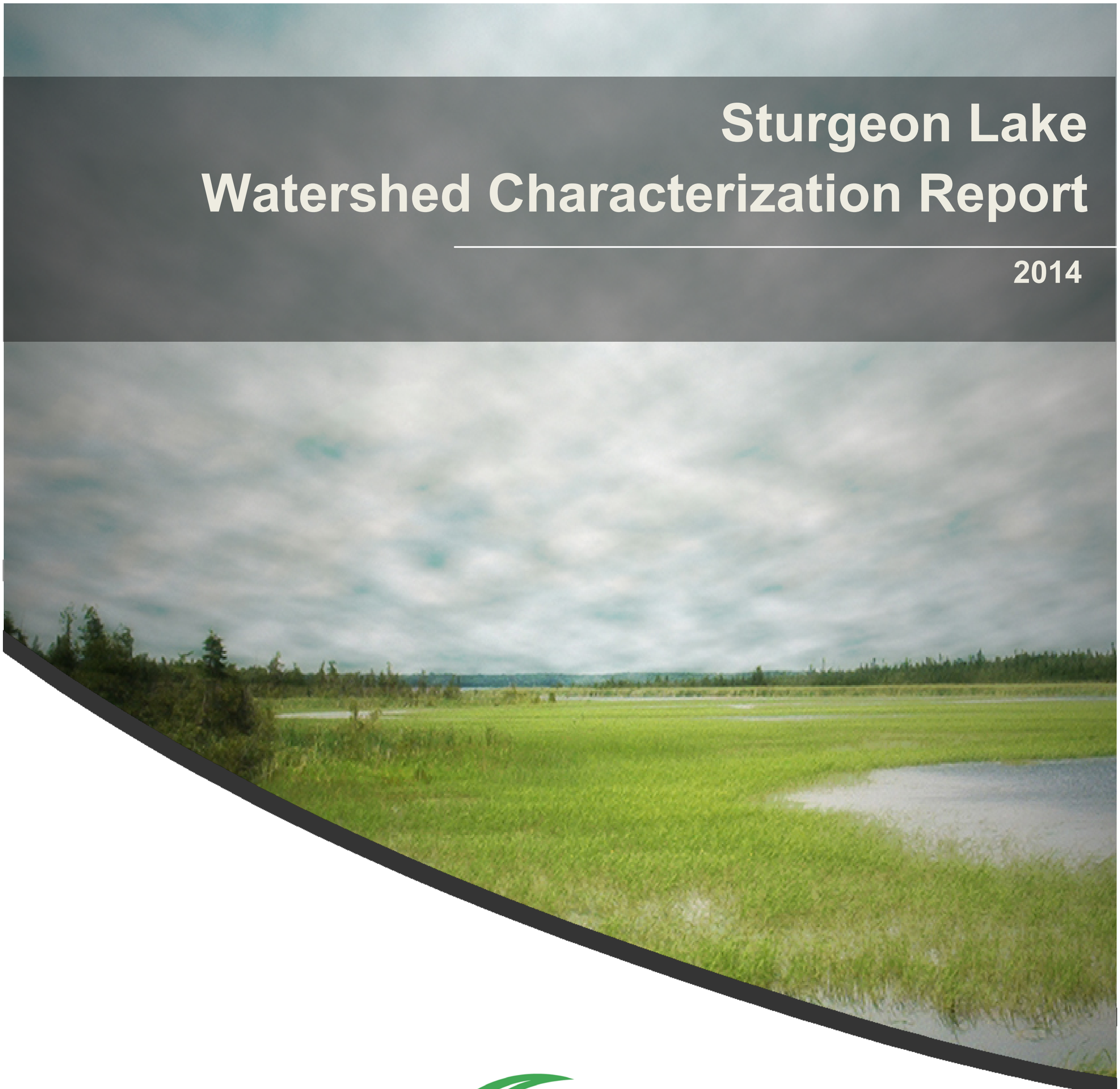
Sturgeon Lake
Watershed Characterization Report

2014



KAWARTHA CONSERVATION

Discover · Protect · Restore

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), Township of Cavan Monaghan, and the Municipality of Trent Lakes.

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Acronyms

MNR: Ontario Ministry of Natural Resources

MOE: Ontario Ministry of the Environment

TSW: Trent-Severn Waterway

EC: Environment Canada

ELC: Ecological Land Classification

WSC: Water Survey Canada

KLSA: Kawartha Lake Stewards Association

PWQMN: Provincial Water Quality Monitoring Network

PGMN: Provincial Groundwater Monitoring Network

CKL: City of Kawartha Lakes

KPOW: Kawartha Protect Our Water

SLMP: Sturgeon Lake Management Plan

PWQO: Provincial Water Quality Objective

TP: Total Phosphorus

TKN: Total Kjeldahl Nitrogen

TSS: Total Suspended Solids

CWQG: Canadian Water Quality Guidelines for the Protection of Aquatic Life

CSeQG: Canadian Sediment Quality Guidelines

PAHs: Polycyclic Aromatic Hydrocarbons

PCBs: Polychlorinated biphenyls

1.0 Introduction

1.1 Project History

Since the 19th century, Sturgeon Lake has been a central hub to the Kawartha Region and its growing economy. For most of the 20th century, the lake served as a vacation destination for residents of the southern Ontario and Greater Toronto Area (GTA). Over time, the lake has transitioned from a seasonal haven into a year-round residential area. Currently, Sturgeon Lake supports many aspects of the local economy in the City of Kawartha Lakes, contributing more than $15 million annually from tourism, fishery and recreational activities concentrated around the lake. In addition, the multiple shoreline residences and small lakeside communities support many local businesses, for example, landscaping, home renovation and property management, as well as commercial enterprises in the Lindsay, Fenelon Falls and Bobcaygeon areas.

However, there are growing concerns about the health of the lake and its surrounding area. Over many decades, the processes of eutrophication, followed by excessive aquatic vegetation growth and blue-green algae blooms have caused navigational, recreational and aesthetic difficulties for permanent and seasonal residents around the lake, as well as those who use the lake for recreational purposes. The main cause of these processes is excessive input of phosphorus and nitrogen, two primary nutrients, into the lake as a result of modern human activities.

In 2010, Kawartha Conservation and the City of Kawartha Lakes, recognizing the importance of the environmental health of Sturgeon Lake, and with support from multiple citizen groups and partner organizations, initiated the Sturgeon Lake Management Plan (SLMP). This was the first phase of watershed-wide lake management planning in the City of Kawartha Lakes. The management plan process has been initiated to identify sources of contamination, measure amounts of phosphorus and nitrogen entering Sturgeon Lake and establish a practical program to implement rehabilitation measures aimed to improve water quality in the lake and health of the overall watershed.

The Sturgeon Lake watershed is the entire area of land around the lake that is drained by its tributaries. The Watershed Characterization Report is an overview of the current state of the aquatic and terrestrial ecosystems within the Sturgeon Lake watershed boundaries. It includes information on the geology, physiography, climate, hydrology and the ecology of the watershed, including land use and economic activities, and characterization of the current water quality in the lake and its tributaries.

This report provides the findings from our scientific research and environmental monitoring for the three-year period from June 2010 to May 2013. Additionally, it includes information and data from previous studies dating back to the 1970s and 1980s. Based on our findings, we identified a number of areas of interest in the Sturgeon Lake watershed that requires close attention and high priority status through recommended management actions. These areas include the Lindsay urban area, Jennings Creek subwatershed, East Cross Creek and Stoney Creek subwatershed, as well as shoreline residential areas and private septic systems around the lake.

Continuous and comprehensive environmental monitoring, as well as the collection of scientific data from other sources, is essential to achieving the main goal and objectives of the Sturgeon Lake Management Plan. The information we gather will help us understand the issues and stressors impacting the lake, enable us to provide an overview of watershed health, and develop effective recommendations for protecting and enhancing lake environmental health in the short- and long-terms.

1.2 Project Goal and Objectives

The planning was initiated to characterize the current environmental health of Sturgeon Lake and its surrounding watershed, identify problems and issues, consider how to more effectively plan for ongoing development pressures, and to determine the sources and amounts of phosphorus and nitrogen entering the lake. These two primary nutrients entering local water bodies in excessive amounts as a result of human activities can accelerate the process of eutrophication in both the lake and its tributaries. This process leads to over-abundant aquatic vegetation and increased occurrence of blue-green algae blooms, causing unpleasant recreational and aesthetic conditions for people around the lake, and impacting drinking water supplies in some communities.

The main goal of the Lake Management Planning project is to ensure the long-term environmental and socio-economic sustainability of Sturgeon Lake by:

- Identifying key environmental impacts and management issues
- Setting priorities for management actions to maintain and improve water quality in the lake
- Increasing the environmental and socio-economical values of the lake
- Maintaining healthy aquatic and terrestrial ecosystems within the watershed, and
- Protecting the lake as a primary source of drinking water for a considerable number of residents in the City of Kawartha Lakes.

In order to improve the current condition of the lake, all areas of future urban growth within the watershed must meet the highest environmental standards for new development. This will require a range of best management practices to be applied to both urban and agricultural land uses. Without informed management actions, we may experience escalating problems including frequent public beach closures, stream degradation and habitat loss. Correspondingly, negative impacts may be observed upon fishery, recreational and tourism industries. Moreover, deteriorating water quality may lead to increased costs associated with drinking water treatment. It is becoming more evident that there is a need to take immediate corrective actions concerning the lake ecosystem and watershed health to prevent further decline and to preserve the lake and its tributaries for future generations.

The collection of sound scientific data and evaluation of the current condition of the Sturgeon Lake ecosystem and its watershed form the base for designing remedial measures. Reducing inputs of phosphorus and nitrogen, and other contaminants to the lake and its tributaries through a wide range of actions; physical, educational, and–where required–legislation, will help to maintain and improve the environmental health of the lake and its watershed. Continuing research will enable the evaluation of action plan implementation, as well as increasing our understanding of a complex and continually evolving lake environment.

1.3 Study Area

The Kawartha Conservation watershed is located in the east-central portion of Southern Ontario. The area of the watershed is 2,563 km^2. The watershed is part of the larger Trent River watershed, which drains into Lake Ontario. The Sturgeon Lake watershed occupies 1,028 km^2 within the central portion of the Kawartha watershed ***(Figure 1.1).*** In addition, Sturgeon Lake is centrally located in the City of Kawartha Lakes and the Trent-Severn Waterway system. Situated as it is, funnelling recreational boat traffic from both Lake Scugog, via the Scugog River, and either Cameron Lake to the west or Pigeon Lake to the east, Sturgeon Lake is a very important part of the Kawartha Lakes chain.

Sturgeon Lake water surface area is 45.6 km^2. Its maximum and average depths are 10.5 m and 3.5 m correspondingly. The lake volume is 163 million cubic meters (Kawartha Conservation, 2008).

The Town of Lindsay with a population of more than 20,000 residents (Statistics Canada, 2012) is the only large urban center situated on the Scugog River – approximately 7 km upstream of the lake. As well, about 20 villages, hamlets and subdivisions are situated within the lake's watershed. Many of these are located in areas adjacent to the shoreline.

Lake Scugog to the south, the Burnt River and Nogies Creek watersheds to the north, the Pigeon Lake basin to the east and the Cameron Lake watershed to the west are bordering the Sturgeon Lake drainage basin. On the southern fringes of the watershed, the East Cross Creek subwatershed extends into the Oak Ridges Moraine.

Figure 1.1. Sturgeon Lake Study Area

2.0 Socio-Economic Characterization

2.1 Summary of Observations and Issues

OBSERVATIONS

- While the population of the entire City of Kawartha Lakes both decreased and aged overall between the 2006 and 2011 Canadian Censuses, the population of the two largest urban centres in the study area, namely Lindsay and Bobcaygeon, increased in this time period.
- The population of the watershed increases by approximately 25% in the spring-summer recreation period.
- Approximately 11% of the total land area in the City of Kawartha Lakes has fertilizer applied to it. If only the study area is considered, this number would be much higher given the large proportion of land south of Sturgeon Lake that is used in agricultural production..
- Sturgeon Lake has six public beaches. Four out of six have been posted as unsafe for bathers due to high *E.coli* levels during the summer recreation season at least once during the past 5 years.
- The economic value of angling activities on Sturgeon Lake has yet to be quantified.

2.2 Historical Overview

The European history of the study area dates back to 1824, when Colonel Duncan McDonnel with the assistance of Patrick Lee and Daniel Shanahan surveyed the township of Ops which had been created and attached to Newcastle District in 1821, with Lots 20 & 21 of Concession V reserved as a town site (Kirkconnell, 1967).

The three major population centres, namely Lindsay, Bobcaygeon and Fenelon Falls in the study area were developed due to the proximity to water and the milling power for grist and sawmills necessary for early settlers. Shortly thereafter, these three centres became the locations for locks of the Trent-Severn Canal System that allowed for the passage of vessels between two adjoining bodies of water that have different heights of the water surface, in this instance, passage between Pigeon and Sturgeon, Sturgeon and Cameron as well as Sturgeon and Scugog Lakes. Rail transportation provided further economic benefit by improving inter-regional transit and access to markets.

In 1827, the government contracted William Purdy to build a ten-foot dam on the Scugog River at Lindsay, followed by a sawmill and grist mill. Work began in the winter of 1827-28, with the dam located at the base of Georgian Street, and the dam and sawmill completed by the winter of 1828. This original dam broke due to pressure from the spring freshet in 1829, but the dam was repaired and sawmill operational by April 1830. In 1838, a group of farmers from Ops, Manvers and Cartwright gathered and subsequently hacked away portions of the Lindsay dam due to the perceived increased incidence of “fever and ague” (the terminology of the day for malaria) in the drowned portions of land covered by the expanded Scugog. A new dam, and lock (upstream of the former location), were begun in 1838 and completed in 1844, with the new dam having a head of seven feet versus ten for the former structure. The present concrete lock was built in 1910. The Lindsay lock is unique on the waterway for two reasons: it is equipped with double doors, allowing a shorter lock chamber to be used by smaller vessels (thereby conserving water in the locking process) and it has a canoe slide on the north side of the dam sluice gates, one of only two canoe slides on the entire Trent-Severn waterway (Bower 2009). The lock at Lindsay raises vessels an average of 2.1 meters, from the average elevation of Sturgeon Lake to Lake Scugog (Trent-Severn Waterway, 2009). The damming of the Scugog River increased both the depth and surface area of Lake Scugog, especially in the southern end which previously had been occupied by a shallow swamp (Buttle, 2009).

Fenelon Township was surveyed in 1822, and in 1841 James Wallis and Robert Jameson built a grist mill on the left bank of the falls (near the modern road bridge). It was demolished in 1851 and replaced with separate grist and sawmills. A pair of flight locks at Fenelon Falls was built in 1882, and the locks and canal from the upper lock to Cameron Lake were completed in the summer of 1886. The flight locks were replaced with a single hydraulic lift lock between 1961 and 1963 (Bower 2009). The lock at Fenelon Falls raises vessels an average of 7.2 meters, from the elevation of the Fenelon River (Sturgeon Lake) to Cameron Lake (Trent-Severn Waterway, 2009).

Verulam Township was surveyed by John Houston and completed in 1831. Thomas Need was given land on and adjacent to Bobcaygeon Island in 1832 in exchange for building a sawmill and grist mill for the new township. A lock at Bobcaygeon was built in 1833, but it remained inoperable for four years due to engineering errors and miscalculations in water levels (Bower 2009). A second, improved lock began construction four years later, finished by 1840, and became the first lock completed on the waterway. The lock has been subsequently rebuilt in 1857 and 1921. The lock at Bobcaygeon raises vessels an average of 1.6 meters, from the average elevation of Pigeon Lake (its level itself regulated by the lock at Buckhorn) to the elevation of Sturgeon Lake (Trent-Severn Waterway, 2009).

The region underwent a period of extensive railway construction beginning in the 1850s, resulting in five major railways. These rail lines were abandoned by the major railways beginning in the 1960s and 90s, with some of the lines having been converted to public-use recreational trails.

In the 1840s, extensive lumbering began in the region, expedited by the waterway and the railways, through the movement of lumber to regional and distant markets. During the 1840s and 1850s, the main export from the area was ship masts and square timber. This industry flourished well into the 1880s, eventually giving way to exports of sawn lumber (Bower, 2009). By the end of the 19^{th} Century, the forest resources were depleted and the lumber industry declined accordingly (Buttle, 2009). With the decline of the lumber industry, the focus of the Trent-Severn Waterway shifted towards recreation pursuits.

Prior to extensive European settlement, the non-manipulated lakes and watercourses were free to seek their own level, with a natural seasonal rhythm, as they contained no artificial obstructions. Runoff delivery to open waters would have been greatly reduced, due to the extensive forest and wetland cover in the headwater reaches of the watercourses. On the contrary, once the runoff entered the watercourses, it would have moved through each water body more quickly than the present, controlled only by the natural capacity of the lakes and watercourses. The result of this rapid movement of water, with a reduced storage capacity, would mean a system prone to flooding during the spring freshet, and a generally lower water body level in the summer. This would shift in the fall season, due to rainstorm events exceeding the evapotranspiration rates (themselves reduced in fall) and leading to frequent, widespread flooding (Buttle, 2009). Thus, the installation of waterway obstructions has resulted in a modern Sturgeon Lake that is much different than the pre-settlement Sturgeon Lake. Water levels in the lake would have been lower except perhaps during the spring freshet. This would have resulted in a smaller water body by expanse, with areas including (counter clockwise around the lake) Ellery Bay, Goose Bay, mouth of Emily Creek, the Little Bob Channel, and the bay fronting Verulam Park “disconnected” (in a navigable sense) from the main water body (Canadian Hydrographic Service, 2006), joined only by small, sluggish overflow channels.

2.3 Demographics

The City of Kawartha Lakes was created on January 1, 2001 following Provincially-imposed legislation, when 15 townships, villages and towns of Victoria County were amalgamated and merged. The City is currently governed by a Mayor and 16 Councillors.

Statistics Canada (2012) calculated a population value for the City of Kawartha Lakes of 73,215 for the year 2011, of which 36,060 and 37,155 are male and female respectively, with an estimated 37,161 private dwellings, 29,681 of which are occupied by permanent residents. The total population by age group breakdown appears in ***Table 2.1***. While the population of the CKL declined between the census of 2006 and 2011, the population of Lindsay increased from 19,361 to 20,354, a growth rate of 5.1%. Bobcaygeon also increased from 3,313 to 3,533, while Fenelon Falls decreased from 2,159 to 2,040.

The municipality has a land area of 3,083 km^2 and a population density of 23.7 individuals per square kilometer. The total population represented a decrease of 1.8% from the census of 2006 (74,561), compared to an increase of 5.7% for the province (from 12,160,282 to 12,851,821). The population in the city is also aging. The 2011 census found that 16,010 residents, or 21.86% of the total population, are considered senior citizens, being 65 years of age or older, versus 19.5% in the previous census of 2006 and the national and provincial averages of 14.8 and 14.6% (Statistics Canada, 2012). The median age in the municipality is 48.4 years which is eight years older than the Provincial median (Statistics Canada, 2012).

The population of the City of Kawartha Lakes is predicted to experience an average permanent population growth of 1.2% annually for the period 2006-2031. As a result a total population of approximately 100,000 individuals in the year 2031is predicted and is consistent with the forecast in the Government of Ontario's Places to Grow: Growth Plan for the Greater Golden Horseshoe (City of Kawartha Lakes, 2009; Ontario Ministry of Infrastructure, 2006). The total seasonal population is forecasted to grow from 31,000 in 2006 to 37,387 in 2031. Employment is also forecasted to grow from 23,900 to 27,000 between 2006 and 2031 (City of Kawartha Lakes, 2009; Ontario Ministry of Infrastructure, 2006).

Table 2.1. Population by Age Group in the City of Kawartha Lakes

	Male	**Female**	**Total**
Total Population By Age Groups	36,060	37,155	73,215
0 to 9 years	3,165	3,105	6,275
10 to 19 years	4,445	4,150	8,595
20 to 29 years	3,680	3,400	7,080
30 to 39 years	3,300	3,325	6,625
40 to 49 years	4,835	5,085	9,920
50 to 59 years	6,185	6,500	12,685
60 to 69 years	5,470	5,575	11,045
70 to 79 years	3,275	3,380	6,655
80 years and over	1,710	2,640	4,345
Median age of the population	47.6	49.2	48.4
% of the population aged 15 and over	85.7	86.5	86.1

*Statistics Canada, 2012

The population in the watershed varies significantly throughout the year due to the seasonal influx of individuals taking advantage of the region's recreational activities, either as seasonal residents on lakes (longer tenure in the area) or temporary visitors to the region (shorter tenure). The influx of seasonal visitors to the region has been estimated to be upwards of 17,500 individuals, an influx of just fewer than 25%. Many of these seasonal visitors withdraw personal use water directly from surface water bodies and private wells, rather than from municipal systems.

2.4 Agriculture

Agriculture is the largest industry in the City of Kawartha Lakes. Direct farm product sales were over $110 million in 2011, and with the multiplier effect generated over $243 million to the local economy. There are a total of 1,366 farms growing a variety of crops and raising livestock on 131,965 hectares (326,091 acres) of land (Statistics Canada, 2011).

Farm sizes are: from 4 to 28 hectares (253), 29-52 hectares (410), 53-72 hectares (161), 73-95 hectares (382) and from 96 to 160 hectares (160 farms). In terms of crops in cultivation, alfalfa (hay) and soybeans (22,640 and 11,839 hectares) are the two largest single crops grown in the City of Kawartha Lakes. Other important crops include winter wheat (6,967 hectares), grain corn (9,915 hectares) and fodder crops (such as corn silage) (8,390 hectares)

The types of farms by enterprise are as follows. The ***Table 2.2*** below shows some changing enterprise trends from 2006 to 2011(Statistics Canada, 2006, 2011).

Table 2.2. Types of Farm by Enterprise from 2006 and 2011

Types of Farm Enterprises	2006	2011
Beef	593	411
Dairy	78	64
Sheep	31	41
Goat	22	15
Pork	9	3
Poultry	21	11
Grain and Hay crops	449	491
Mixed and other	334	330
Total Number of farms	1537	1366
Total Direct Farm Receipts	$97,624,922	$110,704,607
With multiplier impact of 2.2	$215,000,000	$243,000,000

A significant number of farms reported the use of manure, commercial fertilizers and various pesticides ***(Table 2.3****),* with potential for a deleterious impact on water quality due to seasonal and stormwater runoff.

Table 2.3. Fertilizer and Pesticide Application in the City of Kawartha Lakes

Application	**Number of Farms**	**Applied Area (hectares)**
Irrigation	17	78
Manure	913	13843
Commercial Fertilizer	535	34820
Herbicides	374	28022
Insecticides	71	3554
Fungicides	64	4258

(Statistics Canada, 2012)

2.5 Industry

The gross sale of manufactured goods in the City of Kawartha Lakes has been estimated as upwards of $340 million, essentially leading economic growth in the City (City of Kawartha Lakes, 2010). There are approximately 125 manufacturers in the City, of which over 25% are actively involved in exporting to markets around the world.

Companies that have located to the City of Kawartha Lakes have identified the important factors which influenced this choice of locale to be a combination of the cost of land, availability of labour and access to markets. The industrial lease rental rate per square foot net is between $3-$4.50, and $1.50 per Ton-mile (a freight transportation service cost of moving a payload of goods) (City of Kawartha Lakes, 2010). There are currently 373 hectares of serviced industrial lake in the City, occupied by large manufacturers (those with 25+ employees). Manufactured goods are diverse, including grass and agricultural seeds, textiles, electronics, plastics and rubber, among others ***(Table 2.4).***

Table 2.4. Selection of Major Manufacturing Sector Employers in the CKL

Company Name	**Product or Service**	**No. of Workers**
Armada Toolworks Ltd.	Mfg. of plastic injection moulded auto parts	150
Northern Casket Ltd.	Mfg. of hardwood, steel burial caskets	106
Kawartha Dairy Ltd.	Mfg. of milk products	86
Holsag Canada	Mfg. of wooden chairs	75
Mariposa Dairy	Mfg. of goat cheese products	60
Pickseed Canada Inc.	Agricultural seed and grass products	60
CardioMed Supplies Inc.	Mfg. of medical disposable surgical products	50
Crayola Canada Ltd.	Dist and light mfg. of Crayola products	50
TS Manufacturing	Mfg. of sawmill equipment	50
Cameron Steel Inc.	Custom steel fabrication	50
Northern Plastic Lumber	Mfg. of recycled plastic products	45
Canada Builds	Modular construction of homes and cottages	25
Bovie Manufacturing	Converting non-woven and geo-textiles	15
Payne Machine Co. Ltd.	Mfg. of specialty chemicals, fibres, polymers	14

(*City of Kawartha Lakes, 2010)

2.6 Recreation

In 2008, an estimated total of 1,263,000 personal visits were made to the City of Kawartha Lakes, 56% of which were made for pleasure, making it the seventh most visited destination in Ontario (City of Kawartha Lakes, 2010). Total visitor spending was $111,432,000, with 93% coming from Ontarians, 2% from others within Canada, 3% from the United States and 2% from overseas. The average yield per visitor (how much each visitor spends while in the City of Kawartha Lakes) was $88, considerably less than the Provincial average for overnight visitors of $270. The low yield for the City reflects the high use of cottages and campgrounds as well as the larger proportion of visits to friends and relatives. This indicates the effectiveness of the City as a draw for visitors from within a 2-3 hour drive, due to the area's cottage and camping amenities (City of Kawartha Lakes, 2008). In 2011, the total personal visits to the City of Kawartha Lakes were approximately 1,400,000 (Lance Sherk, Personal Communication, December 3, 2012). The quarters in which the majority of the visits happen from 2006 to 2010 were from April to June and from July to September (Ontario Ministry of Tourism Culture and Sport, 2011).

There are over 20 marinas and marine service retailers in the City of Kawartha Lakes, predominantly servicing the water bodies on the Trent-Severn Waterway (City of Kawartha Lakes, 2011). The Trent-Severn Waterway operates from the Victoria Day long weekend in May to the Thanksgiving long weekend in September each year. There were 7054 and 7960 individual vessels which passed through the Fenelon Falls and Bobcaygeon locks respectively in the 2012 season (up from 6799 and 7385 in 2011), making these the fourth most and the busiest lock(s) on the entire Trent-Severn Waterway. In 2012, the overall yearly lock traffic of the entire system was 129,685, which is 65% of the traffic in 1994 (199,340). Recent budget pressures at Parks Canada have brought forth the possibility of shortening the operating season of the TSW in the future. Instead of cutting the length of the operating season, Parks Canada has decided to cut the number of hours the TSW is open between May to Thanksgiving by approximately 30%. In 2008, the Independent Review Panel on the Future of the Trent-Severn Waterway submitted its report to the Minister of the Environment, which contained chapters varying from a vision of the waterway, to improving the condition of waterway infrastructure. The panel's cost estimate for maintenance, repair and replacement of physical infrastructure included a proposed $170 million over a ten year period, with an immediate budget increase of $7.5 million per year that would rise to $21 million by 2013. Parks Canada estimates the replacement value of TSW assets as $1.4 billion, with the Treasury Board calculation for this amount yielding an annual maintenance and replacement of assets investment of $56 million. The total annual expenditure for maintenance and asset replacement is only $10.2 million, this amount being a $46 million annual shortfall compared to the Treasury board guidelines (Panel on the Future of the Trent Severn Waterway, 2008).

There are 9 public and 6 private (cost to use) boat launches directly on Sturgeon Lake, with an additional public launch at Riviera Park, below the locks in Lindsay. Boat Cruises (sightseeing, lunch and dinner cruises) depart Fenelon Falls, through the Fenelon River limestone gorge and into Sturgeon Lake, aboard the 200 passenger Kawartha Spirit tour boat.

Fenelon Falls is also the last stop for the Drag River route, an 80km canoe and kayak route beginning in Haliburton, through Gelert to Kinmount, then down the Burnt River to Cameron Lake and into Fenelon Falls, connecting it with the Trent-Severn Waterway system. Other nearby paddling routes include the Irondale Route, a 74km long route beginning in Gooderham, joining the Drag River route at Howland Junction, and the Gull River route, a 110km paddling route beginning at Kawagama Lake in Haliburton and travelling to Coboconk on Balsam Lake, where it connects with the Trent-Severn Waterway. Kayaks and canoes can be launched at any of the Conservation Areas in the study area. The canoe route maps in the City of Kawartha Lakes are currently being updated and will be available in the spring of 2013.

As of 2012,there are six public beaches on Sturgeon Lake ***(Figure 2.1*****),** including Beach Park and Riverview Beach (both in Bobcaygeon), Verulam Recreational Park Beach, Long Beach, Centennial Beach Park, and Sturgeon Point Beach, and three former beaches, at Ken Reid Conservation Area, Hickory Beach and Thurstonia. Each year, the Haliburton, Kawartha and Pine Ridge District Health Unit runs its beach testing program from June 1st to August 31st. Samples are collected weekly and beaches are posted if the geometric mean of at least 5 samples exceeds 100 colony forming units (cfu) of *Escherichia coli* (E. coli). Beach postings are most likely to occur after rain storms or prolonged hot weather. Water temperature is a controlling factor on bacterial levels, with shallow beaches often having higher temperatures and thus higher potential for bacterial growth. Beaches are posted when there is deemed a risk to bathers, in accordance with the Recreational Water Protocol set by the Ministry of Health (HKPR District Health Unit, 2012). Posting data from 2007-2012 are available for the beaches on Sturgeon Lake ***(Table 2.5).***

Table 2.5. Sturgeon Lake Beaches Tested for E. Coli During the 2007-2012 Summer Seasons

	Number of Postings/Number of Sampling Rounds					
Beach	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Bobcaygeon Beach Park	9/13	7/12	7/12	4/13	4/11	4/13
Centennial Beach - Verulam	5/13	7/12	2/10	0/9	1/10	0/13
Ken Reid Conservation Area*	3/12	1/12	2/11	2/11	0/8	--
Long Beach	0/12	0/12	0/8	0/11	0/9	0/13
Sturgeon Point Beach	0/12	0/12	0/6	0/12	0/9	0/13
Thurstonia Government Dock*	3/12	0/2	--	--	--	--
Verulam Recreational Park	0/12	0/11	0/6	1/10	1/8	2/13
Riverview Beach	7/12	4/12	0/8	3/10	3/11	0/13
Hickory Beach*	1/12	0/11	0/7	--	--	--
Proportion of Postings (%)	25.5	19.8	17.6	13.2	13.6	7.7

*Denotes a location that is no longer being maintained as a beach

Sturgeon Lake contains Muskellunge, Bullhead, Carp, Rock Bass, Sunfish, Smallmouth Bass, Largemouth Bass, Perch, Black Crappie, and Walleye (also known as Pickerel), all of which are targeted by anglers. Bait and Tackle are available from both independent outfitter locations, including Kawartha Lakes Outdoors, Emm's, Kawartha Lakes Bait and Tackle among others, and larger commercial chains including Canadian Tire. The region also boasts many fishing charters and guiding services to prospective fishermen. Ice fishing shelters are available on Sturgeon Lake by reservation through the Long Beach Marina. Sturgeon Lake is part of the Fisheries Management Zone 17, for which the Ontario Ministry of Natural Resources released a Fisheries Management Plan in November of 2009. The report highlights the world class fisheries found within the management zone, and identifies the Kawartha Lakes as the most heavily fished inland lakes in Ontario by resident and non-resident anglers (MNR, 2009). In the most recent survey of recreational fishing in Ontario (2005), Sturgeon Lake was not included in the list of the top 25 water bodies for total number of days fished by resident anglers (although the nearby Balsam, Buckhorn, Pigeon and Rice Lakes were) (Ministry of Natural Resources, 2009). However, both the effort of anglers and the economic value of their activities on Sturgeon Lake have yet to be quantified, identifying a clear need to collect this information in the framework of the Sturgeon Lake Management Plan.

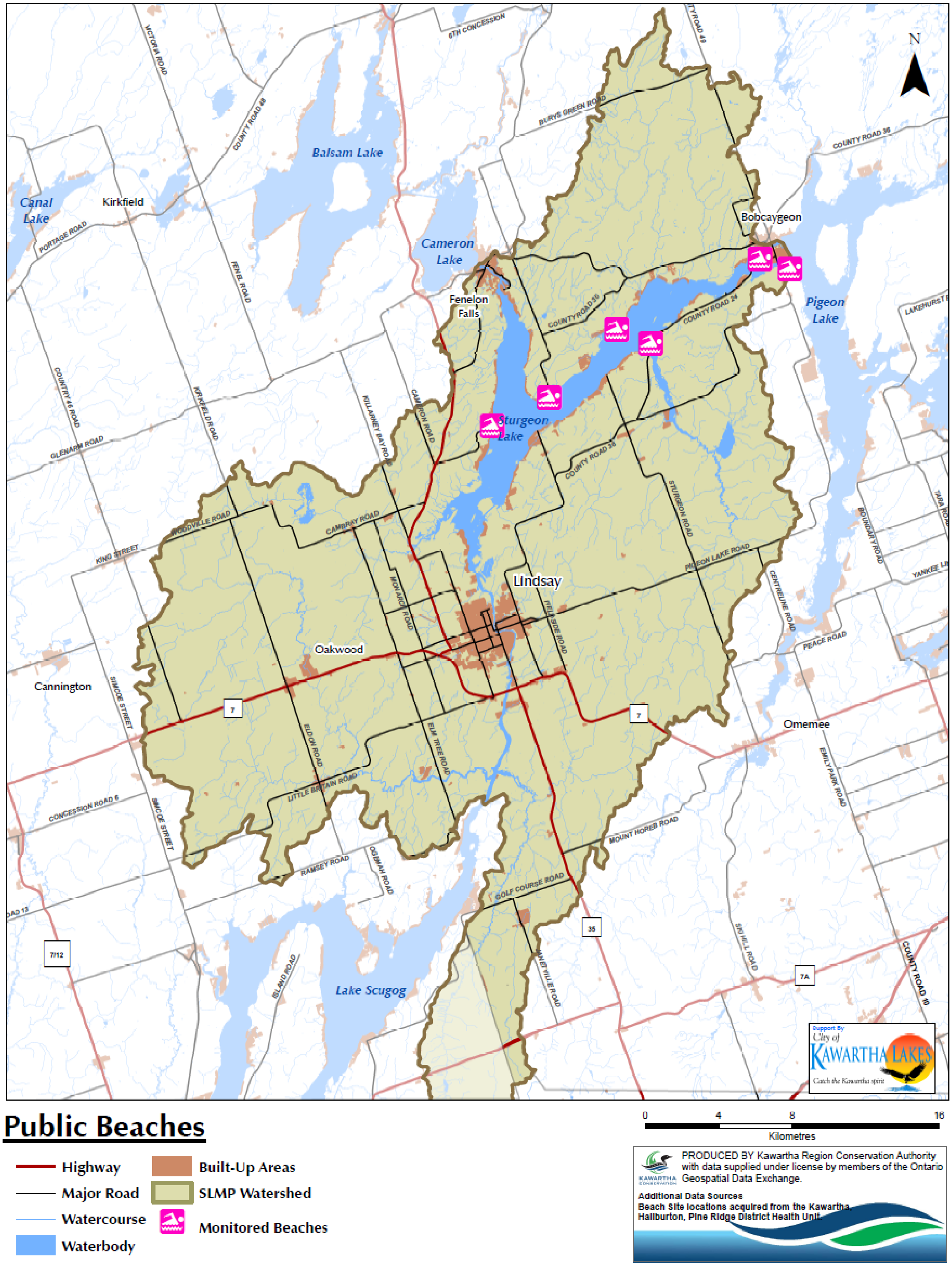


Figure 2.1. Public Beaches in the Study Area Sampled for* E.Coli *by the HKPRD Health Unit

The study area contains 11 different golf courses ***(Table 2.6),*** both 9 and 18 holes, many of which are public or semi-private (City of Kawartha Lakes, 2011). Golf courses have the potential to cause surface or groundwater contamination due to the use of agro-chemicals and the frequent close proximity to both watercourses and lakes. Golf courses are generally in close proximity to bodies of water, due to the substantial irrigation demand of greens and fairways during the growing season. The use and management of various pesticides and fertilizers on golf courses has improved with the implementation of best management practices, so this issue may not be as significant as it once was. The Sturgeon Lake watershed contains 4.25 km^2 of manicured open space (or 0.4% of the total watershed). However, included in this calculation are cemeteries as well as baseball and soccer fields, so the total area represented by golf courses might be slightly smaller.

Table 2.6. Golf Course Details and Locations in the Study Area

Golf Course Name	Location	# of Holes	Yardage	Access
Sheffield Greens	Bobcaygeon	9	2765	Public
Dunsford Golf & Country Club	Dunsford	9	3125	Public
Caygeon Golf Centre	Dunsford	DR*	N/A	Public
Eganridge Inn and Spa	Fenelon Falls	9	2650	Public
Sturgeon Point Golf Club	Fenelon Falls	9	2841	Semi-Private
Wolf Run Golf Course	Janetville	18	6806	Public
Lindsay Golf & Country Club	Lindsay	18	7605	Public
Whitetail Golf & Country Club Estates	Lindsay	9	3544	Public
Deer Run Golf Course	Little Britain	9	2645	Public
Crestwood Golf Club	Manilla	9	2900	Public
Oliver's Nest Golf & Country Club	Oakwood	18	6625	Public

*Denotes a Driving Range

The City of Kawartha Lakes contains many recreational trails on which to hike, cycle, cross-country ski, snowmobile and bird watch. The major trails include the Victoria Rail Trail (approximately 85 km, shared within the much larger Ganaraska Hiking Trail that traverses between Port Hope on Lake Ontario to Wasaga Beach on Georgian Bay), the Kawartha Trans Canada Trail (approximately 44 km, from Highway 7 on the west side of Peterborough, to Simcoe St. south of Manilla), the Dunsford Nature Trail (2.5 km between Heights Rd and Sturgeon Rd, south of CR36), the Scugog River Trail (1.5 km on the east bank of the Scugog River in Lindsay) and the Fleming College Access, Perimeter and River Loop trails (3 km total). These trail systems continue beyond the study area boundary (Peterborough and Uxbridge TransCanada Trail sections, Haliburton County Rail Trail) or intersect other trail systems (Beaverhill River wetland trail) Additional trails can be found in the Conservation Areas, Provincial Parks and municipally owned forest tracts. The trail system of the Kawartha Lakes Snowmobile club (which predominantly uses the Victoria Rail Trail system) joins the Heart of Ontario system to the south and west, Haliburton Snowmobile Association to the north, and Twin Mountains Snowmobile Association to the east.

3.0 Land Use

3.1 Summary of Observations and Issues

OBSERVATIONS

- 74% of the Sturgeon Lake shoreline (excluding the connecting channels) is occupied by residences. Within a 100 meter buffer, 27% of the shoreline area is occupied by urban development
- 25% of the shoreline-lake interface is occupied by artificial installations including armour stone, riprap and concrete, amongst others
- 53.3% of the watershed land area is utilized for agricultural activities, with implications on terrestrial natural heritage and water quality
- 2.0% of the watershed land area is occupied by urban development. With a projected increase in population and the extent of urban development, there will be an increase in impervious surfaces
- 23.8% of the study area is forest-covered (combination of forest and forested wetlands) versus the recommended guideline of a minimum of 30%
- The study area contains rich aggregate resources, which are extensively utilized making the City of Kawartha Lakes the second largest aggregate-producing municipality in the eastern Greater Golden Horseshoe region.

3.2 Agricultural Lands

The soil survey of Victoria County (Gillespie and Richards, 1957) subdivided the soils into land use ratings based on the yield of farm crops generally grown in the County. The “Good” cropland group includes the Otonabee loam, Smithfield clay loam and Solmesville clay loams, which under average conditions produce good yields of farm crops, however during very wet conditions the yields of the Smithfield and Solmesville soils will be greatly reduced (Gillespie and Richards, 1957). The “Good to Fair” cropland group includes the Dundonald sandy loam, Otonabee sandy loam and Emily loam, each having a lower productivity than the soils in the “Good” group. The “Fair” cropland group contains the Simcoe clay, limited in crop type production by poor drainage, but still being suitable for hay and pasture. The “Poor” cropland group includes the Dummer loam soil, used mainly for pasture or woodlot. The “Non-agricultural land” group includes the Cramahe gravel, with physical characteristics preventing cultivation, undeveloped organic soils, and is non-agricultural except for pasture (Gillespie and Richards, 1957). The side slopes of the drumlins and eskers *(**Section 4.3**)* of the region are too steep for good farming (CORTS, 1971).

The Sturgeon Lake watershed was calculated to contain 523.4 km^2 of agricultural land ***(Figure 3.1),*** representing 53.3% of the total watershed land area. For the individual watersheds, percentages ranged from 26% (Martin Creek North) to 66.1% (Mariposa Brook). This is a slight decrease from the 1988 analyses, where 566.3 km^2 of the study area, or 57.7%, contained agricultural land use. However, this slight variation may be explained by the difference in quality of the orthophotographs between 1988 and 2008 (black and white versus colour respectively) and different skills of technicians who have done the analyses.

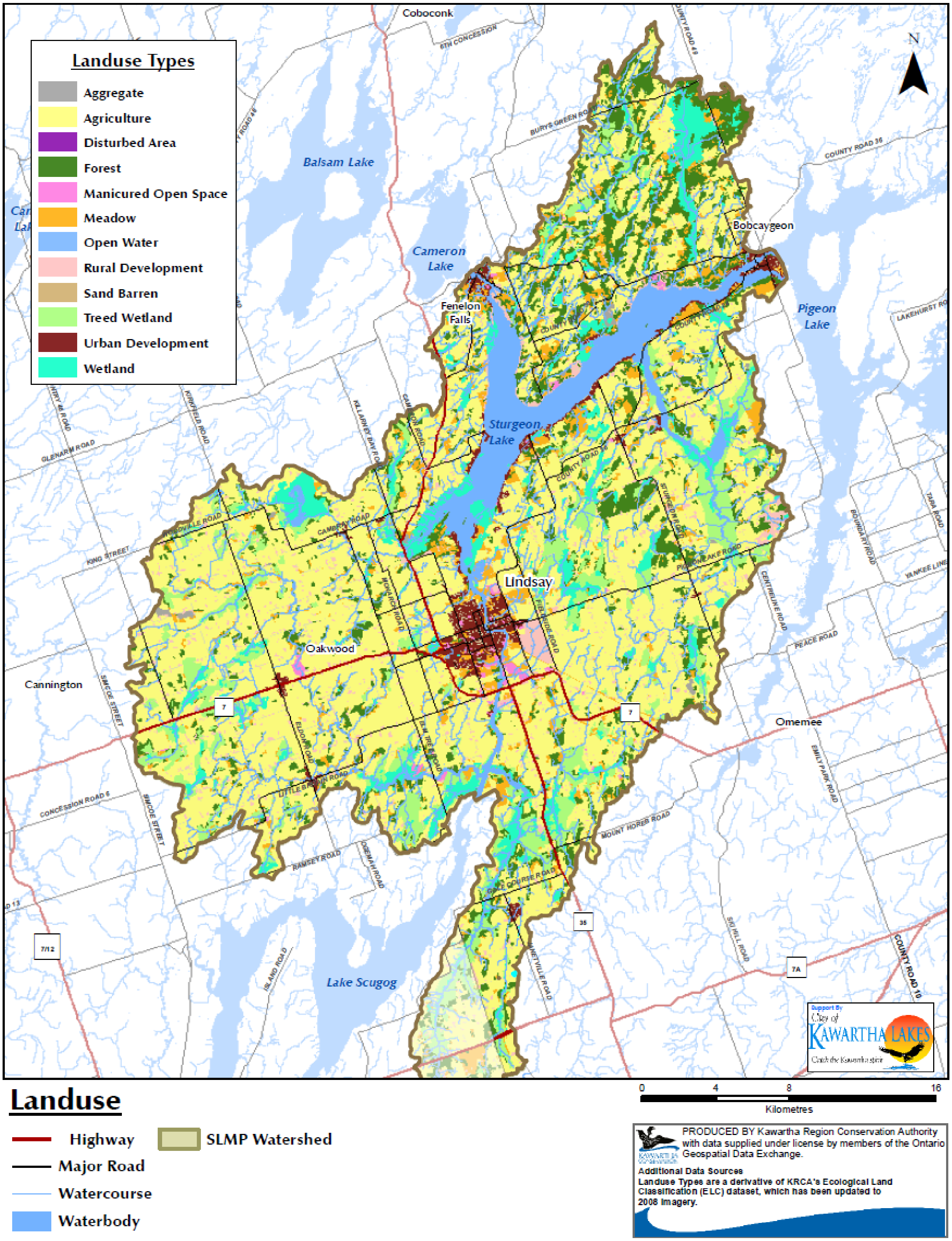


Figure 3.1. Land Use in the Study Area

3.3 Urban Development

The majority of future urban development is anticipated to occur in existing settlement areas within the designated development-envelopes. Three major urban areas in the watershed include Lindsay, Bobcaygeon, and Fenelon Falls, all part of the City of Kawartha Lakes. These towns exhibit much higher population densities than the surrounding rural areas and together with other small urban developments comprise approximately 19.65 km^2, or 2.0%, of the watershed land area ***(Figure 3.1).*** This is a slight increase from 1988 with urban development comprising 16.31 km^2, or 1.7%, of the total land area. The nature of urban development results in an increased proportion of impervious surfaces (concrete, asphalt, etc.) and associated surface runoff, greater demand on water supplies and an increase in waste (both landfill items and sewage) that can impact adjacent water bodies.

Lindsay is not considered an Urban Growth Centre in the Places to Grow report, with the nearest two being Peterborough and Oshawa (Ontario Ministry of Infrastructure, 2006). New housing development is projected to be 10,681 units (averaging 461 units per year) in Lindsay between 2006 and 2031, consisting of 70% low density, 20% medium density, and 10% high density. An additional 2330 units are anticipated to be conversions over that time period, where a seasonal dwelling (cottage, camp etc.) is converted to a permanent dwelling (CKL, 2009). The 45 km extension of Highway 407 from Brock Road in Pickering to Highway 35/115 between Ganaraska Road and Concession Road 8, projected to be finished by 2020, will improve regional transit and relieve congestion on Highway 401 (Ministry of Transportation, 2011) and may spur development in the City of Kawartha Lakes given the improved connectivity with the Greater Golden Horseshoe. However, the growth projections in the reports may have to be adjusted given the disparity between the projected population in 2011 (80,000) and the census population (73,214), but the projections indicate they are based on a perceived census undercount of 4%.

3.4 Rural Residential Areas

Throughout the study area, larger residential lots have been subdivided to create many smaller residential lots, often for the development of retirement communities. A number of recently developed small residential settlements exist throughout the study area. Many older villages and hamlets exist in the watershed acting as service providers to the surrounding rural communities. Villages and hamlets in the study area include Little Britain, Burnt River, Cambray, Cameron, Coboconk, Cunningham's Corners, Downeyville, Dunsford, Glenarm, Janetville, Manilla, Norland, Oakwood, Reaboro and Rosedale. Ecological Land Classification (ELC) calculations, done through analyzing orthophotos in GIS software, indicate that a total area of 40.2km^2 (4% of the Sturgeon Lake watershed) is represented by rural development ***(Figure 3.1).*** However, the cut-off for rural residential areas in ELC mapping is 25 houses, so many of the above hamlets would not qualify and would have been omitted from rural classification, but would have been included in the urban development land use calculation. This is an increase over the 1988 data, which contained 16.5km^2 (1.6%) of the total land area represented by rural development.

3.5 Lakeshore Areas

The quality of the Kawartha Lakes is an attractive feature to both landowners and visitors, and draws many to the area. It has long been understood that the Sturgeon Lake segment of the waterway is dominated by small holding and high density shoreline development (CORTS, 1971). As the baby-boom generation begins to retire, projections indicate a migration by retirees to waterfront areas for both seasonal and permanent residential development. These developments are generally serviced by private wells and septic systems. The number of lakeshore dwellings within 75 meters of Sturgeon Lake as of 2012 is 1774. Within a 100 m buffer of Sturgeon Lake, 27.36% and 19.92% of the area is occupied by urban and rural development respectively. Areas containing a considerable density of lakeshore residential properties around Sturgeon Lake include (in a clockwise direction around the lake) Kenstone Beach, Birch Point, Ancona Point, Cedar Glen, Kenhill Beach, Greenhurst-Thurstonia, Kennedy Bay/Pleasant Point, Snug Harbour, Pickerel Point, Long Beach, Sturgeon Point, Sandy Point and Verulam Park. Of the ~180 km total Sturgeon Lake shoreline, shoreline residences occupy 133.36 km, or 74% of the total length (not including the Fenelon River and the Big and Little Bob Channels).

Table 3.1 provides a summary of land use along the Sturgeon Lake shoreline, as interpreted from 2008 orthophotography. As expected, the Sturgeon Lake shoreline has been significantly altered by settlements. Within 30m of the shoreline, Urban and Residential categories comprise the majority of all lands, and decreases further back from shore. In terms of natural areas, the majority of these are wetlands and forests. Wetlands provide significant aquatic habitat, especially in terms of spawning and nursery for species such as Muskellunge, Largemouth Bass, and Yellow Perch. The dominant wetland types that occur along the shoreline include meadow marsh and thicket swamp. Forested areas provide aquatic habitat in the form of overhanging woody structure providing cover, shade and food. The dominant forest types are coniferous and mixed forests. Among all riparian distances, natural cover is the dominant land use type.

In the summer of 2012, Kawartha Conservation conducted a rapid shoreline classification project (together with students from the University of Toronto in Mississauga) of Sturgeon Lake. This study was done, traveling along the shoreline in boat and delineating approximately 100 km of shoreline into segments of similar type (e.g., marsh, wood, concrete, etc.). A total of 717 individual shoreline segments were evaluated, totaling 103.96 kilometers. Three major shoreline land use categories were found, with 50.87% occupied by natural vegetation, 25.37% occupied by artificial installations and 23.77% occupied by natural non-vegetated land. The sub-categories for each of these three major land uses appear in the following three tables ***(Tables 3.2 – 3.4)***.

Table 3.1.Land Use along the Sturgeon Lake Shoreline at Various Distances from the Shore

LandUse	ELC Community Series	15m (%)	30m (%)	100m (%)	500m (%)	1km (%)
Developed – Urban	Urban Development	25.7	28.3	27.4	10.7	6.7
Developed – Rural	Rural Development	21.4	23.2	19.9	8.0	6.1
Natural – Wetland	Thicket Swamp	12.6	12.1	10.0	4.7	3.3
Natural – Open Water	Open Aquatic	11.9	7.0	4.0	3.5	3.0
Natural – Wetland	Meadow Marsh	11.0	11.0	9.2	3.2	1.7
Natural – Wetland	Shallow Marsh	4.4	4.1	3.0	1.0	0.6
Natural – Forest	Coniferous Forest	4.0	4.3	5.9	11.2	10.1
Natural - Treed Wetland	Coniferous Swamp	3.1	3.8	6.4	9.9	7.2
Natural – Forest	Mixed Forest	2.2	2.3	4.0	5.9	6.1
Natural - Cultural Meadow	Cultural Meadow	1.2	1.3	3.3	11.2	10.7
Developed – Manicured Grass	Manicured Open Space	0.9	1.1	1.5	1.3	0.8
Natural – Meadow	Cultural Thicket	0.8	0.7	0.8	1.9	1.9
Natural - Treed Wetland	Mixed Swamp	0.3	0.3	0.7	1.4	1.6
Natural – Forest	Cultural Woodlot	0.3	0.3	0.3	0.6	0.6
Natural – Forest	Deciduous Forest	0.2	0.3	0.9	1.2	1.5
Agriculture	Intensive Agriculture	0.0	0.0	0.6	8.2	13.2
Agriculture	Nonintensive	0.0	0.1	1.7	13.5	21.9
Natural - Treed Wetland	Deciduous Swamp	0.0	0.0	0.2	0.4	0.3
Natural – Meadow	Cultural Savannah	0.0	0.0	0.3	0.8	1.1
Natural – Forest	Cultural Plantation	0.0	0.0	0.1	0.3	0.3
Natural – Open Water	Submerged Shallow	0.0	0.0	0.0	0.2	<0.1
Natural – Wetland	Floating-Leaved Shallow	0.0	0.0	0.0	0.1	0.2
Developed – Aggregate	Active Aggregate	0.0	0.0	0.1	1.0	1.0
Natural – Wetland	Mixed Shallow Aquatic	0.0	0.0	0.1	0.1	<0.1
Developed – Aggregate	Inactive Aggregate	0.0	0.0	0.0	0.1	<0.1
TOTAL Agricultural		**0.0**	**0.1**	**2.3**	**21.7**	**35.2**
TOTAL Natural		**52.0**	**47.6**	**49.0**	**57.3**	**50.1**
TOTAL Developed		**48.0**	**52.6**	**48.8**	**21.0**	**14.6**

Table 3.2. Length and Percentage of the Surveyed Sturgeon Lake Shoreline Occupied by Categories of Natural Vegetation

Shoreline Category	Length (m)	Percentage of Total Shoreline (%)
Marsh	35508.0	34.2
Forest	12226.0	11.8
Meadow	4655.7	4.49
Swamp	277.5	0.27
Other	113.4	0.11
Total	52780.6	50.9

Table 3.3. Length and Percentage of the Surveyed Sturgeon Lake Shoreline Occupied by Categories of Natural Non-vegetated Units

Shoreline Category	Length (m)	Percentage of Total Shoreline (%)
Cobble	16932.0	16.3
Boulder	4005.9	3.86
Gravel	1750.1	1.69
Bedrock	978.8	0.94
Open Water	927.2	0.89
Sand	38.5	0.04
Other	32.2	0.03
Total	24664.7	23.8

Table 3.4. Length and Percentage of the Surveyed Sturgeon Lake Shoreline Occupied by Categories of Artificial Installations

Shoreline Category	Length (m)	Percentage of Total Shoreline (%)
Concrete	8632.6	8.32
Manicured Lawn	4969.0	4.79
Armourstone	3734.2	3.60
Wooden	3652.2	3.52
Flagstone	1888.5	1.82
Riprap	1450.7	1.40
Beach	867.8	0.84
Gabion Basket	478.2	0.46
Steel	342.2	0.33
Other	299.6	0.29
Total	26315	25.4

3.6 Aggregate Extraction

Quaternary sources of mineral aggregate (sand, gravel etc.) include glaciofluvial ice-contact and outwash sediments, and glaciolacustrine and glaciomarine beach and delta deposits (Barnett, 1992). Outwash deposits are ideal for mineral aggregates as they occur as sheets that can be thick and extensive, with fairly uniform grain size and generally a lack of large boulders (Barnett, 1992). Sand and gravel extraction in the City of Kawartha Lakes is primarily concentrated in Manvers, Emily, Mariposa and Fenelon Townships. Licensed pits are typically located in large ice-contact and esker complexes, subaqueous fans and outwash deposits (Rowell, 2000). In the study area, the Omemee (Hogsback) Esker and has many operating aggregate pits extracting material ***(Figure 3.1).*** The outwash deposits of the watershed have not been exploited to the same degree as the esker (ice-contact) deposits (Finamore and Bajc, 1983). Quarries are concentrated in the northern portion of the City, in which Paleozoic limestones, dolostones, and dolomitic limestones are extracted for crushed and decorative stone. The soft, friable siltstones and sandstone of the lowermost Shadow Lake Formation are considered unsuitable for most aggregate needs.The Gull River formation yields crushed stone that is used in southern Ontario variously for concrete, asphalt and granular base. Furthermore, the Bobcaygeon formation is a major aggregate source in south-central Ontario, with the upper and lower parts useful for concrete (not the middle), and with the entire formation useful for asphalt and granular base. The Bobcaygeon formation has been quarried elsewhere in the Province for lime and cement manufacturing, but the stone is susceptible to abrasion and is therefore less appealing for road building and construction aggregate. The Lindsay formation limestones are used for the manufacture of cement, but have a high clay content causing expansive properties, making them unsuitable for the production of concrete (Rowell, 2000).

Overall, the Kawartha Watershed contains significant aggregate deposits. In 2010, 4,577,148 metric tonnes of aggregate was licensed for extraction in the City of Kawartha Lakes. The 4.57 million tonnes ranks the municipality fourth in the province and second in the region (eastern Greater Golden Horseshoe, second to the Municipality of Clarington) in licensed aggregate extraction and represented approximately 2.7% of the total provincial production of 166 million tonnes (TOARC, 2010). Preliminary statistics for 2011 indicate a slight increase to 4,653,544 metric tonnes of aggregate licensed for extraction, ranking the municipality fifth in the province in licensed aggregate extraction, and representing 2.9% of the total provincial production of 159 million tonnes (TOARC, 2011). The City of Kawartha Lakes has been in the top three of aggregate producing municipalities for the five years period prior to the current production statistics released (2005-2009). ELC calculations indicate that aggregate land use (active and inactive) in the study area represents 2.64km^2, or 0.026% of the total study area.

3.7 Forests

The study area falls within Natural Resources Canada's (NRC) Mixedwood Plains ecozone, the most southern ecozone in Ontario, at its northernmost boundary with the Boreal Shield ecozone. The Mixedwood Plains ecozone contains vegetation represented predominantly by mixed deciduous-evergreen forests and tolerant Carolinian hardwood forests (Ecological and Stratification Working Group, 1995; MNR, 2010). It is further categorized as being in the Manitoulin-Lake Simcoe ecoregion. Vegetation in this ecoregion is characterized by sugar maple, American beech, eastern hemlock, white ash, red oak and basswood at the climax community stage and white pine, red pine, white spruce, paper birch and trembling aspen during the pioneer stage. Sites with greater soil moisture host yellow birch, white elm, and red maple, and - in depressions and near watercourses - slippery elm, black ash and white cedar are frequent. Drier sites tend to host white and red pine and red oak (Ecological and Stratification Working Group, 1995). The study area is further broken down into two ecodistricts, the Peterborough and Madoc ecodistricts (denoted as 6E-8 and 6E-9). The Peterborough ecodistrict spans the entire study area south of Sturgeon Lake, as well as a portion of Sturgeon Point south of County Road 8, while the Madoc ecodistrict represents the remaining study area north of Sturgeon Lake.

Prior to the arrival of European settlers, most of the study area was forested, locally interspersed with lakes, wetlands, rock barrens, and in the southern portion of the Kawarthas, prairie and savannah openings. On sandy and more gravelly soils, the forests were dominated by sugar maple, American beech, American basswood, white ash, red, white and bur oak and scattered white pine. Where the soil was moister, the dominant forest cover shifted to American elm, poplar or aspen, black ash and eastern white cedar (Helleiner et al, 2009).

Ecological Land Classification (ELC) calculations indicate that the entire Sturgeon Lake study area contains 141.03 km^2 of forest, representing 14.4% of the total land area ***(Figure 3.1).*** The forest cover in each individual sub-watershed varies from 1.55% in Jennings Creek to 35.09% in Martin Creek North. The study area also contains an additional 92.33 km^2 of treed wetland, representing 9.4% of the total land area, for a total "forested" cover of 23.8%, below the recommended guideline of 30% forest cover. In the 1988 analyses, the study area contained 222.07 km^2 of forest (representing 21% of the study area), 42.89 km^2 of wetland (4% of the study area), and 68.01 km^2 of treed wetland (6.5% of the study are). Given the large disparity between the 1988 and 2008 data sets, it is assumed that errors were made when interpreting wetlands versus treed wetlands versus forests, over-calculating for forests at the expense of the other two categories. This may be due to the poor quality of the earlier orthophotography.

3.8 Wetlands

A wetland is land that is saturated with water for a sufficient period of time to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation (plants adapted to grow in water), and biological activities which are adapted to a wet environment (NWWG, 1988). The study area lies at the juncture between the Eastern Temperate and Low Boreal wetland regions as demarcated by the National Wetlands Working Group, with the boundary falling along the north shore of Lake Scugog, extending diagonally westward to Lake Simcoe (between Beaverton and Sutton) and eastward south of Pigeon and Chemong lakes (Glooshenko and Grondin, 1988). The wetland forms that have the most common occurrence in the Eastern Temperate region include flat, basin, domed and shore bogs, shore, stream and channel fens, shore and tidal freshwater marshes, and peat margin, basin, stream, shore and spring swamps (Glooshenko and Grondin, 1988). The wetland forms that are most common in the Low Boreal wetland region include domed and basin bogs, basin and shore fens, and coniferous and hardwood and floodplain swamps (Zoltai et al, 1988).On the Peterborough Drumlin Field, the inter-drumlin areas are poorly drained and host swamps dominated by cedar or a combination of elm-ash (Glooshenko and Grondin, 1988).

The Sturgeon Lake watershed contains 69.87 km^2 of wetland, and 92.33 km^2 of treed wetland, for a total of 162.2 km^2, or 16.5% of the total watershed land area ***(Figure 3.1).*** Wetland cover for the sub-watersheds varies from 2.33% for the Scugog River, up to 28.41% for Martin Creek North, and between 0% (Scugog River) and 15.32% (Emily Creek) for treed wetlands. There are a total of 14 evaluated and designated Provincially Significant Wetlands in the Sturgeon Lake watershed, occupying 93.41 km^2 ***(Figure 9.6, Chapter 9).***

Provincially Significant Wetlands (PSWs) are those that have been evaluated and scored using a point-based system known as the Ontario Wetland Evaluation System (OWES), developed by the Ministry of Natural Resources (MNR, 2011). Wetlands are evaluated based on four different criteria. The first, biological component, measures the productivity and habitat diversity of the wetland. The second, social component, grades the direct human uses of wetlands including economic products, recreational and educational activities. The third, hydrological component assesses water-related values, including contributions to groundwater recharge, improvements to water quality, and minimizing flooding. The last, special features component is focused on the rarity of wetlands in the area, the occurrence of rare or species at risk, habitat quality and the age of the ecosystem, amongst other variables (MNR, 2011). A wetland is deemed significant if it garners a total of 600 or more points (to a maximum of 1000) or 200 or more points in either the Biological Component or the Special Features Component.

3.9 Meadows

Meadow ecosystems describe a community type in which herbaceous plants such as grasses, sedges, and forbs (wildflowers) dominate over woody plants (they are treeless or nearly treeless), typically occurring on deep soils (Rodger, 1998). Savanna is a term used to indicate an area where open grown trees and shrubs are established over a continuous ground layer of herbaceous vegetation, and is an ecotone between prairie and forest communities (Rodger, 1998). Oak Savanna, comprised of open-grown oak trees with a tall grass prairie under layer, is most closely associated with southern Ontario's extant tall grass prairie (Rodger, 1998). The National Heritage Information Centre (NHIC) differentiates tall grass prairie as having <10% tree cover, and savannah as having >10-35% tree cover (Bakowski, 1993). It has been estimated that before widespread settlement, southern Ontario contained upwards of between 800 and 2000 km^2 of tall grass communities. By 1992, approximately 21 km^2 of tall grass prairie and savannah were known to be remaining in southern Ontario, less than 3% of the original pre-settlement extent (Rodger, 1998). Most other remnant tall grass ecosystems exist as isolated patches of less than 2 hectares in size. In the Kawartha Conservation watershed, the Dry Black Oak-Pine Tall grass Savanna is a provincially rare vegetation community, and is associated with dry areas on sandy soils (Kawartha Conservation, 2008). The Sturgeon Lake watershed contains 61.5 km^2 of meadow, representing 6% of the total watershed area ***(Figure 3.1).*** The proportion of meadow in each subwatershed varies from 3.34% in McLaren Creek to 12.51% in the Scugog River subwatershed.

3.10 Protected Areas

Within the study region lands are designated as protected areas including federal, provincial, municipal, conservation authority and non-governmental organization owned land.

National Parks

Parks Canada acts on behalf of Canada to protect nationally significant examples of the country's natural and cultural heritage by establishing and maintaining National Parks and National Historic Sites. The study area does not contain any federally protected National Parks, but Parks Canada is responsible for the operation and maintenance of the Trent-Severn waterway. Locks 32, 33 and 34 (Bobcaygeon, Lindsay and Fenelon Falls respectively) are all contained within the study area.

Provincial Parks

A division of the provincial government, Ontario Parks has the responsibility of ensuring that Ontario's Provincial Parks protect significant natural, cultural and recreational environments. There are three Provincial Parks adjacent to the study area: Balsam Lake Provincial Park, Indian Point Provincial Park and Emily Provincial Park.

Balsam Lake Provincial Park encompasses 448 hectares on the western shore of Balsam Lake's North Bay. It is classified as a recreation park, allowing camping, beaches for swimming and other outdoor activities for guests (Ontario Parks, 2008a).

Indian Point Provincial Park encompasses 947 hectares on a peninsula on the north Shore of Balsam Lake. It is classified as a Natural Environmental park, the purpose of which is to protect the landscapes and special features of the region in question, and therefore camping is prohibited and there are no permanent visitor facilities. The park boasts one of the longest undeveloped shorelines in the Kawartha Lakes region and as a low limestone escarpment the lands on which the park is situated is considered an alvar, a provincially significant feature and a rare environmental community type on a global scale (Ontario Parks, 2008b).

Emily Provincial Park encompasses 83 hectares on the eastern shore of the Pigeon River before it drains into Pigeon Lake. It too is classified as a recreation park, allowing the same types of activities as Balsam Lake Provincial Park.

Municipal

The City of Kawartha Lakes manages the Emily and Somerville forest tracts. The Emily tract, located on Peace Road (Arterial Road 14) west of Cowan's Bay, is a 99.2 hectare mixed Forest which offers several trail loops in the vicinity of glacial features including eskers and moraines. The Somerville Tract is a 3,420 hectare municipally owned forest located approximately 5 km west of Kinmount on Monck Road (RR 45), with three developed trail loops 8.5 km in length, containing pine plantations, wetlands, hardwood forests and rock outcrops (CKL, 2006). These lands are managed for recreation and timber resources, although much of the harvesting occurs in the Somerville tract.

Conservation Areas

Kawartha Conservation is responsible for managing protected areas within the study area in the form of Conservation Areas (CAs) and other regulated natural areas.

Ken Reid Conservation Area is located where McLaren Creek outlets into Sturgeon lake, just north of Lindsay. It encompasses 103 hectares, containing loop trails through many forests, meadows and wetlands, including the Provincially Significant McLaren Creek Wetland.

Durham East Cross Forest Conservation Area encompasses 540 hectares, as a Natural Core Area on the Oak Ridges Moraine. Natural Core Areas are so defined because they contain the highest concentration of key natural heritage features that are critical to maintaining the integrity of the Oak Ridges Moraine. While it is slightly outside of the study area, it contains headwater springs of East Cross Creek that flows into the study area (arbitrarily defined as the boundary between the City of Kawartha Lakes and the Township of Scugog).

4.0 Physical Characteristics

4.1 Summary of Observations and Issues

- The bedrock geology of the Sturgeon Lake watershed is formed by two major formations. The northern part of the watershed is of Proterozoic origin and the southern portion is of Ordovician origin.
- The watershed is characterized by several physiographical features including Peterborough Drumlin Field, Schomberg Clay Plains and the Dummer Moraines. On the southern fringes of the watershed, the Oak Ridges Moraine occupies a small area in the East Cross Creek headwaters.
- The depth of glacial drift tends to increase substantially from the south part of the study area to the north, following the major physiographic subdivisions (clay plain giving way to drumlinized till plain to ground moraine) with the exception of the East Cross Creek headwaters area.
- The major soil types follow the geologic and physiographic divides closely, with the clay and clay loams predominating in the south part of the study area and the loams and sandy loams occupying the northern portions of the study area. This has implications for the flora, fauna and water quality of the various subwatersheds.

4.2 Bedrock Geology

The regional bedrock geology is formed of rock from the Precambrian and Paleozoic ages. The study area contains Paleozoic bedrock (overlying surgical Precambrian bedrock) that is a mix of limestone, dolostone, shale, arkose and sandstone of the Simcoe Group and Shadow Lake Formation, which are of Middle Ordovician age ***(Table 4.1)*** (Ontario Geological Survey, 1991). A fault runs through the study area, oriented NNE-SSW, through Mariposa township, passing just west of Oakwood and Little Britain, and continuing north outside the study area through the western part of Balsam Lake (Ontario Geological Survey, 1991).

In the study area, the Paleozoic strata are underlain by igneous and metamorphic rocks of the Canadian Shield consisting of early felsic plutonic, metasedimentary and metavolcanic rocks of Neo to Mesoproterozoic ages (Ontario Geological Survey, 1991; Singer et al, 2003). At locations where these are at or near the surface (i.e. the northern portion of the watershed) they provide an excellent source of groundwater. The study area contains Precambrian inliers, the most conspicuous of which is found 2 km north of Verulam Park, forming a large crag and tail feature (Armstrong and Rhéaume 1994; Finamore and Bajc, 1983), known locally as Red Rock. County Road 30 passes below this outcrop between County Road 8 and Dunbar Drive.

The Canadian Shield is of Precambrian age (in some parts greater than 3 billion years old) and constitutes the core of the North American continent, with younger rock units associated with more recent events arranged in bands surrounding it (Ecclestone and Cogley, 2009). Orogenic uplift occurred at least four times, resulting in rugged mountain ranges, with the most recent period of mountain building termed the Grenville Orogeny (Ecclestone and Cogley, 2009). The long period of mountain building was followed by a long interval of erosion during which the landmass was worn down to a plain-like landscape (Hewitt, 1969).

Immediately surrounding Sturgeon Lake, the basement bedrock is overlain by younger, Paleozoic sedimentary rocks of Middle Ordovician ages. Approximately 480 to 460 million years ago, a period of non-deposition ended when a marine transgression from the Gulf of St Lawrence to the east and the Michigan Basin to the south flooded a large proportion of the North American Continent. This event, called the Tippecanoe, transgressed over older Cambrian sediments (where present) and the Precambrian Shield in the study area (Armstrong, 2000). The marine submergence lasted less than 20 million years in the vicinity of the Kawartha Lakes (Ecclestone and Cogley, 2009). The sediment deposited in the sea began as a coarse grained conglomerate (reflecting proximity to shoreline) and eventually changed to a lime mud (similar to material deposited in shallow seas today that lack sediment input from rivers) that over time was compacted and cemented to form limestone (Ecclestone and Cogley, 2009). These limestone strata are composed of five formations: the basal unit is composed of shale, sandstone and arkose of the Shadow Lake formation which is overlain by the Gull River and Bobcaygeon formations of the Simcoe Group limestones which is overlain by the Verulam Formation, comprised of interbedded layers of limestone and shale which is in turn overlain by the Lindsay Formation, generally comprised of crystalline limestone ***(Table 4.1)***. The Shadow Lake formation was deposited in a near shore environment immediately over an undulating Precambrian landscape (Rowell, 2000). The fauna of the lower member of the Bobcaygeon formation (including gastropods, trilobites, bryozoans etc.) and its bioturbated nature suggest that it was deposited in a subtidal, less restricted environment than the underlying Gull River formation. The very fine grain size further suggests the depositional environment was a protected lagoon (Armstrong, 2000).

Table 4.1. Paleozoic Formations in the Study Area

Formation	Thickness (m)	Characteristics	Location
Shadow Lake	2 – 3	Silty, dolomitic or calcareous sandstone or terrigenous mudstone	Uncomformably overlies Precambrian Grenville basement rocks
Gull River	7.5 – 100	Brown micritic to fine-grained limestone, locally argillaceous, silty, sandy or dolomitic	Overlies Shadow Lake formation
Bobcaygeon	7 – 87	Fossiliferous limestone, with varying argillaceous content	Overlies Gull River formation
Verulam	32 – 65	Limestone interbedded with calcareous shale	Overlies Bobcaygeon formation
Lindsay	Up to 65	Limestone (lower unit), limestone and organic-rich calcareous shale (upper unit)	Overlies Verulam formation

*Note: Data from Armstrong (2000), Beards (1967), Johnson et al (1992) and Singer et al (2003).

This series of limestone, shale and other sedimentary rocks were subsequently uplifted resulting in the beds dipping to the southwest (Buttle, 2009). Streams developed along the lines of the weaker Shadow Lake formation beds prior to the Pleistocene glaciations, downcutting and laterally eroding until they reached the resistant Shield beds and the more resistant overlying Lower Gull River beds (Buttle, 2009). Over time, this lateral erosion resulted in a steep cliff face or scarp, as large blocks of the Lower Gull River formation broke off due to becoming unsupported from below (Buttle, 2009). This Black River cuesta, or Black River escarpment, lying on the border between the southern limestone region and the granitic shield, is evident in outside the study area both in the Gull River valley above Coboconk and in the Burnt River valley (Kirkconnell, 1967).

There is a second escarpment (termed the Trenton cuesta by Kirkconnell) lying south of the Kawartha lakes (most conspicuously Sturgeon) comprised of the Bobcaygeon, Verulam and Lindsay formations. This escarpment is very obvious near the Ken Reid Conservation area, with Highway 35 descending down the face of it, and parallels McLaren’s Creek westward (which interrupts it), continuing north of McLaren’s Creek between Blackbird/Halls Roads and Killarney Bay Road (Gravenor, 1957; Kirkconnell, 1967). This escarpment exhibits multiple interruptions that may mark the locations of preglacial consequent (flowing parallel to the dip of the local strata) and obsequent (flowing opposite to the dip of the local strata) streams (Gravenor, 1957).

To the southwest of the former scarp, some of the Kawartha Lakes occupy old river valleys that eroded into the weaker Ordovician bedrock (Buttle, 2009). The Pleistocene ice sheets likely further eroded and excavated the beds of northeast-southwest oriented valleys that were parallel to the direction of glacier flow (Buttle, 2009), which is consistent with the main axis of Sturgeon Lake. The lakes occupy preglacial river valleys which drained southwest prior to glaciation, a direction now blocked due to morainal debris, and have been deepened due to the erosional effects of ice action and melt water (Chapman and Putnam, 1984; Ecclestone and Cogley, 2009). The modern Kawartha Lakes lie at the juncture of the Paleozoic limestones and the crystalline older rocks of the Canadian Shield (Chapman and Putnam, 1984).

4.3 Surficial Geology

During the Pleistocene Epoch, the study area was exposed to four distinct glacial advances, each punctuated by a corresponding interglacial (non-glaciated) period. The Wisconsinan advance, the most recent glaciation, terminated in the region approximately 12,000 years ago, and many of the surficial deposits ***(Figure 4.1)*** in much of the watershed were transported here during this advance (Ecclestone and Cogley, 2009). Temporal cessation of ice lobe retreats facilitated the ponding of melt water into pro-glacial lakes, resulting in the glaciolacustrine deposits that represent the sand and clay till plains found in the Sturgeon Lake watershed (including the Schomberg clay plain). Recent deposits are characterized by alluvial, peat and muck sediments, found in river valleys, wetlands and other poorly drained areas, which formed during the Holocene Epoch (the current interglacial). In the northernmost reaches of the study area, the Precambrian and Paleozoic bedrock is occasionally not covered by any overburden and is exposed at the surface. Where overburden is present, the thickness tends to be less than 10 meters (Singer et al, 2003). Otherwise, the depth of overburden tends to increase from south to north in the study area, with the north shoreline of Sturgeon Lake covered by 2+ meters of overburden, while the rest of the shoreline has thin cover of <1 meter (OWRC, 1971). This excludes the southernmost reaches of East Cross Creek, which contains a small proportion of the Oak Ridges Interlobate Moraine. The dominant surficial material in the remainder of the watershed is a Diamicton, or a poorly sorted glacial deposit that includes both large grains (gravel and larger) surrounded by a matrix of smaller grained material. The thicker glacial sediments tend to be coarser grained, ice-contact, stratified drift and glaciofluvial deposits. Surficial deposits not falling into these categories include smaller proportions of clay, sand, silt and gravel, in various combinations and proportions.

Many drumlins are present throughout the watershed, occurring predominantly on the Schomberg clay plain and on the Peterborough Drumlin field, a drumlinized till plain. These two physiographic regions comprise the entire study area south Sturgeon Lake. Drumlins are elongated, low-lying hills of till formed by the movement of an ice sheet (Ecclestone and Cogley, 2009). The internal sedimentary structure of drumlins is quite varied, with cross-bedded sands, lenses and other laminar structures indicative of fluvial formation being particularly notable (Ecclestone and Cogley, 2009). The drumlins dictate current flow patterns in the watershed and represent glacial melt water drainage channels, with low-lying poorly drained areas occurring between drumlin clusters. Many of the drumlins of the region are cleared and form pasture lands (Hewitt 1969). The amount of Precambrian material in the till of the drumlins increases with distance south from the Precambrian-Paleozoic rock boundary, contrary to assumptions (Chapman and Putnam, 1984). ***Figure 4.2*** shows the surficial physiography of the watershed, with many of the drumlins occurring south of Lindsay, and north of Sturgeon Lake, extending north-east from Sturgeon Point.

Multiple prominent eskers (most of which are oriented in a NNE-SSW direction, with a few smaller eskers oriented E-W) occur south and east of Balsam and Cameron Lakes, one of which extends into the study area surrounding Goose Lake, and both south and west of Lindsay ***(Figure 4.2).*** The esker south of Cameron Lake follows the valley of Martin Creek South and terminates at Goose Lake, which it surrounds on three (east, west and north) sides as a combined Esker-Kame complex (Chapman and Putnam, 1984). The eskers are oriented in the same direction as the drumlins of the region but because they were formed by flowing melt water beneath the ice sheet, they wander/meander similar to the manner of modern streams or rivers (Ecclestone and Cogley, 2009). Eskers commonly consist of a core of gravel and sand, flanked by more sands, and roughly parallel the direction of local glacial retreat (Barnett, 1992). The eskers in the Kawartha Lakes region are composed predominantly of limestone gravel, with some having very coarse, cobbly materials (Chapman and Putnam, 1984). In Goose Lake's case, it has been suggested that Goose Lake had been occupied by a large stagnant ice block, which upon melting deposited the esker/kame ice-contact stratified materials around its northern border (Gravenor, 1957; Ontario Geological Survey, 2003).

The glacial spillways in the region are the large river valleys that were carved out of the till when the outflow from Glacial Lake Algonquin (proto-Lake Huron) was channeled through the Kawartha Lakes toward Glacial Lake Iroquois (proto-Lake Ontario) near the end of the Wisconsinan glaciation (Ecclestone and Cogley, 2009).

From approximately 12,000 to 11,300 years ago, the Kirkfield low water phase (when the water level dropped between 15 to 30 meters) of Lake Algonquin was facilitated by the drainage of glacial melt water through the Kirkfield/Fenelon Falls outlet, bypassing the Lake Erie basin (Barnett, 1992; Finamore, 1985). A regular, continuous water plane in the study area suggests that Fenelon Falls, rather than Kirkfield, was the actual outlet. This is supported by spillway terraces and shoreline features below the Main Algonquin water level southeast of Fenelon Falls, pointing to the Falls being the controlling sill (Finamore, 1985; Ontario Geological Survey, 2003). If de-glaciation is the sole explanation for the drainage of the Lake Algonquin then this points to the Fenelon Falls spillway having been the first outlet exposed, before the Port Huron or Chicago outlets were active (Larsen, 1987). Originally the Fenelon Falls Spillway followed a route that discharged into Sturgeon Lake further southeast, approximately where the outflow of Rutherford Creek is today, but this old gorge has been buried by glacial drift (Finamore and Bajc, 1983), with only a small arm within the town of Fenelon Falls still exposed and filled with water. The Fenelon outlet closed due to a return of higher water levels in the Main Algonquin phase, brought about by isostatic uplift. Elsewhere in the study area, evidence of the Fenelon Spillway is apparent at the base of Sturgeon Point (Chapman and Putnam, 2007) when higher floodwaters from the Fenelon Falls outlet were channeled through Sturgeon Lake, yielding a much higher lake level (not unlike Glacial Lakes Iroquois and Algonquin) and in the Bobcaygeon area, with exposed or thinly covered Paleozoic bedrock (Finamore and Bajc, 1983) that was washed by the glacial melt waters.

Finally, there is the apparent/suggested Emily Creek Spillway that would have acted as a bypass or second outlet to the Bobcaygeon channel(s). This assertion is supported by a large outwash plain situated on a bedrock plateau that acts as a topographic high between the west side of Pigeon Lake and Emily Lake, the scouring out of Emily Lake, scoured and exposed Paleozoic bedrock at the mouth of Emily Creek and a smaller exposure along the northeast arm draining into Pigeon Lake, and Kame deposits acting as Topographic controls immediately south of Long Point Bay (Gravenor, 1957). The whole of Emily Creek is mapped as muck deposits, which have been able to fill the old spillway in due to a cessation in through-flow. Consulting the NTS map for Lindsay (031D7), it would appear the suggestion of Walters (2009) that with a 1 meter rise in water level of Sturgeon Lake some drainage would follow Emily Creek to Emily Lake and then northeast towards Pigeon Lake is plausible. However, the Emily spillway would be notable in how different its major axis would be compared to the other Kawartha Lakes (including Sturgeon). Most of the spillways in the region are occupied by underfit watercourses (streams or rivers that are too small to have eroded the valley through which they flow) that follow the course of the former glacial rivers, with some also partially occupied by extensive wetlands (Ecclestone and Cogley, 2009).

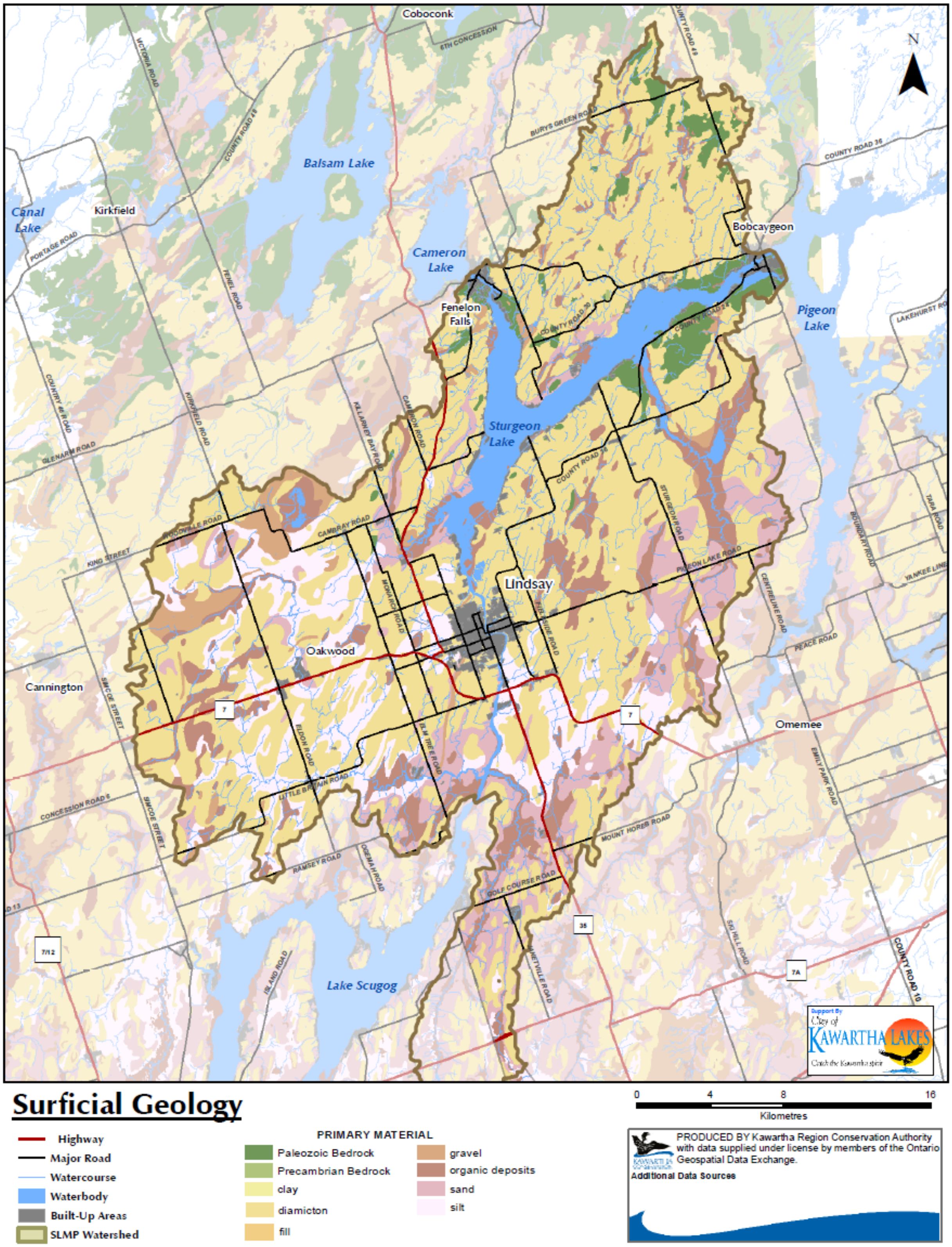


Figure 4.1. Surficial Geology of the Study Area

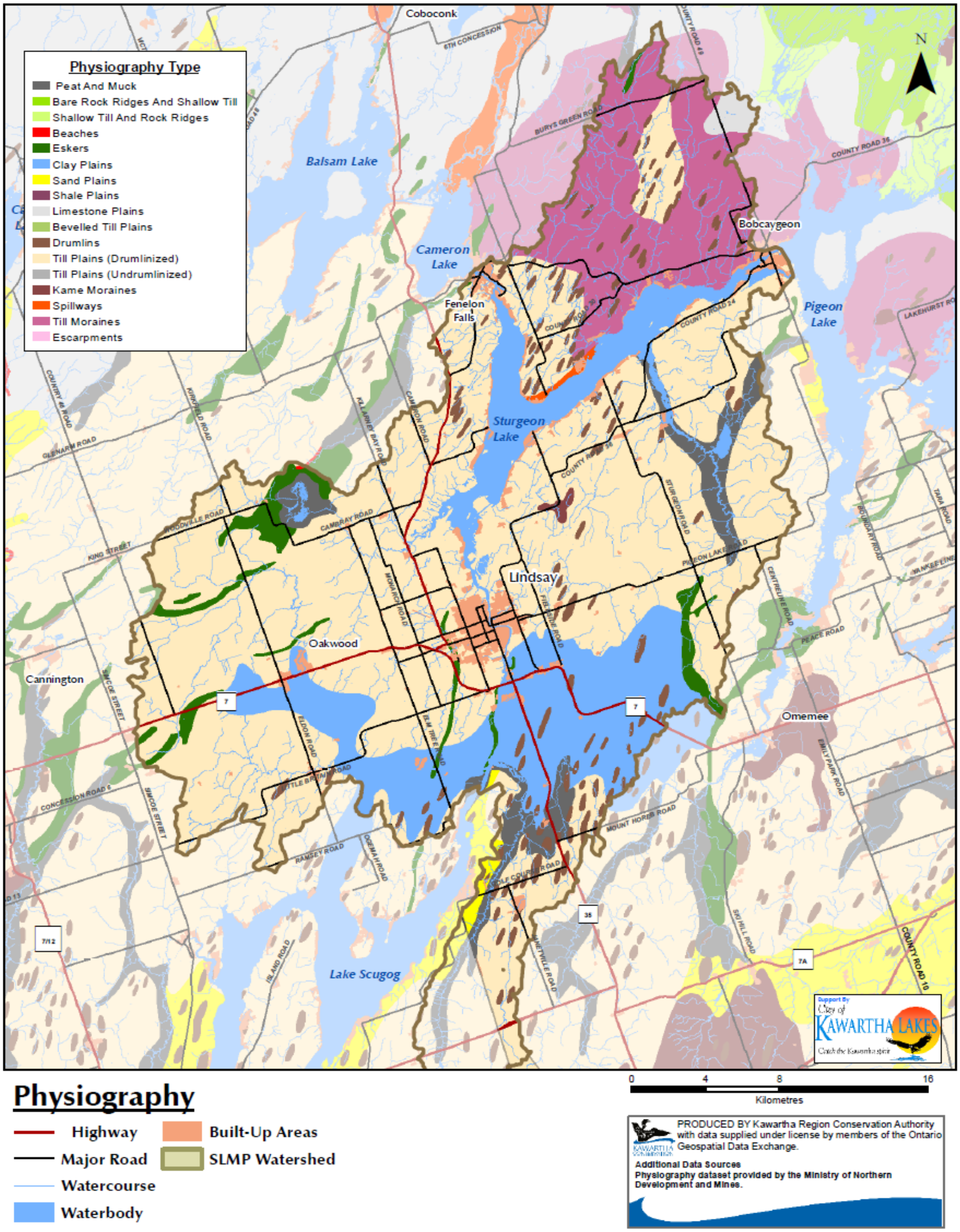


Figure 4.2. Physiography of the Study Area

4.4 Physiography

There are four distinct physiographic regions in the watershed. From north to south these include the Dummer Moraine, Peterborough Drumlin Field, the Schomberg Clay Plain and the Oak Ridges Moraine ***(Figure 4.3).*** The Oak Ridges Moraine acts as a major drainage divide of high sandy ground, extending for approximately 160 km from the Niagara Escarpment to east of Rice Lake. Hummocky topography and kettle lakes characterize the Moraine, yielding complex sedimentary sequences that can exceed 200 m in thickness. The moraine is predominantly composed of permeable glaciofluvial sands and gravels, and impermeable deposits of till, silt and clay. The headwaters of East Cross Creek begin on the moraine between two large wedge-shaped bodies of the Uxbridge and Pontypool sediment wedges.

The Dummer moraine represents an area of rough, hummocky stony land bordering the Canadian Shield from the Kawartha Lakes eastward to Kingston that spans approximately 180 kilometers and roughly follows the boundary between the Paleozoic and Shield rocks (Chapman and Putnam, 1984; Ecclestone and Cogley, 2009). The Dummer moraine encompasses part of the northern portion of the watershed, lying between the Georgian Bay Fringe to the north, Carden Plain to the west, and Sturgeon Lake to the south. The surface is extremely rough and jagged despite the morainic ridges being low (Chapman and Putnam, 1984). The till is composed of coarse boulders and sandy material, with local bedrock outcrops occurring in the region north of the Kawartha Lakes. The underlying Paleozoic rocks form escarpments in some areas (Singer et al, 2003). The limestone terminates on the north portion in an escarpment between 7.5 and 23 meters (25 to 75 feet) in height (Chapman and Putnam, 1984). Frequently, the limestone bedrock of the area is exposed in limestone plains (Hewitt, 1969). The finer matrix of the moraine has a faint reddish colour owing to the red shale and siltstone which occur just under (the Shadow Lake formation) and appear along the northern border of the Gull River Formation (Chapman and Putnam, 1984). The Dummer moraine likely formed as a recessional moraine during a pause in the retreat of the Simcoe ice lobe (Ecclestone and Cogley, 2009).

The Drumlin field encompasses the majority of the watershed south of Sturgeon Lake (with the exception of the Schomberg Clay Plain poundings south of Lindsay) as well as a small area between the northern and eastern arms of Sturgeon Lake, extending up to Fenelon Falls. Drumlins in this region are typically elongated, low-lying hills, less than 1.5 km long, 400 meters or less wide, and 25 meters in height. They are composed of highly calcareous glacial till consisting of sand and gravels. In addition to the drumlins, the region contains many drumlinoid hills and surface flutings of the drift cover (Chapman and Putnam, 1984; CORTS, 1971). A flute is a streamlined subglacial form, parallel to the direction of ice movement, which commonly forms due to the squeezing of saturated debris into linear cavities behind large boulders during lodgement (Barnett, 1992).

The Schomberg Clay Plain is a relatively flat, dish-shaped area bound by the Dummer moraine to the north, and the Peterborough Drumlin field to the south. It occupies the central area of the watershed, north of Lake Scugog, and consists of stratified clay and silt deposits that overlie the drumlinized till plain (Singer et al, 2003). These thick clay and silt rhythmites were deposited into glacial Lake Schomberg, which formed due to ponding between the Oak Ridges moraine, the receding Simcoe lobe, and the Niagara Escarpment (Barnett, 1992). The Schomberg sediments are typically varved clays with annual layers comprising two to four inches (or more) in thickness, likely composed of freshly ground rock flour rather than weathered clay minerals (Chapman and Putnam, 1984). The average depth of deposits in the region is 5 meters, with isolated locations having deposits reaching 8 meters. The result of the clay plain overlying the till plain is a “drumlin and clay flat” landscape near Lindsay, with clay deposits which lie between drumlins having an important influence on the soils of the area (Chapman and Putnam, 1984). Sluggish streams and large wetlands characterize the watersheds of the Schomberg Clay Plain. This region is well suited for agriculture, which has been the dominant land use in the area (Chapman and Putnam, 1984).

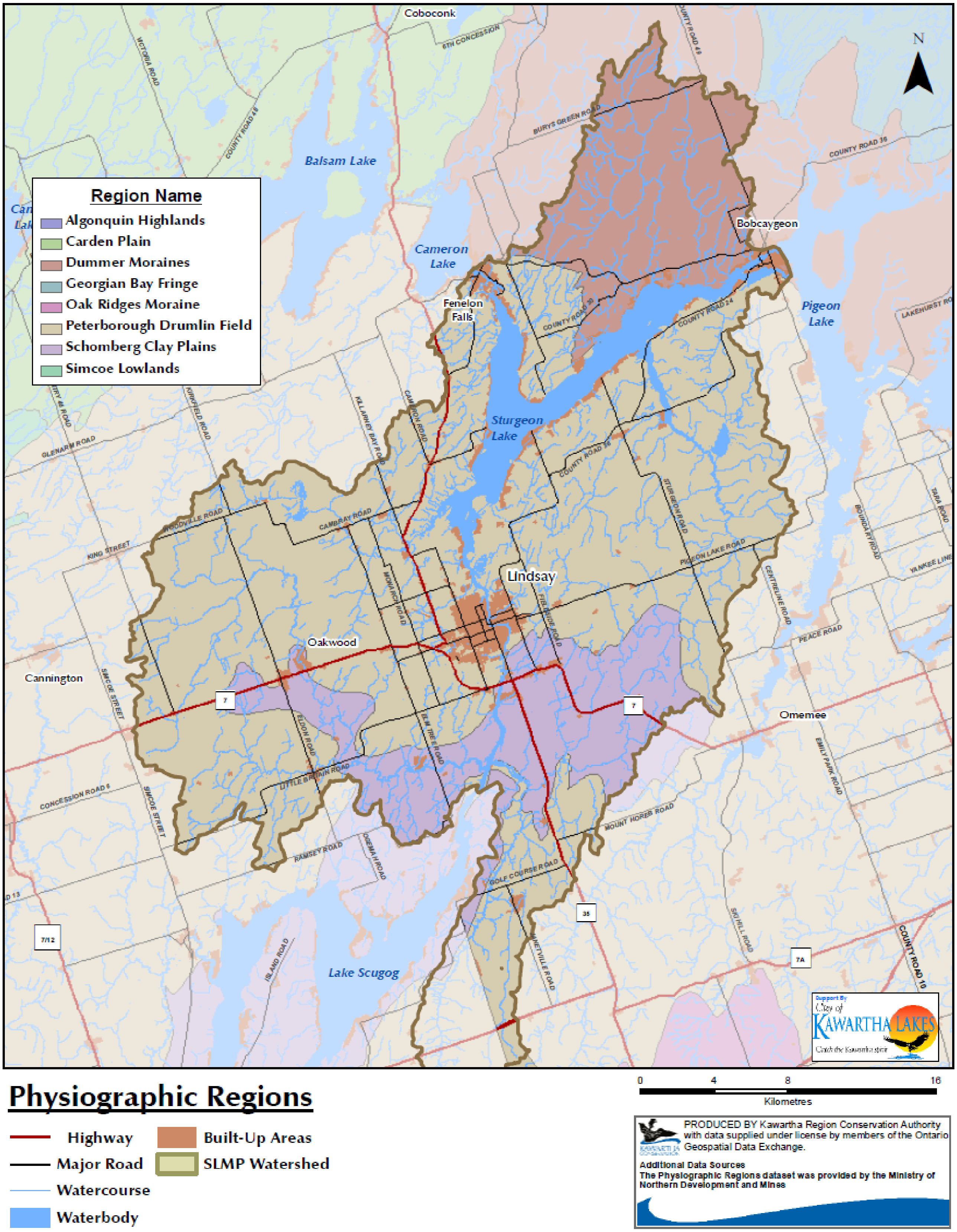


Figure 4.3. Physiographic Regions of the Study Area

4.5 Topography

The current landscape owes its character to glacial activity that occurred during the Pleistocene era. ***Figure 4.4*** provides an illustration of the topography of the study area. Massive ice formations and the resulting melt waters of the glacial lakes shaped many of the surface features found within the watershed area today. To the south, the joining of two massive ice lobes formed the Oak Ridges Interlobate Moraine. This kame type moraine is a dominant feature of the landscape, yielding the headwaters of many watercourses, which originate from and run around this feature.

Other local high points in the study area are represented by glacial deposits such as eskers and drumlins, with changes up to 25 meters in elevation common. The study area contains over 130 drumlins and 10 eskers ***(Figure 4.2),*** with more of these features immediately outside of the area boundary. The surface elevation of the study area varies from a low of 246 meters above sea level at the Big Bob channel outlet of Sturgeon Lake in Bobcaygeon, to a high of 320 meters above sea level near the intersection of County Roads 49 and 37 (Bury's Green Road) north of Sturgeon Lake (Natural Resources Canada, 2012). The general trend of the surface topography (***Figure 4.4***) is lower surface elevations south of Lindsay (towards Lake Scugog), especially in the watersheds of Mariposa Brook and the lower reaches of East Cross Creek, and higher elevations southwest of the East Cross Creek watercourse (the fringes of the Oak Ridges Moraine), and along the western boundary of the study area along County Road 46, as well as gradually increasing toward the northern portion of the study area, punctuated by a decrease in elevation at the Kawartha Lakes basins.

4.6 Soils

The landscapes, and by association the soils, differ greatly between the north and the south. The zone of demarcation closely mimics the major geological/physiographic boundary between the Canadian Shield and Great Lakes-St. Lawrence Lowland. On and adjacent to the Canadian Shield, the soils are frequently too thin to support successful agricultural activities and as a result, large areas of land have reverted back to modified forest cover (Helleiner et al, 2009). In fact, much of the higher ground on the Canadian Shield is exposed bedrock devoid of soil, as the glaciers removed and transported the soil that existed in the past (Helleiner et al, 2009).

The transition between the north and south geological and climatic regions is reflected in three distinct soil orders ***(Figure 4.5).*** On the Precambrian Shield, humoferric podzols developed on the well-drained boreal sites due to the acidic, iron-rich parent material under coniferous and mixed forest vegetation (Baldwin et al, 2000; Helleiner et al, 2009). These podzols are frequently acidic and thin, with their B horizon accumulating organic matter, iron and aluminum compounds, and are most commonly associated with exposed bedrock (Baldwin et al, 2000; Helleiner et al, 2009). The B, or subsurface mineral horizon, is characterized by organic enrichment (Soil Classification Working Group, 1998). The second order are the brunisols (melanic and dystric) immediate south of three lakes, exhibiting weakly developed B horizons, neutral pH and little to no accumulation of organics or clay in the B horizon (Helleiner et al, 2009). Melanic brunisols develop on calcareous, rolling till and lacustrine deposits and dystric brunisols are more closely associated with loamy to sandy acidic glacial till and with outwash and lacustrine material (Baldwin et al, 2000). The third order consists of the luvisols, having a neutral pH status and an accumulation of clay in the B horizon, these soils formed from limestone rich glacial till parent material with deciduous/mixed forest cover (Helleiner et al, 2009). Large areas of luvisols support agriculture in southern and central Ontario (Baldwin et al, 2000).

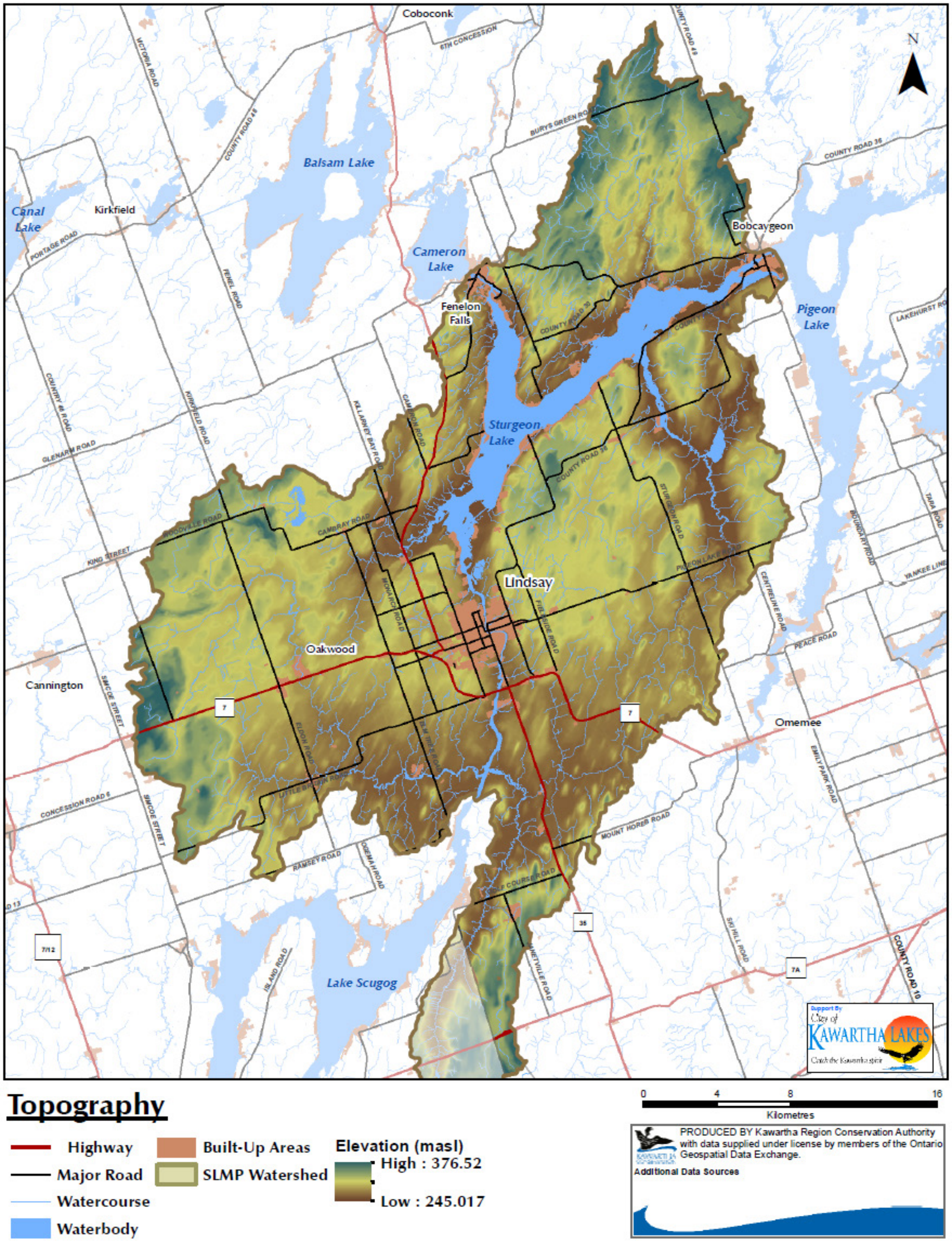


Figure 4.4. Topography of the Study Area

The soils of the Schomberg Clay plain, as categorized by the Ontario Soil Survey, include the well-drained Schomberg silty clay loam, the imperfectly drained Smithfield clay loam and the poorly drained Simcoe silty clay and silt loams (Chapman and Putnam, 1984). The major soil types and the associated drainage characteristics, erosional potential and agricultural capabilities are summarized in ***Table 4.2.***

The major soil types in areal extent include the Dummer Loam, Otonabee Loam, Otonabee Sandy Loam, Simcoe Clay, Smithfield Clay Loam, Solmesville Clay Loam, Cramahe Gravel, Dundonald Sandy Loam and Emily Loam.

The Otonabee soils are well drained externally and internally, with a general surface soil texture of a loam but in a number of areas it is a sandy loam. The soil parent material is a sandy loam textured glacial till containing a moderate amount of stone, and is calcareous, having been derived from limestone (Gillespie and Richards, 1957). The Otonabee loam is commonly found on top of the drumlins in the area, with thin upper horizons that have undergone the vertical transfer of clay particles to deeper soil depths (Helleiner et al, 2009). These soils are the most important agricultural soils in the City of Kawartha Lakes due to their ease of cultivation, as a result of the surface soil being friable and possessing a granular or crumb-like structure (Gillespie and Richards, 1957). The Otonabee soils are very widespread and found south and east of Balsam Lake, extending around Cameron Lake to just north of Fenelon Falls and then on the north shore of Sturgeon Lake to County Road 8. On the south shore of Sturgeon Lake, the Otonabee series is found east of Emily Creek, and from Pleasant Point to just west of Snug Harbour. Overall, the series is patchy but very widespread in Eldon, Fenelon, Mariposa, Emily and Verulam Townships (Experimental Farm Service, 1956b). The Emily soils are in close association with the Otonabee series, but are found at lower topographical positions than the latter, therefore receiving higher amount of surface runoff from adjacent elevated land and remaining in a water saturated condition for a comparatively longer period of time (Gillespie and Richards, 1957). Development in these soils has been less pronounced than in the Otonabee series. Emily soils are found in isolated patches east of Lindsay in Emily Township, near Emily lake in the south part of Verulam Township, and west of Glenarm in Eldon Township (Experimental Farm Service, 1956b).

Table 4.2. Sturgeon Lake Watershed Soil Characteristics

Physiographic Region	Major Soil Types	Drainage Characteristics	Erosional Potential	Agricultural Capability
Dummer Moraine	Shallow loams and muck	Good to excessive with large expanses of wetland	Low to Moderate	Shallow soil, moderate slopes, limiting crop selections to forage crops, some pockets of good soil
Peterborough Drumlin Field	Sandy loams, loams and muck	Good to imperfect drainage with large expanses of wetland	Low to Moderate	Moderate limitations due to low permeability and slopes
Schomberg Clay Plain	Clay, clay loams and muck	Imperfect to poor	Low	Minor limitations, some drainage restrictions

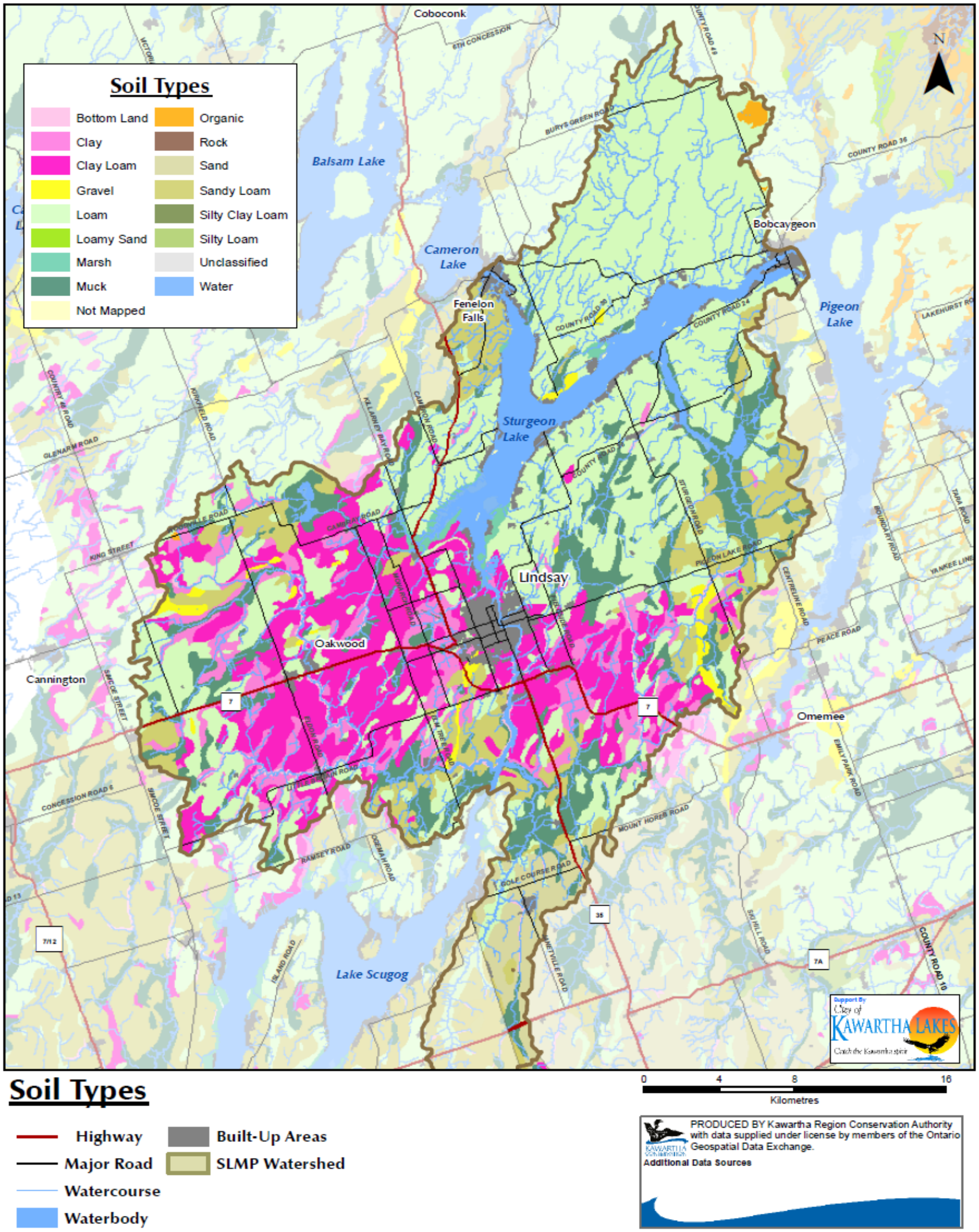


Figure 4.5. Soils of the Study Area

The Dummer soils are well to excessively drained with a variable topography from moderately to steeply hilly (where the till is deeper) with the parent material a very stony loam till (Gillespie and Richards, 1957). The Dummer loam is a thin and very stony soil that is rich in carbonates and in a natural state has a very dark grayish-brown surface horizon rich in organic matter (Helleiner et al, 2009). The Dummer soils are most suitable for pastureland, with some areas under cultivation after extensive stone removal (Gillespie and Richards, 1957**).** The Dummer loam shallow phase extends from north of the Trent Canal on the west side of Balsam Lake, north to Norland, southeast towards the north shore of Four Mile Lake, and extending north in the Burnt River valley north of the town of Burnt River. It is interrupted by a band of the Otonabee loam shallow phase soil, after which it appears as the non-shallow phase Dummer loam in Verulam Township north of County Road 8 (Experimental Farm Service, 1956a).

The Solmesville soils have gently sloping topography yielding imperfect drainage conditions in the soil profiles, commonly a foot of lacustrine clay overlying the stony till of the area (Gillespie and Richards, 1957). The Solmesville soils can produce crops, and if drainage were to be improved could host a wider range of cultivated crops. The Solmesville soils occur at the town of Lindsay, extending north to the Ken Reid Conservation area, south towards Reaboro, and west towards Oakwood, and are interspersed with expanses of Waupoos, Simcoe, and Smithfield soils (Experimental Farm Service, 1956b).

The Smithfield soils developed from calcareous lacustrine clay and occur in the old glacial lake bed in the townships of Mariposa and Ops, with patches of the soil extending to east of Goose Lake in Fenelon Township. The Smithfield clay loam occurs on very gently sloping topography, with imperfect drainage conditions due to slow internal drainage and poor surface drainage. These soils are highly productive. The Simcoe clay soil occurs on similar material as the Smithfield soils but can be differentiated due to poorer drainage. The Simcoe clays are potentially good agricultural soils (they are not in cultivation) but an artificial system of drainage is preferable to raise the productivity of the soil even further (Gillespie and Richards, 1957). The Simcoe soils are also in Mariposa and Ops Townships, with patches extending to just west of the town of Omemee (Experimental Farm Service, 1956b).

The Cramahe gravel soils are very stony, with excessive drainage and are found on the eskers of the region. The materials contain coarse calcareous sand and gravel, cobbles and large boulders. The steep slopes and coarse materials make cultivation impractical, and are simply fair for pastureland (Gillespie and Richards, 1957). The Cramahe soils occur on Sturgeon Point, in Fenelon Township north of the Martin Creek valley, in isolated patches west of Lindsay, and surrounding the town of Downeyville in Emily Township (Experimental Farm Service, 1956b).

The Dundonald soils occur on sandy outwash deposits overlying a calcareous loam to clay loam till and are well drained. The topography on which these soils are found is slightly rolling and the fine material available to deeper rooted plants and few stones in the soil make this series preferable for agriculture, despite the soils occupying a small amount of area (Gillespie and Richards, 1957). The Dundonald soils occur in discontinuous patches in Emily Township, between Emily Lake and Fee’s Landing, and isolated patches north of Lake Scugog in Mariposa Township, and both east and west of the Scugog River in Ops Township (Experimental Farm Service, 1956b).

5.0 Climate

5.1 Summary of Observations and Issues

OBSERVATIONS

- The climate of the Sturgeon Lake watershed is described as moist continental, mid-latitude. It is characterized by warm summers with occasional hot and humid spells, and cold winters with snowstorms, strong winds and cold air from Continental Polar or Arctic air masses. Precipitation is equally distributed through the year.

ISSUES

- Climate conditions are currently projected to change as a part of the global climate change process. Some of the expected changes to weather are:
    - Higher temperatures in all seasons, but especially in winter
    - More variable precipitation, with increases in both the incidence of drought and intense precipitation
    - Decreased snow cover, increased amounts of rain in winter
    - More storms and higher wind speeds.
- A change in climate will bring changes to the lake ecosystem that requires advance preparation and planning.

5.2 Introduction

Climate is a pattern or cycle of weather conditions including temperature, precipitation, wind, humidity and cloud movement over a given region, averaged over many years. The climate of a region is affected by its location on the planet, topography, as well as nearby water bodies and the respective currents.

The climate conditions of the Sturgeon Lake watershed is classified as a moist continental mid-latitude climate with warm to cool summers and cold winters, as categorized by the Köppen Climate Classification System. The Köppen Climate Classification System is one of the most widely used climate classification systems. The system was developed by German climatologist Wladimir Köppen (1846-1940), who divided the world's climates into six major categories based upon general air temperature profile in relation to latitude.

The Köppen system classifies a location’s climate using mainly annual and monthly averages of temperature and precipitation ("normals"). The length of record required to determine climate normals for any particular location is 30 years, as defined by the World Meteorological Organization (WMO). The normals are computed every 10 years by Environment Canada, utilizing all qualified monitoring stations. The current 30-year normals are determined from weather data obtained during the 30 years of 1971-2000. An updated set of 30-year normals for the period of 1981-2010 are being calculated and are expected to be released in late 2013.

According to the Köppen classification, the moist continental mid-latitude climate (Dfb climate category) is characterized by the average temperature of the warmest month greater than 10°C, while the coldest month is below -3°C. Also, no month has an average temperature over 22°C; precipitation is equally distributed across the year. Summers are warm with occasional hot and humid spells; winters are rather severe with snowstorms, strong winds and bitter cold from Continental Polar or Arctic air masses. This climate prevails in most of east-central Ontario with only little variability throughout the region ***(Figure 5.1).***

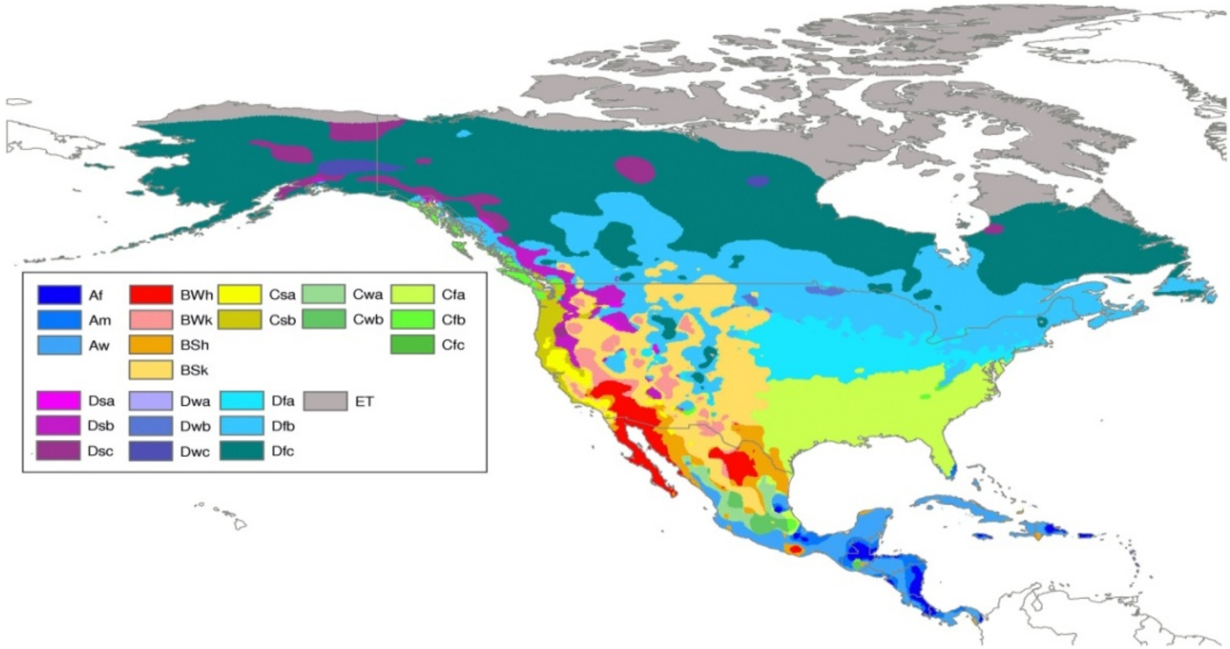


Figure 5.1. The Köppen Climate Classification System for North America

The climate monitoring station in Lindsay (Lindsay Frost, Station ID 6164433) is the most suitable monitoring location from which data can be used to characterize climate variables of the study area. The station was a component of the Environment Canada climate monitoring network, working in accordance with the United Nation's World Meteorological Organization standards and providing high quality monitoring data for over 35 years. Unfortunately, the station was discontinued in 2009. Kawartha Conservation is currently working with Environment Canada to reinstate this monitoring location.

Average monthly temperatures and precipitation values for Lindsay Frost monitoring location are shown in ***Table 5.1*** and on ***Figure 5.2.*** These data confirm the study area as belonging to the moist continental mid-latitude climate category.

5.3 Air Temperature

The average winter monthly air temperature for the Lindsay Frost climate station ranges from -5.1^{o}C in December, to -8.9^{o}C in January, which is the coldest month of the year.

July is the warmest month with the average monthly temperature reaching 20.1^{o}C. August is the second warmest month, with an average temperature of 18.9^{o}C, while the average temperature in June documented as 17.4^{o}C.

An extreme minimum temperature was entered in January 1994 at -36.5ºC, while July 7, 1988 was the hottest day recorded with the temperature at 36.5ºC. The average yearly air temperature is 6.3ºC

Table 5.1. Average Monthly and Daily Extreme Values of Air Temperature and Precipitation for the Lindsay Frost Climate Station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Air Temperature, °C													
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	6.3
Daily Maximum Average	-4.3	-2.7	2.9	11	18.7	23.2	26.1	24.5	19.5	12.6	5.4	-1.1	11.3
Daily Minimum Average	-13.3	-11.9	-6.7	0.5	6.9	11.4	14.1	13.1	8.9	3.1	-2	-9.1	1.3
Extreme Maximum	10.5	11.5	24	29.5	32	33.5	36.5	36.5	31.5	25.5	21.1	17.5	
Year	1995	2000	1998	1985	1980	1988	1988	2001	1983	2001	1974	1982	
Extreme Minimum	-36.5	-35	-30.5	-14	-4	-2.5	5	1.7	-3.5	-9.4	-18.5	-34	
Year	1994	1979	1980	1982	1986	1978	1977	1976	1991	1975	1977	1980	
Precipitation (mm)													
Rainfall	23	19.3	34.6	55.8	81.6	83.9	73.4	89.7	91.7	71	67.7	27	718.8
Snowfall	44.6	28.2	23.8	6.7	0.3	0	0	0	0	1.9	16.3	41	162.8
Total Precipitation	67.6	47.5	58.4	62.5	81.9	83.9	73.4	89.7	91.7	72.9	84.1	67.9	881.6
% of yearly amount	8	6	7	7	9	9	8	10	10	8	10	8	
Extreme Daily Rainfall	31.8	36.8	37.2	36.3	44.2	56.8	92.4	80.2	52.2	53.2	58.8	24	
Year	1995	1985	1990	1976	2000	1998	1980	1995	2000	1995	1999	1979	
Extreme Daily Snowfall, cm	20	28	26	20.3	7.6	0	0	0	0	13	19	35.6	
Year	1979	1993	1982	1975	1976	1975	1975	1975	1975	1981	1995	1992	
Extreme Daily Precipitation	40	36.8	37.8	36.3	44.2	56.8	92.4	80.2	52.2	53.2	58.8	35.6	
Year	1979	1985	1980	1976	2000	1998	1980	1995	2000	1995	1999	1992	
Extreme Snow Depth, cm	50	50	48	21	0	0	0	0	0	13	24	36	
Year	1984	1982	1982	1987	1983	1983	1983	1983	1983	1981	1995	1992	

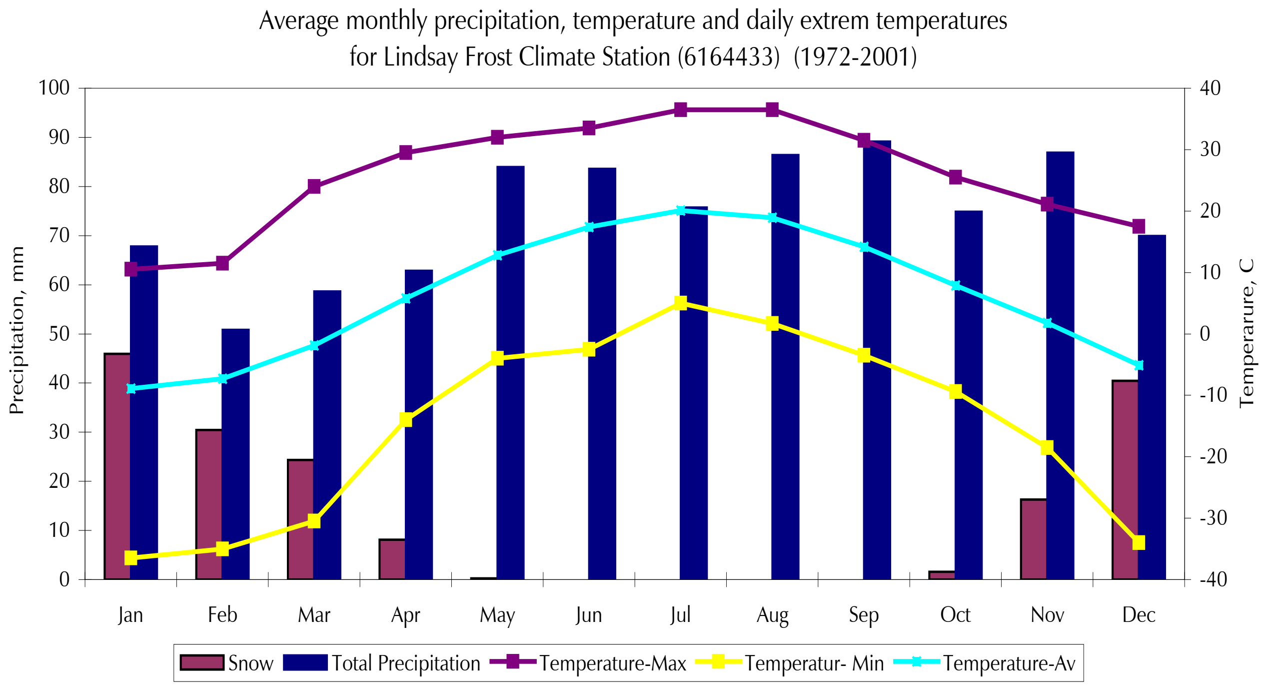


Figure 5.2. Climate Normals and Extremes for Lindsay Frost Climate Station

5.4 Precipitation

Based on the data for the Lindsay Frost climate station, the Sturgeon Lake watershed typically receives over 880 mm of precipitation annually, of which an average of 160 mm (18.2%) falls in the form of snow. Precipitation is fairly evenly distributed throughout the year, with December-April being slightly drier that the rest of the year. The driest month of the year is February with an average of 47.5 mm of precipitation (~6% of yearly amount) falling in a given year. The largest average amount of precipitation is observed in September with 91.4 mm, or more than 10% of the total annual amount. August follows September closely, with 89.1mm of rainfall on average. An extreme daily rainfall of 92.4 mm for the Lindsay Frost monitoring location was observed on July 20, 1980.

Currently, there are two active precipitation monitoring locations within the Sturgeon Lake watershed that are maintained by Kawartha Conservation. One is located in the southern portion of the watershed, in the Ken Reid Conservation Area, close to the Kawartha Conservation administrative centre. Rain and snow fall are measured by the Geonor all-weather precipitation gauge. Daily monitoring data is available from 2005. Observation shows that yearly amounts of precipitation at this location vary from 708 mm (2005) to 1152 (2008), averaging at 868 mm over the seven years of monitoring. This value is close to the long-term amount, available for the Lindsay Frost climate station (881mm).

An additional rain gauge was installed near the Hawkers Creek mouth (the north-eastern corner of the study area), specifically for the purpose of the Sturgeon Lake Management Plan monitoring. It is a manual accumulative gauge that collects and stores precipitation, until a reading is taken. Precipitation amounts for the monitoring locations at Ken Reid Conservation Area and Hawkers Creek are shown in ***Table 5.2.***

Table 5.2. Precipitation Amounts for Hawkers Creek and Ken Reid CA Monitoring Stations Presented by Hydrologic Year

Year, hydrologic	2010-2011		2011-2012		2012-2013	
	Hawkers Cr.	Ken Reid CA	Hawkers Cr.	Ken Reid CA	Hawkers Cr.	Ken Reid CA
June	208.3	178.9	115.7	85.3	112.3	107.3
July	149.4	84.6	91.0	113.0	35.9	58.4
August	112.4	55.2	74.4	100.1	39.5	48.2
September	118.4	106.6	83.5	102.0	103.9	96.1
October	67.0	65.7	90.3	94.6	116.3	140.7
November	97.2	81.9	86.4	94.8	36.4	36.3
December	34.1	39.9	99.2	79.5	87.2	70.7
January	32.4	34.3	67.3	58.3	79.9	65.6
February	36.4	46.2	28.1	28.1	75.8	79.5
March	88.9	86.8	25.8	38.8	11.3	12.7
April	88.0	82.0	47.6	47.7	104.7	99.3
May	63.9	75.0	40.1	47.3	59.7	69.3
Total	**1096.4**	**937.1**	**849.4**	**889.5**	**862.9**	**884.1**

The distance between these two monitoring locations is less that 20 km. However, as illustrated in ***Table 5.2,*** monthly amounts of precipitation vary considerably, up to 50%. The variation is the greatest within the summer months of June, July and August. This can be explained by the effect of convectional precipitation that occurs during the warm period of the year and is quite unevenly distributed.

5.5 Evapotranspiration

Evapotranspiration (ET) is the combination of two simultaneous processes: **evaporation** and **transpiration**, both of which release moisture into the air. Evapotranspiration is a major component of the water balance equation. During evaporation, water is converted from liquid to vapour and evaporates from ground and surface water. During transpiration, water that was drawn up from the soil by the roots evaporates from the leaves ***(Figure 5.3).***

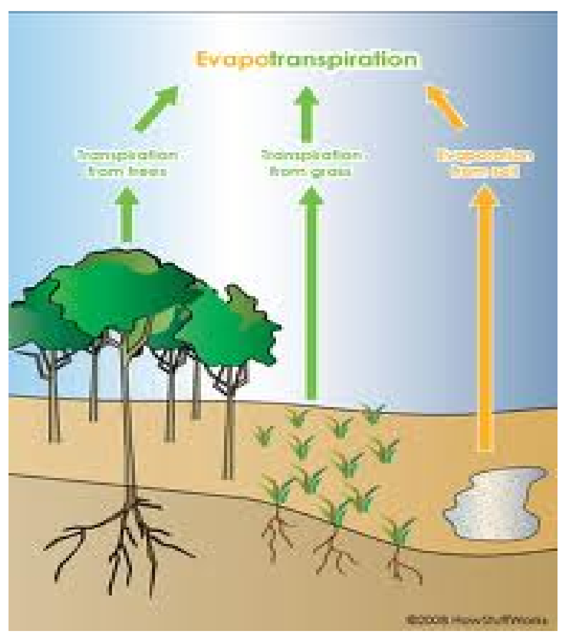


Figure 5.3. Process of Evapotranspiration

Rates of evapotranspiration vary considerably, both spatially and seasonally. Seasonal trends of evapotranspiration within a given climatic region follow the seasonal declination of solar radiation and the resulting air temperatures. Minimum evapotranspiration rates generally occur during the coldest months of the year. Maximum rates generally coincide with the summer season.

Measuring evapotranspiration is a complex and costly process. Because of that, ET is commonly computed from weather data, such as air temperature, daily precipitation and wind speed. A large number of empirical or semi-empirical equations have been developed for assessing evapotranspiration from meteorological data. Numerous studies have been done to analyze the performance of the various calculation methods for different locations. The Penman-Monteith method is now recommended as the standard method for the definition and computation of the reference evapotranspiration by the United Nations. The National Atlas of Canada, published in 1974, includes a coarse-scale map of the potential evapotranspiration (PET) for Canada ***(Figure 5.4).*** According to that map, PET value for the area that encompasses Sturgeon Lake subwatershed is about 560mm (22 inches).

More recent data is available from the National Soil Database (Agriculture and Agri-Food Canada, 1997). This database provides climate normals, including evapotranspiration for area units that are called ecodistricts. Each Ecodistrict is characterized by relatively homogeneous biophysical and climatic conditions including: regional landform, local surface form, permafrost distribution, soil development, textural group, vegetation cover/land use classes, range of annual precipitation, and mean temperature. Average monthly and annual potential evapotranspiration values, available in the database, were estimated from monthly climatic normals for each Ecodistrict using the Penman empirical method.

According to this classification, the Sturgeon Lake watershed is located within two ecodistricts of the Mixed Plans EcoZone **.**Estimated values of the potential evapotranspiration are shown in ***Table 5.3*****.**

As it was mentioned before, ET values follow the trend of the air temperature. The maximum value for both regions is observed during the summer months: July, June and August. Evapotranspiration in March and November is very low, less than 12 mm, declining to 0 mm in winter season. The average annual evapotranspiration between two ecodistricts is 627.3 mm.

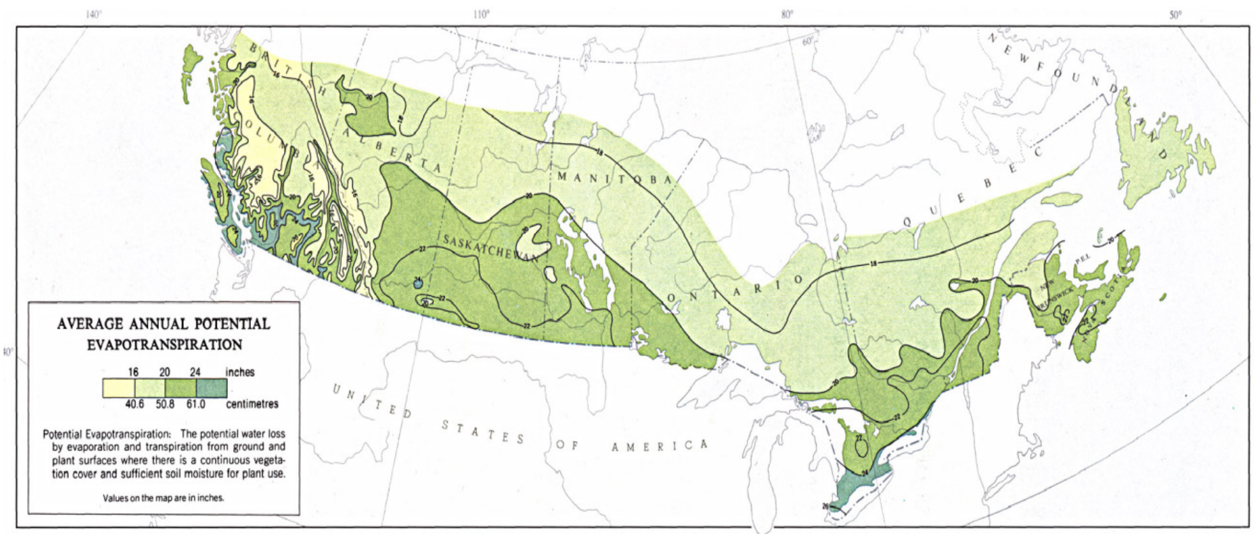


Figure 5.4. Average Annual Potential Evapotranspiration (The National Atlas of Canada, 1974)

Table 5.3. Average Monthly and Annual Potential Evapotranspiration (mm)

Eco Districts	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
552	0	0	9.4	65.0	103	117	132	103	64.2	29.7	7.3	0	631.0
553	0	0	11.6	63.0	97.6	115	129	103	64.7	30.5	8.2	0	622.6

5.6 Climate Change

Climate change is defined as a shift in long-term average weather patterns (with respect to a baseline or a reference period), that can include changes in temperature and precipitation amounts. Climate change may be due to both natural (i.e. internal or external processes of the climate system) and anthropogenic reasons (i.e. increase in concentrations of greenhouse gases). Climate variability is defined as a deviation from the overall trend or from a stationary state, and refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales (CCCSN, 2012). Climate variability can be thought of as a short term fluctuation superimposed on top of the long term climate change or trend. Cycles of high and low values of weather events (drought, floods) are not categorized as climate change unless prolonged over many decades. Low-frequency variability refers to phenomena such as the North Atlantic Oscillation or El Niño which occur at a decadal scale or longer, while high-frequency variability refers to meteorological events and their distribution (i.e. frequency, duration and intensity) at yearly, seasonal or monthly timescales.

Observations throughout the globe show that atmospheric temperature has exhibited an increasing trend during the last century. This somewhat rapid increase in temperatures is referred to as atmospheric global warming. Increasing concentrations of carbon dioxide and methane (greenhouse gases - GHG) in the atmosphere caused by human activities is believed to be the greatest contributing factor to this phenomenon. It is expected that climatic warning in some portions of the globe will bring significant changes to weather and climate conditions, including its variability and magnitude in the near future.

There is a general consensus in the international scientific community that the impacts of climate change are already being felt. An increase of atmospheric greenhouse gas concentrations is expected to occur even if the global-wide commitments to reduce GHG emissions are fully met by all participating countries. While the absolute magnitude of predicted changes is uncertain, there is a high degree of confidence in the direction of changes, and in the recognition that climate change effects will persist for many centuries. As we head towards an increasing atmospheric concentration of both carbon dioxide and methane, we can expect that increasing impacts of climate change will create both negative and positive results for communities everywhere: in our watershed and our communities, in our province, in our country and around the world.

An important tool within this area of study is the construction of climate change scenarios, (alternatives or future options) termed climate change modeling. Each scenario is one created or developed image of how the future might unfold under a different combination of factors such as population growth, energy use, land use change, technology change, etc. A set of scenarios assists in the understanding of possible future developments of complex systems.

The multi-model mean projected change of temperature and precipitation on a monthly, seasonal and annual timescale was determined for the study area using tools, available at Canadian Climate Change Scenarios Network (CCCSN) website (www.cccsn.ec.gc.ca/). CCCSN is a partnership of a several leading-edge research agencies in climate change and adaptation research. One of the main goals of the CCCSN is to provide stakeholders with accessible and understandable information that is customized to the specific location. Information on three different scenarios (high, medium and low emission) is available. Results are obtained by using a multi-model ensemble, with the number of models varying from 20 to 24. Research has indicated that use of the multi-model ensembles is preferred, since each model can contain inherited biases and weaknesses.

Under all scenarios, it is expected that mean annual temperature will increase for the study area (***Table 5.4, Figure 5.5***). The most dramatic increase in temperature will be observed for winter and fall, which can increase by 5.1^{0}C (High Emission Scenario) compared to current normals. An increase of annual mean precipitation is expected under all scenarios, with winter and spring experiencing the highest rise with up to 30 mm per season under the Medium Emission Scenario (MES) (***Table 5.5, Figure 5.6***). It is important to note that with winter being milder, winter precipitation will fall as rain, affecting hydrological cycle and water resources overall (CCCSN, 2012).

These expected weather and climate changes will trigger shifts in all aspects of the environment, including water resources, ecosystems and biodiversity. For example, more frequent and intense rainfall events may lead to increased occurrence of minor and major flooding; development of new, unknown flood-prone areas; and increased transportation of contaminants, pollutants and nutrients from the land surface to lakes, rivers and streams. In addition, increased bank and channel erosion should be anticipated from the rapid rise of water which will contribute to surging of streams and rivers.

Decreased summer runoff will result in low flow conditions that, in turn, will stress fish habitat and can lead to degraded water quality as less water will be available for dilution of sewage treatment plant effluents, agricultural runoff and nutrients entering waterways from urban lands. Low flow conditions may cause increased competition and conflict over reduced water supplies among water users during drought periods.

As winter precipitation increasingly falls as rain, and the accumulated snowpack decreases, groundwater recharge will most likely be negatively impacted, consequently decreasing the groundwater levels and rates of groundwater discharge to local streams and lakes. As a result, streams dependent on baseflow will experience lower levels and reduced flows, adding stress on aquatic ecosystems. The central portion of the Sturgeon Lake subwatershed, as shown further in Chapter 6, is especially vulnerable to experiencing an increase in dry or low flow watercourses.

Decreased groundwater levels and discharges may change forms and functions of wetlands. Some wetlands may become dry. In addition, decreased groundwater levels will also put strain on the groundwater supply, including those that service private wells. Risk of water shortages and additional competition for a scarce supply will increase. More private wells may dry up, perhaps causing water shortages to develop in areas never having experienced them before.

The above-mentioned list is only a small portion of the possible local changes as a result of a potential global climate change. Beyond the environmental effects, a changing climate can impact the social and economic well-being of the Sturgeon Lake watershed residents.

Table 5.4. Mean Air Temperature Predictions under Different Emission Scenarios

Time Period	Annual	Winter	Spring	Summer	Autumn
1971-2000	6.3	-7.1	5.6	18.8	7.9
Low Emission Scenario (LES)					
2020s	7.6 ± 0.4	-5.6 ± 0.5	6.7 ± 0.4	19.9 ± 0.4	9.2 ± 0.4
2050s	8.3 ± 0.6	-4.8 ± 0.7	7.5 ± 0.7	20.7 ± 0.7	9.9 ± 0.6
2080s	9.0 ± 0.7	-3.9 ± 0.8	8.1 ± 0.8	21.3 ± 0.8	10.5 ± 0.8
Medium Emission Scenario (MES)					
2020s	7.7 ± 0.4	-5.5 ± 0.6	6.8 ± 0.5	20.1 ± 0.5	9.2 ± 0.4
2050s	9.0 ± 0.8	-3.9 ± 0.8	8.1 ± 0.9	21.4 ± 0.8	10.5 ± 0.8
2080s	10.1 ± 1.0	-2.7 ± 1.2	9.2 ± 1.1	22.4 ± 1.2	11.6 ± 1.0
High Emission Scenario (HES)					
2020s	7.5 ± 0.4	-5.7 ± 0.5	6.7 ± 0.5	19.9 ± 0.4	9.2 ± 0.4
2050s	9.0 ± 0.6	-3.9 ± 0.8	8.0 ± 0.7	21.4 ± 0.7	10.4 ± 0.6
2080s	10.8 ± 1.0	-2.0 ± 1.1	9.7 ± 1.1	23.3 ± 1.3	12.3 ± 0.9

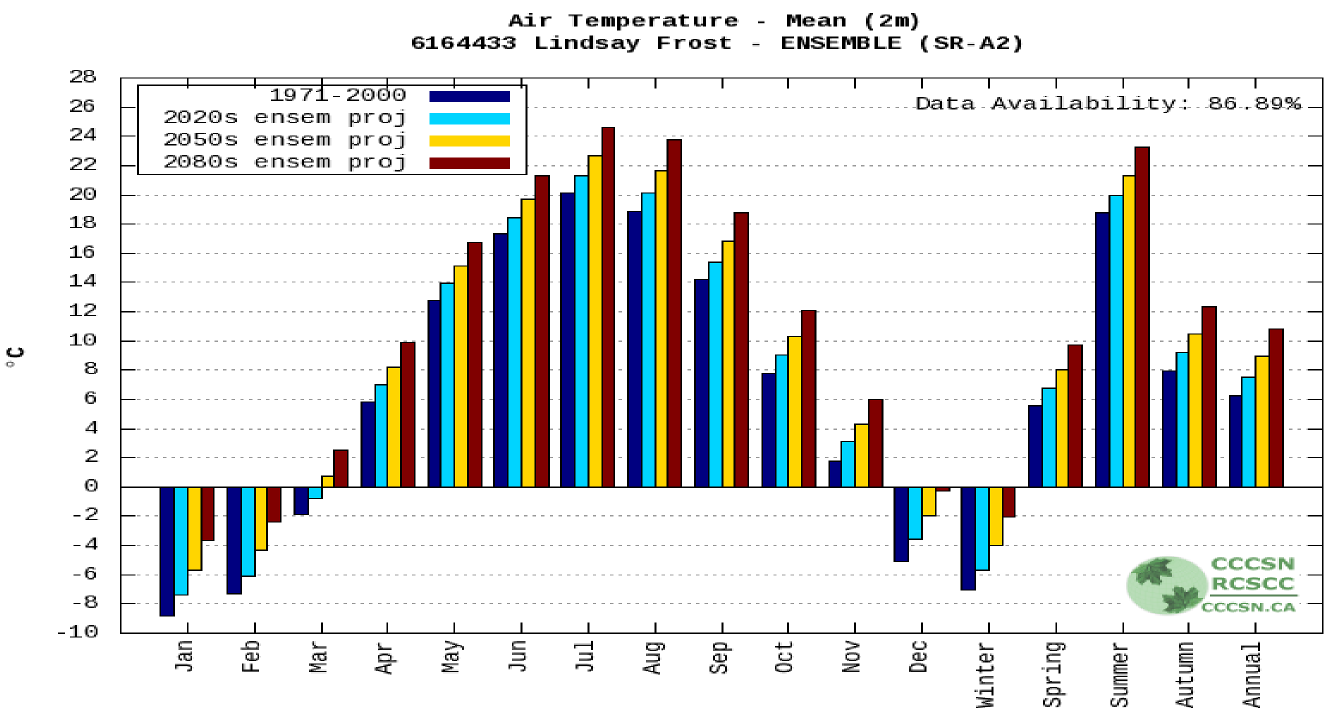


Figure 5.5. Mean Air Temperature - High Emissions Scenario (CCCSN, 2012)

Table 5.5. Total Precipitation Predictions under Different Emission Scenarios

Time Period	Annual	Winter	Spring	Summer	Autumn
1971-2000	**878.3**	**182.9**	**200.7**	**247.0**	**247.7**
Low Emission Scenario					
2020s	903.3 ± 26.0	196.1 ± 6.8	207.6 ± 10.5	251.3 ± 10.8	247.9 ± 15.6
2050s	923.1 ± 31.5	199.1 ± 9.1	216.1 ± 8.9	253.3 ± 17.5	254.9 ± 20.4
2080s	939.9 ± 29.6	207.3 ± 9.9	223.0 ± 12.4	251.0 ± 16.2	256.9 ± 18.0
Medium Emission Scenario					
2020s	910.6 ± 25.2	196.9 ± 7.2	209.9 ± 8.2	251.0 ± 14.3	252.3 ± 14.4
2050s	930.1 ± 33.6	203.9 ± 10.4	219.3 ± 16.4	249.7 ± 17.3	257.1 ± 17.3
2080s	960.3 ± 43.3	213.8 ± 13.4	231.0 ± 19.6	250.4 ± 24.2	264.5 ± 22.6
High Emission Scenario					
2020s	903.3 ± 26.0	196.1 ± 6.8	207.6 ± 10.5	251.3 ± 10.8	247.9 ± 15.6
2050s	923.1 ± 31.5	199.1 ± 9.1	216.1 ± 8.9	253.3 ± 17.5	254.9 ± 20.4
2080s	939.9 ± 29.6	207.3 ± 9.9	223.0 ± 12.4	251.0 ± 16.2	256.9 ± 18.0

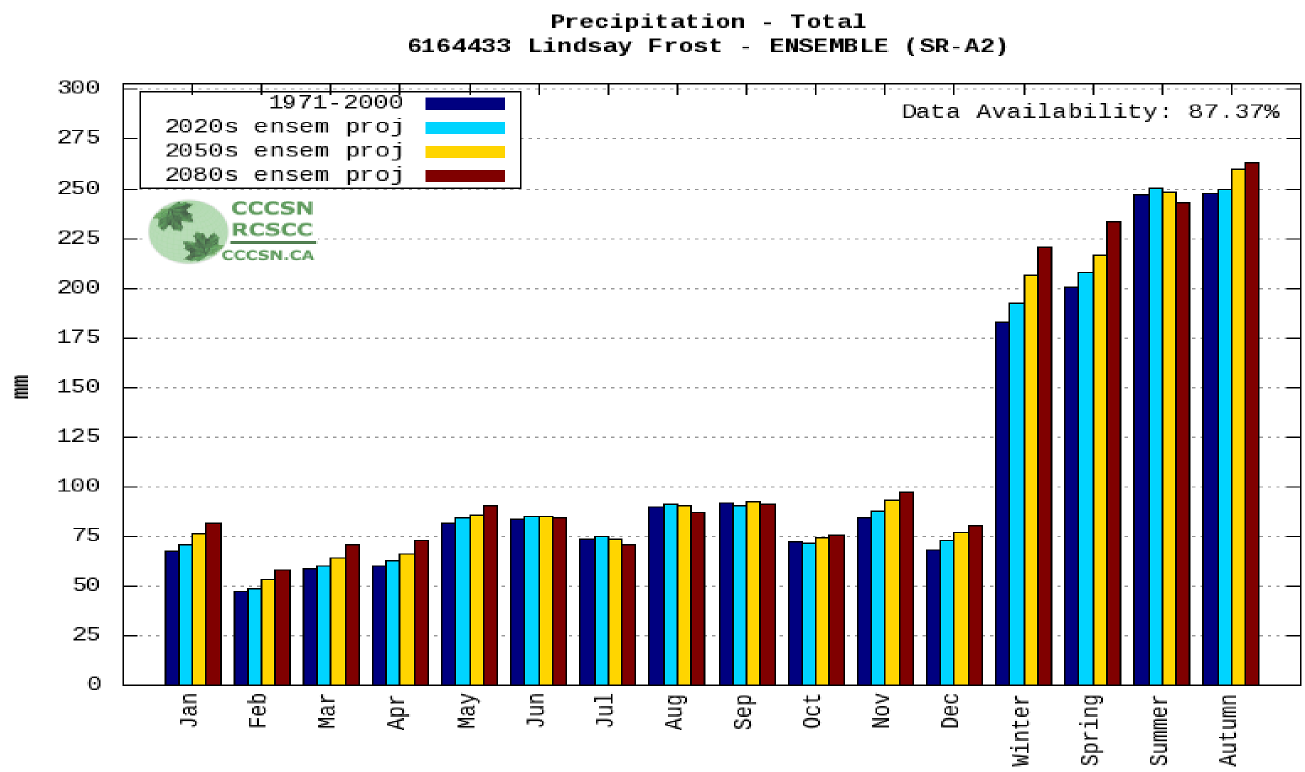


Figure 5.6. Total Precipitation - High Emissions Scenario (CCCSN, 2012)

6.0 Water Quantity

6.1 Summary of Observations and Issues

OBSERVATIONS

- The tributaries of Sturgeon Lake exhibit a natural flow regime with well-defined seasonal flow patterns. High flows typically occur during early spring with snowmelt and throughout the year following high precipitation events. Low flows are typically observed in the summer and winter months.
- The water level regime of Sturgeon Lake generally follows the natural pattern, but it is defined and regulated in accordance with Trent-Severn Waterway's water level management strategy.
- Wetlands and forested areas that are abundant in the northern portion of the Sturgeon Lake watershed provide significant benefits to surface water, moderating stream flow, providing high and low flow mitigation, and assisting in groundwater recharge.

KEY ISSUES

- The groundwater discharge that supports baseflow and is a main component of the stream flow during the dry periods is low (<2 $L/sec*km^2$) or non-existent in the prevailing portion of the watershed. That causes watercourses to flow very low or go stagnant or dry during the periods of limited precipitation. This fact has both natural and anthropogenic causes. The capacity of the shallow aquifers that provide groundwater input to the stream flow is limited. Human activities, such as deforestation, wetland removal and increasing impervious areas can decrease aquifer recharge rates.
- Unregulated excessive water taking during periods of drought conditions decreases available stream flow that is already limited, affecting stream ecosystems.
- Flow monitoring data from the northern portion of the Sturgeon Lake watershed are limited to three years of monitoring in the framework of the SLMP. Monitoring data are a key source of information on water resources conditions and trends. Monitoring should be continued.
- Annual monitoring data on lake evaporation are not available. It adds uncertainty to the calculation of a water budget.
- Data on water taking from the lake that does not require Permit To Take Water (PTTW) is very limited. Only a general estimation that is based on a number of potential water users and on average water consumption is available. The evaluation of water balance includes this uncertainty.
- Some aspects of land use change, such as increasing impervious surfaces, urban development and agricultural practices, can influence the quantity of both surface and groundwater resources.
- Climate change as it is currently forecasted has the potential to impact the flow regime of local watercourses by reducing duration and intensity of spring runoff and aquifer recharge, and increasing the potential for dry conditions and/or extreme high flow events during the summer.
- Changes in stream hydrology and the quantity and nature of precipitation events can result in changes in lake water quality.

6.2 Drainage Network

Sturgeon Lake is a part of the Kawartha Lakes system that includes Balsam, Cameron, Sturgeon, Pigeon, Buckhorn, Chemong and Stoney lakes, and provides a most significant series of linkages within the Trent-Severn Waterway ***(Figure 1.1)***. It is a Y-shaped lake, connected to Cameron Lake upstream in its north-western arm through a short channel called Fenelon River, and to Pigeon Lake downstream in its north-eastern arm by two channels, Big Bob and Little Bob Channels. The Scugog River empties into Sturgeon Lake from the south, bringing water from Lake Scugog as well as Mariposa Brook and East Cross Creek and a number of small tributaries.

There are dams and locks at all major connections: on the Fenelon River, one on each Big Bob and Little Bob Channels as well as a dam and lock on the Scugog River in Lindsay **(*Figure 6.1*)**.Locks facilitate boating between the lakes; they are operated and maintained by the Trent-Severn Waterway.

The Sturgeon Lake watershed is comprised of a number of small and medium size streams that drain into the lake ***(Figure 6.2)***. The total area of the subwatershed is 1,028 km^2, which includes 1,357 km of flowing watercourses. Those include Martin Creek North, Rutherford and Hawkers Creeks flowing from the north; Emily Creek and a number of small unnamed tributaries flowing from the south; and McLaren Creek and several small, unnamed watercourses flowing into the lake from the west.

Mariposa Brook and East Cross Creek are tributaries that are not directly connected to Sturgeon Lake, but drain watersheds that flow into the Scugog River. They empty into the Scugog River approximately 10 km upstream of where the river empties into Sturgeon Lake.

The northern tributaries, including Rutherford Creek, Hawkers Creek, Martin Creek North and some short unnamed tributaries originate at and flow through the Dummer Moraine, an area of rough stony land at the forefront of the Canadian Shield. They flow in a southerly direction, meandering through wetlands, meadows and forested areas. The main channels of the northern watercourses are short, no more than 23.5 km in length. They all have relatively steep average channel gradients, especially Rutherford Creek (7.69 m/km) and Martin Creek North (3.36 m/km).

As the soils and climate of this area are not very suitable for agricultural activities, significant portions of these subwatersheds are covered with wetlands, forest and meadows ***(Table 6.1***). These natural features are very important in keeping water resources abundant and clean. Wetlands provide peak flow mitigation and flood storage as well as assist in improving water quality by sediment trapping, nutrient retention and removal. Similarly to wetlands, forests help to moderate stream flow, provide high and low flow mitigation, and assists in groundwater recharge.

Greater amounts of impervious surfaces alter the spatial and temporal distribution of flow, increasing the flood peaks and volumes and decreasing groundwater storage and contribution. Rural/urban development that directly correlates to the extent of impervious areas comprises no more than 2.9% of northern watersheds. This low level of development allows these streams to provide their normal hydrological functions.

The drainage area of Martin Creek North is the least developed portion of the Sturgeon Lake watershed; more than 70% of it is classified as natural cover by the Ecological Land Classification (ELC) system. Two thirds of the natural areas are occupied by forest, while wetlands comprise another 25%. The portion of the natural areas for both Hawkers and Rutherford Creeks is about 55% of their catchments, with majority of it covered by forest, and then meadows.

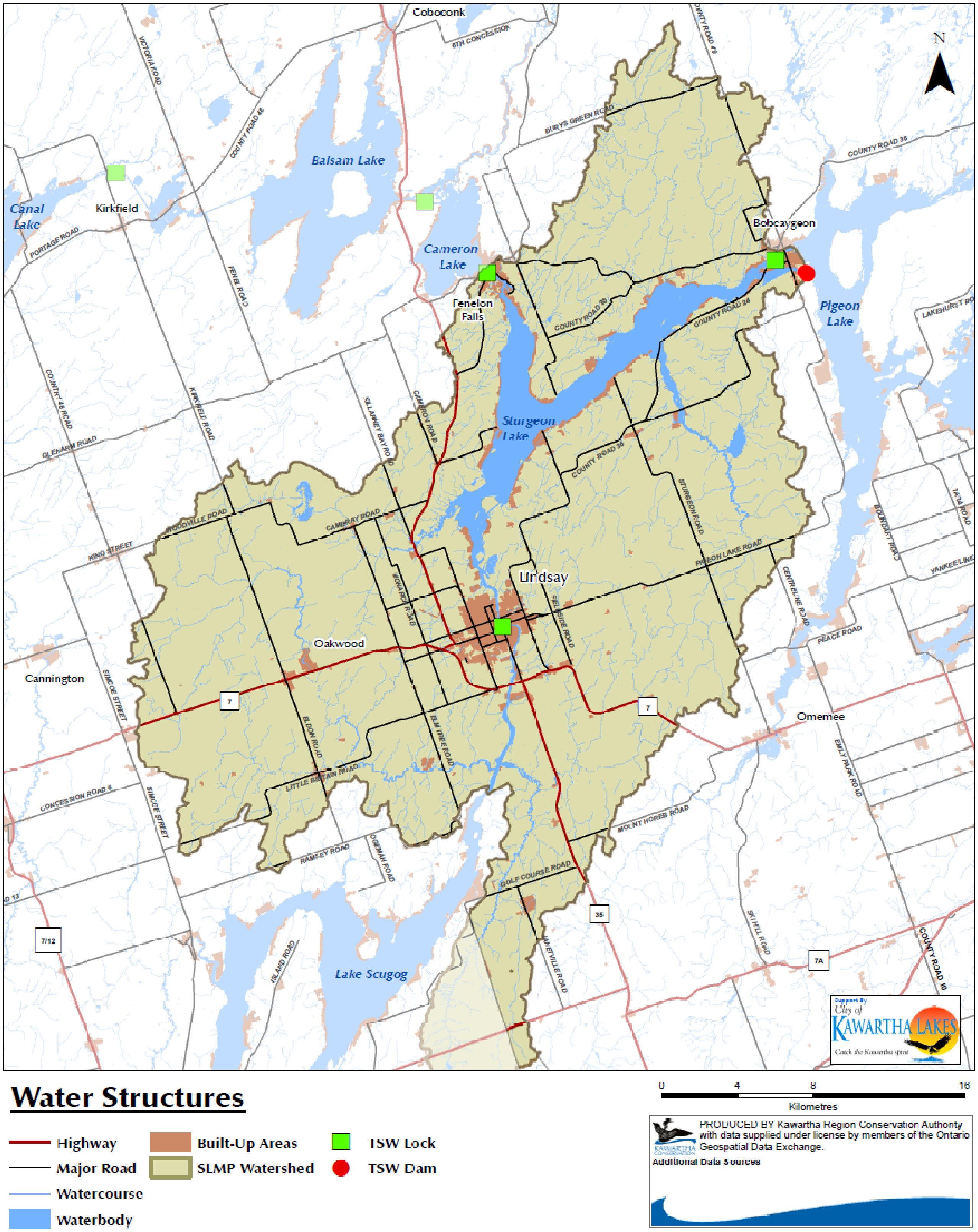


Figure 6.1. Water Structures in the Sturgeon Lake Watershed

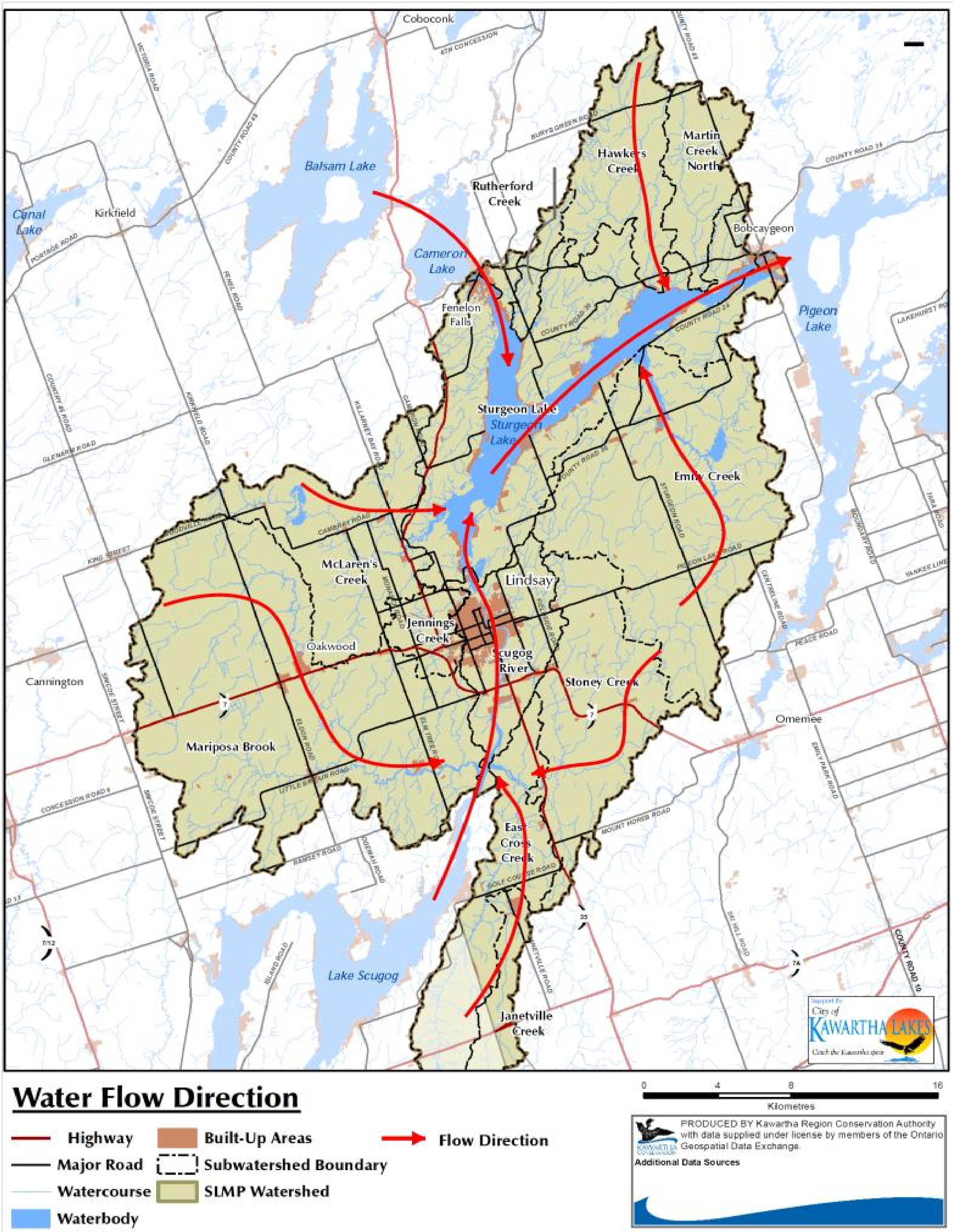


Figure 6.2. Drainage Network and Flow Direction in the Sturgeon Lake Watershed

Table 6.1. Stream and Subwatershed Characteristics, the Sturgeon Lake Watershed

Watershed/ Catchment Name	Drainage Area (km^2)	Stream Network Length (km)	Main Channel Length (km)	Main Channel Gradient (m/km)	Natural Cover (%)	Agriculture (%)	Rural/Urban Development (%)	Stream Density Km/km^2	Average Watershed Slope %
Sturgeon Lake	**1028***	**1357**	**N/A**	**N/A**	**35.5**	**51.0**	**5.8**	**1.3**	**2.54**
Rutherford Creek	9.8	22.9	5.0	7.69	55.7	40.5	2.9	2.4	3.41
Hawkers Creek	51.7	87.6	23.5	1. 62	53.7	42.4	1.9	1.7	3.55
Martin Creek North	33.4	34.3	13.6	3.36	70.4	26.0	2.2	1.3	3.34
McLaren Creek	78.7	90.8	9.5	2.95	26.9	65.3	4.3	1.2	2.22
Emily Creek	160.7	213.3	32.3	0.63	30.7	52.3	5.0	1.3	2.16
Scugog River	46.9	52.1	15.0	0.16	18.0	40.6	26.4	1.1	2.18
East Cross Creek	108.3	147.6	40.3	1.56	52.2	41.7	3.3	1.4	4.29
Stoney Creek	82.4	96.2	22.8	1.10	35.5	59.4	2.9	1.2	2.17
Mariposa Brook	228.8	291.0	72.2**	N/A	26.4	66.1	1.0	1.3	1.92
Unnamed Tributaries	144.8	254.4	N/A	N/A	40.3	45.67	9.2	1.8	2.43

* Including area of water surface of Sturgeon Lake

** The total length of two main branches

Southern streams, including Emily Creek and number of small unnamed tributaries, originate in the Peterborough Drumlin Fields to the south of Sturgeon Lake and flow north toward the lake. Emily Creek is the largest tributary after the Scugog River, which flows directly into Sturgeon Lake. The length of its main channel is about 32.3 km. The average gradient of its main channel is only 0.63 m/km, with wide valleys, broad floodplains and undefined channels along the majority of the stream length. Another important feature of the Emily Creek subwatershed is the extensive wetland areas along its length, which occupy about 24.6 km^2, or 17.3% of the total subwatershed area. Agricultural uses and urban/rural development within the Emily Creek catchment area are high, 52.3% and 5.0% of the land area respectively, as per ELC analysis. While agricultural activities have the potential to impact water quality the most, they change some aspects of stream flow as well. As an example, the higher velocity of run-off is observed over tilled soils comparing to the natural covered areas, that increases peak water level elevations and flows.

McLaren Creek is a larger tributary that drains the western portion of the Sturgeon Lake watershed. Compared to the northern tributaries, its watershed is characterized by a high percent of agricultural lands (65.3%) and lower portion of natural cover; only 26.9% of the watershed. The watercourse flows in an easterly direction through the Peterborough Drumlin Field and empties into Sturgeon Lake at its southern end.

As mentioned, Mariposa Brook does not connect directly to Sturgeon Lake. It is located in the south-western portion of the Sturgeon Lake watershed, originating within the Peterborough Drumlin Field. On its way to the Scugog River, the watercourse crosses the Schomberg Clay Plains near Oakwood. The brook and its tributaries have wide flood plains, low gradients and slow flow. As noted in the Groundwater Recharge Studies Report (Gartner Lee Associates Limited, 1981), the baseflow (groundwater) contribution to this watercourse is low and the flow regime is significantly defined by surface run-off. This means that during the periods of limited precipitation and surface run-off, Mariposa Brook and its tributaries are prone to losing flow, becoming stagnant or even drying up. The direction of flow in the main channel of Mariposa Brook changes dramatically throughout its reach. For the first 20 kilometres it flows northeast, then turns to the southeast, and for the last section, it flows east to the Scugog River. There are two main tributaries to the brook that converge just east of Little Britain. Agricultural operations are the major land use within the Mariposa Brook watershed, occupying more than 66% of its land area, while natural areas cover only 26.4%.

East Cross Creek enters the Scugog River from the east, opposite the mouth of Mariposa Brook. This watercourse is the only one within the Sturgeon Lake watershed that originates at the Oak Ridges Moraine, in the southern portion of the Kawartha Conservation watershed. The length of the main channel of the watercourse is more than 40 km, its average gradient is 1.56 m/km. On its way to the Scugog River, it flows through the Peterborough Drumlin Field and finally, the Schomberg Clay Plain. It is a narrow, oblong-shaped watershed with floodplain and channel characteristics that change according to the physiography. Well-defined valleys and narrow floodplains at the upstream portion of watershed are replaced by large meanders within the flat floodplain at the middle and lower sections. East Cross Creek flows mostly in a northerly direction, turning to the west for the last 5 km. The aquifers of the Oak Ridges Moraine at the creek's headwaters provide significant groundwater contribution, ensuring good flow in the watercourse throughout the year.

Janetville Creek and Stoney Creek are the two major tributaries of East Cross Creek. They are located in two distinct physico-geographical areas. Janetville Creek is located within the Peterborough Drumlin Field covering a small area running parallel to East Cross Creek in its middle section. The creek has a relatively high main channel gradient and watershed slope; and continuous baseflow contribution. Stoney Creek is situated within the Schomberg Clay Plains and flows mostly south, joining East Cross Creek in the last 5 km of its length. It has wide floodplains, vast areas of wetlands along the channel and often goes stagnant or dry during low precipitation periods due to a lack of groundwater contributions.

Agriculture is a major land use within the East Cross Creek subwatershed, taking up to 42% of the drainage area. At the same time, natural areas that consist of forest, treed wetlands, wetlands and meadows, together take up to 52% of subwatershed. In the Stoney Creek subwatershed more than half of the naturally covered area is occupied by wetlands.

The Scugog River is a short but very significant watercourse that enters Sturgeon Lake from the south and connects Lake Scugog to Sturgeon Lake. Its length is only 14.9 km, with a main channel gradient of 0.16 m/km. More than 26% of the Scugog River watershed is occupied by urban/rural development, including the Town of Lindsay. Another 40% of the drainage area is used for agriculture, and only about 18% is covered by forest, wetlands and meadows. These characteristics define the "flashy" nature of smaller tributaries that flow into the Scugog River. They generally respond to rain events very quickly, generating high velocity flow and rapid water level increase.

Lake Scugog in its current state can be considered as a man-made lake that was created by a dam on the Scugog River in Lindsay. Prior to the construction of the dam, there were two small connected lakes east and west of Scugog Island. The Lindsay Dam is operated by the Trent-Severn Waterway. As a result, the flow regime of the Scugog River is now highly regulated by the dam operations.

6.3 Surface Water Flow and Flow Regime

Surface Water Flow

Surface water quantity (volume of water in watercourses and water bodies) assessments are usually achieved through flow and water level monitoring. Collected data assist in identifying changes that may affect the water quality, geomorphic stability and aquatic health of a watercourse as well as providing invaluable data for modeling of water resources, water budget calculation, and water allocation. Changes in flow conditions may reflect changes in climate (precipitation, evapotranspiration), water demand, land use or watershed's natural cover. Water level monitoring data also provide 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 five gauge stations within the Sturgeon Lake watershed ***(Figure 6.3).*** All monitoring gauges consist of a sensor that measures water level on a preset interval (30 min or 1 hour) and a data logger that records measured values. Details on the flow monitoring locations are shown in ***Table 6.2.***

Water levels represent heights of water above the sensor. This information is very important for flood forecasting, floodplain development and other applications. In order to develop a water budget or calculate amount of pollutants carried with water into the lake, data on volume of water flowing through the watercourse is required. In order to convert water level data into flow data, a rating curve has to be developed. Discharge (volume of water that flows through a cross section of a watercourse in one second) and corresponding water levels are measured numerous times at the monitoring location and graphed to develop a relationship. 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.

The monitoring location on Mariposa Brook is a part of the Environment Canada hydrometric monitoring network. It is the oldest flow monitoring station within the Kawartha Conservation watershed, established in 1982. The station is a permanent monitoring location, situated at the downstream portion of Mariposa Brook, east of town of Little Britain and downstream of the confluence of two major tributaries. This gauge captures flow that is produced by almost 90% of the watershed's drainage area. A long term flow dataset for this location is available. In addition to water levels, precipitation amount is also monitored at this hydrometric station.

The water level monitoring gauge on McLaren Creek provides information on its flow regime in the western portion of the Sturgeon Lake watershed. This station is located in the lower part of McLaren Creek (where it crosses Blackbird Road) and monitors flow that is generated by two thirds of the subwatershed. This monitoring location is temporary; it was established specifically for the purposes of the Sturgeon Lake Management Plan. It is operated and maintained by Kawartha Conservation.

In order to obtain information on flow in the northern portion of the watershed, another temporary water level monitoring station was established on Hawkers Creek. The gauge is located in the lower portion of the subwatershed, where the creek crosses County Road 8. Flow, captured at this location, is produced by 97% of the Hawkers Creek subwatershed.

Jennings Creek is a small tributary of the Sturgeon Lake that is very important from the perspective of the urban water quantity and quality research. Its subwatershed has a considerable area classified as urban, which continues to grow. In order to monitor changes in flow regime and nutrient loading from the subwatershed, the flow monitoring station was established at the downstream portion of the creek. It measures flow that is produced by 96% of the Jennings Creeks subwatershed.

The continuous flow measuring station on East Cross Creek was established in 2006 and measures flow that is generated mostly within the Oak Ridges Moraine portion of the subwatershed. Technically this location is outside of the Sturgeon Lake Management Plan study area.

The monitoring location on Martin Creek North at County Road 8, as shown at the ***Figure 6.3***, is not equipped with a sensor/datalogger, but a staff gauge. Discharge and corresponding water level is measured here every time it is measured at Hawkers Creek. As the two watercourses are located within similar physico-geographical settings and have comparable characteristics, the objective is to determine the flow equation for Martin Creek North using flow monitoring information collected at Hawkers Creek location.

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 water levels and flow. Only one monitoring location, Mariposa Brook at little Britain has enough information to determine average monthly and yearly water levels and discharges (***Figure 6.4***). For gauging locations on the McLaren Creek and Hawkers Creek water levels as observed in 2011 and 2012 are used for interpretation (***Figures 6.5 - 6.6***). Precipitation conditions in 2011 and 2012 were different, with 2011 being average year and 2012 being extremely dry. Datasets from McLaren and Hawkers Creeks monitoring locations are not satisfactory for the statistical analysis due to short monitoring periods. As such, any conclusions derived from these data should be treated as strictly preliminary.

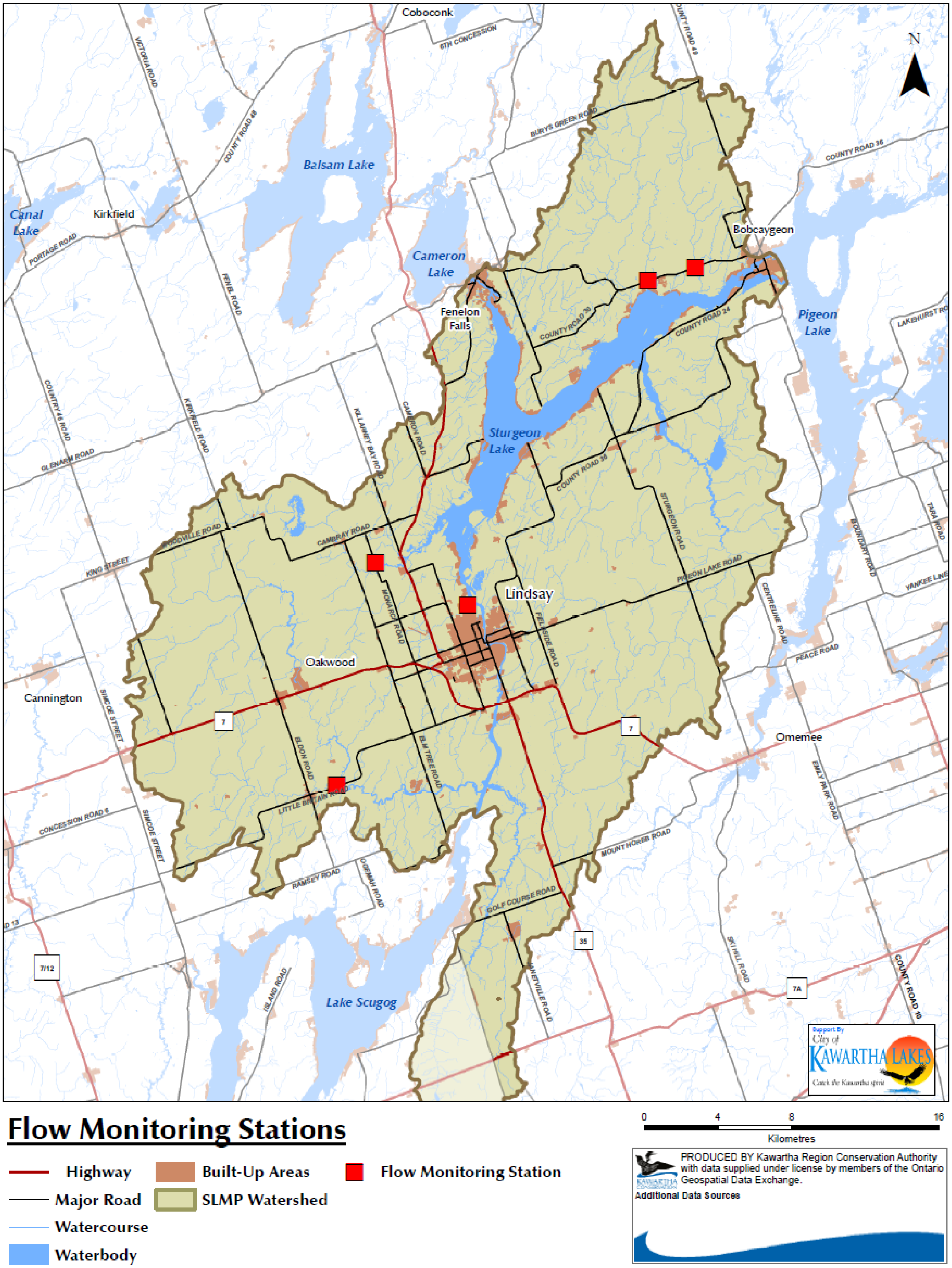


Figure 6.3. Flow Monitoring Locations in the Sturgeon Lake Watershed

Table 6.2. Continuous Stream Flow Monitoring Locations

Water Course	Location	Drainage Area, km^2	% of total subwatershed area	Data Interval	Data Record	Type	Ownership
Mariposa Brook	County Road 4, west of Little Britain	189	83	1 hour	1982 - current	Permanent, steeling well	Environment Canada - Water Survey Division, 02HG003
McLaren Creek	Blackbird Rd.	51.8	66	30 min	2010 - current	Temporary, pressure transducer	Kawartha Conservation
Hawkers Creek	County Road 8	50.1	97	30 min	2010 - current	Temporary, pressure transducer	Kawartha Conservation
East Cross Creek	McKee Rd.	22.9	18	30 min	2006 - current	Temporary, pressure transducer	Kawartha Conservation
Jennings Creek	Williams St. N, Lindsay	16.1	96	30 min	2012 - current	Temporary, pressure transducer	Kawartha Conservation

The data confirm that all monitored watercourses have well-defined seasonal pattern, reflecting seasonal variations of water inflow. The highest water levels and flows were observed in March for Mariposa Brook, McLaren and Hawkers Creeks (2012), caused by a spring freshet. However, in 2011 Hawkers Creek has experienced the highest water levels in April, what can be explained by the fact that subwatershed of this creek is situated at the northern portion of the Sturgeon Lake watershed where snow melt occurs slower, while Mariposa Brook and McLaren Creek compose the south-eastern portion of the lake's watershed. The long-term average data from Mariposa Brook confirm that March is the typical month when the highest water levels are observed.

According to the Mariposa Brook long-term monitoring data, the lowest average monthly flow is typically observed in September, when groundwater reserve is already depleted, but sporadic precipitation and still high evapotranspiration rates keep the surface run-off component of stream flow low. The main source of water supply to the watercourses during that time is groundwater. However, in 2012, the lowest average monthly water levels were observed as early as July (Mariposa Brook) and August (Hawkers Creek). As it was mentioned earlier, precipitation and weather conditions observed in 2012 could be considered as abnormal. Limited snowpack and unprecedentedly warm temperatures in March have caused very early and lower than normal freshet. Precipitation during the subsequent months was about 60-80% of normal. As a result, water levels and flows in local rivers and streams was very low. The occasional rain events, even those of higher amounts and intensity did not produce much runoff, because the overall watershed conditions were dry.

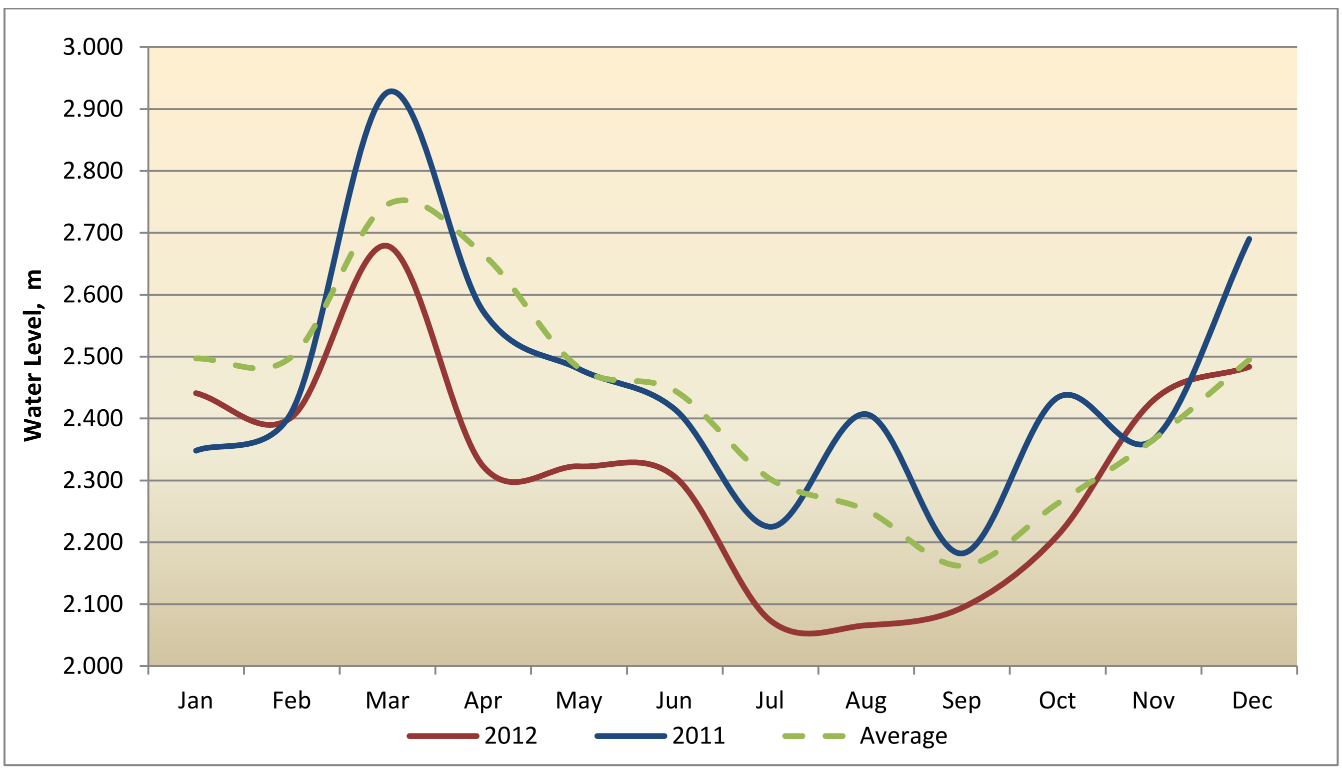


Figure 6.4. Average Monthly Water Levels of Mariposa Brook near Little Britain: Long-term Average, 2011 and 2012.

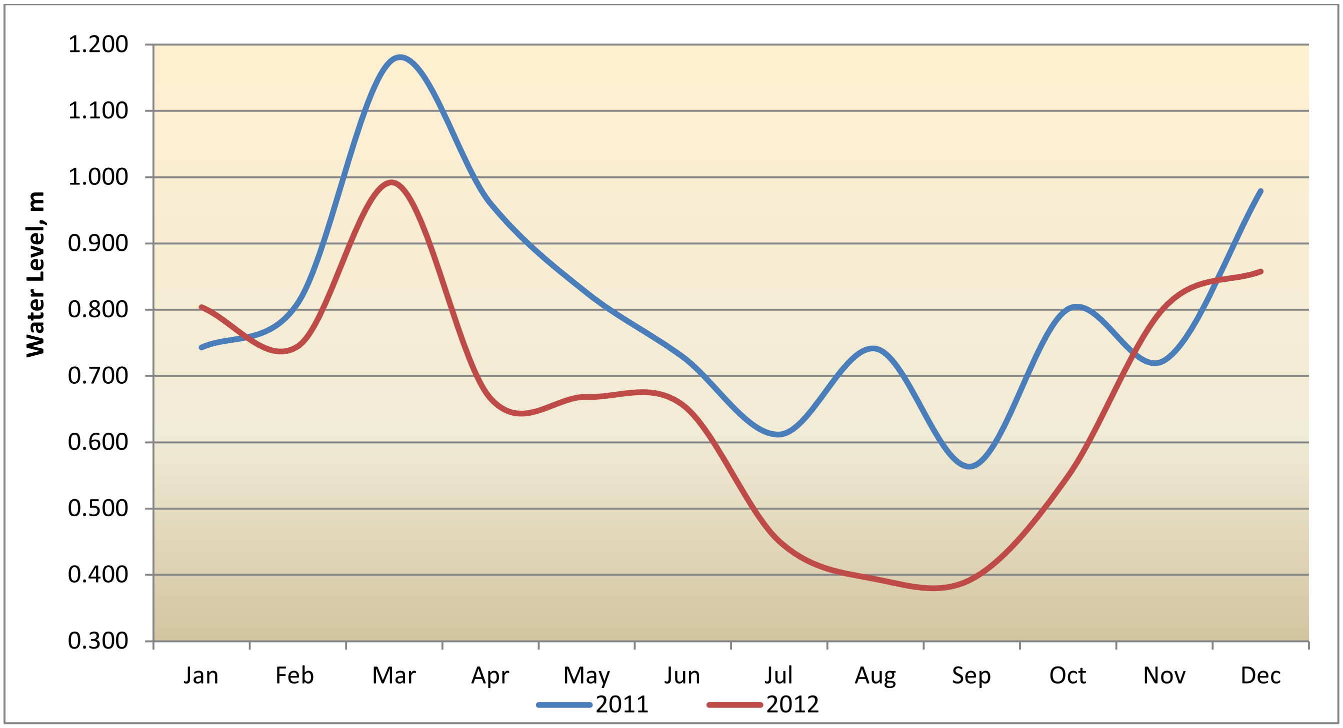


Figure 6.5. Average Monthly Water Levels of McLaren Creek at Blackbird Road Observed in 2011 and 2012

Under these circumstances a number of smaller watercourses within the Sturgeon Lake watershed, including Hawkers Creek had gone dry.

Responding to the higher precipitation volumes and lower rates of evapotranspiration, water levels start gradually increasing in October and keep rising in November-December. During the winter months (December-February), ice cover establishes on the local watercourses, as it was observed on Mariposa Brook and McLaren Creek; water levels remain low. However, it has been observed that the Hawkers Creek at the monitoring location at County Road 8 remains open longer and freezes up only when temperature falls below -15°C. At this time of the year the groundwater component again is the major source of flow in the watercourses. Sometimes winter weather is interrupted by milder temperature and even occasional rain. When a thaw is significant enough to melt the existing snowpack and create a runoff, water levels and flows in the watercourses increase, significantly at times.

As mentioned, there are four dams around Sturgeon Lake: two on the major inflow routes (Cameron Lake outlet in Fenelon Falls and the Scugog River in Lindsay) and two on the major outflow (Big Bob and Little Bob Channels in Bobcaygeon). They are part of the Trent-Severn Waterway. As part of their water management program, the TSW monitors the amount of flow that passes through those dams on a daily basis. These data were utilized for the calculation of the lake water budget and nutrient loads in addition to the monitoring data collected by Kawartha Conservation.

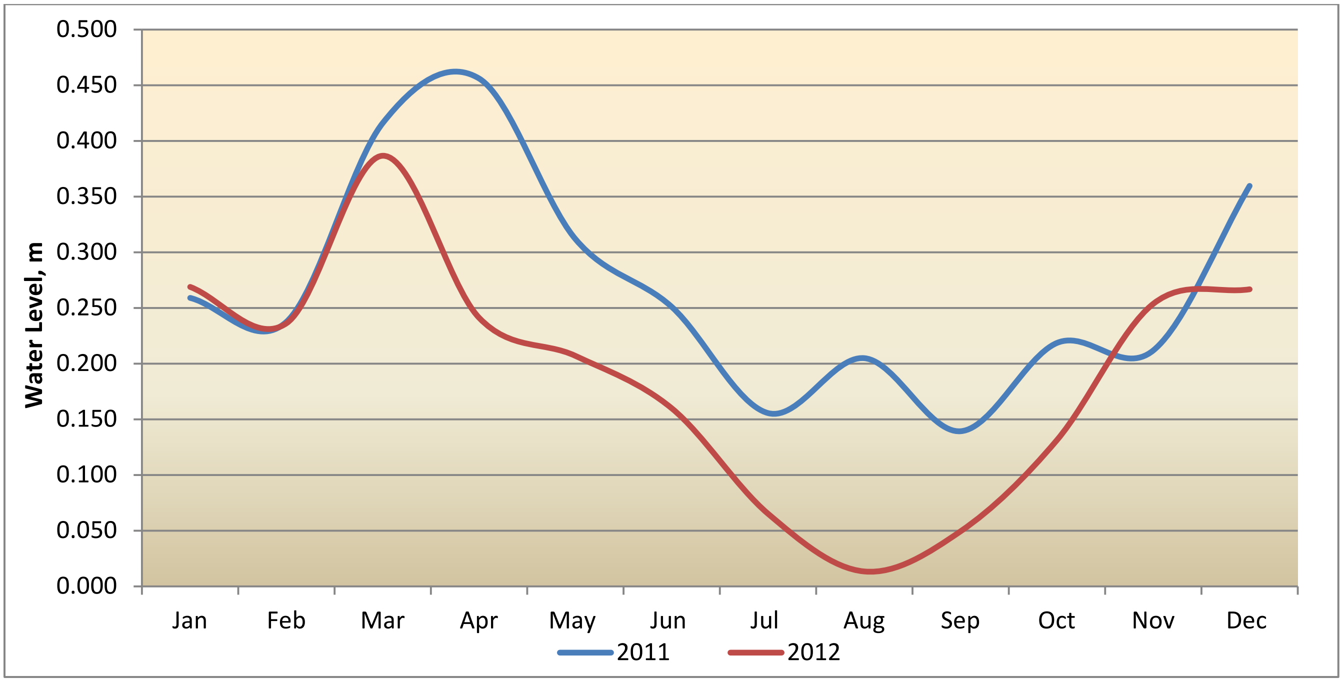


Figure 6.6. Average Monthly Water Levels of Hawkers Creek at County Road 8 Observed in 2011 and 2012

6.4 Baseflow

Baseflow is the portion of flow in a watercourse that comes from groundwater discharge, rather than direct runoff related to rain or snowmelt events. During most of the year, stream flow is composed of both groundwater contribution 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. The amount of sustainable flow in the channel is one of the most important factors for aquatic life. 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. It also provides valuable information for fish and water management.

Methodology

Baseflow monitoring involves measuring the discharge at designated locations during prolonged periods of dry weather. In general, the sample sites were located at every stream-road 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, 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 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.

In order to collect comparable and reliable data, the measurements have to be performed under consistent groundwater inflow conditions; meaning the volume of groundwater storage should not experience significant change. Therefore, the survey is to be conducted under dry conditions when no precipitation has occurred during the previous two weeks, in the shortest possible period of time. Data analysis involves calculation and mapping of discharge and net discharge at every measured point and net discharges per a square kilometer ***(Figure 6.7).***

The baseflow data for the Sturgeon Lake watershed were collected during the summer of 2011. In total, 112 sites throughout the watershed were visited ***(Table 6.3).*** Thirty seven sites were found flowing, but measurements were taken at 23. Fourteen sites were visibly flowing, but not suitable for measurements (too deep, overgrown with weeds, too slow etc.). Sixty nine sites were found dry or with standing water in the channel, indicating that no groundwater contribution is available upstream of the sampling location. Six sites were either not found or not suitable for discharge measurement.

Further data analysis involves the calculation of net discharges at every measuring point and net discharges per square kilometer.

Based on the observed data, map of the groundwater net discharge has been created ***(Figure 6.7).*** This map shows distribution of the groundwater discharge throughout the watershed, allowing identification of areas of significant discharge. Those areas should be protected from the development as they supply the only flow into the local watercourses and, eventually, into the Sturgeon Lake, during periods of limited precipitation.

Overall, analysis has revealed that:

- The study area is characterized by a very limited baseflow (groundwater inflow) discharge. More than 61% of sampled location were found dry or with standing water.
- Where groundwater inflow exists, its value is generally low, less than 6 L/sec/km^2.
- Only 7% of the study area produces groundwater discharge more than 10 L/sec/km^2. Those areas are located in the middle portions of Hawkers and Emily Creeks and in the small unnamed creek subwatershed west of the lake ***(Figure 6.7)***. In general, geology of those areas includes deposits of sand and gravel, which usually indicates productive aquifers.

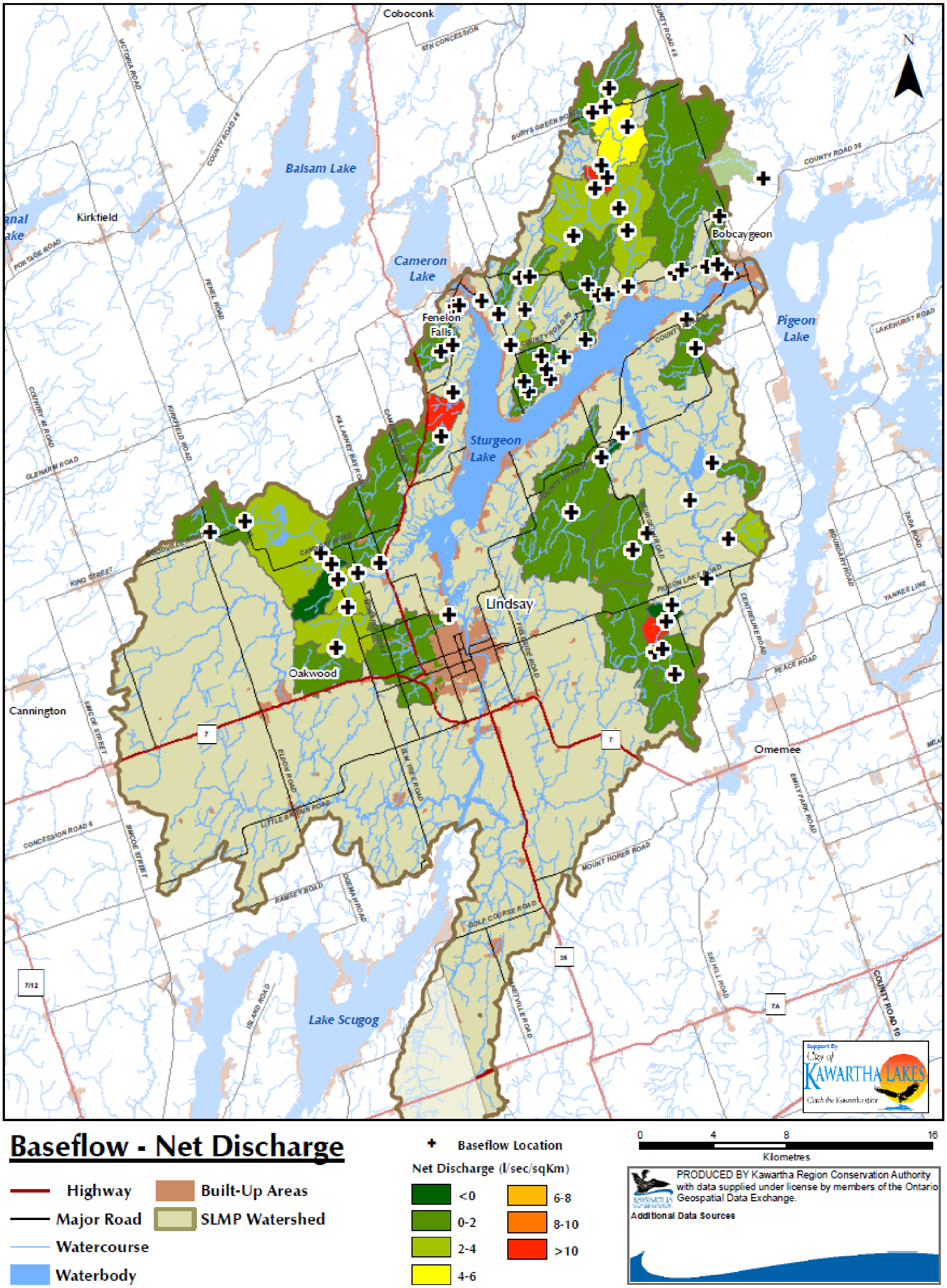


Figure 6.7. Baseflow Distribution in the Sturgeon Lake Watershed

Table 6.3. Baseflow Monitoring in the Sturgeon Lake Watershed

Watershed	**Number of Stations**				
	Total	**Measured**	**Not suitable for measurement**	**Dry / No Flow**	**Not found / Not accessible**
Emily Creek	34	1	4	25	4
Hawkers Creek	20	4	2	14	-
Martin Creek North	10	4	2	4	-
McLaren Creek	8	4	1	3	-
Rutherford Creek	7	0	1	4	2
Jennings Creek	6	1	3	2	-
Sturgeon Lake Tributaries	27	9	1	17	-
Subwatershed Total	112	23	14	69	6

In addition to the field flow monitoring, baseflow separation analysis was performed for monitoring locations where data permitted. This analysis allows to separate groundwater component of the flow for the different hydrological conditions. ***Figures 6.8 and 6.9*** demonstrate the example of the baseflow separation analysis for Hawkers Creek and McLaren Creek. As a part of the analysis, baseflow indexes (BFI) were calculated ***(Table 6.4)***. The BFI indicates proportion of baseflow component 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.

Table 6.4. Calculated Baseflow Indexes for Mariposa Brook, McLaren Creek and Hawkers Creek Subwatersheds

Year	**Mariposa Brook near Little Britain**	**McLaren Creek at Blackbird Rd.**	**Hawkers Creek at County Rd. 8**
2011	0.667	0.646	0.774
2012	0.831	0.670	0.730

Results of analysis show that baseflow makes up to 83% of the total yearly flow for Mariposa Brook near Little Britain, as it was calculated for 2012. As it was already mentioned, precipitation during 2012 was lower than normal; overall watershed conditions were extremely dry and because of that even significant rainfall events produced very little runoff. Calculated BFI for the same monitoring location in 2011 is considerably lower, about 67%, indicating that during the year with average precipitation the surface runoff component of the stream flow is more significant.

Difference in calculated BFIs for 2011 and 2012 for McLaren Creek is less significant, 0.646 and 0.670 correspondingly, but similarly to Mariposa Brook the proportion of baseflow in total flow was larger in 2012. For Hawkers Creek the calculated BFI value in 2012 is slightly lower when compared to 2011, being 0.730 and 0.774 respectively. It is explained by the fact that by August shallow aquifer that provides baseflow to the creek has depleted and the watercourse went dry. It was dry for 34 days during August and September (***Figures 6.8***)

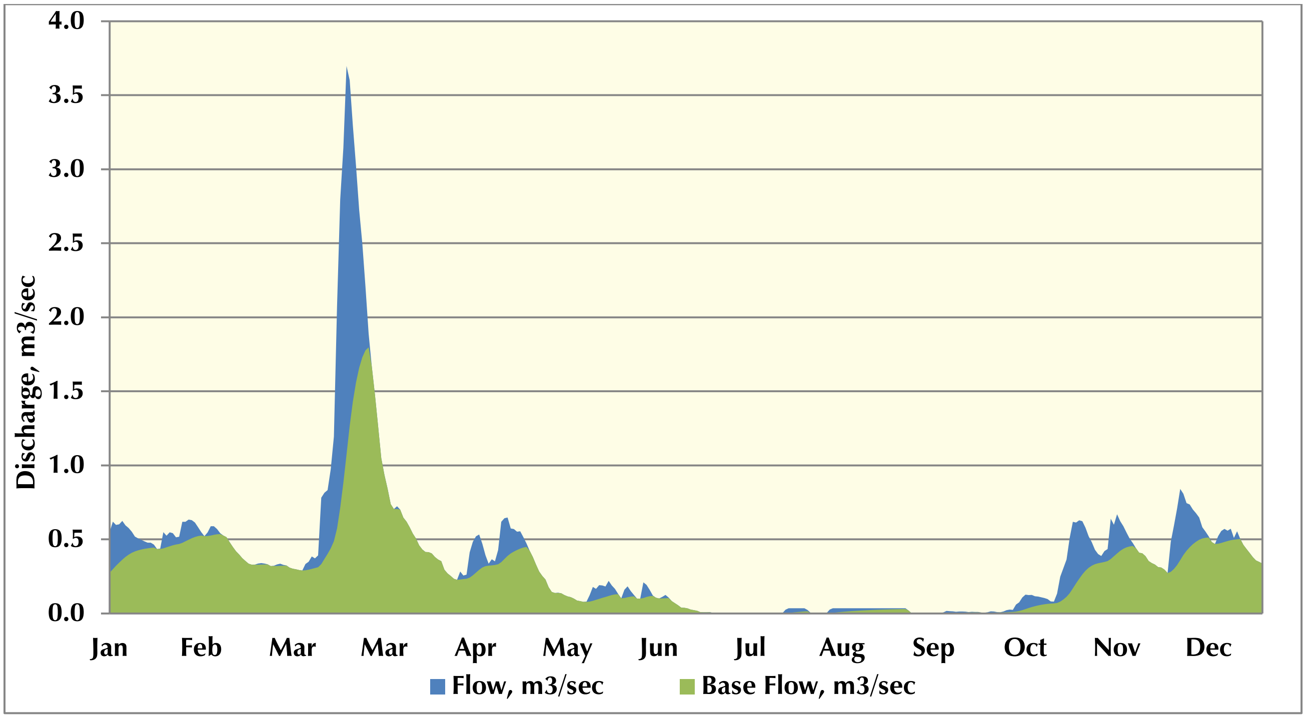


Figure 6.8. Average Daily Hydrograph and its Baseflow Component, Hawkers Creek at County Road 8, 2012

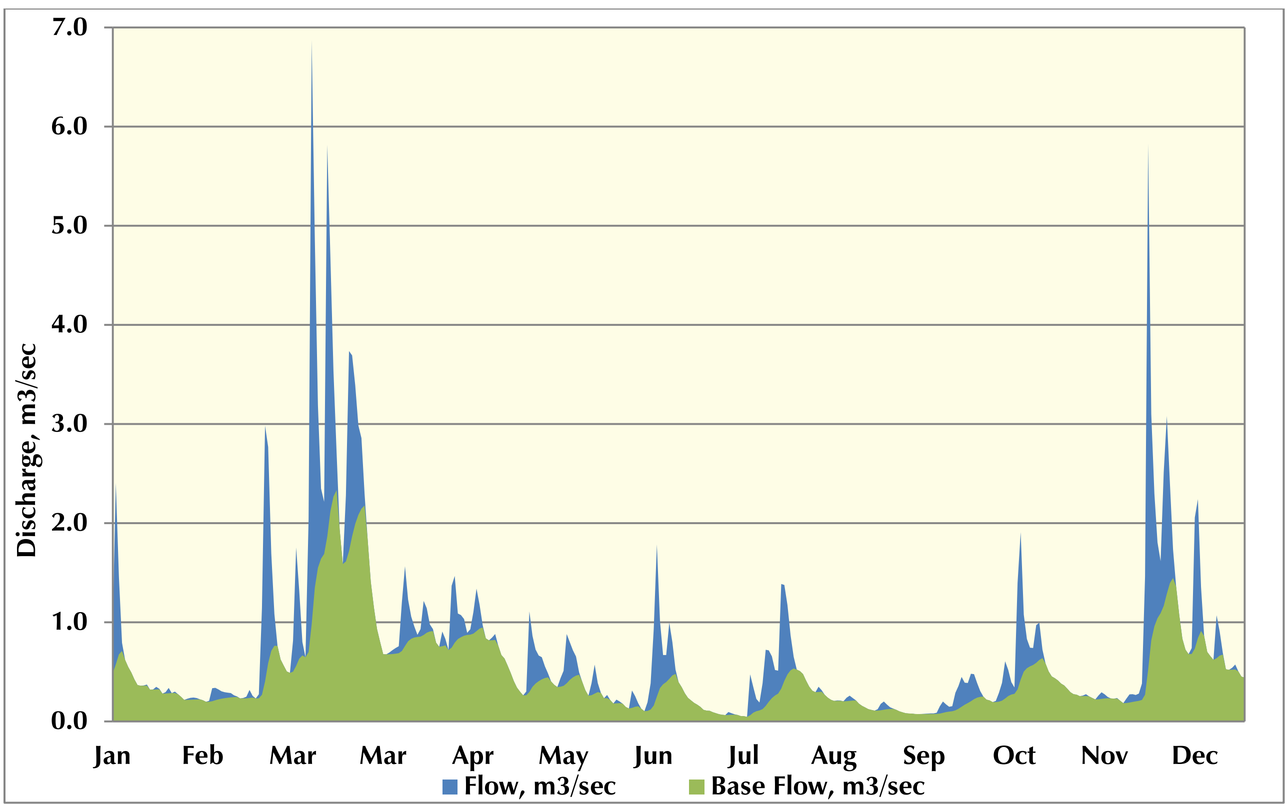


Figure 6.9. Average Daily Hydrograph and its Baseflow Component, McLaren Creek at Blackbird Road, 2011

6.5 Water Use

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 water use within the Sturgeon Lake watershed.

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 MOE was contacted to provide current water taking information in the watershed. The best available data was provided for active permits in the watershed (as of October 2012). Some permits were removed from the analysis in order to give a better representation of water usage (e.g. construction dewatering).

There are twenty nine active Permits to Take Water within the Sturgeon Lake watershed ***(Table 6.5, Figures 6.10 and 6.11)***. Ten of which use surface water as a source, and ten allow withdrawal from groundwater. In nine permits water is taken from ponds, that are considered as surface and groundwater mixed source.

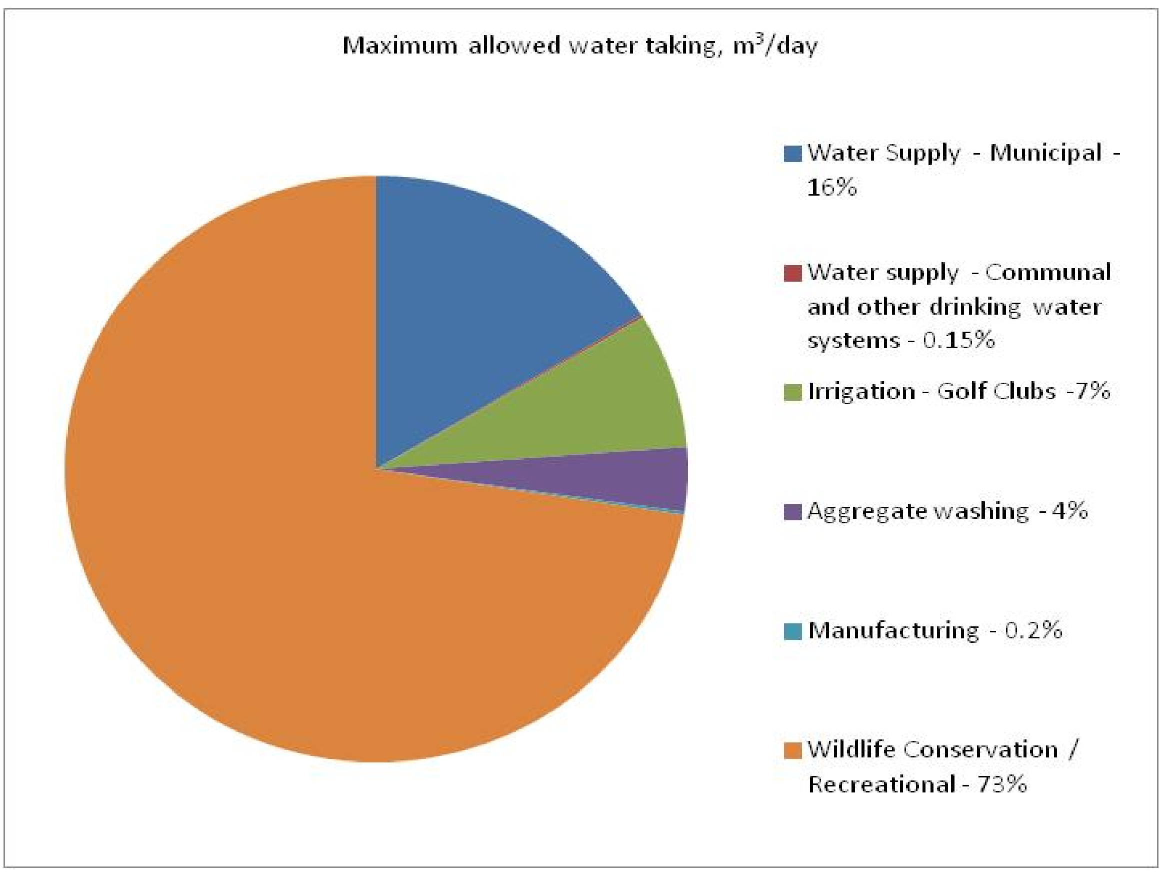


Figure 6.10. Maximum Allowed Water Taking by Categories, Percent of Total

Thirteen permits, or 45% of the total number, are used for water supply: municipal, communal and other drinking water systems. The permitted water taking for this category is substantial; about 38,000 m^3 per day could be potentially taken for water supply. There are three municipal drinking water systems within the Sturgeon Lake watershed. Details on those are shown in ***Table 6.6***.

The largest system is the Lindsay Drinking Water System that supplies water to near 20,000 residents of the Town of Lindsay and surrounding areas. Water is withdrawn from the Scugog River; the permitted maximum daily amount is 30,686 m^3. However, the actual withdrawal rarely if ever goes that high; the reported average pumping rate is less than 8,600 m^3/day.

The Bobcaygeon Drinking Water System is the second largest water supply system within the watershed. It withdraws water from Sturgeon Lake (Big Bob Channel) and provides it to about 3,000 residents of the Town of Bobcaygeon. The average daily pumping rate is about 2,000 m^3, while the maximum allowed water taking for this system is 5,184 m^3 per day.

Southview Estate is a residential subdivision on the west shore of Sturgeon Lake that is also served by the municipal drinking water system. It supplies the population of about 360 people. Water is taken from the lake at the average daily pumping rate of 68 m^3. The maximum permitted withdrawal amount is 484 m^3 per day.

Table 6.5. Summary of Permits to Take Water in the Sturgeon Lake Watershed

<table>
<tr><th>Category</th><th>Purpose</th><th>Source</th><th>Number of Permits</th><th>Maximum allowed water taking, m³/day</th></tr>
<tr><td rowspan="3">Water Supply</td><td rowspan="2">Municipal</td><td>Surface Water</td><td>4</td><td>36,950</td></tr>
<tr><td>Groundwater</td><td>2</td><td>650</td></tr>
<tr><td>Other drinking water systems</td><td>Groundwater</td><td>7</td><td>331</td></tr>
<tr><td rowspan="2">Commercial</td><td>Irrigation</td><td>Ground and Surface Water</td><td>7</td><td>17,280</td></tr>
<tr><td>Other</td><td>Surface Water</td><td>3</td><td>1,360</td></tr>
<tr><td rowspan="3">Industrial</td><td rowspan="2">Aggregate washing</td><td>Ground and Surface Water</td><td>2</td><td>3,000</td></tr>
<tr><td>Groundwater</td><td>1</td><td>5,180</td></tr>
<tr><td>Manufacturing</td><td>Ground and Surface Water</td><td>1</td><td>400</td></tr>
<tr><td rowspan="2">Recreational</td><td rowspan="2">Recreational/Other</td><td>Ground and Surface Water</td><td>1</td><td>820</td></tr>
<tr><td>Surface Water</td><td>2</td><td>870</td></tr>
<tr><td>Wildlife conservation</td><td></td><td>Ground and Surface Water</td><td>4</td><td>166,600</td></tr>
<tr><td>Total</td><td></td><td></td><td>29*</td><td>236,500</td></tr>
</table>

*Some permits are issued for more than one category/purpose

The other drinking water systems are considerably smaller in size with maximum permitted withdrawal amounts between 1.2 - 95 m^3/day. They are used to supply drinking water to the number of small-scale users such as golf courses and campgrounds/trailer parks and all are groundwater based.

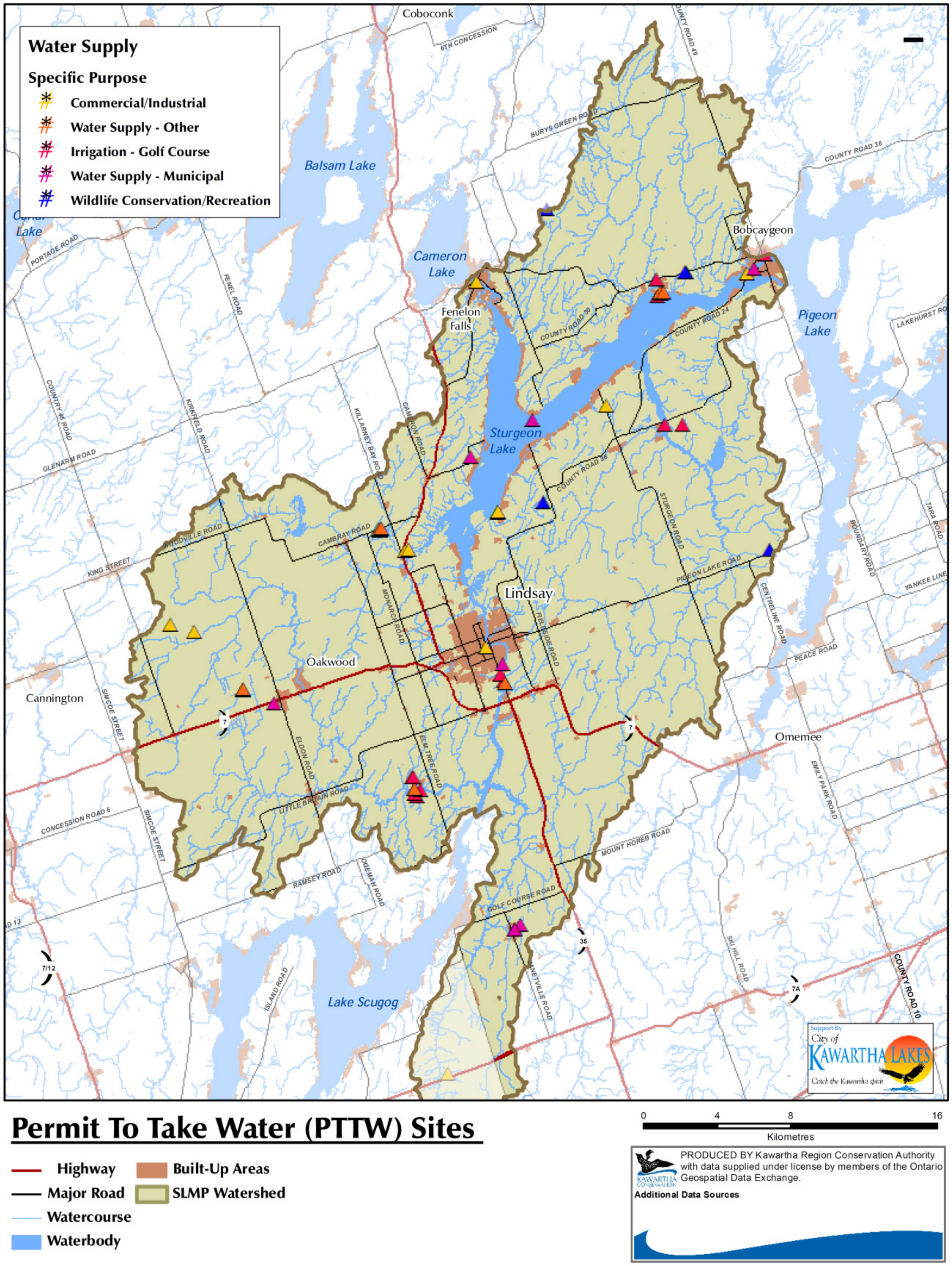


Figure 6.11. Permit to Take Water Sites in the Sturgeon Lake Watershed

Table 6.6. Municipal Drinking Water Systems in the Sturgeon Lake Watershed

System	Type	Source	Population served	Average Pumping rate, m^3/day	Max permitted water taking, m^3/day
Bobcaygeon Drinking Water System	Large Municipal Residential	Sturgeon Lake	3,000	1,961	5,184
Lindsay Drinking Water System	Large Municipal Residential	Scugog River	20,000	8,573	30,686
Southview Estates Drinking Water System	Large Municipal Residential	Sturgeon Lake	360	68	484

Considerable amount of water is permitted to use for golf course irrigation. Seven permits within the Sturgeon Lake subwatershed are issued for this purpose; they fall under Commercial category. It is a seasonal, non-consumptive use of water resources. Collectively, they are allowed to withdraw up to 17,280 m^3/day. The Scugog River, Emily Creek, Mariposa Brook, Sturgeon Lake and a number of ponds are used as source of water for irrigation purposes.

Industrial category includes three permits for aggregate washing and one for manufacturing. Aggregates washing operations potentially could take up to 8,180 m^3 of water per day from groundwater and ponds. The aggregate wash plants are typically "close loop" systems where the wash water is re-used and only that portion that is lost to evaporation (approximately 10%) is replaced. About 400 m^3/day of water from ponds are allocated for manufacturing.

The largest amount of water, maximum up to 168,290 m^3/day or 73% of total permitted, is allocated for wildlife conservation (4 permits) and recreational/aesthetic purposes (3 permits). This type of water taking includes works to create artificial impoundments or improve existing ponds and wetlands and is considered as non-consumptive category of water use.

6.6 Water Budget

A water budget is an essential component of any hydrological and water quality study. In the framework of the Sturgeon Lake Management Plan, the water budget can be used for multiple purposes. For example, the water budget and its components are necessary to evaluate cumulative effects of various land uses on water quality in the lake and its tributaries as well as to determine priority areas for environmental monitoring. Moreover, the accurate water budget of Sturgeon Lake is crucial for the further calculations of phosphorus and nitrogen loadings and balances for the lake.

A water budget for any given water body or watershed is a sum of all water inputs, outputs and changes in storage. It is understandable that all water inputs into the lake such as precipitation, surface and groundwater inflows, discharges from sewage treatment plants and septic systems should be equal the sum of all water outputs from the lake such as evaporation and evapotranspiration, surface and groundwater outflows, water extraction for the water supply purposes. Consequently the water budget equation for Sturgeon Lake can be expressed as:

$$P - E + Q_{in} - Q_{out} + G_{in} - G_{out} + A_{in} - A_{out} \pm \Delta S \pm \Delta = 0$$

Where:
P – precipitation on the water surface of the lake,
E – evapotranspiration from the water surface of the lake,
Q_{in} – sum of all surface inflows into the lake,
Q_{out} – sum of all surface outflows,
G_{in} – groundwater inflow into the lake,
G_{out} – groundwater outflow from the lake (in this case no measurements have been done for the groundwater flows),
A_{in} – anthropogenic inputs from the septic systems along the shoreline and from the municipal waste water treatment plants,
A_{out} – anthropogenic extraction from the lake for the Bobcaygeon Water Treatment Plant,
ΔS – change in lake storage,
$\pm\Delta$ – imbalance.

The numbers of the Sturgeon Lake water budget components for the 2010–2011, 2011–2012 and 2012–2013 hydrologic years are shown below in ***Table 6.7***. The hydrologic year in Ontario begins on June 1st and ends on May 31st of the next year, and reflects the natural hydrological cycle.

The total amount of precipitation has been calculated as an average from two precipitation gauges around Sturgeon Lake: Ken Reid Conservation Area gauge and Hawkers Creek gauge. The average amount of precipitation between the two stations was 1016.8 mm in 2010-2011, 869.5 mm in 2011-2012 and 873.5 mm in 2012-2013. Although the precipitation amount is usually expressed in millimeters, it was converted into cubic meters for the purposes of convenient comparison with flow components.

Evapotranspiration is the least studied component of the water budget. Evapotranspiration depends on many weather factors as, for example, daily air temperature, relative humidity, solar radiation, wind speed and direction as well as on physiographic factors as local elevation and distance to the large water bodies (Great Lakes, oceans). There are no meteorological stations that monitor evaporation and evapotranspiration within the Kawartha Watershed as well as nowhere nearby. That's why average evapotranspiration value can be determined only theoretically taking into consideration available information found in scientific literature. After an extensive research in a variety of scientific sources, the long-term average amount of 630 mm per year was taken from the National Soil Database as the most accurate and appropriate potential evapotranspiration value for Sturgeon Lake (Agriculture and Agri-Food Canada, 1997). This number was also converted into cubic meters for the convenient comparison.

Five flow monitoring stations are currently located within the Sturgeon Lake watershed on the following streams: McLaren Creek, Hawkers Creek, East Cross Creek, Mariposa Brook and Jennings Creek. Those stations have been used for calculations of an annual average flow rate and a yearly flow volume. Hawkers Creek and Jennings Creek have flow stations close to their outlets and observed level and velocity data have been used for the final calculations. The other watercourses have flow monitoring stations far upstream from their mouths and therefore calculated flow rates and volumes have been prorated accordingly to the size of the remained ungauged portion of the corresponding watersheds. The flow of Emily Creek, Martin Creek North and other ungauged subwatersheds have been calculated with the use of the unit area discharge (L/sec/km^2) from similar gauged watersheds. For example, the McLaren Creek data were used for flow volume calculation for Emily Creek.

Table 6.7. Sturgeon Lake Annual Water Budget in the 2010-2011, 2011-2012 and 2012-2013 Hydrologic Years

	2010 – 2011		2011 – 2012		2012 – 2013	
	Volume, mln. m^3	% of total supply or loss	Volume, mln. m^3	% of total supply or loss	Volume, mln. m^3	% of total supply or loss
Total water inflow:	*2172.6*	*100*	*1459.3*	*100*	*1875.9*	*100*
Precipitation	*46.36*	*2.13*	*39.65*	*2.72*	*39.83*	*2.12*
Cameron Lake Outlet	*1602.5*	*73.8*	*983.3*	*67.4*	*1362.3*	*72.6*
Scugog River	*310.7*	*14.3*	*266.7*	*18.3*	*303.1*	*16.2*
Emily Creek	*62.37*	*2.87*	*52.40*	*3.59*	*59.77*	*3.19*
Hawkers Creek	*27.38*	*1.26*	*16.87*	*1.16*	*14.83*	*0.79*
Martin Creek North	*22.97*	*1.06*	*13.79*	*0.95*	*12.67*	*0.68*
McLaren Creek	*30.60*	*1.41*	*25.70*	*1.76*	*29.33*	*1.56*
Jennings Creek	*6.27*	*0.29*	*5.27*	*0.36*	*4.50*	*0.24*
Local surface inflow	*57.76*	*2.66*	*49.74*	*3.41*	*43.80*	*2.33*
Anthropogenic inputs	*5.76*	*0.27*	*5.76*	*0.39*	*5.76*	*0.31*
Total water outflow:	*2039.6*	*100*	*1551.7*	*100*	*1964.6*	*100*
Evapotranspiration	*28.73*	*1.41*	*28.73*	*1.85*	*28.73*	*1.46*
Sturgeon Lake Outlet	*2011.4*	*98.5*	*1522.4*	*98.1*	*1929.0*	*98.2*
Anthropogenic extraction	*0.60*	*0.03*	*0.60*	*0.04*	*0.60*	*0.03*
Change in lake storage (ΔS)	*-1.09*	*0.05*	*0.14*	*0.01*	*6.29*	*0.32*
Imbalance (±Δ), mln. m^3	*133.0*		*-92.36*		*-88.73*	
Imbalance (±Δ), %	*6.3*		*-6.1*		*-4.6*	

*Cameron Lake Outlet, Scugog River and Sturgeon Lake Outlet flow values were obtained from the TSW

The change in lake storage (ΔS) has been calculated as a difference in the lake levels on June 1, 2010 and May 31, 2011; on June 1, 2011 and May 31, 2012; and on June 1, 2012 and May 31, 2013 multiplied by the lake water surface area. These data have been obtained from the Trent Severn Waterway (TSW) water level monitoring station on Sturgeon Lake near Bobcaygeon. The change in lake storage can be positive or negative depending on difference in the lake water levels from year to year.

During the three hydrologic years the water budget had a positive imbalance (6.3% or 133.0 million m^3) in 2010-2011, a negative imbalance (-6.1% or -92.4 million m^3) in 2011-2012 and a negative imbalance (-4.6% or -88.73million m^3) in 2012-2013 ***(Table 6.7)***.A positive imbalance means that more water entered the lake than left it according to calculations. A negative imbalance means that more water left the lake than entered. All imbalance numbers are within the acceptable limit (10%) for the water balance calculations (Scott et al., 2001) thus providing a high level of confidence in phosphorus and nitrogen load calculations.

7.0 Water Quality

7.1 Summary of Observations and Issues

Results and observations presented in this chapter and summary are based on a three-year monitoring period initiated in 2010 and finalized in 2013. It draws from a monitoring network that includes 11 water quality stations on tributaries across the Sturgeon Lake watershed, four water quality stations on the lake, and one precipitation sampler near the southern end of the lake. As well, lake sediment samples have been collected from 12 sites across the lake.

OBSERVATIONS

- Water quality in many lake tributaries has improved since the 1980s, as phosphorus concentrations have decreased, in some streams considerably (e.g., Hawkers Creek, Martin Creek North, the Scugog River, Mariposa Brook).
- Over the last 12 to 15 years, phosphorus levels in the Scugog River have remained stable both upstream and downstream of Lindsay.
- Between 2010 and 2012, phosphorus concentrations noticeably increased downstream of Lindsay, but not upstream. Increasing phosphorus levels downstream of Lindsay demonstrate that urban development is becoming more significant among anthropogenic sources of phosphorus to the river and, consequently, to the lake.
- Overall, Sturgeon Lake can be characterized as a mesotrophic water body with relatively good water quality, but there is still room for improvement. In the southern portion of the lake, excessive aquatic plant growth was been observed.
- In summer, under weather conditions such as prolonged hot and still periods, blue-green algae blooms can develop in the lake, as occurred in 2011.
- Aluminum concentrations are quite often elevated in Jennings Creek (37.5% of samples exceeded the Canadian Water Quality Guideline) and Mariposa Brook (17% of samples) and are easily correlated with total suspended solids levels. Local soils are most likely the source of aluminum in those streams.
- *E. coli* monitoring results showed that most streams in the watershed usually had *E. coli* levels below the Provincial Water Quality Objective (100 cfu/100 mL), except for a couple of streams in which *E. coli* concentrations may be of concern. For example, in Jennings Creek, the geometrical mean *E. coli* concentration was 189 cfu/100 mL in 2011 and 387 cfu/100 mL in 2012.
- Elevated *E. coli* levels in excess of the provincial objective have been often observed at Beach Park and Riverview Park beaches in Bobcaygeon that resulted in frequently posted beaches.
- No elevated *E. coli* levels were detected in two residential canals on Sturgeon Lake.

KEY ISSUES

- A considerable amount of phosphorus is entering the Scugog River system from the Lindsay urban area. As a result, high amounts of phosphorus and nitrogen found in the Scugog River downstream of Lindsay can be identified as one of the main causes of the process of eutrophication in the southern portion of Sturgeon Lake.
- Water quality monitoring shows Sturgeon Lake in its southern and north-eastern arms has elevated phosphorus levels in the summer that often exceed the Provincial Water Quality Objective (PWQO) (0.02 mg/L) and can promote blue-green algae blooms and excessive aquatic plant growth.
- Most of the lake's southern tributaries have elevated phosphorus levels as a result of human activities in their corresponding subwatersheds. East Cross Creek and Jennings Creek exhibited the highest levels of phosphorus throughout the monitoring period.

- The phosphorus levels recorded at Jennings Creek and McLaren Creek show that those tributaries, which flow through a predominantly agricultural area, are also important contributors of phosphorous to Sturgeon Lake. Phosphorus concentrations increased since the 1980s in the water of McLaren Creek.
- The most significant anthropogenic sources of phosphorus to Sturgeon Lake include urban runoff (Lindsay, Fenelon Falls and small urban pockets along the shoreline) and septic systems around the lake.
- Nitrate concentrations occasionally exceed the Canadian Water Quality Guideline for the Protection of Aquatic Life (2.93 mg/L) in the water of several tributaries, namely McLaren Creek, Jennings Creek and Mariposa Brook. While average nitrate concentrations in these streams are below the guideline, the frequency of exceedances is quite high, especially in winter. For example, nitrate values in 20% of all samples from Mariposa Brook exceeded the corresponding guideline. Nitrate concentrations observed in the water of this stream have been measured as high as 4.8 mg/L.
- Chloride concentrations exceeded the corresponding Canadian Water Quality Guideline (CWQG) (128 mg/L) in 50% of water samples collected from Jennings Creek.
- Bottom sediments in the southern portion of the lake are still contaminated with PCBs. Other contaminants found in sediments include Polycyclic Aromatic Hydrocarbons (PAHs), some Organochlorinated Pesticides (OCPs) and some metals including cadmium, lead and zinc.

7.2 Introduction

Water quality of any surface water body or groundwater can be defined as an integrated index of chemical, physical and microbiological characteristics of natural water. Water quality is a function of natural processes and anthropogenic 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 northern part of the Kawartha Conservation watershed have naturally higher levels of metals than those in the south because of the Canadian Shield bedrock. Natural background concentrations of water quality parameters in Southern Ontario usually do not pose any threat to the health of aquatic ecosystems or humans.

Human activities very often have direct and indirect impacts on water quality that can result in changes to the natural environment. 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 landfills. Point sources of pollution are typically more easily identified and managed. In contrast, a non-point source of pollution reflects land use and refers to diffuse sources such as an agricultural drainage, 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 are often difficult to pinpoint to a specific site.

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. Current results can be compared against historical results to establish trends in water quality over time. Obtained results can also be compared to the Provincial Water Quality Objectives (PWQOs) (MOE, 1994) and Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) (CCME, 2007).

The Provincial Water Quality Objectives represent a desirable level of water quality that the MOE strives to maintain in the surface waters. The PWQOs are set at a level of water quality, which is protective of all aquatic species at all stages of their life cycle and are helpful in assessing the degree of impairment to a surface water body. In some cases they are established to protect recreational water uses, which are based on public health and/or aesthetic values (MOE, 1994).

Canadian Water Quality Guidelines are intended to provide protection of freshwater and marine life from anthropogenic stressors such as chemical inputs or changes to physical components (e.g., pH, temperature, and debris). Guidelines are numerical limits or narrative statements based on the most current, scientifically defensible toxicological data available for the parameter of interest. Guideline values are meant to protect all forms of aquatic life and all aspects of the aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term. Ambient water quality guidelines developed for the protection of aquatic life provide the science-based benchmark for a nationally consistent level of protection for aquatic life in Canada (CCME, 1999).

Finally, it can be said that the main goal of the water quality data analysis is to convert water quality observations into information for educational purposes and decision-making at various levels of government.

7.3 Methodology

Water quality monitoring plays an important role in meeting the objectives of the Sturgeon Lake Management Plan. Water quality data are obtained by collecting water samples at monitoring sites across the Sturgeon Lake watershed. As of 2013, the Sturgeon Lake watershed has four long-term monitoring sites (ST2, ST5, ST7 and ST11) sampled in the framework of the Provincial Water Quality Monitoring Network (PWQMN). Sampling at those sites started in the period between 1966 and 1996. As well, extensive additional sampling for the purposes of the Sturgeon Lake Management Plan development was done in 2010-2013 at 11 sites including four PWQMN sites. There are also four sampling sites on Sturgeon Lake itself ***(Figure 7.1).***

The monitoring stations are dispersed across the entire watershed at key locations covering all major tributaries. The monitoring stations on the lake are located in such way as to cover all main parts of the water body. At each site, water samples are collected by grab method according to the planned monitoring schedule and then sent to a certified private laboratory to be analyzed for total suspended solids and nutrients including ammonia, nitrites, nitrates, total Kjeldahl nitrogen and total phosphorus. Samples for the PWQMN program are collected during the ice-free period eight times per year and sent to the MOE's Laboratory Services Branch to be analyzed for alkalinity, metals, hardness, total suspended solids, anions such as chlorides, and all nutrients including ammonia, nitrites, nitrates, total Kjeldahl nitrogen, total phosphorus and orthophosphates. 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 lake management planning monitoring program are collected bi-weekly year round and analyzed for phosphorus and nitrogen. As well, three to four times a year during both wet and dry conditions samples were collected for metals and general chemistry. A number of tributaries have been sampled during summer periods for Escherichia Coli (*E. coli*). A complete list of parameters sampled and corresponding guidelines or objectives are available in ***Appendix WQ1.***

Statistical analysis of data was completed for total phosphorus (TP), nitrites/nitrates ($NO_2^- + NO_3^-$), aluminum (Al), chlorides (Cl^-), *E. coli* and total suspended solids (TSS) for sites with enough samples for analysis. ***Table 7.1*** shows the site ID, location, number of samples and date of the most recent sample. Historical water quality information from the 1970s, 1980s and 1990s has been also used for a comparison of current water quality data against long-term data sets in order to determine whether the lake's and tributaries' water quality is improving or deteriorating.

7.4 Sturgeon Lake Tributaries

From a hydrological point of view the Sturgeon Lake watershed includes all areas that supply water to the lake. This means that the Sturgeon Lake watershed is comprised of Lake Scugog with its tributaries, Balsam and Cameron Lakes with their tributaries, including the Gull River and the Burnt River. It is a vast area that extends far beyond the Kawartha Conservation jurisdiction. Therefore, for practical purposes we will consider only that portion of the Sturgeon Lake watershed, which includes tributaries flowing into the lake itself or into the Scugog River. Consequently, the study area includes the Scugog River subwatershed, which, in turn, comprises Mariposa Brook and East Cross Creek subwatersheds; the McLaren Creek subwatershed, Emily Creek subwatershed, Hawkers Creek subwatershed, Martin Creek North subwatershed as well as drainage areas adjacent to the lake. As previously mentioned, Sturgeon Lake also receives inflow from Cameron Lake via Fenelon Falls and from Lake Scugog via the Scugog River. The Sturgeon Lake watershed mostly occupies the central portion of the Kawartha Conservation watershed.

The total area of the Sturgeon Lake watershed within the Kawartha Conservation jurisdiction is 1028 km^2 including the surface water area of the lake, which is 45.6 km^2. The dominant human land use in the watershed is agriculture, which occupies more than 53% of the land portion of the watershed. Forests (14%) and wetlands (16%) also cover a considerable portion of the drainage area. The lake has three major points of inflow:

- The Cameron Lake outlet which supplies more than 70% of water inflow into the lake,
- The Scugog River – the largest tributary that also carries water from Lake Scugog, and
- Emily Creek that empties into the north-eastern portion of the lake.

The major water quality concern in the Sturgeon Lake watershed is elevated concentrations of phosphorus in the southern tributaries. Other parameters of interest that can be a concern from the ambient water quality perspective include nitrogen in the form of nitrates in three tributaries, chlorides in Jennings Creek, aluminum and total suspended solids in Jennings Creek and Mariposa Brook, and *Escherichia Coli* in the water of Jennings Creek. All other parameters have concentrations far below the corresponding PWQOs or CWQGs and do not currently present any threat to aquatic life or human health.

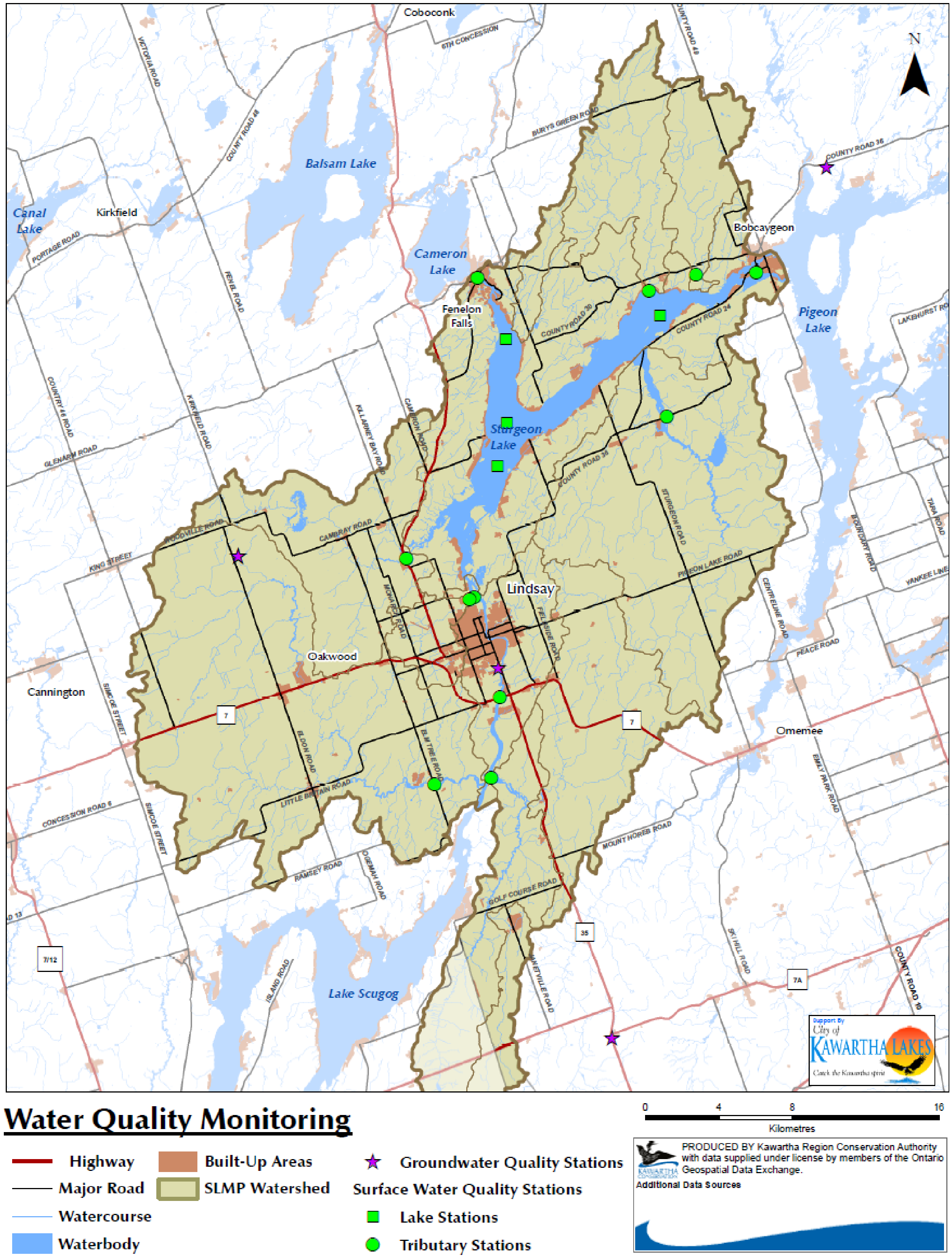


Figure 7.1. Water Quality Monitoring Stations in the Sturgeon Lake Watershed

Table 7.1. Water Quality Monitoring Stations in the Sturgeon Lake Watershed

Station ID	Location	Number of Samples	Most Recent Sample
ST1	McLaren Creek at Hwy 35	74	June-2013
ST2	Cameron Lake outlet in Fenelon Falls	94	June-2013
ST3	Hawkers Creek at County Road 8	77	June-2013
ST4	Martin Creek North at County Road 8	76	June-2013
ST5	Sturgeon Lake outlet in Bobcaygeon at R.R. 36	95	June-2013
ST6	Emily Creek at Regional Road 36	73	June-2013
ST7	Scugog River at Hwy 7/35	93	June-2013
ST8	Scugog River downstream Lindsay	76	June-2013
ST9	Jennings Creek	79	June-2013
ST10	East Cross Creek at River Road	58	June-2013
ST11	Mariposa Brook at Elm Tree Road	87	June-2013
PR1	Precipitation sampler	86	June-2013
SL1	Sturgeon Lake near Muskrat Island	16	Sept-2013
SL2	Sturgeon Lake near Sturgeon Point	16	Sept-2013
SL3	Sturgeon Lake downstream of Fenelon Falls	16	Sept-2013
SL4	Sturgeon Lake near Snug Harbor	16	Sept-2013

** Stations ST2, ST5, ST7 and ST11 are monitored through the CKL LMP and PWQMN monitoring programs*

Phosphorus

Phosphorus is one of the two primary nutrients required for the growth of aquatic plants and algae in streams and lakes. Phosphorus is not considered toxic to plants and animals, but elevated levels of this nutrient in water can cause the process of eutrophication, which results into excessive algae and aquatic plant development, and a corresponding depletion of dissolved oxygen in the water column. The PWQO for total phosphorus (TP) concentrations in watercourses is set at 0.030 mg/L, in order to prevent nuisance algae and aquatic plant growth. The PWQO for TP concentrations in lakes is 0.020 mg/L and/or it is 0.010 mg/L if those lakes have natural TP level below this value (MOE, 1994). 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 as part of the total suspended sediments (solids). This form of phosphorus is not readily available to plants, and does not instantly change the 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.

Phosphorus concentrations often exceed the PWQO in the southern tributaries of Sturgeon Lake that results in averages often being above the provincial objective. In the northern streams of the watershed TP levels are considerably lower and very seldom exceed the PWQO. As a result, phosphorus averages in Hawkers Creek, Martin Creek North and Emily Creek are always below 0.02 mg/L ***(Figure 7.2).***

McLaren Creek carries its water from Goose Lake through mostly agricultural areas into the southern portion of Sturgeon Lake. Current water quality in the creek is characterized by slightly elevated phosphorus concentrations. Phosphorus levels over the period of monitoring varied from 0.006 mg/L to 0.127 mg/L. The average TP concentration in the creek over the three-year period is 0.034 mg/L that is somewhat above the PWQO. The annual averages ranged from 0.030 mg/L in 2011-2012 to 0.036 mg/L in 2010-2011 and 2012-2013 ***(Figure 7.2).***

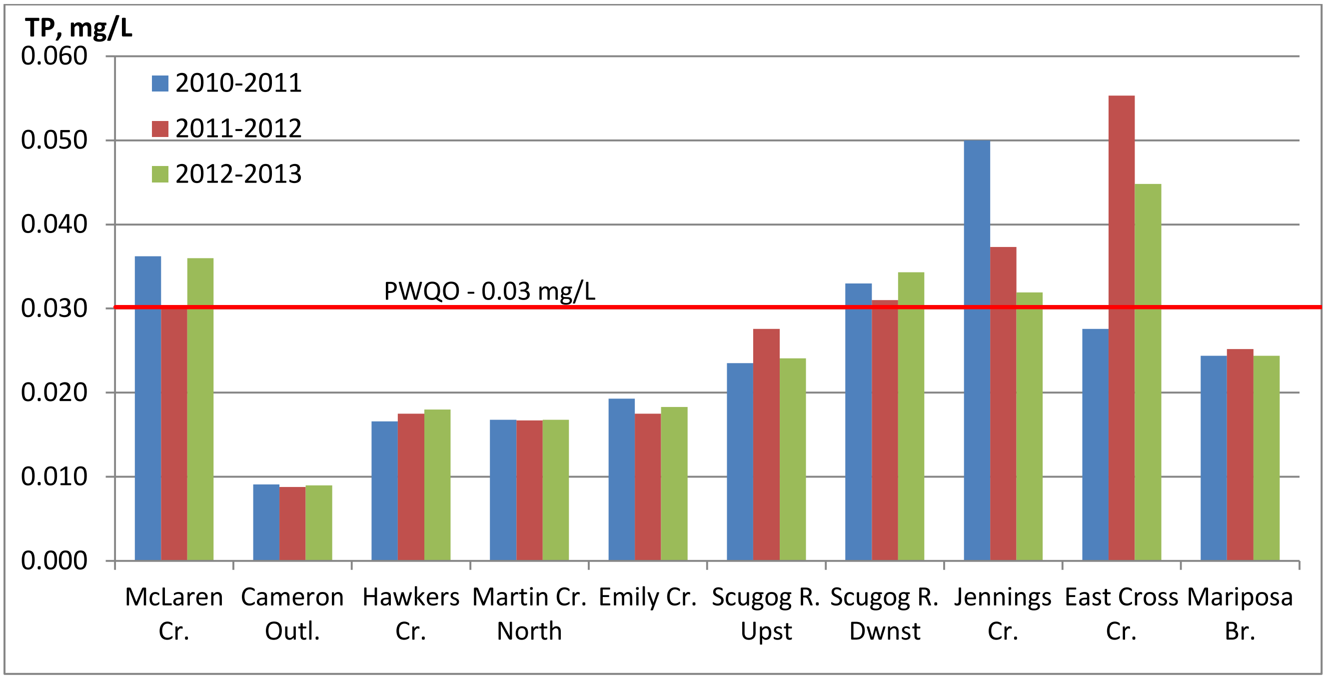


Figure 7.2. Average Phosphorus Concentrations in the Sturgeon Lake Tributaries in 2010-2013

Comparing phosphorus levels in the creek during the 2010-2013 monitoring period with results from 1983-1990 that were collected by the MOE staff during that period **(*Table 7.2*),** it was found that phosphorus concentrations in McLaren Creek are currently higher than in the 1980s, perhaps reflecting increased human pressure on the stream watershed. Average and median values over the current period of monitoring increased compared to 1983-1990 – 0.034 vs. 0.028 mg/L and 0.029 vs. 0.023 mg/L respectively. Minimum, 25th and 75th percentiles increased as well. Only the maximum value declined between the two periods of study from 0.160 to 0.127 mg/L.

Table 7.2. Results of Statistical Analysis of Total Phosphorus Concentrations in McLaren Creek for the Periods of 1983-1990 and 2010-2013

Statistical Parameters	1983-1990	2010-2013
Maximum	0.160	0.127
75th percentile	0.035	0.039
25th percentile	0.015	0.017
Minimum	0.003	0.006
Average	0.028	0.034
Median (50th percentile)	0.023	0.029
Exceedances, %	35	46
Number of samples	80	74

In the 1980s 35% of all samples exceeded the PWQO, in 2010-2013 phosphorus levels exceeded the PWQO in 46% of all collected samples **(*Table 7.2*).** Most exceedances were detected in the summer. When considering the seasonal distribution of total phosphorus in McLaren Creek, the lowest TP concentrations are usually observed throughout late autumn into early spring. The highest phosphorus readings were observed in spring during intensive snowmelts and corresponding freshets. In the summer months under both high and low flow conditions, phosphorus concentrations are generally quite high, which can indicate that phosphorus is coming into the watercourse with both stormwater runoff and groundwater discharge.

Hawkers Creek flows into Sturgeon Lake from the north. Most of its subwatershed is occupied by forests and wetlands. As a result, the creek has very good water quality with low phosphorus and nitrogen concentrations. Since the beginning of monitoring in 2010, phosphorus concentrations in Hawkers Creek have mostly been below the PWQO*.* The average phosphorus concentration is 0.017 mg/L, with results ranging between 0.004 and 0.049 mg/L. The highest readings were observed during the spring freshet and after significant rain events. The lowest TP concentrations are usually observed throughout late autumn into early spring. Phosphorus levels exceeded the PWQO only in 10% of all samples that is one of the lowest figures among all monitored watercourses in the watershed ***(Table 7.3).***

A comparison of phosphorus concentrations from the 1983-1990 and 2010-2013 monitoring periods indicates that water quality in Hawkers Creek has improved considerably. Phosphorus levels in the water of the creek decreased substantially since the 1980s **(*Table 7.3*)**. The average TP concentration in 2010-2013 was 0.017 mg/L while in 1983-1990 it was 0.028 mg/L. The number of exceedances also decreased substantially – from 32% to 10%. There is a possibility that this decreasing trend may continue into the future if supported by best management practices in the subwatershed.

Table 7.3. Results of Statistical Analysis of Total Phosphorus Concentrations in Hawkers Creek for the Periods of 1983-1990 and 2010-2013

Statistical Parameters	**1983-1990**	**2010-2013**
Maximum	0.145	0.049
75th percentile	0.032	0.025
25th percentile	0.015	0.008
Minimum	0.004	0.004
Average	0.028	0.017
Median (50th percentile)	0.022	0.014
Exceedances, %	32	10
Number of samples	94	77

Martin Creek North occupies the north-eastern corner of the lake watershed and is located just east of the Hawkers Creek subwatershed. Monitoring results collected from 2010 to 2013 don't show any apparent trend in total phosphorus levels in this creek. The average phosphorus concentration in the creek is 0.017 mg/L **(*Table 7.4*).** The annual average concentrations during three years had the same value, 0.017 mg/L, which is well below the PWQO. The highest phosphorus concentrations (0.051 and 0.054 mg/L) occurred during spring runoffs in March 2011 and March 2012.

The lowest TP concentrations in the range of 0.003-0.009 mg/L have usually been observed throughout late autumn to early spring. Phosphorus levels exceeded the PWQO in 12% of all samples ***(Table 7.4).*** Compared to the results from the 1980s phosphorus concentrations in the creek decreased considerably, similar to the trend observed in Hawkers Creek. For example, the average phosphorus concentration decreased by 0.010 mg/L, which is one-third of the value in the 1980s (0.027 mg/L). The maximum value from the 2010-2013 period is half the value from 1983-1990, 0.054 vs. 0.108 mg/L.

Table 7.4. Results of Statistical Analysis of Total Phosphorus Concentrations in Martin Creek North for the Periods of 1983-1990 and 2010-2013

Statistical Parameters	**1983-1990**	**2010-2013**
Maximum	0.108	0.054
75th percentile	0.036	0.021
25th percentile	0.012	0.009
Minimum	0.002	0.003
Average	0.027	0.017
Median (50thpercentile)	0.021	0.014
Exceedances, %	31.5	12
Number of samples	89	76

Emily Creek is one of the larger Sturgeon Lake tributaries, draining 161 km^2 of land just south of the lake. The major land use in the Emily Creek subwatershed is agriculture (56%). At the same time, forest (15.4%) and wetlands (18.2%) together occupy more than one-third of the drainage area. Emily Creek has a wide and shallow estuary, which extends from County Road 24 up to Hwy 36. Over the period of observation, water quality in the creek was very good with phosphorus concentrations mostly below the PWQO. The average phosphorus concentration in the creek is 0.018 mg/L, with results ranging from 0.006 to 0.039 mg/L ***(Table 7.5).*** The highest readings were usually observed after significant rain events. Similar to other Sturgeon Lake tributaries, the lowest TP concentrations are typically observed throughout late autumn to early spring. Phosphorus levels exceeded the PWQO only in 7% of all samples – the lowest number among all monitored streams in the Sturgeon Lake watershed **(*Table 7.5*).** Extensive swamps and wetlands upstream of the monitoring location significantly decrease phosphorus concentrations in the creek water. Reductions in phosphorous can be attributed to filtering and uptake of phosphorus by marsh vegetation and the settling of suspended solids in the slow-moving water of the estuary.

Since the 1983-1990 period phosphorus concentrations in the creek remained virtually unchanged ***(Table 7.5)***. Both the long-term average and median concentrations changed slightly from 0.021 to 0.018 and 0.017 mg/L respectively. The maximum concentration in 2010-2013 went down from 0.048 to 0.039 mg/L, while the minimum value increased from 0.002 mg/L in 1983-1990 to 0.006 mg/L during the current monitoring period.

Table 7.5. Results of Statistical Analysis of Total Phosphorus Concentrations in Emily Creek for the Periods of 1983-1990 and 2010-2013

Statistical Parameters	**1983-1990**	**2010-2013**
Maximum	0.048	0.039
75th percentile	0.028	0.024
25th percentile	0.016	0.013
Minimum	0.002	0.006
Average	0.021	0.018
Median (50th percentile)	0.021	0.017
Exceedances, %	14	7
Number of samples	94	73

East Cross Creek is one of the two major tributaries of the Scugog River and has a significant influence on water quality in the latter. The East Cross Creek subwatershed extends far south to the Oak Ridges Moraine area. As well, it includes the Stoney Creek subwatershed, which is located to the southwest from Emily Creek, and the Janetville Creek subwatershed.

The major water quality concern through the entire East Cross Creek watershed is elevated concentrations of phosphorus. As well, high levels of nitrates have been detected in the headwaters of the creek. Since the beginning of monitoring activities, phosphorus concentrations in East Cross Creek have mostly exceeded the PWQO. Phosphorus levels in the creek near its mouth (East Cross Creek at River Road) varied from 0.007 to 0.129 mg/L, with an average of 0.044 mg/L ***(Table 7.6***). Maximum values of 0.129 and 0.127 mg/L were observed in May of 2012 and August of 2011 respectively under dry weather conditions. It is possible to conclude that high phosphorus concentrations in East Cross Creek during dry hot weather are the result of phosphorus desorption from bottom sediments in the lower reaches of the creek, which is flowing through a large wetland. Consequently, seasonal distribution of total phosphorus in East Cross Creek is characterized by the highest readings in summer during both high and low flow conditions. The lowest TP concentrations are usually observed throughout late autumn, winter and early spring before snowmelt.

Phosphorus data from the station at Regional Road 57, which is located 9 km upstream, show almost the same results ***(Table 7.6).*** Phosphorus concentrations ranged from 0.016 to 0.161 mg/L with an average of 0.048 mg/L. The median value is a somewhat higher, 0.041 mg/L versus 0.034 mg/L at the River Road location.

Monitoring data collected at both stations during 2005-2013 do not show any apparent temporal trend in total phosphorus levels in East Cross Creek. Continuous regular sampling is required in order to determine if an increasing or decreasing trend exists.

The major land use in the subwatershed is agriculture. Agricultural lands occupy 50% of the subwatershed area. It can be assumed that elevated phosphorus levels in the creek are the result of the cumulative effect of agricultural land use in the subwatershed. As well, local soils can have a significant effect on phosphorus concentrations. Interestingly, there is no notable difference in phosphorus concentrations between the two monitoring locations despite the fact that Stoney Creek, which has elevated phosphorus levels, empties into East Cross Creek three kilometers upstream of the River Road station.

Table 7.6. Results of Statistical Analysis of Total Phosphorus Concentrations in East Cross Creek for the Period of 2005-2013

Statistical Parameters	**East Cross Cr. at RR. 57**	**East Cross Cr. at River Rd.**
Maximum	0.161	0.129
75th percentile	0.060	0.063
25th percentile	0.026	0.021
Minimum	0.016	0.007
Average	0.048	0.044
Median (50th percentile)	0.041	0.034
Exceedances, %	69	53
Number of samples	39	58

Generally, East Cross Creek can be characterized as a eutrophic water body (0.035–0.100 mg/L), according to the CCME classification, with a distinctive increase in phosphorus concentrations in the summer (CCME, 2007).

Mariposa Brook is another large tributary of the Scugog River. It occupies 229 km^2 in the south-western corner of the lake watershed. Similar to the other large subwatersheds, the major land use in the Mariposa Brook subwatershed is agriculture (66%). Despite the high percentage of the agricultural land use, phosphorus levels in the stream are not very high. This may be explained by the influence of local soils, which are mainly poorly drained clay, cay loam and silt clay loam.

During the current monitoring period phosphorus concentrations have mostly been below the PWQO. Only 22% of samples exceeded the 0.03 mg/L benchmark **(*Table 7.7*).** The average phosphorus concentration in the creek is 0.025 mg/L, with results ranging from 0.007 to 0.099 mg/L ***(Table 7.7).*** The highest TP levels are usually observed after significant rain events, but the maximum value of 0.099 mg/L was detected during the spring freshet in 2011. The lowest TP concentrations are typically observed throughout late autumn into early spring.

Data from the four monitoring periods clearly demonstrate that since 1982-1985 phosphorus concentrations in the stream have been decreasing ***(Table 7.7).*** The long-term average was 0.046 mg/L in 1982-1985, 0.030 mg/L in 1986-1990, 0.029 mg/L in 2004-2009 and only 0.025 mg/L in 2010-2013. Each of the maximum concentration, 75th and 25th percentiles as well as median value considerably decreased in 2010-2013 compared to the phosphorus results from 1982-1985. There is no significant difference between the 1986-1990 and 2004-2009 period results.

Table 7.7. Results of Statistical Analysis of Total Phosphorus Concentrations in Mariposa Brook for the Periods of 1982-1990, 2004-2009 and 2010-2013

Statistical Parameters	**1982-1985**	**1986-1990**	**2004-2009**	**2010-2013**
Maximum	0.410	0.115	0.150	0.099
75th percentile	0.045	0.038	0.032	0.030
25th percentile	0.024	0.017	0.018	0.015
Minimum	0.007	0.002	0.006	0.007
Average	0.046	0.030	0.029	0.025
Median (50th percentile)	0.032	0.025	0.026	0.022
Exceedances, %	53.5	40.5	35	22
Number of samples	43	42	43	87

Jennings Creek is a small urbanized watercourse, which drains the western portion of Lindsay and some agricultural lands to the west from Lindsay. The total catchment area of the creek is 16.2 km^2. Agricultural lands occupy a larger portion of the subwatershed at 61%. The second major land use is urban development, which occupies more than 15% of the total area.

Water quality in Jennings Creek is affected by human activities in the subwatershed. Phosphorus levels over the period of monitoring varied from 0.009 mg/L to 0.213 mg/L ***(Table 7.8).***The average phosphorus concentration in the creek for the three-year period is 0.039 mg/L, while the median concentration is 0.026 mg/L. The highest TP readings usually coincide with high flow after significant rain events and during the spring freshet. The lowest phosphorus concentrations were observed during low water periods. Phosphorus levels exceeded the PWQO in 39% of all samples ***(Table 7.8).***

Table 7.8. Results of Statistical Analysis of Total Phosphorus Concentrations in Jennings Creek for the Periods of 1991-1992, 2010-2011 and 2010-2013

Statistical Parameters	1991-1992	2010-2011 Trent U. data*	2010-2013 Kawartha Conservation data
Maximum	0.410	0.453	0.213
75th percentile	0.072	0.076	0.040
25th percentile	0.012	0.025	0.018
Minimum	0.002	0.003	0.007
Average	0.069	0.061	0.039
Median (50th percentile)	0.049	0.043	0.026
Exceedances, %	60	-	39
Number of samples	25	340	79

*Trent University data are obtained from Shanel Raney's Master's thesis (Raney, 2012) and represent the monitoring period from December 2010 to November 2011

Our findings are supported by one-year of intensive monitoring data collected by Shanel Raney, a graduate student from Trent University, for her Master's thesis research (Raney, 2012). Shanel collected more than 300 water samples from Jennings Creek during the December 2010 to November 2011 period, including all stormwater events, which explains why the maximum and average values of that set of data are higher than in the Kawartha Conservation data set ***(Table 7.8).***

Elevated phosphorus levels in the creek reflect the high percentage of agricultural lands in the subwatershed and, more importantly, percentage of urban land use, which is much higher than in other subwatersheds. High percentage of urban lands in the subwatershed determines the flow regime resulting in accelerated runoff and, as a result, higher total suspended solids concentrations and associated phosphorus levels and loads.

The Kawartha Conservation data collected in 1991-1992 for the Rural Beaches Study show much higher phosphorus concentrations ***(Table 7.8).*** These high concentrations can be explained by the time frame when the samples have been collected. In 1991-1992 samples were collected only in the summer that can skew the results and corresponding statistics because phosphorous concentrations are typically higher in the summer period.

The Scugog River is the second largest source of water flowing into Sturgeon Lake. It carries a combined flow from Lake Scugog, Mariposa Brook and East Cross Creek as well as from several small tributaries within the Town of Lindsay. Two monitoring stations are located on the Scugog River. One is located upstream of Lindsay and the other one is downstream of Lindsay ***(Figure 7.1).*** These two sites allow a comparison of water quality in the river above and below the town and help to determine how much phosphorus is coming into the river from the urban area. A significant portion of land adjacent to the river is occupied by the Lindsay urban area.

The average annual TP concentrations in the Scugog River upstream of Lindsay fluctuated from 0.024 mg/L (in 2010-2011 and 2012-2013) to 0.028 mg/L (in 2011-2012) ***(Figure 7.2)*** with a range of individual results from 0.009 to 0.060 mg/L ***(Table 7.9).*** The average annual phosphorus concentrations downstream of Lindsay ranged from 0.031 mg/L in 2011-2012 to 0.033 and 0.034 mg/L respectively in 2010-2011 and 2012-2013. The individual results varied from 0.008 to 0.114 mg/L ***(Table 7.11).***

Table 7.9. Results of Statistical Analysis of Total Phosphorus Concentrations in the Scugog River Upstream of Lindsay for the Periods of 1970-71, 1981-85, 1997-2001, 2004-09 and 2010-2013

Statistical Parameters	1970-1971	1981-1985	1997-2001	2004-2009	2010-2013
Maximum	0.160	0.110	0.072	0.050	0.060
75^{th} percentile	0.062	0.045	0.032	0.029	0.029
25^{th} percentile	0.039	0.024	0.020	0.019	0.017
Minimum	0.002	0.008	0.008	0.011	0.009
Average	0.055	0.036	0.028	0.025	0.025
Median (50^{th} percentile)	0.046	0.031	0.026	0.024	0.024
Exceedances, %	87.5	51	31.5	20.5	23
Number of samples	16	59	54	44	93

The highest readings were observed during spring freshet and in the summer during extended periods of dry and hot weather. Similar to other streams in the watershed the lowest TP concentrations were usually observed throughout late autumn to early spring.

Phosphorus concentrations quite often exceeded the PWQO in both sampling locations with 23% of all samples upstream of Lindsay and 43% downstream of Lindsay showing exceedances **(*Tables 7.9 and 7.11*).** The results from the two monitoring locations along the river indicate that phosphorus levels noticeably increase in the river downstream of Lindsay due to the substantial amount of phosphorus that enters the river in stormwater from the Lindsay urban area.

The long-term monitoring data demonstrate an apparent decreasing trend in phosphorus concentrations in the Scugog River since the 1970s through 1980s, 1990s and 2000s, both upstream and downstream of Lindsay. During the last 10 years since 2004 TP levels have been relatively stable upstream of Lindsay ***(Table 7.9),*** while in the downstream location phosphorus concentrations were decreasing until 2009 but then increased in the 2010-2013 period ***(Table 7.10).***

Table 7.10. Results of Statistical Analysis of Total Phosphorus Concentrations in the Scugog River Outlet Downstream of Lindsay WPCP for the Periods of 1971-75, 1981-85, 1997-2001, 2004-09 and 2010-2013

Statistical Parameters	1971-1975	1981-1985	1997-2001	2004-2009	2010-2013
Maximum	0.800	0.360	0.082	0.055	0.063
75^{th} percentile	0.248	0.078	0.046	0.029	0.036
25^{th} percentile	0.052	0.032	0.027	0.018	0.017
Minimum	0.020	0.013	0.016	0.013	0.008
Average	0.178	0.065	0.038	0.024	0.030
Median (50^{th} percentile)	0.125	0.055	0.033	0.022	0.030
Exceedances, %	95	75	59.5	18	52
Number of samples	44	59	42	45	25

It is interesting to note that during the current monitoring period phosphorus levels have been approximately the same in both downstream locations – downstream of Lindsay but upstream of the Lindsay WPCP and downstream of the Lindsay WPCP ***(Tables 7.10 and 7.11).*** The PWQMN station downstream of the wastewater treatment plant has data dating back to 1971. These data reflect the obvious progress in the wastewater treatment technology over the period of record. While in 1971-1975 the average phosphorus concentration in the river was 0.178 mg/L as a result of the release of the poorly treated wastewater from the sewage lagoons. In the 2004-2009 period this value was only 0.024 mg/L. At the same time, the recent increase in phosphorus concentrations in the Scugog River downstream of Lindsay demonstrates that phosphorus loading from the growing Lindsay urban area increases and considerably influences water quality in the river.

Table 7.11. Results of Statistical Analysis of Total Phosphorus Concentrations in the Scugog River Downstream of Lindsay but Upstream of Lindsay WPCP for the Period of 2010-2013

Statistical Parameters	**2010-2013**
Maximum	0.114
75th percentile	0.040
25th percentile	0.022
Minimum	0.008
Average	0.033
Median (50th percentile)	0.030
Exceedances, %	43
Number of samples	76

Nitrogen

Nitrogen is another key nutrient, which is vital for the development of algae and aquatic plants. Nitrogen is present in surface water in several chemical forms such as ammonia, nitrite, nitrate and organic forms of nitrogen. The nitrite values are usually combined with the nitrate concentrations, as nitrite-ions are the transitional form of nitrogen from ammonia to nitrate-ions that are present in surface water in very low concentrations. Eventually all nitrites in lake or river water are 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 the presence of fresh organic pollution in a water body or the level of phytoplankton development in lake water.

In streams, nitrates often 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. Concentrations of total nitrates in surface water reflect general land use and anthropogenic pressure within the various parts of the watershed.

Within the Sturgeon Lake watershed nitrates occasionally exceed the limit set by the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) at 2.93 mg/L in water of several tributaries, namely McLaren Creek, Jennings Creek, Mariposa Brook and very rarely in the Scugog River **(*Table 7.12*).** At the same time, average nitrate levels in these streams as well as in other tributaries are well below the guideline ***(Figure 7.3).*** While average nitrate concentrations in these streams are below the guideline, the frequency of exceedances is quite high, especially in winter. For example, nitrate values in 20% of all samples from Mariposa Brook (ST11) exceeded the corresponding guideline. In Jennings Creek (ST9) 9% of samples exceeded the guideline. The maximum nitrate concentrations observed in these streams were as high as 4.8 mg/L ***(Table 7.12).***

Table 7.12. Results of Statistical Analysis of Nitrate Concentrations in the Sturgeon Lake Tributaries for the Period of 2010-2013

Stat. Parameters	ST1	ST2	ST3	ST4	ST6	ST7	ST8	ST9	ST10	ST11
Maximum	4.60	0.18	0.33	0.34	0.50	4.50	3.70	4.80	2.30	4.80
75th percentile	1.70	0.07	0.06	0.11	0.07	0.80	0.85	1.85	0.93	2.47
25th percentile	0.17	0.01	0.02	0.02	0.02	0.02	0.03	0.84	0.03	0.35
Minimum	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.13	0.01	0.01
Average	1.02	0.05	0.06	0.08	0.07	0.51	0.58	1.50	0.60	1.68
Median	0.72	0.03	0.03	0.04	0.02	0.13	0.28	1.30	0.27	1.62
Exceedances, %	5.3	0	0	0	0	2.1	1.3	8.9	0	20
Number of samples	75	92	77	76	74	94	77	79	60	87

In the Scugog River nitrate levels are somewhat elevated in comparison with background concentrations, ranging from 0.01 to 4.50 mg/L upstream of Lindsay and from 0.01 to 3.70 mg/L downstream of Lindsay. There is a slight but noticeable increase in nitrate levels in the river downstream of Lindsay. The average nitrate concentration in the Scugog River downstream of Lindsay is 14% higher than upstream of the town (0.58 and 0.51 mg/L correspondingly) and median concentration is more than twice higher (0.28 and 0.13 mg/L respectively). Over the three-year period of monitoring average nitrate concentrations in the Scugog River increased from 0.41 mg/L in 2010-2011 to 0.64 mg/L in 2012-2013 downstream of Lindsay and from 0.32 mg/L in 2010-2011 to 0.66 mg/L upstream of Lindsay ***(Figure 7.3)*.**

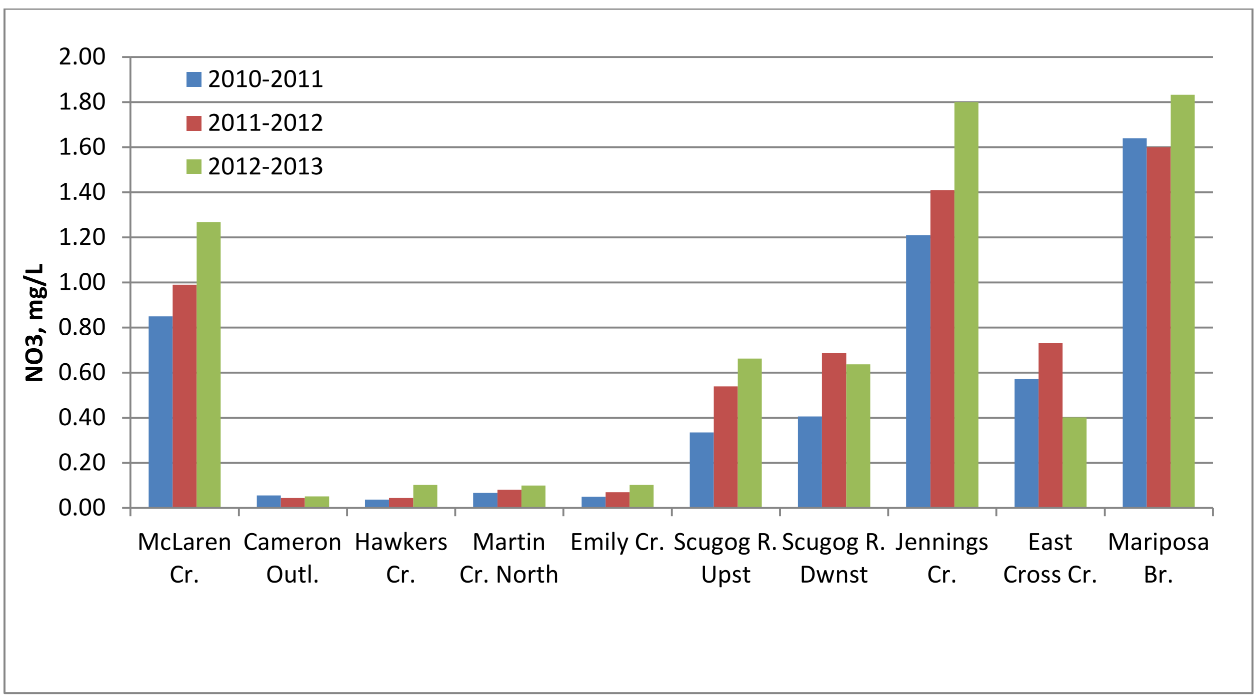


Figure 7.3. Average Nitrate Concentrations in the Sturgeon Lake Tributaries in 2010-2013

Seasonal distribution of nitrates in streams of the watershed is characterized by high concentrations in winter and early spring. In general, the highest levels of nitrates in the lake tributaries were detected in the middle of winter in January and February, when groundwater contributes the most to the flow in tributaries and natural processes of nitrate assimilation are very slow.

Looking at the watershed wide scale one can see that the highest nitrate levels are detected in the three streams in the southwest corner of the watershed, namely Mariposa Brook, McLaren Creek and Jennings Creek. The average nitrate concentrations among these three streams varied from 4.6 mg/L in McLaren Creek to 4.8 mg/L in Mariposa Brook and Jennings Creek ***(Table 7.12).*** Elevated nitrate concentrations were also observed in the upper East Cross Creek subwatershed. All the above-mentioned streams have high percentage of agricultural lands in their subwatersheds.

Examination of the gathered hydrological and hydrochemical information suggests that shallow groundwater in these areas has elevated nitrate levels due to intensive agricultural activities and is the major source of inorganic nitrogen for the aquatic systems of local streams. It is also important to note that nitrate concentrations in these streams generally decrease downstream due to intensive uptake of NO_3^- by aquatic biota. As a result, anthropogenically generated nitrates along with phosphorus play important role in the process of eutrophication of the watercourses.

At the end, it is possible to conclude that the main source of inorganic nitrogen in the southern watercourses of the watershed is groundwater discharge. In turn, high levels of nitrates in shallow groundwater are most likely caused by agricultural activities in the watershed.

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 (CCME, 2003).

Elevated aluminum concentrations have been observed in two streams in the Sturgeon Lake watershed, namely Jennings Creek and Mariposa Brook. As well, aluminum levels considerably increase in the Scugog River downstream of Lindsay from 0.016 to 0.064 mg/L when looking at the average concentrations ***(Table 7.13)***. A significant effect of the Lindsay urban area on water quality in the river is quite obvious in this case.

Table 7.13. Results of Statistical Analysis of Aluminum Concentrations in the Sturgeon Lake Tributaries for the Period of 2010-2013

Stat. Parameters	**ST1**	**ST2**	**ST3**	**ST7**	**ST8**	**ST9**	**ST11**
Maximum	0.044	0.020	0.026	0.039	0.126	0.199	0.162
75th percentile	0.041	0.013	0.009	0.021	0.070	0.167	0.092
25th percentile	0.033	0.001	0.007	0.009	0.048	0.066	0.054
Minimum	0.029	0.000	0.007	0.001	0.029	0.042	0.018
Average	0.037	0.008	0.011	0.016	0.064	0.106	0.076
Median	0.040	0.006	0.008	0.015	0.055	0.084	0.064
Exceedances, %	0	0	0	0	12.5	37.5	17
Number of samples	7	23	5	26	8	8	23

In Jennings Creek the average aluminum concentration is above the CWQGs limit of 0.100 mg/L. This stream has the highest levels of aluminum recorded throughout the observation period with a maximum of 0.199 mg/L and an average of 0.106 mg/L ***(Table 7.13).*** As well, it has the highest number of exceedances above the CWQG at 37.5% of all samples. Only two samples were taken at instances when the pH of the surface water exceeded 8.5 with one at 8.52 and one at 8.53, which is positive news from toxicity to aquatic life standpoint. Mariposa Brook also has high aluminum concentrations, with an average value of 0.076 mg/L and 17% of all samples above the guideline. None of the samples from Mariposa returned pH values above 8.5.

Aluminum concentrations in Jennings Creek are the highest in the watershed that can be explained by more intensive erosion and the effects of urban land use in this subwatershed. In addition, elevated levels of aluminum were detected under high flow conditions and can be easily correlated with high TSS concentrations in the water. It seems that local soils are the major source of this element in Jennings Creek and Mariposa Brook.

No aluminum exceedances were detected in any other tributaries within Sturgeon Lake watershed, which is a very positive finding from a water quality perspective.

Total Suspended Solids

Total suspended solids (TSS) may have significant effects on aquatic organisms because of shading, abrasive action, habitat alteration and sedimentation. Suspended solids or sediments have a significant effect on community dynamics when they interfere with light transmission. Most flowing waters have considerable variation in suspended solids 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: the concentration of suspended solids 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 long term exposure (30 days and more) (CCME, 2002).

Background concentrations of total suspended solids in streams of the Sturgeon Lake watershed are usually 1-2 mg/L. After some rain events, TSS concentrations increase substantially at a few monitoring stations ***(Table 7.14).*** From time to time high TSS levels have been observed in Jennings Creek (station ST9) as a result of a sharp increase in flow volume after storm events. The maximum TSS concentration detected in this watercourse is 130 mg/L, while the average is 13.1 mg/L, which is substantially higher than in other streams in the watershed. As well, 8.9% of samples from this stream had TSS concentrations in excess of 25 mg/L above the background level ***(Table 7.14).*** Another stream where a few TSS exceedances were detected was McLaren Creek with a maximum concentration being at 37 mg/L. The other monitoring stations did not have exceedances. Average and median TSS concentrations in all monitored streams are well below the CCME guideline ***(Table 7.14).*** The lowest TSS concentrations, as it was anticipated, were detected in the water that enters the lake from Cameron Lake (station ST2).

Table 7.14. Results of Statistical Analysis of TSS Concentrations in the Sturgeon Lake Tributaries for the Period of 2010-2013

Stat. Parameters	ST1	ST2	ST3	ST4	ST6	ST7	ST8	ST9	ST10	ST11
Maximum	37.0	3.2	11.0	26.0	8.0	14.8	26.0	130	22.0	15.0
75th percentile	4.0	1.3	3.0	4.0	2.0	6.0	9.0	11.5	5.0	6.9
25th percentile	1.0	0.7	1.0	1.0	1.0	2.0	4.0	2.0	1.0	2.0
Minimum	1.0	0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Average	4.0	1.1	2.3	3.7	1.8	4.3	7.5	13.1	3.8	4.8
Median	3.0	1.0	1.0	3.0	1.0	4.3	7.0	5.5	3.0	3.5
Exceedances,%	3.8	0	0	0	0	0	0	8.9	0	0
Number of samples	53	28	54	53	37	61	57	56	25	46

The Scugog River downstream of Lindsay has the second highest average and median TSS concentrations subsequent to Jennings Creek. As well, the TSS levels significantly increase in the Scugog River downstream of the town.

Chloride

During the period of monitoring chloride concentrations in most tributaries of Sturgeon Lake were considerably below the recently developed CWQG for the Protection of Aquatic Life for Chloride, which is set at 128 mg/L (CCME, 2010). Only seven tributaries have enough data for statistical analysis ***(Table 7.15)***. From those that were analyzed, the only stream that shows chloride concentrations in excess of the CWQG is Jennings Creek, which collects surface runoff from the western portion of the urban area of Lindsay.

Jennings Creek has the highest chloride concentrations in the watershed with an average of 125 mg/L and a range of 61 to 250 mg/L clearly indicating anthropogenic contamination (road salt application) due to urban stormwater runoff ***(Table 7.15).*** Water quality in this stream indicates elevated chloride concentrations in excess of the CWQGs limit. As a result, the stream can have a negative effect on water quality in the Scugog River in addition to the detrimental effect from the Lindsay area storm water runoff. The Scugog River downstream of Lindsay has the highest chloride levels among larger tributaries with an average of 29.3 mg/L and a range of 24 to 37 mg/L showing a noticeable increase in concentrations in comparison with the sampling location upstream of Lindsay ***(Table 7.15).***

Table 7.15. Results of Statistical Analysis of Chloride Concentrations in the Sturgeon Lake Tributaries for the Period of 2010-2013

Statistical Parameters	**ST1**	**ST2**	**ST3**	**ST7**	**ST8**	**ST9**	**ST11**
Maximum	57.0	7.2	13.0	31.0	37.0	250	33.1
75th percentile	26.5	6.7	5.8	26.8	31.3	130	29.9
25th percentile	20.5	5.9	5.6	23.8	25.8	91.3	21.9
Minimum	20.0	5.0	4.1	21.5	24.0	61.0	19.0
Average	27.9	6.3	6.9	25.4	29.3	125	24.6
Median	24.0	6.3	5.8	24.9	29.5	125	24.1
Exceedances,%	0	0	0	0	0	50	0
Number of samples	7	23	5	23	8	8	23

Hawkers Creek has the lowest chloride levels among small and medium tributaries with an average of 6.9 mg/L and a range of 4.1 to 13 mg/L, while the Cameron Lake outlet in Fenelon Falls has the lowest chloride concentrations among the large inlets with an average of 6.3 mg/L and a range of 5.0 to 7.2 mg/L ***(Table 7.15)***. Despite low chloride concentrations in water entering Sturgeon Lake from Cameron Lake, an increasing trend in Cl^- levels was observed since the 1980s, possibly reflecting an increased use of road salt in the watershed **(*Figure 7.4*)**.

Escherichia Coli

The Provincial Water Quality Objective for Escherichia coli (*E. coli*) is based on the recreational water quality guideline established by the Ontario Ministry of Health for swimming and bathing beaches (MOEE, 1994). *E. coli* characterizes bacteriological contamination of surface or ground water. *E. coli* was selected for the guideline because it was found that *E. coli* is the most suitable and specific indicator of fecal contamination (MOEE, 1994). The PWQO is set at 100 colony forming units per 100 mL (cfu/100 mL) and based on a geometric mean of at least five samples.

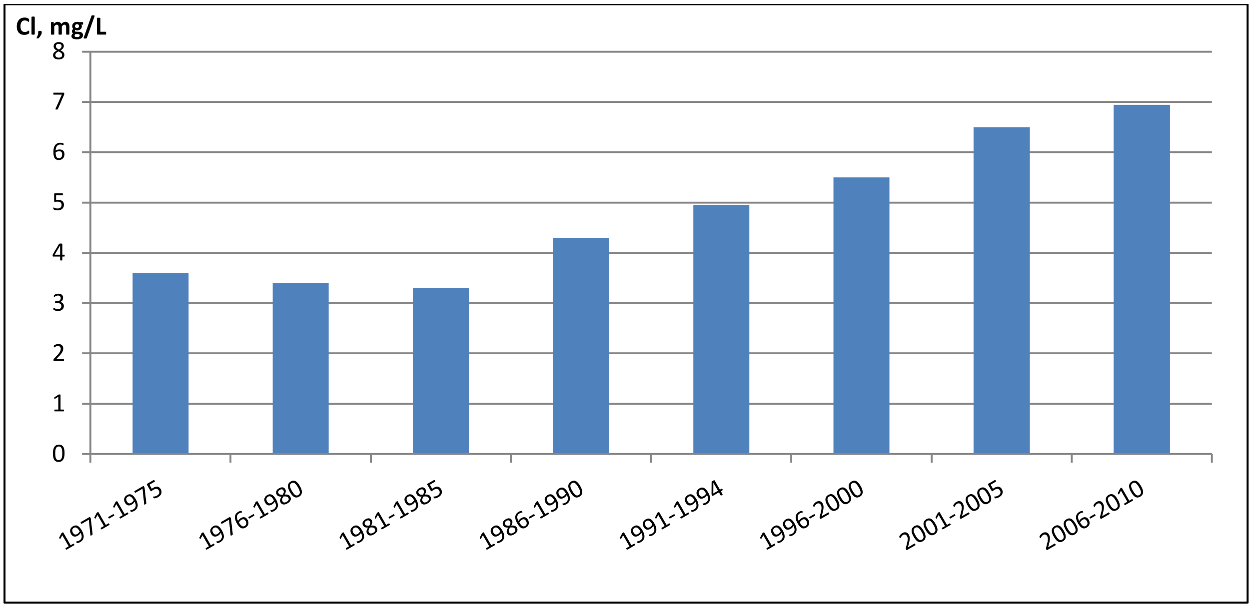


Figure 7.4. Average Chloride Concentrations at the Cameron Lake Outlet in 1971-2010

E. coli monitoring results from 2011-2013 have revealed that most streams in the watershed usually had *E. coli* levels below the PWQO, except for a couple of streams in which *E. coli* concentrations may be a concern. In Jennings Creek, the geomean *E. coli* concentration was 189 cfu/100 mL in 2011, 387 in 2012 and 187 in 2013 ***(Figure 7.5).*** Furthermore, *E. coli* concentrations exceeded the PWQO in 63% of water samples collected from the creek in 2011, in 89% of samples in 2012 and in 75% of samples in 2013. In 2012, the maximum E. coli concentration reached 2240 cfu/100 mL; that being the highest value observed in three years of monitoring across the watershed.

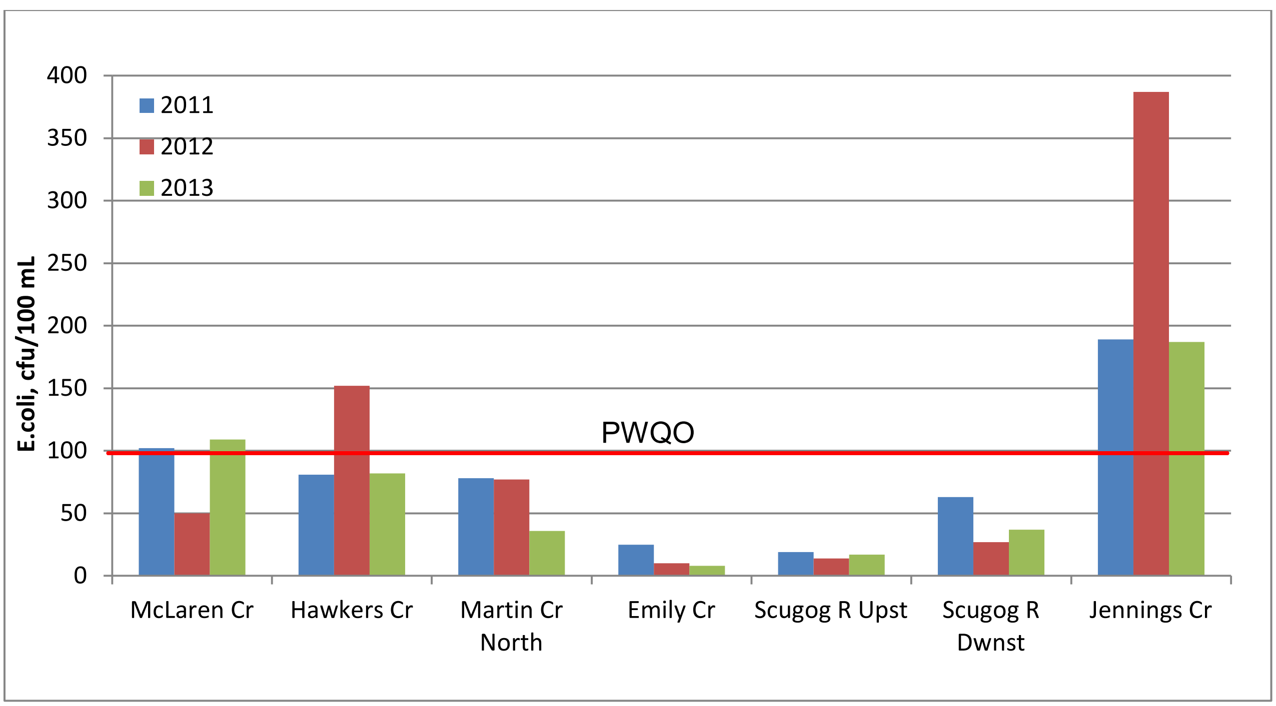


Figure 7.5. Geomean E. coli Concentrations in Sturgeon Lake Tributaries in 2011, 2012 and 2013

In McLaren Creek the geomean *E. coli* concentration exceeded the PWQO in 2011 and 2013, while in Hawkers Creek only in 2012. *E. coli* concentrations occasionally exceeded the PWQO in all streams, generally following intensive rain events. In 2012, dry weather samples from several streams (e.g. Jennings Creek, Hawkers Creek and Martin Creek North) have shown *E. coli* concentrations in excess of the PWQO, in some cases extremely high that may be the result of low water volumes and, consequently, increased stream vulnerability to contamination from natural and human-induced sources. In the three-year monitoring period no *E. coli* exceedances were detected in Emily Creek and the Scugog River upstream of Lindsay.

7.5 Lake Water Quality

Overall, Sturgeon Lake can be characterized as a mesotrophic water body. This conclusion is based on phosphorus concentrations in the lake water in recent years, the intensity of aquatic vegetation development and Secchi disk depth readings. According to the Canadian Council of Ministers of the Environment (CCME) classification, a lake can be defined as a mesotrophic water body if it has total phosphorus concentration less than 20 µg/L during the open water period (CCME, 2007). During the 2010-2012 monitoring period phosphorus levels in Sturgeon Lake were generally below the above-mentioned limit ***(Figure 7.6).*** However, the southern portion of the lake (from the Scugog River mouth to Ball Point) can be placed into a meso-eutrophic category according to the CCME classification. The average annual phosphorus concentration in that part of the lake is usually above the 20 µg/L limit.

Water quality in Sturgeon Lake is determined by a number of abiotic and biotic factors. Among abiotic factors it is necessary to mention the hydrological regime, lake water levels, shoreline development and population density along the shoreline. As well, meteorological conditions at any given year play an important role in the water quality configuration. The amount of precipitation, solar radiation, number of sunny and cloudy days, wind conditions, and average annual air temperature all has a significant effect on water quality in the lake.

Biotic factors are also very important for water quality in Sturgeon Lake. These factors include bottom sediments and conditions at the water-sediment interface, the amount and consumption rates of dissolved oxygen in different layers of water, the amount of macrophytes, algae and phytoplankton in the lake and competition between them for nutrients, light and oxygen. The lake depth can have a considerable effect on the amounts of phosphorus and nitrogen in the water and their movement through the water column.

Sturgeon Lake can be divided into three portions: the north-western arm, southern arm and north-eastern arm. These three parts of the lake have quite different hydrographical features and hydrological regimes. As a result, the hydrochemical regime is determined to a high degree by the hydrography and hydrology of the three portions of the lake. The hydrochemical regime is also influenced by abiotic anthropogenic factors including the urban areas of Lindsay and Fenelon Falls, private septic systems near the shoreline as well as a considerable influx of nutrients from some local tributaries. As a result, the southern arm of the lake always has higher phosphorus and nitrogen concentrations and has remarkably more aquatic vegetation compared to the deeper north-western and north-eastern arms. This condition is aggravated by the shallowness of the southern portion and considerable load of phosphorus from the Lindsay urban area via the Scugog River.

The north-western arm of Sturgeon Lake extends from Fenelon Falls to Sturgeon Point. A huge amount of water from Cameron Lake passes through this part of the lake annually and has a significant effect on water quality there. The monitoring stations near Sturgeon Point (SL2), located near the centre of the lake, and south of Fenelon Falls (SL3), located approximately 4 km downstream of the Cameron Lake outlet in Fenelon Falls, represent water quality in this part of Sturgeon Lake.

Average annual phosphorus concentrations at station SL3 ranged from 7.3 µg/L during the summer of 2012 to 9.7 µg/L in the summer of 2010. At station SL2 phosphorus levels were higher, possibly under the influence of the water from the southern arm of the lake. Average TP concentrations at this location ranged from 11.5 µg/L in 2012 to 13.0 µg/L in 2011. Actually, in 2012 all monitoring stations across the lake, but the Sturgeon Lake outlet, have shown relatively low phosphorus levels ***(Figure 7.6)***.

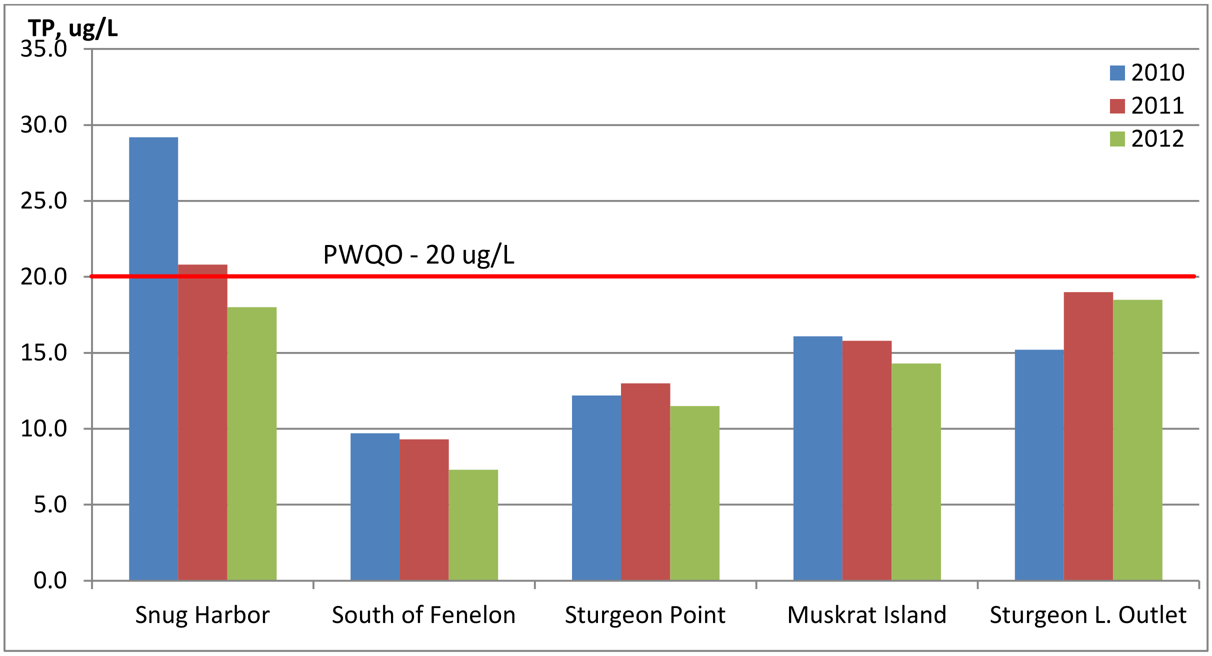


Figure 7.6. Average Phosphorus Concentrations in Sturgeon Lake during the May-September Period in 2010-2012 in Comparison with the PWQO

Over the monitoring period, phosphorus levels downstream of Fenelon Falls fluctuated from as low as 6 µg/L during July-August of 2012 to as high as 12 µg/L in June of 2011 and July of 2010. Phosphorus levels in this part of the lake appear to be highest at the beginning of summer (June) as a result of spring turnover and a considerable influx of well-mixed water from Cameron Lake. However, the highest TP concentrations near Sturgeon Point were observed every year in September (15.0, 20.0 and 17.0 µg/L in 2010, 2011 and 2012 correspondingly).

It is important to note that while phosphorus concentrations are relatively low at monitoring stations in the middle of the lake, at the nearshore zone they can be much higher. Our monitoring data from Scugog Lake demonstrated that while average TP concentrations were 15-20 µg/L in the middle of the lake, the nearshore average TP levels fluctuated from 29.8 to 45.3 µg/L in 2007-2008 (Kawartha Conservation, 2010).

Total nitrogen (TN) concentrations are quite low in the north-western arm of the lake ***(Figure 7.7).*** In 2010, at station SL3 total nitrogen levels ranged from 0.21 mg/L in September to 0.43 mg/L in May. In 2011 and 2012 nitrogen concentrations were lower, ranging from 0.13 mg/L to 0.31 mg/L. At station SL2 total nitrogen concentrations ranged from 0.22 mg/L in August 2012 to 0.51 mg/L in September 2010. It is difficult to determine an apparent seasonal pattern in total nitrogen concentrations.

Organic nitrogen (TKN minus ammonia) constitutes most of the total nitrogen amount in the lake water, ranging from 54% of TN amount in May to 95% during summer and early autumn.

Nitrate levels tend to be higher in winter and early spring, up to 0.22 mg/L. During summer and autumn nitrate concentrations are often below the laboratory detection limit (0.02 mg/L) or in the range just above the limit – 0.02-0.05 mg/L.

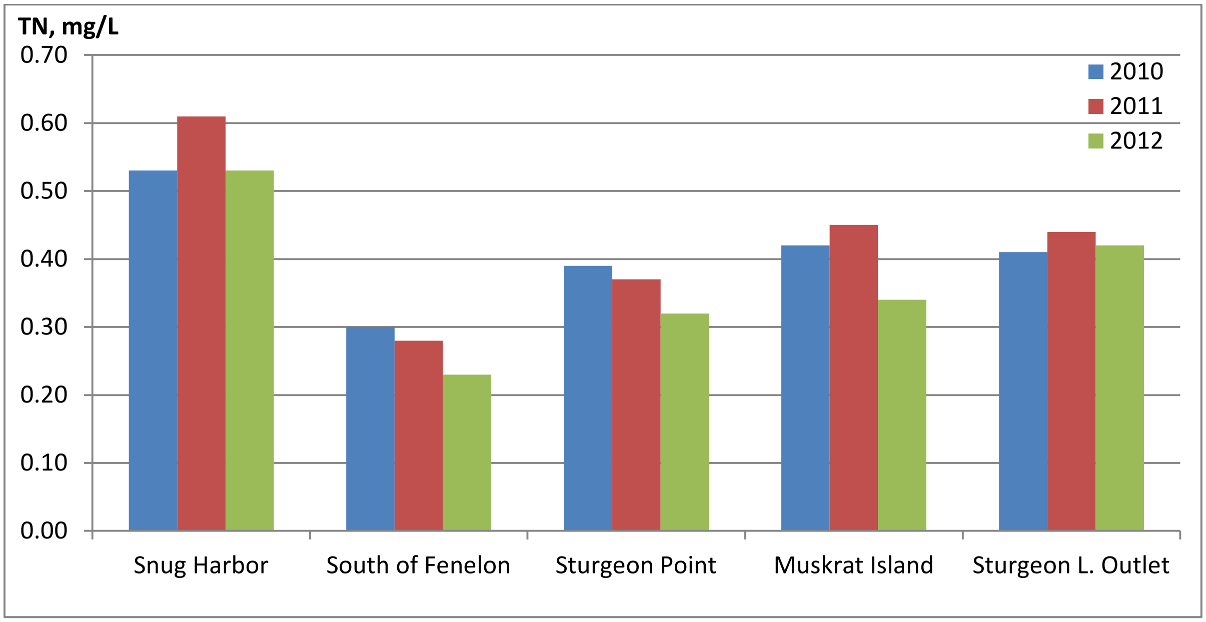


Figure 7.7. Average Total Nitrogen Concentrations in Sturgeon Lake during the May-September Period in 2010-2012
*No guideline exists for total nitrogen.

The north-eastern arm of the lake extends from Sturgeon Point all way to the Sturgeon Lake outlet in Bobcaygeon. This portion of the lake receives inflow from several large tributaries, namely Emily Creek, Hawkers Creek and Martin Creek North. The waters of Cameron Lake and the Scugog River are also passing through this portion of the lake towards Pigeon Lake. Many lakeside communities are located along the shores of this part of the lake.

Two monitoring stations represent the north-eastern portion of the lake: Muskrat Island (SL1) and Sturgeon Lake outlet in Bobcaygeon (ST5).

Phosphorus concentrations in the north-eastern arm of Sturgeon Lake varied between 8.0 and 32 µg/L at two stations during the summers of 2010-2012. The average phosphorus level near Muskrat Island was the highest in 2010 (16.1 µg/L). Near the lake outlet the average TP concentration was the highest in 2011 (20.2 µg/L). During the summer of 2011, when a blue-green algae bloom developed in the entire north-eastern part of the lake, phosphorus levels fluctuated from as low as 9.0 µg/L in the middle of May to as high as 29 µg/L in the beginning of September. Generally speaking, phosphorus concentrations were much higher in 2011 compared to 2010 ***(Figure 7.8).*** It appears that, combined with a considerable influx of phosphorus with stormwater runoff after heavy rainfall at the end of July and hot still weather in the beginning of August, these elevated TP levels were a significant contributor to the widespread blue-green algae bloom that developed in the beginning of August and lasted for three weeks.

The entire north-eastern arm of the lake from Sturgeon Point to Bobcaygeon was affected. During the bloom and after it, phosphorus concentrations were in the 20-29 µg/L range. It appears that under some weather conditions, blue-green algae blooms can be triggered by phosphorus concentrations that are lower than the PWQO for lakes (20 µg/L). In this case, it seems that the trigger point was somewhere around 17 µg/L. It would be beneficial to consider the possibility of establishing a draft interim guideline for Sturgeon Lake as per Policy 1 of the MOE's *Water Management –Policies, Guidelines, Provincial Water Quality Objectives*; but more study is needed. Blue-green algae blooms in Sturgeon Lake can present a serious danger for lake ecosystem health as well as for shoreline residents' recreational water use. As well, it can be a serious concern for the Bobcaygeon and Southview Estates WTPs that draw water from the lake.

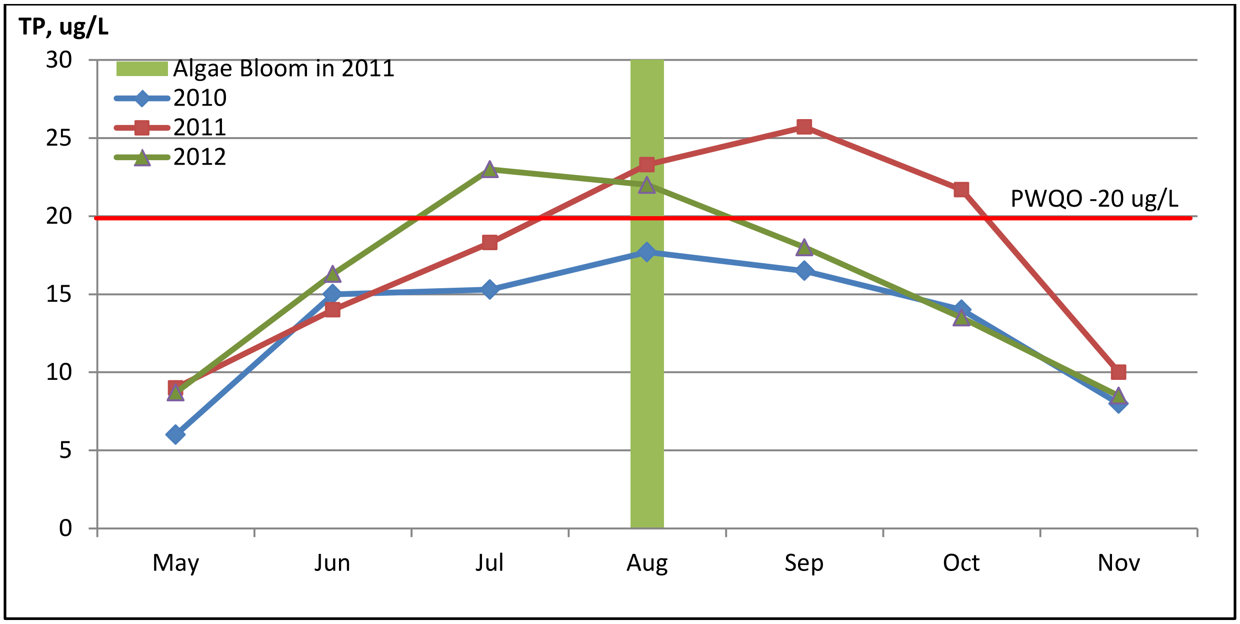


Figure 7.8. Monthly Average Phosphorus Concentrations at the Sturgeon Lake Outlet in 2010, 2011 and 2012

In 2012, a small-scale short-lived blue-green algae bloom was noticed in the beginning of June in the vicinity of Muskrat Island close to the northern shore (Hawkers Bay).

The long-term data collected through the PWQMN program at the Sturgeon Lake outlet demonstrate that phosphorus concentrations in the lake was steadily decreasing since the 1970s until the 2000s ***(Table 7.16)***.

Table 7.16. Results of Statistical Analysis of Total Phosphorus Concentrations at the Sturgeon Lake Outlet During May-October Period for the 1971-1975, 1981-1985, 1990-1994, 1997-2001, 2004-2009 and 2010-2013 Monitoring Periods

Statistical Parameters	**1971-1975**	**1981-1985**	**1990-1994**	**1997-2001**	**2004-2009**	**2010-2013**
Maximum	0.054	0.093	0.067	0.046	0.024	0.032
75th percentile	0.034	0.035	0.025	0.024	0.019	0.022
25th percentile	0.021	0.017	0.014	0.012	0.013	0.012
Minimum	0.012	0.008	0.010	0.006	0.009	0.004
Average	0.029	0.029	0.022	0.019	0.016	0.017
Median (50th percentile)	0.027	0.022	0.020	0.019	0.016	0.017
Exceedances, %	84	54	39	30	15	30
Number of samples	32	41	28	30	34	53

In recent years there is some indication that the decreasing trend can be reversed and phosphorus concentrations can begin to increase. While during the 2010-2013 period average and median TP concentrations, from a statistical point of view, stayed basically the same as during the previous 2004-2009 period, the number of exceedances has doubled, from 15 to 30% ***(Table 7.16).***

In the north-eastern arm of the lake total nitrogen concentrations fluctuated in the range of 0.27-0.58 mg/L. The highest concentrations were observed in 2011 resulting in average concentrations 0.44-0.45 mg/L ***(Figure 7.7).*** In 2012, similar to the north-western part, nitrogen concentrations were lower, ranging from 0.27 mg/L to 0.49 mg/L. Organic nitrogen also constituted most of the total nitrogen amount in the water, ranging from 51% of TN amount in May to 95-96% in August-September. Similar to the north-western arm, nitrate concentrations were much higher in winter and spring (0.10-0.46 mg/L). During summer and autumn nitrate levels usually fluctuated in the range of 0.007-0.080 mg/L.

Average phosphorus concentrations in the southern arm of Sturgeon Lake varied between 18.0 (2012) and 34.8 µg/L (2010) based on the results from the monitoring station near Snug Harbor. During 2010, phosphorus levels fluctuated from as low as 14.0 µg/L in July to as high as 81.0 µg/L in May. In 2012, the lowest detected TP concentration was 8.0 µg/L in August and the highest level of 35.0 µg/L was observed in June. The available data demonstrate that the lowest phosphorus concentrations were usually detected in July-August, when the macrophyte growth and orthophosphate consumption is the most intensive. Total suspended solids and suspended forms of phosphorus also settle much quicker in dense vegetation. The highest TP levels observed in May-June resulted from phosphorus input from the Scugog River flow, which is at the maximum in spring.

In the southern arm of the lake total nitrogen concentrations were observed in the range from 0.30 to 0.80 mg/L. The highest average concentration was in 2011 and reached 0.61 mg/L ***(Figure 7.7).*** In 2010 and 2012, total nitrogen levels were lower, averaging at 0.53 mg/L during both summers.

In all analyzed water samples organic nitrogen constitutes most of the total nitrogen amount ranging from 64% of TN amount in May to 97% in August. The highest nitrate concentration of 0.20 mg/L was observed in May 2010. As in other parts of the lake, nitrate levels are very low during summer and autumn – from below the laboratory detection limit (0.02 mg/L) to 0.08 mg/L.

We conducted intensive *E. coli* sampling in two residential canals on Sturgeon Lake, namely South Bayou Canal and Pleasant Point Canal ***(Figure 7.9).*** In May, June and August 2011, fifteen water samples (five per sampling event) were collected from each canal. *E. coli* levels were below 50 cfu/100 mL in all samples. The geometric mean was 16.2 cfu/100 mL in South Bayou Canal and 10.4 cfu/100 mL in Pleasant Point Canal. Despite the presence of some Canada geese near the canals *E. coli* levels were very low.

The Haliburton, Kawartha, Pine Ridge (HKPR) District Health Unit monitors bacteriological contamination at seven beaches on Sturgeon Lake ***(Figure 2.1).*** In order to ensure that Sturgeon Lake beaches are safe for swimming, the Health Unit inspectors collect water samples for *E. coli* analysis every week from the beginning of June until the end of August.

The Health Unit *E. coli* data for 2010-2012 demonstrate that while in some locations (Long Beach, Sturgeon Point) bacteriological water quality was excellent, in others (Beach Park and Riverview Park in Bobcaygeon) there were serious concerns about water quality and swimming safety ***(Table 7.17).***The Health Unit *E. coli* data from 1997-2004are presented in ***Table 7.18*** for comparison.

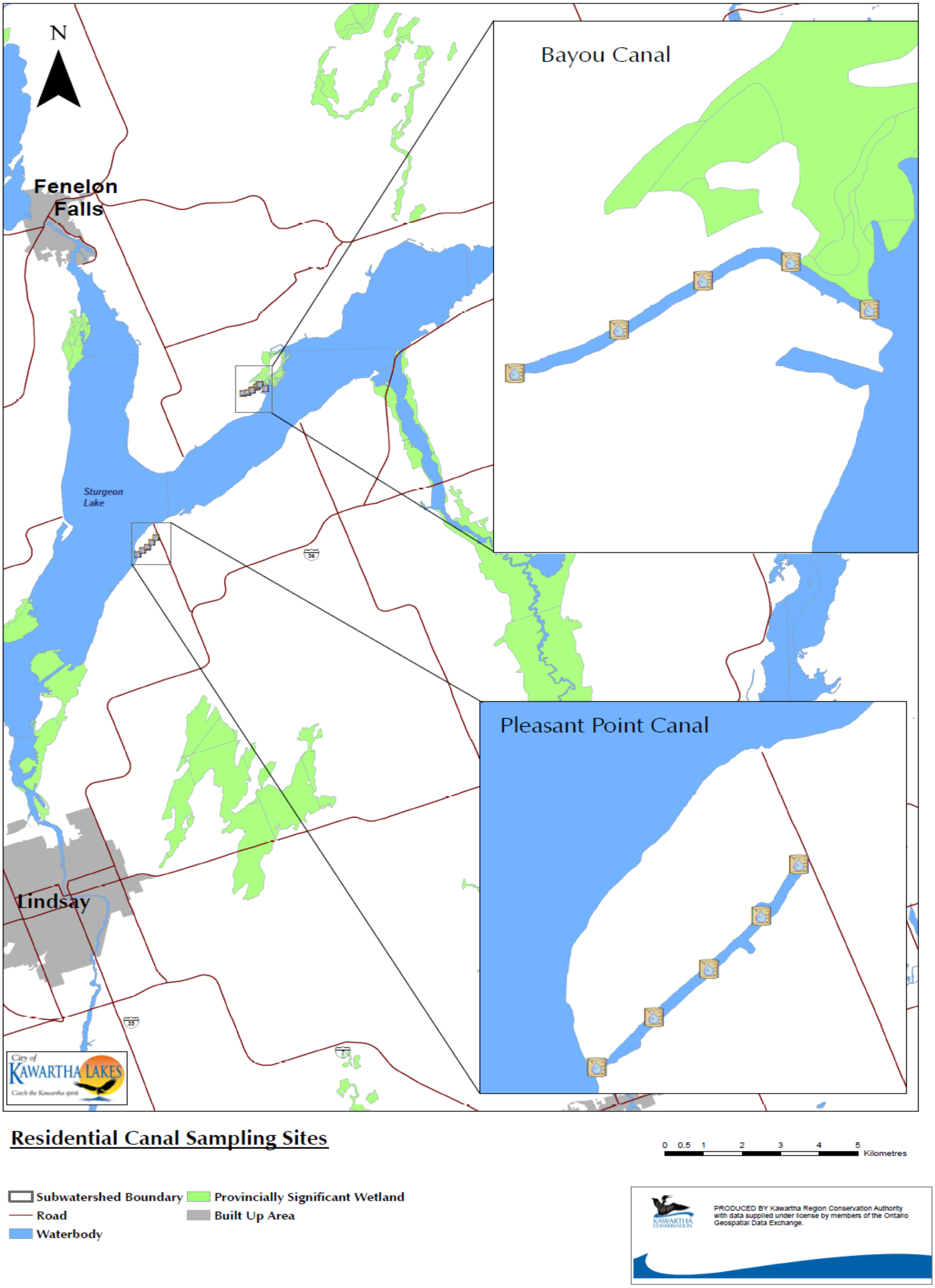


Figure 7.9. Sturgeon Lake Residential Canal E.coli Sampling Sites

Table 7.17. E.coli Concentrations at the Sturgeon Lake Beaches in 2010 - 2012

Beach	Location	2010		2011		2012	
		Geomean, cfu/100mL	Exceed-ences, %	Geomean, cfu/100mL	Exceed-ences, %	Geomean, cfu/100mL	Exceed-ences, %
Beach Park	Bobcaygeon	55	31	75	36	57	31
Riverview Park	Bobcaygeon	39	30	47	27	21	0
Centennial	Verulam	15	0	23	10	16	0
Verulam Park	Verulam	21	10	28	12	21	15
Sturgeon Point	Sturgeon Point	13	0	12	0	13	0
Long Beach	Long Beach	16	0	13	0	13	0
Ken Reid Beach	Ken Reid CA	27	18	20	0	-	-

During the last three years the Beach Park location in Bobcaygeon has had the worst water quality among seven beaches with the annual geomean *E. coli* concentration exceeding 50 cfu/100 mL ***(Figure 7.10).*** *E. coli* concentrations at this location exceeded the PWQO in 31% of samples in 2010, in 36% of samples in 2011 and in 31% of samples in 2012 that often resulted in beach posting ***(Table 7.17).*** The beach at Riverview Park in Bobcaygeon was also often posted in 2010-2011 (30 and 27%) but surprisingly had no exceedances in 2012. The remaining beaches had low *E. coli* levels that occasionally exceeded the provincial objective.

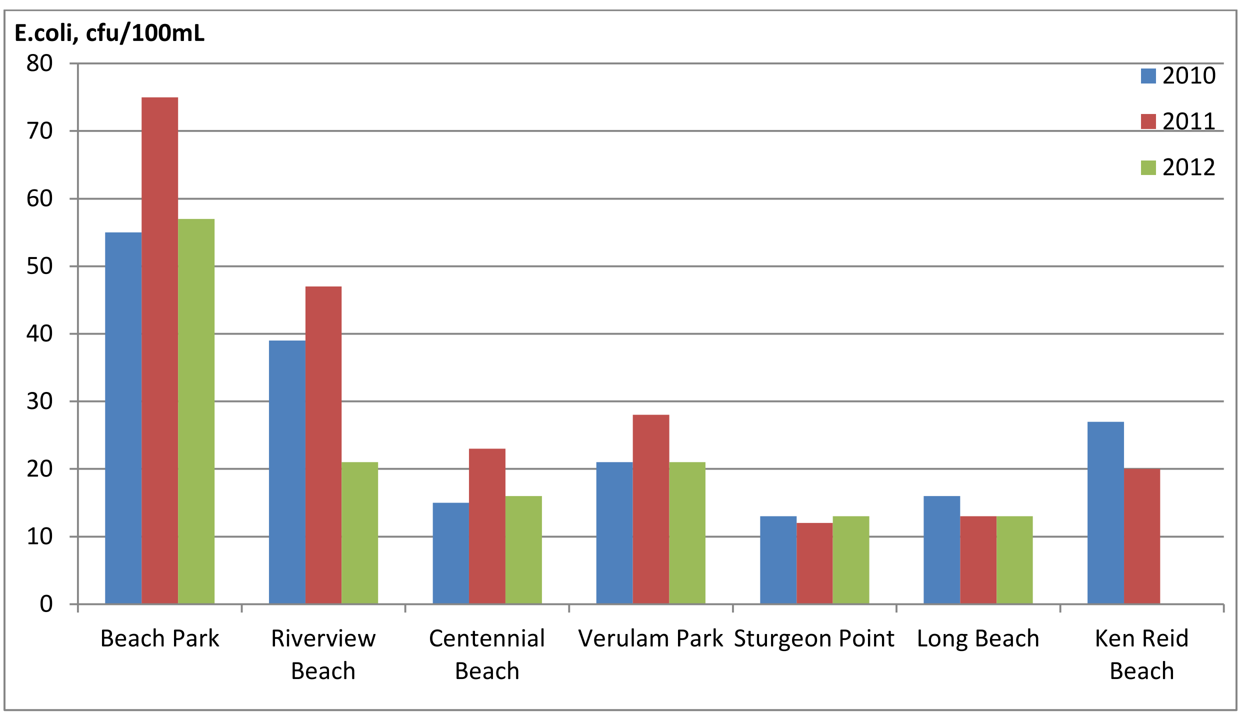


Figure 7.10. Annual Geometric Mean E. coli Concentrations at the Sturgeon Lake Beaches

Table 7.18.E.coli Concentrations at the Sturgeon Lake Beaches in 1997 - 2004

	1998		**1999**		**2000**		**2001**		**2002**		**2003**		**2004**	
Beach	Geomean, cfu/100 mL	Exceedences, %	Geomean, cfu/100 mL	Exceedences, %	Geomean, cfu/100 mL	Exceedences, %	Geomean, cfu/100 mL	Exceedences, %	Geomean, cfu/100 mL	Exceedences, %	Geomean, cfu/100 mL	Exceedences, %	Geomean, cfu/100 mL	Exceedences, %
Beach Park, Bobcaygeon	90	36	77	40	18	0	80	27	39	0	35	9	44	14
Riverview Park	88	10	53	0	10	0	31	11	43	0	185	45	140	43
Centennial Park	11	0	n/d		67	25	16	0	172	33	42	10	26	0
Ken Reid Conservation Area	12	0	18	0	17	0	22	0	13	0	26	0	28	0
Long Beach	n/d*		n/d		n/d		39	20	16	0	13	0	11	0
Sturgeon Point	25	0	10	0	48	33	61	33	12	0	11	0	14	0
Hickory Beach	17	0	n/d		14	0	60	9	n/d		14	0	18	0
Thurstonia Public Beach	68	17	n/d		48	0	23	0	42	25	64	9	14	0
Thurstonia Government Dock	32	13	n/d		46	25	16	0	30	0	54	9	10	0

*n/d – no data

Each summer the Kawartha Lake Stewards Association conducts *E. coli* testing at eight locations across Sturgeon Lake. Their data also demonstrate that bacteriological water quality in the lake is generally good with samples from only one location (NS3) frequently having *E. coli* concentrations above the PWQO (KLSA, 2010, KLSA, 2011, KLSA, 2012).

7.6 Lake Sediment Quality

Bottom sediments are an important part of any aquatic ecosystem. Sediments are the living environment for benthic organisms that are a food source for many fish species. Bottom sediments are formed as a result of the interaction between minerals, aquatic plants and benthic organisms. Remnants of aquatic plants and organisms (detritus) are accumulated on the lake bottom as well as suspended sediments that have been brought into the lake with river flow and surface runoff from urban and agricultural areas. Furthermore, bottom sediments accumulate chemicals including nutrients (carbon, nitrogen and phosphorus), iron, aluminum and other metals as well as various micropollutants, e.g. pesticides, hydrocarbons etc. During the last century, as a result of human activities, many new contaminants found their way into aquatic ecosystems and have accumulated in bottom sediments.

Human-induced organic and inorganic pollutants are a substantial threat to the health of aquatic ecosystems and many of them are extremely toxic and dangerous to aquatic life and human health. In many Canadian rivers and lakes contaminated sediments are a widespread and serious problem. A number of compounds being investigated are very persistent, such as the Organochlorinated Pesticides (OCPs), Polychlorinated Biphenyls (PCBs) and some metals, which may have been released into the environment years ago but are still dangerous for biota and humans.

Over the last century, Sturgeon Lake has experienced some pressure from human activities within its watershed, especially in the Lindsay urban area. As a result, bottom sediments in the lake were heavily contaminated by PCBs in the past. Currently, all previous point sources of the PCB contamination have been eliminated. As for the other contaminants, such as heavy metals and Polycyclic Aromatic Hydrocarbons (PAHs), it is possible that more and more will accumulate in the lake, as human impacts on the Sturgeon Lake watershed increase. Lake sediments may serve as a contaminant reservoir and source of water pollution. Contaminated sediments can significantly impact the benthic environment and, as a result of bioaccumulation, some contaminants can work their way up the food chain.

In 2011, in partnership with the MOE, Peterborough District Office, Kawartha Conservation initiated a sediment sampling study, which was aimed to enhance and refresh current knowledge about toxic contaminants in the bottom sediments of Sturgeon Lake. This study evaluated the condition of sediments in the nearshore areas with regard to the presence of selected organic (PAHs, PCBs and OCPs) and inorganic (metals) contaminants. As well, sediment samples have been analyzed for total organic carbon (TOC), total organic nitrogen (TKN) and total phosphorus (TP). Sediment samples were collected from five monitoring locations in the south-western part of the lake in July 2011 and from seven sites across the eastern portion of the lake in September 2012 ***(Figure 7.11).***

Elevated concentrations of organochlorinated pesticides (DDE, H-Epoxide) and PCBs in excess of the corresponding guidelines have been detected in sediment samples from two sampling locations, SD3 and SD4 in the southern part of the lake ***(Figure 7.11).*** These contaminants are especially dangerous for aquatic organisms, waterfowl and humans as they can be biomagnified as they move up the food chain. Some of these chemicals are infamous carcinogens and all of them capable of causing severe health effects in humans as well as in wildlife.

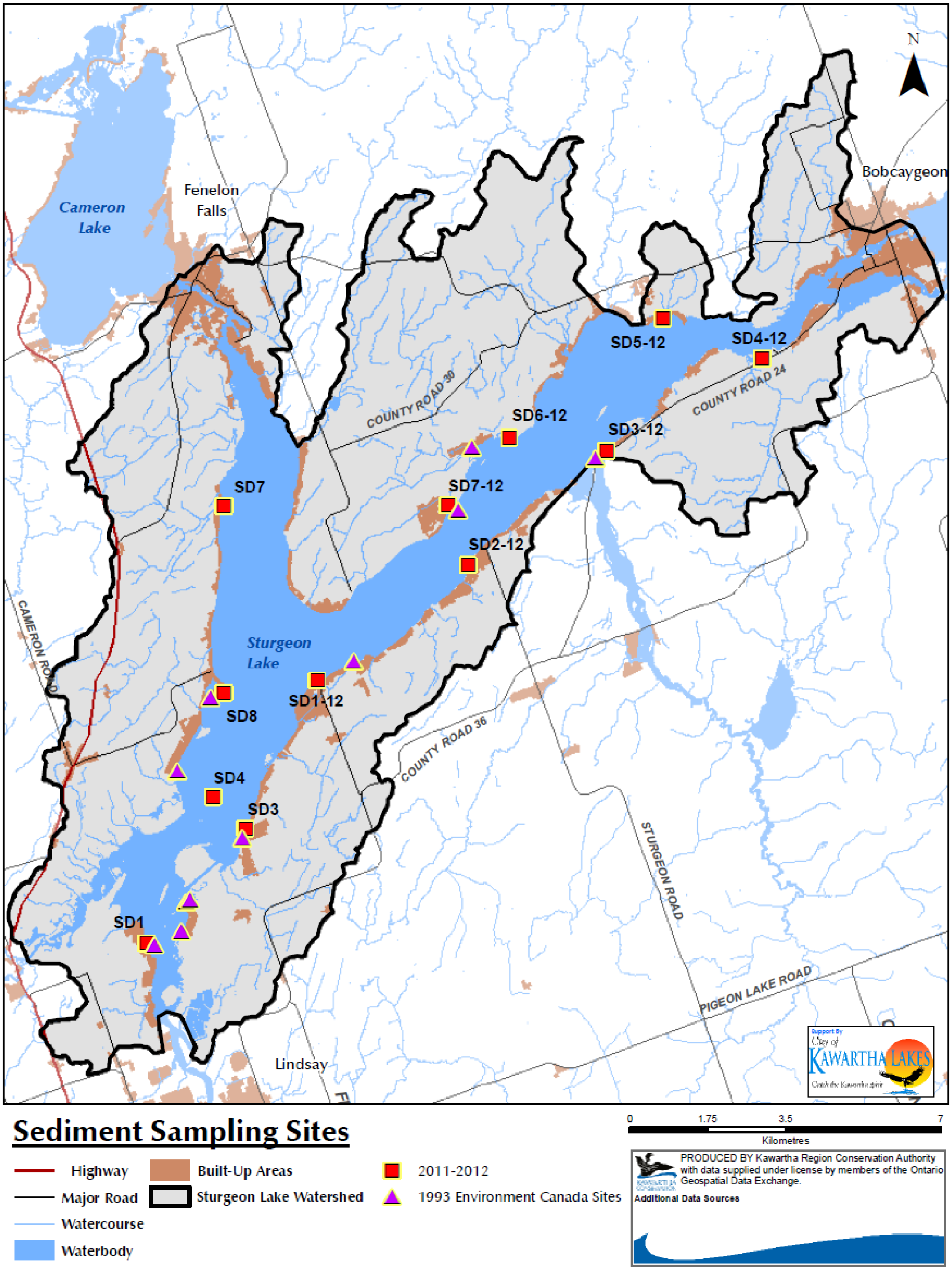


Figure 7.11. Current and Historical Sediment Sampling Locations at Sturgeon Lake

DDE is the breakdown product of DDT. As no DDT was detected in sediment samples and only quite low concentrations of DDE and DDD (another breakdown product of DDT) it means that the contamination has a historical origin.

As a result of historical contamination, elevated PCB concentrations in the southern portion of the lake still continue to be a serious threat to the health of aquatic life in the lake. Trace amounts of PCBs have been detected in sediments from nine other sampling sites ***(Table 7.19).***

Some other pollutants are also widely present in Sturgeon Lake sediments. Polycyclic Aromatic Hydrocarbons are a large group of toxic chemicals that are product of the incomplete burning of oil, coal, gas, wood and garbage. Many are carcinogenic and have other undesirable effects on human health. Concentrations of individual PAHs measured in sediment samples are presented in ***Table 7.20***, along with the Canadian Sediment Quality Guidelines (CSeQGs) and Ontario Sediment Quality Guidelines (where applicable). PAH concentrations above the provincial and federal sediment guidelines have been detected in sediment samples from seven stations ***(Table 7.20).***

Table 7.19. Organochlorinated Pesticides and PCBs Concentrations in Sturgeon Lake Sediments, (ng/g)

Parameter	OSeQGs, ng/g	Monitoring Station and Sample ID											
		SD1	SD3	SD4	SD7	SD8	SD1-12	SD2-12	SD3-12	SD4-12	SD5-12	SD6-12	SD7-12
Total PCBs	70	6.0	550	280	n/d	7.0	6.0	8.0	5.0	18	6.0	7.0	38
Total DDT	7.0	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	2.0	n/d	1.0	2.0
DDD	3.54*	n/d	2.0	3.0	n/d	n/d	n/d	n/d	n/d	1.0	n/d	n/d	1.0
DDE	1.42*	n/d	2.0	3.0	n/d	n/d	n/d	n/d	n/d	1.0	n/d	n/d	2.0
H-Epoxide	5.0	n/d	11	6.0	n/d	n/d	1.0	n/d	1.0	1.0	1.0	1.0	1.0
Endrin	3.0	n/d	n/d	n/d	n/d	n/d	1.0	n/d	n/d	1.0	1.0	1.0	1.0

OSeQGs - Ontario Guidelines for the Protection and Management of Aquatic Sediment Quality, Lowest Effect Level
* Canadian Sediment Quality Guidelines for the Protection of Aquatic Life
Concentrations above the guideline are highlighted in yellow, n/d – not detected

Analysis of PAH distribution in Sturgeon Lake has revealed that elevated PAH concentrations are observed in the area downstream of Lindsay, which is affected by urban stormwater runoff (stations SD3 and SD4), in areas with an intensive boat traffic (stations SD2-12 and ST7-12) and in one location without any obvious human effects (ST4-12) ***(Figure 7.11).*** The highest concentration of total PAHs was detected in the sediment sample collected from station SD2-12 (25,825 µg/kg) ***(Table 7.20).*** Concentration of total PAHs at SD2-7 was more than six times above the corresponding guideline. Moreover, all 15 individual PAH parameters exceeded corresponding guidelines. It is important to note that sediments at this location have low organic matter content (TOC is only 20 mg/g or 2.0% and TKN is only 1.1 mg/g) which emphasizes severe sediment contamination. Fourteen individual PAHs exceeded the corresponding guidelines at station SD4-12, which does not have any plausible explanation. Concentration of total PAHs at this station (8,667 µg/kg) also exceeded the OSeQGs. At stations SD1, SD7, SD8, SD1-12, SD3-12, SD5-12 and SD6-12 PAHs have been detected in sediments in very low concentrations, mostly below the guidelines.

Elevated concentrations of some metals in sediments are indicators of anthropogenic contamination. Many heavy metals are toxic and have adverse effects on aquatic organisms as well as on humans. Some metals, such as cadmium and mercury, similar to other contaminants, can be biomagnified through the food chain. Cadmium and mercury are toxic to aquatic organisms in very low concentrations and can bioaccumulate in mussels and fish (CCME, 1999). They also impair development of fish and benthics, reduce fertilization and increase mortality. Lead is toxic relatively low concentrations and affects the central nervous system of aquatic organisms. Adverse biological effects of elevated concentrations of lead include increased lethality, decreased benthic invertebrate abundance and diversity as well as abnormal development (CCME, 1999). Copper and zinc are essential trace metals that are toxic to aquatic biota at elevated concentrations. These elements can cause behavioural changes in benthic invertebrates as well as decreasing their diversity and abundance (CCME, 1999).

Table 7.20. PAHs Concentrations in Sturgeon Lake Sediments, (µg/kg)

Parameter	**CSeQG, µg/kg**	**Monitoring Station ID**											
		SD1	SD3	SD4	SD7	SD8	SD1-12	SD2-12	SD3-12	SD4-12	SD5-12	SD6-12	SD7-12
Naphthalene	34.6	26	34	32	11	22	n/d	41	n/d	23	n/d	n/d	5.4
Acenaphthylene	5.87	2.6	23	12	5.6	3.9	n/d	820	2.8	280	9.6	14	37
Acenaphthene	6.71	2.2	12	4.2	n/d	n/d	n/d	44	n/d	14	n/d	n/d	5.4
Fluorene	21.2	6.8	28	15	4.2	3.9	n/d	310	n/d	60	n/d	2.9	11
Phenanthrene	41.9	25	200	74	24	27	7.4	2800	7.3	620	18	29	57
Anthracene	46.9	3.0	27	8.9	2.5	3.1	n/d	990	n/d	190	4.6	8.0	22
Fluoranthene	111	17	430	150	50	49	18	6100	14	1900	60	88	150
Pyrene	53	15	380	120	39	37	14	4100	10	1400	45	66	120
Benzo (a) anthracene	31.7	20	150	41	14	14	5.2	1800	2.7	590	18	25	49
Chrysene	57.1	15	280	92	28	23	6.9	1500	4.0	600	20	27	56
Benzo (k) fluoranthene	240*	6.8	250	94	27	23	4.8	940	3.2	370	15	21	41
Benzo (a) pyrene	31.9	13	220	63	22	16	7.1	1900	4.3	740	27	36	67
Perylene		1200	230	320	97	40							
Indeno(1,2,3,-cd) pyrene	200*	9.6	220	85	26	22	6.6	1200	4.0	520	21	31	60
Dibenzo(a,h) anthracene	6.22	n/d	35	11	4.2	3.0	2.9	380	n/d	150	6.7	9.0	17
Benzo(g,h,I) perylene	170*	9.2	220	96	27	22	6.1	1200	3.1	510	20	29	62
Total PAHs	4000*	1392	3199	1392	434	355	97.5	25825	70.5	8667	299	430	837

CSeQGs - Canadian Sediment Quality Guidelines for the Protection of Aquatic Life
* Ontario Guidelines for the Protection and Management of Aquatic Sediment Quality, Lowest Effect Level
Concentrations above the guideline are highlighted in yellow; n/d – not detected

Metals are always present in the aquatic environment, so they have been detected in all sediment samples. However, in samples from six stations one or more metals, such as cadmium, chromium, copper, lead and zinc, exceeded related guidelines ***(Table 7.21).*** Cadmium (Cd) was the prevailing parameter among this group of contaminants. It has been detected in concentrations above the OSeQGs limit in sediments from four stations. Its highest concentrations were found in sediments at stations SD3 and SD4. At each of these two stations five metals exceeded the corresponding guidelines ***(Table 7.21).***

Table 7.21. Metal Concentrations in Sturgeon Lake Sediments, (µg/g)

Parameter	**OSeQGs, µg/g**	**Monitoring Station ID**											
		SD1	SD3	SD4	SD7	SD8	SD1-12	SD2-12	SD3-12	SD4-12	SD5-12	SD6-12	SD7-12
Cadmium	0.6	0.7	1.4	1.4	0.7	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.3
Chromium	26	18	33	18	7.8	4.8	4.2	4.4	2.6	9.4	4.4	3.8	13
Copper	16	19	41	34	7.4	5.4	1.0	2.2	0.4	20	1.2	0.6	14
Iron	2 %	1.0%	1.2%	1.3%	0.8%	0.5%	0.7%	0.6%	0.3%	1.3%	0.5%	0.5%	1.6%
Lead	31	9.0	70	45	12	9.0	12	12	4.0	8.0	3.5	3.5	24.0
Manganese	460	180	390	250	310	130	170	240	64	270	110	110	460
Mercury	0.2	0.04	0.14	0.14	0.04	0.03	0.01	0.01	0.01	0.05	0.01	0.01	0.08
Nickel	16	7.9	15	14	5.1	3.4	1.9	2.1	1.0	7.5	1.7	1.5	9.1
Zinc	120	46	150	130	47	33	12	22	5.0	68	16	9.3	140

OSeQGs - Ontario Guidelines for the Protection and Management of Aquatic Sediment Quality, Lowest Effect Level
Metal concentrations above the guideline are highlighted in yellow

Table 7.22. Total Organic Carbon, Organic Nitrogen and Total Phosphorus Concentrations in Sturgeon Lake Sediments

Parameter	**OSeQGs, mg/g**	**Monitoring Station ID**											
		SD1	SD3	SD4	SD7	SD8	SD1-12	SD2-12	SD3-12	SD4-12	SD5-12	SD6-12	SD7-12
TOC, mg/g	100	130	180	280	58	34	21	20	10	46	34	34	56
TKN, mg/g	4.8	5.9	12	20	3.4	2.4	0.9	1.1	1.3	4.3	1.4	1.8	15
TP, mg/g	2.0	1.0	0.97	0.91	1.3	0.66	0.49	0.50	1.4	2.4	1.5	1.1	1.4

OSeQGs - Ontario Guidelines for the Protection and Management of Aquatic Sediment Quality, Severe Effect Level
TOC – Total Organic Carbon; TKN – Total Kjeldahl Nitrogen; TP – Total Phosphorus

Stormwater runoff from the Lindsay urban area is an apparent source of contamination. At station SD4-12 only copper has a slightly elevated concentration of 20 µg/g and at station SD7-12 only zinc exceeded the corresponding guideline ***(Table 7.21).*** It seems that sediments in the southern part of the lake are the most contaminated by metals as a result of the close proximity to the Lindsay urban area and to the Lindsay WPCP.

Sediment samples have also been analyzed for total phosphorus, total Kjeldahl nitrogen and total organic carbon. Total organic carbon represents the amount of organic matter in sediments. It is important to know the concentration of organic matter in sediments as it often determines the level of toxicity of heavy metals, PAHs and some other contaminants found in the sediments. The higher concentration of organic matter in the sediments, generally the lower the toxicity of inorganic and human-induced organic contaminants, and metals in particular.

The level of total organic carbon in sediment samples varied from 10 mg/g (1.0% of dry weight) to 280 mg/g (28% of dry weight) ***(Table 7.22).*** The lowest TOC concentration was detected in sediments from station SD3-12 and the highest level of TOC was found in sediments from station SD4 (280 mg/g). The lowest TKN concentration was detected in sediments from station SD1-12, while the highest value (20 mg/g) was found at station SD4 ***(Table 7.22).*** Overall, the highest levels of TOC and TKN were found in sediment samples from the southern portion of the lake, demonstrating a significant input of organic matter to sediments from decomposing aquatic plants and algae. In turn, bottom substrate, rich in organic matter, is an excellent source of nutrients for the next generation of submerged aquatic vegetation (Eurasian milfoil etc.).

Most sediment samples have shown very high levels of total phosphorus. TP concentrations varied from 0.49 mg/g to 2.40 mg/g ***(Table 7.22).*** The average TP concentration in Sturgeon Lake sediments is 1.14 mg/g that can be easily projected into the total amount of phosphorus in sediments, which can be estimated as approximately 750-780 tonnes in the upper 5 cm of sediments through the entire lake bottom area. While most of the phosphorus is bound to sediment particles and generally not available for algae (but available for rooted macrophytes), changes in the aquatic environment can cause phosphorous migration into the water column in a dissolved form, which is readily available for algae consumption. Migration occurs when the concentration of dissolved oxygen in the bottom layer of the water is low, pH values go down and the process of phosphorus desorption and, consequently, internal loading from sediments can be initiated. As well, reducing conditions at the water-sediment interface can lead to the mineral dissolution of iron-phosphorus, manganese-phosphorus and aluminum-iron-phosphorus minerals present in sediments, thus increasing phosphorus and metal influx into the water column.

7.7 Sources of Phosphorus and Nitrogen

Phosphorus and nitrogen are the two most significant nutrients in aquatic ecosystems. Without nutrients it would be no aquatic life in watercourses and lakes. However, because of increasingly intensive human activities during the last century nutrients have been entering natural water bodies in excessive amounts. As a result, phosphorus and nitrogen have become responsible for the process of eutrophication and overabundant development of macrophytes, multicellular algae and phytoplankton in many lakes and rivers across Canada, including Sturgeon Lake. Other chemical elements such as copper, iron, manganese, molybdenum, zinc and some others, called micronutrients, are also vital for the development of aquatic vegetation. They are usually present in small but sufficient quantities such that only phosphorus and nitrogen concentrations affect the rate of algae and vegetation grows and, consequently, the rate of eutrophication.

As explained previously, phosphorus and nitrogen enter Sturgeon Lake from various sources. It can be runoff from agricultural fields and urban areas, shoreline development and recreational activities, wastewater treatment plant and industrial discharges, and atmospheric deposition. It is impossible to determine a single source of nutrients that is responsible for the entire process of eutrophication; rather this process is a consequence of many factors and causes, most of them having a human origin.

All nutrient sources can be separated into two large groups: point sources and non-point sources. Point sources of nutrients include industrial and municipal sewage outflows, individual septic tanks, single wastewater discharge pipes from farms, other businesses, etc. Non-point sources include nutrients that are entering water bodies with urban runoff, agricultural runoff, and atmospheric deposition (wet and dry) as well as natural sources such as shoreline and riverbank erosion, groundwater discharges, wild waterfowl, local geological and soil conditions etc.

Sturgeon Lake receives nutrient input from many of the above-mentioned sources. In order to quantify nutrient load into the lake, all sources have been separated into six major categories:

1) River flow and surface water runoff including:
   1a) Cameron Lake outlet flow;
   1b) Scugog River flow;
   1c) Local stream and surface water flow;
2) Atmospheric deposition on water surface of the lake;
3) Direct urban runoff into the lake;
4) Lindsay urban runoff via the Scugog River;
5) Septic systems along the shoreline and
6) Municipal point sources.

A detailed description and characteristics of the above-mentioned categories of phosphorus and nitrogen sources are provided below.

River Flow and Surface Water Runoff

Almost 98% of the total volume of water is entering Sturgeon Lake as surface or river flow ***(Table 6.7).*** The river flow is a derivative of precipitation, which is the main and determinative source of water in our physiographical zone. Approximately 35% of the total annual precipitation amount is entering the lake as surface runoff. This 35% can be separated into two components: instantaneous surface runoff and shallow groundwater runoff. Groundwater runoff or discharge includes precipitation infiltrated into shallow aquifers as well as water from deeper aquifers. Approximately 65% of the precipitation amount eventually returns to the atmosphere through the processes of evaporation and evapotranspiration.

Rivers and streams collect runoff from their corresponding drainage basins and eventually deliver all of their water into the lake. Watercourses in the Sturgeon Lake watershed have a distinct seasonal distribution of flow volume as can be seen from the annual hydrograph ***(Figures 6.7 and 6.8).*** Even a quick analysis of a typical annual hydrograph demonstrates that the largest portion of flow enters the lake during the spring period (40 – 55% of the total annual flow) followed by winter (30 – 35%) and finally by the summer-autumn period (15 – 25%). Consequently, the highest concentration of phosphorus and nitrogen in rivers is usually observed during periods of high water levels and discharges that occur during spring freshet, winter thaws and after intensive rain events in spring, summer and fall. Due to these hydrological particularities, the largest portion of the nutrient load is delivered into the lake during the spring. Under high flow conditions, phosphorus concentrations in the stream water have been observed as high as 0.127-0.213 mg/L or 4-7 times above the PWQO.

River flow incorporates phosphorus from both natural and anthropogenic sources. As a result, natural surface water always has some amount of phosphorus, even in the most pristine natural environments.

Natural sources of phosphorus and nitrogen include shoreline and riverbank erosion, groundwater discharges, lake sediments, local bedrocks and soils, wild waterfowl, fallen tree branches and leaves, and remnants of other organic materials.

Anthropogenic sources of nutrients in surface water include urban runoff and agricultural runoff. Urban areas are the source of a significant amount of nutrients that can substantially pollute local watercourses. As a result of a high percentage of impervious surfaces in urban areas, and, consequently, low infiltration rates, rainfall and water from snowmelt enter adjacent streams and lakes faster and in larger volumes thus transporting larger amounts of pollutants that can be found in urban environment.

Agricultural sources of nutrients in surface water include manure, chemical fertilizers, milkhouse wastewater discharge, cropland erosion and livestock operations. Manure and chemical fertilizer field applications along with soil erosion are probably the most significant sources of phosphorus and nitrogen among the above-mentioned agricultural activities. It is very important to promote and apply advanced techniques in modern agricultural land management.

Unrestricted access of livestock to watercourses is an additional source of nutrients and can also increase bacteriological contamination of surface water (*E. coli*, Total coliform, Fecal coliform etc.) and erosional processes along the riverbanks.

Atmospheric Deposition

Atmospheric deposition of phosphorus and nitrogen includes wet deposition (rain, snow, dew) and dry deposition (dust etc.). Air circulation and precipitation can bring nutrients into the lake from both local sources, such as wind erosion of bare ground, construction sites, local industrial emissions, and locations thousands of kilometers away.

Concentrations of phosphorus and nitrogen in precipitation samples vary significantly during the year. Usually the highest concentrations are observed in the spring season and the lowest during late fall-winter. Atmospheric deposition of phosphorus and nitrogen was calculated as a sum of a number of precipitation volumes collected in two-week periods multiplied by phosphorus or nitrogen concentrations in the corresponding rain and snow samples.

Urban Runoff

Urban runoff is one of the main human-generated sources of phosphorus, nitrogen and other contaminants to Sturgeon Lake. Urban centers have large impervious areas paved with asphalt and concrete as well as plenty of building roofs. Due to the high percentage of impervious surfaces, urban areas have higher runoff coefficients and, as a result, generate much larger volumes of stormwater runoff into adjacent streams and lakes. As a result, the rapid rainwater or snowmelt runoff carries large quantities of phosphorus and nitrogen as well as other pollutants, which can easily contaminate water in nearby streams and lakes. According to multiple research data, high-density urban areas generate nutrients and other pollutants at a much higher rate per unit area than agricultural lands. In order to mitigate this, all new urban developments are required to be serviced by stormwater management facilities such as stormwater ponds, constructed wetlands or other SWM controls. Yet, a substantial portion of urban areas around Sturgeon Lake do not have stormwater treatment facilities, thus making them a significant source of pollutants including phosphorus and nitrogen for the lake and its tributaries, and the Scugog River in particular.

To calculate phosphorus loading from urban areas, a phosphorus export coefficient of 132 kg/km^2/year, based on the MOE research data from 2006 SWAMP studies, has been accepted (Hutchinson Environmental Sciences, 2012, MOE, unpublished data). This value is very close to our own data obtained in the framework of the urban stormwater monitoring program in the Port Perry urban area, when an average TP export coefficient of 133 kg/km^2/year was derived from water quality data collected in 2006-2009. This value can be slightly adjusted annually depending on the amount of precipitation in each hydrologic year.

Urban areas intersecting the Sturgeon Lake shoreline occupy 4.18 km^2 of the watershed. These areas include Fenelon Falls, Bobcaygeon, Sturgeon Point, Snug Harbor as well as a number of other urban and semi-urban subdivisions and hamlets adjacent to the lake's shoreline. They generate direct urban runoff into the lake. In addition, the largest in the watershed, the Lindsay urban area occupies 10.39 km^2 with an additional 1.37 km^2 of the adjacent lands classified as a rural development and drains into the Scugog River and then into Sturgeon Lake.

Septic Systems

Nearshore septic systems can be a significant source of phosphorus and nitrogen loading to the adjacent water bodies. There has been a considerable scientific discussion over the recent decades about phosphorus loading from septic systems and whether some portion of it can be retained in soils. While the Ministry of the Environment has recognized that the degree of retention may vary with soil type and grain size, it has consistently held the position that all of the phosphorus deposited in septic systems eventually migrates to lake ecosystems. This approach reflects the predominance of thin, organic or sandy soils and tills on the Precambrian Shield, the fractured nature of the bedrock, and the predominance of aging septic systems that were designed for hydraulic purposes (*i.e.,* to ensure fast infiltration) rather than for nutrient retention (Lakeshore Capacity Assessment Handbook, 2010). Given that ecological state of Canadian Shield lakes was a high priority for the Ministry, it recommends a cautious approach, adhering to the "precautionary principle" and assumes that 100% of phosphorus from septic systems within 100 m from the shoreline will reach the nearest water body (Paterson et al., 2006).

At the same time, there is a considerable list of scientific literature on septic systems and phosphorus behaviour in/under leaching beds and in septic plumes. According to the multiple studies there is clear evidence that phosphorus concentrations in plumes from septic tile beds are usually much lower than in effluent from septic tanks. The percent of phosphorus retention can vary from 23 to 99% (Robertson et al. 1998). It was shown that the movement of phosphorus from septic tank – tile bed systems may be retained to some degree depending on soil type and thickness. It was also shown that phosphorus retention in the vadose zone (the layer of soil between the land surface and the groundwater table) is mostly achieved due to reactions of chemical precipitation (Zanini et al., 1998).

It was also shown that phosphorus from a nearshore septic system can and will reach the adjacent water body (Robertson W.D., 1995; Harman J., 1996; Zurawsky M.A., 2004; Zanini L., 1998). The question is how far and how fast the phosphorus plume can travel and what is the possible average/maximum phosphorus concentration in the plume? That's why it is important to note that there is a substantial difference in degree of phosphorus retention in calcareous and non-calcareous soils. Phosphates have much higher mobility and form long distinct plumes with higher phosphorus concentrations (0.5-5.0 mg/L) in shallow groundwater located under and downgradient of septic systems placed on calcareous soils (Robertson, 1998). Additional data have shown that percent of retention on calcareous soils in the vadose zone varies from 23 to 84%, with an average of 51%. On non-calcareous soils such as those found on the Canadian Shield (Muskoka region) phosphorus retention in the vadose zone can be much higher, up to 75-99% under some specific conditions (Robertson, 2003).

In general, there are two approaches to determining septic system phosphorus loading into water bodies. The first assumes that 100% of phosphorus from septic tank effluent near the lake shoreline eventually will reach the lake (Lakeshore Capacity Assessment Handbook, 2010). However, the Handbook's authors recognize that it is mainly related to Canadian Shield areas with very thin or no soils, and fractured bedrock underneath. Another approach is that some of the phosphorus from septic tanks, which can be quite substantial, is retained in the soil. The level of irreversible attenuation (retention) depends on many factors including soil type and thickness, chemical composition of soil, distance to the shore, depth of saturated zone, etc. As the result, it is very difficult to determine one single average percent of attenuation for the entire lake shoreline. The Trent University researchers believe that it is unrealistic to assume that all 100% of phosphorus from septic tank effluent can reach the lake or stream; coefficient of phosphorus retention will depend on condition, size and maintenance of the septic system (Dr. Paul Frost, personal communications).

As well, new septic systems do not immediately add phosphorus to the nearby water body; it may take years for the phosphorus plume to reach the lake or stream depending on the distance from the lakeshore or river bank.

Sturgeon Lake is surrounded by predominantly calcareous soils underlined by limestone formations. As a result, and taking into consideration the above-mentioned information, it is reasonable to assume that phosphorus attenuation (retention) in septic beds and soils around Sturgeon Lake is somewhere near 50%.Therefore, until new data and methods of estimation become available, it has been recommended by the SLMP Science and Technical Committee to use a 50% retention rate in all future calculations of septic system phosphorus loading within the Sturgeon Lake watershed. It was also recognized that in cases where septic systems are malfunctioning for various reasons, then virtually all phosphorus and nitrogen from septic tank effluent can reach nearby water bodies. There is common opinion that approximately 5% of septic systems are failed or malfunctioning (Walker, 1997).

There are approximately 1,774 houses with private septic systems within 75 meters of the Sturgeon Lake shoreline, something to consider when phosphorus loading to the lake littoral zone is in question. Property usage values from ***Table 7.23*** have been used in phosphorus loading calculations. We have also applied the water usage number of 200 L/day/capita in our calculations (Paterson et al., 2006).

Table 7.23. Septic System Usage Values for Shoreline Properties (Paterson et al. 2006)

Development Type	**Usage (capita years·yr^{-1})**
Permanent residence	2.56
Extended seasonal residence (cottage with winter access)	1.27
Seasonal residence (cottage – no winter access)	0.69
Resorts (serviced, housekeeping cabins)	1.18
Trailer parks	0.69
Campgrounds/tent trailers/RV parks	0.37
Youth Camps	125 grams of P·capita^{-1}·yr^{-1}

The average phosphorus concentration in septic tank effluent according to the most recent data is 8.2 mg/L based on 174 samples (Hutchinson, 2002, Paterson et al., 2006). Other researchers demonstrate similar data, 7.5 mg/L (weighted average from 64 samples) and 8.1 mg/L (average from five septic tanks) (Robertson et al., 1998). The Lakeshore Capacity Assessment Model uses 9.0 mg/L (MOE, 2010). Applying a 50% retention factor to the value of 8.2 mg/L, we will obtain phosphorus concentration of 4.1 mg/L in a plume that can reach Sturgeon Lake. According to the previous research data, a phosphate plume from a septic system can extend for 70-75 m (Harman et al., 1996). Consequently, on average each year-round house will generate 0.778 kg of phosphorus per year.

The average nitrogen concentration in regular septic tank effluent is 45 mg/L (MOE, 1982). Approximately 25% of nitrogen can easily be attenuated while effluent is passing through soils and shallow aquifers on its way to the closest water body. The remaining nitrogen amount (in nitrate form), taking into consideration the possible extension of the plume from conventional septic systems (Harman et al., 1996, MPCA, 1999), will reach the lake.

As more accurate data from new studies for all components becomes available, it will be possible to refine current calculations. In particular, Dr. Frost from Trent University intends to undertake the research project, which is aimed at collecting more accurate information on nutrient (phosphorus and nitrogen) fluxes in the nearshore zones and possible effects of shoreline development on water quality.

Kawartha Conservation's "Blue Canoe" program was initiated during summer of 2012. In the framework of this program, Kawartha Conservation staff conducts surveys among shoreline residents and collects information on septic systems including type, age, distance from the lake etc. These new endeavours can help to better understand septic system effects on Sturgeon Lake water quality.

Municipal Point Sources

Two municipal point sources of phosphorus and nitrogen, namely the Lindsay Water Pollution Control Plant and Fenelon Falls Wastewater Treatment Plant release final wastewater effluent into Sturgeon Lake.

The Lindsay Water Pollution Control Plant (Lindsay WPCP) was built in 1963 and originally treated the town's sewage through a series of lagoons with the final effluent discharged into the Scugog River (City of Kawartha Lakes, 2011). The plant serves the Town of Lindsay and community of Oakwood with a total serviced population of approximately 19,000 people (City of Kawartha Lakes, 2012).

Since 1963 the Lindsay WPCP was upgraded several times with the most recent improvement occurring in 1999. Currently, the WPCP consists of a headworks building containing a mechanical barscreen and a grit removal channel. In the event of high flows, raw sewage is diverted from this building into a flow equalization pond. The sewage is returned to the headworks during times of normal and/or low flows. The waste collected in this stage is diverted to landfill. The raw sewage is then moved into an extended aeration pond. As the mixed liquor makes its way to the clarifiers, alum is added to aid the coagulation, flocculation and sedimentation process. Sludge is collected from the bottom of the clarifiers and transferred to storage lagoons. The clarifier effluent is piped into the tertiary treatment building. Aluminum is added as it enters the building. The tertiary treatment consists of two trains of the John Meunier Actiflo system. The Actiflo system uses polymer and sand to bind with the floc to induce rapid settling. The sand is recycled back into the Actiflo process. Wastewater from this process is returned back to the headworks. The final effluent passes through a UV bank before being piped to the outfall at the Scugog River (City of Kawartha Lakes, 2012).

The plant is situated north-east of Lindsay on the eastern bank of the Scugog River. The plant's final effluent is discharged into the river year round. The Lindsay WPCP was designed and approved to treat wastewater at an annual average daily flow rate of 21,500 m^3/day and has a peak flow rate of 30,100 m^3/day (City of Kawartha Lakes, 2012). The average daily flow in 2010 was 14,221 m^3/day or 66.1% of capacity. The average daily flow in 2011 was 15,794 m^3/day or 73.5% of capacity and 1,573 m^3/day more than in 2010. In 2012 the average daily flow was 13,188 m^3/day or 61.3% of capacity. The Lindsay WPCP treated a total of 5,162,133 m^3 of raw sewage in 2010, 5,764,895 m^3 in 2011 and 4,826,970 m^3 in 2012 (City of Kawartha Lakes, 2011, 2012, 2013).

The MOE Certificate of Approval objective for phosphorus concentration in the effluent is 0.15 mg/L that translates into TP loading of 4.3 kg/day. The Certificate of Approval limit for TP is 0.2 mg/L. The average phosphorus concentration in the plant final effluent was 0.049 mg/L in 2010 that translates into TP loading of 0.70 kg/day, 0.05 mg/L or 0.79 kg/day in 2011 and 0.037 mg/L or 0.49 kg/day in 2012 (City of Kawartha Lakes, 2011, 2012, 2013).

The MOE Certificate of Approval objective for total ammonia concentrations in the effluent is 1.0 mg/L for the non-freezing period and 2.0 mg/L for the freezing period. Correspondingly, the CofA objective for total ammonia loading is set at 32.3 kg/day and 64.5 kg/day. The average ammonia concentration in the plant's final effluent was 0.705 mg/L, which translates into loading of 9.17 kg/day during the non-freezing period and 1.075 mg/L or 17.0 kg/day during the freezing period in 2010, 0.218 mg/L (3.44 kg/day) during the non-freezing period and 0.38 mg/L (6.0 kg/day) during the freezing period in 2011 and, finally, 0.456 mg/L (6.01

kg/day) during the non-freezing period and 0.177 mg/L or 2.33 kg/day during the freezing period in 2012 (City of Kawartha Lakes, 2011, 2012, 2013).

The MOE Certificate of Approval objective for TSS concentrations in the effluent is 7.4 mg/L that translates into a TSS loading of 238 kg/day. The Certificate of Approval limit is 11.0 mg/L. The average TSS concentrations in the plant's final effluent was 4.69 mg/L in 2010, which translates into a TSS loading of 66.7 kg/day, 4.60 mg/L or 75.6 kg/day in 2011 and 3.88 mg/L or 47.14 kg/day in 2012 (City of Kawartha Lakes, 2011, 2012, 2013).

The Fenelon Falls Wastewater Treatment Plant was built approximately 40 years ago in the mid-1970s. The plant serves the Village of Fenelon Falls with a total serviced population of approximately 1,800 people.

The plant is situated in the south-western corner of Fenelon Falls, west of Sturgeon Lake. The plant's final effluent is discharged into the lake year round. The Fenelon Falls plant was designed and approved to treat wastewater at an annual average daily flow rate of 1,800 m^3/day (Ontario Clean Water Agency, 2010). The average daily flow in 2010 was 1,073 m^3/day or 59.6% of capacity. The average daily flow in 2011 was 1,070 m^3/day (just 3 m^3/day less than previous year) or 59.4% of capacity. In 2012 the average daily flow was 985 m^3/day or 54.7% of capacity. The Fenelon Falls WWTP treated a total of 390,396 m^3 of raw sewage in 2010, 390,565 m^3 in 2011 and 360,568 m^3 in 2012 (Ontario Clean Water Agency, 2011, 2012, 2013).

The MOE Certificate of Approval objective for phosphorus concentrations in the effluent is 0.5 mg/L. The Certificate of Approval limit is also 0.5 mg/L. The average phosphorus concentrations in the plant's final effluent was 0.094 mg/L in 2010 that translates into TP loading of 0.101 kg/day, 0.078 mg/L or 0.088 kg/day in 2011, and 0.053 mg/L or 0.053 kg/day in 2012 (Ontario Clean Water Agency, 2011, 2012, 2013).

The MOE Certificate of Approval objective for total ammonia concentrations in the effluent is 3.5 mg/L for the non-freezing period and 7.0 mg/L for the freezing period. The average ammonia concentration in the plant's final effluent was 1.365 mg/L that translates into loading of 1.355 kg/day in 2010, 1.145 mg/L (1.102 kg/day) in 2011 and, finally, 0.237 mg/L (0.239 kg/day) in 2012 (Ontario Clean Water Agency, 2011, 2012, 2013).

The MOE Certificate of Approval objective for TSS concentrations in the effluent is 15.0 mg/L. The Certificate of Approval limit is 25.0 mg/L. Average TSS concentrations in the plant's final effluent was 4.77 mg/L in 2010 that translates into TSS loading of 5.1 kg/day, 3.32 mg/L or 3.7 kg/day in 2011, and 2.504 mg/L or 2.5 kg/day in 2012 (Ontario Clean Water Agency, 2011, 2012, 2013).

Annual phosphorus loads from the Lindsay WPCP and Fenelon Falls WWTP were calculated as a sum of monthly loads, which, in turn, have been calculated as the monthly average phosphorus concentration found in the final effluent from the lagoons multiplied by the monthly volume of effluent. The initial numbers of daily flow and the average phosphorus concentrations have been received from the City of Kawartha Lakes Public Works Department.

7.8 Phosphorus Load and Balances

The three year average annual total phosphorus load into Sturgeon Lake is 26,480 kg. The highest phosphorus loading was in 2010-2011 – 28,700 kg and the lowest loading was observed in 2011-2012 – 22,498 kg that was a result of very low flow that spring and summer. The phosphorus load into Sturgeon Lake is distributed quite unevenly between the five major sources:

1) The total river flow TP loading was 24,779 kg in 2010-2011, 18,469 kg in 2011-2012 and 24,586 kg in 2012-2013 ***(Table 7.24)***. The phosphorus load with river flow can be further split up among three sources: the Cameron Lake flow – 12,945 kg, 9,738 kg and 14,300 kg; the Scugog River flow – 6,861 kg, 5,720 kg and 7,337kg as well as local stream flow and overland runoff – 4,973 kg, 3,259 kg and 2,949 kg in the 2010-2011, 2011-2012 and 2012-2013 hydrologic years respectively. The average phosphorus load from local tributaries over the three year period was 3,727 kg.

2) Atmospheric deposition (wet and dry) of total phosphorus on the lake's water surface was 560 kg in 2010-2011, 576 kg in 2011-2012 and 424 kg in 2012-2013. The average atmospheric load over the three year period was 520 kg.

3) Shoreline urban stormwater phosphorus loading into Sturgeon Lake was estimated at approximately 626 kg in 2010-2011, 539 kg in 2011-2012 and 541 in 2012-2013.The average load over the three-year period was 569 kg. The phosphorus load from the Lindsay urban area into the Scugog River and then into the lake was estimated at 1,398, 1,327 and 1,319 kg in the 2010-2011, 2011-2012 and 2012-2013 hydrologic years respectively. The average Lindsay area TP load was 1,348 kg. The total average urban phosphorus load was 1,917 kg over the three year period.

4) Phosphorus loading from private septic systems around the lake was estimated at 1,080 kg annually. This amount includes 652 kg from year-round houses, 231 kg from summer cottages, 42 kg from trailer parks and campgrounds, 12 kg from houses with holding tanks (some grey water) and 140 kg from failed systems.

5) The total phosphorus input from the municipal wastewater treatment plants (Lindsay WPCP and Fenelon Falls WWTP) was 257 kg in 2010-2011, 259 kg in 2011-2012 and 291 kg in 2012-2013 with the average load over the three year period being at 269 kg.

Calculated average and annual phosphorus loadings into Sturgeon Lake as well as average and annual phosphorus exports from the lake via the lake outlet in Bobcaygeon are presented in ***Table 7.24***. Distribution of the average phosphorus load between the major phosphorus sources in the 2010-2011, 2011-2012 and 2012-2013 hydrologic years is presented at ***Figure 7.12.***

It can be seen that the Cameron Lake flow, which transports 47% of the total phosphorus load, is a single largest source of phosphorus for Sturgeon Lake ***(Figure 7.12)***. Between years this value varied from 43 to 51%. All that phosphorus is generated outside the Sturgeon Lake watershed ***(Figure 7.12)***. The Scugog River flow is the second largest source of phosphorus for Sturgeon Lake. It brings more than 25% of the total phosphorus load. Some portion of that phosphorus amount comes from outside the watershed with the Lake Scugog flow and another portion is generated within the study area, in the Mariposa Brook, East Cross Creek and Scugog River subwatersheds.14% or 3,727 kg of the total phosphorus load enters the lake with local surface runoff and local stream flow.

Table 7.24. Sturgeon Lake Phosphorus Budget for 2010-2011, 2011-2012 and 2012-2013 Hydrologic Years

Sources of Phosphorus	2010-2011		2011-2012		2012-2013		Average	
	TP, kg	TP, %	TP, kg	TP, %	TP, kg	TP, %	TP, kg	TP, %
River flow as:								
Cameron Lake outlet	12,945	45.1	9,738	43.3	14,300	50.6	12,328	46.5
Scugog River	6,861	23.9	5,720	25.4	7,337	26.0	6,639	25.1
Local streams and overland flow	4,973	17.3	3,259	14.5	2,949	10.4	3,727	14.1
Atmospheric deposition	560	2.0	576	2.6	424	1.5	520	2.0
Shoreline urban runoff	626	2.2	539	2.4	541	1.9	569	2.1
Lindsay urban runoff	1,398	4.9	1,327	5.9	1,319	4.7	1,348	5.1
Septic systems	1,080	3.8	1,080	4.8	1,080	3.8	1,080	4.1
Municipal point sources	257	0.9	259	1.2	291	1.0	269	1.0
Total Load	**28,700**	**100**	**22,498**	**100**	**28,241**	**100**	**26,480**	**100**
Sturgeon Lake TP Export	**23,721**	**83**	**19,049**	**85**	**20,385**	**72**	**21,052**	**80**
TP net loading*	**4,979**	**17**	**3,449**	**15**	**7,856**	**28**	**5,428**	**20**

*Net loading – amount of phosphorus that is annually accumulated in the lake and is a difference between total annual load into the lake from all sources and annual loss of phosphorus from the lake with the flow via Big and Little Bob Channels in Bobcaygeon.

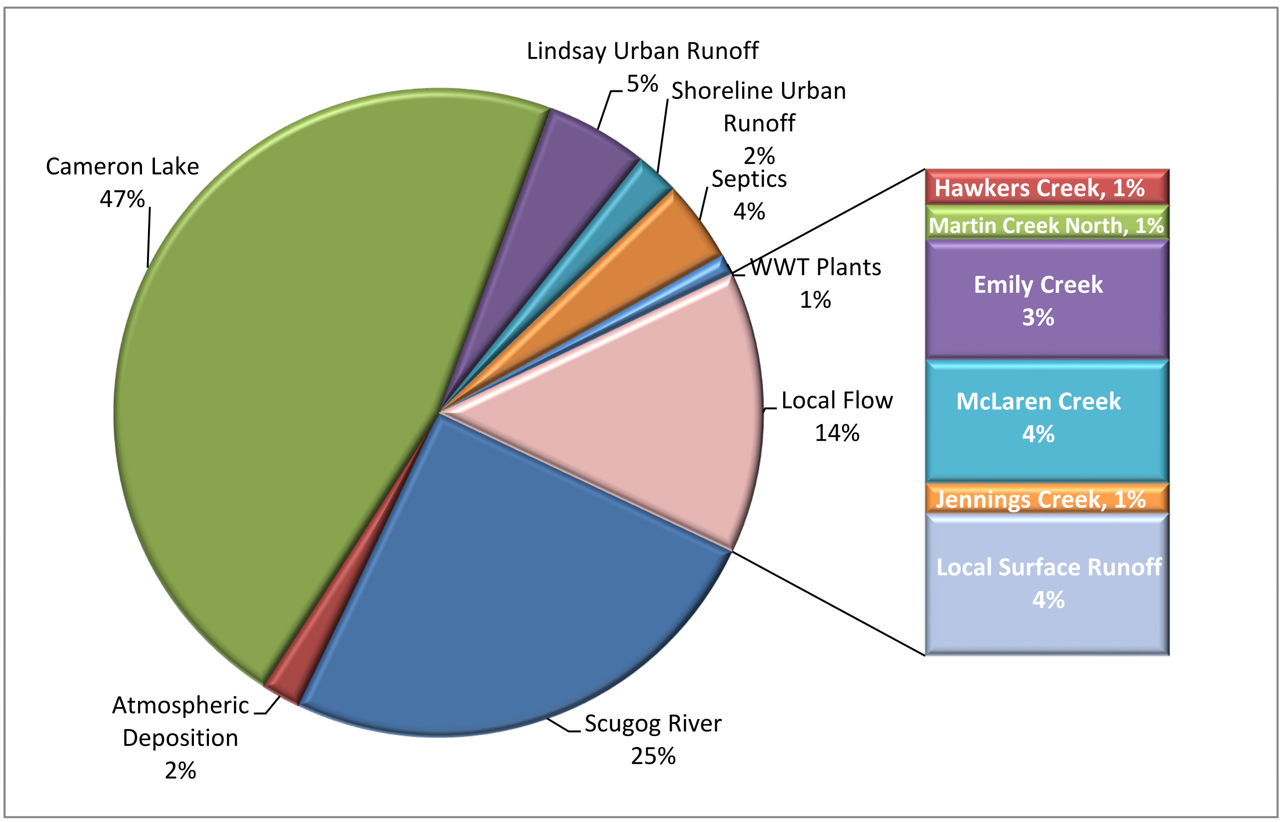


Figure 7.12. Average Percent of Phosphorus Load into Sturgeon Lake from Different Sources during 2010-2013 Monitoring Period

McLaren Creek is the largest source of phosphorus among local watercourses. Its subwatershed generates 3.6% of the total phosphorus load or 4.2% of TP load with river flow ***(Table 7.26).*** Five percent of phosphorus enters Sturgeon Lake with the Lindsay urban runoff and two percent with the shoreline urban runoff that, in total, is 7% of the total phosphorus load. This is an entirely human-generated phosphorus as well as TP from shoreline septic systems, which counts up 4% of the total load. Two percent of phosphorus falls on the lake surface from the sky with dust and all kinds of precipitation, such as rain, snow, hail, dew, etc. Finally, 1% of the total phosphorus loading enters the lake with treated wastewater from the two local wastewater treatment plants in Lindsay and Fenelon Falls.

Phosphorus loadings and balances for Sturgeon Lake were also calculated in the past. The first ever attempt to quantify amount of phosphorus that is entering Sturgeon Lake was done in 1976 for the 1971-1972 study period by the MOE and MNR staff (The Kawartha Lakes Water Management Study, 1976). The second time phosphorus loadings and balances of Sturgeon Lake were calculated over the 1986-1989 three-year monitoring period in the framework of the comprehensive study of Rice Lake and Sturgeon Lake by the Ministry of the Environment (Hutchinson et al, 1993). Two previous phosphorus budgets from 1971-1972 and 1986-1989 along with our current phosphorus budget for the 2010-2013 monitoring period are presented in ***Table 7.25*** below.

Septic system loading estimates from 1971-1972 (The Kawartha Lakes Water Management Study, 1976)and 1986-1989 (Hutchinson et al., 1993) were recalculated assuming septic system retention efficiency of 0.50 instead of 0.8 and 0.74 previously used for the majority of households around the lake but resorts. As well, urban runoff TP loading from the 1986-1989 period was recalculated using a phosphorus export coefficient of 132 kg/km^2/year instead of 54.2 kg/km^2/year, which was used at that time.

Table 7.25. Comparison of Sturgeon Lake Phosphorus Budgets from the 1971-1972, 1986-1989 and 2010-2013 Monitoring Periods

Sources of Phosphorus	**1971-1972**		**1986-1989**		**2010-2013**	
	TP, kg	**TP, %**	**TP, kg**	**TP, %**	**TP, kg**	**TP, %**
River flow as: Cameron Lake outlet Scugog River Local streams and overland flow	 16,200 3,350* 13,190	 35.4 7.3 28.8	 11,537 7,310 3,603	 38.0 24.1 11.9	 12,328 6,639 3,727	 46.5 25.1 14.1
Atmospheric deposition	1,050	2.3	2,120	7.0	520	2.0
Urban runoff	n/d**	-	1,060^	3.5	1,917	7.2
Septic systems	2,900***	2.5	980***	3.2	1,080	4.1
Municipal point sources	10,800	23.6	3,714	12.3	269	1.0
Total Load	**47,490**	**100**	**30,324**	**100**	**26,480**	**100**
Sturgeon Lake TP Export	**42,100**	**89**	**22,440**	**74**	**21,052**	**80**
TP net loading	**5,390**	**11**	**7,884**	**26**	**5,428**	**20**

* Scugog River/Lake flow only, without Mariposa Brook and East Cross Creek flow.
** Urban runoff in 1971-1972 was included into the local stream and overland flow.
^ Urban runoff loading for 1986-1989 was recalculated using a phosphorus export coefficient of 132 kg/km^2/year instead of 54.2 kg/km^2/year, which was used at that time. The original number was 435 kg.
*** Septic system loadings for 1971-1972 and 1986-1989 were also recalculated assuming septic system retention efficiency of 0.50 instead of 0.80 used in 1972 and 0.74 used in 1989. The original numbers were 1,160 kg in 1971-1972 and 665 kg in 1986-1989 with TP retention, while total loading without retention was 5,800 and 1,959 kg respectively.

The most significant change between three phosphorus budgets is the remarkable reduction in phosphorus loading from the municipal point sources over the 40-year period. In 1971-1972 it was estimated that 10,800 kg of phosphorus was entering Sturgeon Lake annually with an effluent from the Lindsay WPCP alone. The Fenelon Falls WWTP did not exist at the time. In 1986-1989 phosphorus loading from the two wastewater treatment plants (Lindsay WPCP and Fenelon Falls WWTP) was almost three times less comparing to the early 1970s, just 3,714 kg. Currently, phosphorus loading from the municipal point sources is less than 3% of the amount from the 1970s and just 7% of the amount from the 1980s ***(Table 7.25).***

Another significant reduction in phosphorus loading can be observed with atmospheric deposition, which generates now only 520 kg of phosphorus that is half of the amount from the 1970s.Generally speaking, phosphorus loading decreased from all sources except urban runoff, which currently transports almost double amount of phosphorus comparing to the 1980s ***(Table 7.25).***

Average phosphorus export from Sturgeon Lake into Pigeon Lake is estimated at 21,052 kg per year that is approximately half of the amount exported in 1971-1972 and 1,400 kg less than in 1986-1989. At the same time, net phosphorus loading into the lake is about the same as in the 1970s, 5,428 kg and 5,390 respectively but less than in the 1980s, when it was 7,884 kg annually over the three-year period.

Average phosphorus loading with river flow and surface runoff is 22,694 kg annually or almost 86% of the total phosphorus load. Distribution of the total river flow phosphorus load between different tributaries and subwatersheds is shown in ***Table 7.26***. Two the most significant sources are Cameron Lake and Lake Scugog/Scugog River, which supplies 12,328 kg or 54.3% and 3,192 kg or 14.1% respectively. East Cross Creek and Mariposa Brook are responsible for 1,893 kg (8.3%) and 1,554 kg (6.8%) of phosphorus load into Sturgeon Lake annually. The smallest source of phosphorus among tributaries is Jennings Creek, which transports 229 kg annually.

Table 7.26. Phosphorus Load into Sturgeon Lake with River Flow in the 2010-2011, 2011-2012 and 2012-2013 Hydrologic Years

Watercourse / Subwatershed	2010-2011		2011-2012		2012-2013		Average	
	TP, kg	TP, %	TP, kg	TP, %	TP, kg	TP, %	TP, kg	TP, %
Cameron Lake Outlet	12,945	52.2	9,738	52.0	14,300	58.2	12,328	54.3
Emily Creek	1,174	4.7	771	4.1	812	3.3	919	4.0
Hawkers Creek	422	1.7	246	1.3	167	0.7	278	1.2
Jennings Creek	350	1.4	172	0.9	166	0.7	229	1.0
Martin Creek North	380	1.5	231	1.2	173	0.7	261	1.2
McLaren Creek	1,186	4.8	871	4.7	791	3.2	949	4.2
Scugog River/Scugog L.	3,323	13.4	2,190	11.7	4,063	16.5	3,192	14.1
Mariposa Brook	1,682	6.8	1,439	7.7	1,542	6.3	1,554	6.8
East Cross Creek	1,856	7.5	2,091	11.2	1,732	7.0	1,893	8.3
Sturgeon Wtshd North	520	2.1	302	1.6	206	0.8	343	1.5
Sturgeon Wtshd East	316	1.3	208	1.1	219	0.9	248	1.1
Sturgeon Wtshd West	625	2.5	458	2.4	416	1.7	500	2.2
TOTAL with River Flow	**24,779**	**100**	**18,717**	**100**	**24,586**	**100**	**22,694**	**100**

It is important to remember that Cameron Lake is the largest source of phosphorus not because it has high phosphorus concentrations but because a huge amount of water flow passes through it into Sturgeon Lake.

If we look at the Sturgeon Lake water budget, we will see that 71.3% of the lake total water supply originates from Cameron Lake *(**Table 6.7**)*.

Distribution of phosphorus load among local sources excluding loading from Cameron Lake is shown at ***Figure 7.13***. If we do not take into account the Scugog River/Lake Scugog loading, which is partly external source as well, then, among local tributaries, East Cross Creek transports the largest amount of phosphorus, 1,893 kg annually, followed by Mariposa Brook (1,554 kg) and the Lindsay urban area (1,348 kg).

Phosphorus loading from local subwatersheds was split between different categories of total phosphorus sources in order to show how much phosphorus is entering the lake with agricultural and urban runoff and as a result of natural processes in an addition to shoreline septic system category and wastewater treatment plant category. For this modeling exercise loading coefficients from the CANWET model were used. During calculations the MOE Phosphorus Loading Tool was also utilized (MOE, 2012).

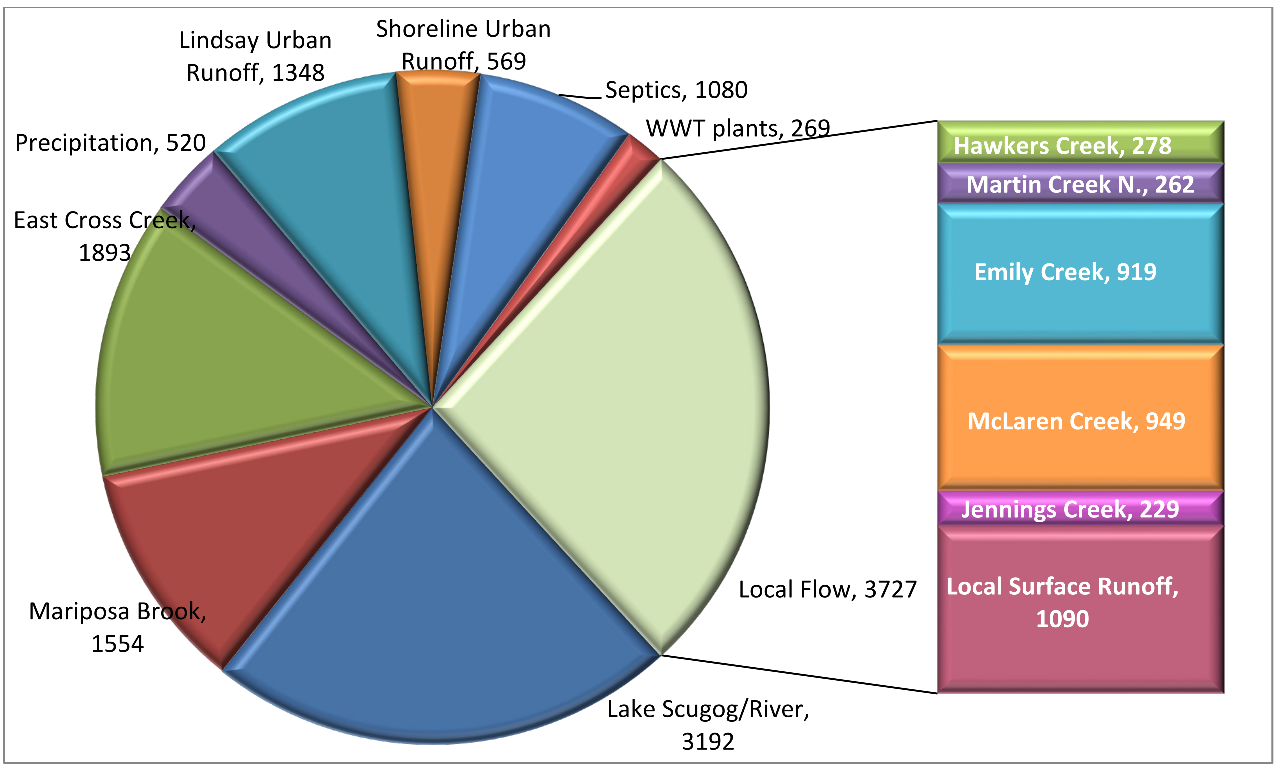


Figure 7.13. 2010-2013 Average Annual Phosphorus Load from Local Sources, (kg/year)

Estimated loads from three major land use categories, namely agricultural runoff, urban runoff and natural sources, together with septic systems, wastewater treatment plants and precipitation categories are shown at ***Figure 7.14***. Loads from two external sources, namely Cameron Lake and Lake Scugog, are shown at the same graph as well. The results of calculations are also presented in ***Table 7.27***.

Table 7.27. Phosphorus Load in Sturgeon Lake from Different Categories of Sources

Source / Category of Sources	TP Load, kg	% of Total Load	% of Local Flow Load
Cameron Lake	12,328	46.6	n/a
Lake Scugog	2,531	9.6	n/a
Precipitation	520	2.0	n/a
Local Natural Sources	4,242	16.0	43.5
Local Urban Runoff	2,229	8.4	22.9
Local Agricultural Runoff	3,281	12.4	33.6
Septics	1,080	4.1	n/a
Wastewater Treatment Plants	269	1.0	n/a
Total	26,480	100.0	n/a
Total Load with Local Flow	9,752		100.0

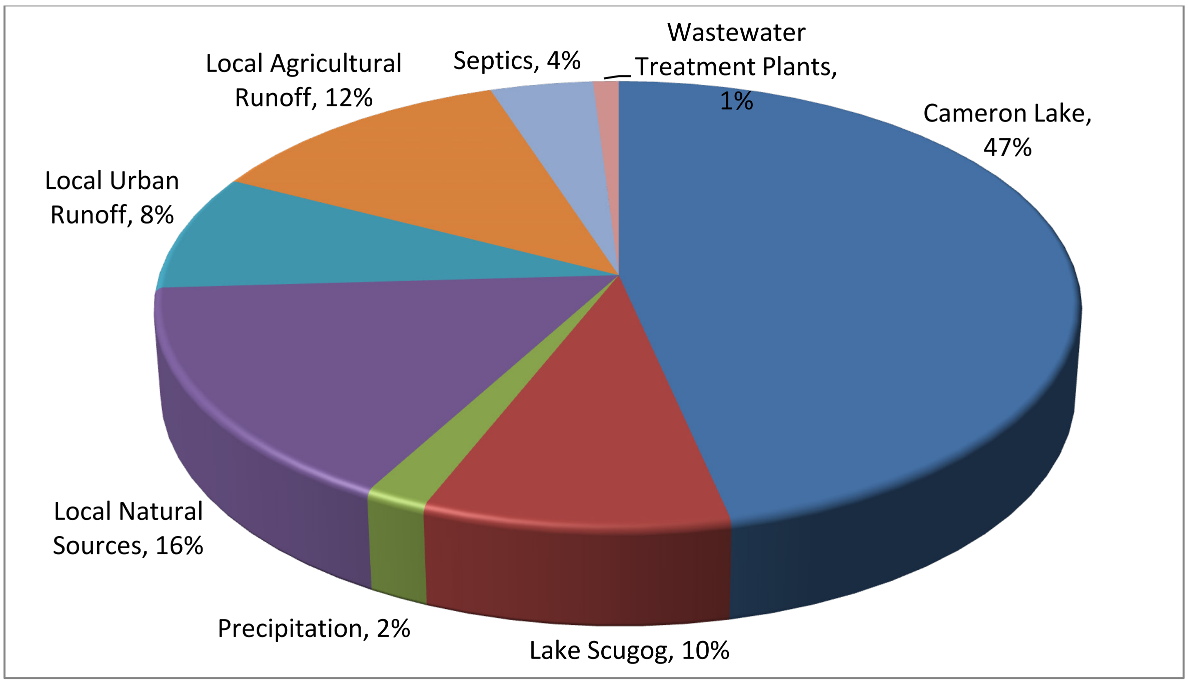


Figure 7.14. Average Percent of Phosphorus Load into Sturgeon Lake from External Sources (Cameron and Scugog Lakes) and Local Sector-based Sources in 2010-2013

In order to develop phosphorus loading targets for the local subwatersheds, we utilized modeling methods based on the loading coefficients and Best Management Practices reduction coefficients used in the CANWET model and previously applied in the neighbouring Lake Simcoe watershed. Applying the Best Management Practices (BMPs) reduction coefficients to the current anthropogenic land use and comparing obtained data with observed phosphorus loading data, we were able to establish desirable phosphorus loading targets for each local stream and its corresponding subwatershed (***Table 7.28***).

Table 7.28. Past, Current and Desirable Phosphorus Loads from Local Subwatersheds

Watercourse/ Subwatershed	Pre-development Annual TP Loading, kg	2010-2013 Average Annual TP Loading, kg	Achievable TP Loading with BMPs, kg	TP Amount Reduction, kg
Emily Creek	796.7	918.9	918.9	0
Hawkers Creek	263.1	278.4	278.4	0
Martin Creek North	217.0	261.5	241.5	20
McLaren Creek	387.4	949.3	589	360
Jennings Creek	81.5	229.3	189.1	40
Sturgeon Lake	778.0	1,659	1,166	493
Scugog River	240.2	2,009	768	1,241
Mariposa Brook*	1,142	2,209	1,856	353
East Cross Creek*	1,063	2,777	1,897	880
Total	**4,969**	**11,291**	**7,904**	**3,387**

* Full phosphorus loads from Mariposa Brook and East Cross Creek into the Scugog River, not into Sturgeon Lake

7.9 Nitrogen Load and Balances

The three year average total nitrogen load into Sturgeon Lake is 1,332,379 kg. The highest nitrogen loading was in 2012-2013 – 1,593,199 kg and the lowest loading was observed in 2011-2012 – 1,098,005 kg as a result of very low spring flow. The total nitrogen load into Sturgeon Lake can be distributed between the five major sources:

1) The total river flow TN loading was 1,174,887 kg in 2010-2011, 969,224 kg in 2011-2012 and 1,462,468 kg in 2012-2013. The average load over the three year period was 1,202,193 kg ***(Table 7.29)***. The nitrogen load with river flow can be further split up among three sources: the Cameron Lake flow – 569,400 kg, 312,924 kg and 726,050 kg; the Scugog River flow – 399,201 kg, 492,327 kg and 521,955 kg as well as local stream flow and overland runoff – 206,286 kg, 163,973 kg and 214,463 kg in the 2010-2011, 2011-2012 and 2012-2013 hydrologic years correspondingly. The average nitrogen load from local tributaries over the three year period was 194,907 kg.

2) Atmospheric deposition (wet and dry) of total nitrogen on the lake water surface was 34,929 kg in 2010-2011, 32,012 kg in 2011-2012 and 35,312 kg in 2012-2013. The average atmospheric load over the three year period was 34,084 kg ***(Table 7.29).***

3) Direct shoreline urban stormwater nitrogen load to Sturgeon Lake was estimated at 7,405 kg in 2010-2011, 6,573 kg in 2011-2012 and 6,600 kg in 2012-2013 resulting at the average value of 6,859 kg. Nitrogen load from the Lindsay urban area was estimated at 14,345 kg in 2010-2011, 13,619 kg in 2011-2012 and 13,537 kg in 2012-2013 resulting at the average value of 13,834 kg. The total average urban nitrogen load was 20,786 kg over the three year period.

4) Nitrogen load from private septic systems around the lake was estimated at 9,721 kg annually. This amount includes 7,038 kg from year-round houses, 2,274 kg from summer cottages and 409 kg from trailer parks and campgrounds.

5) The total nitrogen input from the municipal wastewater treatment plants (Lindsay WPCP and Fenelon Falls WWTP) was 64,646 kg in 2010-2011, 66,856 kg in 2011-2012 and 65,561 kg in 2012-2013. The average load over the three year period was 65,688 kg.

The Cameron Lake flow is a largest source of nitrogen for Sturgeon Lake. On average, it transports 40% of total nitrogen load every year ***(Figure 7.15)***. This value varied from 28.5% in 2011-2012 to 45.6% in 2012-2013. Nitrogen that enters Sturgeon Lake with the Cameron Lake flow is generated outside the Sturgeon Lake watershed ***(Figure 7.1)***. The Scugog River flow is the second largest source of nitrogen for Sturgeon Lake. It brings more than 35% of the total nitrogen load. In the 2011-2012 hydrologic year the Scugog River flow was even the largest source of nitrogen, when it transported almost 45% of total nitrogen load ***(Table 7.29)***. Some portion of that nitrogen amount comes from outside the watershed with the Lake Scugog flow and another portion is generated within the study area, in the Mariposa Brook, East Cross Creek and Scugog River subwatersheds. 14.6% or 194,907 kg of the total nitrogen load enters the lake with local surface runoff and local stream flow. McLaren Creek is the largest source of nitrogen among local watercourses. Its subwatershed generates 4.5% of the total nitrogen load or 5.0% of TN load with river flow ***(Table 7.30).***

Table 7.29. Sturgeon Lake Nitrogen Budget for 2010-2011, 2011-2012 and 2012-2013 Hydrologic Years

Sources of Nitrogen	**2010-2011**		**2011-2012**		**2012-2013**		**Average**	
	TN, kg	**TN, %**	**TN, kg**	**TN, %**	**TN, kg**	**TN, %**	**TN, kg**	**TN, %**
River flow as:								
Cameron Lake outlet	569,400	43.6	312,924	28.5	726,050	45.6	536,125	40.2
Scugog River	399,201	30.6	492,327	44.8	521,955	32.8	471,161	35.4
Local streams and overland flow	206,286	15.8	163,973	14.9	214,463	13.5	194,907	14.6
Atmospheric deposition	34,929	2.7	32,012	2.9	35,312	2.2	34,084	2.6
Shoreline urban runoff	7,405	0.6	6,573	0.6	6,600	0.4	6,859	0.5
Lindsay urban runoff	14,345	1.1	13,619	1.2	13,537	0.8	13,834	1.0
Septic systems	9,721	0.7	9,721	0.9	9,721	0.6	9,721	0.7
Municipal point sources	64,646	5.0	66,856	6.1	65,561	4.1	65,688	4.9
Total Load	**1,305,933**	**100**	**1,098,005**	**100**	**1,593,199**	**100**	**1,332,379**	**100**
Sturgeon Lake TN Export	**1,041,698**	**80**	**682,265**	**62**	**1,437,146**	**90**	**1,053,703**	**79**
TN net loading*	**264,235**	**20**	**415,740**	**38**	**156,053**	**10**	**278,676**	**21**

*Net loading – amount of nitrogen that is annually accumulated in the lake and is a difference between total annual load into the lake from all sources and annual loss of nitrogen from the lake with the flow via Big and Little Bob Channels in Bobcaygeon.

Almost five percent of nitrogen enters Sturgeon Lake with treated wastewater from two municipal wastewater treatment plants. This is an entirely human-generated nitrogen as well as TN from shoreline septic systems (0.7%) and urban runoff (1.5%). Finally, 2.6% of nitrogen falls on the lake water surface with dust and all kinds of precipitation, such as rain, snow, hail, dew, etc.

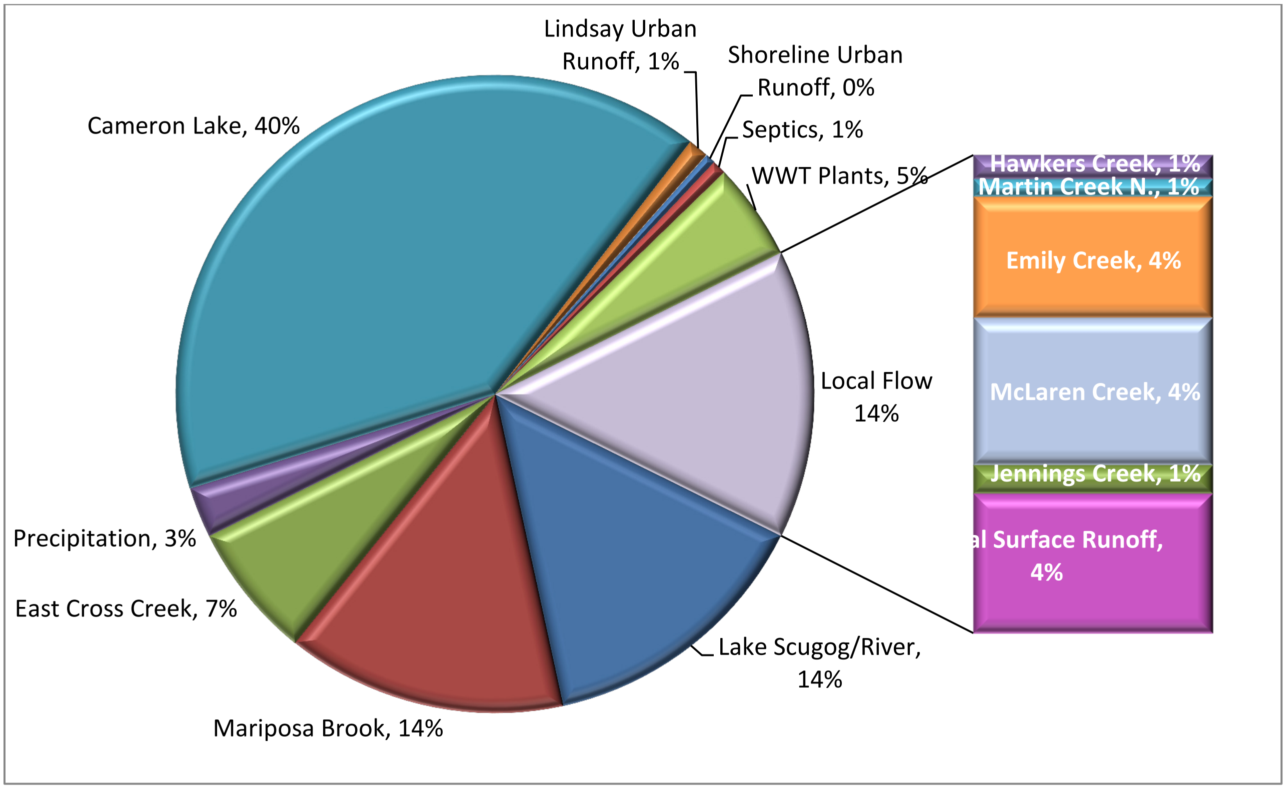


Figure 7.15.Average Percent of Nitrogen Load into Sturgeon Lake from Different Sources during the 2010-2013 Monitoring Period

Table 7.30. Nitrogen Load into Sturgeon Lake with River Flow in 2010-2011, 2011-2012 and 2012-2013 Hydrologic Years

Watercourse / Subwatershed	**2010-2011**		**2011-2012**		**2012-2013**		**Average**	
	TN, kg	**TN, %**	**TN, kg**	**TN, %**	**TN, kg**	**TN, %**	**TN, kg**	**TN, %**
Cameron Lake Outlet	569,400	48.5	312,924	32.3	726,050	49.6	536,125	44.6
Emily Creek	54,126	4.6	41,218	4.3	52,836	3.6	49,393	4.1
Hawkers Creek	13,588	1.2	7,484	0.8	8,649	0.6	9,907	0.8
Jennings Creek	11,846	1.0	12,071	1.2	10,749	0.7	11,555	1.0
Martin Creek North	9,680	0.8	5,705	0.6	5,838	0.4	7,074	0.6
McLaren Creek	56,230	4.8	50,606	5.2	73,371	5.0	60,069	5.0
Scugog River/Scugog L.	151,930	12.9	181,304	18.7	237,903	16.3	190,379	15.8
Mariposa Brook	172,313	14.7	198,822	20.5	196,325	13.4	189,153	15.7
East Cross Creek	74,958	6.4	112,201	11.6	87,727	6.0	91,629	7.6
Sturgeon Wtshd North	16,682	1.4	9,197	0.9	10,243	0.7	12,041	1.0
Sturgeon Wtshd East	14,583	1.2	11,121	1.1	14,237	1.0	13,314	1.1
Sturgeon Wtshd West	29,551	2.5	26,571	2.7	38,540	2.6	31,554	2.6
TOTAL River Flow	**1,174,887**	**100**	**969,224**	**100**	**1,462,468**	**100**	**1,202,193**	**100**

Average nitrogen loading with river flow and surface runoff is 1,202,193 kg annually or more than 90% of the total nitrogen load. Distribution of the total river flow nitrogen load between different tributaries and subwatersheds is shown in ***Table 7.30***. Two the most significant sources are Cameron Lake and Lake Scugog/Scugog River, which supply 536,125 kg or 44.6% and 190,379 kg or 15.8% respectively. Mariposa Brook follows closely and transports annually 189,153 kg (15.7%) of nitrogen. The smallest amount of nitrogen enters the lake with the Martin Creek North flow, 7,074 kg annually.

Cameron Lake is the largest source of nitrogen not because its water has high nitrogen concentrations but because a huge amount of water flow passes through it into Sturgeon Lake. If we look at the Sturgeon Lake water budget, we will see that 71.3% of the lake total water supply originates from Cameron Lake ***(Table 6.7)*** and only 40% of the total nitrogen load ***(Table 7.29).***

8.0 Aquatic Ecosystems

Aquatic ecosystems are formed by the complex relationships between aquatic living organisms and the physical, chemical and biological elements of natural water. Healthy aquatic ecosystems provide benefits to lake users in terms of enjoyment and lake-based economy, as well as maintaining good water quality and a resilient lake environment. This chapter provides an overview of the types of aquatic communities that exist within Sturgeon Lake and its tributaries, and important aquatic habitat features that support these communities. The presence and distribution of aquatic resources is largely a function of watershed geography (e.g., latitude, slope, and geology), hydrological conditions (e.g., intensity, timing, and duration of flows), land use (e.g., human influences), and connection to other water bodies. 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.

Sturgeon Lake is highly valued for fisheries resources, and communities around the lake rely on healthy aquatic ecosystems to provide recreational opportunities, tourism and other lake-related benefits. Functioning aquatic ecosystems sustain these benefits. Also, by monitoring aquatic life and aquatic habitat indicators, we can understand the condition and health of the lake. This chapter characterizes key components of the Sturgeon Lake aquatic ecosystem, including: lake-based, tributary-based elements.

8.1 Summary of Observations and Issues

OBSERVATIONS

- ***Sturgeon Lake supports diverse, cool/warm water fish communities****.* Twenty-one fish species have been documented within lake, and thirty-one fish species have been documented within streams that drain directly into the lake. Most of these fishes are common throughout the warm/cool waters of the Kawartha Lakes. The fish community structure in the lake has become increasingly complex due to intentional stocking, range extensions, unintentional introductions and non-native species invasions. Sensitive coldwater fishes are limited in distribution to the deep waters of the northeast arm (Lake Herring), and coldwater sections within Martin Creek North and Emily Creek (Brook Trout and Mottled Sculpin). There are no known species of conservation concern.
- ***Sturgeon Lake tributaries provide important ecological pathways to-and-from the lake****.* Tributaries draining directly into the lake provide spawning habitat for important migratory lake-dwelling species such as Walleye, Muskellunge, and White Sucker. The lower reaches of Emily Creek, McLarens Creek, Hawkers Creek and Scugog River (below the Lindsay dam) are large tributaries that likely provide significant spawning habitat for lake-based species. The dams/locks located at Fenelon Falls, Lindsay, and Bobcaygeon act as physical barriers that may limit migratory spawning routes and other ecological pathways.
- ***Nearshore areas provide important habitat for lake-dwelling fishes****.* Shallow nearshore areas (<3.0 meters) are extremely productive areas for fishes, and are utilized by many including important top predator species for spawning and feeding. Compared to other Kawartha Lakes, Sturgeon Lake has a relatively small nearshore area, comprising approximately 37% of lake surface area. Extensive nearshore habitat is concentrated to two areas of the lake: the northwest arm and Goose Bay.
- ***The lake supports a significant recreational fishery****.* The Kawartha Lakes, of which Sturgeon Lake is central, supports one of the largest inland lake recreational fisheries in Ontario. A healthy and sustainable recreational fishery contributes to the tourism-based economy of local communities and municipalities. Important fishery species include: Walleye, Muskellunge, Largemouth Bass, Smallmouth

Bass, and Common Carp. Recreational angling opportunities on Sturgeon Lake have diversified to include panfish such as Yellow Perch, Black Crappie, and sunfish.

- ***Physical aquatic habitat conditions and fish community structure within Sturgeon Lake have changed****.* Over last 30 years, Sturgeon Lake aquatic habitat has shifted from turbid, nutrient enriched waters towards a clear-water, aquatic plant-dominated system. Changes in habitat can affect aquatic communities by creating favourable conditions to one species that in turn shifts aquatic community composition or available prey resources. Although the exact mechanisms remain unclear, changes in the Sturgeon Lake aquatic habitat have resulted in declines in the production of Walleye and increases in abundance of bass species and panfish. Reductions in nutrient loadings, coupled with the invasion of zebra mussels, increasing water temperatures, along with other factors have likely contributed to these fish community changes.

KEY ISSUES

- ***Changes in nutrient levels***. The management of nutrient inputs into Sturgeon Lake has been primarily focused on phosphorus sources because it is the primary nutrient limiting algae growth in the lake. Phosphorus levels in Sturgeon Lake have been reduced to below the Provincial Water Quality Objective (< 20 µg/L). This has resulted in the decreased nutrient input into the lake limiting the potential for lake-based production. Alternatively, decreases in nutrient levels increase water clarity, in turn promoting plant growth which can deplete oxygen sources, negatively affecting aquatic invertebrates and fish. Efforts to reduce nutrient input to improve water quality may actually reduce the overall productive capacity of the fisheries.
- ***Establishment of non-native aquatic species****.* Sturgeon Lake has been exposed to a variety non-native aquatic species, including Common Carp, Bluegill, Black Crappie, zebra mussels and Eurasian watermilfoil. In addition to these existing exotic species, there are others that are at immediate risk of becoming established as invasive in Sturgeon Lake. Northern Pike and Round Goby are potential invaders due to range expansions through the Trent-Severn Waterway. Numerous other exotic fishes (e.g., Rainbow Trout, Brown Trout, Goldfish and Koi) are often intentionally stocked into local waters such as private ponds. Practices on the surrounding landscape can have a significant effect on the transport and occurrence of exotic species.
- ***Climate change has the potential to continue to alter aquatic ecosystem condition****.* The impacts of climate change will emanate from well beyond the watershed; however, they will affect physical and biotic attributes and ecological functions within the watershed. Climate change trends can be considered a large factor influencing the productive capacity of fisheries. Water temperature increases associated with climate change can influence factors such as year-class strength, recruitment, growth, and survival of fishes. It is generally predicted, on a provincial scale, that increases in water temperatures will favour the production of warm-water fishes, while reducing production of cool/coldwater fishes. Coldwater fishes in particular, are sensitive to increasing water temperatures, which could lead to reduced populations of the already limited lake-dwelling (Lake Herring) and stream-dwelling (Brook Trout) coldwater fish communities of Sturgeon Lake.
- ***Loss and fragmentation of aquatic habitat along the lake shoreline and small-to-medium sized tributaries****.* Over 50% of the shoreline has been developed within a 30m distance from shore. Much of this area has been hardened with concrete and armourstone, which provides reduced aquatic habitat potential and isolates land from water. In many small-to-medium sized lake tributaries, existing natural riparian land cover does not meet minimum recommended guidelines of 75% to maintain ecological integrity. Existing benthic macroinvertebrate communities appear to reflect stream habitat degradation. Riparian cover loss is largely due to conversion of natural lands for agricultural activities.
- ***Walleye population levels are in decline****.* Walleye abundance has shown a considerable decline since 1998. Measures of Walleye recruitment also appear to be in overall decline in the last 15 years; however

recent monitoring indicates a potential variation in the recruitment trend, relative to previous years, with the presence of a strong year class in 2010. Variation in recruitment can be attributed to a large number of factors, including water temperature, water level characteristics, predation on and competition among individual walleye fry.

- ***Physical changes to Sturgeon Lake have made aquatic habitat less suitable for top level predators and more suitable for other fish species***. Aquatic habitat has become less suitable for walleye because of increased water transparency. Other species such as bass may benefit from the increase in rooted aquatic vegetation. Habitat effects on the top predator muskellunge have not been demonstrated. Changes in the fish community may occur as a result of decreased predation by walleye.
- ***Maintaining adequate spring water levels.*** Regulating spring water levels can promote spawning success for walleye by providing access to spawning habitat, enhanced environment for egg development, and protection for hatching larval. Sturgeon Lake water levels as managed by Trent-Severn Waterway reveal little fluctuation throughout the spring, suggesting that current operating levels are adequate for walleye spawning. Increased velocity during periods of high water discharge into and out of Sturgeon Lake may pose a risk to walleye spawning due to physical disruption of spawning, scouring of eggs or impairment of emerging fry.
- ***Exploitation pressure.*** Exploitation of the fishery resource by anglers occurs at a significant level. The yield of walleye was estimated at 2 kg/ha in 1988 which is near the upper limit of sustainability. Exploitation of other species is not likely to be a concern for sustainability.
- ***Lack of "healthy aquatic ecosystem standards" against which to compare existing communities.*** Currently, no know standards exist for determining what constitutes a "healthy" and/or "impacted" aquatic community, in any given area within Sturgeon Lake watercourses. This is particularly important for assessing health of tributaries, where no long-term data set exists. Biotic indices utilized to evaluate aquatic ecosystem health have not been tested for applicability on local streams.
- ***Unknown effects of cumulative development on aquatic ecosystem condition.*** It is unknown at what point development within the watershed/shoreline can cause serious negative implications for the lake aquatic ecosystem. Shoreline areas in particular, are at risk of increasing development and urbanization.
- ***Status of small-bodied nearshore fish communities is unknown.*** Sampling precedent has been largely focused on large-bodied sport fishes, therefore, efforts to assess status and trends of smaller-bodied fish in the nearshore area should be given consideration.

8.2 Introduction

This chapter provides an overview of important components of the Sturgeon Lake aquatic ecosystem. An aquatic ecosystem is life within water bodies and their relationship to, and connection with living and non-living components. Maintaining healthy aquatic ecosystems is integral in maintaining a healthy Sturgeon Lake. Communities and individuals that rely on the lake benefit from a healthy aquatic ecosystem through the goods and services it provides, such as: quality recreational opportunities, clean water, biodiversity, and other lake-based functions. Local municipalities rely on healthy aquatic ecosystems to support their lake-based economy (the foundation of which is tourism), and to provide high quality lifestyle opportunities for residents and business.

The key aquatic ecosystem components that are critical in supporting the above-mentioned benefits are characterized below. A particular emphasis is placed on aquatic life (communities of species) and aquatic habitats (features and functions that maintain life) that exist/interact within the lake and its tributaries.

8.3 Lake-Based Ecosystems

8.3.1 Aquatic Habitat

The abundance, composition and productivity of aquatic communities are dependent on the quality and availability of habitats in a lake. Changes in habitat can affect aquatic communities by, for example, creating favourable conditions to one species that in turn shifts aquatic community composition or available prey resources. Physical habitat includes all spatial and temporal extents of lake morphology, hydrology, substrate type and physical cover, nutrient, optical and thermal features of an aquatic ecosystem. These habitat components differ among zones of a lake; most obviously between the littoral – nearshore zone (depths ~ 1 – 3 m) and the pelagic/profundal - offshore zone (depths > 3 m). This section will characterize the lake-based aquatic habitat of Sturgeon Lake specific to aquatic communities, associate aquatic communities with defined habitat areas, and describe recent changes observed in the abiotic and biological habitat components detailing potential consequences for the resident aquatic communities.

<u>Defining the Aquatic Habitat in Sturgeon Lake</u>

Sturgeon Lake can be divided into a series of physical spatial domains using characteristics such as shoreline contour and bottom topography that relate directly to the suitability and the availability of aquatic habitat. In particular, the spatial differences in the amount and access to the littoral zone coupled with the distinctive bottom morphology provide unique habitat structure compared to the other larger Kawartha Lakes that are similar in surface area but have different bottom morphology (e.g. less slope and reticulate shape). These spatially explicit areas provide variable aquatic habitat differing in local drainage, hydrology, nutrient loadings, optical features, and substrate and physical cover and ultimately affect aquatic communities and biological productivity.

Sturgeon Lake has a surface area of 4587 ha and it is one of the deeper lakes in the series of connected water bodies having a maximum depth of 9.0 m (restricted to a deep hole near the centre of the lake off Sturgeon Point), with a mean depth of 3.96 m. Sturgeon Lake has a distinctive “Y” shape that was exaggerated by the suppression of seasonal water level fluctuation and flow in the 1800s to render the Trent and Severn watersheds united and navigable for steamboats. The unique lake shape, amplified by water regulation, consists of three general areas: the Northwest arm (extending south from Fenelon Falls to Sturgeon Point), Goose Bay (south end) and the Northeast arm (extending north from Goose Bay to Bobcaygeon) ***(Figure 8.1)***. Sturgeon Lake’s distinctive shoreline shape can be considered reticulate (i.e. high shoreline convolution based on a perimeter to volume ratio) compared to neighbouring lakes (e.g. Balsam Lake and Pigeon Lake). Reticulation relates positively to the amount of littoral space reflecting the potential for greater development of littoral communities in proportion to the volume of the lake (Wetzel, 2001). The littoral zone is most productive area of the lake as there is fast turnover of essential nutrients due to erosional run-off and stream discharge, most lake-based fish spawn in the nearshore area and the prey of game fish are mainly restricted to the littoral zone (Keast and Harker, 1977). The amount, quality and access to this productive area are essential for biological productivity.

Despite the high reticulation, the littoral habitat in Sturgeon Lake is limited in both geographic area and water capacity. Bottom topography reveals that the littoral habitat (< 3 m) is only ~ 37% of the lake surface area and is confined primarily to two areas of the lake. Northwest arm bathymetry shows a littoral shelf 1 – 3 m deep and of variable width from the shoreline along most of the region leading into a relatively flat plain ~ 3 – 4 m deep towards Goose Bay. Goose Bay is uniformly shallow (~ 1 – 2 m deep) while the Northeast arm has a very limited littoral zone with a steep bottom slope leading into deep channel (~ 10 m deep) that extends the length of the region. Thirty-six percent of lake surface area is in waters > 6 m, primarily found along the Northeast arm and Sturgeon Point. This distinctive lake morphology results in 55% of the available water volume contained at depths of < 3 m, 33% of water contained at depths > 3 and < 6 m, and 10% of available water at depths > 6 m. This is in contrast to the lakes in the southern Kawartha Lakes region (i.e. Rice and Scugog) that are more uniformly shallow holding ~ 90% of the available water in the littoral region as opposed to 45% of available water in less productive limnetic or pelagic regions as evident in Sturgeon Lake. Therefore, the most productive area of Sturgeon Lake is reduced compared to neighbouring water bodies.

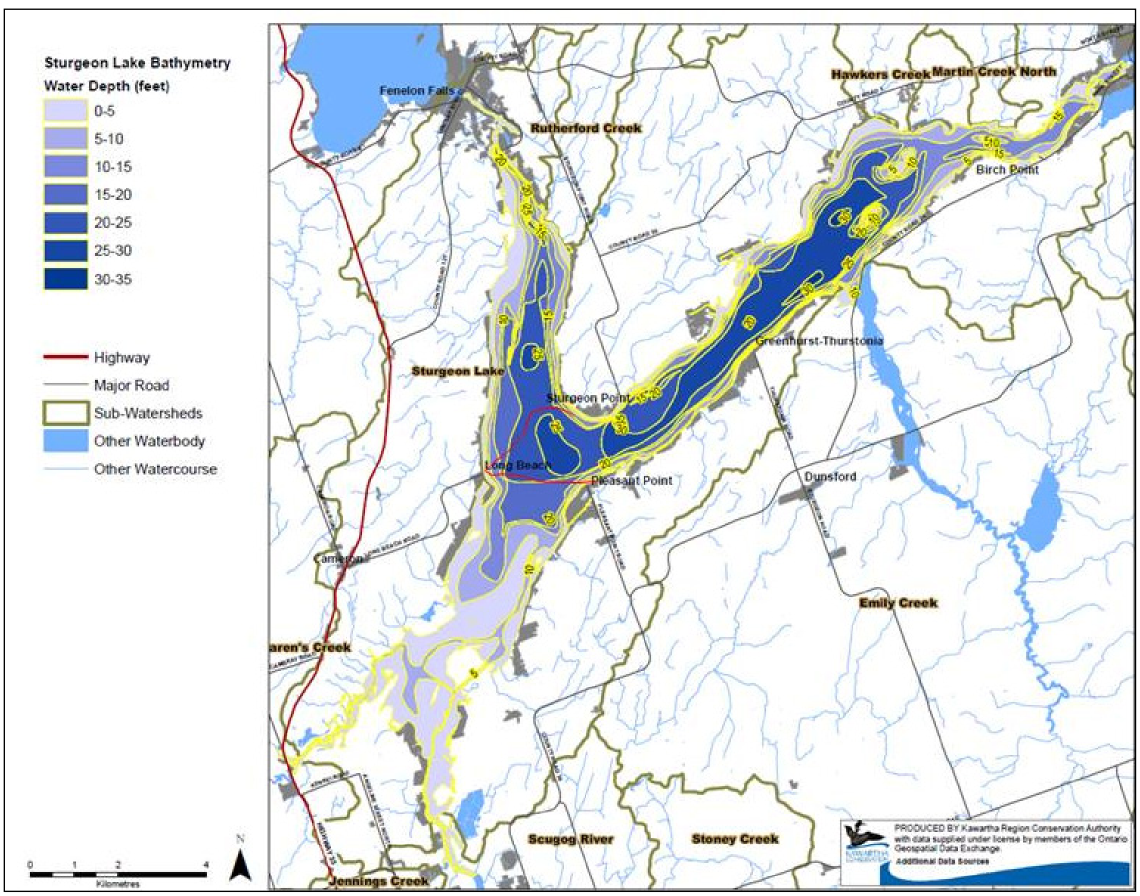


Figure 8.1. Bathymetric Map of Sturgeon Lake Showing Location of Three Unique Areas of Sturgeon Lake (Northwestern, Southern, and Eastern Arms)

Further reduction in the littoral area is also a consequence of water level fluctuation. Lake-based water levels are regulated by a series of dams and locks operated by TSW, Parks Canada. Maintaining adequate water levels in spring (March – June) provide critical habitat to promote spawning success. Insufficient water levels can impede access to spawning habitat, can scour eggs, or be harmful to hatching larval.

The suitability of aquatic habitat is also influenced by nutrient availability. Nutrient loadings, in particular phosphorus, are commonly the first element to limit biological productivity and are influenced by local hydrology and drainage (land use). Sturgeon Lake is situated near the upper portion of the Kawartha Lakes systems residing almost entirely within limestone plains, except for northern boundary that resides over bedrock. Sturgeon Lake receives water from Cameron Lake at the northwest input via the Fenelon River, from the Scugog River at Goose Bay, and from Emily Creek at the middle of the northeast arm.

Water discharges out through Bobcaygeon into Pigeon Lake, replacing 1.74×10^8 m3 of water, on average, every 37 days. Nutrient input coupled with the general northwest – northeast water flow creates a progressive downstream increase in phosphorus concentrations largely resulting from a change in forested drainage basins on the Shield that contain small concentrations of the alkaline earth elements to rich, agricultural basins which drain calcareous sediments (MOE, 1976).

Furthermore, the coupling of nutrient input and flow regime creates areas of nutrient depleted and nutrient enriched habitat. The Northwest arm has mainly low nutrient and low mineral water originating mostly on the Shield, Goose Bay has high nutrient and mineral content waters and Northeast arm has a mixture of both nutrient and mineral waters and low water retention periods (MOE, 1976). Consequently, the northwest and northeast regions of Sturgeon Lake can be considered mesotrophic exhibiting lower levels of productivity than Goose Bay, which is considered meso-eutrophic exhibiting higher productivity.

Nutrient loadings are inherently linked to water clarity, which also plays an important role in determining habitat quality. Water clarity can be a limiting factor to aquatic organisms that rely on visual cues for predation and/or predator detection. It is also important for the production and distribution (spatially and at depth) of aquatic plants by limiting the amount of light available for photosynthesis. Secchi disk depth is routinely measured in Sturgeon Lake as an estimate of water clarity. Secchi depth alone is not sufficient to estimate light at a given depth, but it can provide a crude measure of light attenuation based on total suspended solids. Sturgeon Lake exhibits variation in water clarity among the three geographic regions, coinciding with the known nutrient input and basic hydrological features. Goose Bay has the most turbid waters (secchi depth = 2.3 m) compared to the northwest arm which exhibits the highest water clarity (secchi depth = 2.7 m).

Vegetative cover and bottom substrate are other important physical characteristics of aquatic habitat that have implications for the productivity of aquatic communities. Generally, macrophytes are expected to increase nearshore productivity (Jude and Pappas, 1992). In addition, macrophytes increase the structural complexity of the littoral habitats, which has been shown to increase fish species richness and influences predator–prey interactions (Crowder and Cooper, 1982; Eadie and Keast, 1984). In Sturgeon Lake, macrophytes are largely confined to the littoral zone of the lake in the Northwest arm and Goose Bay regions. In the Northwest arm, macrophyte biomass is low to moderate in the nearshore regions of this area as the prevalence of soft substrate is variable. In the southern portion of the lake, Goose Bay has considerably higher macrophyte density. This section of the lake provides ideal conditions for plant growth since it has increased nutrient enrichment, it is extremely shallow and has soft sediment deposition. The bottom substrate of the Northeast arm is generally hard with variable regions of soft sediments and minimal macrophyte presence along the nearshore region.

Thermal regime is another important habitat component with strong links to aquatic communities. Water temperature is a crucial habitat component for all fish communities, with each species having preferred thermal habitat conditions for reproduction, survival and growth. Surface thermal conditions across Sturgeon Lake are not routinely monitored and therefore thermal spatial gradients among the three regions are not well defined. However, mean annual ice-free (April – November) surface water temperatures recorded daily at Gannon Narrows (Pigeon Lake outlet) have ranged from 16.7^{o}C to 19.7^{o}C over the last decade. Thermal regime not only affects suitability of aquatic habitat but also accessibility to habitat due to vertical thermal structure. In the summer months, the vertical thermal structure in Sturgeon Lake is relatively uniform with depth (~Δ 1^{o}C) with occasional periods of temporary thermal stratification observed in the deep hole off Sturgeon Point. The sustained thermal mixing is likely due to the prevailing wind conditions promoting a long fetch and high flow rate throughout the lake.

Other physical limnological attributes that may enhance or limit access to aquatic habitat are adequate dissolved oxygen concentrations to support aquatic respiration. Summer dissolved oxygen concentrations appear relatively stable in the surface waters and are somewhat uniform with depth. Historical dissolved oxygen profiles indicate occasional oxygen reductions in the bottom waters during prolonged periods of warm calm waters. However, the high level mixing throughout the water column likely promotes adequate dissolved oxygen levels to various aquatic habitats (e.g. offshore profundal) throughout the open water season.

Mapping the Sturgeon Lake Fish Communities onto the Aquatic Habitat

Fish production, as inferred from relative abundance estimates, varied spatially in the littoral areas and is likely related to specific biological and physical habitat characteristics. Overall, Sturgeon Lake supports warm/cool-water fish communities that primarily inhabit the littoral zone due to thermal preference, feeding or reproductive requirements. Regionally, Goose Bay provides a complex habitat of low flowing, nutrient rich, turbid waters and exhibits high level of macrophyte cover. The region supports higher abundances of Largemouth Bass, Bluegill and Pumpkinseed, compared to the other two regions. Walleye, although a turbidity preferring species, are found equally distributed among the three regions, using the littoral slope as an intermediary habitat between prime feeding locations (shallow, weedy waters inhabited by smaller forage species) and thermal refuge (cooler, deeper waters). Smallmouth Bass and Rockbass are found primarily along the harder substrates of the Northwest and Northeast arm. Black Crappie, a recent addition to the Sturgeon Lake piscivore guild, are found in higher abundances in the shallow, warmer waters of Goose Bay and Northwest arm. Yellow Perch, an abundant cool water species, are found ubiquitous, whereas less abundant species such as Muskellunge, are typically found along in the Northeast arm. However, the detection of less abundant species within the Northeast arm is likely due to the increased probability of detection due to the higher number of sampling sites.

Sturgeon Lake does not support coldwater fish communities however, monitoring in the deep channel that extends along the Northeast arm shows the presence of Lake Herring. Lake Herring are a cold-water species that are atypical to the Kawartha Lakes and while they have found their way into Sturgeon Lake, possibly originating from northern cold headwaters, they likely do not form a reproducing lake-based population.

Recent Changes in Sturgeon Lake Aquatic Habitat and Consequences for Aquatic Communities

Over the last 50 years, changes in shoreline development have included deforestation, land clearance for agriculture, increasing urbanization and hardening of shoreline – lake interface. Coincident with changes in shoreline development and land use patterns, several important changes in the abiotic and biotic characteristics of the lake have been observed to modify the nearshore – littoral landscape and have wide-spread implications aquatic habitat. The features that are readily related to nearshore littoral habitat characteristics are: decreases in nutrient loadings, water clarity, introduction of non-indigenous species and changes in macrophytes abundance and distribution.

Over the recent decades, some increases in water clarity have occurred in Sturgeon Lake as a result of reduced nutrient loadings starting in the late 1980s. Phosphorus levels in the lake have, for the most part, been reduced to below the PWQOs limit (< 20 µg/L) as a result of the decreased phosphorus input into the lake limiting the potential for primary production. The observed decline in nutrient input could result in an increase in water clarity. The arrival of zebra mussels (*Dreissena polymorpha*) in the mid-1990s amplified clarity in the lake water.

The introduction of zebra mussels changed many aspects of physical aquatic habitat. Their filtering activities greatly reduced the amounts of material suspended in the water column (i.e., turbidity). Average turbidity measures decreased by 65% from 2000 – 2010 compared to 1990 – 1999, thereby increasing light penetration throughout the water column over the last 13 years. Increased light penetration has in turn allowed the re-establishment and/or increase distribution of extensive macrophyte beds in many littoral areas where basic morphometric and substrate regimes were suitable. Overall, macrophyte growth and distribution (presence of macrophyte at lower depths) has increased in Sturgeon Lake, in the nearshore areas. These changes have increased the amount of potential spawning and feeding habitat for Muskellunge, bass, and other littoral panfish that are well adapted to feeding in conditions of abundant macrophyte growth.

Changes in nutrients, water clarity and macrophyte density have defined implications for the fish populations of Sturgeon Lake. For example, Bluegill established in Sturgeon Lake in the mid-1980s (Kawartha Lakes Fisheries Assessment Unit, OMNR, Lindsay, unpublished data) and showed relatively low, stable population measures until after the detection of zebra mussels in Sturgeon Lake (~ mid 1990s), when relative abundance measures increased six-fold. Black Crappie was first detected in 1998 through routine monitoring on Sturgeon Lake and the population has shown a steady increase in relative abundance since the early 2000s. The increased water clarity and change in macrophyte abundance and distribution have favoured species such as Bluegill and Black Crappie that prefer vegetated habitat and benefit from clear water for feeding. Long-term monitoring on Sturgeon Lake reveals substantially higher relative abundances of Bluegill and Pumpkinseed in Goose Bay since 2002, when increases in water clarity and macrophyte abundance were noticeable. Similarly, Largemouth Bass are well adapted to feeding in clear water conditions and prefer vegetated nearshore regions and have increased in relative abundance in both Goose Bay and the northwest arm over the last 10 years.

Alternatively, changes towards clear water, macrophyte-dominated system in the littoral zone has resulted in a habitat loss for other large fish predators such as Walleye. For example, ambient light is the principal abiotic controlling variable that determines the temporal and spatial dimensions of feeding in Walleye (Ryder 1977), therefore changes in water clarity are expected to influence Walleye production. These turbidity-preferring predators have shown a decrease in overall relative abundance in the lake and particularly in the once highly abundant Goose Bay, likely due to changes in suitable nearshore predation grounds.

Climate change is also a continuing stressor affecting thermal and hydrologic lake conditions. Sturgeon Lake has shown a slight increase by ~1oC in sustained summer (June, July, and August) water temperatures. Such changes in water temperature over time are becoming increasingly recognized as factors to that influence year-class strength, recruitment, growth, and survival of fishes. For example, in eastern Lake Ontario, it has been predicted that an increase in water temperature of 1 °C above the mean would result in an almost 2.5-fold increase in the relative recruitment of Smallmouth Bass, whereas cool water species would experience a 2.4-fold decline in relative recruitment (Casselman et al., 2002). Furthermore, Walleye growth is linked to ambient temperature and the length of the growing season. Sturgeon Lake Walleye are likely to achieve greater size-at-age values compared to populations in northern latitudes due to the longer and warmer growing season (Venturelli et al., 2010a). However, a warmer and extended growing season has also been associated with shorter life span; therefore, as temperatures continue to rise, Walleye may grow larger faster, but decrease in longevity.

Changes in thermal regime may also affect the availability of deep, cold waters along the Northeast arm in Sturgeon Lake. Currently, coreogonids and salmonids populations are considered rare in the Kawartha Lakes; however recent deep water gillnetting has captured occasional Lake Herring likely from populations resident to northern headwaters. The presence of coregonids indicates suitable summer profundal habitat for cold-water species. Changes in thermal attributes (absolute values and vertical structure) may compromise accessibility and/or suitability of deep-water habitat for these uncommon species.

8.3.2 Fish Communities

General Species Composition

Sturgeon Lake's fish community composition reflects its warm / cool-water thermal regime and mesotrophic nutrient status. The lake supports fish species that are mostly represented in the esocid, centrarchid, percid and cyprinid families. Historically, the large-bodied fish species were most often represented by Muskellunge, Smallmouth Bass, Pumpkinseed and Yellow Perch populations ***(Table 8.1).*** However, the large-bodied fish community structure has become increasingly diverse due to intentional stocking, range extensions of native species, unintentional introductions and non-native species invasions. Walleye were intentionally introduced to the Kawartha Lakes region in the 1930s to provide recreational angling opportunities. Largemouth Bass and Rock Bass are native to the Trent River system and the construction of locks and canals between waterways have allowed this species to expand their range into Sturgeon Lake. More recently, Bluegill and Black Crappie have become established in the lake; both species are native to eastern and central North America preferring the warm shallow waters of large and small lakes that have abundant aquatic vegetation. They have expanded their ranges through the Trent-Severn Waterway after initially establishing in Rice Lake. Bluegill was first detected in Sturgeon Lake in the mid-1980s, whereas Black Crappie only appeared in late 1990s (Kawartha Lakes Fisheries Assessment Unit, OMNR, Lindsay, unpublished data). Northern Pike have expanded along the same watercourse, alternatively from Lake Simcoe into the Kawartha Lakes, and have become established in adjacent and connected water bodies (i.e., Balsam Lake), although they have not been confirmed in Sturgeon Lake (Kawartha Lakes Fisheries Assessment Unit, OMNR, Lindsay, unpublished data). Other less common warm/cool water species found in Sturgeon Lake include, Brown Bullhead, Common White Sucker and Common Carp. Common Carp were accidentally introduced into the Great Lakes system approximately 100 years ago. The Round Goby is considered an invasive species and it poses a threat to native fish community structure by negatively impacting species diversity through competition with, and predation on, native fish species in areas where they have become established (Kornes et al., 2012). Round Goby has not been detected in Sturgeon Lake yet.

The warm/cool water fish community also includes small-bodied, forage fish species, such as minnows, darters, shiners and trout-perches. Little is known about the status of the small-bodied species, such as cyprinids, within the Sturgeon Lake basin; however historic records from other Kawartha Lakes and warm water river tributaries indicate the potential for a diverse community ***(Table 8.1).*** Overall, typical species of the Sturgeon Lake fish community are members of the warm/cool water guild. Lake Herring, a cold-water species, are an exception and have been captured in low numbers at depths along the northeast arm.

Spatial Distribution of Fish Communities

The majority of Sturgeon Lake fish populations reside in (or temporarily utilize) the warmer waters of the littoral (nearshore) zone due to their thermal preferences, feeding ecology and reproductive requirements.

Fish communities that inhabit the Sturgeon Lake nearshore habitat have been routinely assessed using Nearshore Community Index Netting (NSCIN), a standard trapnet methodology that was developed to assess the status of fish populations (specifically large-bodied piscivores) that live in the nearshore area of a lake in late summer and early fall. The NSCIN program has been adopted province-wide allowing for the comparison of centrarchid (bass and sunfish) populations through time and among lakes (Stirling, 1999).

Table 8.1. Comparison of Fish Species Present or Recorded Historically in the Kawartha Lakes, Warm Water Tributaries and within Sturgeon Lake Proper

[1] denotes species that are non-native to the Kawartha Lakes region

Fish Species - Common Name	Kawartha Lakes	Tributaries within the SLMP planning boundary	Sturgeon Lake
Banded Killifish	x		
Black Bullhead	x	x	
Black Crappie[1]	x		x
Blackchin Shiner	x		
Blacknose Dace	x	x	
Blacknose Shiner	x		
Bluegill[1]	x	x	x
Bluntnose Minnow	x	x	
Bowfin	x		
Brassy Minnow	x	x	
Brook Silverside	x		
Brook Stickleback	x	x	
Brook Trout	x	x	
Brown Bullhead	x	x	x
Burbot	x	x	x
Central Mudminnow	x	x	
Central Stoneroller	x	x	
Channel Catfish	x		
Cisco	x		x
Common Carp[1]	x	x	x
Common Shiner	x	x	x
Creek Chub	x	x	x
Emerald Shiner	x		
Fallfish	x		
Fantail Darter	x		
Fathead Minnow	x	x	x
Finescale Dace	x	x	
Golden Shiner	x	x	x
Greenside Darter	x		
Hornyhead Chub	x		

Iowa Darter	x	x	
Johnny Darter	x	x	
Lake Chub	x		
Lake Sturgeon	x		
Lake Whitefish	x		
Largemouth Bass[1]	x	x	x
Logperch	x	x	x
Longnose Dace	x	x	
Longnose Sucker	x		
Mimic Shiner	x		
Mottled Sculpin	x	x	
Muskellunge	x	x	x
Northern Pike	x		
Northern Redbelly Dace	x	x	
Pearl Dace	x	x	
Pumpkinseed	x	x	x
Rainbow Darter	x		
Rainbow Smelt	x		
Rainbow Trout	x		
Redside Dace	x		
Rock Bass	x	x	x
ShortheadRedhorse	x		
Silver Redhorse	x		
Smallmouth Bass	x	x	x
Splake	x		
SpoonheadSculpin	x	x	
Spottail Shiner	x	x	x
Striped Shiner	x	x	
Trout-perch	x		x
Walleye[1]	x	x	x
White Sucker	x	x	x
Yellow Bullhead	x		x
Yellow Perch	x	x	x

However, in Sturgeon Lake, NSCIN also targets non-centrarchid species such as Walleye, Muskellunge and Brown Bullhead. Since 1998, a NSCIN survey has been conducted annually on Sturgeon Lake by Sir Sandford Fleming College (SSFC) as part of their academic programming, until 2012, when Kawartha Lakes Fisheries Assessment Unit, OMNR conducted a fall NSCIN survey.

Fourteen large-bodied fish species have been caught in the nearshore habitat of Sturgeon Lake in early fall using the NSCIN methodology from the 1998 – 2012 ***(Figure 8.2)***. Based on total number of individuals caught in NSCIN surveys, the most frequently caught species in the nearshore zone were Bluegill, Pumpkinseed, Black Crappie, Rock Bass, Smallmouth Bass, and Walleye ***(Figure 8.2)***. These species comprise approximately 90% of the total catch. Several species were caught less frequently in the

nearshore habitat of Sturgeon Lake including: Largemouth Bass, Yellow Perch, Brown Bullhead, Common Carp, Common White Sucker and Muskellunge. Rarely, Burbot and larger Common Shiners have been caught. These species may be present but infrequently show in catch records because they are less abundant (i.e., Muskellunge), non-permanent residents of the nearshore area (i.e., Common White Sucker) or less vulnerable to being captured by the NSCIN sampling gear (i.e., Yellow Perch). Small-bodied species,

such as cyprinids, other percids, forage fish, and juveniles of large-bodied species are also primarily found in the nearshore zone; however, these fish are not vulnerable to NSCIN gear and are currently not subject to routine monitoring.

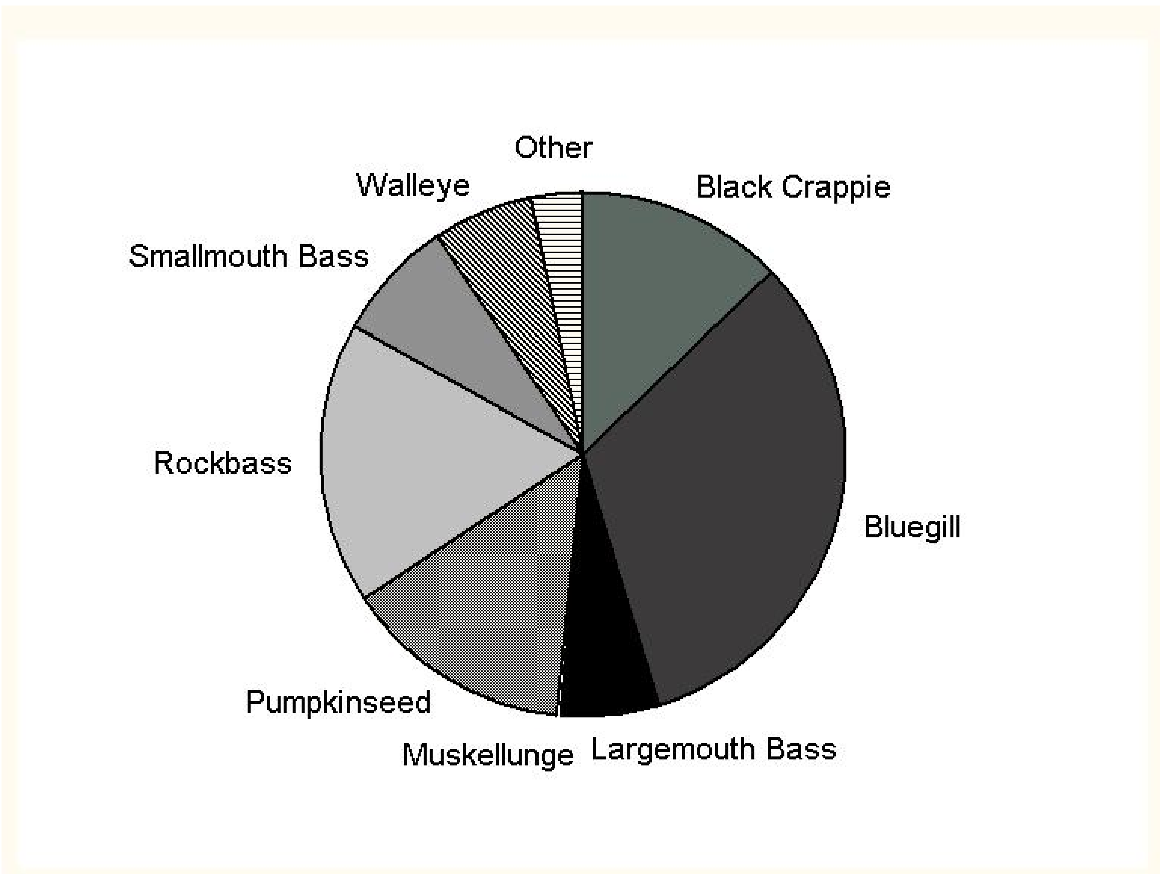


Figure 8.2. Average Catch Frequency of Occurrence of Each Species Caught in the Nearshore Habitat in the Later Summer - Early Fall During the NSCIN Program (1998 – 2012)
Species grouped in Other include - Common White Sucker, Common Carp, Common Shiner, Brown Bullhead, Burbot, Yellow Perch

Large-bodied fish species are widely distributed throughout the nearshore zone; they may be present in different proportions, or relative abundance, from one area to another based on variation in nearshore habitat types and habitat preferences of the species. ***Figure 8.3*** shows that the relative abundance of individual fish species (as shown by catch per unit trapnet effort) can be higher or lower in a particular region of the lake than represented by relative abundance determined for the lake as a whole. For example, Largemouth Bass, Bluegill and Pumpkinseed exhibit higher relative abundances in the shallow, more productive vegetated nearshore waters of Goose Bay compared to the other two regions ***(Figure 8.3 a, b, c)***. Conversely, Smallmouth Bass and Rock Bass are found primarily along the harder substrates of the Northwest and Northeast arm ***(Figure 8.3 d, e)***. Black Crappie, an introduced species, were first caught in the nearshore habitat of Sturgeon Lake using NSCIN gear in 1998. Since then, Black Crappie have comprised up to 14% of total individuals caught *(**Figure 8.2**)*, and for the last six years have been found at 97% of the sites sampled, showing higher abundances in the nutrient rich waters of Goose Bay and the waters of the Northwest Arm *(**Figure 8.3 f**)*. Percids, such as Walleye, and Muskellunge are generally found in similar abundances among the three regions ***(Figure 8.3 g, h)***.

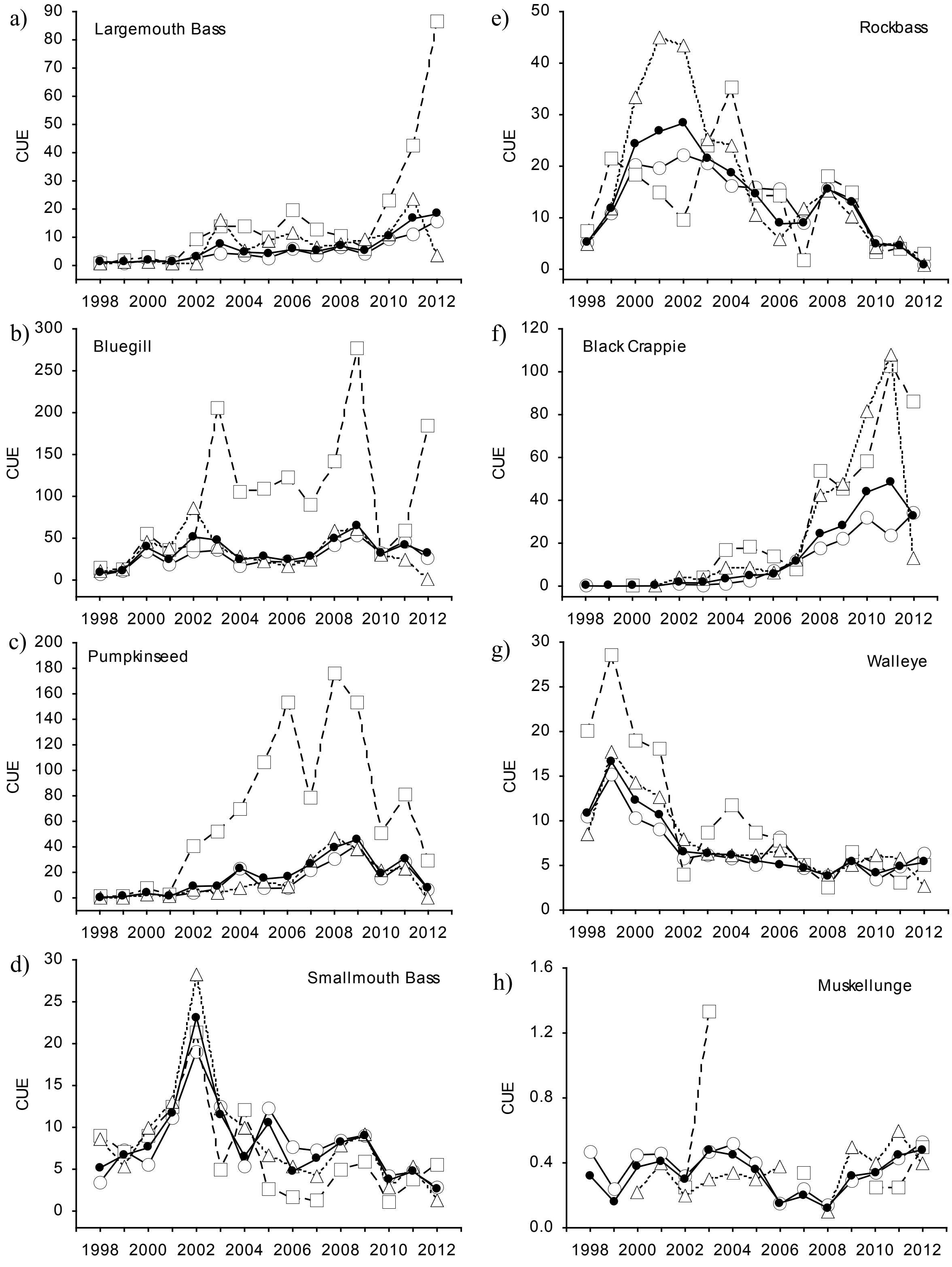


Figure 8.3. Trend Through Time Catch per Unit Trapnet Effort (CUE)
for a) Largemouth Bass, b) Bluegill, c) Pumpkinseed, d) Smallmouth Bass, e) Rockbass, f) Black Crappie, g) Walleye, and h) Muskellunge by region (○ – Northwest Arm, □ – Goose Bay, □ – Northeast Arm). ●represents lake-wide CUE

Sturgeon Lake has a marginal capacity to sustain species that require offshore, cold-water habitat because of its overall warm/cool thermal profile. Assessment of the pelagic and profundal (deepest) regions of Sturgeon Lake have been conducted using a combination of two OMNR standard inland lake index gillnetting programs, Fall Walleye Index Netting (FWIN) and Broad-scale Monitoring (BSM). FWIN surveys assess the status of walleye populations in the fall and BSM surveys assess the status of angler harvested freshwater fish species in the summer. Three FWINs have been conducted on Sturgeon Lake (2006, 2007, 2010), and in 2010, BSM was conducted monthly throughout the summer months (July, August, September). These recent lake-wide monitoring programs reveal an offshore community structure that is dominated by Yellow Perch, Rock Bass, Smallmouth Bass and Walleye (***Table 8.2***). Smaller bodied fish, such as Logperch, Spottail Shiner, Golden Shiner and Trout-Perch have been observed in pelagic areas; however these species are likely only detected in the offshore regions (in proportions higher relative to the nearshore habitat) due to their greater vulnerability to the smaller gillnet mesh sizes of both FWIN and BSM gear compared to trapnet gear.

Table 8.2.Comparison of Catch per Unit Effort Measures for Each Survey Type, by Species and Year. Broad-scale Monitoring Values Were Averaged over the Three Monthly (July - September) Surveys

	Muskellunge			Smallmouth Bass			Largemouth Bass			Walleye		
	NSCIN	FWIN	BSM	NSCIN	FWIN	BSM	NSCIN	FWIN	BSM	NSCIN	FWIN	BSM
1998	0.32			5.16			1.24			10.76		
1999	0.16			6.71			1.03			16.61		
2000	0.38			7.56			1.69			12.34		
2001	0.41			11.74			1.21			10.65		
2002	0.29			23.15			3.09			6.56		
2003	0.48			11.60			7.79			6.29		
2004	0.45			6.55			4.71			6.22		
2005	0.35			10.52			4.35			5.54		
2006	0.15	0.25		4.74	1.94		5.67	0.28		5.13	1.34	
2007	0.20	0.13		6.22	2.53		5.02	0.00		4.76	2.16	
2008	0.12			8.22			6.88			3.84		
2009	0.32			8.94			5.21			5.49		
2010	0.34	0.32	0.15	3.70	0.38	2.98	10.54	0.09	0.15	4.08	1.32	1.25
2011	0.45			4.74			16.60			4.89		
2012	0.48			2.63			18.26			5.33		

	Rockbass			Pumpkinseed			Bluegill			Black Crappie			Yellow Perch		
	NSCIN	FWIN	BSM	NSCIN	FWIN	BSM	NSCIN	FWIN	BSM	NSCIN	FWIN	BSM	NSCIN	FWIN	BSM
1998	5.20			0.56			8.00			0.08			1.28		
1999	11.77			0.94			11.71			0.00			1.00		
2000	24.25			3.47			38.91			0.03			1.84		
2001	26.74			1.35			24.94			0.09			0.47		
2002	28.35			9.06			51.50			1.56			0.88		
2003	21.52			9.43			47.88			1.40			1.45		
2004	18.76			22.96			24.39			3.53			2.45		
2005	14.56			14.79			27.88			4.92			1.90		
2006	8.82	3.13		16.44	0.31		23.38	0.56		5.67	0.09		1.51	15.53	
2007	9.00	6.78		26.46	0.22		28.39	0.25		11.50	0.41		3.33	11.97	
2008	15.63			39.51			49.65			24.20			1.63		
2009	12.94			45.98			65.00			28.34			2.98		
2010	4.90	2.59	3.27	19.00	0.21	0.67	31.26	0.35	0.44	43.84	0.00	0.47	4.54	21.88	18.99
2011	4.53			31.09			42.66			48.13			3.89		
2012	0.96			7.11			31.89			33.00			0.78		

	Lake Herring			Common White Sucker			Common Carp			Common Shiner			Brown Bullhead			Burbot		
	NSCIN	FWIN	BSM	NSCIN	FWIN	BSM	NSCIN	FWIN	BSM	NSCIN	FWIN	BSM	NSCIN	FWIN	BSM	NSCIN	FWIN	BSM
1998				1.60			0.60						0.76			0.04		
1999				2.48			0.45						0.13			0.03		
2000				1.94			0.38						0.53					
2001				1.29			0.18						0.24			0.03		
2002				1.35			0.65						0.18					
2003				0.76			0.52						0.05					
2004				0.80			0.35						0.02					
2005				0.77			0.29						0.08					
2006		0.03		0.44	0.34		0.33	0.34			0.06		0.05					
2007				0.39	0.69		0.17	0.19					0.04					
2008				0.29			0.18						0.02					
2009				0.72			0.34			0.02			0.09					
2010		0.09	0.19	0.06	0.50	0.31	0.08	0.09	0.06				0.06			0.02		
2011				0.30			0.26						0.04					
2012				0.15			0.67						0.04					

The standardized netting reveals the presence of smaller Walleye in the pelagic and deeper waters relative to the nearshore areas. Also, smaller Yellow Perch are found more often in nearshore regions compared to the size distributions observed in deeper, offshore waters. Deep water gillnet sets reveal the presence of Lake Herring along the Northeast arm channel. Lake Herring are a cold-water species that were historically found in the northern Kawartha Lakes; however, Stoney Lake is considered to be the only lake to currently support a reproducing coregonid population. Therefore, Lake Herring likely move into Sturgeon Lake from northern cold headwater rivers and are able to maintain a presence due to high oxygen levels (> 4.0 mg L^{-1}), coupled with generally cooler, water temperatures (< 20^oC), at depth.

Long-term changes in Sturgeon Lake fish communities

The Sturgeon Lake fish community has experienced long-term directional changes in species composition, catch rate, total biomass and other community and population measures from 1998 – 2012. Long-term changes in fish community and population structure can reflect anthropogenic effects such as exploitation, modification of predator-prey interactions within the community, recruitment success and variation in life history traits such as growth rates. Standard index netting information, from NSCIN, FWIN and BSM, coupled with historic non-standard netting records, highlights the magnitude of the changes in Sturgeon Lake fish populations.

The sequence in which fish community structure has changed in Sturgeon Lake corresponds well with a noted shift in significant ecological and environmental conditions (Robillard and Fox, 2006). Sturgeon Lake supported abundant walleye populations following their initial stocking introduction into Kawartha Lakes from the 1920s through to the 1940s. Historical netting indicates that by the late 1980s, Smallmouth Bass was becoming more abundant in trapnet catches and the appearance of Largemouth Bass into the system contributed to this shift in the piscivore guild (species or predator composition) (Robillard and Fox, 2006). The changes in species composition continued throughout the 1990s with the appearance of two new species (Black Crappie and Bluegill) and subsequently the contribution of Walleye to the trapnet catch declined (***Figure 8.4 a, c, Table 8.2***). Since 1998, when recent routine annual monitoring began, the Sturgeon Lake nearshore fish community has moved away from percids towards a community dominated by centrarchids (e.g., Pumpkinseed, Black Crappie, Bluegill), including Largemouth Bass as an emerging top level predator (***Table 8.2***). This noted change in species composition and relative abundance maybe related to an increase in water clarity due to a reduction of nutrient loadings and the invasion of the zebra mussels.

Shifts in the fish community structure are also reflected in biomass. The nearshore area of Sturgeon Lake is currently supporting over twice as much fish biomass since 2007: the current biomass translates into approximately 40 kg of fish mass per unit trapnet effort (***Figure 8.4 b, d***). Collectively, the biomass of large-bodied predators (***Figure 8.4 d***) have remained relatively stable over 15 years, with the contribution of Largemouth Bass increasing three-fold from 2007, Smallmouth Bass decreasing, and Walleye and Muskellunge showing little fluctuation from year-to-year. Alternatively, panfish species have shown significant increases in biomass, currently contributing up to 60% of the total biomass in the nearshore area (***Figure 8.4 b***). This is in contrast to the late 1990s where the total biomass contribution for panfish was less than 30%. Pumpkinseed, Bluegill and Black Crappie have seen defined annual increases in biomass, whereas Rock Bass biomass has declined. The changes in community biomass are likely reflecting the alterations in predator-prey dynamics in response to the on-going variations in species diversity and abundance, and environmental conditions.

Long-term changes in Sturgeon Lake aquatic communities are also reflected in the characteristics of the individual large-bodied fish populations. Walleye catch rates have shown a considerable decline in both the warm nearshore waters and offshore pelagic regions over the last 15 years (***Table 8.2***). However, average Walleye biomass per net has remained relatively stable of the years (BUE ~ 6.5 kg/net) (***Figure 8.4 d***). There is an increase in the relative proportion of larger to smaller Walleye in the entire nearshore population. This may be attributed to the population size structure shifting towards a higher proportion of larger, older individuals (***Figure 8.5***), e.g., 1999: $\bar{x}_{size}$ = 36.5 cm, $\bar{x}_{age}$ = 4; 2012: $\bar{x}_{size}$ = 46.7 cm, $\bar{x}_{age}$ = 7). A progressive decline in smaller sized Walleye (< 40 cm) may be indicative of lower recruitment. Recruitment, or the amount of young fish that have potential to grow into catchable, harvestable, or adult size, is necessary to sustain any population fishery and is influenced primarily by year-class strength. Long-term data on Sturgeon Lake reveals a decline in Walleye year-class strength since 1995 (***Figure 8.6***).

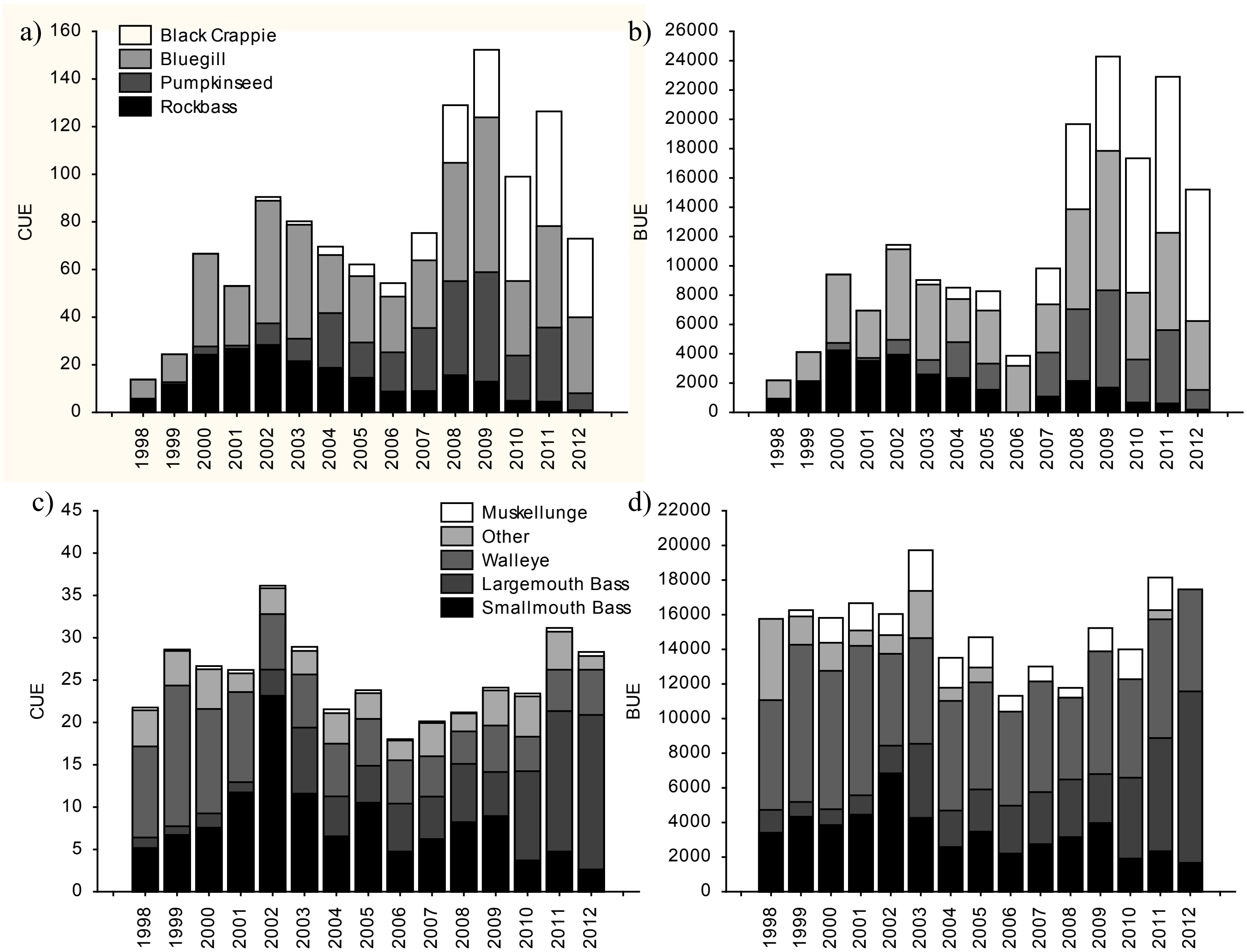


Figure 8.4. Catch and Biomass per Unit Trap Net Effort
for a. and, b. commonly caught panfish (Rockbass, Pumpkinseed, Bluegill, Black Crappie) and c. and d. sport fish (Smallmouth Bass, Largemouth Bass, Walleye, Muskellunge and Other – Common White Sucker, Common Carp, Common Shiner, Brown Bullhead, Burbot, Yellow Perch)

Recent monitoring indicates potential variation in the recruitment trend, relative to historical years, with the presence of a strong year class in 2010 (not shown on ***Figure 8.5***). Variation in recruitment can be attributed to a large number of factors, including water temperature, water level characteristics, predation on and competition among individual walleye fry.

Long-term data on Muskellunge indicates potential improvement of the population. Muskellunge in standard index surveys are caught at a much lower level of abundance than other fish species due to their size and consequently, have decreased vulnerability to trapnet and gillnet gear. Annual relative catch measures of Muskellunge in the nearshore area are variable, but a there is a general increase of total individuals caught per survey year (***Table 8.2***). Furthermore, population metrics show that the current age distribution has expanded from two age classes in 1998 to eight age classes in 2012. Higher numbers of age classes indicates increased survivorship and possible population enhancement through successful recruitment. Threats to the native muskellunge populations include the possible introduction of Northern Pike to Sturgeon Lake. Northern Pike compete with muskellunge for critical factors that influence the health of the population, including habitat and prey resources. Consequently, the potential impacts of Northern Pike expansion include lowering of relative abundance and overall population condition.

Yellow Perch catch rates have shown a general increase in the offshore pelagic regions of Sturgeon Lake (***Table 8.2***). Accompanying the overall increase in abundance, Yellow Perch size distribution reveals a higher proportion of larger, quality-sized individuals (> 20 cm) in the offshore regions. The increase in quality-sized, or stock-sized, individuals indicates the potential for enhanced recreational fishing opportunities throughout the year. Changes in the population levels and size structure of Yellow Perch may be a result of reduced predation pressure due to fewer Walleye in the system (Walters and Kitchell, 2001).

The decline of Walleye abundance also corresponds to significant increases in bass and the emergence of other centrarchids. Largemouth Bass catch rates and biomass in the nearshore region have shown an exponential increase since 1998 and are currently at 18 fish per trapnet effort (***Table 8.2***). The abundance of Smallmouth Bass has shown variability over the last 15 years ranging from 3-12 fish per unit trapnet effort (***Table 8.2***). Both bass populations exhibit broad size and age distributions that have remained relatively stable despite changes in environmental and ecological changes to Sturgeon Lake. The age distribution shows good representation of fish from age 1 - 13 in most years for both species; however, age 2 - 5 comprise the largest portion of Smallmouth Bass catch, whereas as age 1 - 4 comprise the largest portion of Largemouth Bass catch. Overall, the age distributions of both species are indicative of successful recruitment. Despite the observed increases in abundance, growth rates for both Largemouth and Smallmouth bass have shown slight decreases (smaller size at age), indicating that population is likely stabilizing.

Other centrarchids, including Pumpkinseed, Bluegill and Black Crappie, have shown annual increases in relative abundance and biomass in their preferred nearshore habitat. Black Crappie was first detected in trapnet gear in the nearshore region 1998 and showed a typical abundance trend of an introduced species. After its initial establishment, Black Crappie catch rates and biomass show dramatic annual increases since 2003 (***Figure 8.4 a, b, Table 8.2***). 2012 is the first year that black crappie abundance has declined from previous years, indicating that the population may be approaching stabilization. Similarly, the abundance and biomass of Pumpkinseed have increased from low levels in 2002, peaking in 2009 and are currently in decline (***Figure 8.4 a, b, Table 8.2***). Bluegill, having likely invaded Sturgeon Lake between the late 1980s and early 1990s, remained relatively low in abundance and biomass until the late 1990s. Since then, the trends through time for both population measures have been variable with noticeable peaks in 2002 and 2009 (***Figure 8.4 a, b, Table 8.2***). Alternatively, Rock Bass abundance and biomass has progressively declined over the 15 year time period.

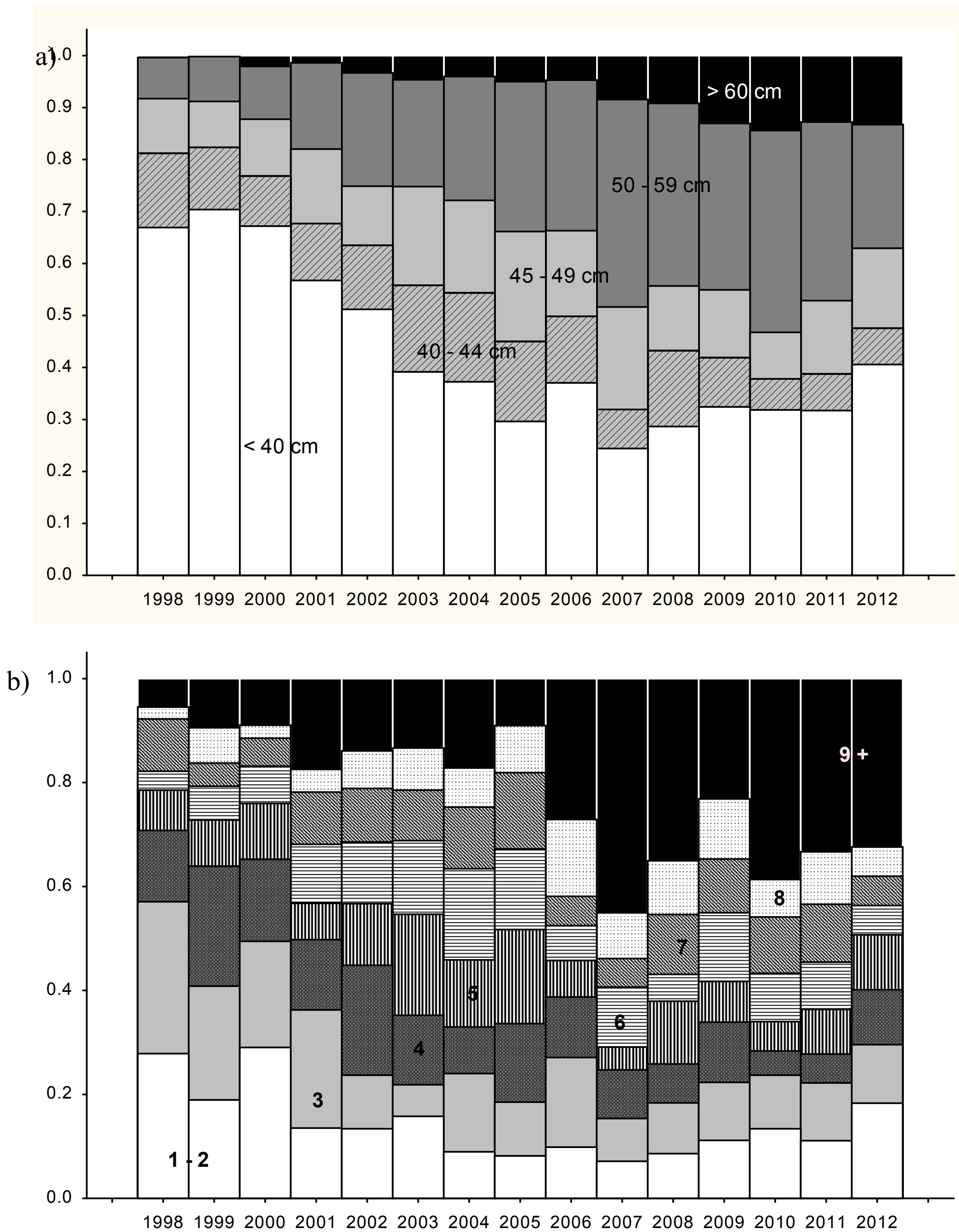


Figure 8.5. Relative Proportion of Walleye Total Catch per Year Based on a) Size (Fork Length – cm) and b) Age

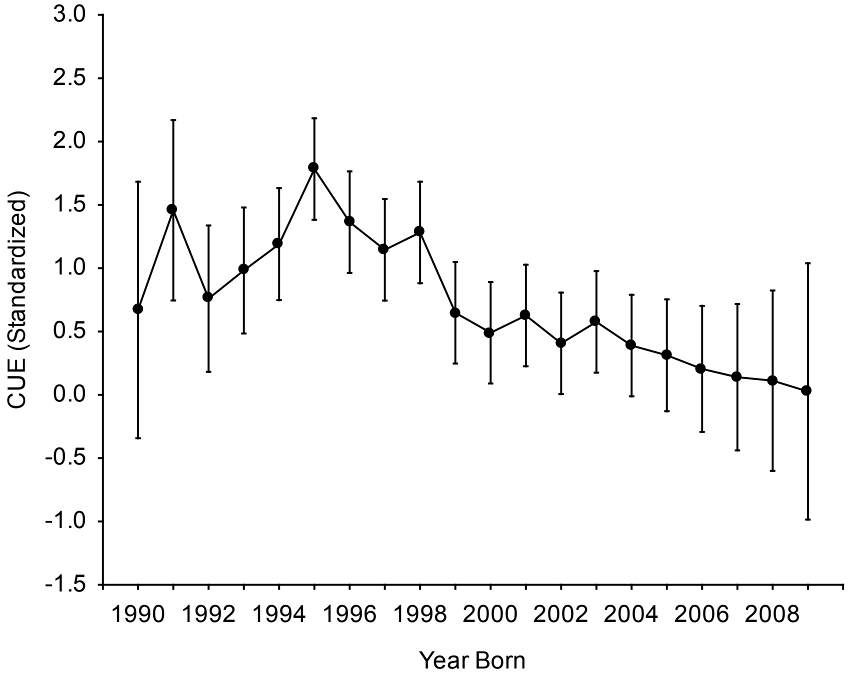


Figure 8.6. Standardize Catch per Unit Trapnet Effort (CUE) from 1998 – 2012 for Walleye for Individuals Aged 3–8

Status of the Sturgeon Lake Recreational Fishery

Directional changes in individual fish populations impact, not only the ecological framework of the lake but also, the recreational fishery. Sturgeon Lake is located within the Kawartha Lakes area which supports a significant recreational fishery. It is a competitively fished lake (≥ 10 tournaments per year; Kerr 2009). In the open water season, the most sought after species have traditionally been Walleye, Muskellunge and Yellow perch. Recent changes in the population structure of these species have shifted angling efforts towards bass and other centrarchid species. The recreational fishery is assessed by conducting angler (creel) surveys on individual lakes to estimate the magnitude of the fishery (hours spent fishing), and the harvest by species. These surveys indicate that approximately 30 hours of fishing per hectare of water is expended across the Kawartha Lakes. During the open-water fishing season, anglers predominantly target Walleye although bass, Muskellunge, and panfish species are targeted as well. The harvest of walleye estimated from these surveys have ranged from 1 to 2 kg/ha in the most recent surveys. A winter ice fishing season was recently opened in 2010 that permits angling for panfish species.

It has been more than 20 years since the Sturgeon Lake recreational fishery has been assessed with an angler survey. However, angler activity on Sturgeon Lake was recently estimated as part of MNR's Broad-scale Monitoring program by using aircraft to directly count angler activity. In 2009, the numbers of fishing boats were counted on 16 flights during the open-water season to estimate the number of angler-hours during the open-water fishing season (***Table 8.3***). In 2010, the numbers of ice anglers and active ice huts were counted on 12 flights during the winter ice fishing season to estimate the number of angler-hours during the open-water season (***Table 8.3***).

Table 8.3. Angler Effort on Sturgeon Lake Estimated from Angler Activity Counts Conducted during the 2009 Open-water Fishing Season and the 2010 Winter Ice Fishing Season

Season	Mode	Day-type	Mean Number Counted	St Dev. Number Counted	Estimated Angler-hours	Estimated Angler-hours/ha
Open water	Angling Boats	Weekday	28.0	20.6	68,040	15.5
		Weekend day	71.8	20.2	86,100	19.6
		Total			154,140	35.1
Winter	Open Ice Anglers	Weekday	1.4	1.5	324	0.1
		Weekend day	18.4	16.9	1,100	0.3
		Total			1,424	0.3
	Active Angler Huts	Weekday	0.6	0.6	1,512	0.3
		Weekend day	5.0	3.2	8,096	1.8
		Total			9,608	2.2

8.3.3 Benthic Macroinvertebrates

Benthic macroinvertebrates (benthos) are small, bottom-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 substrates of watercourses for a significant portion of their life cycles. In shallow lakes, they play a key role in the aquatic-based food web.

Shoreline benthos communities

Information on benthos within Sturgeon Lake is limited to shoreline-based assemblages. In fall of 2011 students from Sir Sandford Fleming College collected benthos from numerous stations along the Sturgeon Lake shoreline to obtain a better understanding of the major community types present. Benthos was collected at 16 sites following the shoreline module outlined in the Ontario Benthos Biomonitoring Network protocol (Jones et al., 2007). The locations of these sites are shown in ***Figure 8.7***, and are generally located in easily-accessible cobble/gravel shoreline areas.

Raw benthos counts for each site are located in ***Appendix AE1.*** In terms of diversity, 20 unique taxa were documented along the shoreline. Taxa richness at any given site ranged from 8 to 13, with an average of 10.2. When examining both richness and evenness using Simpson's Diversity Index, values ranged from 0.24 to 0.81 at each site, with an average of 0.59. The average diversity value is relatively low, and is likely explained by the high numbers of Scuds in every sample. Scuds were the dominant benthic invertebrate found amongst all shoreline samples, comprising over half of total relative abundance (***Figure 8.8***). This is not unusual, considering their affinity towards lentic habitats. Scuds, together with snails, mayflies, beetles, sow bugs, caddisflies, clams/mussels and midges comprise over 98% of all taxa documented. Sensitive organisms including Mayflies, Stoneflies and Caddisflies comprise approximately 15% of the benthos community when all samples are combined, with values ranging from 2.4 to 50.5% at each site.

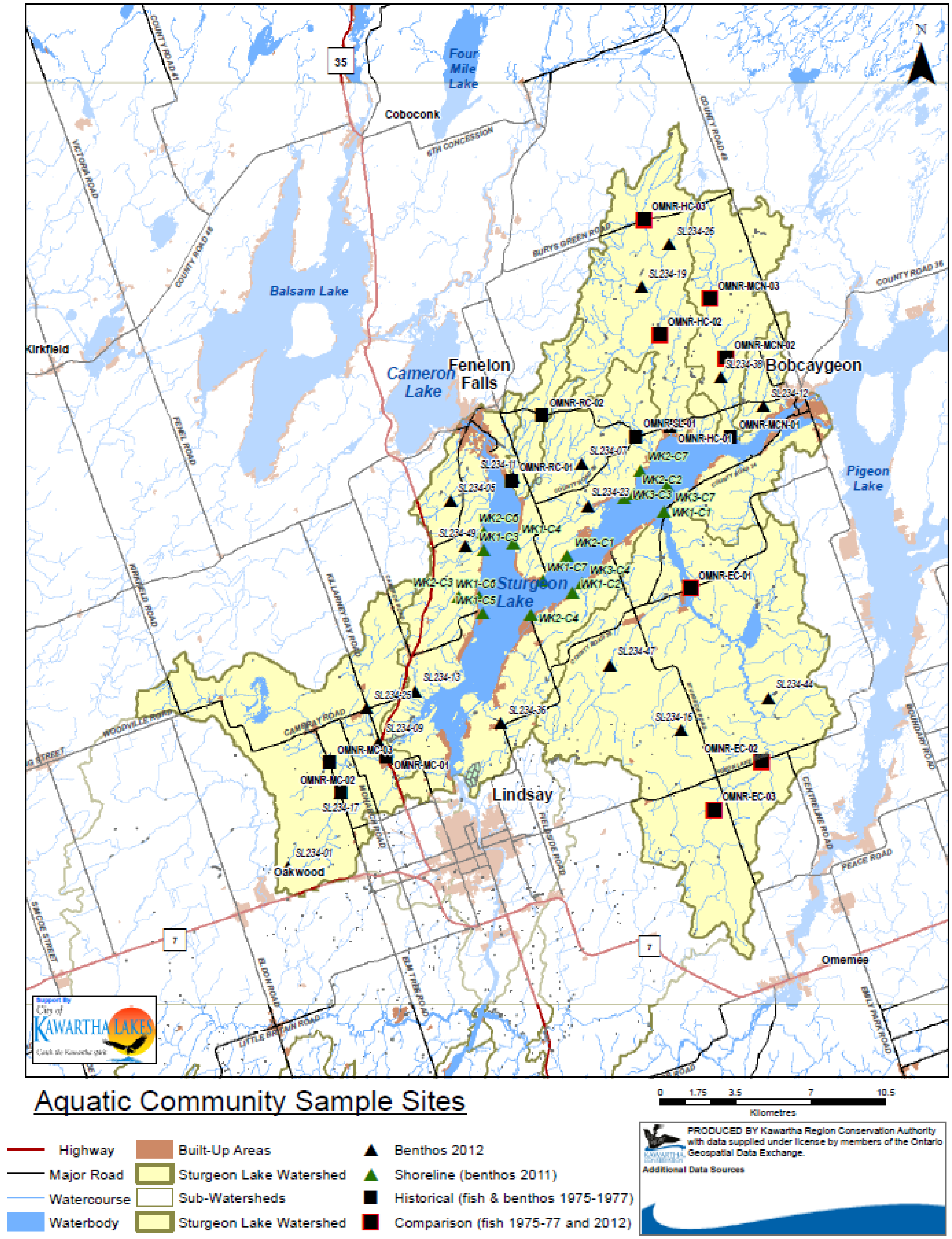


Figure 8.7. Aquatic Community Sample Site Locations

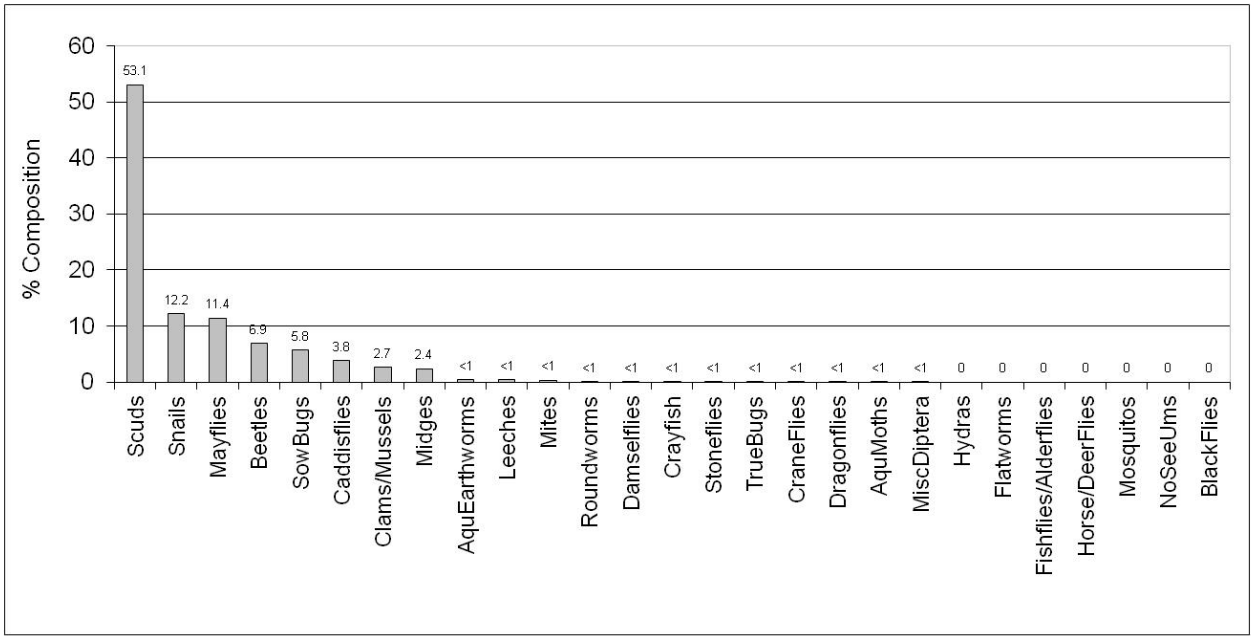


Figure 8.8. Percent Community Composition of Benthos Collected along Sturgeon Lake Shoreline, Categorized by OBBN Classes

<u>Interpreting aquatic ecosystem health using shoreline benthos communities</u>

No “healthy standard” currently exists against which these benthic macroinvertebrate communities can be compared; at this time these data are useful for providing baseline shoreline benthos community composition. Monitoring changes in benthos communities over time at these sites, particularly when using sensitive taxa (e.g., Stonefiles, Mayflies, Caddisflies) as indicators, would provide insight into potential changes in shoreline aquatic habitat conditions.

8.4 Tributary-Based Ecosystems

8.4.1 Aquatic Habitat

Sturgeon Lake is fed by many creeks and rivers which provide important aquatic habitat pathways to-and-from the lake. The largest tributaries draining into the lake are Scugog River (draining Lake Scugog; flowing into the lake from the south) and Fenelon River (draining Cameron Lake, flowing into the lake from the north-west). As well, there are numerous other watercourses connected to the lake. The largest of these "secondary watercourses" is Emily Creek. Mariposa Brook and East Cross Creek are large tributaries of Scugog River. Dozens more small-to-medium sized tributaries also drain into the lake. Tributaries are important to the lake ecosystem from many perspectives, including: providing spawning habitat for lake-based migratory fishes, providing a corridor for the movement of aquatic organisms, flow, food and energy transport, and contributing to the aquatic biodiversity of the lake basin.

This section provides an overview of some key aquatic habitat types that support aquatic resources within the tributaries, with an emphasis on flow regime, stream connectivity, riparian areas, and thermal regime.

<u>Flow Regime and Stream Ordering</u>

Tributaries are often grouped into three generalized classes: (i) ephemeral streams, that flow for small periods following precipitation events, such as rain or snowmelt; (ii) intermittent streams, that flow more continuously but tend to dry-up during parts of year; and, (iii) perennial streams, that flow all year and rarely dry-up. Typically, flows become more permanent as one moves in a downstream direction, however there are many factors that contribute to the duration and intensity of stream flows (***Chapter 6.2: Surface Water Flow and Flow Regime).***

Figure 8.9 shows the network of all known watercourses within the SLMP planning area, regardless of their ephemeral, intermittent or perennial flow regime, as well as by stream order. Stream ordering is a method of classifying the branching complexity, and size, of the stream network. 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). This can be a useful approach to assist in identifying watercourse reaches of similar biological, physical and chemical conditions, and can help delineate between headwaters, mid-reach and outlet habitats.

Table 8.4 lists all the tributaries within the SLMP planning area, as well as their respective lengths in each stream order. Orders range from one to five, and the length of streams in each order decreases as stream order increases (i.e., small streams account for more length than large streams). The majority of all stream lengths (over 70%), are small first- and second-order streams. These "headwaters" are typically small, inconspicuous ephemeral or intermittent streams that tend to dry up during extended dry periods (e.g., during summer and winter) but nonetheless are significant in terms of providing food, nutrients, and flow conveyance pathways following periods of flow for use by aquatic life residing in the downstream, larger and more identifiable watercourses. Third-order streams are typically intermittent or perennial, whereas fourth-order and fifth-order streams are typically perennial.

The majority of tributaries enter into Sturgeon Lake and/or Scugog River as fourth-order streams (Sturgeon Lake Tributaries, Scugog River Tributaries, Stoney Creek, McLaren Creek, Hawkers Creek, Jennings Creek), followed by third-order (Martin Creek North, Janetville Creek, Rutherford Creek), and then fifth-order (Emily Creek, East Cross Creek, Mariposa Brook).

Table 8.4. Total Length and Individual Stream Order Length of Watercourses that Drain Directly into Sturgeon Lake

Subwatershed	**1st Order**	**2nd Order**	**3rd Order**	**4th Order**	**5th Order**	**Total, km**
East Cross Creek	72.6	35.5	20.3	15.5	3.7	147.6
Emily Creek	114.1	55.4	23.0	27.5	8.4	228.5
Hawkers Creek	40.0	19.6	9.5	18.5	0.0	87.7
Janetville Creek	10.7	14.5	1.8	0.0	0.0	27.0
Jennings Creek	7.9	6.7	3.4	3.1	0.0	21.1
Mariposa Brook	126.0	89.8	31.4	30.4	13.0	290.6
Martin Creek North	14.8	9.6	9.9	0.0	0.0	34.3
McLaren Creek	41.0	23.7	25.6	4.0	0.0	94.2
Rutherford Creek	10.6	5.4	7.0	0.0	0.0	23.0
Scugog River Tributaries	27.2	12.1	11.4	1.1	0.0	51.8
Stoney Creek	41.3	21.2	24.0	9.7	3.5	99.7
Sturgeon Lake Tributaries	177.8	85.7	28.6	11.7	0.0	303.8
Total, km	**684.1**	**379.1**	**195.8**	**121.5**	**28.6**	**1409.1**

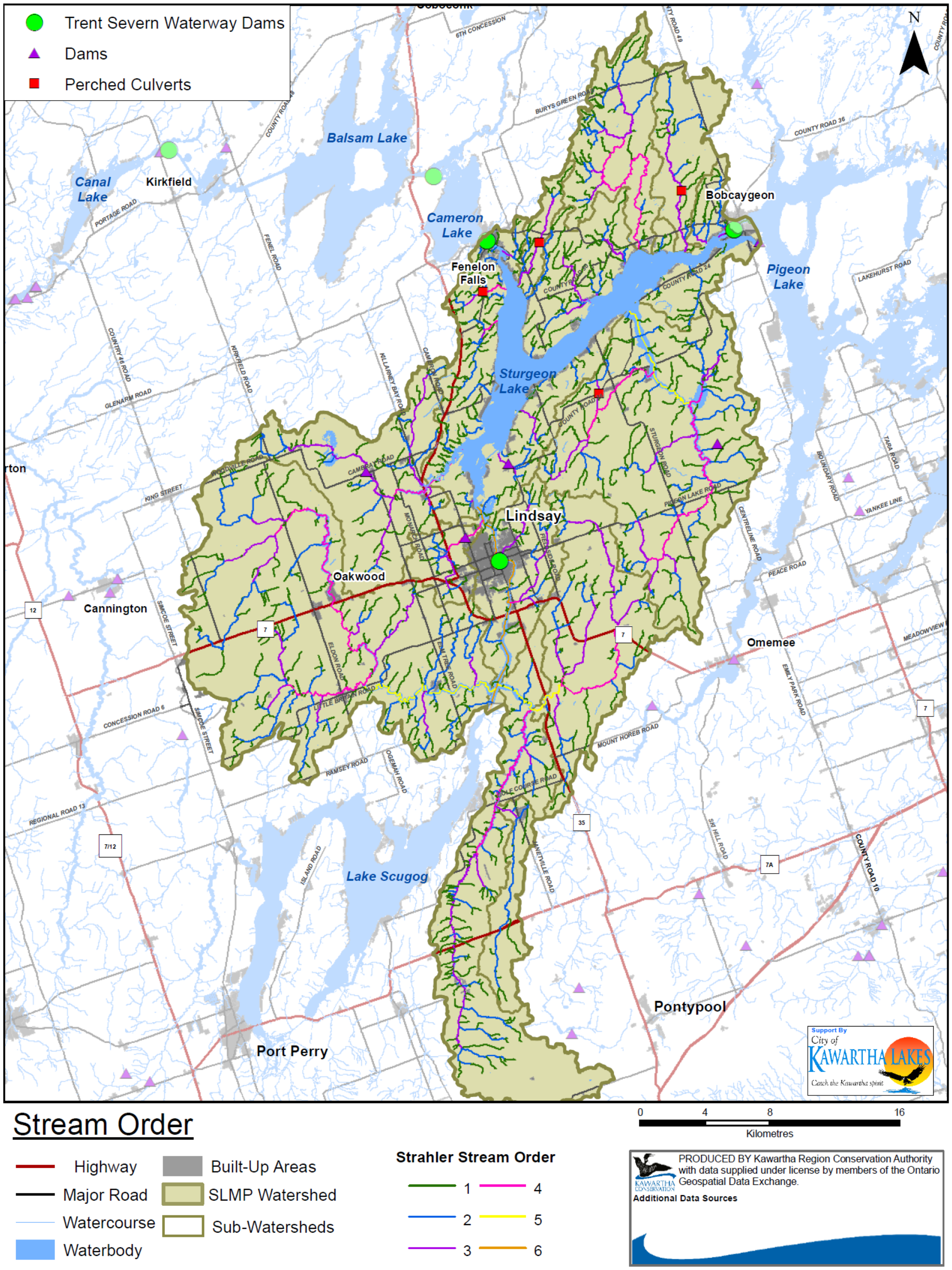


Figure 8.9. Watercourses Draining Directly into Sturgeon Lake, Showing Stream Order and Known Barriers that Fragment Aquatic Habitat Connectivity

Stream Connectivity

Many fishes within Sturgeon Lake migrate up lake tributaries in late winter/early spring to reproduce (e.g., Walleye, Muskellunge, and White Sucker). Many tributary-dwelling fishes also migrate to the lake, and to refuge pools to avoid stream freeze-up during winter months. Therefore, unimpeded access both along tributaries, as well as to-and-from the lake is critical to maintain healthy fish populations in Sturgeon Lake. Access to aquatic habitat can be fragmented by man-made obstructions including dams, weirs, and perched or blocked culverts. Not only do these structures impede migration, but they can also isolate populations and limit their access to suitable habitat. In some instances, however, in-stream barriers have proven to be beneficial (e.g., in tributaries entering Lake Ontario) by preventing/delaying dispersal of non-native species.

Figure 8.9 shows the location of known barriers within the SLMP study area that have the potential to fragment aquatic habitat. Historically, aquatic habitat within the Scugog River (and to a lesser extent Fenelon River), was accessible by fishes from Sturgeon Lake. Now, the Trent-Severn Waterway dams provide barriers to fish access to tributaries upstream of these areas. These include access to Cameron Lake (Fenelon Falls dam), access to the Scugog River south of Lindsay (Lindsay dam), and Pigeon Lake (Bobcaygeon dam). The locations of perched culverts on third-, and fourth-order streams at road-stream crossings were assessed in 2012 by Kawartha Conservation, as a component of the thermal regime survey. Of the sixty-five sites that were visited, four perched culverts were identified. Perched culverts often results from either improper installation (rare) or from high water velocities scouring the bed of the stream over time (more common).

In addition to the large dams and perched culverts, there are dozens of in-stream ponds (those that are directly connected to a watercourse). Typically, these ponds are held back by small dams or weir structures at their outlet, which can also create an in stream barrier.

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 similar benefits to tributaries as natural shorelines do around lakes, 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). To characterize riparian areas within the SLMP planning area, 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) was classified according to methods developed to complement this protocol by Credit Valley Conservation (1998). Riparian zones were delineated by using the centre-line of the watercourses and buffering to 15m, 30m and 100m on both sides. Due to this methodology, the riparian areas of larger-width streams (i.e., fifth-order streams) may not be accurately characterized as the centreline of these streams is well away from its banks. This results in more “open water” classification in larger (wider) streams.

Various studies have investigated the minimum riparian buffer width that is necessary to maintain the ecological integrity of watercourses. These often range from 5 meters to 300 meters depending on the functions they provide (***Figure 8.10*****).** 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).

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). Appropriate lengths of riparian coverage along watercourses have been investigated as well. ***Table 8.5*** shows the percentage of major land cover types that occupy the riparian areas for 15m, 30m and 100m along both sides of Sturgeon Lake tributaries. Natural lands account for the majority of riparian area coverage among all widths (56-69%), and streams flow mostly through swamp habitat. Agricultural lands account for the second-most riparian area coverage (28-38%), and streams flow most through crop fields. Developed lands account for the least amount of riparian area coverage (3-5%), and streams flow most through rural-residential areas. Natural and non-natural riparian areas are shown in ***Figure 8.11***.

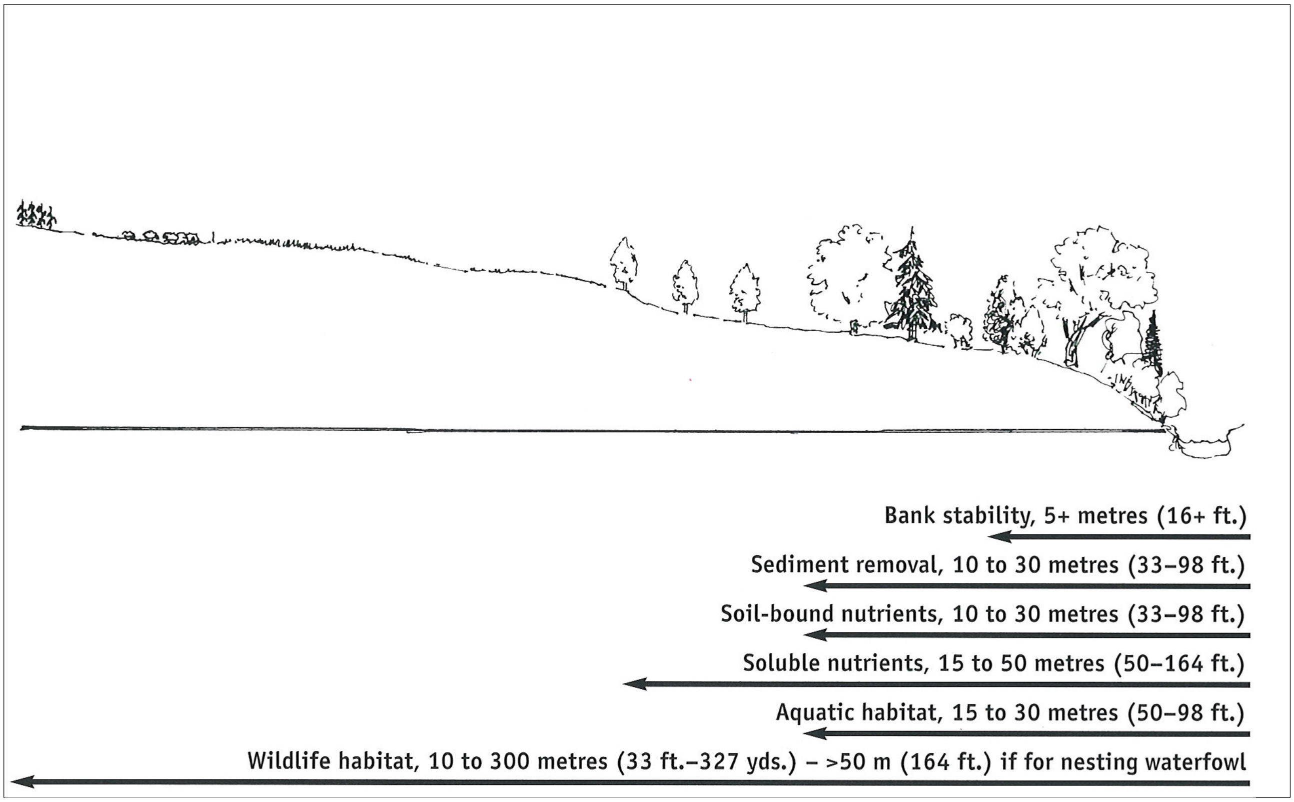


Figure 8.10. Summary of Important Functions of Natural Riparian Areas by Width

When combining all tributaries, the amount of existing natural riparian areas is greatest at 15m, but for all widths do not meet minimum recommended guidelines for maintaining ecological integrity. As the riparian zone increases in width, natural areas decline while agricultural and developed areas increase.

Riparian area coverage in natural, agricultural, and developed lands for all streams within the SLMP study area, by stream order, is shown in ***Table 8.6***. As stream order increases, riparian areas in a natural state decrease from a high of 94% in fifth-order streams to a low of 60% in first-order streams. Recommended minimum ecological requirements for riparian areas are not met along first-order, second-order, or third-order streams. Fourth- and fifth-order streams tend to have extensive natural cover along their banks, and as such meet these guidelines. When examining all tributaries combined, natural riparian cover accounts for only 64% of their total length. In order to achieve the 75% guideline along 30 meters adjacent to all streams, over $8km^2$ of land would have to be restored to a natural state.

Table 8.5. Land Use Types within 15, 30 and 100 m on both Sides of all Watercourses in the Study Area

Land Use	**ELC Community Series**	**15m (%)**	**30m (%)**	**100m (%)**
Agriculture	Intensive Agriculture	16.05	17.83	24.84
Agriculture	Nonintensive Agriculture	11.96	12.26	13.50
Natural – Wetland	Thicket Swamp	11.31	10.91	8.46
Natural - Treed Wetland	Coniferous Swamp	8.17	8.34	8.25
Natural - Treed Wetland	Mixed Swamp	7.88	7.87	7.37
Natural – Forest	Coniferous Forest	7.87	7.93	7.40
Natural – Forest	Mixed Forest	6.61	6.56	5.92
Natural - Cultural Meadow	Cultural Meadow	6.56	6.20	5.27
Natural – Open Water	Open Aquatic	5.66	4.43	2.68
Natural – Wetland	Meadow Marsh	2.97	2.69	1.72
Natural – Meadow	Cultural Thicket	2.59	2.41	1.90
Developed – Rural	Rural Development	2.22	2.43	3.28
Natural - Treed Wetland	Deciduous Swamp	2.03	2.01	1.78
Natural – Forest	Deciduous Forest	1.87	1.91	1.86
Natural – Meadow	Cultural Savannah	1.57	1.52	1.25
Natural – Forest	Cultural Woodlot	1.57	1.46	1.11
Natural – Wetland	Shallow Marsh	1.36	1.33	1.01
Developed – Urban	Urban Development	0.63	0.77	1.21
Developed – Manicured Grass	Manicured Open Space	0.35	0.40	0.51
Natural – Forest	Cultural Plantation	0.25	0.26	0.29
Natural – Open Water	Submerged Shallow	0.17	0.14	0.08
Natural – Wetland	Floating-Leaved Shallow	0.13	0.12	0.08
Developed – Aggregate	Active Aggregate	0.11	0.11	0.13
Natural – Wetland	Mixed Shallow Aquatic	0.09	0.07	0.05
Developed - Disturbed Area	Disturbed Area	0.02	0.02	0.02
Developed – Aggregate	Inactive Aggregate	0.00	0.00	0.01
Developed – Dump	Dump	0.00	0.00	0.01
TOTAL Agricultural		**28.01**	**30.09**	**38.34**
TOTAL Natural		**68.66**	**66.16**	**56.48**
TOTAL Developed		**3.33**	**3.73**	**5.17**

Riparian area coverage in natural, agricultural, and developed lands by subwatershed is shown in ***Table 8.7***. Natural riparian area coverage ranges from 49-90%, agricultural areas ranges from 4-43%, and developed lands ranges from <1-9%. Seven out of 12 subwatersheds do not meet minimum ecological requirements, they include: Mariposa Brook, unnamed Sturgeon Lake Tributaries, Emily Creek, Stoney Creek, McLaren Creek, Scugog River Tributaries and Jennings Creek. Four of the five and five of the seven largest watercourses (by length) do not meet minimum requirements. Jennings Creek would require the least amount of additional natural cover (0.3km^2) to achieve the 75% guideline, whereas the several unnamed Sturgeon Lake tributaries would require the most (2.4km^2).

Thermal Regime

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 watercourses. 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).

Table 8.6. Land Use Within Riparian Areas (30m), by Stream Order, of all Tributaries Draining Directly into Sturgeon Lake and Scugog River

Stream Order	Natural Cover(km^2)	Agricultural Lands (km^2)	Developed Lands(km^2)
1	24.62 (60%)	14.69 (36%)	1.54 (4%)
2	14.37 (67%)	6.34 (30%)	0.67 (3%)
3	8.05 (74%)	2.34 (22%)	0.48 (4%)
4	5.24 (81%)	0.94 (15%)	0.27 (4%)
5	1.17 (94%)	0.05 (4%)	0.02 (1%)

Thermal habitat is often categorized into two broad types: warm water and coldwater. Warm water designations imply that the watercourse is known to contain, or is likely to support warm water fishes (e.g., Bluntnose Minnow, Fathead Minnow, Largemouth Bass, etc.), and coldwater designation implies that these watercourses are known to contain, or are likely capable of supporting coldwater fishes (e.g., Brook Trout, Mottled Sculpin, etc.). Coldwater streams are particularly sensitive to land use impacts, which is due to the relatively narrow habitat requirements of coldwater fishes (e.g., the need for stable groundwater discharge areas, clean cold water, high levels of dissolved oxygen, etc.).

Of the approximately 1,338km of watercourses that exist within the SLMP planning area, 134km (10%) have been classified as coldwater streams (***Table 8.8***), which includes watercourses within the subwatersheds of: Martin Creek North (33.3km), East Cross Creek (70.8km), Janetville Creek (21.2km), Emily Creek (8.2km), and Mariposa Brook (0.7km). Martin Creek North is almost entirely coldwater, from the outlet to Sturgeon Lake and upstream. Janetville Creek is coldwater south of the grouping of dams, and East Cross Creek is coldwater south of Edgerton Road. Emily Creek has one coldwater tributary that flows east, near Four Points Road and Heights Road. Mariposa Brook has a small section of coldwater habitat near Eldon Road and Black School Road.

In summer of 2012, all third-order and fourth-order stream/road crossings were assessed to obtain more detailed information on thermal regime for tributaries that drain directly into Sturgeon Lake. These watercourses are McLaren Creek, Emily Creek, Hawkers Creek, Rutherford Creek, Martin Creek North, and Sturgeon Tributaries. In total 65 sites were sampled by taking spot-measurements of water temperature following the module outlined in the Ontario Stream Assessment Protocol (Stanfield et al., 2007). The data from these surveys were used to assigned a thermal regime status (coldwater, cold-cool water, cool water, cool-warm water, or warm water) to each sample site, based on the relationships between air temperatures and water temperatures observed in streams across southern Ontario and the types of resident fishes (Chu et al., 2010). ***Figure 8.12*** shows the locations of sample sites. Thermal regime was determined at 47 sites, and the remaining eighteen sites were dry.

Table 8.7.Riparian Areas (30m) of all Streams within the SLMP Planning Boundary. Does not Include Scugog River or Sturgeon Lake Shoreline

Subwatershed	**Total Riparian Area (km^2)**	**Developed Lands (km^2)**	**Agricultural Lands (km^2)**	**Natural Cover (km^2)**	**Natural Cover (km^2) needed to achieve 75%**
Mariposa Brook	16.93	0.51 (3%)	5.88 (35%)	10.53 (62%)	+2.17
Sturgeon Tribs	14.81	0.62 (4%)	4.67 (32%)	8.72 (59%)	+2.39
Emily Creek	12.46	0.52 (4%)	4.06 (33%)	7.44 (60%)	+1.91
East Cross Creek	8.57	0.21 (3%)	1.51 (18%)	6.84 (80%)	-0.413
Stoney Creek	5.79	0.08 (1%)	2.16 (37%)	3.55 (61%)	+0.793
McLaren Creek	5.22	0.11 (2%)	1.98 (38%)	3.08 (59%)	+0.835
Hawkers Creek	5.11	0.06 (1%)	1.15 (22%)	3.90 (76%)	+0.068
Scugog River Tribs	3.87	0.64 (17%)	1.05 (27%)	2.17 (56%)	+0.733
Martin Creek North	2.00	0.02 (1%)	0.18 (9%)	1.79 (90%)	-0.290
Janetville Creek	1.19	0.11 (9%)	0.05 (4%)	1.03 (87%)	-0.138
Rutherford Creek	1.30	0.03 (2%)	0.25 (19%)	1.02 (79%)	-0.045
Jennings Creek	1.27	0.10 (8%)	0.55 (43%)	0.62 (49%)	+0.333
ALL	78.52	2.94 (4%)	23.69 (30%)	50.15 (64%)	+8.74

The majority of the sites were classified as warm water, and the number of sites decreased as water temperature categories become colder (***Table 8.9***). Emily Creek, Hawkers Creek, Sturgeon Tributaries and McLaren Creek all have coldwater, cold-cool water, or cool water sites present that may suggest sensitive coldwater habitats. All sites sampled within Martin Creek North, a designated coldwater streams, did not show thermal regimes that could support coldwater fishes. The known coldwater section on Emily Creek still had coldwater temperatures in the watercourse.

Table 8.8. Known Coldwater Streams within the SLMP Planning Area and Associated Length of Coldwater Sections within Each

Subwatershed	**All Streams (km)**	**Coldwater Streams(km)**	**Coldwater Streams(%)**
East Cross Creek	206.2	70.8	34.3
Martin Creek North	34.3	33.3	97.1
Janetville Creek	29.2	21.2	72.7
Emily Creek	201.5	8.2	4.1
Mariposa Brook	259.1	0.7	0.3

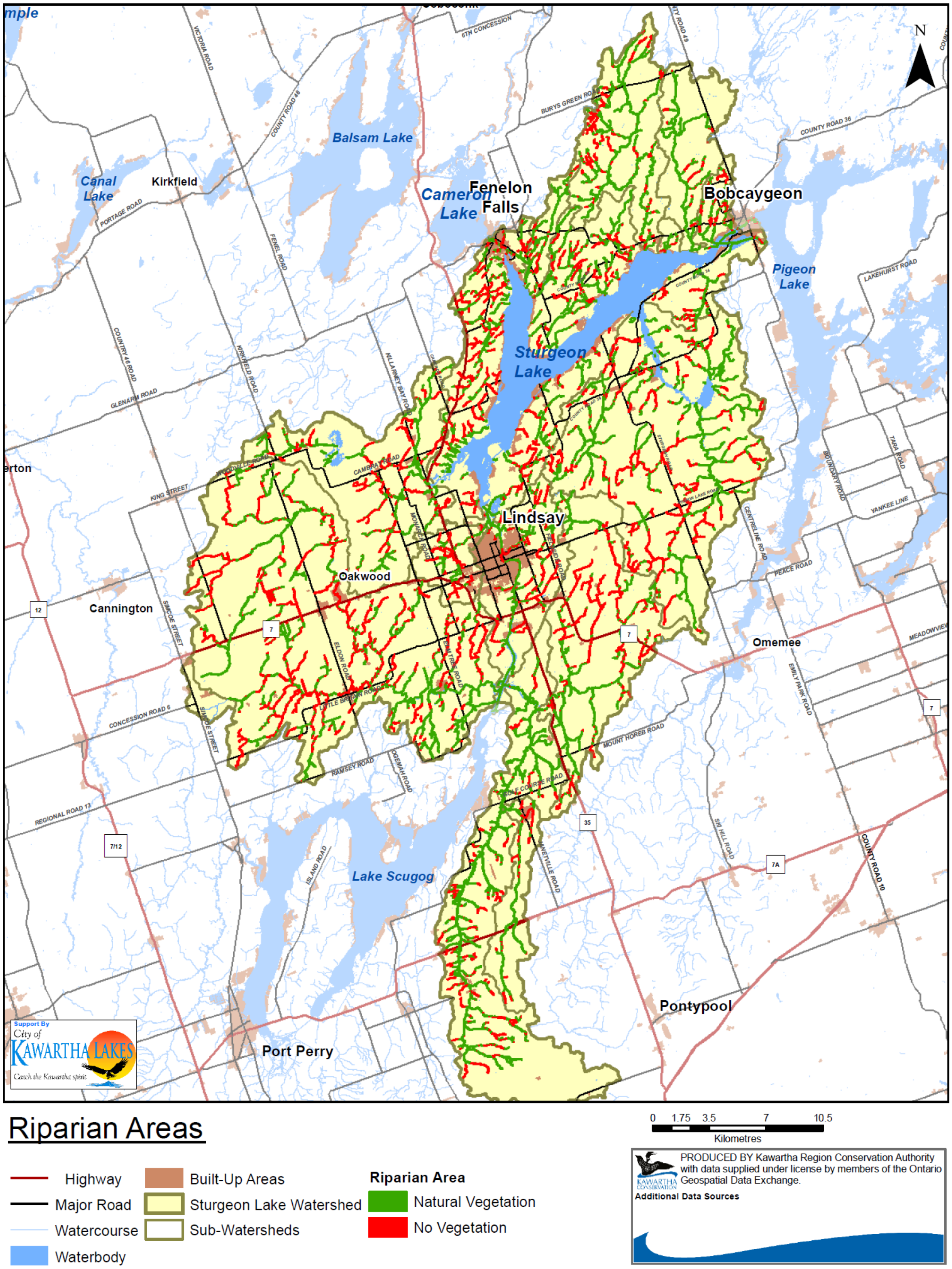


Figure 8.11. Riparian Areas with Either Natural Vegetation, or no Vegetation within 30m on both Sides of Watercourses Draining Directly into Sturgeon Lake and Scugog River

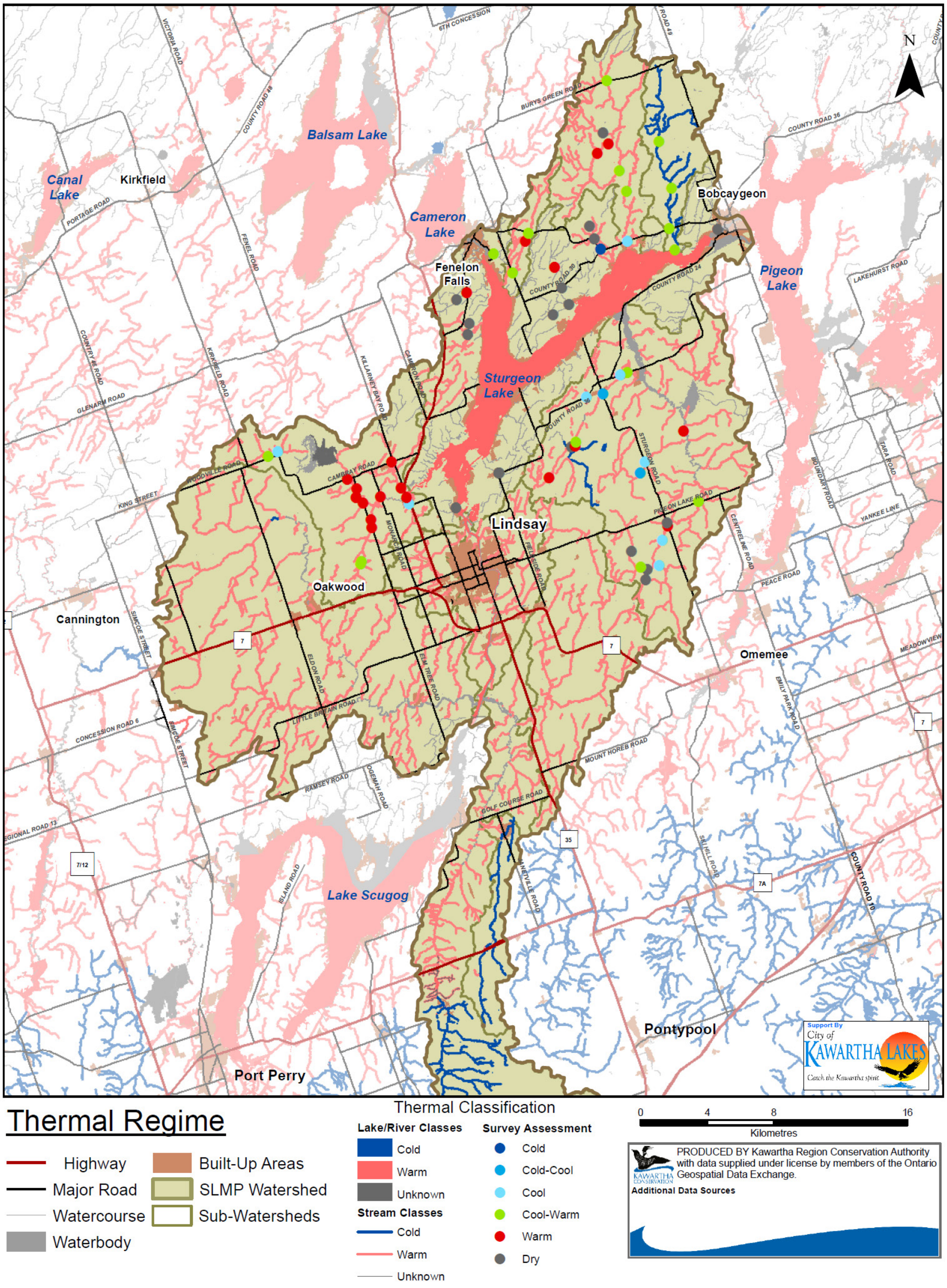


Figure 8.12. Thermal Regime Classification of Watercourses, and 2012 Sample Sites

Table 8.9. Thermal Regime Classification of 2012 Sample Sites within 3rd order and 4th order Watercourses Draining Directly into Sturgeon Lake

Watercourse	# of Sites	Dry	Cold	Cold-cool	Cool	Cool-warm	Warm
Emily Creek	20	5	0	2	6	4	5
Hawkers Creek	8	2	0	0	1	3	2
MartinCreekNorth	4	0	0	0	0	4	0
McLarensCreek	15	0	0	0	2	3	10
RutherfordCreek	3	0	0	0	0	2	1
SturgeonTribs	15	11	1	0	0	1	2
ALL	65	18 (28%)	1 (2%)	2 (2%)	9 (14%)	17 (26%)	20 (31%)

8.4.2 Fish Communities

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. The tributaries provide important spawning habitat for lake-based migratory fishes such as Muskellunge, Walleye, and White Sucker, as well as other fishes that utilize the more lake-like backwater areas around the stream outlets.

Within the tributaries of the SLMP planning area, approximately 35 unique fish species have been documented ***(Table 8.1).*** By watercourse, 27 species have been found in East Cross Creek; 26 in Mariposa Brook; 22 in Emily Creek; 21 in both Scugog Tributaries and McLaren Creek; 17 in both Martin Creek North and Stoney Creek; 16 in Jennings Creek; 15 in Hawkers Creek; 13 in both Rutherford Creek and Janetville Creek; and 7 in Sturgeon Tributaries. Fish species records by subwatershed are found in ***Appendix AE3.*** Most of the fishes are considered common to the area, except for some historic records of fishes such as Burbot and Spoonhead Sculpin. There has not been a formal documentation of record for these two species in the tributaries for more than 50 years. The majority of fishes are considered warm water fishes, but coldwater fishes (Brook Trout, Burbot, Spoonhead Sculpin, Mottled Sculpin) have also been documented. There are no fishes that are considered to be at risk, or of Special Concern, Threatened, or Endangered.

The high number of species in certain watercourses is related to both the amount of sampling effort as well as the relatively large size of the watercourses. Data was summarized from OMNR Stream Surveys in 1975-76, Kawartha Conservation East Cross Creek Watershed Planning project sampling in 2006-08, Kawartha Conservation SLMP sampling in 2012, Kawartha Conservation/CKL/DFO Drain Study sampling in 2002, SSFC Electrofishing Training in 2003-05, and data exported from OMNR Aquatic Resources Areas in 2006.

Of the 35 documented species within the SLMP planning area, 5 are not native to this area ***(Table 8.1).*** Common Carp have been in the system for approximately 100 years, as they were accidentally introduced into the Great Lakes drainage system. The rest of the SLMP non-native species are native to the Lake Ontario Basin, but were traditionally restricted access to Kawartha Lakes system. Walleye were introduced in the early 1900s to provide recreational opportunities, as was Largemouth Bass in the mid-1900s. Rock Bass and then Bluegill expanded their range from the construction of locks and canals. More recently, Black Crappie have expanded their range from neighboring waterways via Trent canal system.

Other potential invasive fish species on the horizon, that could negatively impact Sturgeon Lake and/or its tributaries include: Round Goby, which is expanding its range west through Otonabee River and east from Lake Simcoe; Northern Pike, which has been confirmed in Balsam Lake; Rainbow Trout and Brown Trout, popular coldwater sport fishes that are often stocked in coldwater streams; Goldfish and Koi, which are often stocked in private ponds for aesthetic appeal; and, Asian Carp, which is a major threat to the Great Lake Basin.

To provide insight whether fish communities within tributaries have changed over time, the historical OMNR mid-1970s sites were re-sampled in 2012 by Kawartha Conservation. Due to resource constraints not every historic site within the SLMP planning area was resampled, only sites that existed on tributaries that drained directly in Sturgeon Lake were targeted. ***Table 8.10*** provides a summary of this historical vs. present comparison. There were 7 sites that were sampled in 2012 and in 1975-76, on the following tributaries: Emily Creek, Hawkers Creek, and Martin Creek North.

Unfortunately, for the historical sites it is unknown what type of gear was used to sample the site, as well as how much effort (e.g., how large an area sampled, in how much time) was put in to catch fishes. What was certain was at which road/stream intersection the sampling site had occurred. In 2012 sampling was conducted using 2 techniques. In wadeable flowing stream sections, single-pass electrofishing method, as outlined in the Ontario Stream Assessment Protocol (Stanfield et al., 2007), was used to determine fish species composition. In wadeable pooled stream sections, triple-haul seine netting was employed to catch fishes. Fish species documented at comparison sites are found in ***Appendix AE4.***

Table 8.10. Species Richness and Similarity between Tributary Fish Sites Sampled both in 2012 and in 1975-1976

Sturgeon Lake Tributary	SiteID	1975-76 Richness	2012 Richness	% Similarity
Emily Creek	EC01	6	6	50
	EC02	4	2	0
	EC03	6	7	18
	ALL SITES COMBINED	12	13	56%
Hawkers Creek	HC02	4	12	23
	HC03	7	8	50
	ALL SITES COMBINED	10	13	64%
Martin Creek North	MCN02	3	7	25
	MCN03	3	7	25
	ALL SITES COMBINED	5	9	40%
All Tributaries and Sites Combined		**17**	**19**	**71%**
Unique fishes in 1975-76	Smallmouth Bass, Mottled Sculpin			
Unique fishes in 2012	Bluegill, Logperch, Bluntnose Minnow, Blacknose Dace			

When examining all fishes caught from both time periods, 2 measures were used: species richness, which is an index of diversity, and % similarity, which means how many species were common to both sampling events. Since there were relatively few sites in each watershed, for comparison purposes it is beneficial to pool the results for all sites. This gives us an indication if any major shifts in community composition have occurred. In terms of species richness, 17 and 19 species were recorded during the 1975-76 and 2012 sampling events respectively. Also, there was good similarly (>70%) between the species of fishes found between sampling events. This suggests that fish communities, based on our sampled sites, remain relatively similar. The unique species found in 1975-76 surveys include: Smallmouth Bass and Mottled Sculpin. The unique species found in 2012 include: Bluegill, Logperch, Bluntnose Minnow, and Blacknose Dace.

8.4.3 Benthic Macroinvertebrates

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).

In spring of 2012, Kawartha Conservation conducted a bioassessment of streams that flow directly into Sturgeon Lake. Benthos and aquatic habitat conditions were sampled in May at 18 sites, from a randomly selected base number of fifty sites on second-, third-, and fourth-order streams (***Figure 8.7; Table 8.11***), following methodology outlined in stream module of the Ontario Benthos Biomonitoring Network protocol (Jones et al., 2007). Benthos was identified to a family-level taxonomic resolution wherever possible. Raw benthos data are found in ***Appendix AE2.***

Table 8.11. Summary of Chosen vs. Sampled Sites for Bioassessment and Reason for not Sampling

Subwatershed	Random Chosen	Sampled	Not Sampled	Dry or Too Shallow	Wetland/ No Channel	Access Denied/ No Contact
EmilyCreek	15	3	12	7	1	4
UnnamedCreek	17	8	9	3	1	5
McLarenCreek	8	4	4	2		2
HawkersCreek	7	2	5	1	3	1
MartinCreekNorth	3	1	2		2	
TOTAL	50	18	32	13	7	4

The aquatic habitat conditions at these sample sites are shown in ***Table 8.12***. Fine particles (e.g., silt and sand) were the dominant substrate types and were found far more frequently than coarse substrates (e.g., gravel and cobble); channel widths ranged from 0.5 to 6.5 meters; channel maximum depths ranged from 60-600mm; velocities, measuring in hydraulic head, ranged from 0 – 50mm; temperatures ranged from 8 to 22 degrees Celsius.

In terms of general benthos groups, snails and clams accounted for the majority of the relative abundance of all sites combined (***Figure 8.13***). Snails and clams, combined with midges, beetles, sow bugs, scuds, mayflies, stoneflies, and caddisflies comprise for over 90% of all taxa. Sensitive taxa such as beetles and mayflies, stoneflies and caddisflies account for approximately 20% of benthos within all sites.

Table 8.12. Bioassessment Site-specific Aquatic Habitat Data

SiteID	Watershed	Water Temp (^oC)	Substrate (dom+subdom)	Depth (mm)	Hydraulic Head (mm)	Width (m)
SL234-47	EmilyCreek	14	sand and silt	500-510	0-0	2.3-2.8
SL234-16	EmilyCreek	15	silt and sand	350-460	0-0	1.3-1.8
SL234-44	EmilyCreek	11	sand and clay	50-180	0-5	0.6-0.8
SL234-19	HawkersCreek	15	sand and silt	150-270	5-20	1.9-2.8
SL234-26	HawkersCreek	8	silt and sand	200-300	0-5	1.5-2.0
SL234-38	MartinCreekNorth	22	sand and gravel	165-480	0-10	3.0-3.6
SL234-01	McLarenCreek	8	silt and sand	200-285	0-5	1.2-1.5
SL234-25	McLarenCreek	12	clay and silt	400-590	5-15	1.0-1.9
SL234-09	McLarenCreek	18	sand and cobble	240-510	0-25	1.5-3.3
SL234-17	McLarenCreek	11	sand and cobble	255-600	0-20	3.0-4.2
SL234-11	RutherfordCreek	16	silt and sand	370-410	0-0	3.0-3.4
SL234-07	UnnamedCreek	15	sand and cobble	130-240	0-20	3.1-6.5
SL234-36	UnnamedCreek	10	gravel and cobble	100-130	0-5	1.2-1.8
SL234-23	UnnamedCreek	12	sand and silt	80-125	0-0	0.8-1.8
SL234-12	UnnamedCreek	13	gravel and sand	60-100	5	0.6-0.7
SL234-49	UnnamedCreek	16	clay and sand	230-400	10-50	1.0-1.5
SL234-05	UnnamedCreek	14	silt and sand	170-250	0-0	1.2-1.9
SL234-13	UnnamedCreek	13	sand and gravel	110-200	0-30	0.5-1.1

To characterize biological water quality at each site, benthos data are summarized using a biotic index. A Biotic Index is commonly used to assess the degree of impairment at the site level. In this approach, taxa identified down to the 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. A modified Hilsenhoff Biotic Index approach was utilized, that averages tolerance values found in Mandaville (2002) for the family taxonomic level. This is a similar approach as used by conservation authorities in Watershed Reporting. 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. Overall, it has been to be a good rapid assessment technique to provide insight into water quality and ecological health status of watercourses. However, it should be noted that the biotic index was originally developed, and tested, for use on streams with fast flowing water (i.e., riffles) and coarse substrates (i.e., gravel, cobble).

Index values were calculated for each SLMP sample site and compared to a range of values that specify the degree of organic pollution (***Table 8.13***). Of the 18 sites samples for biological water quality, 0 sites exhibited water quality that was excellent or very good; 2 sites (11%) were good; 4 (22%) were fair; 2 (11%) were fairly poor; 7 (39%) were poor; and 3 (17%) were very poor. In total, only 33% of all sites sampled were found to have water quality that rated in a state that was fair or better. In other words, two-thirds of all sites sampled were worse than fair. The sites that rated fair or better typically showed good representation of families within Ephemeroptera (mayflies), Plecoptera (stoneflies) and Tricoptera (caddisflies) within the sample. Taxa percentages of benthos within these families have been shown to decrease in response to increasing perturbation (Barbour et al., 1999). However, this could simply be related an abundance of low gradient, silt-dominated stream systems which naturally contain tolerant benthos. Currently, no know biocriteria standards exist for these types of streams.

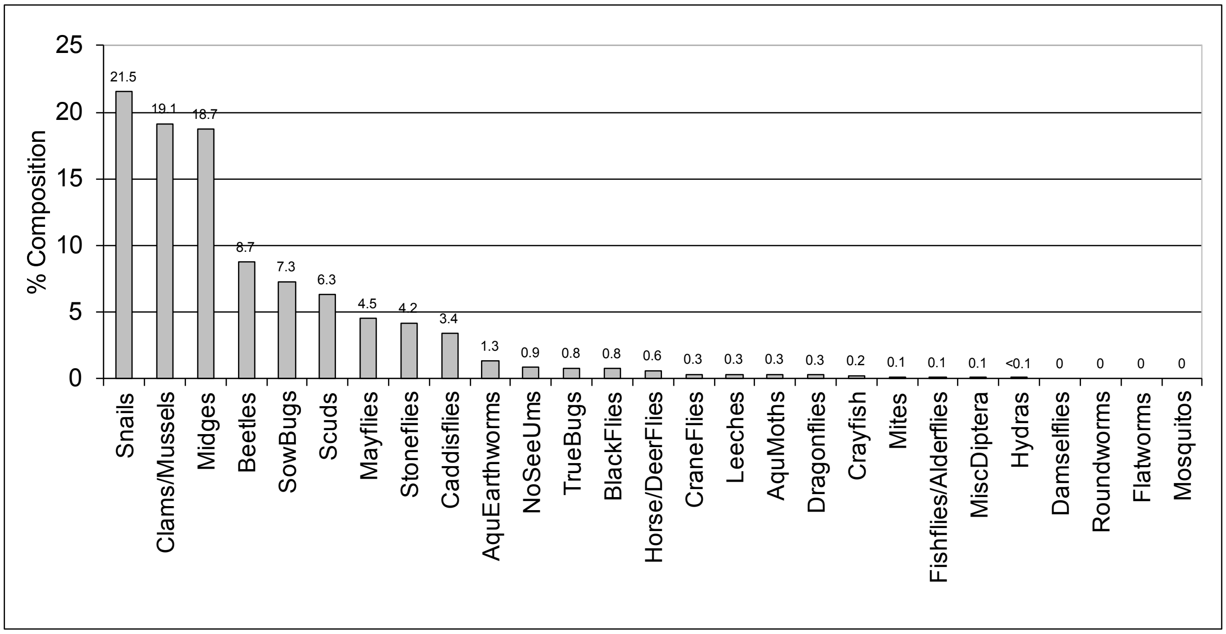


Figure 8.13. Percent Community Composition of Benthos Collected at all 2012 SLMP Sites Combined, Categorized by OBBN Classes

It is well documented that pollution of streams reduces the number of species in an aquatic ecosystem (i.e., species diversity), while frequently creating an environment that is favorable to only a few species (i.e., pollution-tolerant forms) (Logan and Badwa, 1998). Thus, in impacted streams, there are usually large numbers of a few species, while in a clean stream there are moderate numbers of many species. Among the SLMP 18 sample sites, 63 unique benthos families were documented. Approximately 24 of these are considered sensitive to ecosystem disturbance. Sensitive families were documented at 16 of the 18 sites. In terms of biodiversity, the Simpson's Diversity Index (Simpson, 1949) is a useful measure because it considers both taxonomic richness and evenness. The values range from 0 (low diversity) to 1 (high diversity). Healthy benthic macroinvertebrate communities tend to have a higher Simpson's Diversity Index value. Among the SLMP sample sites, index values ranged from 0.63 to 0.87.

Table 8.13. Modified Family Biotic Index Values at Bioassessment Sites

Degree of Organic Pollution	Water Quality	Index	# of Sites	Grade
Organic Pollution Unlikely	Excellent	0.00-3.75	0 (0%)	A
Possible Slight Organic Pollution	Very Good	3.76-4.25	0 (0%)	A
Some Organic Pollution Probable	Good	4.26-5.00	2 (11%)	B
Fairly Substantial Organic Pollution Likely	Fair	5.01-5.75	4 (22%)	C
Substantial Organic Pollution Likely	Fairly Poor	5.75-6.50	2 (11%)	D
Very Substantial Organic Pollution Likely	Poor	6.51-7.25	7 (39%)	F
Severe Organic Pollution Likely	Very Poor	7.26-10.00	3 (17%)	F

9.0 Terrestrial Ecology

This section reports on the terrestrial natural heritage system within the Sturgeon Lake watershed through an analysis of existing natural cover, vegetation communities, wildlife habitat, biodiversity, and significant natural heritage features.

9.1 Summary of Observations and Issues

OBSERVATIONS

- Natural Heritage conditions are better in the northern part of the Sturgeon Lake watershed where there is less urban development and less intensive and non-intensive agriculture.
- There are 11 terrestrial species at risk in the Sturgeon Lake watershed including birds, amphibians, and plants.
- 6% of the Sturgeon Lake watershed includes Areas of Natural and Scientific Interest (ANSI).
- The Sturgeon Lake watershed has an abundance of wetlands, the majority being swamp type wetlands.

ISSUES

- A number of natural heritage features exist in the Sturgeon Lake watershed that may be considered locally significant, however they are not afforded any legislative protection.
- Forest cover is below 30% in 8 of 12 subwatersheds, and is at 23% for the entire watershed area.
- Interior forest and deep interior forest is below guidelines for the entire Sturgeon Lake watershed.
- There has not been any assessment of forests, interior forests or wetlands for quality, species diversity, impacts of invasive species, etc.
- There has been no assessment of interior forest on a subwatershed basis.
- The existing natural heritage features are fragmented and lacking in connections, particularly in the southern more developed areas in the watershed.
- Ecological Land Classification field verification is required for community series data.
- With increasing farmland values and cash crop returns, there is a trend to clear more land for agriculture. This often means clearing brush from former agricultural lands of lower land classes that were abandoned, reducing natural buffers alongside watercourses, or even converting grown forest areas into agriculture.

9.2 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 runoff;
- improving air quality through filtration and oxygen release;
- improving the natural aesthetic of communities thus contributing to the wellbeing 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 runoff;
- 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 headwater and riparian buffer areas, may affect any or all of the above functions.

The watershed contains 365 km^2 of natural cover, representing 35% of the total watershed area and 38% of the terrestrial area. This includes all areas classified as forest, wetland or meadow. ***Figure 9.1*** details these natural cover types existing within the watershed and ***Table 9.1*** illustrates the percentage of each land use type within the watershed.

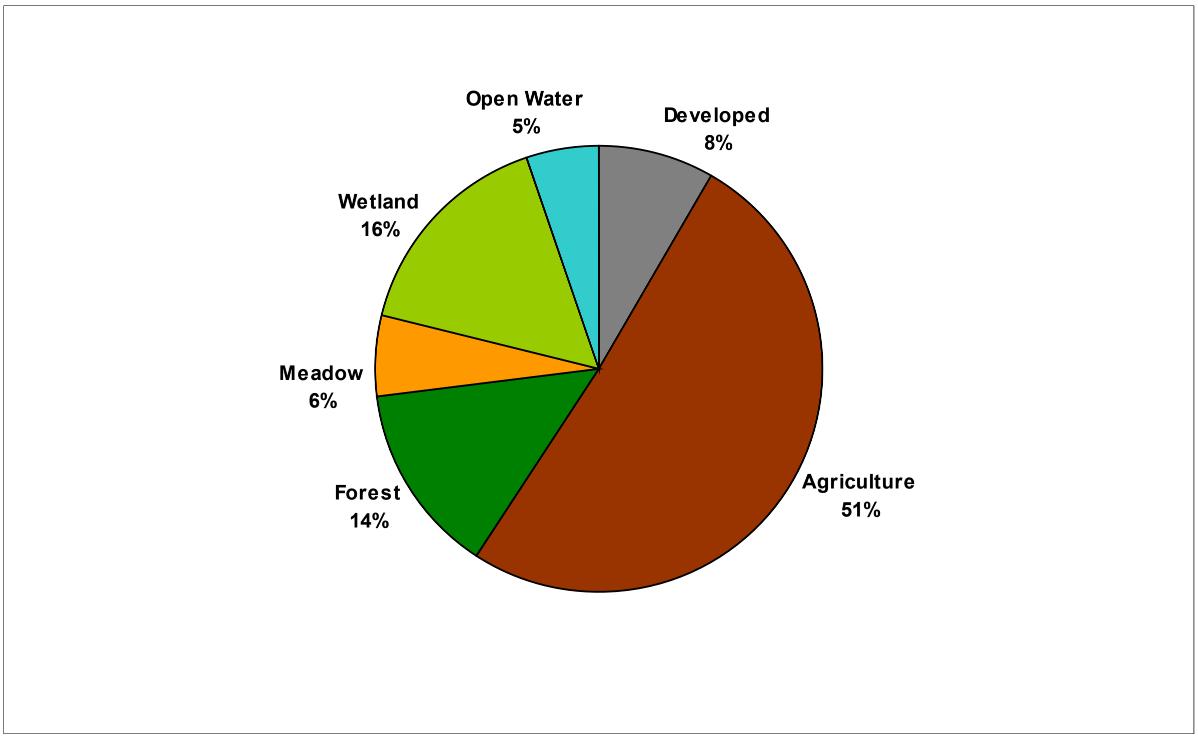


Figure 9.1.Sturgeon Lake Watershed Land Cover Based on Ecological Land Classification and Including Sturgeon Lake Water Surface

For management purposes, ecologists have created a hierarchy for the naming of ecosystems to reduce the complexity of managing the ecological resources on our planet. The area that the Sturgeon Lake watershed falls in has been separated into management units known as eco-districts. Eco-districts, 71 of which are found in Ontario, are distinguished by their characteristic pattern of landscape features, with similar climate, soils and elevation. Eco-district 6E-8 represents the largest portion of the Sturgeon Lake watershed, while eco-district 6E-9 makes up the remainder in the north. Ecodistrict 6E-8 is the drumlinized till plain that extends across the Kawartha Lakes and eastward and consists of deciduous, mixed and coniferous forests, with extensive areas of swamp and to a lesser extent, marsh. Eco-district 6E-9 follows the southern edge of the Canadian Shield and includes the limestone plains of the Carden Alvar. An extensive area of almost 70% natural cover exists in this eco-district, consisting of mostly mixed and deciduous forests, as well as almost 20% wetlands. The Great Lake Conservation Blueprint would require that 30% of eco-district 6E-8 and 23% of eco-district 6E-9 be set aside in order meet conservation targets.

Forests

Forests covered more than 90% of Southern Ontario prior to European settlement *(*Larson et al, 1999*)* and currently account for 25% of the terrestrial portion of the Sturgeon Lake watershed (a combination of upland forests (15%) and forested/treed wetlands (10%)). The forests that are found in the Sturgeon Lake watershed are most likely either cleared areas that were abandoned and regenerated over time, or the remnants of forests that were cleared during European settlement. Today most of the forests and woodlands found in this area are relatively young and quite different from older forests that survived the clearing of the landscape and are now quite rare in Ontario. Today's forests are found in areas that are unsuitable for agriculture or development, such as swamps and river valleys that are prone to flooding, and are therefore often quite fragmented. This is reflected in the fact that the dominant natural area type is coniferous swamp and that coniferous, mixed and deciduous swamps account for 11% of the landscape and over half of the forests in the watershed.

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 25% forest cover, falling below target levels of 30%forest cover for Areas of Concern watersheds within the great lakes basin (Environment Canada, 2004), and below the target of 35% forest cover for watersheds in Ontario (Conservation Ontario, 2011)***(Figure 9.2).***

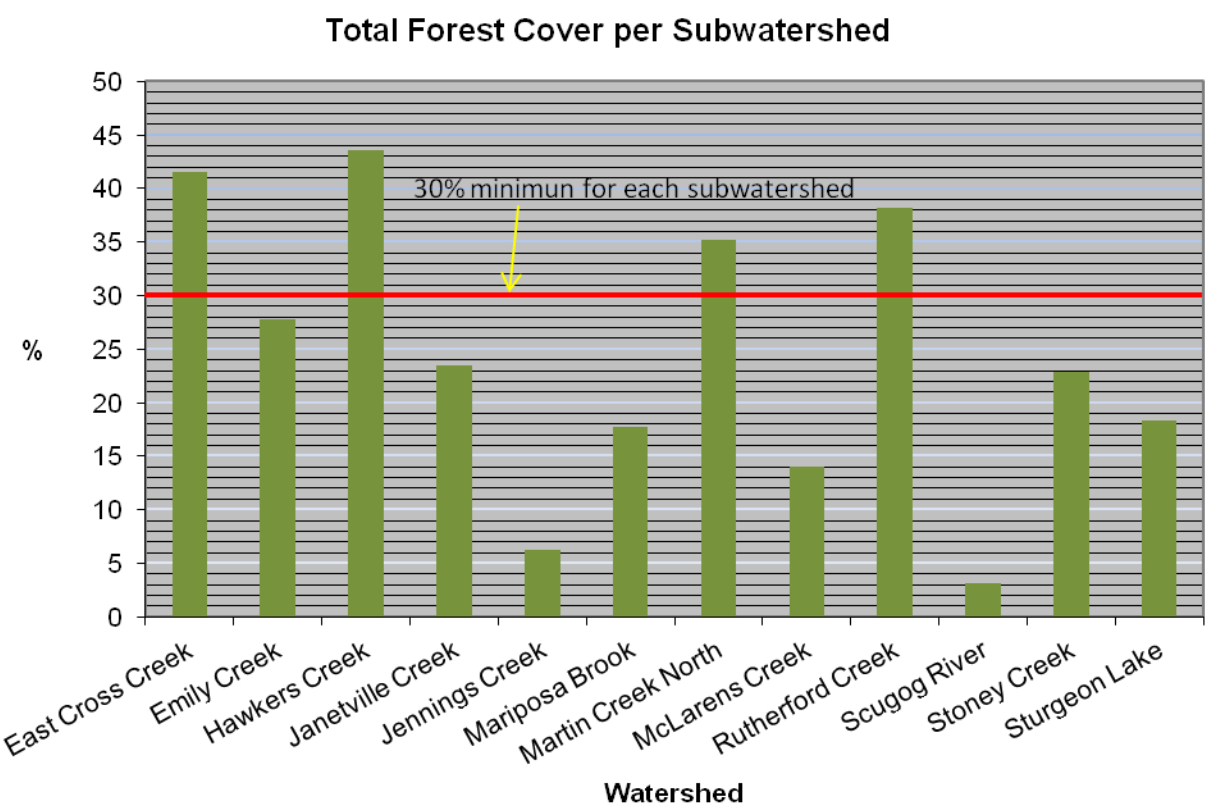


Figure 9.2. Forest Cover by the Sturgeon Lake Subwatersheds

Comparing 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, inactive landfill, manicured open space, urban areas, aggregate extraction areas, and rural development ***(Chapter 3: Land Use)***. This determination was made based on an assessment of the amounts of each vegetation community type and land use type existing in the watershed. Areas that are inappropriate for forest restoration include roads, active landfill 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 enough to meet target levels. Additionally, restoration efforts will have the highest benefit if they are focused on areas where habitat connectivity can be simultaneously improved.

Table 9.1. Percentage of Natural Cover in the Sturgeon Lake Watershed

Land Use	**Watershed Area (km^2)**	**Watershed Area (%)**
Forest	141.02	14.5
Forested Wetland	99.41	10.2
Non-Forested Wetland	61.56	6.3
Meadow	61.51	6.3
Total	363.5	37.4

9.3 Ecological Land Classification

Ecological Land Classification (ELC) is a method to further classify natural cover types into vegetation community types within the Sturgeon Lake watershed. Vegetation communities for the watershed were classified and mapped in 2011-2012 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. In total, 15 unique types of cultural areas and 16 unique types of natural areas, based on the community series level of detail, were identified for the watershed. Cultural areas refer to communities that have resulted from, or are maintained by human-based influences. Cultural areas are often disturbed and, where plant species are present, a high proportion are of non-native origin and often invasive. Natural areas refer to natural cover that has not been subject to recent severe human-based disturbance, and therefore offer higher quality habitat and are a valuable watershed resource. Vegetation community types are described in ***Table 9.2***, and mapped in ***Figure 9.3***.

The ELC assessment shows that the watershed contains 67%cultural community types, and 33% natural community types. Coniferous forests encompass the greatest area of the natural cover community types, accounting for 5.4%, coniferous swamps and mixed forests are the next two most dominant community types at 5.3% and 4.4% respectively. Nine different wetland types have been identified within the watershed and account for 15.8% of the watershed with coniferous swamp, mixed swamp and thicket swamp making up the majority of wetland areas. There are nearly equal amounts of deciduous swamp, meadow marsh and shallow marsh, only minimal areas of aquatic wetland communities within the watershed, and very little bog and fen communities. The areas classified as marsh types do not include the areas in/on Sturgeon Lake, as the ELC classification was only applied to terrestrial communities.

Table 9.2. Community Series Description

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Watershed Area (km^2)	Watershed Area (%)
	Cultural Areas		
AA - Active Aggregate	Barren, heavily disturbed open pit or quarry	2.0	0.2
AI - Inactive Aggregate	Surface cover ≥ 25% or barren, currently unused open pit or quarry	0.6	0.06
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%.	38.5	3.8
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%.	11.3	1.1
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%.	9.1	0.9
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%.	13.9	1.4
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%,	6.7	0.7
DIS – Disturbed Areas	No natural cover, areas that have been disturbed by human influences, e.g. trails	0.3	0.03
DMP – Landfill	Barren, land that is actively being used for waste disposal	0.06	0.01
IAG – Intensive Agriculture	Annually cultivated, crop fields, gardens, nurseries, tree farms. Variable	399.7	38.9
***MOS -** Manicured Open Space	Regularly maintained, gardens, parks, ski hills, cemeteries, open spaces. >2ha and resulting from or maintained by, cultural or anthropogenic-based disturbances	4.3	0.41
***NAG** – Non Intensive Agriculture	No cultivation, grasses, hay, pasture, grazing. Variable	123.6	12.0
***RD** – Rural Development	Variable. 0.2 ha < area < 2.0 ha containing development not associated with agriculture	40.2	3.9
***URB** – Urban Development	Variable. > 5 residential units in an area > 2 ha, generally residential	19.6	1.9

[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 (%)
Natural Areas			
BO - Bog	Bogs are areas with ≤ 25% tree cover (trees over 2m) where substrate organic layer is > 40cm Sphagnum peat, rarely flooded, always saturated with water. The pH is moderate to highly acidic (<4.2).		
BOO – Open Bog	Bog with tree cover ≤ 10%, shrub cover ≤ 25%	0.000	0.0
BOT – Treed Bog	Bog with 10% < tree cover ≤ 25%	0.01	0.0
FOC – Coniferous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% coniferous tree species	55.8	5.4
FOD – Deciduous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% deciduous tree species	21.5	2.1
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	45.6	4.4
MAM – Meadow Marsh	Areas with <2m of water over substrates. Often seasonally flooded with soils drying out by mid-summer. Tree and shrub cover is ≤ 25% and area is dominated by emergent hydrophytic macrophytes. Represents the wetland-terrestrial interface.	6.9	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 ≤ 25% and cover of emergent hydrophytic macrophytes is greater than or equal to 25%.	4.2	0.4
OAO – Open Aquatic	Areas with water >2m deep. Plankton dominated with no macrophyte vegetation and no tree or shrub cover.	54.4	5.3
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.	0.3	0.03
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.	0.2	0.02
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 macrophytes. Often influenced by shoreline energy.	0.2	0.02
SBS – Shrub Sand Barren	Bare sand substrates not associated with distinct topographic features (i.e. sand dune), subject to periods of prolonged drought and disturbances (e.g. fire)	0.009	0.0

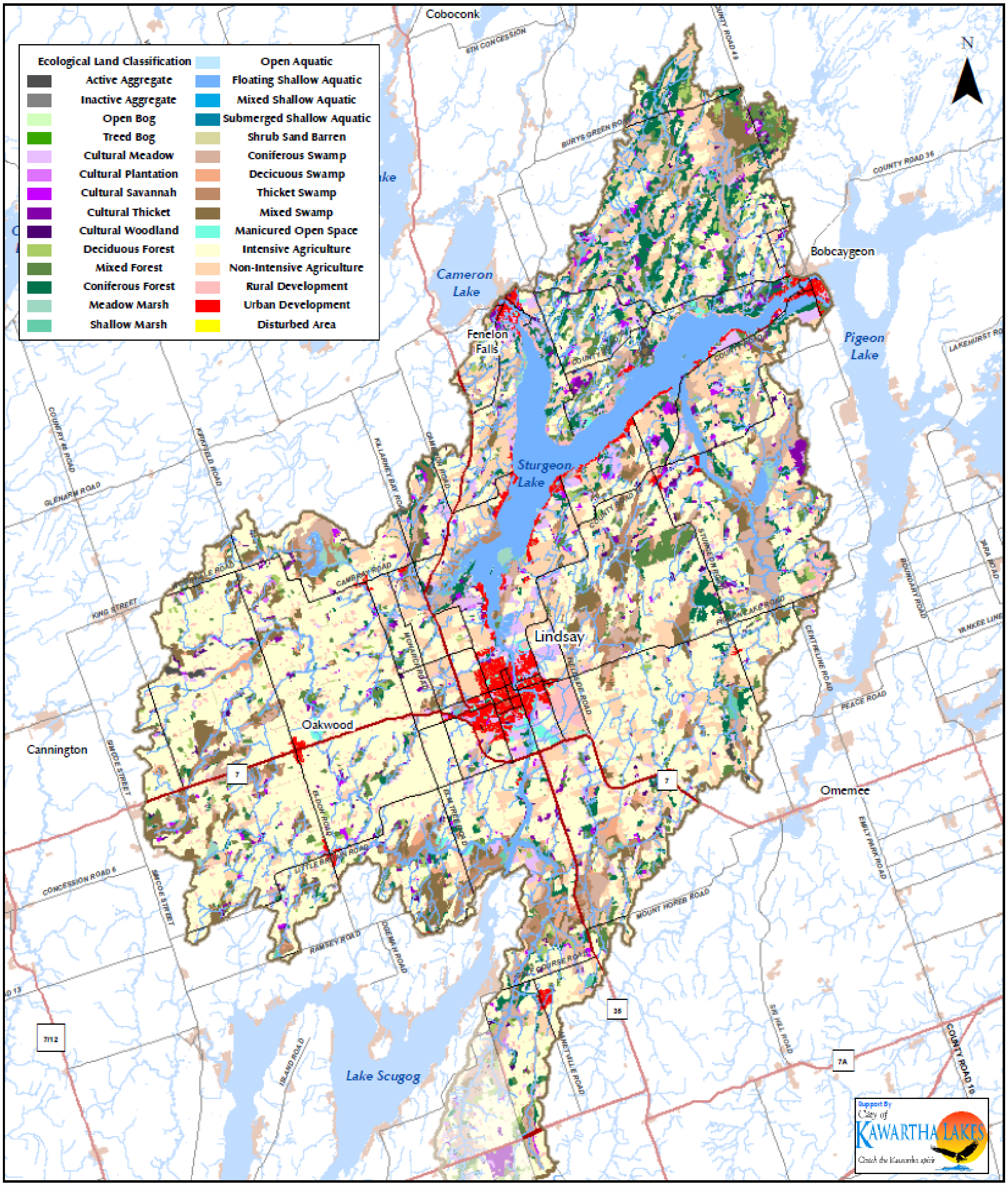
Community Series (Code -Descriptive Name)[1]	Description of Community Series	Watershed Area (km^2)	Watershed Area (%)
	Tree cover≤25%, shrub cover ≤ 25%		
SWC – Coniferous Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. 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.	54.7	5.3
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.	9.9	1.0
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 make up >25% of the canopy, and coniferous tree species make up >25% of the canopy. Hydrophytic shrubs and herbs present.	48.4	4.7
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 ≤ 25% and hydrophytic shrub cover is >25%.	37.7	3.7
Cultural Areas		669.81	65.2
Natural Areas		339.9	33.1
Combined Areas of Cover*		365.01	35.54
Roads		17.25	1.68

* All natural areas + CUM, CUP, CUS, CUT, CUW

9.4 Terrestrial Biodiversity

The diversity of terrestrial flora and fauna species that are supported by the available habitat within the watershed can provide an insight into the overall ecological health and condition of the watershed. 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.

The Great Lakes Blueprint for Biodiversity has identified 29 species at risk as conservation targets within ecodistricts 6E-8and 6E-9, of those species; five have been confirmed within the Sturgeon Lake Watershed. In addition, the Ontario Ministry of Natural Resources' Natural Heritage Information Center identifies an additional six species at risk not identified by the Great Lakes Blueprint. It is important to consider the species identified at an ecodistrict level as well as a watershed level since terrestrial species are not bounded by watersheds, and therefore they may be dependent on specific features found either inside or outside of the Sturgeon Lake watershed. Furthermore, when developing a terrestrial natural heritage system, it makes sense to follow an established blueprint for biodiversity rather than creating one at the Sturgeon Lake watershed level.



Ecological Land Classification (ELC)

Highway
Major Road
Watercourse
Waterbody
Built-Up Areas
SLMP Watershed

0 4 8 16
Kilometres

PRODUCED BY Kawartha Region Conservation Authority with data supplied under license by members of the Ontario Geospatial Data Exchange.
Additional Data Sources

Figure 9.3. Ecological Land Classification of the Sturgeon Lake Watershed

Table 9.3. Significant Species Identified as Conservation Targets in the Great Lakes Conservation Blueprint for Biodiversity

Scientific Name	Common Name	Species Target for Ecodistrict 6E-8	Species Target for Ecodistrict 6E-9	Species Target for Tertiary Watershed 2HH	OMNR Status	EO[2] in Sturgeon Lake Watershed
Birds						
Buteo lineatus	Red-shouldered Hawk		√		SC	
Chlidonias niger	Black Tern	√		√	SC	√
Coturnicops noveboracensis	Yellow Rail		√		SC	
Dendroica cerulea	Cerulean Warbler	√			SC	
Haliaeetus leucocephalus	Bald Eagle	√			END-R	
Ixobrychus exilis	Least Bittern	√		√	THR	√
Lanius ludovicianus	Loggerhead Shrike	√			END-R	√
Melanerpes erythrocephalus	Red-headed Woodpecker		√		SC	√
Rallus elegans	King Rail	√			END-R	
Seiurus motacilla	Louisiana Waterthrush		√		SC	
Reptiles						
Apalone spinifera	Spiny Softshell		√		THR	
Clemmys guttata	Spotted Turtle		√		SC	
Glypternys insculpa	Wood Turtle		√	√	END	
Graptemys geographica	Northern Map Turtle			√	SC	
Elaphe obscleta	Eastern Ratsnake		√		THR	
Eumeces fasciatus	Common Five-lined Skink	√	√		SC	√
Heterodon platirhinos	Eastern Hog-nosed Snake	√	√		THR	
Sternotherus odoratus	Stinkpot			√	THR	
Vascular Plants						
Carex juniperorum	Juniper Sedge		√		END-R	
Carex schweinitzii	Schweinitz's Sedge	√				
Celtis tenuifolia	Dwarf Hackberry	√	√		THR	

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

Scientific Name	Common Name	Species Target for Ecodistrict 6E-8	Species Target for Ecodistrict 6E-9	Species Target for Tertiary Watershed 2HH	OMNR Status	EO[2] in Sturgeon Lake Watershed
Cypripedium candidum	Small White Lady's-slipper		√		END-R	
Festuca occidentalis	Western Fescue	√				
Gratiola aurea	Golden Hedge-hyssop		√			
Juglans cinerea	Butternut	√	√		END	
Nymphoides cordata	Floating-heart		√			
Panax quinquefolius	American Ginseng		√		END	
Platanthera leucophaea	Eastern Prairie Fringed-orchid		√		END	
Poa languida	*Drooping Bluegrass*		√			
Woodsia glabella	*Smooth Woodsia*		√			

END-Endangered, END-R-Endangered with a recovery plan, THR-Threatened, SC-Special Concern

Table 9.4. Terrestrial Species at Risk Identified in the Sturgeon Lake Watershed

Scientific Name	***English Name***	***Global rank***	***Sub-national rank***	***Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Status***	***Species At Risk in Ontario (SARO) Status***	***Canada General Status***	***Ontario General Status***
Birds							
Ammodramus henslowii	Henslow's Sparrow	G4	SHB	END	END	At risk	At Risk
Chlidonias niger	Black Tern	G4	S3B	NAR	SC	Secure	Sensitive
Ixobrychu sexilis	Least Bittern	G5	S4B	THR	THR	At risk	At Risk
Lanius ludovicianus	Loggerhead Shrike	G4	S2B	END	END	At risk	At Risk
Melanerpeserythr ocephalus	Red-headed Woodpecker	G5	S4B	THR	SC	May be at risk	May be at risk
Vascular Plants							
Juglans cinerea	Butternut	G4	S3	END	END		
Reptiles							
Emydoidea blandingii	Blanding's Turtle	G4	S3	THR	THR	May be at risk	At Risk
Lampropeltis triangulum	Milksnake	G5	S3	SC	SC	Sensitive	Sensitive
Plestiodon fasciatus pop. 2	Common Five-lined Skink (Southern Shield population)	G5T4	S3	SC	SC		

Scientific Name	English Name	Global rank	Sub-national rank	Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Status	Species At Risk in Ontario (SARO) Status	Canada General Status	Ontario General Status
Sternotherus odoratus	Eastern Musk Turtle	G5	S3	THR	THR	At risk	At Risk
Thamnophis sauritus	Eastern Ribbonsnake	G5	S3	SC	SC	Sensitive	Sensitive

G4-Common, G5 – Very Common, SH-Possibly Extirpated, S2-Imperiled, S3-Vulnerable, S4-Apperenty Secure, END-Endangered, THR-Threatened, SC-Special Concern

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 meters from any edge – a field, road or hydro corridor. To put this into perspective, a square 4 hectare (10 acre) woodlot measures 200 meters by 200 meters, 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 watershed that is forest cover 100 meters or further from the forest edge should be greater than 10%. The proportion of the watershed that is forest cover 200 meters or further from the forest edge should be greater than 5%. The Sturgeon Lake watershed has only 7.9% forest coverage that is >100 meter from edge and 2.3% forest coverage that is > 200 meter form edge. Therefore the Sturgeon Lake watershed is below the targets for interior forest cover. ***Figure 9.4*** shows the distribution of interior forest areas within the watershed.

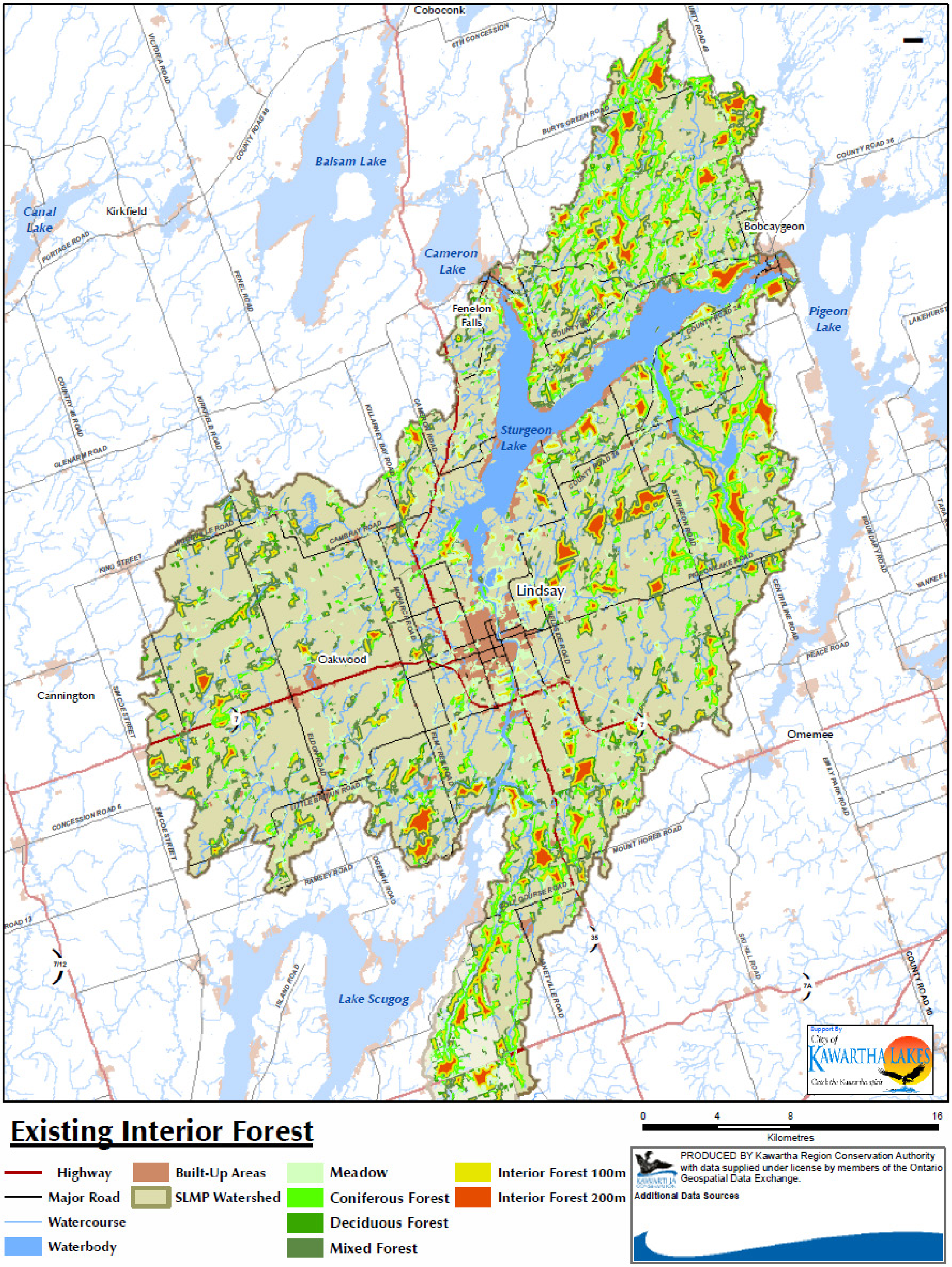


Figure 9.4. Areas of Interior Forest in the Sturgeon Lake Watershed

Table 9.5. Anticipated Response by Forest Birds to the Size of the 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.

* Environment Canada (2004)

9.5 Species and Habitats at Risk

Endangered, rare and threatened species and their habitat

Significant portions of endangered, rare and threatened species and their habitat exist within several areas of the watershed. There are 11 species that have been identified as endangered, rare or threatened in the Sturgeon Lake watershed ***(Table 9.4).*** A full list of species and their habitats is available on the Ministry of Natural Resources, for this report a brief summary of that information is provided here.

Henslow's Sparrow is a small sparrow that could potentially breed in the Sturgeon Lake watershed, its habitat is mainly old fields, which are quickly disappearing due to changes in farm practices, urbanization, and the succession of fields to thickets and forest.

Black Terns are small Terns were once common in North America, however the draining of wetlands and increased disturbance, particularly boat traffic, has reduced their nesting success in recent years and their numbers continue to decline.

Least Bittern is a secretive marsh bird that, because of its reclusive nature, makes determination of the actual number of decline somewhat unreliable. Like the Black Tern, Least Bitterns are threatened by the draining of wetlands for conversion to farmland and urban development. Least Bitterns generally require large, quiet marshes, which are currently in decline.

Loggerhead Shrikes are robin-sized song birds with a robust hooked bill, black face mask, white under parts, and black wings with a prominent white wing patch. Easily confused with the Northern Shrike (L. excubitor), Loggerhead Shrikes are confined to limestone plains at the southern edge of the Canadian Shield. The three main breeding areas in the province are in the vicinity of Lindsay (Carden Plain), Kingston and Ottawa. Intensive farming practices, natural plant succession, reforestation and development have all reduced the amount of habitat available for the Loggerhead Shrike.

Red-headed Woodpeckers are medium-size birds (20cm) that live in open woodland and woodland edges, especially in oak savannahs and riparian forest, which can often be found in parks, golf courses and cemeteries. The Red-headed Woodpecker population has declined by more than 60% in Ontario in the last 20 years because of habitat loss due to forestry and agricultural practices, and competition from European Starling for nest sites. The removal of dead trees which provide nesting sites for this species is also a significant factor in its decline.

Butternut is a medium-sized tree that belongs to the Walnut family. Butternut trees are normally found scattered at low density in forests, and were thus never common in Ontario. Historically, they have declined as forests have been cleared. Today, the main threat to Butternut is a serious fungal disease called Butternut Canker.

Blanding's Turtle is identified by its bright yellow throat and jaw. It has a smooth, domed shell that resembles a military helmet. This medium-sized turtle inhabits a network of lakes, streams, and wetlands, preferring shallow wetland areas with abundant vegetation. It can also spend significant portions of time in upland areas moving between wetlands. Blanding's Turtle is threatened by habitat destruction, road mortality, predation by raccoons and skunks, and collection for the pet trade.

Milksnakes are beautifully marked snakes that can grow to a length of one meter or more. Dorsal blotches are usually red with black borders, but colouration is quite variable and blotches may be brown or even green. It is the only snake in Ontario that is reddish. Even though this is a non-venomous snake, human persecution has been a threat. Other threats to this species are road mortality, habitat destruction, and aggressive behaviour that makes it more prone to being killed by humans.

The Common Five-lined Skink is a small, smooth-bodied lizard, with black or grey colouring and five white or yellow stripes along the back. Adults can reach a length of 20 centimeters. Development of land for cottages and recreational trail use has impacted the Great Lakes/St. Lawrence population. Illegal collecting for the pet trade is a threat to remaining populations, as are dogs, cats, raccoons, and road mortality

The Eastern Musk Turtle grows to a maximum length of about 13 cm; it is one of the smallest turtles in Ontario. It has a dark-coloured carapace that becomes algae-covered in older individuals. The adult has two bright yellow stripes along the side of the head. It frequents shallow, slow-moving water where it typically walks along the bottom rather than swimming.

Eastern Ribbon Snakes are slim snakes with three bright yellow, longitudinal stripes running down the sides, contrasting sharply with the dorsal background colour of chocolate brown or black. There is little historical data in Ontario on abundance trends, but it is likely that the reduction of wetland habitat through urban and agricultural development resulted in a decrease in abundance in Ontario (Species at risk characteristics and threats from Royal Ontario Museum/MNR, 2012).

9.6 Significant Natural Heritage Features

Identifying significant natural heritage features provides an understanding of the unique conservation values associated with the watershed. This understanding allows natural heritage management efforts within the watershed 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.

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 are designated based on ecological significance, and Earth Science ANSIs are designated based on geological significance. There are six ANSI sites within the Sturgeon Lake watershed encompassing 63 km^2 or 6% of the total watershed area ***(Figure 9.5). Table 9.6*** describes each candidate ANSI site.

There are a number of locally significant areas of natural and scientific interest located in the Sturgeon Lake Watershed that have not been classified or identified by the province or Kawartha Conservation as regionally or provincially significant. Examples are the buried Rutherford Creek outlet gorge and the

Precambrian inliers (one being Red Rock) north of Verulam Park. These locally significant areas are an opportunity for further study, characterization, and potentially, inclusion into a natural heritage system.

Significant Wildlife Habitat

The identification of significant wildlife habitat (SWH) areas for the watershed was guided by the Significant Wildlife Habitat Technical Guide (OMNR, 2000), and mapping provided by the Ontario Ministry of Natural Resources.

SWH is defined by 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 (OMMAH, 2002).

Table 9.6. ANSI Sites in the Sturgeon Lake Watershed

Name	Type	Area	Description
Cameron Site	ANSI – Earth Science (Provincial)	51161m^2	The Cameron site exposes a 3 m (10 ft) section of the upper Verulam Formation of the Upper Ordovician Period.
Cameron Rock Drumlin	ANSI – Earth Science (Provincial)	3.6 km^2	This ANSI contains a true rock drumlin and partially formed drumlinoids. Site shows evolution of bedrock escarpment into rock drumlins.
East Cross Creek Swamp	ANSI- Life Science (Regional)	583 ha	This area encompasses approximately 0.5% of the total watershed area, located at the mouth of East Cross Creek where it enters the Scugog River. The swamp transitions from grass/sedge/ to riverside meadow to dense alder thicket with scattered tamarack to very wet open spruce, tamarack, birch, elm swamp.
Emily River Swamp	ANSI- Life Science (Provincial)	36.9 km^2	Emily River Swamp is an extensive wetland complex containing a lake and river system which flows into Sturgeon Lake.
Goose Lake Wetland	ANSI- Life Science (Provincial)	17.0 km^2	The Goose Lake Wetlands are an extensive shallow lake and wetland complex forming in headwaters of McLaren Creek.
Lindsay North Road Cut	ANSI – Earth Science (Provincial)	6906 m^2	This section is exposed on Hwy 35 showing a 6-7 m thickness of Lindsay Formation limestones (Middle Ordovician Period).

This discussion of SWH excludes types of habitat addressed in other sections of this report. SWH described in this section includes seasonal concentration areas, rare vegetation communities and animal movement corridors.

Seasonal Concentration Areas

Seasonal concentration areas include areas where a particular wildlife species congregates or that a species relies on during a certain time of year such as deer wintering yards, migratory bird stop-overs, or reptile hibernation areas. Known seasonal concentration areas for wildlife within this watershed include deer wintering yards.

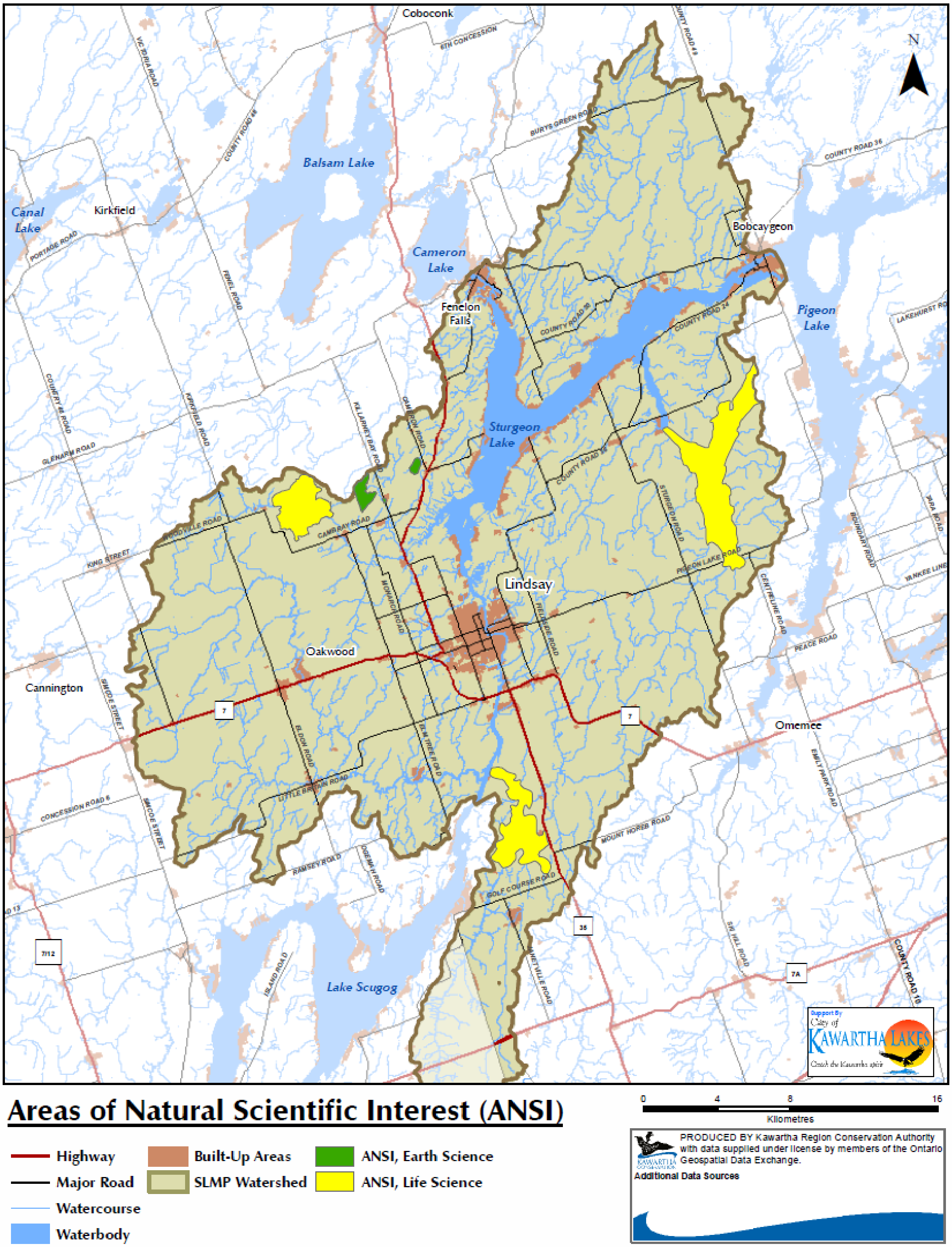


Figure 9.5. Areas of Natural Scientific Interest in the Sturgeon Lake Watershed

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, percent natural vegetation cover, and species composition.

The areas of the Sturgeon Lake Watershed that are natural heritage features such as wetlands and forests, are composed of both Core (large, unbroken areas that support a greater number of species and diversity) and linkages in the form of corridors. These areas of natural cover are clustered primarily along the shoreline of Sturgeon Lake and within the natural areas along the surrounding tributaries. The natural areas within the Sturgeon Lake watershed tend to be quite fragmented and therefore improving corridors and linkages would be a planning priority.

Significant Woodlands

Woodlands are considered significant because of the features and functions that they provide. Significant woodlands 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 KNHF, or act as an ecological linkage between KNHFs. Significant woodlands within the watershed are illustrated in ***Figure 9.6.***

Wetlands

Wetlands are key natural heritage features and hydrologically sensitive features in the Sturgeon Lake Watershed. ***Figure 9.7*** illustrates the location of wetlands within the watershed. ***Figure 9.3*** also illustrates wetland locations and provides a greater level of detail about each wetland by indicating the vegetation community series.

Wetlands occur on the landscape as single contiguous entities, or as complexes made up of a grouping of several small wetlands. All wetlands have high ecological value, and are significant to the management of the watershed, however, the classification of provincially significant wetlands assists with prioritizing wetlands for conservation protection.

Environment Canada's guideline on wildlife habitat recommends that approximately 10% of each watershed and 6% of each subwatershed in the Great Lakes basin should be wetland (Environment Canada, 2004). 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 occurrences begin to level off.

The Sturgeon Lake watershed contains approximately 162 km^2 of wetland, which represents almost 16%of the total watershed area; this exceeds the 10% minimum recommended percentage of wetland cover. Of those wetlands, approximately 93.4 km^2 (84%) have been designated as provincially significant. All evaluated wetlands including provincially significant wetlands (PSWs) are illustrated in ***Figure 9.7.***

Wetlands have also been classified through air photo interpretation to a community series level using the Ecological Land Classification System for Southern Ontario, first approximation (Lee et al, 1998). The wetland types identified are further described in ***Table 9.2.***

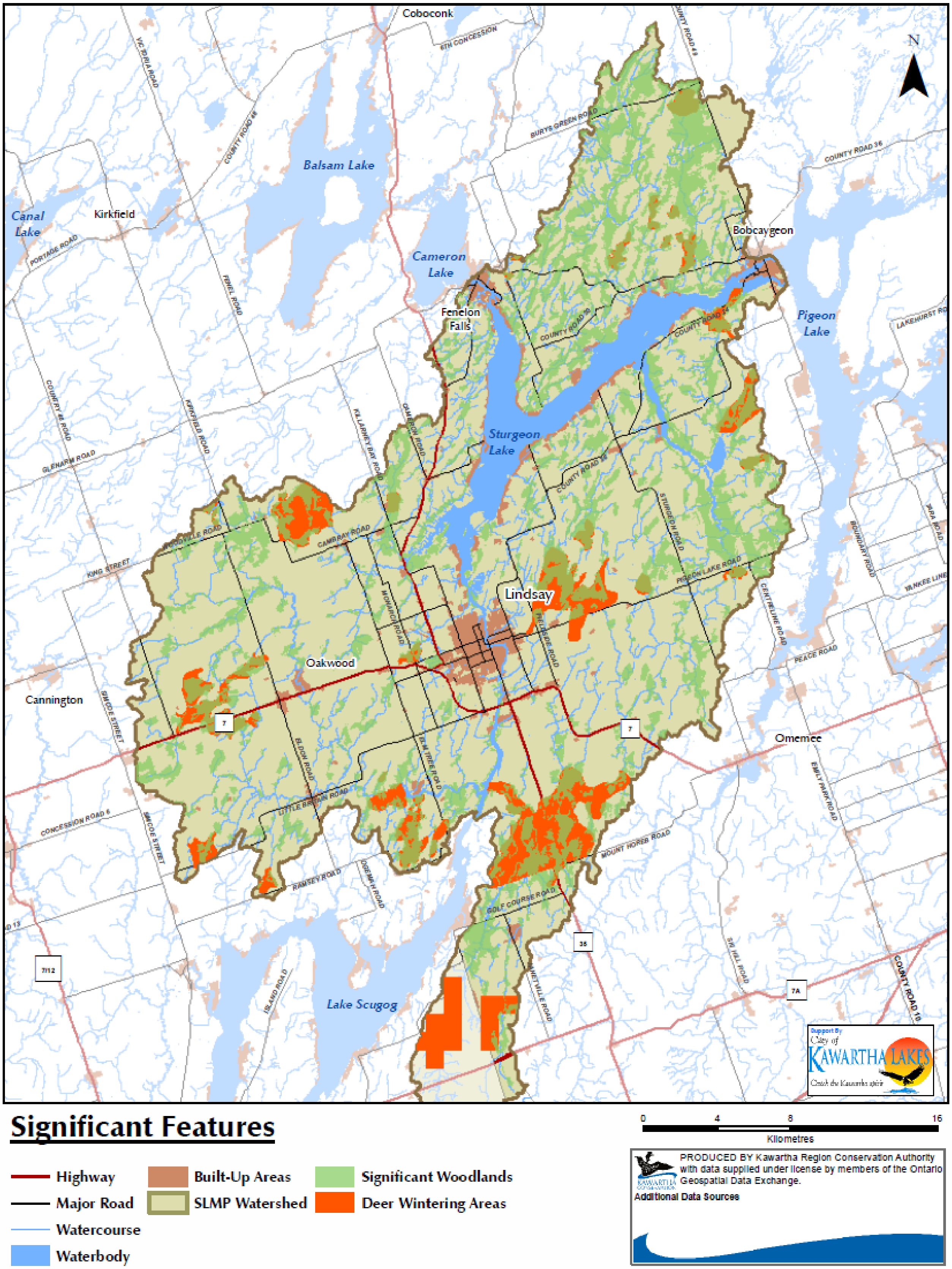


Figure 9.6. Areas of Significant Natural Features in the Sturgeon Lake Watershed

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 water filters, having the capacity to remove harmful impurities, bacteria and excess nutrients. In fact wetlands are such effective filters that constructed wetlands have been used to treat urban storm water runoff in Europe (and now in Ontario) for several decades. A study conducted on 57 wetlands from around the world concluded that 80% of wetlands studied reduced nitrogen loadings and 84% of wetlands studied reduced phosphorus loadings with the water flowing through them (Fisher and Acreman, 2004).
- 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. After storms or spring snow melt water is gradually released into streams and rivers, and can be critical at maintaining stream flow during periods of drought.

Ecological Goods and Services

Natural areas such as wetlands and forests are a critical part of all terrestrial ecosystems and a large component of what makes life possible in any environment. However, the value of natural areas goes far beyond the role they play in the local ecosystems, and recently it has become more common to identify the benefits that are produced by the ecological functions, and translate those benefits into the monetary value of the ecological goods and services that they produce. Examples of ecological goods and services are clean air, fresh water, maintaining biodiversity, renewal of soil and vegetation, carbon storage, pollination and natural biological controls.

The type of natural area may influence its ecological goods and services value, but its location on the landscape is also a major factor. For example, wetlands found in non-urban, non-coastal areas are valued at $15,170/ha, however an urban wetland is valued at $161,420/ha (Troy, 2009).The values placed on various land cover types was estimated by looking at the benefits that people obtain directly or indirectly from ecological systems. Some examples are food production, climate stabilization and flood control, aesthetic views, and recreational opportunities to name a few. A joint study by Ducks Unlimited and the University of Guelph determined that the riparian wetlands in the Black River subwatershed (Lake Simcoe CA) provide phosphorous removal that equates to $292,661 in water treatment services (Pattison, 2011).

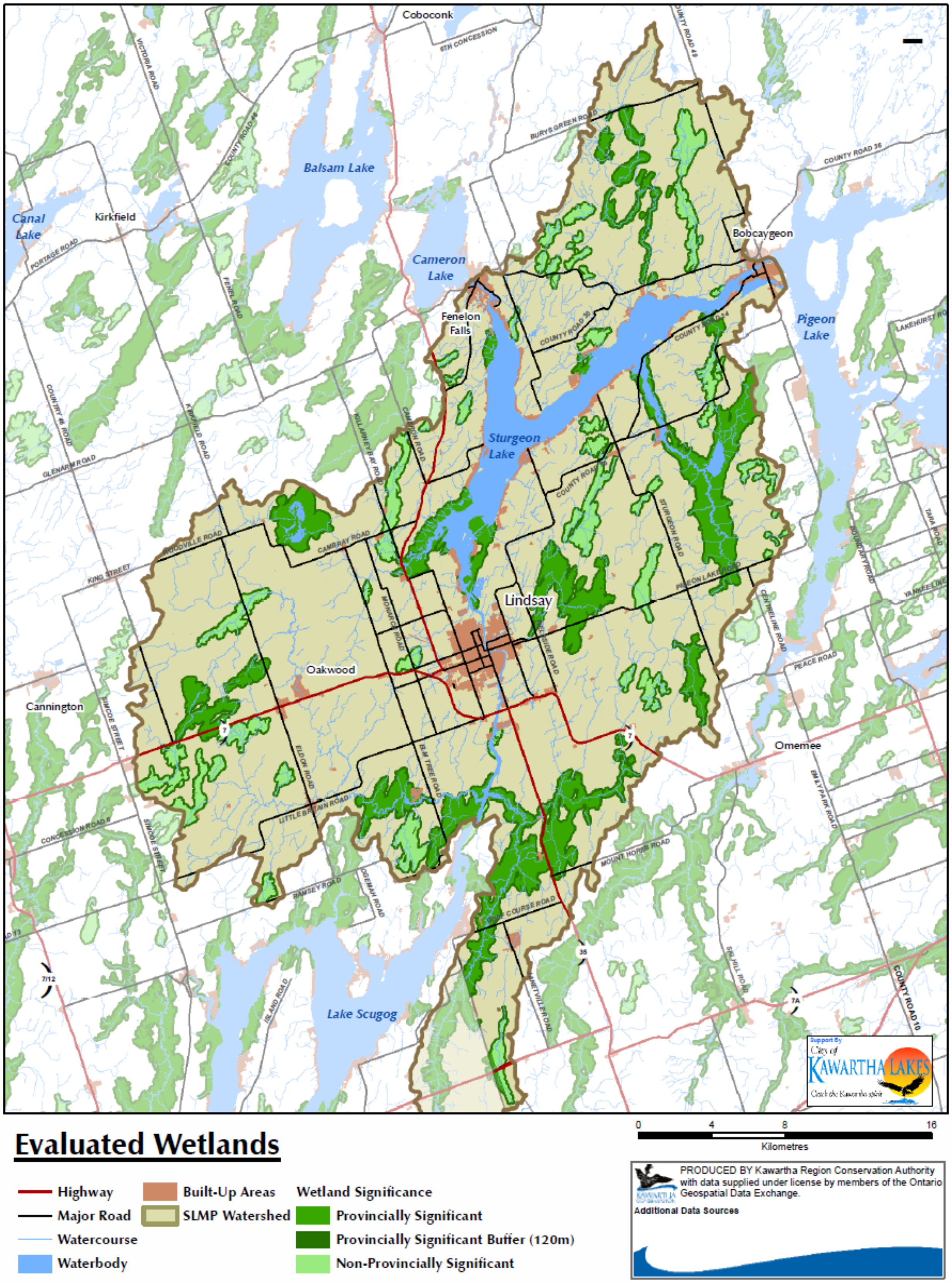


Figure 9.7. Evaluated Wetlands in the Sturgeon Lake Watershed

10.0 Conclusions

The collected scientific and monitoring data provide us with an opportunity to define current and potential issues in the watershed and make informed conclusions about the current state of the lake and its watershed.

The physiography of the Sturgeon Lake watershed is represented by Peterborough Drumlin Field, Schomberg Clay Plains and the Dummer Moraines. On the southern fringes of the watershed the Oak Ridges Moraine occupies a portion of the East Cross Creek headwaters. The major soil types in the watershed include the silty clays and clay loams in the southern part of the study area and the loams and sandy loams in the northern part.

Land use of the watershed is characterized by a dominance of agricultural lands. 53.3% of the watershed land area is utilized for agricultural activities that can have considerable effects on terrestrial natural heritage and water quality. 23.8% of the study area is forest-covered that is below the recommended guideline of a minimum of 30%. 2.0% of the watershed land area is occupied by urban developments. With a projected increase in population and the extent of urban development, there can be potentially an increase in impervious surfaces that can affect the hydrological regime and water quality in streams of the watershed.

Natural heritage conditions are better in the northern part of the Sturgeon Lake watershed where there is less urban development and less intensive and non-intensive agriculture. A number of natural heritage features exist in the watershed that may be considered locally significant; however they are not afforded any legislative protection. The existing natural heritage features are fragmented and lacking in connections, particularly in the southern more developed areas in the watershed.

The Sturgeon Lake watershed has an abundance of wetlands, the majority being swamp type wetlands. At the same time, forest cover is below 30% in 8 of 12 subwatersheds and is at 23.8% for the entire watershed area. Interior forest and deep interior forest is below guidelines for the entire Sturgeon Lake watershed.

There are 11 terrestrial species at risk in the Sturgeon Lake watershed including birds, amphibians, and plants. 6% of the watershed are areas of natural and scientific interest (ANSI).

The climate of the Sturgeon Lake watershed is described as moist continental, mid-latitude; characterized by warm summers with occasional hot and humid spells and cold winters with snowstorms, strong winds and cold air from Continental Polar or Arctic air masses. Precipitation is equally distributed through the year.Climate conditions are currently projected to change as a part of the global climate change process. Change in climate will bring changes to the lake ecosystem that requires advance preparation and planning.

The tributaries of Sturgeon Lake exhibit a natural flow regime with well-defined seasonal flow patterns. High flows typically occur during early spring, associated with snowmelt, and throughout the year following high precipitation events. Low flows are typically observed in the summer and winter months. Wetlands and forested areas that are abundant in the northern portion of the Sturgeon Lake watershed provide significant benefits for the stream flow regime, providing high and low flow mitigation and assisting in groundwater recharge.

The groundwater discharge to the tributaries of Sturgeon Lake that supports baseflow and is a main component of the stream flow during the dry periods is low (<2 L/sec*km^2) or non-existent for the prevailing portion of the watershed. That causes watercourses to flow very low or go stagnant or dry during the periods of limited precipitation. This fact has both natural and anthropogenic causes. The capacity of the shallow aquifers in the region that provide groundwater input to the stream flow is limited. Human activities, such as deforestation, wetland removal, increasing areas of impervious surfaces as a result of urban development, can considerably affect aquifer recharge rates as well as both surface and groundwater levels.

Flow monitoring data from the northern portion of the Sturgeon Lake watershed are limited to three years of monitoring in the framework of the SLMP. Monitoring data are a key source of information on water resources conditions and trends. Monitoring should be continued. Annual monitoring data on lake evaporation is not available. It adds uncertainty to the calculation of a water budget.

The water level regime of Sturgeon Lake generally follows the natural pattern, but it is regulated in accordance with Trent-Severn Waterway's water level management strategy.

Water quality in many lake tributaries has improved since the 1980s; phosphorus concentrations have decreased in some streams considerably (e.g., Hawkers Creek, Martin Creek North, the Scugog River, Mariposa Brook). At the same time, most of the lake's southern tributaries still have elevated phosphorus levels as a result of human activities in the corresponding subwatersheds. East Cross Creek and Jennings Creek exhibited the highest levels of phosphorus throughout the monitoring period. In McLaren Creek phosphorus concentrations have increased since the 1980s.

Nitrate concentrations occasionally exceed the Canadian Water Quality Guideline for the Protection of Aquatic Life (2.93 mg/L) in the water of several tributaries, namely McLaren Creek, Jennings Creek and Mariposa Brook. While average nitrate concentrations in these streams are below the guideline, the frequency of exceedances is quite high, especially in the winter.Nitrate values in 18% of all samples from Mariposa Brook exceeded the corresponding guideline. Nitrate concentrations observed in the water of this stream have been measured as high as 4.8 mg/L.

E. coli monitoring results have revealed that most streams in the watershed usually had *E. coli* levels below the Provincial Water Quality Objective (100 cfu/100 mL), except for a couple of streams in which *E. coli* concentrations may be a concern. For example, in Jennings Creek, the geometrical mean *E. coli* concentration was 189 cfu/100 mL in 2011, 387 cfu/100 mL in 2012 and 187 cfu/100 mL in 2013. No elevated *E. coli* levels were detected in two residential canals on Sturgeon Lake. Elevated *E. coli* levels in excess of the provincial objective have been often observed at Beach Park and Riverview Park beaches in Bobcaygeon that resulted in frequently posted beaches.

Sturgeon Lake can be characterized as a mesotrophic water body. Water quality in the lake has improved considerably since the 1970s to1980s. At the same time, water quality monitoring revealed that in summer Sturgeon Lake in its southern and north-eastern arms has elevated phosphorus levels that often exceed the Provincial Water Quality Objective (0.02 mg/L) and can promote blue-green algae blooms and excessive aquatic plant growth.

The phosphorus and nitrogen balances for Sturgeon Lake were calculated for three hydrologic years (2010-2011, 2011-2012 and 2012-2013). The average total annual phosphorus load in Sturgeon Lake is 26,480 kg, which is 3,844 kg less than it was during the 1986-1989 monitoring period.

The most significant anthropogenic sources of phosphorus for Sturgeon Lake include urban runoff (Lindsay, Fenelon Falls and small urban areas along the shoreline) and septic systems around the lake.

A considerable amount of phosphorus enters the Scugog River system from the Lindsay urban area. The average annual loading over the three-year period is 1,348 kg, which is 5.1% of total annual load. As a result, high amounts of phosphorus and nitrogen found in the Scugog River downstream of Lindsay can be identified as one of the main causes of the process of eutrophication in the southern portion of Sturgeon Lake.

Overall, the total average urban phosphorus loading into the lake was 1,917 kg (7.2% of total load) over the three year monitoring period.

Phosphorus loading from private septic systems within 75 m around the lake was estimated at 1,080 kg (4.1%) annually while applying a 50% retention rate. If no retention rate is applied, then TP loading would be approximately 2,160 kg annually.

The average annual phosphorus load from municipal wastewater treatment plants, namely the Lindsay WPCP and Fenelon Falls WWTP, is 269 kg or just 1% of the total annual load.

The largest amount of phosphorus enters Sturgeon Lake from outside the watershed from Cameron Lake, and varies from 9,738 kg in 2011-2012 to 14,300 kg in 2012-2013. The average loading over the three year period is 12,328 kg (46.5% of total load). The average loading from the Scugog River is 6,639 kg (25.1%) annually, while local streams and overland flow transport 3,727 kg (14.1%) of phosphorus annually.

The average annual atmospheric deposition of total phosphorus on the lake water surface is 520 kg (2%).

Approximately 21,052 kg of the phosphorus, on an annual basis, is leaving Sturgeon Lake via Big Bob and Little Bob channels for Pigeon Lake. As a result, the average total phosphorus net loading (phosphorus that remains in the lake) is about 5,428 kg annually. This phosphorus stays in the lake and contributes to eutrophication, which leads to blue-green algae blooms and excessive aquatic vegetation growth.

The average annual nitrogen load in Sturgeon Lake is 1,332,379 kg. The river flow is the major source of nitrogen – more than 90% of total loading amount. The river flow loading was split between three sources. Cameron Lake flow transports on average 40% or 536,125 kg of nitrogen annually. The Scugog River carries every year 35% or 471,161 kg of nitrogen and almost 15% or 194,907 kg of nitrogen enters Sturgeon Lake with local overland and stream flow.

Approximately 5% of total load or 65,688 kg of nitrogen is released annually into the lake by municipal wastewater treatment plants.

Annually, 34,084 kg of nitrogen (2.6% of total load) falls on the lake water surface as atmospheric deposition (rain, snow, dust, dew, etc.).

A considerable amount of nitrogen enters Sturgeon Lake from local urban areas. The average annual nitrogen loading over the three-year period is 20,693 kg or 1.5% of total load.

Finally, it was estimated that 9,721 kg of nitrogen or0.7% of total load is released into the lake from septic systems located near the lakeshore.

Sturgeon Lake average annual nitrogen export into Pigeon Lake is 1,053,703 kg. The average total annual nitrogen net loading is about 278,676 kg or 21% of the total loading. Similar to phosphorus, this nitrogen remains in the lake and contributes to eutrophication.

Sturgeon Lake supports diverse, cool and warm water fish communities. Twenty-one fish species have been documented within the lake, and thirty-one fish species have been documented within streams that directly empty into the lake. The lake supports a significant recreational fishery.A healthy and sustainable recreational fishery contributes to the tourism-based economy of local communities and municipalities.

Important fishery species include: Walleye, Muskellunge, Largemouth Bass, Smallmouth Bass, and Common Carp.

Sturgeon Lake tributaries provide important ecological pathways to and from the lake. Tributaries draining directly into the lake provide spawning habitat for important migratory lake-dwelling species such as Walleye, Muskellunge and White Sucker.

Nearshore areas provide important habitat for lake-dwelling fishes. Shallow nearshore areas (<3.0 meters) are extremely productive areas for fishes, and are utilized by many fish, including important top predator species, for spawning and/or feeding. Compared to other Kawartha lakes, Sturgeon Lake has a relatively small nearshore area, comprising approximately 37% of lake surface area. Extensive nearshore habitat is concentrated to two areas of the lake: the northwest arm and south arm (Goose Bay area).

Sturgeon Lake has been exposed to a variety non-native aquatic species, including Common Carp, Bluegill, Black Crappie, zebra mussels and Eurasian watermilfoil. In addition to these existing exotic species, there are others that are at immediate risk of becoming established as invasive in Sturgeon Lake. Northern Pike and Round Goby are potential invaders due to range expansions through the Trent-Severn Waterway. Numerous other exotic fishes (e.g., Rainbow Trout, Brown Trout, Goldfish and Koi) are often intentionally stocked into local waters such as private ponds.

Walleye abundance has shown a considerable decrease since 1998. Measures of Walleye recruitment also appear to be in overall decline in the last 15 years; however, recent monitoring indicates a potential variation in the recruitment trend, relative to previous years, with the presence of a strong year class in 2010.

Over 50% of the lake shoreline has been developed within a 30m distance from the shore. Much of the shoreline has been hardened with concrete and armour stone resulting in reduced aquatic habitat potential and isolated land from the water. In many small to medium sized lake tributaries, existing natural riparian land cover does not meet minimum recommended guidelines of 75% to maintain ecological integrity. Existing benthic macroinvertebrate communities, most of which show biological impairment, appear to reflect stream habitat degradation. Riparian cover loss is largely due to conversion of natural lands for agricultural activities.

Currently, it is unknown at what point development within the watershed/shoreline can cause serious negative implications for the lake aquatic ecosystem. Shoreline areas in particular, are at risk of increasing development and urbanization.

The results of the research and monitoring programs undertaken during the 2010-2013 period reveal that while Sturgeon Lake water quality, environmental health and the ecological state of the lake are generally in good condition, the lake, nevertheless, needs a long-term management strategy in order to address current issues, prevent potential issues and maintain/improve the environmental sustainability of the lake aquatic ecosystem. A considerable amount of phosphorus and nitrogen is retained in the lake every year that contributes to the process of eutrophication. In order to decrease phosphorus accumulation in the lake, it is necessary to reduce phosphorus loading from several major sources, primarily of human origin. Besides phosphorus and nitrogen problem, there are several other issues that require attention during Sturgeon Lake Management Plan implementation. They include elevated *E. coli* concentrations at public beaches, contaminated sediments in the southern portion of the lake, modified and hardened shorelines, a lack of vegetated buffers along streams and shorelines, the presence of exotic species in the lake, and others.

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Glossary

Agricultural Area: A portion of the watershed where the predominant land use is agriculture or agriculture related

Agricultural activities: Refers to any actions related to farm operations. This includes but is not limited to: growing crops, raising livestock, spreading manure, irrigation and clearing fields

Anthropogenic: Effects, processes or materials that are derived from or as a result of human activities

Aquatic system: An ecosystem located within a water body (Also see: Ecosystem)

Aquatic vegetation: Refers to plants and algae that grow within an aquatic environment

Aquifer: Layer of permeable rocks or loose materials (gravel, sand) that is saturated with water and through which groundwater moves and can be extracted using water well

Baseflow: The portion of stream flow that is entirely attributed to groundwater inputs

Benthics: Organisms that live in the benthic zone at the bottom of a water body

Best management practice (BMP): A term used to describe the preferred method of management that has proven to reliably lead to a desired result. Usually associated with stormwater management or agricultural practices

Bioaccumulation: The build-up of substances such as pesticides or heavy metals within an organism. This occurs when the organism obtains a substance at a greater rate than it can dissipate it.

Biodiversity: The variability among living organisms and the ecological complexes of which they are part. A healthy ecosystem is traditionally one with a high level of biodiversity.

Biosolids: A term used in wastewater management referring to treated sludge from commercial and domestic sewage and wastewater treatment.

Biota: The total collection of organisms of a geographic region.

Coldwater fish: Fish species such as brook trout that prefer colder water temperatures (usually below 15˚C).

Conductivity: In regards to water, conductivity measures the ability of a water sample to conduct electricity. This is dependent on the concentration of dissolved salts and other ionizing chemicals.

Dissolved oxygen (DO): An amount of oxygen that is being dissolved in the water column.

Drumlin: A geographic feature created through glaciation in the form of a “tear drop” shaped hill. Usually occurs in clusters or “fields”.

Dry deposition: Materials such as dust that fall out of the atmosphere onto the earth's surface.

Ecological functions: The natural processes, products or services that living and non-living environments provide or perform within or between species, ecosystems and landscapes.

Ecosystem: A recognizable ecological unit such as a group of plant and animal species living together in a particular area.

End-of-pipe practices: Stormwater management controls or facilities located at a storm sewer outlet. (Also see: stormwater management controls, stormwater management facilities)

Erosion: The removal of soil sediment and rock in the natural environment. This may be as a result of natural processes such as weathering or through anthropogenic processes such as deforestation and poor farm management practices.

Eutrophication: A natural or human-caused process whereby water bodies receive excess nutrients (phosphorus and nitrogen specifically) that stimulate excessive aquatic plant and/or algae growth. Nutrients can come from natural sources such as erosion of soils or stream banks, or human sources (fertilizers, urban runoff, sewage treatment plant discharges, etc.).

Eutrophic water body: A lake, stream or any other natural or man-made water body that has high levels of nutrients in its water, is highly productive and supports high growth rates of aquatic vegetation and/or algae.

Evaporation: The transfer of water from the earth's surface into the atmosphere under influence of solar radiation and heat, and wind.

Evapotranspiration: The transfer of water from vegetation into the atmosphere.

Farming activities: (See agricultural activities)

Freshet: High water levels resulting from heavy rains or snowmelt. Usually associated with a spring thaw event.

Groundwater: Water located beneath the surface, usually in aquifers or other porous spaces.

Groundwater discharge: The flow rate of groundwater through an aquifer usually expressed in cubic meters per second.

Habitat: An ecological or environmental area that is inhabited by a particular organism and that influences or is utilized by that organism.

Hardness: In regards to water, hardness measures the concentration of dissolved minerals such as calcium and magnesium. Hard water has a high mineral concentration.

Infiltration: Water entering the ground via pores in the earth's surface.

Invasive species: A non-indigenous plant or animal, e.g., Eurasian milfoil (Also see: native species)

Lot level practices: In regards to stormwater, these are changes that can be made on a lot or property to reduce the quantity or improve the quality of stormwater runoff, e.g., installation of rain barrels.

Macrophytes: Aquatic plants that grow in or near the water.

Mesotrophic water body: A lake, stream or any other natural or man-made water body that has moderate levels of nutrients in its water and consequently moderate plant growth.

Heavy metals: In regards to water quality, this refers to metals located within the water column as a result of natural or anthropogenic processes. Heavy metals are usually toxic for aquatic organisms and humans, e.g., lead, cadmium, thallium and mercury.

Moraine: A geographic feature consisting of a mound of earth and rock pushed up in front of an advancing glacier.

Naturalization: (See restoration)

Native species: A species that is indigenous to an ecosystem in that it occurs there naturally without any human intervention.

Nutrients: In terms of water quality, this refers to the chemicals that aquatic vegetation requires for vital functions. Nutrients include phosphorus, nitrogen, potassium and some other chemical elements.

Oligotrophic water body: A lake, stream or any other natural or man-made water body that has very low levels of nutrients, such as phosphorus and nitrogen, in its water and, as a result, low productivity with few aquatic plants.

Petroleum hydrocarbons (PHCs): A group of several hundred chemicals that originally come from crude oil. These chemicals are present in many petroleum products made from crude oil. PHCs are a mixture of chemicals, but all of them are made mainly from hydrogen and carbon and therefore called hydrocarbons.

Polycyclic aromatic hydrocarbons (PAHs): A group of over one hundred different chemicals made up of only hydrogen and carbon. They are the standard product of the incomplete burning of carbon-containing materials like oil, wood, garbage or coal. Automobile exhaust, industrial emissions and smoke from burning wood, charcoal and tobacco contain high levels of PAHs. Several PAHs, such as anthracene, benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-c,d)pyrene and some others are carcinogenic.

Precipitation: The transfer of water from the atmosphere to the earth’s surface in the form of rain, snow, hail, dew, etc.

Provincially significant wetland (PSW): Based on the guidelines for wetland management (MNR, 1984), these are wetlands classed as 1 through 3 in the wetlands policy (Section 3 of the Planning Act).

Recharge:	In regards to groundwater, recharge refers to water being added to a groundwater system such as an aquifer.
Restoration:	Returning an altered landscape back to its original form through physical restructuring and the reintroduction of native species. For example, shoreline restoration or naturalization refers to the removal of non-natural features such as lawns and break walls and the addition of native plant species.
Riparian zone/area:	The interface between land and a stream or lake.
Secchi disk:	White and black disk 20 centimeters in diameter used to measure water transparency in lakes. The disc is lowered into the water on the line. The depth at which the pattern on the disk is no longer visible is taken as a measure of the transparency of the water. This measure is known as the Secchi depth and is related to water turbidity in the lake.
Sediments:	Any particulate matter that can be transported by flowing water, and eventually deposited on the bottom of a water body.
Sewershed:	The total area of land that drains to a sewer system.
Stormwater:	A term used to describe water that originates during a precipitation event. Usually used to define water that flows through storm sewer systems in urban areas.
Stormwater management control:	A device or system used to treat stormwater quality or quantity. Examples are oil grit separators, infiltration trenches, etc.
Stormwater management facility:	A constructed wet pond, dry pond or wetland used to detain stormwater in order to treat for quality or quantity. Water quality treatments primarily rely on the settling of sediments.
Subwatershed:	A subsection of a watershed. (Also see: watershed)
Surface water:	Precipitation that does not soak into the ground or return to the atmosphere but instead flows through streams, rivers, lakes and wetlands.
Suspended sediments:	Sediments that are still situated within a water column. (Also see: Sediments)
Sustainable development:	A pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for future generations.
Total phosphorus (TP):	A measure of both soluble and insoluble phosphorus forms within a water column. The insoluble component is primarily decaying plant and animal matter or soil particles. Soluble phosphorus (e.g., orthophosphates) is dissolved in water column in molecular form. It is readily available to aquatic plants and algae.
Transpiration:	Evaporation from aerial parts of a plant such as the leaves. (Also see: Evaporation, Evapotranspiration)

Urban area:	An area with an increased density of human-created structures and population when compared to surrounding areas. In Canada, an urban area is defined as having more than 400 people per square kilometer and has more than 1,000 people in total.
Warm water fish:	Fish species that prefer warmer water temperatures such as muskellunge and smallmouth bass.
Water budget:	A summary of the quantity of water in the atmosphere, ground and surface water systems within a watershed.
Water quality:	An integrated index of chemical, physical and microbiological characteristics of natural water that determines suitability of water for the aquatic life and various human uses.
Watershed:	The total area of land that drains to a river or other large body of water.
Wet deposition:	Materials deposited on the surface by precipitation.
Wetland:	Lands that are seasonally or permanently covered by shallow water as well as lands where the water table is close to or at the surface. The four major types of wetlands are swamps, marshes, bogs and fens.
Woodland:	Treed areas that provide environmental and economic benefits such as erosion prevention, water retention, provision of habitat, recreation and the sustainable harvest of woodland products.

Appendix WQ1

Surface Water Quality Standards and Guidelines

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
E. coli	100 cfu/100 mL	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 (streams)
Phosphorus	0.020 mg/L	Provincial Water Quality Objectives (lakes)
Total Suspended Solids	Background +25.0 mg/L	Canadian Water Quality Guideline for the Protection of Aquatic Life

Appendix AE1

Shoreline benthos collection data from 2011 surveys.

OBBN Group	WK1-C1	WK1-C2	WK1-C3	WK1-C4	WK1-C5	WK1-C6	WK1-C7	WK2-C1	WK2-C2	WK2-C3	WK2-C4	WK2-C6	WK2-C7	WK3-C3	WK3-C4	WK3-C7		Total_All
Hydras	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**0**
Flatworms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**0**
Roundworms	0	0	5	0	1	0	0	0	0	0	0	0	1	0	0	0		**7**
AquEarthworms	1	3	7	2	0	0	0	1	2	1	2	1	0	1	0	0		**21**
Leeches	1	1	0	2	1	0	3	1	1	0	1	1	0	2	2	4		**20**
SowBugs	4	65	20	28	0	0	0	40	5	14	8	7	0	2	62	32		**287**
Clams/Mussels	1	1	1	2	9	14	12	0	3	25	0	0	65	1	0	0		**134**
Scuds	201	115	131	189	110	121	162	52	77	163	287	263	48	238	182	309		**2648**
Crayfish	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1		**3**
Mites	1	1	1	1	4	0	6	0	2	0	0	0	2	0	0	0		**18**
Mayflies	11	50	20	36	3	46	1	141	71	1	5	44	2	30	77	33		**571**
Dragonflies	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**1**
Damselflies	0	0	0	0	0	0	0	4	1	0	0	0	0	0	1	1		**7**
Stoneflies	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0		**2**
TrueBugs	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0		**2**
Fishflies/Alderflies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**0**
Caddisflies	10	8	20	16	36	14	13	1	25	15	3	3	13	2	9	2		**190**
AquMoths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0		**1**
Beetles	34	36	36	10	5	19	4	35	77	17	4	19	12	1	6	29		**344**
Snails	19	5	23	15	105	62	85	1	21	63	11	6	173	16	4	2		**611**
Midges	4	10	0	19	7	4	2	5	23	0	9	3	0	14	20	0		**120**
Horse/DeerFlies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**0**
Mosquitos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**0**
NoSeeUms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**0**
CraneFlies	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0		**2**
BlackFlies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		**0**
MiscDiptera	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0		**1**

Abundance Total	287	297	264	322	281	281	288	281	309	300	330	347	318	307	365	413		**4990**
Richness Count	11	13	10	13	10	8	9	10	13	9	9	9	9	10	11	9		**20**
Index SimpsonsDiversity	0.49	0.76	0.71	0.63	0.69	0.73	0.59	0.68	0.81	0.65	0.24	0.41	0.64	0.39	0.68	0.42		**0.68**
Index_FamilyBiotic	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		**n/a**
%EPT	7.3	19.5	15.2	16.1	13.9	21.4	4.9	50.5	31.1	5.3	2.4	13.5	5.3	10.4	23.6	8.5		**15.3**
%Coleoptera	11.8	12.1	13.6	3.1	1.8	6.8	1.4	12.5	24.9	5.7	1.2	5.5	3.8	0.3	1.6	7.0		**6.9**
%Isopoda	1.4	21.9	7.6	8.7	0.0	0.0	0.0	14.2	1.6	4.7	2.4	2.0	0.0	0.7	17.0	7.7		**5.8**
%Chironomidae	1.4	3.4	0.0	5.9	2.5	1.4	0.7	1.8	7.4	0.0	2.7	0.9	0.0	4.6	5.5	0.0		**2.4**
%PelecypodaGastropoda	7.0	2.0	9.1	5.3	40.6	27.0	33.7	0.4	7.8	29.3	3.3	1.7	74.8	5.5	1.1	0.5		**14.9**
%Other	71.1	41.1	54.5	60.9	41.3	43.4	59.4	20.6	27.2	55.0	87.9	76.4	16.0	78.5	51.2	76.3		**54.7**

Appendix AE2

Benthic macroinvertebrate raw counts (pooled for each site) and summary data for 18 bioassessment sites.

OBBN group	Family	SL234-38	SL234-07	SL234-01	SL234-36	SL234-47	SL234-16	SL234-44	SL234-25	SL234-23	SL234-19	SL234-12	SL234-49	SL234-11	SL234-05	SL234-13	SL234-09	SL234-26	SL234-17	Total_All	(Mandaville2002)
Coleoptera	Elmidae	174	63					1			38	37			5			1	73	392	4
	Psephenidae	9	1								1									11	4
	Noteridae	1				1			1	1										4	4
	Gyrinidae			1			1													2	4
	Hydrophilidae			1			1					1				1				4	5
	Dytiscidae				59		4			2		6				1		1		73	5
	Haliplidae					2							3	1		1				7	5
	Hydraenidae															1				1	4
Oligochaeta	UnkownOligochaeta		1	6	7	1	43		9			1	4		1		1		2	76	8
Decapoda	Cambaridae	1	3			1											3		6	14	6
Hemiptera	Corixidae					1													41	42	5
	Notonectidae						1													1	5
	Veliidae											3								3	5
Diptera	Chironomidae	64	80	12	1	57	147	50	105	10	74	93	30	4	99	47	58	50	75	105 6	7
	Tipulidae	4	1	1						1	4		3		2	1			2	19	3
	Empididae	1																		1	6
	Simuliidae		9		1			2	11		11	1	5		3					43	6
	Tabanidae		1	1	1	3		3	1	1	2		3		15		3			34	6
	Ceratopogonidae		1			5	8	1	6	6	5		3	4	5			4		48	6
	Stratiomyidae												1		1	1				3	7
Acarina	UnknownAcarina	2																		2	6
	Tetragnathidae		1						2										1	4	-
	Pisauridae											1								1	-
	UnknownDivingWasp								1											1	-
Megaloptera	Corydalidae	1																		1	0
	Sialidae		2								2									4	4

Ephemeroptera	Siphlonuridae	26					2					55			1				8	92	7
	Heptageniidae	2																	6	8	4
	Ephemeridae																		2	2	4
	Leptophlebiidae	1																	3	4	2
	Baetidae		111									1					5			117	4
	Caenidae					3														3	7
	UnknownEmphemeroptera	10									3								15	28	5
Pelecypoda	Sphaeriidae	9	4	184	2	70	15	115	117	87	40	1	56	51	84	128	31	65	21	1080	8
Anisoptera	Libellulidae					1									1		3			5	9
	Cordulegastridae							1			2	6								9	3
	Aeshnidae																		1	1	3
Hirudinea	Glossiphoniidae			2			2		4				5						1	14	8
	Erpobdellidae				1				2							2				5	8
Ceolenterates	UnknownCeolenterates														1					1	-
Tricoptera	Hydropsychidae	31	3								7	11							25	77	4
	Phryganeidae	1							1											2	4
	Psychomyiidae											6								6	2
	Helicopsychidae	5									1								1	7	3
	Polycentropodidae	1																		1	6
	Philopotamidae		27								5	51								83	3
	Brachycentridae			2					1								2			5	1
	Leptoceridae														2					2	4
	Lepidostomatidae																		1	1	1
	Glossosomatidae											5			1					6	0
	UnknownTricoptera										1							1		2	5
Lepidoptera	Crambidae	2						1	1			3			1	1			10	19	5
Isopoda	Asellidae			8	162	2		1		100		17	93	4	1	9	11		4	412	8
Plecoptera	Perlodidae	10	10		37			1	4	1	70	2				31	1		5	172	2
	Chloroperlidae															1	2			3	1
	Nemouridae		28								17							7		52	2
	Taeniopterygidae			7																7	2
	UnknownPlecoptera							1												1	1
Gastropoda	Lymnaeidae	1		22	11	8	1	3	8	10	10		18	39	10	17	26	23	3	210	6
	Planorbidae		2	17	6	92	11	27	7	27	20	1	37	170	25	18	23	62	1	546	7
	Physidae			40	8	8	23	3	21	13			24	20	2	9	9	18	3	201	8

	Hydrobiidae			6	5	2		85		2	13		2	7	5	23		108		258	7
Amphipoda	Gammaridae			2	16		58	9	29	21	1	5	17	4	1	31	133		30	357	4
	Abundance Total	356	348	312	317	257	317	304	331	282	327	307	304	304	266	323	311	340	340	5646	
	Richness FamilyCount	21	18	16	14	16	14	16	19	14	21	21	16	10	21	18	15	11	25	63	
	Index SimpsonsDiversity	0.71	0.80	0.63	0.69	0.75	0.73	0.75	0.76	0.76	0.87	0.83	0.84	0.64	0.75	0.79	0.76	0.80	0.87	0.89	
	Index FamilyBiotic	4.83	4.53	7.50	6.42	7.22	6.64	7.21	6.96	7.37	5.09	5.44	7.28	7.06	7.03	6.57	5.66	7.04	5.27	6.35	
	%EPT	24.4	51.4	2.9	11.7	1.2	0.6	0.7	1.8	0.4	31.8	42.7	0.0	0.0	1.5	9.9	3.2	2.4	19.4	12.1	
	%Coleoptera	51.7	18.4	0.6	18.6	1.2	1.9	0.3	0.3	1.1	11.9	14.3	1.0	0.3	1.9	1.2	0.0	0.6	21.5	8.7	
	%Isopoda	0.0	0.0	2.6	51.1	0.8	0.0	0.3	0.0	35.5	0.0	5.5	30.6	1.3	0.4	2.8	3.5	0.0	1.2	7.3	
	%Chironomidae	18.0	23.0	3.8	0.3	22.2	46.4	16.4	31.7	3.5	22.6	30.3	9.9	1.3	37.2	14.6	18.6	14.7	22.1	18.7	
	%PelecypodaGastropoda	2.8	1.7	86.2	10.1	70.0	15.8	76.6	46.2	49.3	25.4	0.7	45.1	94.4	47.4	60.4	28.6	81.2	8.2	40.6	
	%Other	3.1	5.5	3.8	8.2	4.7	35.3	5.6	19.9	10.3	8.3	6.5	13.5	2.6	11.7	11.1	46.0	1.2	27.6	12.5	

Appendix AE3

List of documented fish species within SLMP planning area. 1 = native; 2 = non-native to region.

Fish Species	Emily	McLaren	Martin North	Hawkers	Sturg Tribs	Rutherford	Mariposa	Stoney	East Cross	Jennings	Janetville	Scugog Tribs
Creek Chub[1]	x	x	x	x	x	x	x	x	x	x	x	x
White Sucker[1]	x	x	x	x	x	x	x	x	x	x	x	x
Brook Stickleback[1]	x	x	x	x	x	x	x	x	x	x	x	x
Bluegill[2]	x		x	x		x	x					x
Northern Pearl Dace[1]	x		x	x		x		x	x	x	x	x
Common Shiner[1]	x	x	x	x		x	x	x	x	x	x	x
Brassy Minnow[1]	x	x	x	x	x				x	x	x	
Northern Redbelly Dace[1]	x	x	x	x	x	x	x	x	x	x	x	x
Fathead Minnow[1]	x	x	x	x		x	x	x	x	x	x	x
Central Mudminnow[1]	x	x	x	x	x	x	x	x	x			x
Golden Shiner[1]						x	x	x	x			
Yellow Perch[1]	x	x				x	x	x	x	x		x
Blacknose Dace[1]		x	x	x	x	x	x	x	x	x	x	x
Longnose Dace[1]				x			x		x	x	x	
Largemouth Bass[2]	x	x				x	x		x			x
Rock Bass[2]	x	x		x			x	x	x	x		x
Pumpkinseed[1]	x	x	x				x	x	x	x	x	x
Log Perch[1]	x						x		x			x
Brook Trout[1]	x		x				x		x		x	
Bluntnose Minnow[1]		x		x			x		x	x		x
Finescale Dace[1]	x		x	x			x	x				
Smallmouth Bass[1]	x	x					x		x			
Mottled Sculpin[1]			x				x		x		x	
Brown Bullhead[1]	x	x					x	x	x			x
Walleye[2]	x	x							x			
Iowa Darter[1]		x					x	x		x		x
Striped Shiner[1]									x			x
Common Carp[2]		x					x		x			
Spottail Shiner[1]							x		x			
Johnny Darter[1]												x

Black Bullhead[1]								x				
Central Stoneroller[1]										x		x
Burbot[1]	x	x	x									
Spoonhead Sculpin[1]			x									
Muskellunge[1]	x	x					x		x			
TOTAL	**22**	**21**	**17**	**15**	**7**	**13**	**26**	**17**	**27**	**16**	**13**	**21**
OMNR Stream Survey (1975-76)	x	x	x	x	x	x	x	x	x	x	x	
Kawartha Conservation ORM Watershed Plans (2006-08)									x			
Kawartha Conservation SLMP (2012)	x	x	x	x		x						
Kawartha Conservation/CKL/DFO Drain Study (2002)		x					x	x	x	x		x
SSFCEfishing Training (2003-05)										x		x
OMNR ARA data (exported 2006)	x	x	x	x		x	x	x	x		x	

Appendix AE4

Fish captured at comparison sites.

	OMNR-EC-01		OMNR-EC-02		OMNR-EC-03		OMNR-HC-02		OMNR-HC-03		OMNR-MCN_02		OMNR-MCN_03	
	2012	1975	2012	1975	2012	1975	2012	1976	2012	1976	2012	1976	2012	1976
Rock Bass	x	x						x						
Yellow Perch	x	x				x								
Largemouth Bass	x	x		x		x								
Pumpkinseed	x	x												
Bluegill	x				x				x					
Log Perch	x													
Central Mudminnow			x				x	x	x		x		x	x
Brook Stickleback			x		x	x	x	x	x		x		x	
Creek Chub		x		x	x		x		x	x	x	x	x	x
White Sucker					x		x				x	x		
Northern Redbelly Dace						x	x	x	x	x	x		x	
Common Shiner				x	x		x		x	x	x			
Brassy Minnow				x	x		x		x	x				
Fathead Minnow						x	x		x	x				
Blacknose Dace							x				x		x	
Northern Pearl Dace					x	x	x			x			x	
Finescale Dace							x			x				
Bluntnose Minnow							x							
Golden Shiner														
Brook Silverside														
Smallmouth Bass		x												
Brook Trout												x	x	
Mottled Sculpin														x

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