key threats to the health of existing natural areas, particularly in woodlands. Climate change has the potential to exasperate these negative effects.

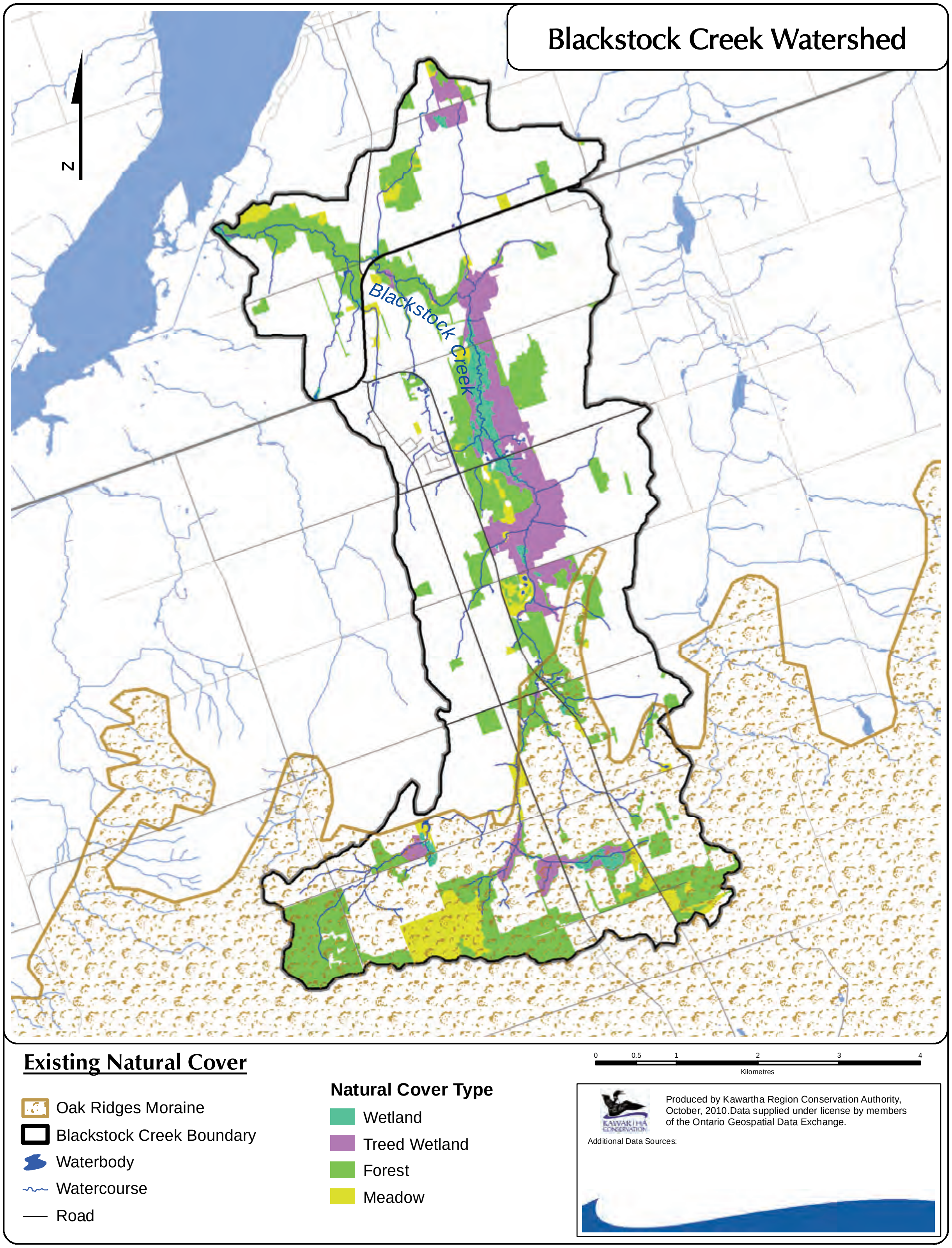


Figure 9.1: Existing natural cover.

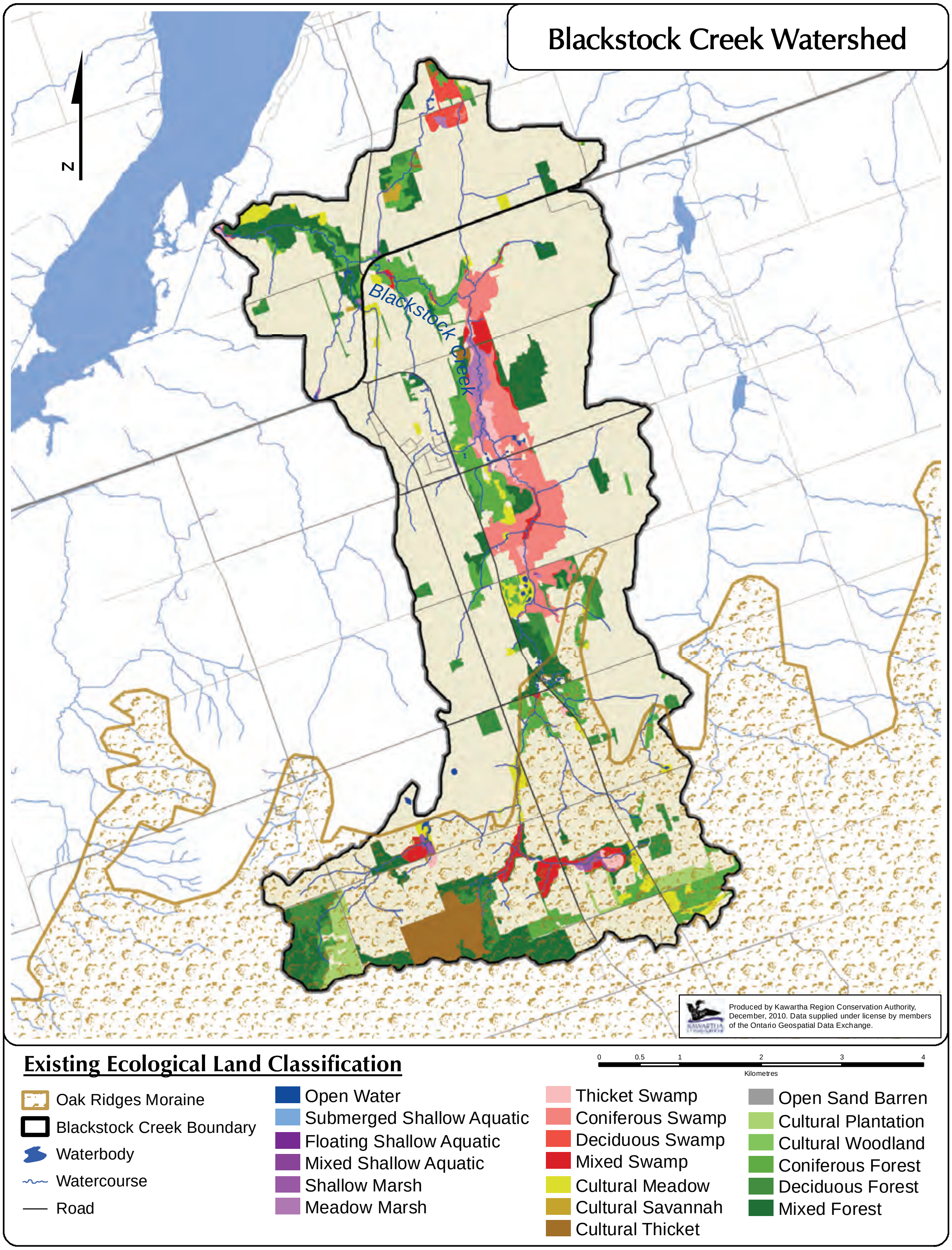


Figure 9.2: Existing ecological land classification.

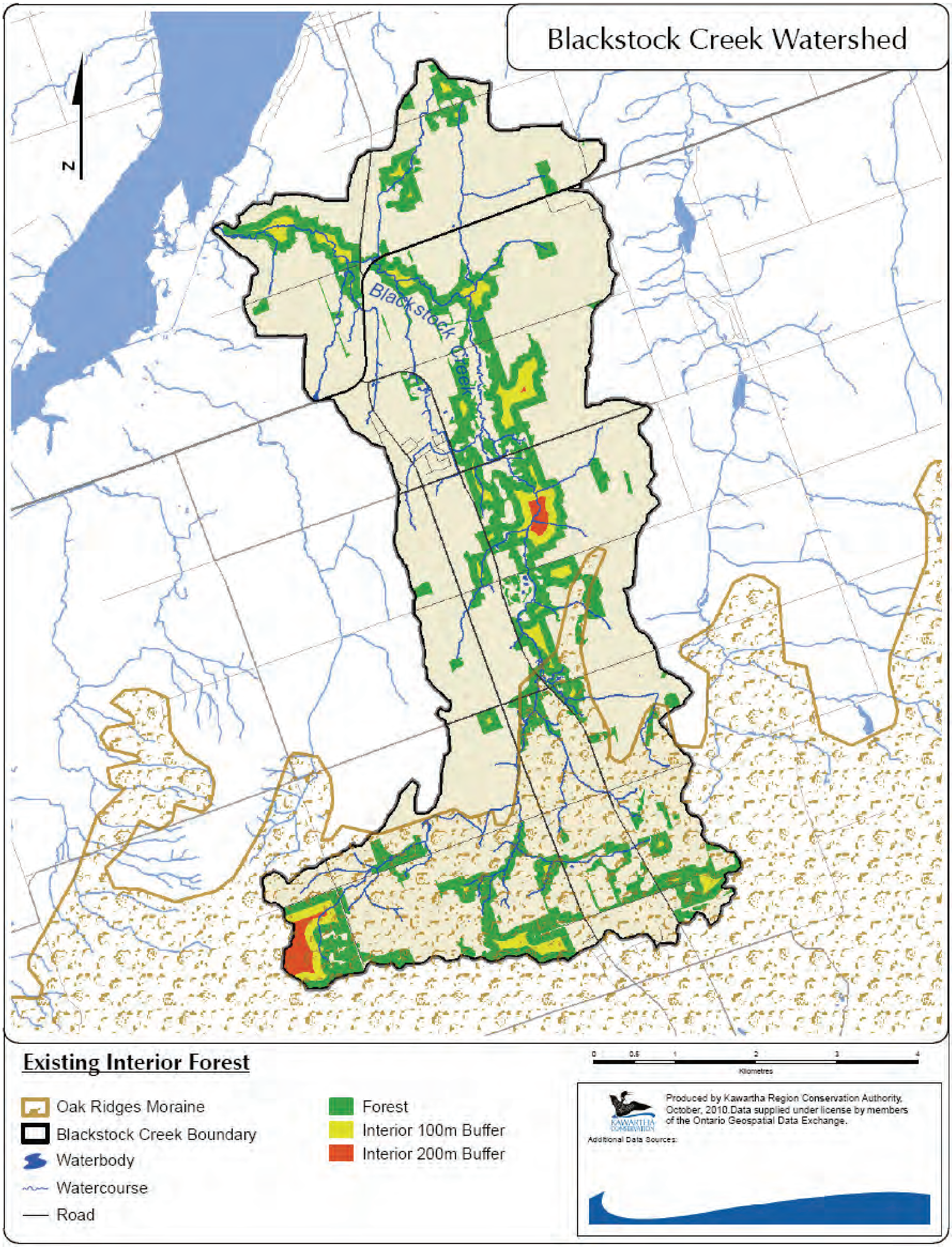


Figure 9.3: Existing interior forest.

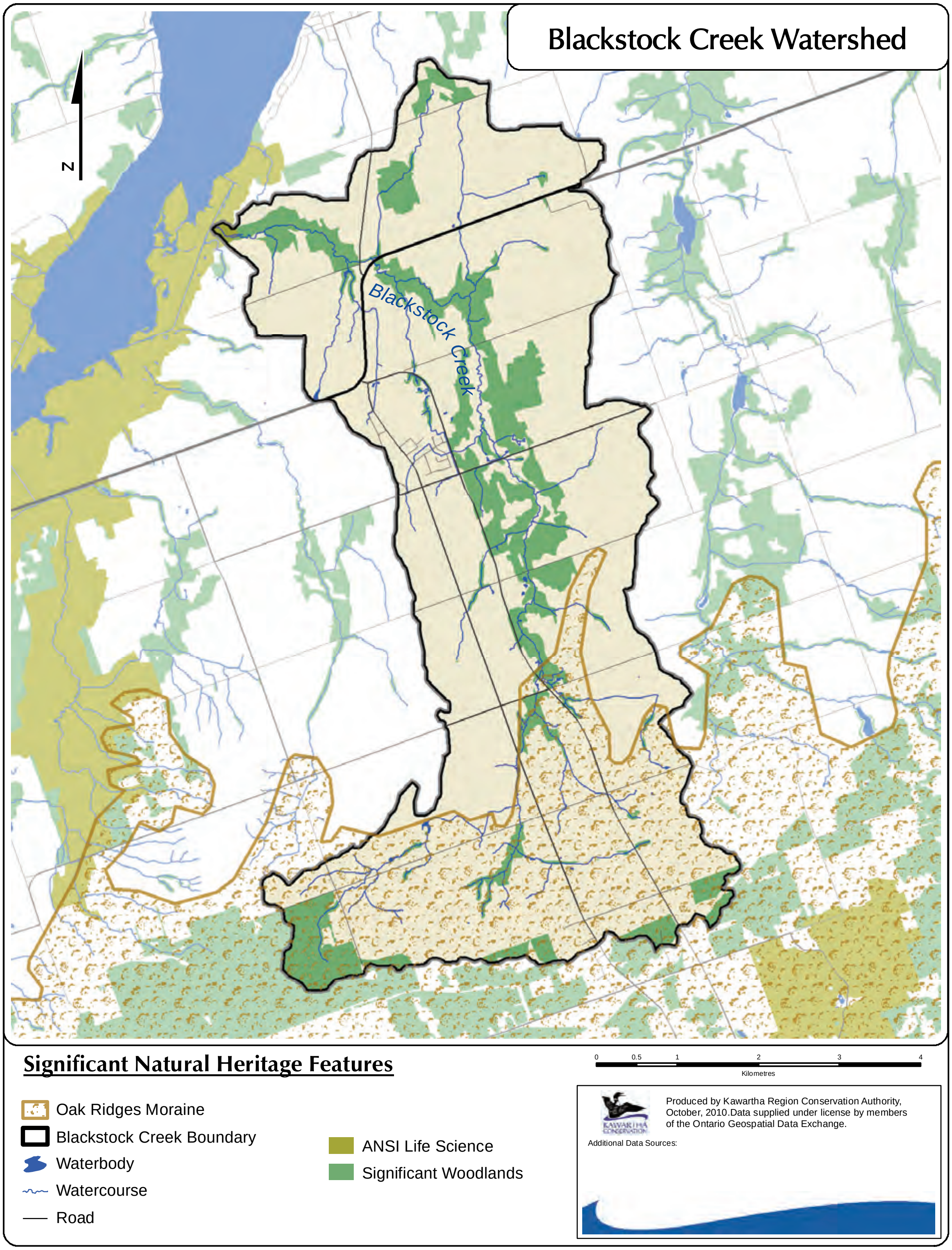


Figure 9.4: Significant natural heritage features.

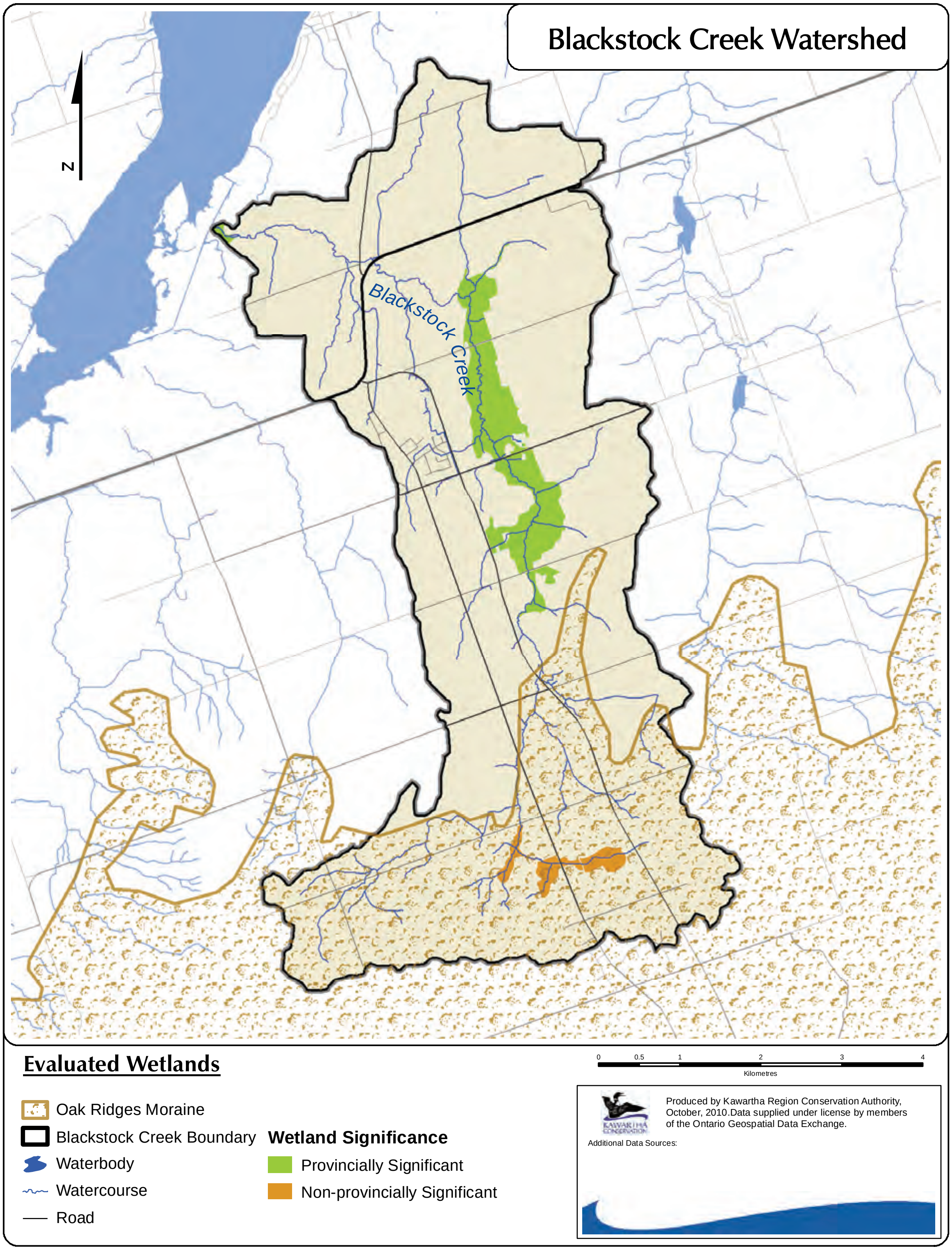


Figure 9.5: Evaluated wetlands.

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Appendix

Appendix A: Water Quality Parameters.

Parameter	Units	Parameter	Units
Alkalinity	mg/L as CaCO3	Magnesium	mg/L
Aluminum	mg/L	Manganese	mg/L
Ammonia	mg/L	Molybdenum	mg/L
Anion Sum	meq/L	Nickel	mg/L
Anion-Cation Balance	% difference	Nitrate	mg/L
Antimony	mg/L	Nitrite	mg/L
Arsenic	mg/L	Phosphorus	mg/L
Barium	mg/L	Potassium	mg/L
Beryllium	mg/L	Saturation pH	pHs @20°C
Bicarbonate	mg/L as CaCO3	Saturation pH	pHs @ 4°C
Boron	mg/L	Selenium	mg/L
Cadmium	mg/L	Silver	mg/L
Calcium	mg/L	Sodium	mg/L
Carbonate	mg/L as CaCO3	Strontium	mg/L
Cation Sum	meq/L	Sulphate	mg/L
Chlorides	mg/L	Thallium	mg/L
Chromium	mg/L	Titanium	mg/L
Cobalt	mg/L	Total Suspended Solids	mg/L
Copper	mg/L	Total Dissolved Solids	mg/L
Ion Ratio		Total Kjeldahl Nitrogen	mg/L
Iron	mg/L	Uranium	mg/L
Langolier’s Index	@4°C	Vanadium	mg/L
Langolier's Index	@20°C	Zinc	mg/L
Lead	mg/L		

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