Silver and Shadow Lakes Watershed Characterization Report 2018

KAWARTHA CONSERVATION

Discover · Protect · Restore

About Kawartha Conservation

Who we are

We are a watershed-based organization that uses planning, stewardship, science, and conservation lands management to protect and sustain outstanding water quality and quantity supported by healthy landscapes.

Why is watershed management important?

Abundant, clean water is the lifeblood of the Kawarthas. It is essential for our quality of life, health, and continued prosperity. It supplies our drinking water, maintains property values, sustains an agricultural industry, and contributes to a tourism-based economy that relies on recreational boating, fishing, and swimming. Our programs and services promote an integrated watershed approach that balance human, environmental, and economic needs.

The community we support

We focus our programs and services within the natural boundaries of the Kawartha watershed, which extend from Lake Scugog in the southwest and Pigeon Lake in the east, to Balsam Lake in the northwest and Crystal Lake in the northeast – a total of 2,563 square kilometers.

Our history and governance

In 1979, we were established by our municipal partners under the *Ontario Conservation Authorities Act*.

The natural boundaries of our watershed overlap the six municipalities that govern Kawartha Conservation through representation on our Board of Directors. Our municipal partners include the City of Kawartha Lakes, Region of Durham, Township of Scugog, Township of Brock, Municipality of Clarington, Municipality of Trent Lakes, and Township of Cavan Monaghan.

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We are particularly thankful for the information, input, and advice received from the following organizations that comprise the Science and Technical Committee.

Centre for Alternative Wastewater Treatment

Fleming College

Haliburton Kawartha Pine Ridge District Health Unit

Kawartha Lakes Fisheries Assessment Unit

Kawartha Lakes Stewards Association

Shadow Lake Association

Ontario Ministry of Environment and Climate Change

Ontario Ministry of Agriculture, Food, and Rural Affairs

Trent University

Lakehead University

University of Ontario Institute of Technology

Ontario Federation of Anglers and Hunters

Haliburton, Kawartha, and Pine Ridge District Health Unit

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Acronyms

CKL: City of Kawartha Lakes

CWQG: Canadian Water Quality Guideline

EC: Environment Canada

ELC: Ecological Land Classification

SHL: Shadow Lake

SLSP: Silver & Shadow Lakes Stewardship Plan

KLSA: Kawartha Lake Stewards Association

masl: Meters above sea level

OMNRF: Ontario Ministry of Natural Resources and Forestry

MOECC: Ontario Ministry of the Environment and Climate Change

PGMN: Provincial Groundwater Monitoring Network

PLMP: Pigeon Lake Management Plan

PWQMN: Provincial Water Quality Monitoring Network

PWQO: Provincial Water Quality Objectives

SLMP: Sturgeon Lake Management Plan

TKN: Total Kjeldahl Nitrogen

TN: Total Nitrogen

TP: Total Phosphorus

TSS: Total Suspended Solids

TSW: Trent Severn Waterway

WSC: Water Survey Canada

Executive Summary

The purpose of the Silver and Shadow Lakes Watershed Characterization Report is to provide a technical, comprehensive report on the current state of Shadow Lake and its subwatersheds that supports the development of a Silver and Shadow Lakes Stewardship Plan (SLSP). Emphasis has been placed on characterizing the immediate drainage area around Shadow Lake (including the lake itself). This area is referred to as the 'core planning area'. Information within the core planning area is presented within several themes including: introduction, socio-economics, land use, climate, water quantity, water quality, aquatic ecosystems, and terrestrial ecology. The following is a summary of the key observations, issues, and information gaps within each main theme. There is an identifiable gap of knowledge for Silver Lake which needs to be addressed in the future.

<u>Introduction</u>

The Shadow Lake watershed (including Silver Lake) occupies a small area (62.83km^2) located to the north east of Kawartha Conservation's jurisdiction within the municipality of the City of Kawartha Lakes. The study area for the Shadow Lake Management Plan is defined as the lowest portion of the Gull River watershed that starts at the Norland Dam and runs downstream to the dam in Coboconk and includes Silver Lake. The hydraulic regime is heavily influenced by the Gull River system and Shadow Lake is often referred to as a 'flow through' lake with a retention time of 12.5 days.

<u>Socio-economics</u>

The Silver and Shadow Lakes Watershed has an estimated year round population of approximately 200. Seasonal residents and visitors to this area increase greatly during the summer months adding increased pressure to the total watershed and a positive impact on the economy. There are many private businesses in the vicinity of the Silver and Shadow Lakes that support the tourism industry and water-based recreation. Boating and fishing accounted for 15% and 12%, respectively of the total person visits to the Kawartha Lakes Region. These businesses benefit from the recreation opportunities the lakes provide, and help re-circulate money into the local economy.

<u>Land Use</u>

The major human land use in the watershed is rural development, which dominates more than 63% of the land portion of the watershed. Development is focussed on the Shadow Lake shoreline areas. Roads occupy less than 1% of the watershed which provides opportunity for natural areas to occupy the landscape such as forests (33.9%) and wetlands (2.23%).

The Silver and Shadow Lakes watershed lies within a geological transition area between the Canadian Shield (a region characterized by relatively hard, Precambrian bedrock with bare or shallow soils), and the St. Lawrence Lowlands (a region characterized by relatively soft, sedimentary bedrock with shallow to deep soils). The study area includes three dominant physiographic landforms: Limestone Plains, Bare Rock Ridges and Shallow Till, and Spillways.

The Limestone Plains occupy the central and southern section of the planning area. This area is also referred to as Carden Alvar, and consists of mostly continuous sedimentary limestone bedrock having extremely shallow soils. Shadow Lake exists mostly within this region, and as such its underlying bedrock is limestone, which is evident when it surfaces along certain section of the shoreline. Limestone has high levels of calcium carbonate and as such is highly alkaline, which means that the lake is well buffered from acidification, a water quality stressor that has affected many lakes within the Canadian Shield that do not have buffering capacity. Soils within this area are relatively shallow and as such are more conducive to non-intensive agriculture (e.g., pasturelands).

Climate

The climate conditions of the Shadow Lake core planning area is classified as a moist continental mid-latitude climate (Dfb climate category) with warm to cool summers and cold winters, as categorized by the Köppen Climate Classification System. Climate conditions are currently projected to change as a result of the global climate change process, shifting towards warmer air and water temperatures, changes in precipitation patterns, and more frequent and severe storms events.

Water Quantity

Shadow Lake is a flow-through lake at the lower portion of the Gull River system, created by a natural constriction at the river’s channel (bedrock outcrop). Gull River, in turn, makes part of the Trent Severn Waterway. The Gull River flows through the rugged landscape of Canadian Shield in a southwesterly direction for more than 120 km before it enters Balsam Lake at Coboconk. Its watershed drains 1356 km^2 and includes 17 lakes controlled by 21 dams.

The northern, unregulated tributary (Site SHL2) of Shadow Lake that was studied for the purpose of the Shadow Lake Management Plan has exhibited natural flow regime with well-defined seasonal flow pattern. High flows occur in spring, associated with snowmelt, and throughout the year following high-volume precipitation events. Low flows are observed in the summer and winter months.

Shadow Lake, on average, receives 794.79 million m^3 of water inflow every year. The water inputs include; Shadow Lake Northwest subwatershed (1.2%), Shadow Lake North subwatershed (0.6%), Shadow Lake Northeast subwatershed (0.5%), Shadow Central (0.1%) and direct precipitation (0.7%). Water exits Shadow Lake & Silver Lake through the Coboconk outlet exiting into Balsam Lake.

Water Quality

Shadow Lake can be characterized as an oligotrophic (low productivity) water body with excellent water quality. Water quality concerns in the Shadow Lake watershed are negligible. All parameters studied have concentrations far below the corresponding PWQOs or CWQGs and do not currently present any threat to aquatic life or human health. The majority of phosphorus enters the lake during the spring, when elevated runoff caused by snowmelt and precipitation carries large quantities of nutrients into the lake. The Gull River contributes 95% of the total phosphorus input into the lake, local subwatersheds account for 4%, and Atmospheric deposition accounts for 1%. However, elevated phosphorus concentrations have been observed in hypolimnion (bottom) samples. Additionally, Shadow Lake has often experienced periods of time with very low dissolved oxygen concentrations in the hypolimnion.

The Haliburton, Kawartha, Pine Ridge District Health Unit beach posting data (due to elevated *E. coli* concentrations) shows that the public beach on Shadow Lake has been posted at least once per season during the monitoring years of 2011-2017.

Aquatic Ecosystems

Lake morphology is distinct between the two lakes. In Shadow Lake the north section contains most of the deepest areas (up to 22m) in the lake, while the south section contains a deep pocket (up to 20m). Most of the shoreline has relatively narrow and steep nearshore areas. In Silver Lake, the greatest depths (up to 16m) occur in the central, south-west section of the lake. The western nearshore areas are relatively narrow and steep while the eastern nearshore areas slope more gradually into the lake. Shallow nearshore areas (less than 3m) are relatively limited in both lakes, occupying only 2.8% of their surface area. There is limited data available regarding substrates on the lakebed, and aquatic plants.

Approximately 20 fish species have been documented within Shadow and Silver Lakes, many of which are important (e.g., walleye, smallmouth bass, muskellunge) in supporting a small recreational fishery. According to the most recent available data (2009), the fish community in Shadow Lake and Silver Lake consists of warm- and cool-water species dominated by yellow perch, smallmouth bass, rock bass, white sucker, walleye, bluegill, muskellunge, and cisco. Coldwater native coldwater fish species, including cisco, mottled sculpin, and trout-perch, have also been documented in the lake

Several key information gaps have been noted including: limited understanding of how stressors such as climate change, cumulative development and invasive species will impact the aquatic ecosystem, limited understanding of coldwater aquatic habitat and communities, very limited benthic community data within the subwatersheds due in large part to the remoteness of aquatic habitat within those areas.

Terrestrial Ecology

The area surrounding Shadow Lake contains large tracts of forests and some areas of wetlands, providing not only habitat for many species, but also helping to maintain good water quality through mitigating runoff, providing filtering and uptake of nutrients and solids, and creating connections between the lake and the natural areas to the north, particularly the unique features of the Land Between. The entire Shadow Lake watershed contains 50 km^2 of natural cover, representing 80% of the total terrestrial area. This includes only areas classified as forest, wetland, rock barren and open water. There is a further 6% cover found in meadows, thickets, woodlots and plantations.

A number of natural heritage features exist in the Shadow Lake watershed that may be considered locally significant; however they are not afforded any legislative protection. ANSI's and Provincially Significant Wetlands are the only areas that are afforded protection due to their provincial significance, yet none are identified in the Shadow Lake Watershed. There are a number of other natural heritage features that are important locally that have not yet been identified or set aside for protection.

The entire Shadow Lake watershed is currently 33% higher than the target of 30% forest cover for Areas of Concern watersheds within the great lakes basin (Environment Canada, 2004), and Shadow Lake is 28% higher than the Conservation Ontario target (Conservation Ontario, 2011) of 35% forest cover for watersheds in Ontario. No watershed in the Shadow Lake study area falls below 60% forest cover.

Eight Species at Risk have been identified in the Shadow Lake study area and include the Blandings Turtle, Butternut, Common Five-lined Skink, Eastern Hog-nosed Snake, Eastern Meadowlark, Milk Snake, Rusty-patched Bumble Bee, and Snapping Turtle. Of the eight species, two are dependent on the lake and/or its tributaries for survival; the Blanding's and Snapping Turtles.

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1.0 Introduction

1.1 Project History

Shadow Lake is located just north of the town of Coboconk to the east of Norland, Ontario within the municipality of the City of Kawartha Lakes (Ward 3). Similar to other local lakes, for the most of the 20th century, the lake serves as a vacation destination for residents of the southern Ontario and Greater Toronto Area (GTA). Over time, more and more people converted their seasonal cottages into year-round homes. To create the framework for the future management of Shadow and Silver Lakes, including best management practice recommendations, the City of Kawartha Lakes (CKL) initiated the development of the Silver and Shadow Lakes Stewardship Plan (SLSP) as a continuation of the Kawartha watershed-wide lake management initiative. The first phase of watershed-wide Lake Management Planning in the City of Kawartha Lakes was initiated in 2010. During that year, 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, commenced the Sturgeon Lake Management Plan (SLMP). This plan was completed in 2014. In 2011, the Balsam and Cameron Lake Management Plan was started and completed in 2015. The Pigeon Lake Management Plan (PLMP) followed and was initiated in 2012 and has been completed, but final approval is currently stalled until First Nations Consultations have been completed. The Four Mile Lake plan was completed in 2016 and in the finalizing steps of being approved by the Board of Directors and then the City of Kawartha Lakes Council.

The Watershed Characterization Report is an overview of the current state of the aquatic and terrestrial ecosystems within the Shadow Lake core planning area. The core planning area includes all of the subwatersheds that drain directly into Shadow Lake. This report includes information on geology and physiography, climate and hydrology, terrestrial and aquatic ecology of the watershed, land use and economic activities within the watershed, as well as characterization of the current water quality in the lake and its' receiving tributaries. It provides the findings from our scientific research and environmental monitoring for the three-year period from June 2014 to June 2017. Additionally, it includes information and data from previous studies dating back to the 1980s and early 2000s.

The information gathered will help to further understand the issues and stressors impacting the lake, provide an overview of watershed health, to ultimately inform the Shadow Lake Stewardship Plan in terms of developing effective recommendations for protecting and enhancing lake health.

1.2 Study Area

The Shadow Lake watershed (including Silver Lake) occupies a small area (62.83km^2) located to the north east of Kawartha Conservation's jurisdiction within the municipality of the City of Kawartha Lakes. The study area for the Shadow Lake Management Plan is defined as the lowest portion of the Gull River watershed that starts at the Norland Dam and runs downstream to the dam in Coboconk and includes Silver Lake. The major human land use in the watershed is rural development, which dominates more than 63% of the land portion of the watershed. Development is focused on the Shadow Lake shoreline areas. Roads occupy less than 1% of the watershed which provides opportunity for natural areas to occupy the landscape such as forests (33.9%) and wetlands (2.23%).

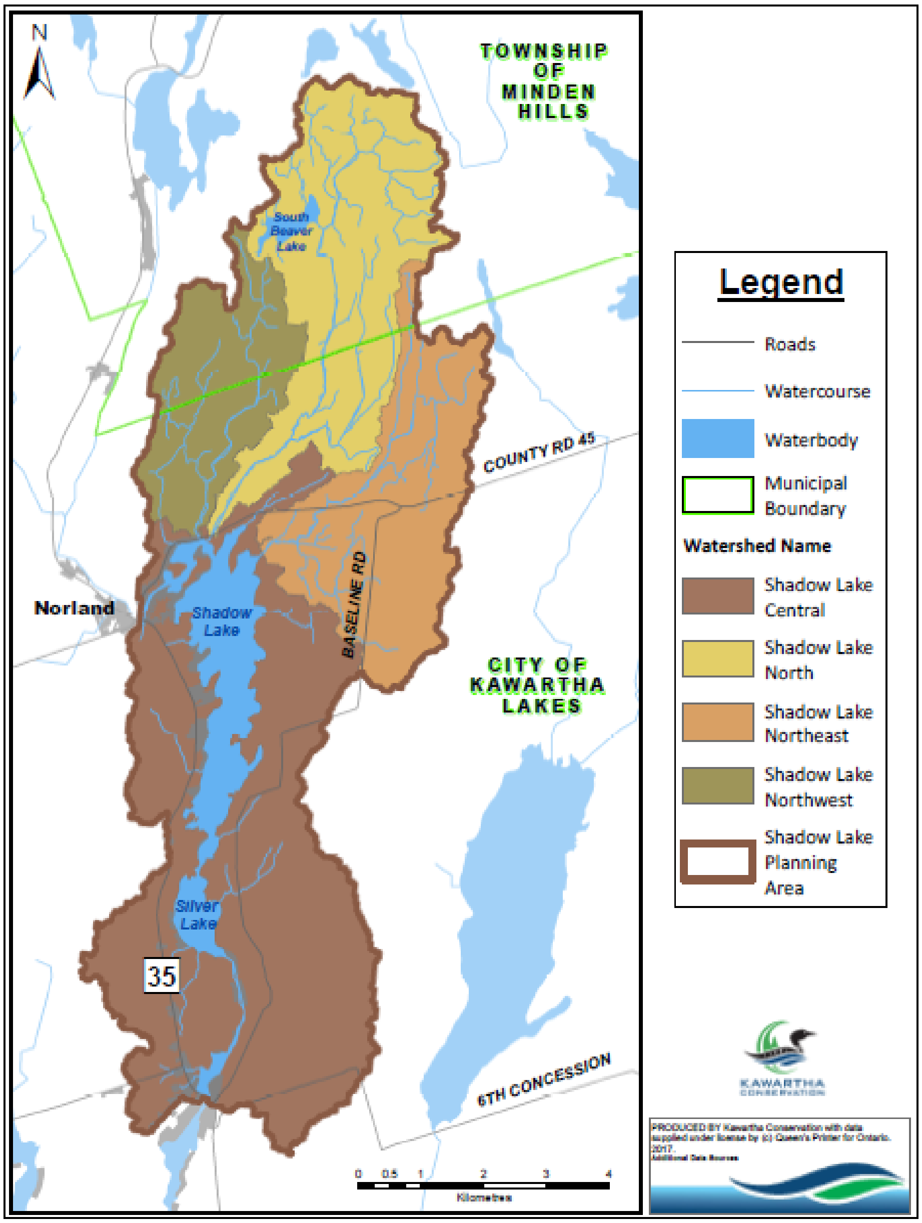


Figure 1.1. Silver and Shadow Lakes Stewardship Plan Study Area.

The Shadow Lake planning area is located within the highly variable transition zone between Paleozoic and Precambrian bedrocks. Northern part of the study area (Shadow Lake Northwest, Shadow Lake North and Shadow Lake Northeast sub-watersheds) is composed of rock ridges and shallow tills, while southern portion is characterized by limestone plateau. Watercourses running through the study area are small, no longer that 10.6 km; their drainage areas are covered with wetlands and forests. Natural cover at the sub-watersheds varies from the 74% within the Shadow Lake Central sub-watershed to 95% for the Northwest sub-watershed. Numerous small lakes are located within the study area, especially at its northern portion. Only two of them are named: South Beaver Lake and Spar Lake **(Figure 1.1).** There are data gaps for the Silver Lake subwatershed.

The overall characteristics of the Shadow Lake study area and its subwatersheds, including Shadow Lake are shown in **Table 1.1**.

Table 1.1. Shadow Lake Subwatershed Characteristics.

Subwatershed	Area (km^2)	Total Stream Network (km)	Natural Cover (%)	Agriculture (%)	Rural / Urban Development (%)
Shadow Lake Northeast	11.06	23.32	85.0	10.1	0.81
Shadow Lake North	13.27	38.56	89.5	1.53	1.56
Shadow Lake Northwest	7.21	17.31	95.0	2.06	0.34
Shadow Lake Central	27.05	19.63	74.2	8.79	9.7

2.1 History

Prior to European settlement, the Shadow Lake area was settled by First Nation Peoples. In the past three different First Nation communities were present in the region: the Huron, the Iroquois and the Mississaugas (**Kirkconnel, 1921)**. The Huron peoples were believed to first occupy the Shadow Lake region through much of the 1400s and 1500s and participated in agriculture **(LeCraw, 1967)**. In the late 1500s and 1600s the Iroquois First Nation entered the region from what is now New York State and war ensued between the Iroquois and Huron **(LeCraw, 1967)**. Jesuit priests were present in this area in the late 1500s and reported two Huron groups present near Shadow Lake named the Rock and the Deer people (**LeCraw, 1967**). With the attack from the Iroquois, the Rock and Deer people fled the region in 1590 and 1610 respectively to join up with other indigenous peoples at nearby Lake Simcoe in defense against the Iroquois **(LeCraw, 1967)**. The Iroquois overtook the Huron First Nations between 1649 and 1650 and retreated southeast, leaving the Shadow Lake Region absent of First Nations for over 100 years **(LeCraw, 1967)**.

In the early 1700s, the Mississauga First Nations living in the Sault St. Marie area sent people south to fight the Iroquois but had little success **(LeCraw, 1967).** In 1740 the Algonquin council of war was formed and larger scale attacks on the Iroquois ensued with significant battles just outside of Coboconk (to the south of Shadow Lake), and at Indian Point (north of Balsam Lake) **(LeCraw, 1967)**. The Mississauga First Nation proved victorious and settled in the Shadow Lake region.

Samuel de Champlain was the first European to explore the Kawarthas in 1615 **(Kirkconnel, 1921).** Shortly after the British took over control of Canada in 1790, the former area of Victoria County was sold to the British from the Mississauga First Nation in 1818 in Port Hope **(LeCraw, 1967).** Also during this time, the British government sent out survey parties throughout southern/central Ontario with the intention of findings a safe passage from Ottawa to Georgian Bay that was south of the French River. The large scale survey efforts were spurred by numerous threats to the south at this time including the American Revolution, the War of 1812, and the Oregon Boundary Dispute **(LeCraw, 1967)**. In 1819 Lt. J. P. Catty and a party of surveyors left Lake Simcoe and found Balsam Lake, where they travelled north along the Gull River to find Shadow Lake **(LeCraw, 1967)**.

The town of Coboconk, south of Shadow Lake, was settled in 1852 and extensive logging took place in the Shadow Lake region at this time **(LeCraw, 1967).** Shortly after in 1859 a road was constructed to connect Coboconk to Fenelon Falls (at the time known as *Cameron Falls*), and in 1872 the Toronto and Nipissing Railway was continued to Coboconk which allowed easy transportation of mail and goods into the town (the railway was later removed in 1965 and highways became the main mode of transportation in and out of Coboconk) **(LeCraw, 1967).** In 1873 the Rosedale Lock (now referred to as lock 35 on the Trent-Severn Waterway) was constructed between Balsam and Cameron Lakes which allowed boats to enter into Coboconk from Balsam Lake in the south.

The first mill in Norland (just upstream of Shadow Lake) was built in 1858, though squatters may have been present near the Gull River's inlet into Shadow Lake as early as 1855 **(LeCraw, 1967).** In the later part of the 1800s a number of dams and timber slides were built along the Gull River to assist with the transportation of logs downstream **(LeCraw, 1967)**. Two dams were constructed on the Gull River upstream of Shadow Lake (Moore Lake Dam (aka Elliot Falls), and the Norland Dam), and the Coboconk Dam was built on the Gull River just downstream (south) of Shadow and Silver Lakes. In 1903 the Moore Lake Dam (Elliot Falls) became a hydroelectric dam that supplied electricity to Norland, Kirkfield, and to Raven Lake **(LeCraw, 1967).** Today, little logging occurs in the Shadow Lake region and the dams serve to store water in the lakes, mitigate flooding, and allowing boat traffic to transverse the Gull river.

Shadow Lake has gone by several names in the past. It is believed that Shadow Lake was originally named Inaskingiquash by First Nation peoples in the area, and was named Lac Des Isles by early French settlers in the area **(LeCraw, 1967).** In the late 1800s what is now Shadow Lake was once known as Mud Turtle Lake due to the large number of Mud Turtles in the lake, but was later named Shadow Lake between the 1920s to the 1940s to improve the image of the lake to tourists. Furthermore, Shadow Lake has been part of multiple municipalities. Prior to the amalgamation of the City of Kawartha Lakes in 2001, where Shadow Lake is currently located, Shadow Lake bordered the townships of Somerville (to the west), Bexley (to the southeast), and Laxton (to the northeast), and was entirely in Victoria County.

2.0 Physiography/Land Use

2.1 Key Observation/Issues

- ***Overburden thickness surrounding the lake is generally <10m and bedrock both north and south of the lake is highly fractured.*** Thin overburden and bedrock fracturing causes bedrock aquifers around the lake to be highly vulnerable to contamination, and contaminates may enter Shadow Lake quickly through this fracture network
- ***Most of the development in the Shadow Lake region is along the shoreline of the lake or along the Gull River upstream of Shadow Lake (i.e. Norland).*** Development close to the lake may be an issue for pollution from septic systems, gas/chemical spills etc. and sediment loading from poor construction practices
- ***Shadow Lake transverses the boundary between the Canadian Shield to the north and the St. Lawrence Lowlands to the south.*** The limestone bedrock underlying the southern portion of the lake gives Shadow Lake a greater buffering capacity to acid rain than other lakes in the Canadian Shield
- ***There may be uranium deposits below the southern portion of Shadow Lake.*** Uranium present in rocks may present issues for tailings contamination in future or current aggregate mining in the Shadow Lake region

Infomration Gaps

- ***Investigations may be needed to determine the concentrations of uranium in the bedrock surrounding Shadow Lake and if any threats exist***
- ***More detailed investigations of bedrock conductivity will be need to help identify the speed of contaminant transport into the lake***

2.2 Land Use

Only two small villages are located near Shadow Lake, Norland (pop. 600) is situated northwest of Shadow Lake near Gull River's outlet into the lake, and Coboconk (pop. 800) is located just south of Silver Lake on the Gull River downstream of the lake **(Figure 2.1).** The Shadow Lake region has little mining, agricultural, or forestry activities, and the area contains a high proportion of natural forests, wetlands, and open rock barrens **(Figure 2.2)**. Population densities surrounding the villages are low, though the shoreline of Shadow Lake is host to 600 homes and cottages, with home density the highest on the western side of the lake. Of these 600 waterfront houses, approximately 100 houses are for permanent residence (with a population of approximately 200 residents), while 5/6 of these homes are seasonal cottages. With the total shoreline of Shadow and Silver Lakes equaling 22 km (Gartner Lee, 2002), the building density around Shadow and Silver Lakes is approximately 27 buildings/km.

Within 100 m of the Shadow Lake shoreline, urban/rural development makes up almost half of the land-use (45%) almost equally that of forests within 100 m of the shore (47%) **(Table 2.1).** However, when extended to 1000 m from the shoreline, urban/rural development only constitutes 10% of the land use with forests occupying 60% of the area. Within 1000 m of the shore other notable land uses include agriculture (11%), wetlands (5%), and meadows (4%).

Table 2.1. Land use at 100 and 1000 meters from the shoreline of Shadow Lake within the Shadow Lake Planning area. Note that 'development' includes both roads and buildings.

Land Use	100m from shoreline (%)	1000m from shoreline (%)
Rural/Urban Development	52.2	9.7
Forest	42.1	72.0
Agriculture	0.7	7.6
Wetland	2.0	3.6
Meadow	0.6	2.5
Open Water	2.3	4.7

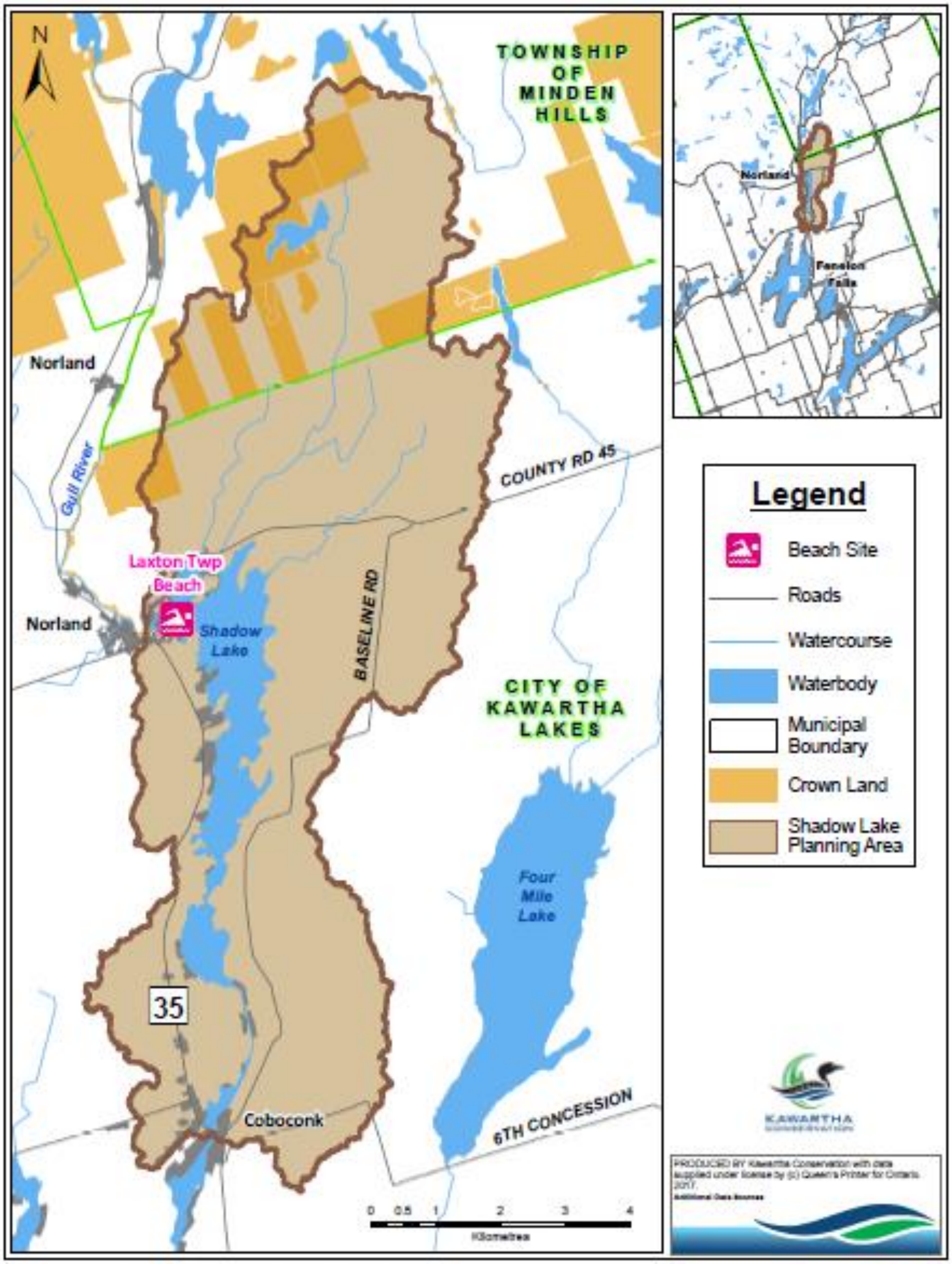


Figure 2.1. Map of Shadow Lake study area.

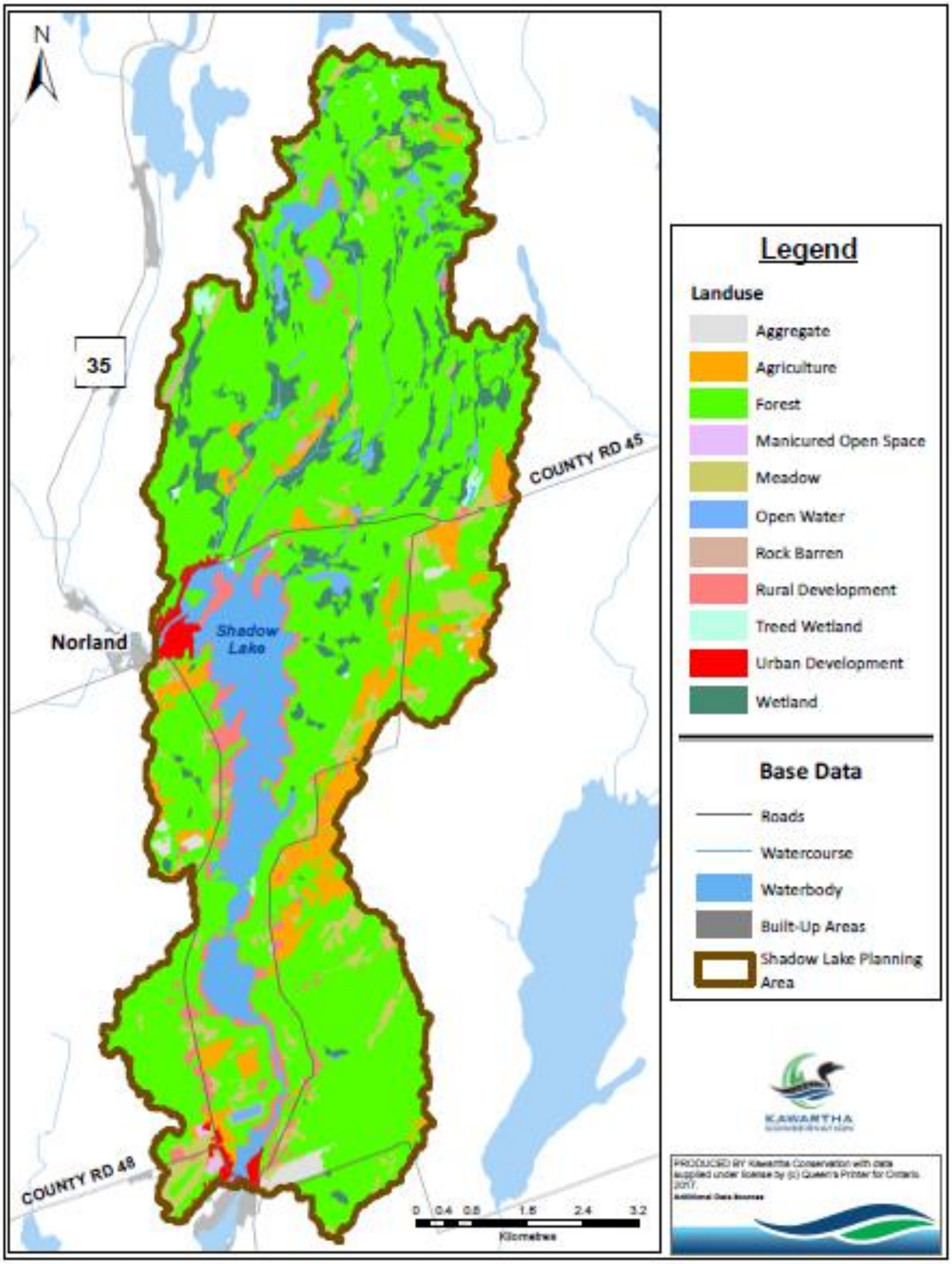


Figure 2.2. Map of natural heritage features in the Shadow Lake planning area.

The Shadow Lake Planning Area consists of four named subwatershed as follows: SL Central, SL North, SL Northeast, and SL Northwest as shown on **Figure 2.3.** Of these sub-watersheds, SL central is predominately underlain by Paleozoic limestone (below the Carden Plain), SL Northeast is underlain by an approximately equal combinations of the Canadian Shield and Paleozoic limestone, while SL North and SL Northwest are entirely within the Canadian Shield **(Figures 2.2 & 2.3)**. All four of these sub-watersheds are heavily forested with >65% forest cover, however there are some noticeable differences in the other land-use categories **(Table 2.2)**. As SL Central envelopes Shadow and Silver Lake it has a considerably greater proportion of development and roads (13.5%) than any of the other sub-watershed, where development/roads constitutes <3% of the land area. Agriculture is not prevalent in any sub-watersheds, though what agriculture does exist in the Shadow Lake Planning Area is generally constrained to the Carden Plain physiographic zone in the SL Central and SL Northeast watersheds (making up 9% and 10% of the total land area), with the SL North and SL Northeast watersheds having <3% agriculture **(Figures 2.2, 2.3, 2.4).** In the planning area, natural meadows are found mostly in the Carden Plain portion of the SL Central and SL Northeast watersheds (comprising 7% of the land in both sub-watersheds), whereas the proportion of both forests and wetlands are higher in the Canadian Shield-dominated SL North and SL Northwest watersheds **(Figures 2.2, 2.3, 2.4)**.

There are four aggregate operations in the Shadow Lake Planning Area, all of them located in the SL Central sub-watershed. Three of the quarries are clustered closely together west of Shadow Lake, and all on Otter Lane. These three quarries are operated by:

1. Central Ontario Northern Stone (Batty Quarry), where limestone is extracted for the production of flagstones
2. W.G. Jackett and Sons Construction Limited, which has an aggregate yard that produces sand and gravel for construction
3. James Chynoweth Trucking & Natural Stone which provides stones to landscapers.

The final quarry is located just east of Coboconk and is owned by Cedarhurst Quarries & Crushing Limited which provides aggregates for construction and landscaping companies. However, aggregates combined make up <1% of the total Shadow Lake Planning Area **(Table 2.2).**

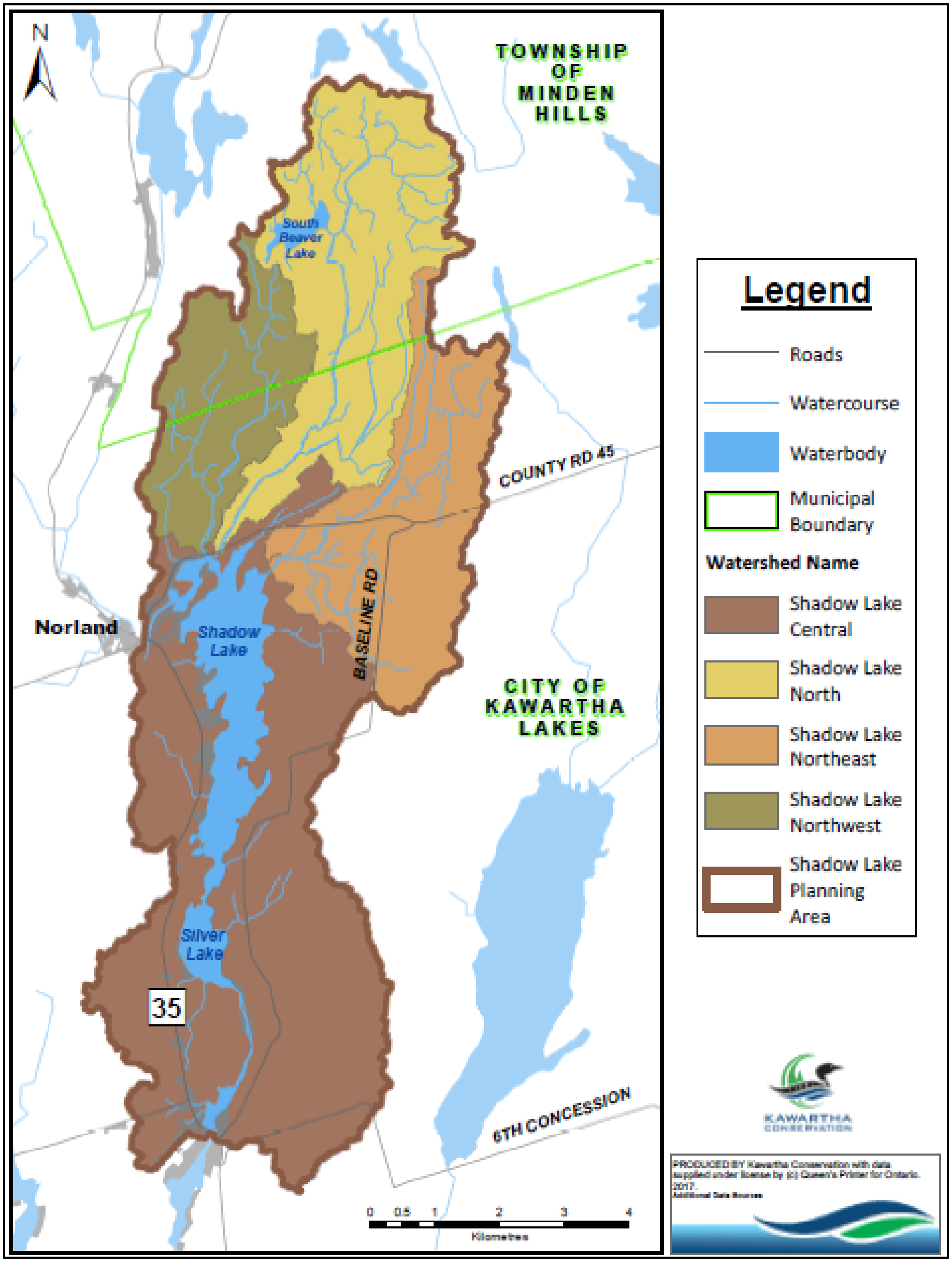


Figure 2.3. Subwatersheds included in the Shadow Lake planning area.

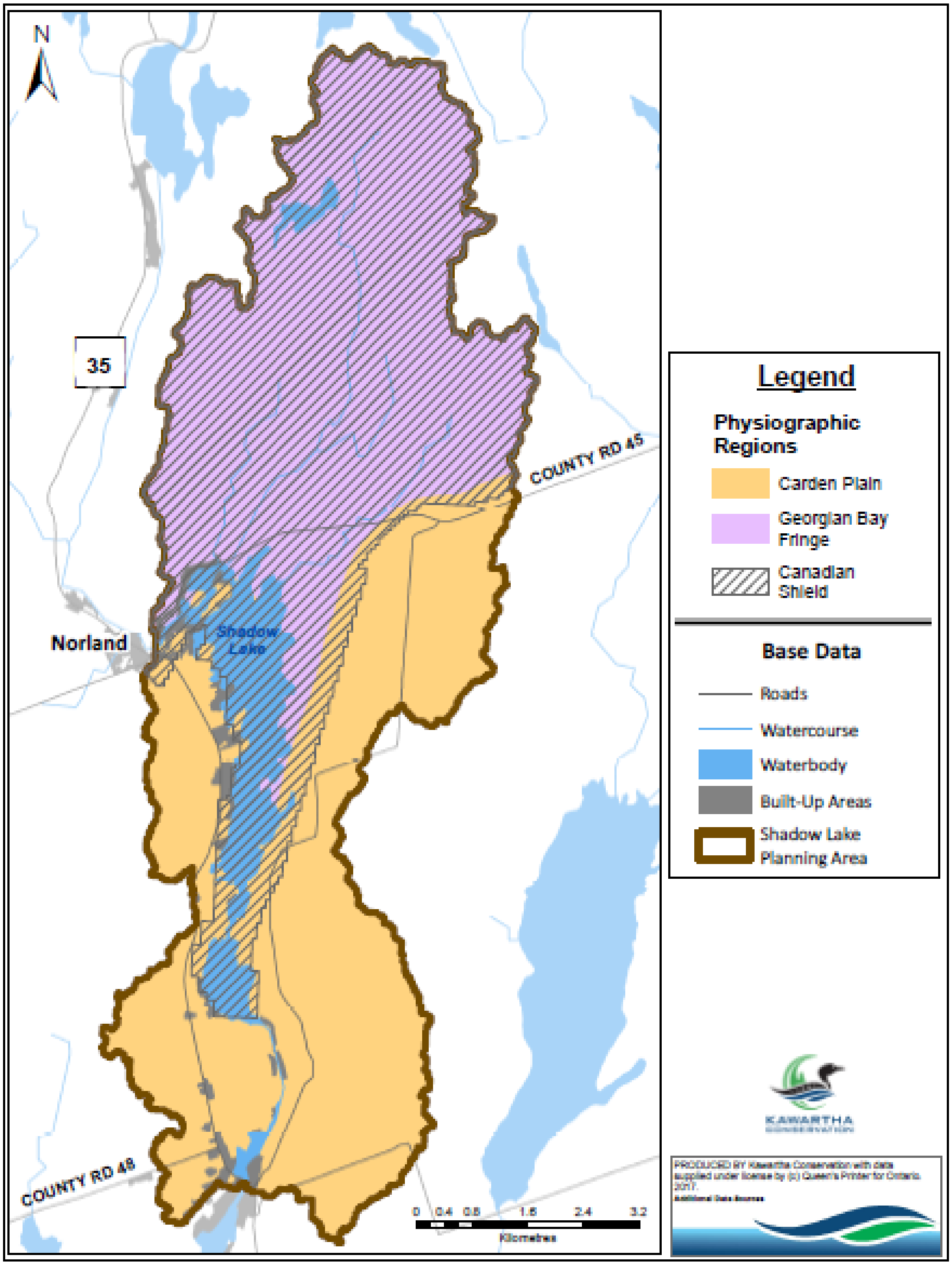


Figure 2.4. Physiographic regions of the Shadow Lake planning area.

Table 2.2. Land-use by sub-watershed in the Shadow Lake Planning Area. Note that 'development' includes both roads and buildings. Refer to Figure 2.3 for sub-watershed locations.

	Sub-watershed Name			
Land Use	**SL Central**	**SL North**	**SL Northeast**	**SL Northwest**
Aggregate	1.4	0.0	0.0	0.6
Agriculture	8.8	1.5	2.1	10.2
Development	13.5	3.0	0.4	2.4
Forest	65.3	73.5	76.5	67.2
Meadow	7.2	3.2	1.3	6.9
Open Water	2.2	5.4	2.1	2.0
Rock Barren	0.0	0.6	1.2	0.3
Wetland	1.3	12.9	16.5	10.4

2.3 Geology and Soils

Shadow Lake traverses the transition zone between older Precambrian bedrock of the Canadian Shield to the north and younger Paleozoic limestone bedrock to the south **(Figure 2.4)**. Within the Canadian Shield to the North of Shadow Lake, Precambrian bedrock transverses both the Central Gneiss Belt (GGB) on the northwestern portion of the planning area and the Central Metasedimentary Belt (CMB) on the northeastern side of the planning area (**Ontario Geological Survey, 2000**). Bedrock in both the CGB and CMB are highly metamorphosed as a result of the Grenville Orogeny (which took place between approximately 0.98 to 1.19 billion years ago), with the CGB consisting of mostly metavolcanic rocks, while the CMB is a combination of both clastic metasedimentary rocks and metavolcanic rocks (**Rivers, 1997**).

Furthermore, the northern portion of the lake is contained within the Georgian Bay Fringe physiographic zone which continues west to Georgian Bay and then north to Parry Sound **(Chapman and Putnam, 1984) (Figure 2.4)**. The Georgian Bay Fringe is characterized by thin soils, and numerous bedrock ridges with intervening valleys and depressions that run approximately NNE-SSW in the vicinity of Shadow Lake **(Figure 2.5)**, and is highly fractured as a result of glacial activity and pre/post glacial erosion **(Easton, 1992).** Fractures tend to be largest within 30m of the surface, providing a suitable bedrock aquifer for residents in the area **(Ontario Geological Survey, 2000)**. The landscape of the Georgian Bay Fringe is a mosaic of exposed bedrock and shallow overburden generally less than 5m thick, as much of the sediment was scraped away from this region during the Pleistocene glaciations **(Chapman and Putnam, 1984) (Figure 2.6).** Overburden thickness tends to be deepest in valleys and depressions and thinner or absent on the bedrock ridges. Much of the existing mineral soil in the region has been deposited from glacial outwash and morainic deposits. Soils north of Shadow Lake tend to have a high silt and clay content and low infiltration rates/permeability, and numerous patchy wetlands occupy many of the depressions/valleys north of Shadow Lake resulting in a large proportion of surficial organic soils **(Figures 2.2, 2.7).** Soils north of Shadow Lake tend to be nutrient poor and acidic. Due to thin and nutrient poor soils, little agriculture is possible in the Georgian Bay Fringe **(Kawartha Conservation, 2008a)**.

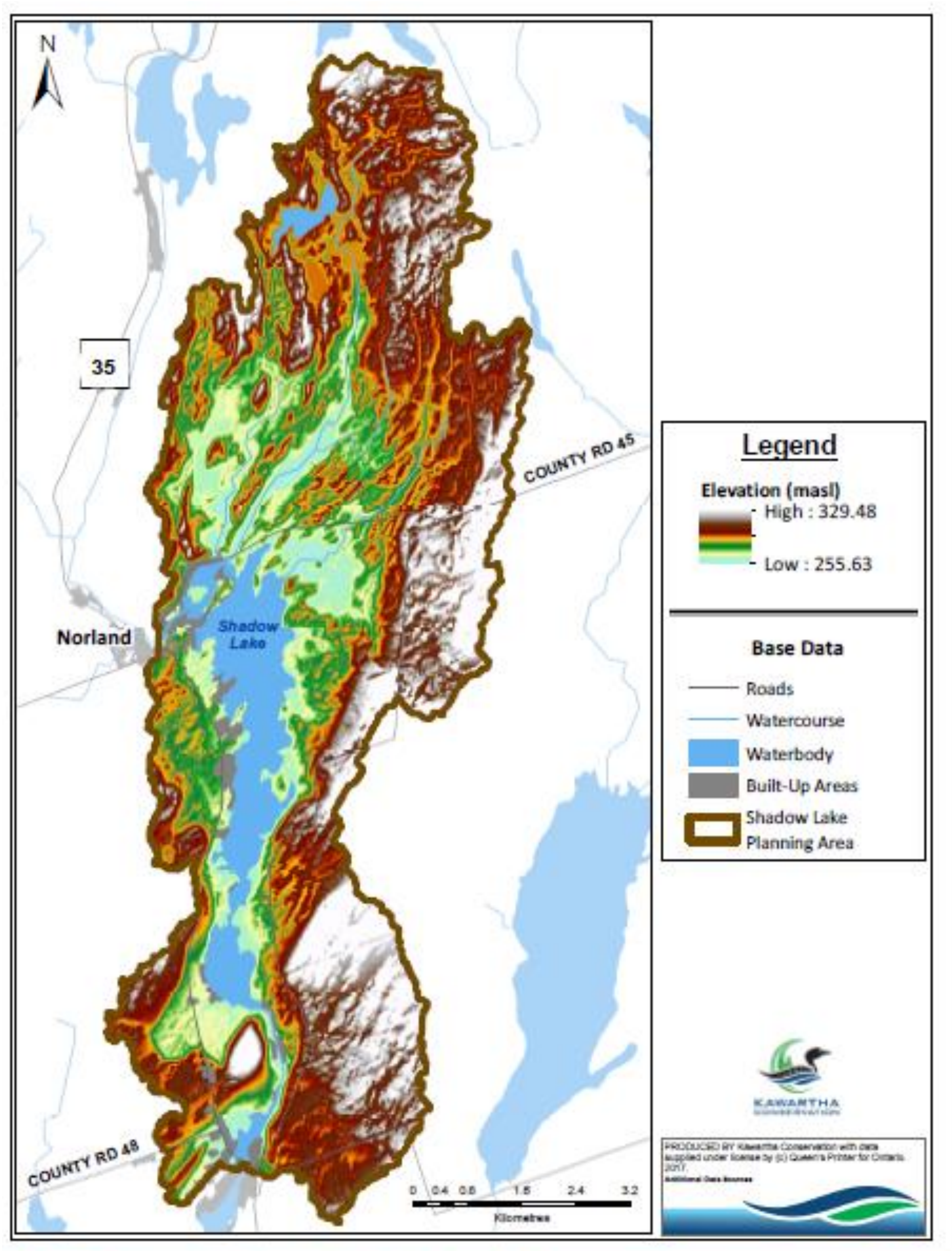


Figure 2.5. Elevations within the Shadow Lake planning area.

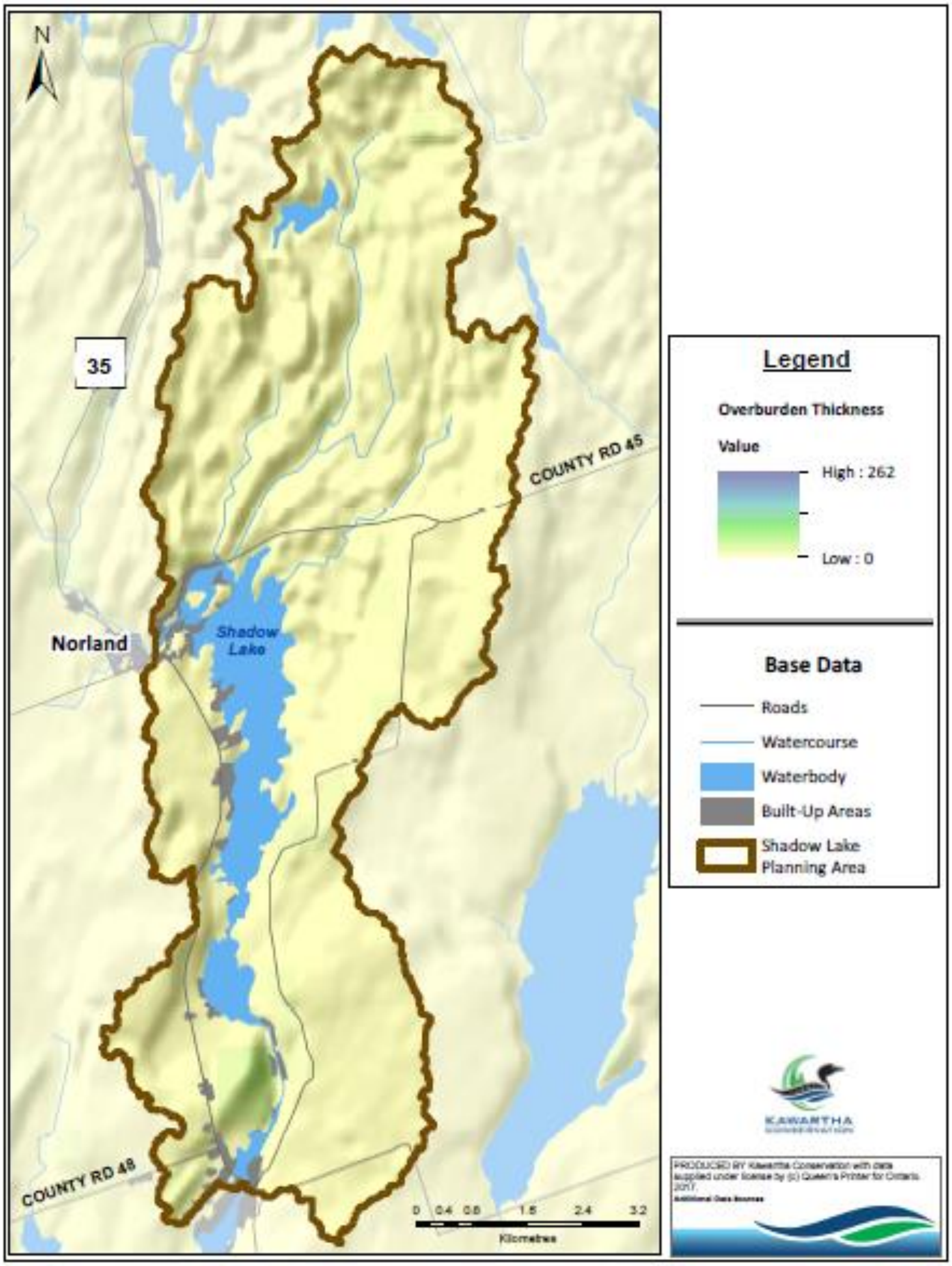


Figure 2.6. Overburden thickness values for the Shadow Lake planning area.

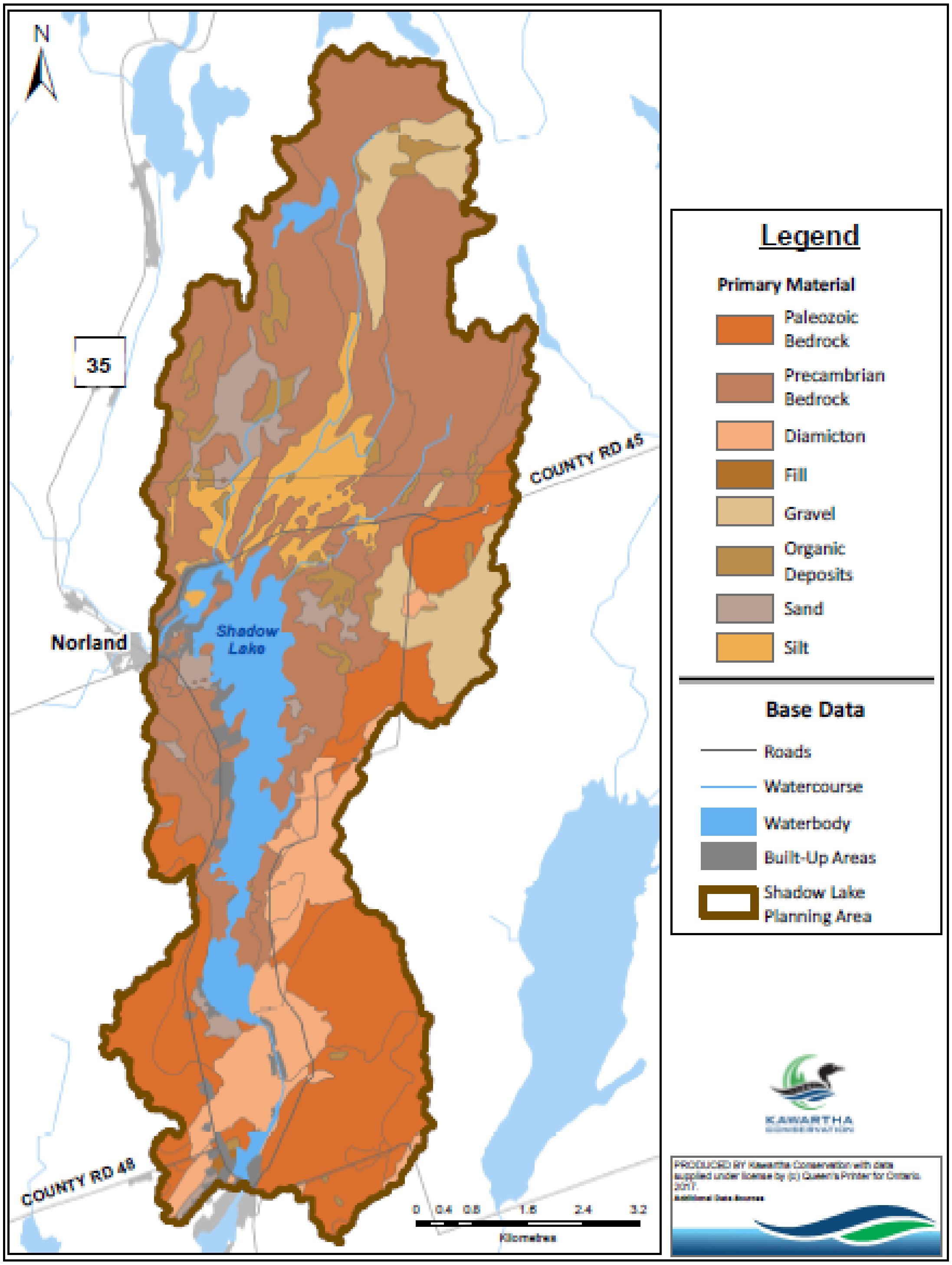


Figure 2.7. Sedimentary parental composition within the Shadow Lake planning area.

The southern portion of Shadow Lake is underlain by Paleozoic limestones of the Simcoe Group and is Middle-Ordovician in age **(Johnson et al., 1992).** Within the Simcoe group, the Gull River Formation underlies most of the southern portion of Shadow Lake, while the Bobcaygeon Formation is located south of the Gull River Formation in the southern reaches of the Shadow Lake Planning Area. The Gull River Formation is composed of layers of fine to medium grained limestones and shales **(Johnson et al., 1992)**. The Paleozoic bedrock of the Gull Formation ranges between 7 to over 100 metres in depth and thins to the north as it approaches the transition zone with the Canadian Shield **(Ontario Geological Survey, 2000; Morrison Environmental, 2004).** As a result of the fracturing, the Gull Formation allows for the storage and the rapid infiltration and movement of groundwater. The Bobcaygeon Formation generally consists of fine grain, heavily bioturbated limestone beds with occasional shale interbedding, and minimal fracturing **(Ontario Geological Survey, 2000).** Furthermore, rock sampling next to Moore and South Beaver Lakes suggest that there are localized uranium deposits (in the form of (U_3O_8)) near Shadow Lake **(Lundberg Explorations Ltd., 1955**). Radiation surveying overtop of Shadow Lake suggest that there may be significant uranium concentrations in the southern portion of the lake **(Wilson, 1955).**

The Paleozoic bedrock on the southern portion of Shadow Lake Planning Area is contained within the Carden Plain physiographic zone which is a limestone plain that stretches from the northern portion of the Kawartha Lakes to Lake Couchiching (north of Lake Simcoe) **(Chapman and Putnam, 1984) (Figure 2.4).** Soils overlying the limestone plateau of the Carden Plain are generally thin (<10m thick) **(Figure 2.6)** and are well drained ranging from silt loams to sandy loams **(Gillespie and Richards, 1957)**. Two major soil series exist on the Carden Plain near Shadow Lake; the Dummer Loam-Shallow Phase skirts the entire southern portion of the lake while a small region of the Otonabee Loam is located just east of the lake **(Figure 2.8).** The Dummer Loam consists of stony, calcareous morainic deposits from the Dummer Moraine that stretch east toward the Frontenac region **(Gillespie et al., 1966) (Figure 2.8).** The soil here is coarse grained and poorly suited to agriculture as it is prone to drought conditions **(Gillespie and Richards, 1957; LSRCA map).** The Otonabee Loam is coarse grained till deposits ranging from loams to sandy loams, and are well drained conditions **(Gillespie and Richards, 1957).** Water retention is slightly greater and the overburden thickness is several meters thicker in the Otonabee Loam as compared to the Dummer Loam-Shallow Phase surrounding Shadow Lake, causing the Otonabee Loam to be a better substrate for agricultural purposes than the Dummer Loam **(Gillespie and Richards, 1957)**. While agriculture within the study area is generally limited, a small region southeast of Shadow Lake primarily in the Otonabee Loam is host to a number of agricultural fields **(Figures 2.2, 2.8).**

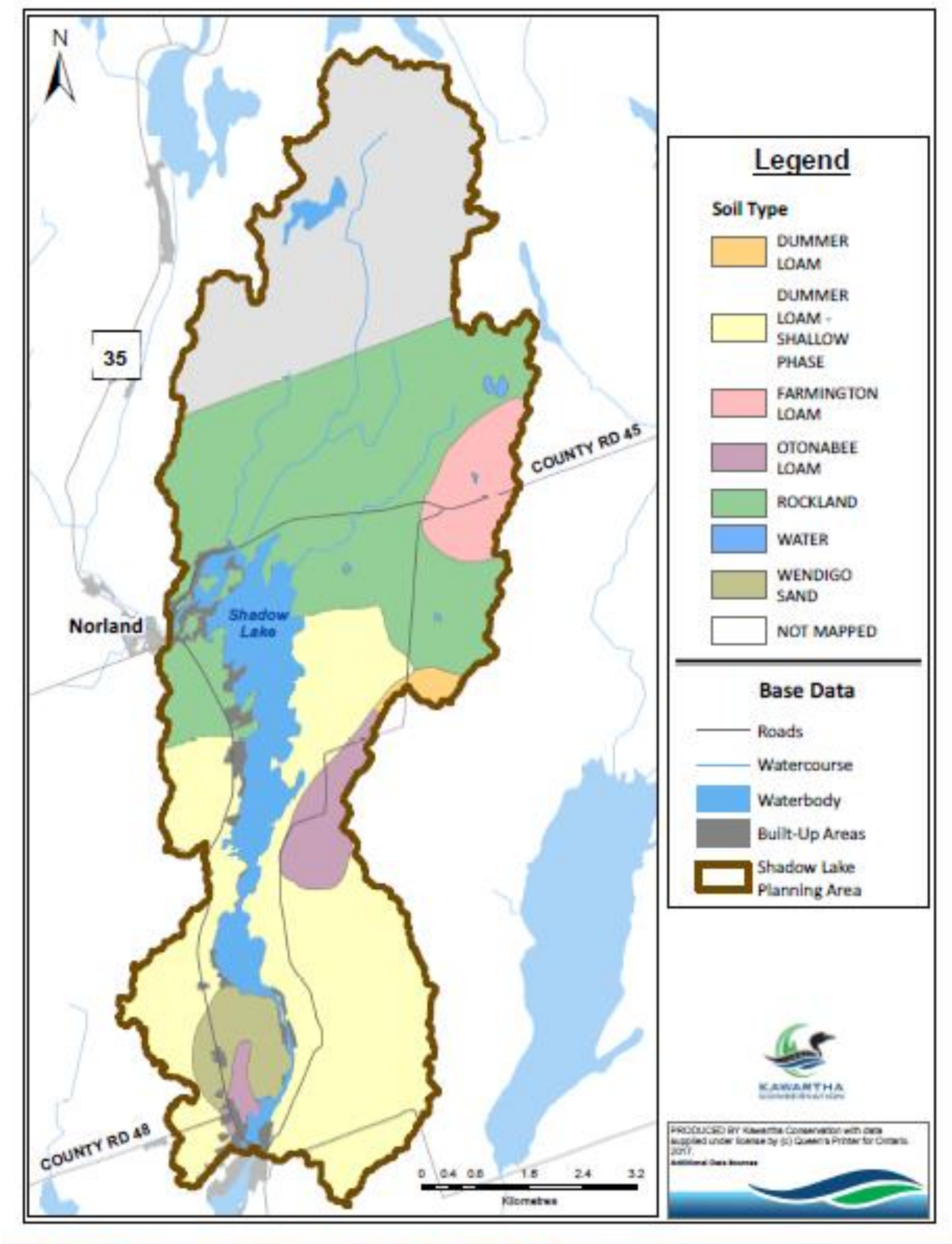


Figure 2.8. Soil composition within the Shadow Lake planning area.

Topography

The topography surrounding Shadow Lake is closely linked with the underlying geology. The northern portion of Shadow Lake planning area that is underlain by Precambrian bedrock is rugged and characterized by a series of bedrock ridges and valleys that run approximately NNE-SSW to the north of the lake **(Figure 2.5).** Forests and rock barrens are common on the bedrock ridges, while wetlands and ephemeral streams are common among the intervening valleys and depressions **(Figure 2.2).** In contrast to the land north of the lake, the Carden Plain, underlain by Paleozoic limestones, is relatively flat **(Figure 2.5).** The flatter topography to the south allows for some agriculture southeast of the lake, and natural areas tend to be forested with few wetlands due to the well-drained nature of the soils (Map 2-2). The total range in elevation for the Shadow Lake Planning Area ranges from 256 to 329 masl.

The Land Between Transition Zone

As a result of the contrasting geology and topography, the Georgian Bay Fringe (to the north of Shadow Lake) and the Carden Plain (to the south of Shadow Lake) are host to unique vegetation and ecosystem characteristics. The transition zone between the younger Paleozoic limestone bedrock in southern Ontario and the Canadian Shield to the north has been named the 'Land Between'. The Land Between in the Shadow Lake region contains elements of both the Georgian Bay Fringe and Carden Plain ecosystems, but also contains features that are unique to the transition zone itself as species ranges for flora and fauna in each ecosystem overlap **(Berman, 2008)**.

Relationship between Soil/Geology and hydrology

While the Gull River is the major inlet and outlet to Shadow Lake, the smaller tributaries of different stream orders also flow into the lake. Three tributaries with a stream order >2 enter the northern and northeastern shore of Shadow Lake **(Figure 2.9).** Those watercourses form base for three named subwatersheds defined within the Shadow Lake Planning: SL North, SL Northeast, and SL Northwest (**Figure 2.3).**

Based on facts that overburden deposits are generally very thin within the study area and the Precambrian bedrock comes close to the surface, we can make a conclusion that tributaries at Shadow Lake subwatershed are mainly surface-runoff fed. The groundwater component of their flow is limited and not always sustained. Flow measurements, conducted at the two tributaries that drain the northern portion of planning area, confirm this suggestion.

Measurements were conducted as part of the baseflow study for the Burnt and Gull River Watersheds Characterization Report (Kawartha Conservation, 2008b). Protocol requires that flow to be measured after an extended period of stable dry weather in order to estimate the groundwater input, as no surface runoff would be occurring by that time. Ultimately, the discharge measured at some point of the stream is expressed as volume of water per a square kilometer, representing amount of inflow from a watershed area unit (1 square kilometer) upstream of the location of measurement. Net discharge observed at northern tributary (SL North subwatershed, location GR-39) was 0.29 l/sec/ km^2. Similar measurement at the north-eastern tributary (SL Northeast watershed, location GR-40) revealed that the stream did not flow at that particular location. Subsequently, no groundwater was coming to the stream.

Furthermore, flow regime of northern tributary was studied by means of the permanent monitoring equipment installed at the location where stream inflows into the Shadow Lake. Details of the flow monitoring are available at Chapter 4. Data analysis revealed that the tributary has exhibited natural flow regime with well-defined seasonal flow pattern when changes in streamflow correlate very closely with precipitation and surface runoff. High flows were observed in spring (March-April), associated with snowmelt, and throughout the year following high-volume precipitation events. Low flows are observed in the summer and winter months. As 2016 was an extremely dry year, the tributary has minimal flow and even became dry for some time in July-August. This proves the conclusion that the Precambrian bedrock that is the underlays very shallow overburden deposits does not provide local watercourses within the study area with sustained groundwater inflow.

The southern portion of Shadow Lake planning area, which situated within the Garden Plain physiographic region, has much flatter topography and fewer permanent watercourses. There are no larger water courses with a stream order >2 that enter the southern portion of Shadow Lake **(Figure 2.9)**.

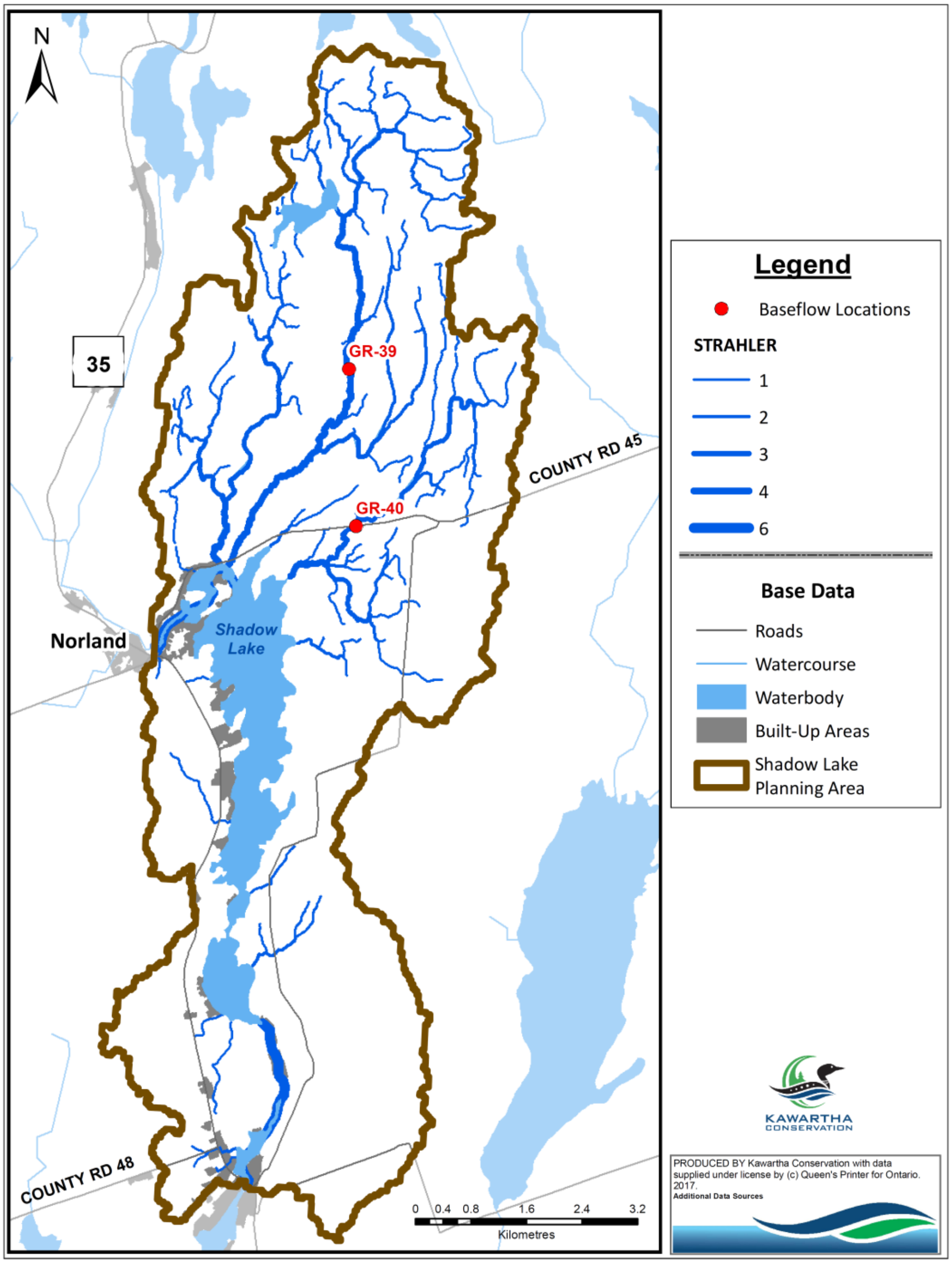


Figure 2.9. Map of various stream orders and baseflow measurement locations within the Shadow Lake Planning area.

Due to the thin overburden and highly fractured nature of the near surface bedrock surrounding Shadow Lake, groundwater inputs to Shadow Lake are suspected to come primarily from these fractured bedrock aquifers. While it is unknown how the magnitude of groundwater inputs into the lake compares with surface water inputs, surface water temperatures of the Gull River both north and south of Shadow Lake, and of the nearby Burnt River and Corben Creek, indicate that major water courses in the Land Between tend to be warm and therefore likely dominated by surface water contributions. Furthermore, Shadow Lake itself is considered a 'warm' lake, indicating that surface water may be the primary water inputs into the lake **(Figure 2.10)**. With that said, the combination of thin or absent overburden combined with highly fractured near surface bedrock may allow rapid recharge and flow in the bedrock aquifers surrounding Shadow Lake, and groundwater inputs may be a significant fraction of the Shadow Lake water budget. Groundwater recharge rates may be particularly high in the Carden Plain, where soils have higher proportions of sand and are more permeable.

Furthermore, estimates of the 'Aquifer Vulnerability Index' (AVI) suggest that groundwater aquifers surrounding Shadow Lake have a medium to high susceptibility to contamination resulting from poor water management practices **(Kawartha Conservation, 2008a)**. The high susceptibility of these aquifers to contamination is the result of thin/absent overburden and highly fractured bedrock which allow rain water to recharge quickly and provides limited adsorption of contaminates onto soil/rock surfaces. Recharge rates are likely particularly high in the Carden Plain on the southern portion of the lake where soils have a higher proportion of coarse sand and overburden permeability is greater. Furthermore, fracture flow through bedrock aquifers may be rapid which could allow rapid migration of contaminates into the Gull River and Shadow Lake. While water quality is generally good in the Shadow Lake region, strong water management practices are suggested to maintain the water quality in Shadow Lake.

As the Gull River is the primary water source to Shadow Lake, and the Gull River watershed upstream of Shadow Lake is entirely within the Canadian Shield, the water chemistry and nutrient inputs into Shadow Lake is expected to be more strongly influenced by the geology of the Georgian Bay Fringe than of the Carden Plain. The granites and metasedimentary bedrock of the Canadian Shield typically have a low buffering capacity and are relatively resistant to weathering suggesting that natural water inputs to the lake may have a low nutrient content and may be more acidic than surface/groundwater south of Shadow Lake in the St. Lawrence Lowlands. However, as Shadow Lake itself is partially underlain by Paleozoic limestones, it is expected that Shadow Lake has a greater buffering capacity than other lakes in the Canadian Shield and would be more resilient to the effects of acid rain.

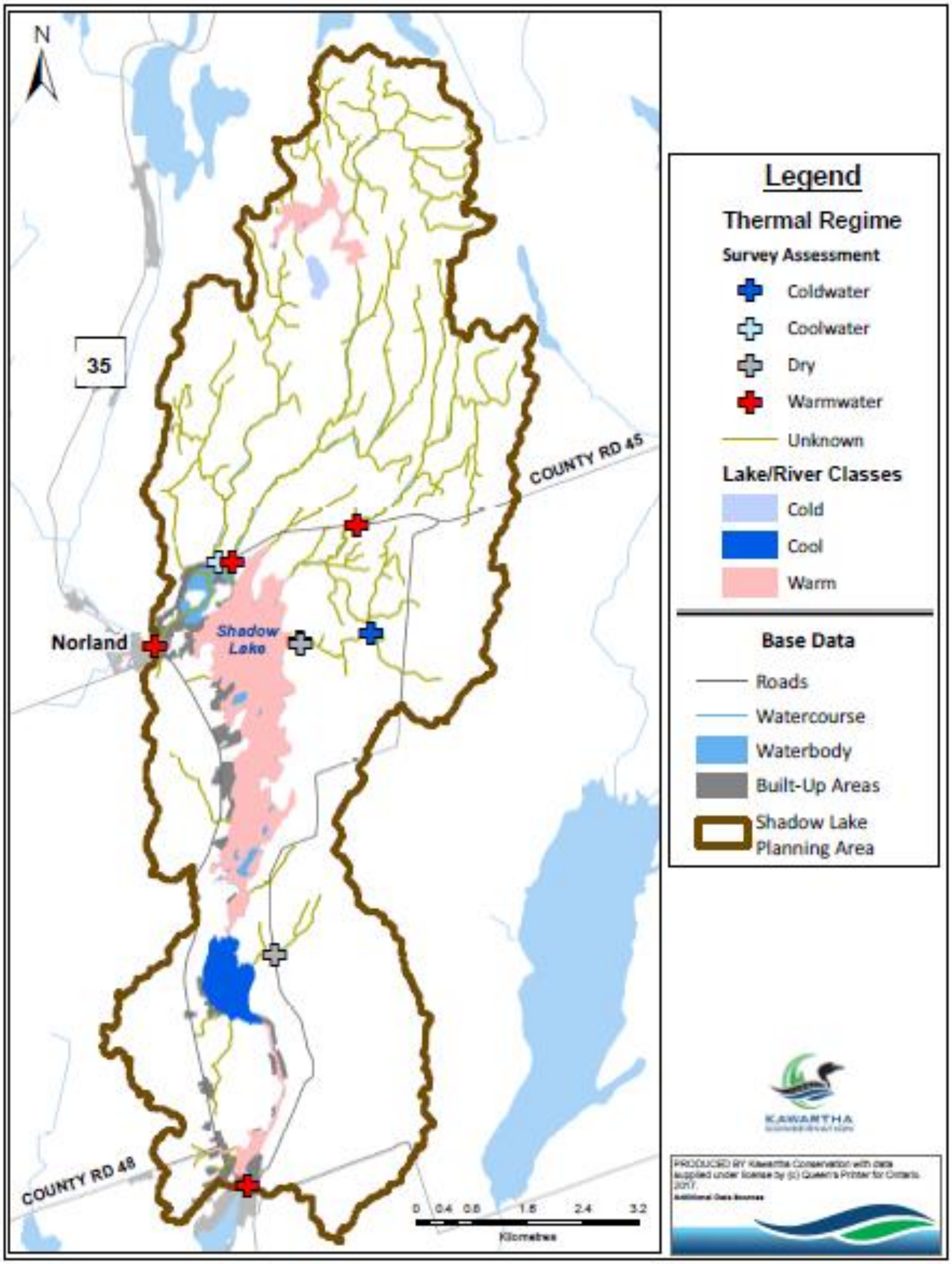


Figure 2.10. Map of thermal regime in various tributaries within the Shadow Lake planning area.

3.0 Climate

3.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- ***Climate within the Shadow Lake planning area 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 fairly equally distributed through the year.

KEY ISSUES

- ***Climate conditions are currently projected to change as a part of the global climate change process. Some of the possible changes to the weather are:***
    - Higher temperatures in all seasons, especially in winter;
    - More variable precipitation with increases in both the incidence of drought and intense precipitation;
    - Decreased snow cover and increased amounts of rain in winter;
    - More violent storms and higher wind speeds.

- ***Changes in climate may bring changes to the lake ecosystem that requires advance preparation and planning.***

INFORMATION GAPS

- ***Current data on evaporation and evapotranspiration for the study area is not available.***

3.2 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 Shadow Lake core planning area is classified as a moist continental mid-latitude climate (Dfb climate category) 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 **(Strahler and Strahler, 1979).** 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 and precipitation profiles 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). For Canada, the normals are computed every 10 years by Environment Canada, utilizing all qualified monitoring stations. The current 30-year normals are determined from the weather data obtained during the 30-year period of 1981-2010.

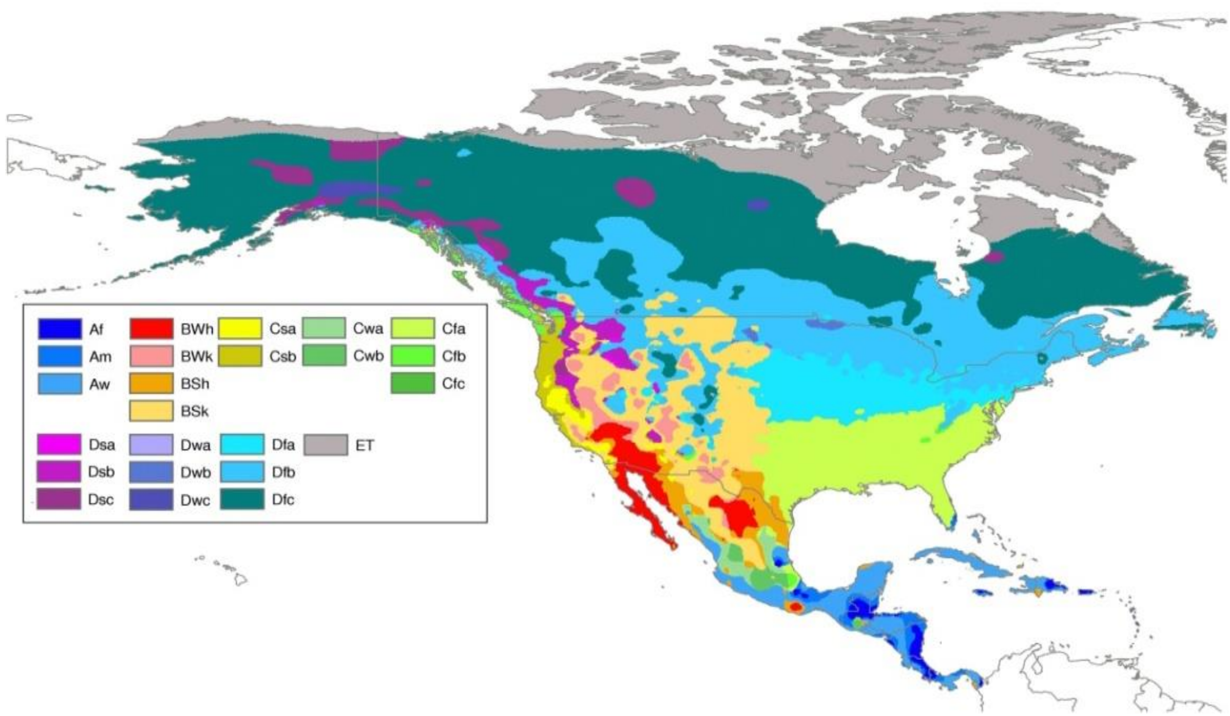


Figure 3.1. The Köppen Climate Classification System for North America
Source: http://www.eoearth.org

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 and 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 3.1).**

The climate monitoring station in Minden (Minden, Station ID 6165195) is the closest monitoring location from which data can be used to characterize climate variables of the study area. It is located outside of the study area, but no stations with the long-term records exist within the Shadow Lake subwatershed or its immediate vicinity. The Minden 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 60 years. Unfortunately, the station was decommissioned in 2011.

Average monthly temperatures and precipitation values for the Minden monitoring location are shown in **Table 3.1** and **Figures 3.2 to 3.4.** These data confirm the study area as belonging to the moist continental mid-latitude climate category.

Table 3.1. Average Monthly and Daily Extreme Values of Air Temperature and Precipitation for the Environment Canada Climate Monitoring Station Minden (6165195) 1981-2010.

Characteristic	Month												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Air Temperature													
Daily Average (°C)	-9.7	-7.8	-2.7	5.1	11.8	16.8	19.3	18.2	13.8	7.3	1	-5.6	**5.6**
Extreme Maximum (°C)	11	13	23	30.5	34	34	**35.5**	35	33	28	23.3	17	
	2005/13	1984/23	1998/30	2002/16	2006/30	1994/16	2002/01	1887/02	2002/09	2005/05	1961/03	1982/03	
Extreme Minimum (°C)	**-41.1**	-39.4	-36.5	-24.4	-10	-3.9	-0.6	-3.3	-9.4	-13.9	-27.2	-40	
	1888/21	1962/02	1980/02	1887/01	1966/07	1972/11	1893/24	1965/30	1888/28	1887/30	1958/30	1980/25	
Precipitation													
Rainfall (mm)	30.9	25.4	38.7	67.9	97.6	90.6	82.2	78	100.2	93.8	84.3	34.4	824
Extreme Daily Rainfall (mm)	44.4	47.6	43.4	41.9	55.9	93.7	99.8	71.6	57.2	55.1	55.4	41.9	
	1998/05	1997/21	1948/19	1956/27	1894/20	1957/28	1986/25	1974/16	1965/05	1893/14	1993/27	1949/22	
Snowfall (mm)	58.8	41	32.5	10.9	0.2	0	0	0	0	3.4	25	60.3	232.1
Extreme Daily Snowfall (mm)	29.2	30.5	33	22.9	6.4	0	0	0	0	17	30	48	
	1949/02	1887/11	1943/10	1975/03	1966/03	1886/01	1886/01	1886/01	1886/01	1979/08	1987/25	2000/11	
Total Precipitation (mm)	89.8	66.4	71.1	78.7	97.8	90.6	82.2	78	100.2	97.2	109.3	94.7	1056

Source: http://climate.weather.gc.ca/climate_normals

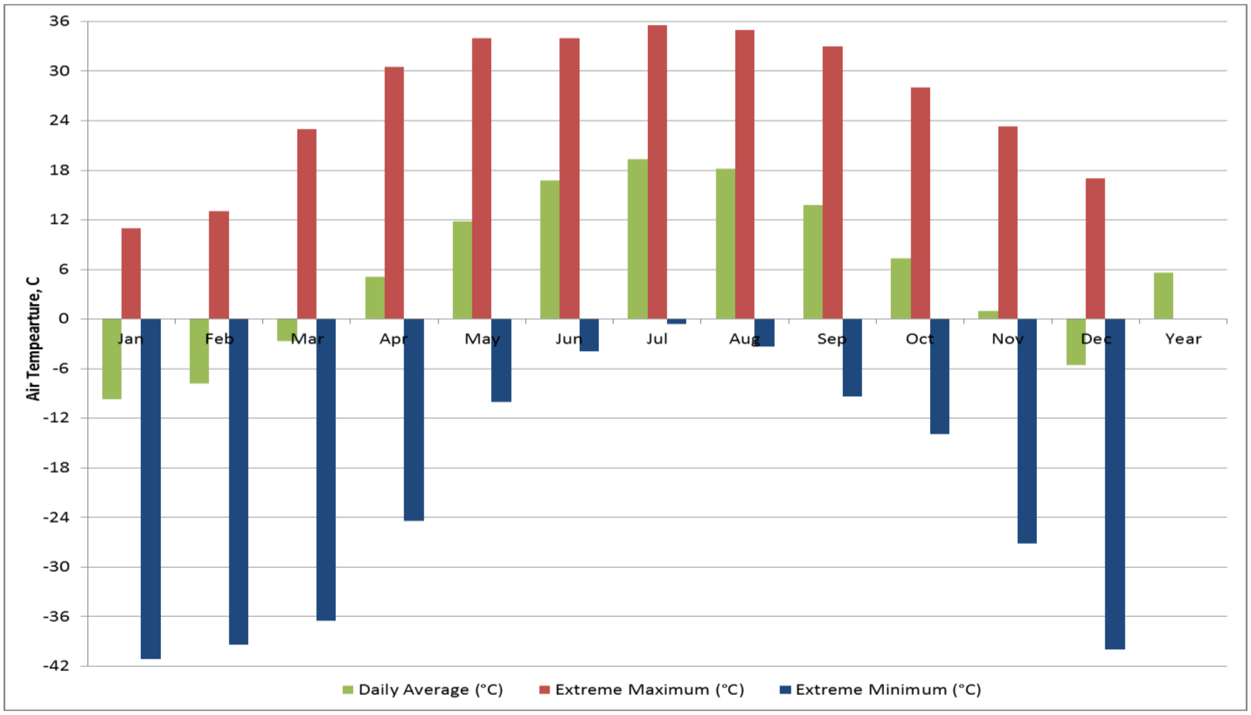


Figure 3.2. Monthly Air Temperature for the Minden Climate Monitoring Stations (Environment Canada, 6165195): Daily Average, Extreme Maximum and Extreme Minimum (1981-2010).

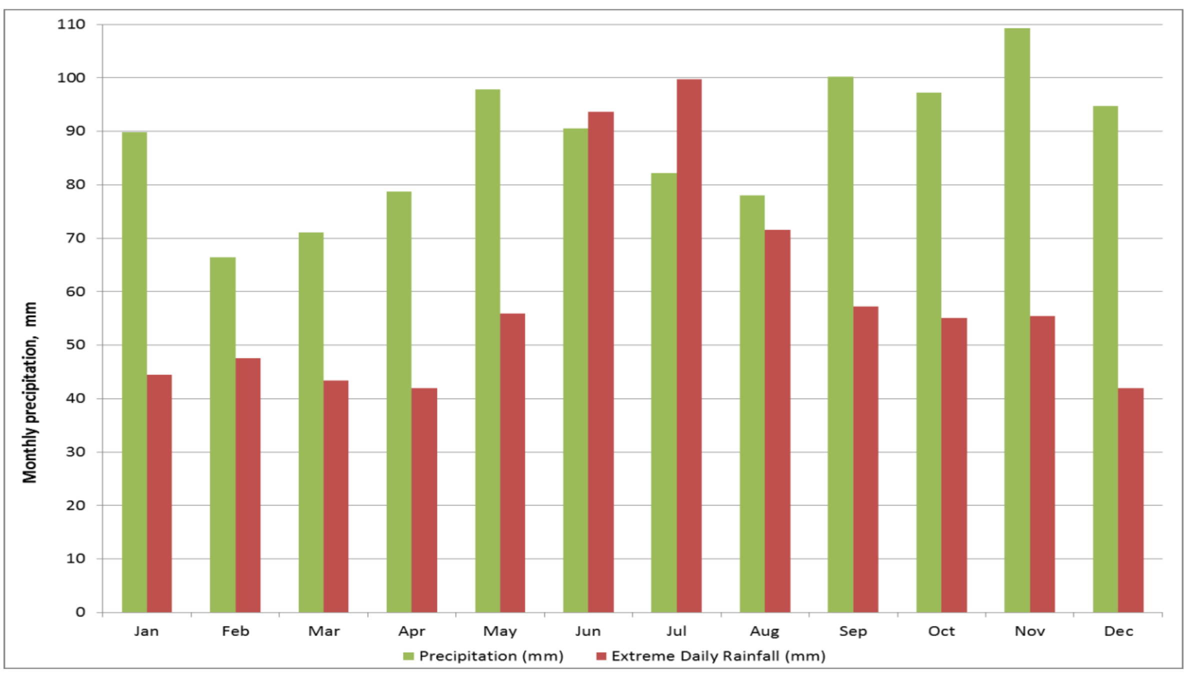


Figure 3.3. Monthly Precipitation Normals and Extreme Rainfall Values for the Minden Climate Monitoring Station (Environment Canada, 6165195: 1981-2010)

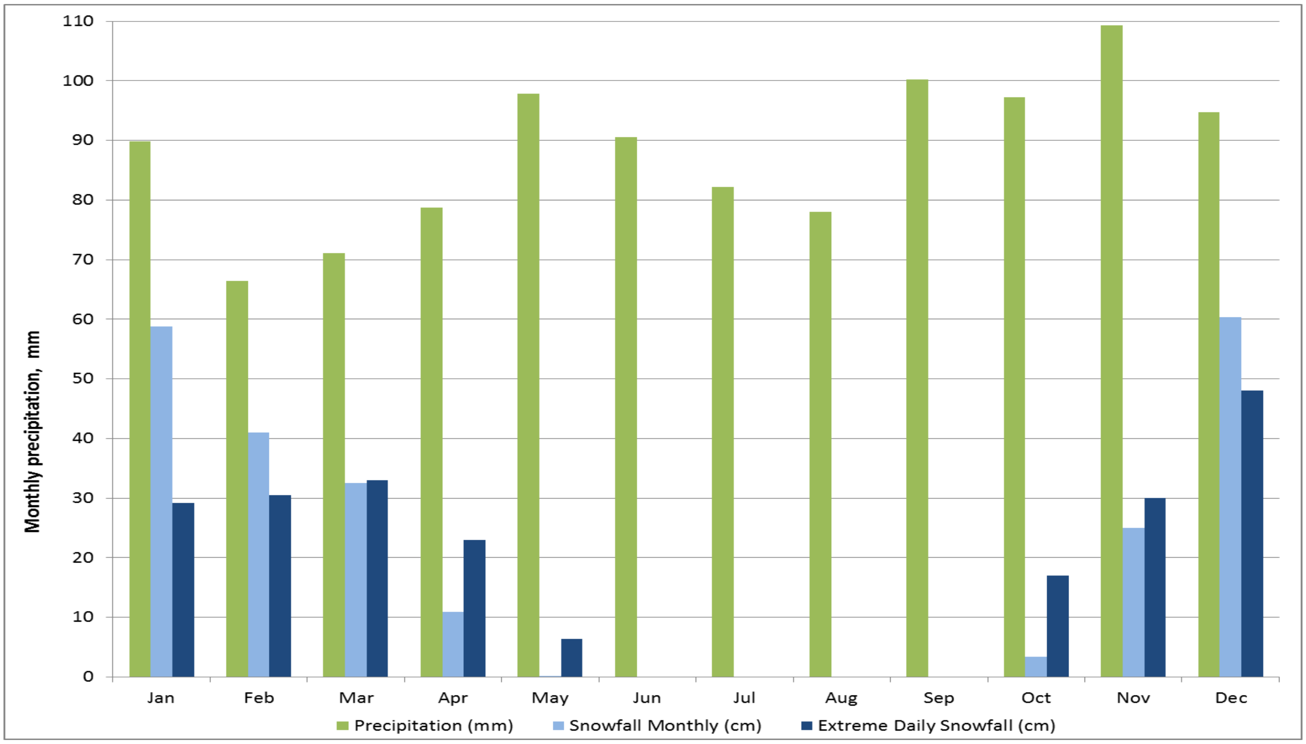


Figure 3.4. Monthly Precipitation Normals for the Environment Canada Climate Monitoring Stations: Minden (6165195: 1981-2010).

3.3 Air Temperature

The average winter monthly air temperature for the Minden climate station ranges from -5.6^{o}C in December to -9.7^{o}C in January, which is the coldest month of the year **(Table 3.1).**

July is the warmest month with the average monthly temperature reaching 19.3^{o}C. August is the second warmest month, with an average temperature of 18.2^{o}C, while the average temperature in June is 16.8^{o}C.

According to climate observation records, an extreme minimum temperature was observed in January 1881 at -41.1^{o}C, while July 1, 2002 was the hottest day recorded with the temperature at 35.5^{o}C. The average daily air temperature is 5.6^{o}C.

3.4 Precipitation

Precipitation is fairly evenly distributed throughout the year, with January-April being slightly drier than the rest of the year. The driest month of the year is February, which has on average approximately 6% of the total annual amount of precipitation. The largest average monthly precipitation is observed in November and is approximately 10% of the total annual amount. The highest daily rainfall recorded in 1986 was 99.8 mm.

There is a one active precipitation monitoring location within the Shadow Lake study area. Initially, the manual all-weather precipitation gauge was installed in 2013 at the Norland Dam for the purposes of the Shadow Lake Management Plan monitoring. It was installed and maintained by Kawartha Conservation. The monitoring location consisted of a manual accumulative gauge that collect and store precipitation until a reading is taken.

In October 2016 a permanent automated precipitation monitoring station was established by the Trent-Severn Waterway at the same location. It consists of the all-weather OTT weighing precipitation gauge, a data logger and transmitting equipment that ensures remote access to the gauge. Precipitation amounts for the period December 2016 - May 2017 was provided by the TSW officials. **Table 3.2** summarizes monthly precipitation data recorded at the Norland dam from June 2014 to May 2017.

Table 3.2. Precipitation Amounts for the Norland Dam Precipitation Monitoring Station Presented by Hydrologic Year over the study period.

Hydrologic year	2014-2015	2015-2016	2016-2017
June	108.1	128.1	57.1
July	65.7	88.7	92.3
August	76.6	102.2	117.7
September	91.9	77	54.7
October	120.3	89.1	73.1
November	77.2	66.6	40.3
December	60.5	95.1	110.9
January	31.4	61.7	96.3
February	19.4	58.4	80.5
March	20.4	186.4	79.4
April	83.6	56.2	103.5
May	39	57.6	179.8
Total	**794.1**	**1067.1**	**1085.6**

Recorded precipitation amounts demonstrate that the 2014-2015 hydrologic year was lower in precipitation comparing to the long-term average value. For example, precipitation observed during period of January - March 2015 was only 71.2 mm, representing only ~29% of long-term amount for this period (246 mm) recorded at Minden climate monitoring station. Furthermore, records show that the hydrological year 2014-2015 was the driest during the observation period. The amount of precipitation recorded that hydrological year was only seventy five percent of long-term average value.

3.5 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 3.4)**.

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.

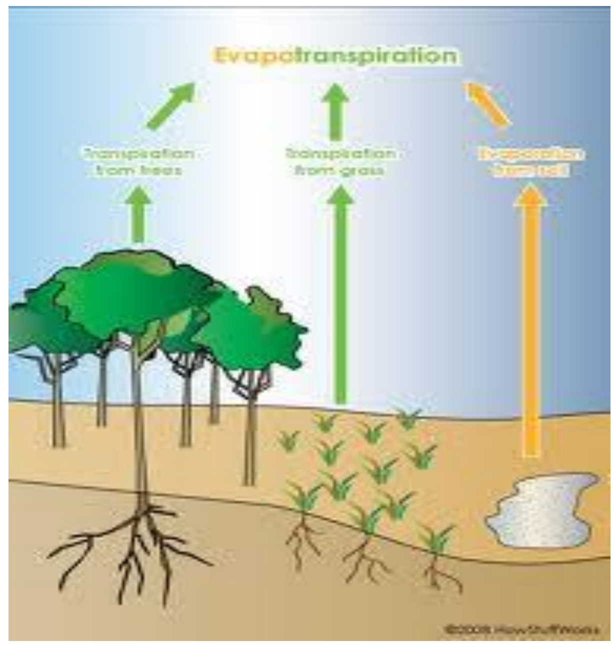


Figure 3.4. Process of Evapotranspiration
Source: http://science.howstuffworks.com

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 3.5).** According to that map, PET value for the area that encompasses the Shadow Lake planning area is about 560 mm (22 inches).
More recent data are available from the National Soil Database **(Soil Classification Working Group, 1998).** 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 Shadow Lake watershed is located within the EcoDistrict 552 of Manitoulin – Lake Simcoe Mixwood Plains EcoRegion (134); within Mixed Plains EcoZone. Estimated values of the potential evapotranspiration for those ecoregions are shown in **Table 3.3.**

Since ET values follow the trend of the air temperature, the maximum values for both regions are observed during the summer months: July, June and August. Evapotranspiration in March and November is very low, less than 10 mm, declining to 0 mm in the winter season. The average annual evapotranspiration is 630.6 mm.

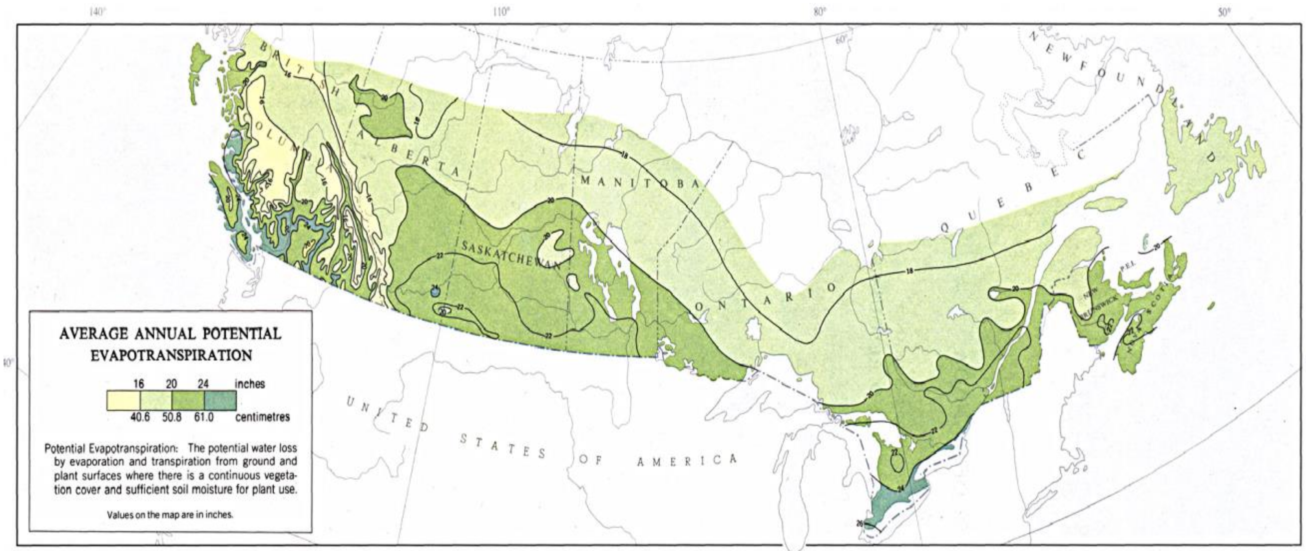


Figure 3.5. Average Annual Potential Evapotranspiration
Source: The National Atlas of Canada, 1974

Table 3.3. 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	630.6

3.6 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, 2014).** Climate variability can be thought of as a short term fluctuation superimposed on top of the long term climate change or trend.

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 important contributing factor to this phenomenon. It is expected that climatic warming 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 increasing atmospheric concentrations 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: at our local, national and global scales.

A considerable amount of research on climate change has been undertaken in Ontario. The Ministry of Natural Resources and forestry has produced a report where climate change projections from the Intergovernmental Panel on Climate Change's Fifth Assessment Report are summarized for the province of Ontario **(McDermid et al., 2015).** Projected changes in climate are described under the three greenhouse gases emission scenarios. Each scenario is a 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.

- RCP 2.6 – a medium-low scenario with aggressive mitigation. Emissions peak early, and then fall due to active removal of atmospheric carbon dioxide. Requires all the main GHG emitters, including developing countries, to participate early on in climate change mitigation policy.
- RCP 4.5 – a medium stabilization scenario where emissions stabilize by 2100.
- RCP 8.5 – a very high emission scenario and a failure to curb warming by 2100. GHG emissions are up to seven times higher than preindustrial levels.

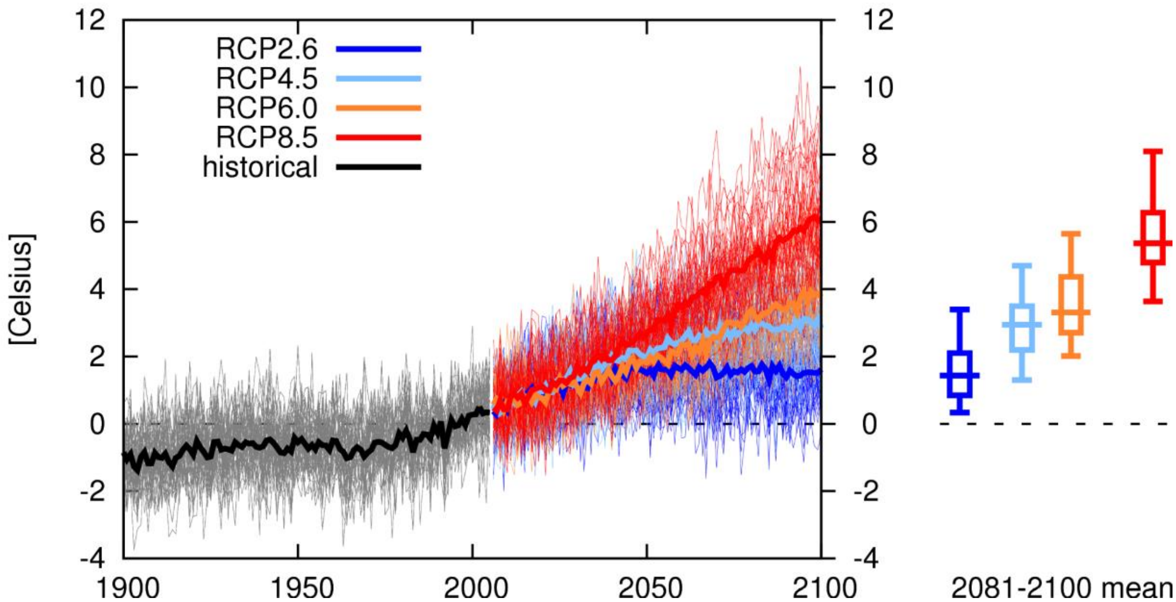
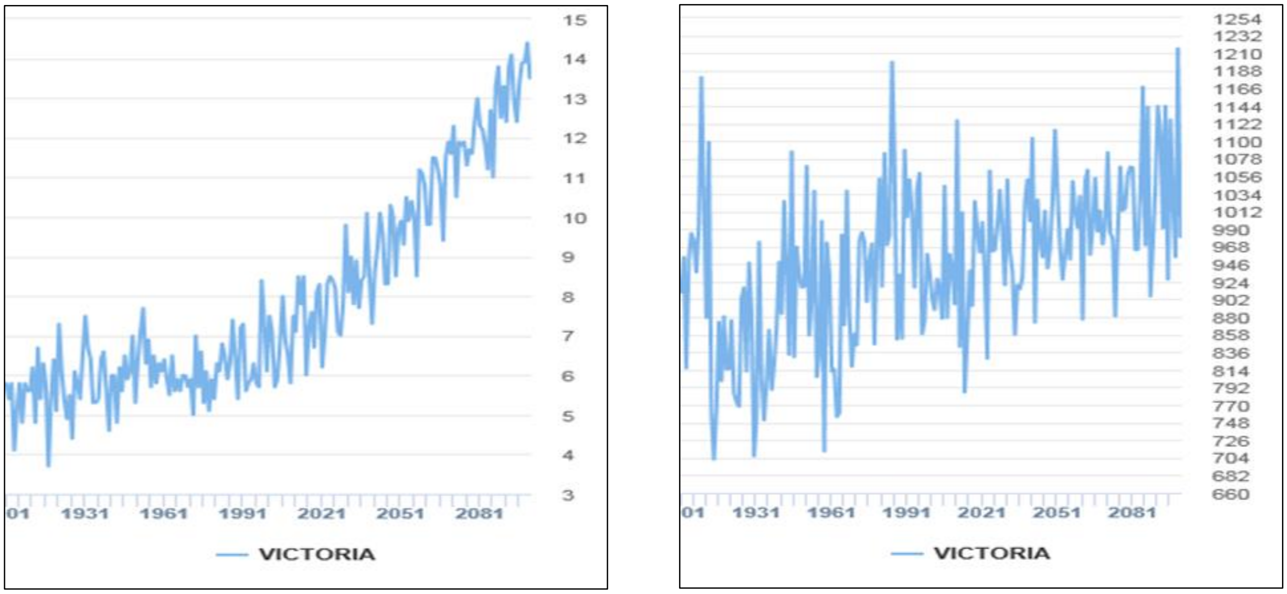


Figure 3.6. Trends in change of yearly mean air temperature in southern Ontario under different GHG emissions scenarios (Source: York University, 2016 http://lamps.math.yorku.ca/occp/)

Projected mean annual, summer, and winter temperatures and total annual, summer, and winter precipitation are shown for three 30-year time periods: 2011–2040 (the 2020s), 2041–2070 (the 2050s), and 2071–2100 (the 2080s).

Figure 3.7 demonstrates the projected average temperature (a) and precipitation (b) trends for City of Kawartha Lakes jurisdiction under the scenario RCP 8.5 as shown at the Ontario Climate Change Projection data portal (http://lamps.math.yorku.ca/occp/).

As indicated at the "Climate Change Projections for Ontario: An updated synthesis for policymakers and planners" report, it is expected that mean annual temperature will increase for southern Ontario, including the study area under all scenarios **(Table 3.4).** Within the Great Lakes Basin, temperature changes are projected to be largest in the northern portions of the basin. Mean annual air temperatures will increase the most in the Lake Superior sub-basin, ranging from 3.2 to 8.3 °C above historical levels by the 2080s, and lowest in Lake Erie, ranging from 2.8 to 7.2 °C above historical levels for the same time period. Winter warming will exceed summer warming.



a) Temperature b) Precipitation

Figure 3.7. Projected average temperature, °C (a) and precipitation, mm (b) trends for the City of Kawartha Lakes (Victoria County) jurisdiction under the very high emission scenario (RCP 8.5). Source: (Ontario Climate Change Projection data portal, http://lamps.math.yorku.ca/occp/).

Projected precipitation changes also indicate an annual increase in precipitation across the Lake Ontario basins, with the highest potential increases in Lake Superior sub-basin. However, increase in precipitation will be unevenly distributed throughout the year. Summers are projected to be drier, while winter precipitation is likely to increase. Changes in winter precipitation are expected to be more dramatic than summer precipitation, where the greatest change is projected in the Lake Huron sub-basin, averaging up to 85.2 mm above historical levels by the 2080s. As winter become milder, winter precipitation will fall as rain, affecting the hydrological cycle, monthly stream flows, lake levels, and water resources overall.

Table 3.4. Changes in temperature and precipitation for Lake Ontario watershed from 1971–2000 baseline values under three representative emission scenarios and for three time periods (2011–2040, 2041–2070, and 2071–2100). Source: http://lamps.math.yorku.ca/occp/node/113

Change from 1971–2000 baseline			2011–2040			2041–2070			2071–2100		
			Med-low emissions RCP 2.6	Med emissions RCP 4.5	Very high emissions RCP 8.5	Med-low emissions RCP 2.6	Med emissions RCP 4.5	Very high emissions RCP 8.5	Medium-low emissions RCP 2.6	Medium emissions RCP 4.5	Very high emissions RCP 8.5
Annual	Temp °C	Mean	2.3	2.3	2.4	3.1	3.8	4.6	3	4.6	7.6
		Range across the watershed	1.8 to 2.6	1.8 to 2.6	1.9 to 2.7	2.6 to 3.4	3.3 to 4.1	4 to 4.9	2.4 to 3.3	4.1 to 4.9	6.9 to 8
	Precip mm	Mean	55.1	22.9	36.3	62.5	61	72.6	74.3	66.7	102
		Range across the watershed	16 to 121	-16 to 96	-2 to 105	23 to 142	20 to 141	33 to 154	35 to 143	26 to 144	62 to 186
Summer	Temp °C	Mean	1.9	2	2.1	2.6	3.2	4.4	2.6	4.1	7.6
		Range across the watershed	1.4 to 2.3	1.5 to 2.4	1.6 to 2.5	2.1 to 3.0	2.8 to 3.7	3.9 to 4.9	2.1 to 3.1	3.7 to 4.6	6.9 to 8.1
	Precip mm	Mean	-0.1	-7.5	-3.3	-3	-4.8	-9.5	5.2	2.7	-10.6
		Range across the watershed	- 11 to 17	- 16 to 6	- 12 to 10	- 13 to 12	- 14 to 10	- 18 to 5	- 5 to 21	- 6 to 18	- 23 to 7
Winter	Temp °C	Mean	2.7	2.4	2.8	3.5	4.5	5.2	3.5	5.4	8.1
		Range across the watershed	2.2 to 3	1.9 to 2.8	2.3 to 3.2	3.0 to 3.9	4 to 4.9	4.6 to 5.6	2.9 to 3.9	4.8 to 5.7	7.3 to 8.6
	Precipitation, mm	Mean	22.2	25	20.9	35.5	26.4	44.3	33.7	38.5	72
		Range across the watershed	1 to 46	3 to 48	2 to 40	12 to 62	5 to 49	22 to 71	13 to 57	17 to 65	50 to 105

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, unsuspected 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, have the potential to impact aquatic habitat and 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 base flow (i.e. the portion of stream flow that comes from groundwater discharge, rather than direct runoff related to rain or snowmelt events) will experience lower levels and reduced flows, adding stress on aquatic ecosystems. Some portions of the study area, as shown further in Chapter 4, could be especially vulnerable to an increase in periods of dry or low flow.

Decreased groundwater levels and discharges may change forms and functions of wetlands. 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 global climate change. Beyond the environmental effects, a changing climate can impact the social and economic well-being of the Shadow Lake watershed residents.

4.0 Water Quantity

4.1 Summary of Observations, Key Issues and Information Gaps

OBSERVATIONS

- ***Shadow Lake is a naturally formed flow-through lake located at the bottom of the large and highly regulated Gull River system.*** Numerous man-made lakes within the watershed act as reservoirs, collecting spring runoff and discharging it during the low-water periods in order to provide sufficient navigation levels at the Trent Severn Waterway.
- ***The Shadow and Silver Lakes' water levels are highly influenced by anthropogenic activities occurring upstream of the lake.*** Resulting from the changing circumstances at the upper and middle portions of the Gull River system, flow at the downstream part of Gull River varies significantly, causing significant and very often sudden fluctuations of the water levels at the reach between Norland and Coboconk that includes Shadow and Silver lakes.
- ***According to information, provided by the Trent-Severn Waterway officials and public members, the water levels of Shadow Lake closely correlate with amount of flow conveyed through the dam in Norland.***
- ***The northern, unregulated tributary of Shadow Lake that was studied for the purpose of the Shadow Lake Management Plan has exhibited natural flow regime with well-defined seasonal flow pattern.*** High flows occur in spring, associated with snowmelt, and throughout the year following high-volume precipitation events. Low flows are observed in the summer and winter months.
- ***There are four active Permits To Take Water within the study area.*** Two permits allow water withdrawal from Gull River and other two from groundwater.
- ***Intake for the Norland municipal drinking water system is located upstream of the Norland dam and has an established minimal water level value required for proper function of the system which may potentially may affect amount of flow conveyed through the dam.***
- ***The long-term flow data for the hydrometric station Gull River at Norland demonstrate the increase of maximum volumes of flow during the observation period while minimum flow decreases at the same time.*** Further investigation of this phenomenon is outside of the scope of the Shadow Lake Management Planning project.

KEY ISSUES

- ***Water levels of Shadow Lake are prone to the wide-ranging and sometimes sudden fluctuation, responding to the inflows from the upstream portion of watershed, which is highly regulated.*** That causes distress for the shoreline residents of lake that expect a more stable water level regime and respond negatively to the sharp changes in water levels or extremely high or low levels.

- ***Climate change has the potential to impact the flow regime of local watercourses by seemingly increasing the duration and intensity of spring runoff, as well as increasing the potential for dry conditions and/or extreme high-flow events during the summer season.***

INFORMATION GAPS

- ***Annual monitoring data on lake evaporation are not available. This adds uncertainty to the calculations of a water budget.***
- ***Cumulative effects of water taking that does not require permitting cannot be evaluated accurately because of absence of data.***
- ***There is no water level measuring facility on Shadow Lake. As a result, there is no accurate information on lake levels.***

4.2. Drainage Network

Shadow Lake is a flow-through lake at the lower portion of the Gull River system, created by a natural constriction at the river's channel (bedrock outcrop). Gull River, in turn, makes part of the Trent Severn Waterway. The Gull River flows through the rugged landscape of Canadian Shield in a southwesterly direction for more than 120 km before it enters Balsam Lake at Coboconk. Its watershed drains 1356 km^2 and includes 17 lakes controlled by 21 dams.

The study area for the Shadow Lake Management Plan was defined as the lowest portion of the Gull River watershed that starts at the Norland Dam and runs downstream to the dam in Coboconk (**Figure 4.1**). Both water control structures are operated and managed by the Trent Severn Waterway.

As Trent-Severn Waterway defines the hydrologic regime of Shadow Lake, it is important to describe the overall system. The TSW was created by utilizing and alternating natural drainage network in order to create a navigable route from Georgian Bay to Lake Ontario. It runs 386 km from Port Severn located in the south of Georgian Bay (Lake Huron) to the Bay of Quinte on Lake Ontario. There are 44 locks and 143 dams within the system that are operated by the Ontario Waterway Unit of Parks Canada (**Figure 4.2**).

There are three major components to the Waterway: the Trent River watershed, the reservoir lakes and the Severn River watershed. The Gull River watershed, including the Shadow Lake study area, is the headwaters of the Trent River basin and is part of the Haliburton reservoir system. The reservoir lakes act as water storage units helping to manage water levels within the Trent Severn Waterway, particularly within the Kawartha Lakes.

The Shadow Lake subwatershed, as designated for the purpose of the lake management planning project, excludes the Gull River watershed upstream of the dam in Norland. It includes drainage areas of three prominent, but unnamed tributaries that enter lake at its northern end. At the central and southern portion of the study area only a few small intermittent watercourses identified. **Table 4.1** contains characteristics of the watercourses and sub-watersheds defined within the planning area.

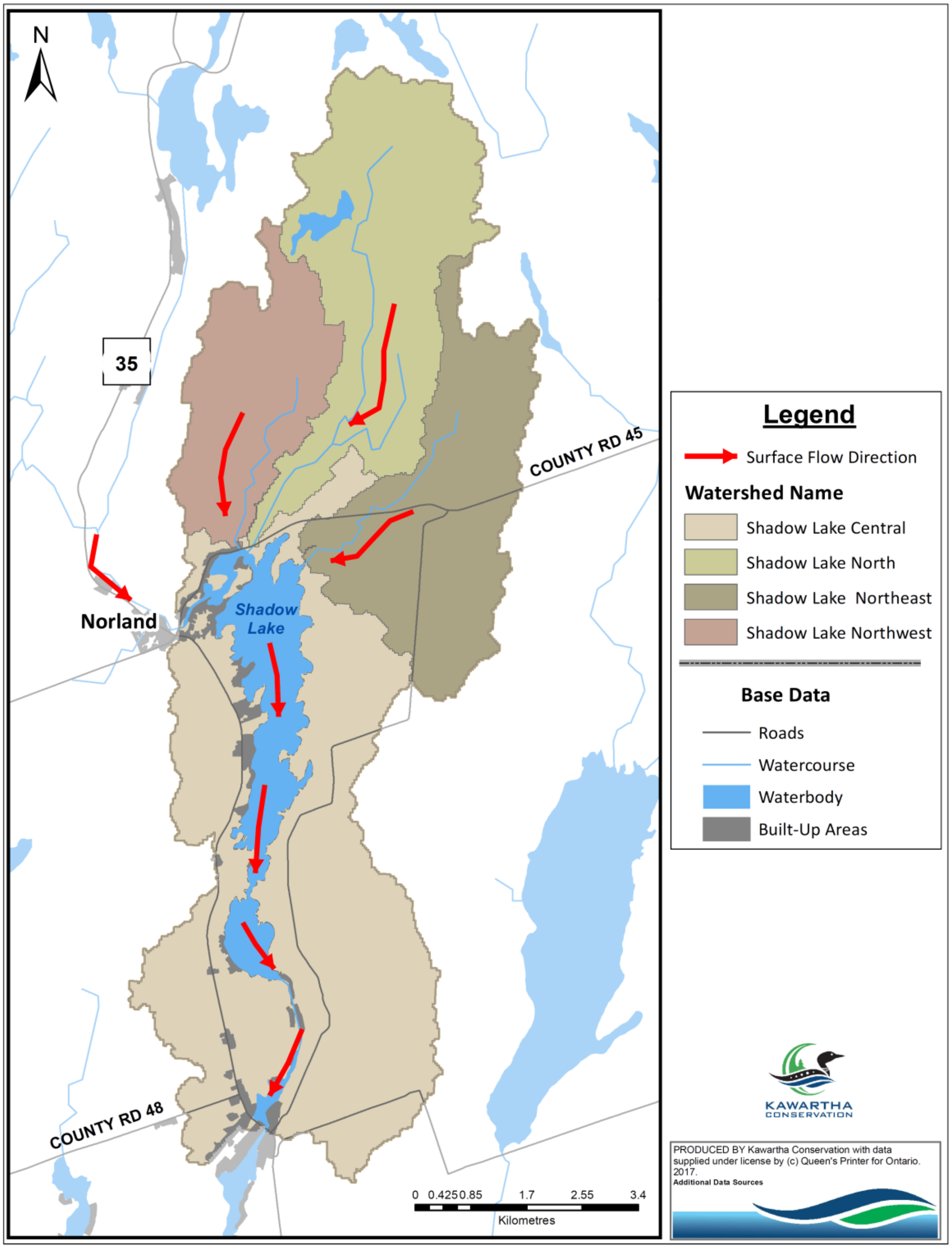


Figure 4.1. Drainage Network and Flow Direction at the Shadow Lake Management Planning Area

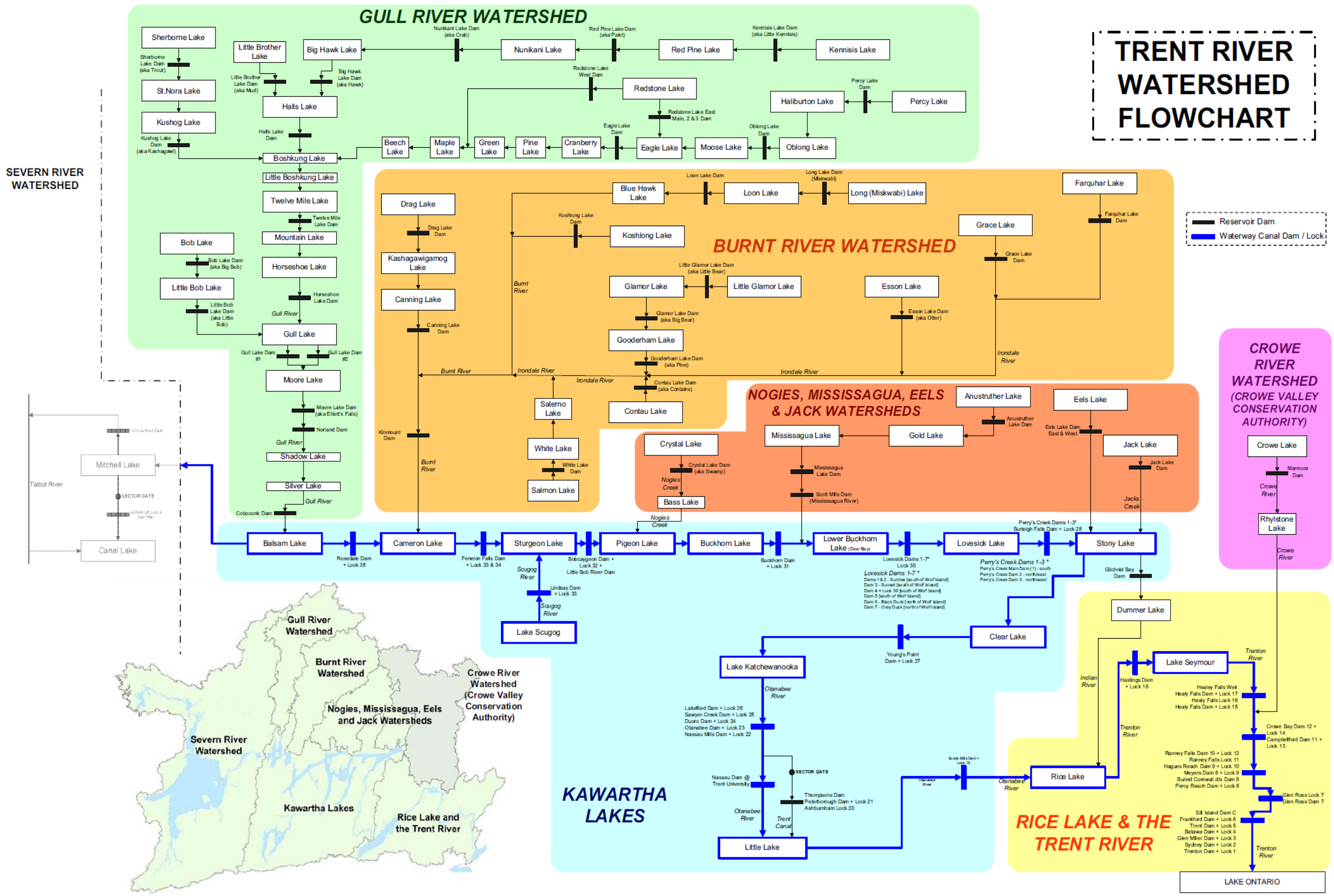


Figure 4.2. Trent River Watershed Flow Chart (Source: Parks Canada- Trent Severn Waterway).

Table 4.1. Stream and Subwatershed Characteristics, the Shadow Lake Planning Area

Sub watershed	Area (km^2)	Total Stream Network (km)	Main Channel Length (km)	Main Channel Gradient (m/km)	Natural Cover (%)	Agriculture (%)	Development (%)	Stream Density (km/km^2)	Average Watershed Slope (%)
Shadow Lake Northeast	11.06	23.32	6.59	4.63	85.0	10.1	0.81	2.10	5.74
Shadow Lake North	13.27	38.56	10.58	2.38	89.5	1.53	1.56	2.90	7.73
Shadow Lake Northwest	7.21	17.31	5.67	2.83	95.0	2.06	0.34	2.40	8.45
Shadow Lake Central	27.05	19.63	4.96	1.41	74.2	8.79	9.7	0.72	4.26

The Shadow Lake planning area is located within the highly variable transition zone between Paleozoic and Precambrian bedrocks. The northern part of the study area (Shadow Lake Northwest, Shadow Lake North and Shadow Lake Northeast sub-watersheds) is composed of rock ridges and shallow tills, while southern portion is characterized by limestone plateau. Watercourses running through the study area are small, no longer that 10.6 km; their drainage areas consist of wetlands and forests. Natural cover at the sub-watersheds varies from the 74% within the Shadow Lake Central sub-watershed to 95% for the Northwest sub-watershed. Numerous small lakes are located within the study area, especially at its northern portion. Only two of them are named: South Beaver Lake and Spar Lake.

4.3 Water Levels and Flow Regime

4.3.1. Water Levels and Flow Regime Overview

Water levels and flow vary over time and space. Floods and low-flow periods occur, sometimes in a predictable seasonal pattern, and sometimes less predictably. Rivers and lakes in variable climates tend to have variable flows, and rivers and lakes that are groundwater fed tend to have more constant and predictable water levels and flows. Flow regime describes the average seasonal water level and flow variability for a particular river or lake and reflect climatic and physiographic conditions in a watershed.

Surface water quantity (volume of water in watercourses and water bodies) assessments are usually achieved through water level and flow monitoring. Collected long-term data assist in identifying changes that may affect water quality, geomorphic stability and aquatic health of a watercourse as well as providing invaluable data for modeling of water resources, water budget calculations and water allocation. Changes in flow conditions may reflect changes in climate (precipitation, evapotranspiration), water demand, land use or the watershed's natural cover. Water level monitoring data also provide information for flood forecasting, warning and emergency management.

As mentioned before, the water level of Shadow Lake is highly influenced by anthropogenic activities occurring upstream of the lake. Resulting from the changing circumstances at the upper and middle portions of the Gull River system, flow at the downstream part of the Gull River varies significantly, causing significant and very often sudden fluctuations of the water levels at the reach between Norland and Coboconk that includes Shadow and Silver lakes. Factors that cause and effect fluctuation include but are not limited to changing runoff, increased water demands, flooding augments, environmental concerns.

For better understanding of the water level regime of Shadow Lake, it is necessary to review the Trent-Severn Waterway's water management objectives and strategy.

Originally, the TSW was created to provide safe navigation from Lake Ontario to Georgian Bay and open up the interior of Ontario for commercial and settlement purposes. The Haliburton reservoir lakes, including those located on the Gull River, were constructed to collect spring runoff and act as reservoirs, supporting sufficient water levels in the TSW during the dry periods. When those reservoirs were built, there was very little permanent settlement in the region. Now, when the region is densely populated, secondary water management objectives are taken into account in the management of water levels at the TSW such as: public safety, flood mitigation, community water supplies, water quality, protection of natural resources, green power generation and providing water for recreational activities.

While flood management is not the main objective of the operations at dams of the Gull River system, it is required that dams are operated to keep risk of flooding as low as reasonably practical.

The management of water levels in the reservoir lakes including lakes located upstream of Shadow Lake, is a balancing act. Water must be released from the lakes over the dry summer season to maintain navigation at the downstream portion of the TSW; without this augmentation from the reservoirs, navigation would not be possible in many summers. In addition, there are several municipal drinking water intakes (such as one in Norland) and wastewater discharges that require appropriate water levels to function properly.

It is common for the shoreline residents of the reservoir lakes and flow-through lakes such as Shadow Lake, to expect a more stable water level regime and respond negatively to the sharp changes in water levels or extremely high or low levels. To mitigate the impact of the required water levels adjustments on any one particular lake, Parks Canada has long practiced an equal percentage drawdown across all reservoir lakes based on available depth. It is important to remember that many of the reservoir lakes were not lakes before the construction of the dams and would therefore be dry; recreational use is linked to the presence of the dam. In addition to human uses of the lakes, there are certain lakes and channels that require fishery consideration for species such as Lake Trout or Walleye.

Coordination with hydro facilities, such as one that was recently constructed at the Norland dam, is an important objective of water management as well. Typically, the TSW staff makes water management decisions based on the need to provide for navigation and flood mitigation. The hydro utilities are informed of the available amount of flow and are given the option to use water for energy production, funneling it through the turbines and spillways owned by the hydro utility. Water that is not used by the hydro utility is conveyed through the Parks Canada infrastructure. The overall amount of water conveyed downstream does not change as a result of the operation of the hydro utility **(Gull River Flood Review, AECON, 2013)**.

The management of water levels and flow through the Trent-Severn Waterway is performed in accordance to their water management strategy. The first comprehensive examination of the operations and procedures for water control was undertaken by the Acres Consulting Services Limited in 1973 (**Acres, 1973**). Resulting from that analysis, the Plan of Operation was developed that has been serving as a frame for the Trent-Severn Waterway water management strategy until modern days.

The policies and procedures were initially developed as a result of that analysis were based on:

- Reviews of previous operational procedures and experience, including previous responses of the system to particular events or system changes;
- The current water demands placed on the system;
- Available historical records and observations of the system; and
- Testing and assessment of the policies and procedures using available computer modeling.

The operational policies and procedures included the following fundamental concepts:

- Reservoir Zone water level limits for each reservoir;
- Target water levels for each reservoir for each season;
- Channel flow limits;
- Interreservoir relationships (both priority and equal function definitions); and
- Variations in the above items season to season in response to changing water duty and stakeholder demands.

The use of these concepts provided for a set of policies and procedures which are robust and capable of addressing and balancing the increasingly complex set of competing demands of water within the current system (AECON, 2011).

Some of the procedures have remained constant over time. Even prior to the 1970's, the system was operated so that the Haliburton Lakes were drawn down by equal percentage. In addition, in the spring lakes were filled in accordance with a priority listing. This approach is still utilized. However, minor alterations have been made over the years to the procedures in order to better accommodate the enhanced demands and complexity of the operating environment. For example, slight adjustments have been made to the priority order for filling lakes, and well as to the target water levels for different seasons.

The following is a description of the typical operational procedures carried out by the Trent-Severn Waterway during the year within the Haliburton sector of the system.

- **Spring:**

The objective of spring operations within the Haliburton sector, including the Gull River system, is to manage spring freshet both to fill up the reservoir lakes in preparation for the summer navigation season and to mitigate the impact of flooding. In most years there is more inflow that is required to fill the lakes and surplus of water is released to the rest of the system. Sometimes the rate of release is limited by conditions in the downstream portions of the Waterway. The equal filling of lakes during extreme events is also practiced to mitigate water level fluctuation throughout the sector.

- **Summer (Navigation) Season:**

The operation objective for summer operations in Halliburton sector that includes the Gull River is to provide water to the navigable portion of the system so that the average navigational water levels are achieved. This is to be accomplished while minimizing release of water from the reservoirs.

Water is retained in the reservoirs for as long as possible during the summer until downstream conditions require additional flow. When required, water is drawn from each of the lakes on an equal percentage basis according to the storage range established for the lake.

- **Fall (Post-Navigation Season):**

The operational goal during the fall season is to draw down the lakes to winter settings as soon as possible to create storage capacity to accommodate freshet during the following spring. The fall season begins after the Thanksgiving holiday weekend, when the navigation season on the waterway officially closes.

- **Winter Season:**

During the winter season only minimal management of the reservoir lakes is practiced, due to difficulty of the dam adjustment operations during winter and decreased accessibility at some of more remote lakes. The low winter levels require coordination with hydroelectric and municipal partners to ensure that power production and water supply facilities continue to function properly.

In recent decades complexities and demands of the system operation has substantially increased as a result of the following factors (**AECON, 2011**):

- The Haliburton Lakes have become one of the most significant cottage regions in the province; and more recently there has been a shift toward year round residency on these lakes;
- Shoreline development has increased and densified, and with that the demands to maintain the levels of the Haliburton Reservoirs have increased;
- Growing cities and towns along the shorelines and increasing infrastructure demands to draw water from the system;
- The shorelines are home to thousands of business that rely on local residents and visitors;
- The societal awareness of and desire to protect the natural environment is increasing;
- There are legitimate concerns about global warming and the potential impacts of climate change; and

- Growing environmental concern has led to an interest in the potential for hydroelectric power generation as a source of renewable energy, with a corresponding increase in the number of hydro generation facilities.

These changes to the operation environment have resulted in an evolution of system operations, including the following:

- A more detailed account of water levels, flows and climate within the system;
- Development of policies and procedures regarding the water management operations; and
- Use of modeling to assist in the development of daily operational activities.

As Shadow and Silver lakes are the last lakes at the Gull River system before it inflows into Balsam Lake, their water level reflects all the dam operations and flow adjustments that happen upstream.

4.3.2. Water Level Monitoring

Continuous water level and flow monitoring for the Shadow Lake management planning project has been performed by two gauge stations, one located on the Gull River and another on the one of northern tributaries **(Figure 4.3).**

The hydrometric gauge on the Gull River at Norland (**02HF002 Gull River at Norland**) is a component of the Canada-wide hydrometric monitoring network that is maintained by the Water Survey Division, a division of Environment Canada. The gauge is situated ~850 m upstream of the Norland dam and monitors flow produced by 88% of the Gull River watershed. The station was established in 1962. It is important to remember that data from this monitoring location reflects flow that is highly regulated by the dams upstream operated by the TSW to address its objectives.

An additional temporary flow monitoring location was established on the lake's northern tributary **(Figure 4.4)**, in order to investigate amount of runoff produced by the smaller, ungauged watercourses at the northern and central portions of the study area. The station was established at the tributary's outlet at the downstream end of the culvert at Monck Road, adjacent to Buller Road, in 2013 by Kawartha Conservation specifically to obtain data for the Shadow Lake Management Plan.

Both monitoring locations consist of a sensor that measures the water level at pre-set intervals and a data logger that records measured values. Data from the Norland hydrometric station is available at the real-time format through the internet and is downloaded to both federal and provincial databases every 12 hours. For the gauge at the northern tributary, Kawartha Conservation staff members download data on monthly basis. Details on the flow monitoring locations are shown in **Table 4.2.**

Table 4.2. Continuous Water Level and Stream Flow Monitoring Locations within the Shadow Lake Planning Area

Water course	Location	Drainage Area, km^2	% of total Sub watershed Area	Measuring Interval	Data Record	Regulation	Type	Ownership
Gull River	~ 850 m upstream of Norland Dam	1280	88.5	15 min	1962 - 2017	Regulated	Permanent, stilling well	Water Survey Division – Environment Canada, 02HF002
Unnamed Tributary	Monck Rd.	13.27	100	1 hour	2014 - 2017	Unregulated	Temporary, pressure transducer	Kawartha Conservation

As it was mentioned before, water levels at Shadow Lake are function of the dam operations occurring upstream of the lake. Lake water levels correlate directly to the flow through the Norland dam. **Figure 4.4** demonstrates the long-term monthly flow for the Gull River observed at the Norland Dam hydrometric station. Despite of extreme regulation, water level regime of the Gull River follows seasonal pattern representative for watercourses in southern Ontario. This pattern reflects seasonal variations of water inflow. The highest water levels and flows on the Gull River are observed in May in response to the spring freshet, and are often combined with rain events. After peaking, the river's water level recedes and stays low through the summer and fall's months, reaching the lowest level of the season in October. In November and December increase in water level is observed, that is followed by decline during the winter season, when rivers and lakes do not receive surface run-off and flow is supported by the groundwater inflow only. As a result, yearly lowest water levels and flows are observed in February-March.

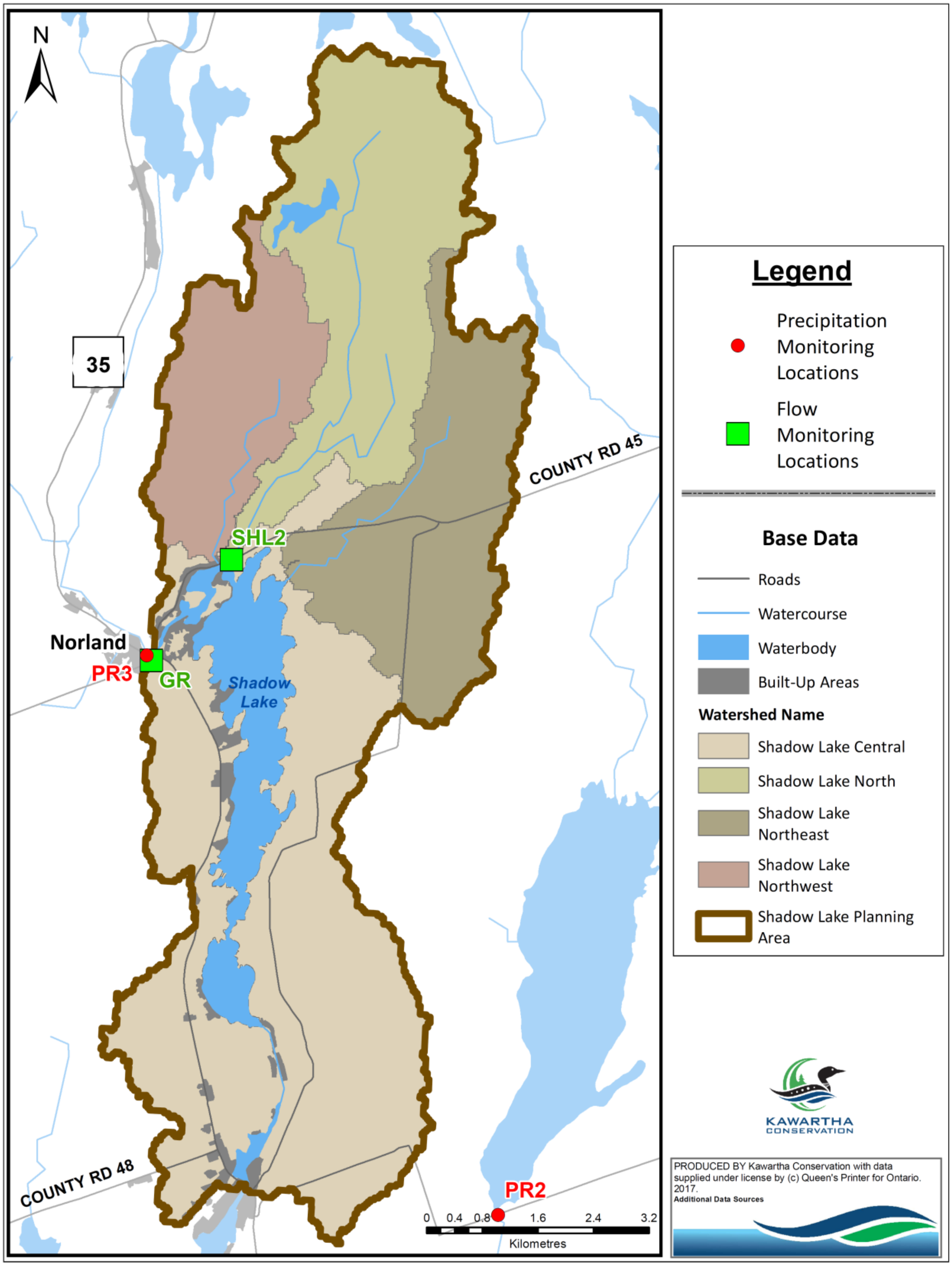


Figure 4.3. Flow Monitoring Locations within the Shadow Lake Management Planning Area.

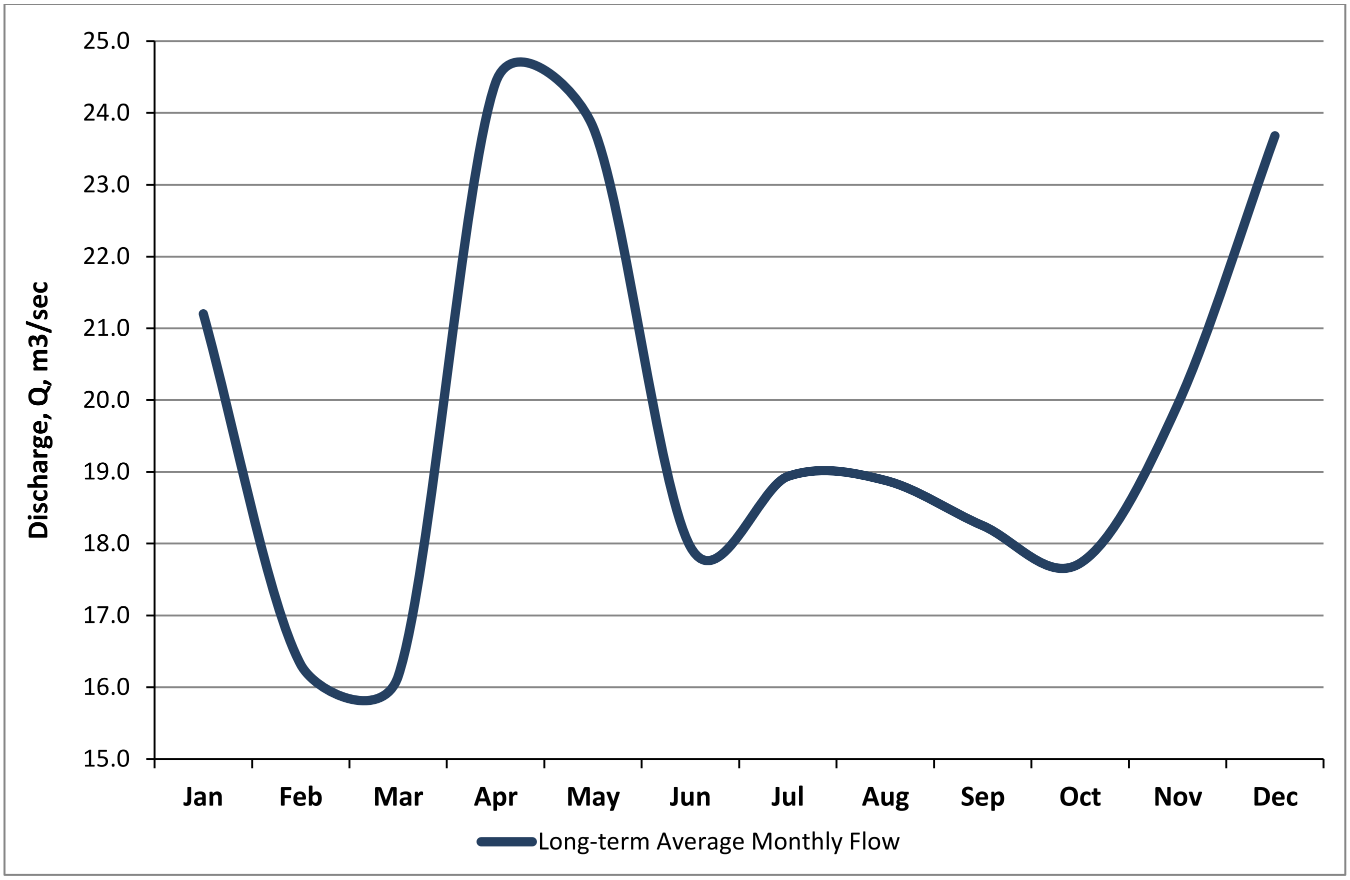


Figure 4.4. Long-term Average Monthly Flow Observed at the Gull River at Norland Hydrometric Station, 1962-2017

The dam located in Coboconk before the Gull River inflows into Balsam Lake, does not influence water level of Shadow Lake.

The northern, unregulated tributary of Shadow Lake that was studied for the purpose of the Shadow Lake Management Plan has exhibited natural flow regime with well-defined seasonal flow pattern (**Figure 4.5**). High flows were observed in spring (March-April), associated with snowmelt, and throughout the year following high-volume precipitation events. Low flows are observed in the summer and winter months. As 2016 was an extremely dry year, the tributary has minimal flow and even became dry for some time in July-August.

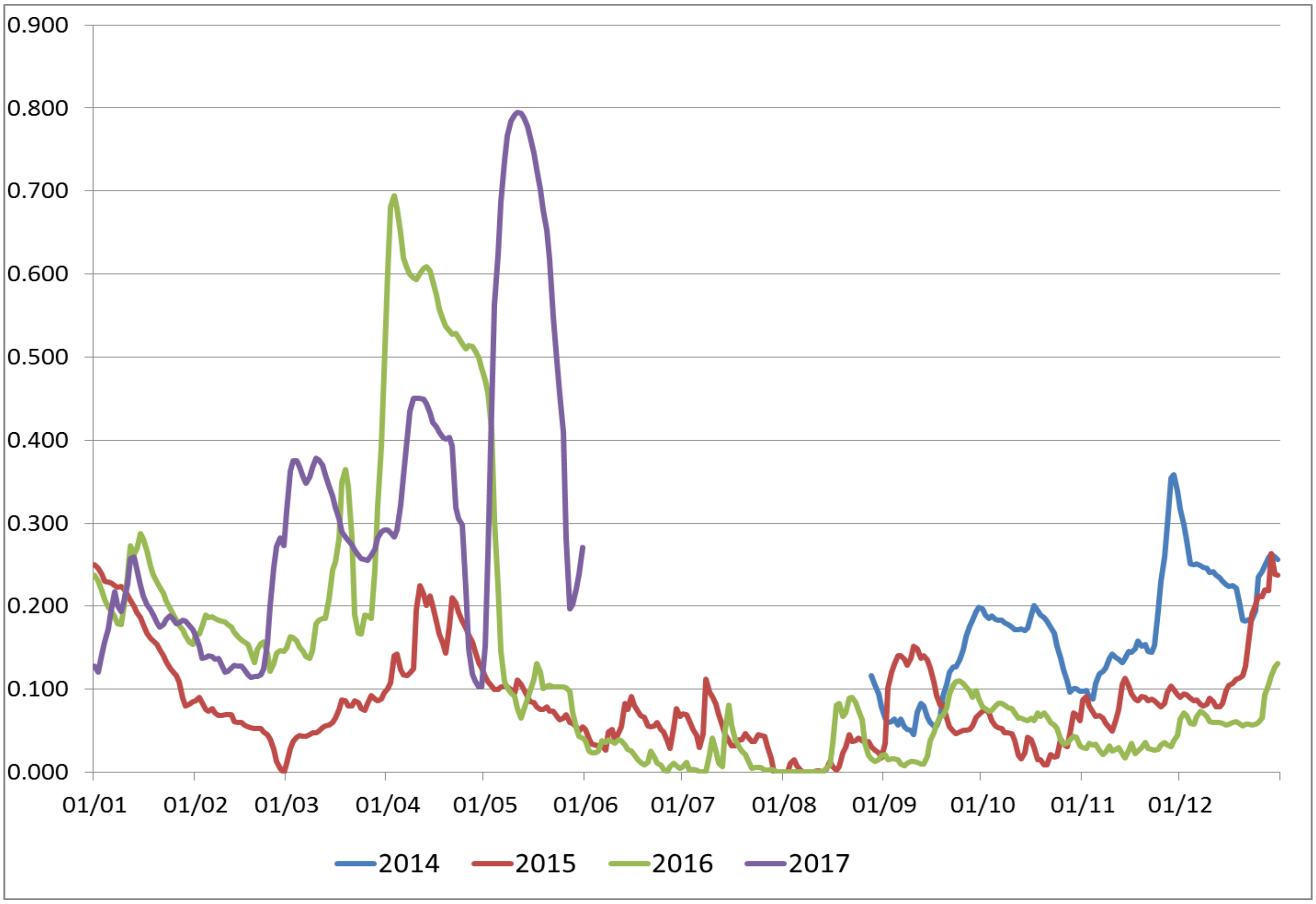


Figure 4.5. Average Monthly Flow at Tributary at County Rd. 45, Observed during 2014-2017

4.3.3. Long-term Dynamics of Water Levels of the Gull River

During the course of the project lots of concerns have been raised about dynamics of water levels in Shadow and Silver lakes. As a result, simple trend analysis has been performed on extreme and daily average water levels at the Gull River at Norland hydrometric station to investigate if long term trends do exist.

As it was mentioned at the section 4.3.2, first in-depth review of the water operations by the TWS was performed in 1973 by Acres Consulting Services Limited in 1973 (**Acres, 1973**). The Acres report has introduced the concept of the Reservoirs Zones to the waterbodies of the Trent-Severn waterway for the first time. Horizontal zoning was defined as a fundamental parameter to provide a measure of cross referencing in use and “duty” of water from any one reservoir to any other in a system, for any level of drawdown range.

The study suggested five Reservoir Zones:

- **Spill Zone:** This zone corresponds to water levels above that which can be retained in the reservoir by the control structures. Water levels and discharges create flood damage and high user dissatisfaction.
- **Flood Control Zone:** This zone accommodates sudden inflows to the reservoir. The top of the zone corresponds to the top water retention level, and the depth of the zone varies season to season in response to the changing inflow rates. Water levels are acceptable to users, and water can be retained to avoid flooding in downstream areas.
- **Conservation Zone:** The target levels for summer operation (to satisfy navigation, recreation, etc.) fall within this zone, located immediately below the Flood Zone. User satisfaction decreases with decreasing water level within this zone. Discharges can be limited to avoid flooding and to satisfy water quality.
- **Buffer Zone:** This zone lies below the Conservation Zone and corresponds to reduced user satisfaction, while ensuring minimum standards for navigation, water quality and water supply for consumption.
- **Inactive Zone:** The zone corresponds to generally unacceptable reservoir levels for all uses. In the Kawartha Lakes, the upper limit of this zone is the minimum navigational level. In the northern reservoirs, the zone corresponds to historical reservoir levels which are deemed unacceptable.

Table 4.3 shows flow limits for the Reservoirs Zones in Shadow and Silver lakes, using average daily flow rate at the Gull River at Norland monitoring gauge, as it was determined by the Acres study. The conservation zone, that presumably satisfies majority of users, is the target zone for summer season. It has been recommended to keep flow at the Norland Dam in range 12.7 - 21.2m^3/sec for Shadow Lake to remain within the conservation zone.

Table 4.3. Flow Limits for Shadow and Silver Lakes by the Reservoir Zone (Acres, 1973).

Periods	Reservoir Zones, presented by discharge at the Norland Dam				
	Spill	Flood Control	Conservation	Buffer	Inactive
Summer (Navigation)	Uncontrolled	< 42.5	**12.7 – 21.2**	5.66 - 12.7	>1.41
Spring	Uncontrolled	5.66 – 42.5			
Fall/Winter	Uncontrolled	5.66 – 42.5			

In order to identify the shifts in distribution of average daily flow over the long-term period, we have analyzed the frequency of appearance of the flow in the Buffer and Conservation Zones (combined) using two time periods: all available records and records for the last 10 years, 2007-2017 (**Table 4.4**).

Table 4.4. Distribution of Days within the Average Daily Flow by Reservoir Zones; Gull River at Norland Hydrometric Station

Zone	Recommended discharge, m^3/sec	Period of records	
		1963 - 2017	2007 - 2017
Conservation Zone	12.7 – 21.2	35.4%	33.7%
Buffer Zone	5.66 – 12.7	22.7%	19.5%
Conservation and Buffer Zone Combined	5.66 – 21.2	58.1%	53.2%
Below Buffer Zone	Under 5.66	1.98%	4.00%

Results of the analysis confirm that in more recent period (2007-2017) occurrence of the discharges that lower than those that are recommended for a buffer zone has become more frequent. In addition, during the last decade flow that entered Shadow Lake was more frequently outside of the recommended “comfort zone” (Conservation Zone). Only 33.4% of records (days) were within the conservation zone limits during the period 2007-2017, comparing to 35.4% over the all recorded data. Also, number of days with flow within the Buffer Zone has decreased. As a result, during the last decade daily average flow has gone outside of the recommended “comfort” levels more often than earlier. That increase can be quantified as much as almost 5%.

It means that more and more days, flow that enters Shadow Lake through the dam in Norland is either too high or too low to sustain comfortable water levels in the lake. This finding is confirmed by local residents.

Furthermore, the Shadow Lake Association has developed a table that describes the relationship between flow entering Shadow Lake through the dam in Norland and conditions such as safety, navigation, property and habitat and ecosystem (personal communication, 2017) (**Table 4.5**). We have also analyzed the distribution of the daily average flow over the full period of records (1963-2017) and over the last decade by the flow range used in this table (**Table 4.6**).

Table 4.5. Impact of the Flow (by Range) on Shadow Lake and the Gull River (Shadow Lake Association, 2017)

Impact of different Gull river flow rate ranges at Norland dam on Shadow Lakes and Gull river

for real time flow rate information go to : **https://wateroffice.ec.gc.ca/search/real_time_e.html**
enter '**Norland**' as station name

Flow rate at Norland dam (cubic metres per second)	Overall condition	Impacts on safety, property, navigation and habitat
70+	**Flooding**	Some property access roads underwater EMS and municipal services compromised Widespread basement and crawl space flooding Property loss of unsecured items such as docks and sheds Boat houses inaccessible and platforms submerged Debris clogging channels and waterfronts Severe shoreline erosion Some septic tank inundation Dangerous currents in narrow river sections
50 to 70	**Extremely high water level for summer months, high water level for spring freshet**	Permanent docks underwater Seasonal docks require securing or sandbagging Boathouse platforms submerged Navigation and hazard marker placement delayed Sandbagging required for some properties to control shoreline erosion Disruption of fish spawning habitat Waterfowl nesting disrupted
25 to 50	**High water level for summer months, normal water level for spring freshet**	Beach areas significantly reduced in size or underwater Nutrient loading from flooded ground producing green algae as waters warm during summer Navigation and hazard marker placement can proceed All river channels are navigable with moderate current
10 to 25	**Historically normal water levels during summer months**	Ideal flow range for recreational use of all waterbodies Sufficient depth for water intakes Sufficient depth on lower Gull river for watercraft with jet drives or outboards to 90 HP.
5 to 10	**Lower than historical minimum during conservation period**	Some water intakes pulling surface water Shallow water at many docks requires beaching of watercraft Navigation of lower Gull river limited to outboards up to 10HP
less than 5	**Extremely lower than historical minimum during conservation period**	Many water intakes exposed Water level in sections of lower Gull river less than 12 inches Many permanent and seasonal docks high and dry

Table 4.6. Distribution of Days within the Flow Ranges as per Table 4.5 during the Full Period of Records and Last Decade

Flow at Norland, m³/sec	Conditions	1962 - 2017		2007 - 2017	
		# of days	%	# of days	%
70 +	Flooding	51	**0.25**	40	**0.8**
50 to 70	Extremely high water levels	446	**2.21**	179	**3.41**
25 to 50	High Water Levels	4239	**21.03**	1375	**26.18**
10 to 25	Normal Water Levels (comfort zone)	12903	**64.03**	2896	**55.14**
5 to 10	Lower than normal	2219	**11.01**	607	**11.56**
Less than 5	Extremely low	295	**1.50**	155	**2.9**
Combined ranges:					
50 +	High	497	**2.46**	219	**4.21**
5 to 25	Medium	15122	**75.04**	3503	**66.7**
Less than 10	Low	2514	**12.51**	762	**14.46**

Results of this analysis confirms that occurrence of days with extreme low and high water levels and flow (combined) has increased in last 10 years, comparing to the full period of records. The increase can be quantified as almost 4%, from 14.97% to 18.67%. Meanwhile, the number of days with water levels/flows within the moderate range that is satisfactory to majority of shoreline residents and visitors has decreased by almost 9%.

The long-term maximum and minimum flows have been also analyzed (**Figure 4.6**) in order to identify possible trends. Results have revealed an increasing trend in maximum daily and instantaneous discharges during the full observation period (1963-2017). At the same time the decreasing trend in minimum discharges is observed. In other words, the high flows and water levels are becoming higher, and low are becoming lower.

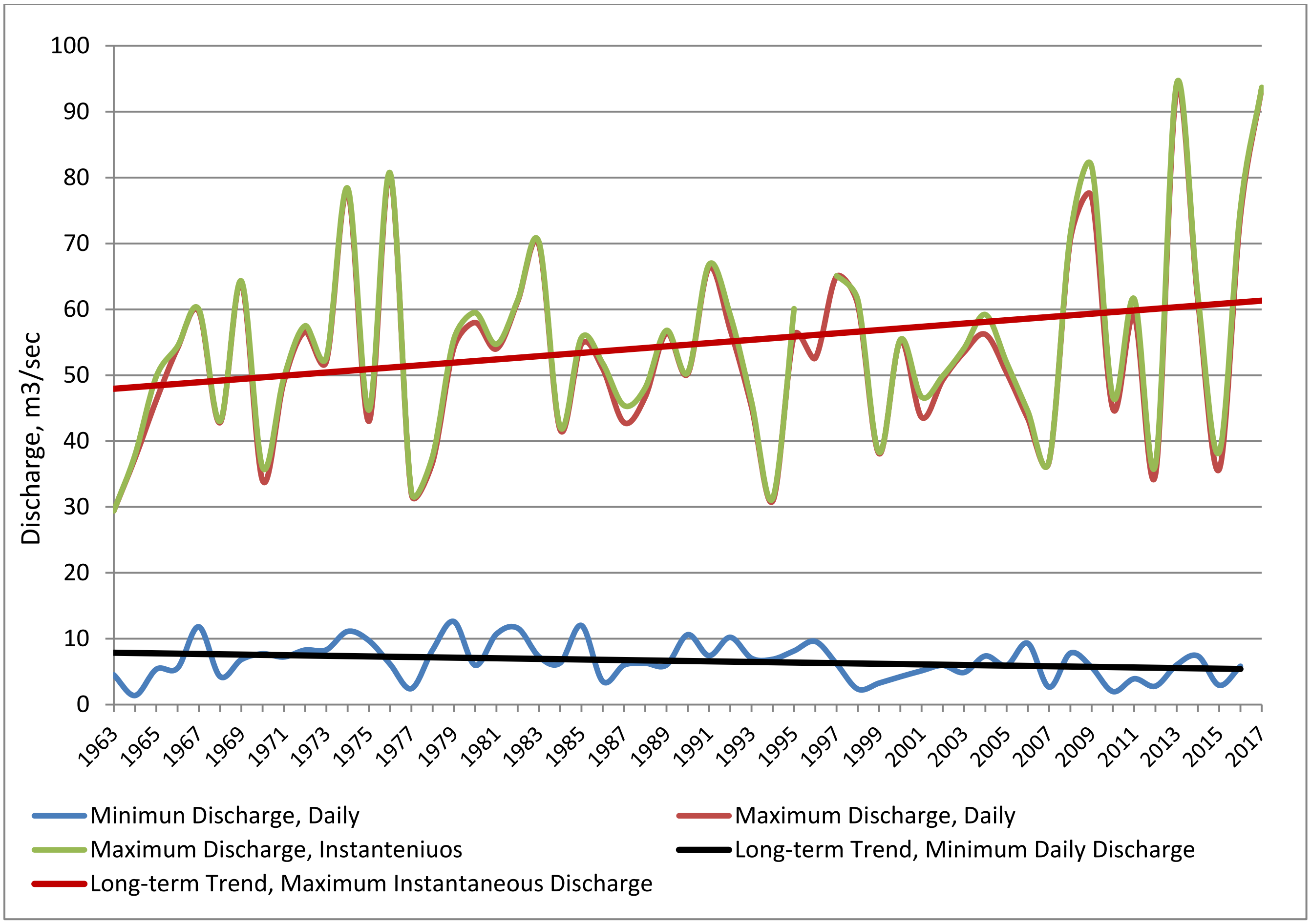


Figure 4.6. Long Term Yearly Maximum and Minimum Discharges, Gull River in Norland Hydrometric Station, 1963-2017

In order to investigate the possible cause of the increase in the Gull River water levels, we have gathered and evaluated the local long-term precipitation data. As it was mentioned at Section 3.0, the most representative climate monitoring data for study area, including precipitation dataset, is available from the Minden climate station. Good quality precipitation data for that station is available starting 1943. **Figure 4.7** demonstrates the yearly total precipitation amounts for period 1943-2016. The regression analysis undertaken on data confirms that the increasing trend in total yearly precipitation for the monitoring period is being observed as well.

In addition, **Figure 4.8** shows how total precipitation and average yearly discharges relate to each other. Precipitation values in a specific year were compared to the average yearly discharge at the same year. Graph reveals a close relationship between those two parameters, with coefficient of determination R^2 more than 60%. This is good evidence that changes in precipitation bring changes in river flow and, as a result lake's water levels. There are number of potential reasons for change in precipitations, its amounts, intensity and timing, including climate change. More information on climate change are available at Section 3.

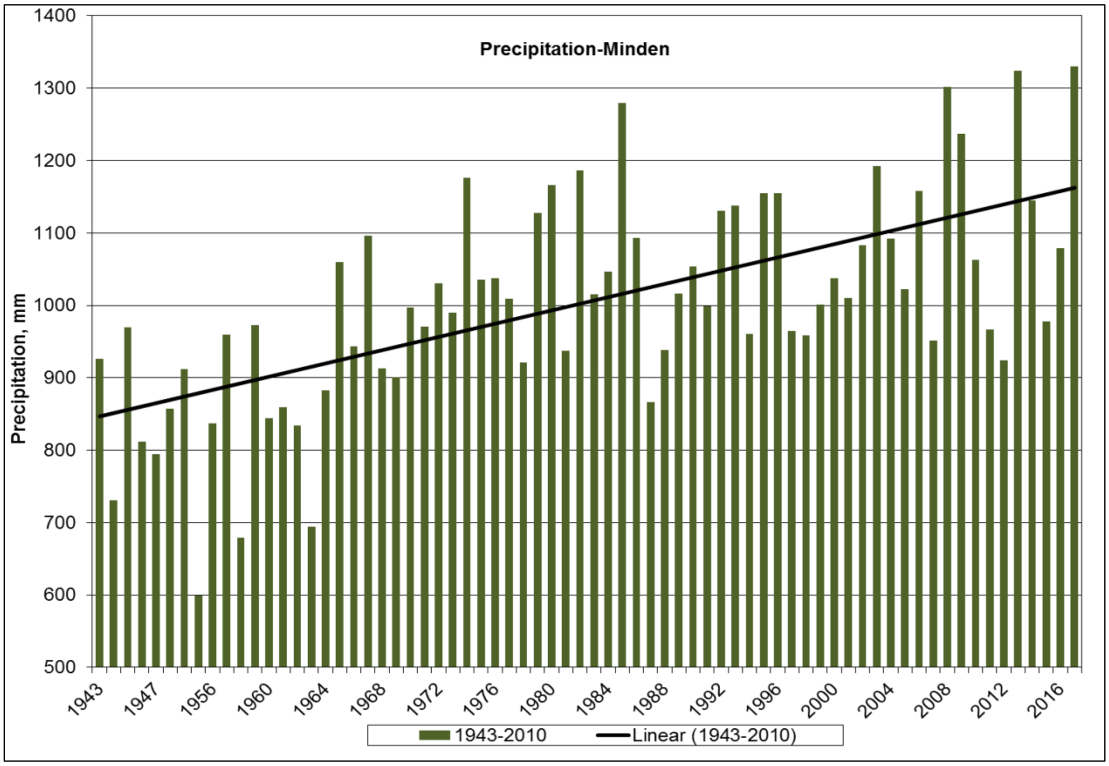


Figure 4.7. Long Term Yearly Precipitation, Minden Climate Station (6165195), 1943-2010.

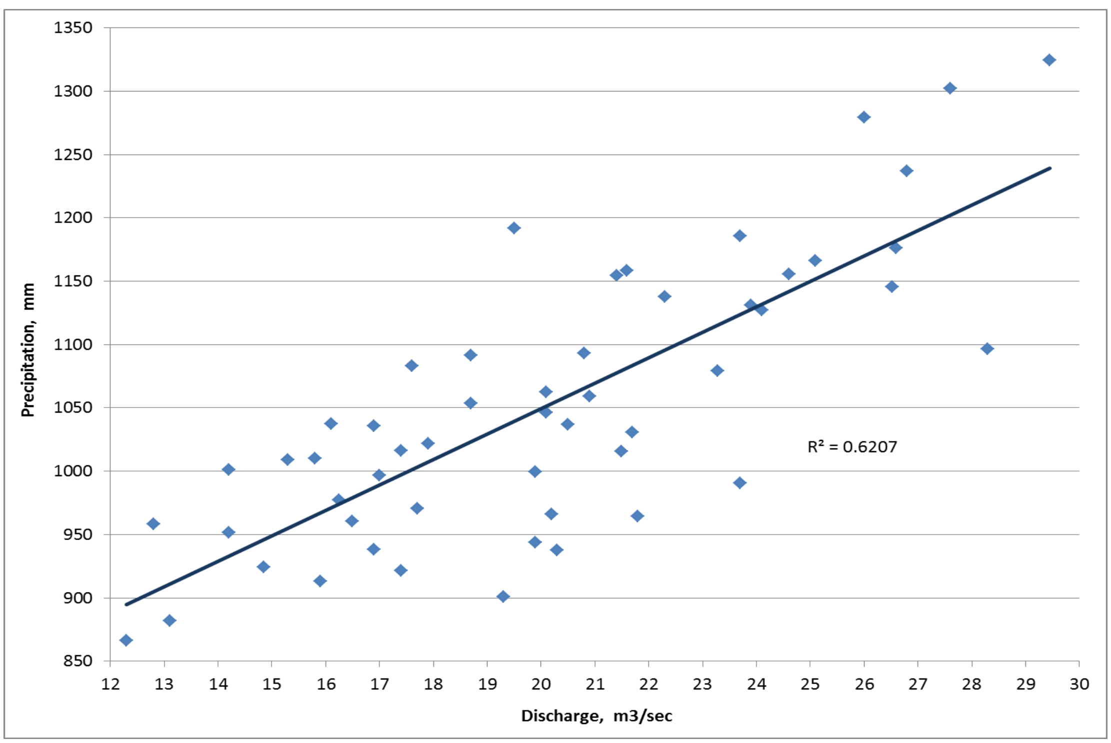


Figure 4.8. Long-term Relationship between Precipitation (Minden) and Flow of the Gull River in Norland, 1963-2016.

As concerns about the sharp fluctuations of water levels in Shadow and Silver lakes have existed for a long period of time, there have been attempts made to resolve this problem. One of the earlier reports **(Chrysler and Letham. Water Control Study, Gull River, 1972)** recommended to remove the channel constraints in three locations along the reach between Norland and Coboconk and construct a control water structure at the outlet of Silver Lake. This was expected to "…reduce water level fluctuations in the reach and discharges from the Gull River system, both of which will benefit greatly the water balance of the system" (**Acres, 1973**). The estimated cost of the project was $550.000 (~$3.2 mln in 2018 cost) that is probably why the recommendation was never implemented.

4.3.4. Lakes Morphology and Bathymetry

Shadow Lake is long and narrow with an irregular and often rocky shoreline; its shape factor that is length of the lake divided on its width, is 3.606. Lake's surface area was calculated as 3.57 km^2 (**Table 4.7**). There are many bays with weed beds in the shallower sections. The deepest portion of the lake, including its deepest point is located at the northern portion of the lake, close to the Gull River inflow site. Another deep basin, 20 m, is observed at the southern part. The most southern portion of the lake is the shallowest area of the lake, where depth does not exceed 1.2 m.

Silver Lake is considerably smaller; its surface area is only 0.68 km^2. It has a different shape, being more elliptical, with a shape factor only 1.625.

Table 4.7. Morphologic Characteristics of Shadow and Silver Lakes

Water body	Surface water area, km^2	Maximum length, m	Maximum width, m	Shape factor, L/W	Depth, m	
					Average	Maximum
Shadow Lake	3.57	5294	1468	3.606	7.8	22
Silver Lake	0.68	1238	1238	1.625	6.8	20

A combined analysis of Shadow and Silver lakes surface area by depth was performed; results are shown in **Table 4.8**.

Table 4.8. Shadow and Silver Lakes Surface Area by Depth

Depth, m	Area, km^2	% of total lake area
0-2	0.62	14.66
2-4	0.99	23.41
4-6	0.86	20.39
6-8	0.47	11.10
8-10	0.48	11.33
10-12	0.19	4.46
12-14	0.09	2.08
14-16	0.21	4.90
16-18	0.11	2.63
18-20	0.17	4.03
20-22	0.04	0.96
Total	**4.23**	**100**

There are numerous rocks and shallow spots around both lakes; they are marked by the hazard markers that are maintained by the Shadow Lake Cottagers Association.

4.4 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 section is to provide a summary of permitted water use within the Shadow Lake management planning area.

Water users that withdraw or holdback (e.g., through impoundments) more than 50,000 litres of water per day are considered major water takings and are regulated under the Ontario Water Resources Act. These activities require a Permit to Take Water (PTTW) from the Ontario Ministry of Environment and Climate Change and the amount of water used is documented and reported to the MOECC. 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 and Climate Change, 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. All major water takers are required to report the total volume of water taken each year.

The current water taking information for study area was obtained from the MOECC. The best available data were used to determine active permits and volume of permitted water withdrawals within the watershed (as of July 2016) **(Table 4.9).**

Table 4.9. Active Permits to Take Water within Shadow Lake Management Planning area

Category	Purpose	Source	Number of Permits	Water Body	Maximum allowed water taking, m^3	
					daily	yearly
Water Supply	Municipal Water Supply	Surface Water	1	Gull River	300	109500
Construction	Dewatering Construction	Ground Water	2	Ponds	450	163800
Industrial	Industrial Aggregate Wash	Surface Water	1	Gull River	3590	789888
Total			**4**		**4,340**	**1,063,188**

Overall, the permitted water taking within the study area is not significant. There are only four active Permits to Take Water within the Shadow Lake management planning area (**Figure 4.10**). Furthermore, one of those is issued for the construction dewatering activities which involves removing ground or surface water from a construction site and is considered a non-consumptive use of water resources.

One PTTW is issued for the municipal drinking water system. The system is located in Norland, draws water from Gull River upstream the Norland dam and provide water supply to about 90 households with population of ~225 people. Its average pumping volume is 90 m^3/year.

For private water supply it is assumed that local residents withdraw water from the ground water or directly from the lake (from shoreline properties) for use. **Figure 4.11** shows groundwater wells as they are registered with the Ministry of the Environment and Climate Change. The current status of the well (active, abandoned) is not always reflected correctly; withdrawal volumes are not known.

Information on the non-permitted surface water taking (less than 50,000 L/day) does not exist. As water withdrawal from the lake is not required to be reported, data such as the number of connections and volume of pumping water is unknown.

As a result, because of the absence of data, is it not possible to evaluate cumulative the effect of private ground water and direct water-taking.

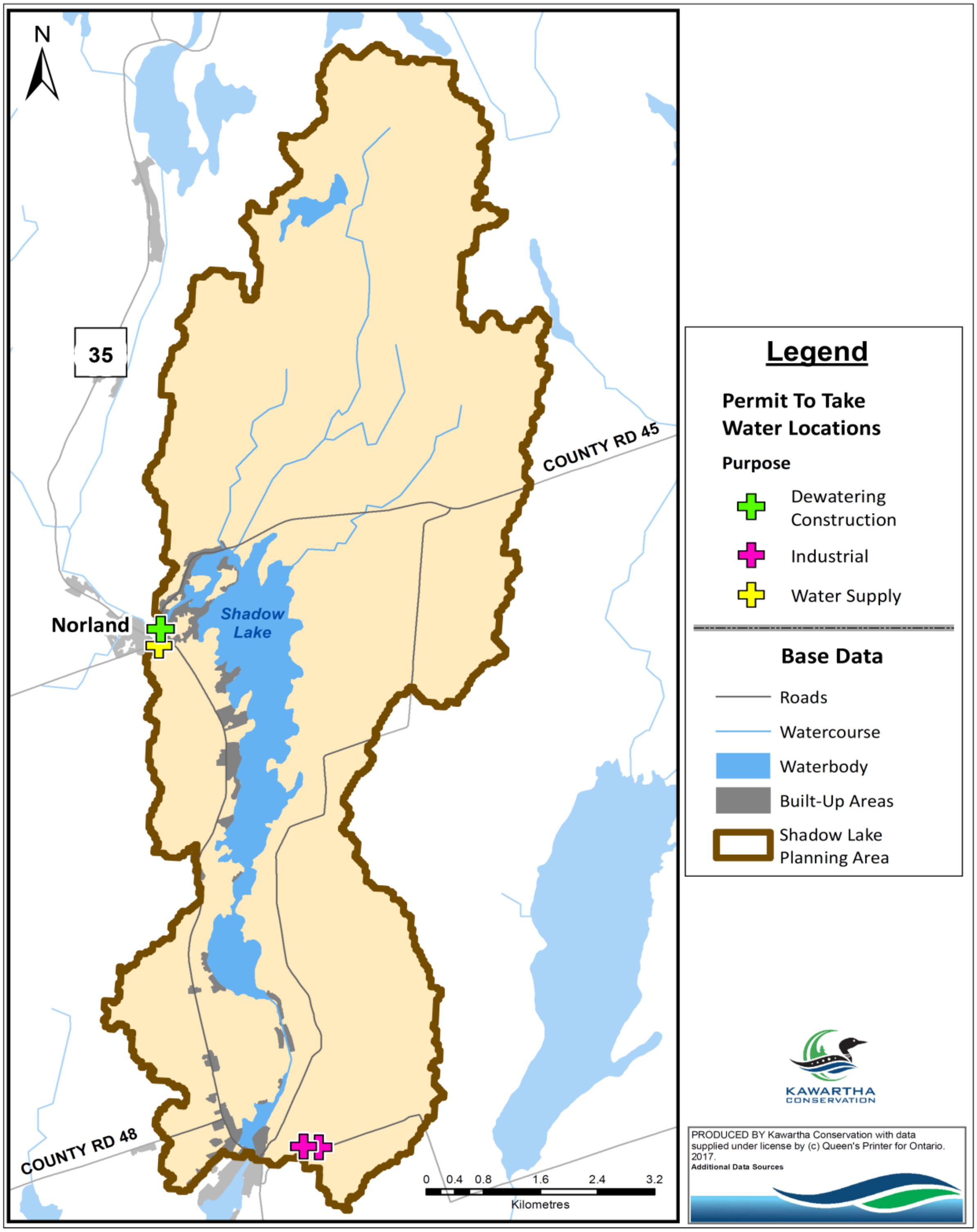


Figure 4.10. Active Permits to Take Water in the Shadow Lake Management Planning Area

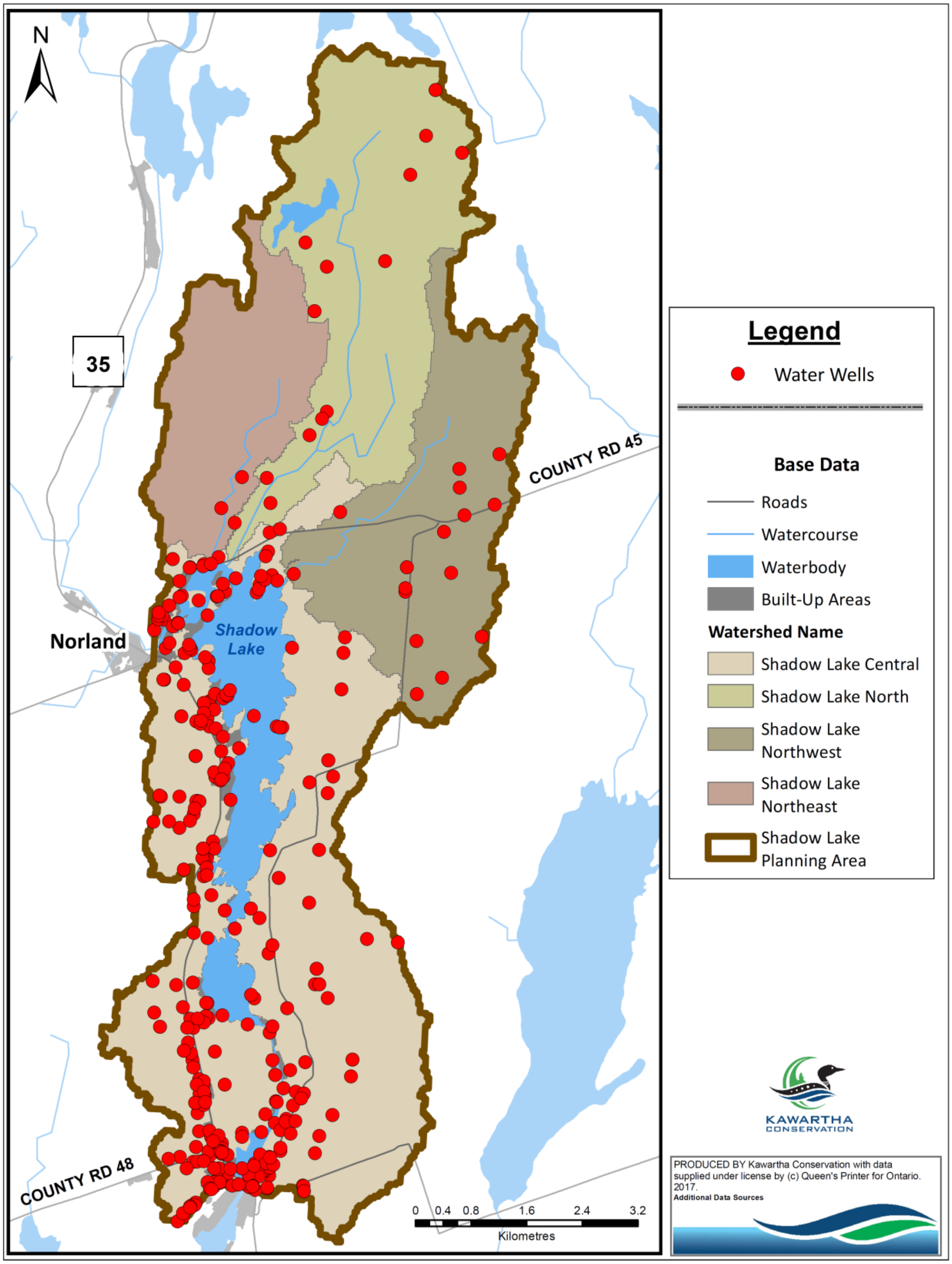


Figure 4.11. Water Wells within the Shadow Lake Management Planning Area

4.5 Water Budget

A water budget is an essential component of any hydrological and water quality study. In the framework of the Shadow 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 lakes and their tributaries as well as to determine priority areas for environmental monitoring. Moreover, the accurate water budget of Shadow Lake is crucial for 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. Total water input into the lake including sources such as precipitation, surface and groundwater inflows, discharges from sewage treatment plants and septic systems should equal the total water output from the lake such as evaporation and evapotranspiration, surface and groundwater outflows, water extraction for the water supply purposes. Therefore, the water budget equation for a lake is as following:

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

Where:
P – precipitation on the water surface of the lake,
E – evaporation 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 shorelines,
A_{out} – anthropogenic extraction from Cameron Lake for the Fenelon Falls Water Treatment Plant,
ΔS – change in lake storage,
$\pm\Delta$ – imbalance.

The combined water budget of Shadow and Silver lakes for the 2014–2015, 2015–2016, 2016–2017 hydrologic years and average for study period is shown in **Table 4.10**. The hydrologic year in Ontario begins on June 1st and ends on May 31st of the next year, and reflects the natural hydrological cycle from the beginning of the summer low water period to the end of the spring freshet. **Figure 4.12** presents inflow portion of the average water budget for Shadow Lake over period of study.

The total amount of precipitation for the lake has been measured at the Norland Dam by means of simple precipitation gauge established specifically for the lake management project. In October 2016 the TSW has established an automatic all-weather precipitation gauge. Recorded data was made available for the Kawartha Conservation project team. The amount of precipitation over the period of monitoring varied significantly. Only 793.7 mm of precipitation were recorded in 2014-2015, while next hydrological year, 2015-2016 almost 1100 mm were registered at this monitoring location. Although the precipitation amount is usually expressed in millimeters, it was converted into cubic meters for the purposes of convenient comparison with flow components.

Table 4.10. Shadow and Silver Lake Water Budget

	2014-2015		*2015 – 2016*		*2016 – 2017*		*Average*	
	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	Volume, mln. m^3	% of total supply or loss
Total water inflow:	**700.73**	**100**	**803.9**	**100**	**855.58**	**100**	**786.76**	**100.00**
Precipitation (P)	3.37	0.48	4.53	0.56	4.61	0.54	4.17	0.53
Gull River	686.97	98.04	787.75	97.98	838.93	98.06	771.22	98.02
Shadow Lake North	4.16	0.59	4.68	0.58	4.81	0.56	4.55	0.58
Shadow Lake Northeast	3.47	0.49	3.9	0.49	4.01	0.47	3.79	0.48
Shadow Lake Northwest	2.26	0.32	2.54	0.32	2.61	0.31	2.47	0.31
Shadow Lake Central	0.50	0.07	0.58	0.07	0.61	0.07	0.56	0.07
Total water outflow:	**700.81**	**100**	**804.04**	**100**	**855.69**	**100**	**786.85**	**100**
Evaporation (E)	2.6	0.37	2.6	0.32	2.6	0.30	2.6	0.33
Shadow/Silver Lake Outlet	**698.21**	99.64	**801.44**	99.68	**853.09**	99.70	**784.25**	99.67
Change in lake storage (ΔS)	-0.09		0.07		0.12		0.09	

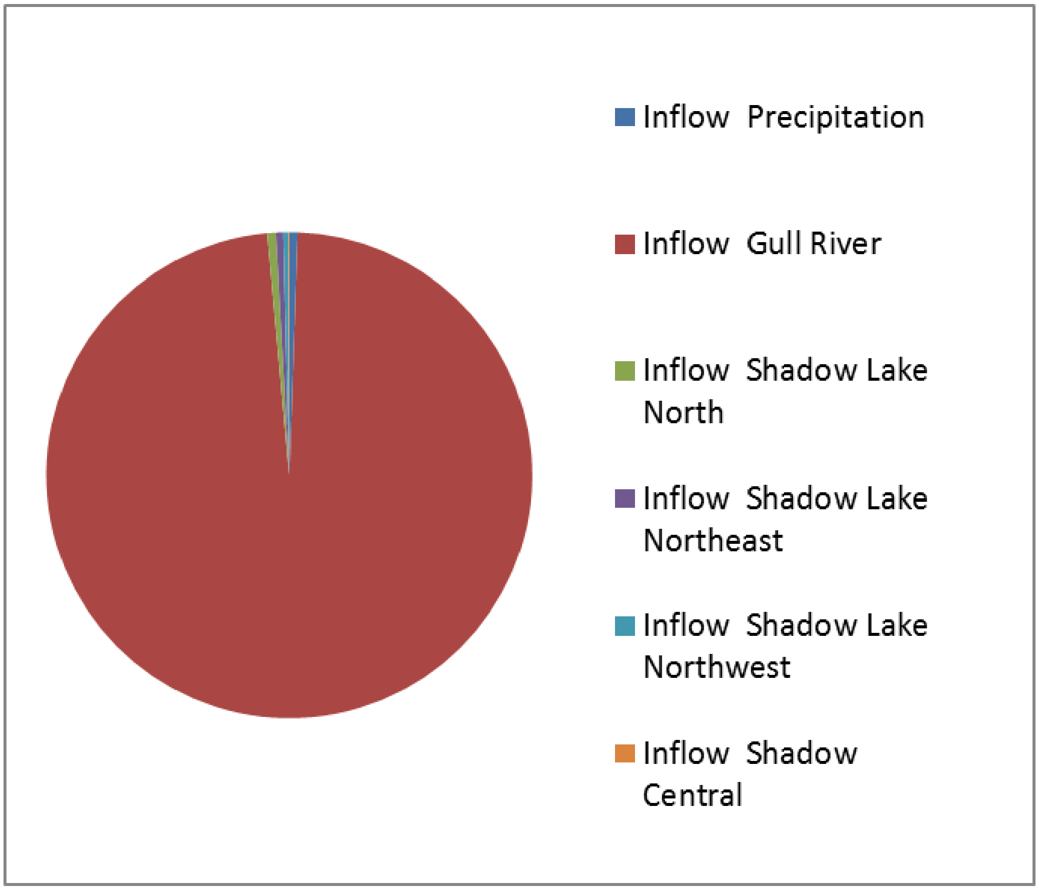


Figure 4.12. Inflow Portion of the Average Water Budget for Shadow and Silver Lakes

As **Table 4.10** and **Figure 4.12** show prevailing amount of water (98%) enter Shadow Lake through the Gull River. Three northern subwatersheds bring 1.34% of the total inflow, while Shadow Central subwatershed supplies only 0.07%.

5.0 Water Quality

Summary of Observations, Key Issues, and Information Gaps

Results and observations presented in this summary and the following chapter were obtained during a three-year monitoring period, which was initiated in 2014 and ended in 2017. The water quality monitoring network in the Shadow Lake watershed included 3 stations on the lake's tributaries across the study area, including the Gull River, the Coboconk outlet into Balsam Lake and 2 smaller northern tributaries with 2 open water sites and one precipitation sampler situated at the Norland dam.

OBSERVATIONS

- ***Shadow Lake can be characterized as an oligotrophic water body with excellent water quality.*** Average phosphorus concentrations in Shadow Lake are well within the Provincial Water Quality Objectives for lakes (below 10µg/L for naturally low TP lakes). Long term trends indicate stable low phosphorus concentrations for Shadow Lake and its tributaries which are well within the Provincial Water Quality Objectives.

- ***Nitrogen concentrations are well within the Provincial Water Quality Objectives in Shadow Lake and its tributaries (1.0mg/L).*** Organic nitrogen constitutes most of the total nitrogen amount in the lake water, ranging from 57 to 99% of TN amount. Organic nitrogen originates in living material and often enters lake water in dissolved or particulate forms as from sources such as tissues from living or dead organisms, bodily waste from animals, discarded food material, a component of cleaning agents and from organic forms of fertilizer (manure). Nitrogen, like Phosphorous, is a macronutrient in aquatic ecosystems and can lead to increased aquatic macrophyte and algae growth.

- ***Tributary and Lake E. coli monitoring results indicate that concentrations have not exceeded the Provincial Water Quality Objective with the tributaries and lake sites.*** Shadow Lake's citizen science long term monitoring program results demonstrate very low *E.coli* concentrations at all 4 sites with Shadow Lake and Silver Lake and have not exceeded the Provincial Water Quality Objective. Additionally, Kawartha Conservation conducted *E.coli* sampling in the tributaries in 2014, 2015, & 2016 which resulted in negligible concentrations which fell well within the Provincial Water Quality Objectives.

- ***Beach E. coli monitoring results indicate that concentrations rarely exceed the Provincial Water Quality Objective with the tributaries and lake sites.*** The Haliburton, Kawartha, Pine Ridge District Health Unit beach posting data (due to elevated *E. coli* concentrations) show that the public beach on Shadow Lake (Norland swim area) is posted at least once a year and twice in 2017.

KEY ISSUES

- ***Decreased dissolved oxygen concentrations in the hypolimnion at the end of season.*** End of season concentrations of dissolved oxygen in the hypolimnion are very low by the end season (September). This may also have a relationship with the increased hypolimnetic phosphorus concentrations and algal productivity within the photic zone. Further investigation is needed to determine lake productivity and any possible interconnected relationships.

- ***Higher concentrations of total phosphorus in the hypolimnion at end of season***. Although the surface water sampling resulted in total phosphorus concentrations well within the Provincial Water Quality Objective (PWQO), the bottom samples revealed slightly elevated concentrations above the PWQO (10µg/L). Further investigation is suggested to quantify internal TP inputs.

- ***Steep slopes >25% encompassing Shadow Lake.*** These steep slopes may lead to increased run off, erosion and constrain building and increase the need for the foreign fill to accommodate areas for septics and or buildings **(Garter Lee 2002)**.

INFORMATION GAPS

- ***Lack of water chemistry data for Silver Lake.*** Water sampling took place in Shadow Lake and the Coboconk outlet site was used a proxy for water quality in Silver Lake. More data from Silver Lake is needed for accurate quantification of the health of Silver Lake.

- ***No information on nearshore water quality data***. Water sampling on Shadow Lake has taken place in the pelagic zone (mid lake area), while no data exists on nearshore water quality, therefore little is known about the relationship between shoreline conditions and activities and the impacts to water quality directly adjacent to those areas.

- ***No data collected during the ice cover period on the lake.*** Winter ice cover changes the availability of oxygen below the ice and therefore all biotic systems are impacted. The decomposition of plants and algae can reduce available oxygen for fish and other aquatic organisms. A comprehensive set of data for the entire year would create a more holistic view of water quality within Shadow Lake.

- ***No data collected to determine if Shadow Lake contains any emerging contaminants.*** Emerging contaminants such as Endocrine disrupting chemicals, Pharmaceuticals and personal care products, Polybrominated diphenyl ethers and road salt. Endocrine disruptors originating from pharmaceuticals and pesticides can alter the overall physiology and reproductive health of aquatic animal species. Personal care products including microbeads can impact aquatic systems greatly and have a great effect on habitat for juvenile fish and benthic feeders. Polybrominated diphenyl ethers are a group of chemicals used as flame retardants in a number of manufactured products which bioaccumulate and are persistent in the environment and are considered toxic to the environment as defined under the Canadian Environmental Protection Act. Elevated concentrations of chloride and sodium originating from road salt can have an effect on aquatic plant and animal communities in addition to an impact on human health.

7.1 Introduction

Water quality, in either surface or ground water, can be defined as an integrated index of chemical, physical and biological characteristics of natural water. Water quality is a function of natural processes and anthropogenic (human) impacts. Natural processes such as the weathering of minerals and erosion can affect the quality of ground and surface water. Factors such as the type of bedrock and soil type can impact water quality. For instance, water samples from the northern portion of Kawartha Conservation's 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 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, gray water discharges 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) **(MOECC, 1994)** and Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) **(CCME, 2007**).

The Provincial Water Quality Objectives represent a desirable target for water quality concentrations that the MOECC strives to maintain in 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, including the most sensitive life stages of the most sensitive species over the long term 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 **(MOECC, 1994).**

Canadian Water Quality Guidelines are intended to provide protection for freshwater and marine life from anthropogenic stressors such as chemical inputs or changes to physical components (e.g., pH, temperature, and sedimentation). Guidelines are numerical limits or narrative statements based on 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 in addition to planning effectively for mitigation and remedial purposes.

5.2 Methodology

Water quality monitoring plays an important role in meeting the objectives of the Shadow Lake Management Plan. Water quality data are obtained by collecting water samples at predetermined monitoring sites across the entire study area. Intensive sampling for the purposes of the Shadow Lake Management Plan development was undertaken in 2014-2017 at three tributary/inlet sites, one outlet (Coboconk) and also two open water sampling sites on the lake **(Figure 5.1).**

The monitoring stations are dispersed across the entire watershed at key locations covering all major tributaries in a cumulative monitoring approach. The monitoring stations on the lake are located to represent the lake in its entirety (north & south portions). At each site, water samples are collected by grab method and then sent to a certified private laboratory (Caduceon, Richmond Hill) to be analyzed for total suspended solids and nutrients including ammonia, nitrites, nitrates, total Kjeldahl nitrogen and total phosphorus. Samples are collected bi-weekly year round from tributaries and monthly from May to September from the lake monitoring sites. Furthermore, pH, dissolved oxygen, conductivity and temperature readings are taken at the time of sampling using an YSI hand held multi-meter.

This report also includes total phosphorus (TP), Secchi and calcium data collected by volunteers through the Lake Partner Program **(MOECC 2017).** Total phosphorus grab samples are collected at the north site (deep spot) monthly from May to September. Secchi readings and temperature are taken by a Lake Steward on a monthly basis and recorded and submitted to the MOECC Dorset.

An analysis of alkalinity, metals, hardness, anions such as chlorides and other parameters were performed on water samples collected three times over the summer field season in 2015 (June, July & August) for characterizing baseline values. In order to characterize the bacteriological quality of surface water, all tributaries have been sampled during the summer period (2015 & 2016) for *Escherichia Coli* (*E.coli*). Additionally, surface samples were collected and analyzed for various parameters including alkalinity, metals, hardness, and anions such as chlorides to provide a baseline characteristic of the watershed.

Statistical analysis of data was completed for all YSI handheld meter parameters (conductivity, temperature, dissolved oxygen and pH), and total phosphorus (TP), total nitrogen (TN), *E.coli* and total suspended solids (TSS). Water temperature and dissolved oxygen data were also analyzed and graphically presented for the open lake monitoring sites. Final values were calculated as an average over the sampling period (2014-2017). The use of statistical tests such as a T test and One way ANOVA were performed on surface and bottom lake data as well as variation of nutrient concentration data between tributaries to determine if streams were statistically significantly different from one another. **Table 5.1** shows the site ID, location, and number of samples.

5.3 Shadow Lake Tributaries

From a hydrological point of view the Shadow Lake watershed includes all areas that supply water to the lake. This means that the Shadow Lake watershed is comprised of small local subwatersheds (Central, North, Northwest, Northeast) as seen in **Figure 5.1**.

The Shadow Lake watershed (including Silver Lake) occupies a small area (62.83km^2) located to the north east of Kawartha Conservation's jurisdiction within the municipality of the City of Kawartha Lakes. The study area for the Shadow Lake Management Plan is defined as the lowest portion of the Gull River watershed that starts at the Norland Dam and runs downstream to the dam in Coboconk and includes Silver Lake. The hydraulic regime is heavily influenced by the Gull River system and Shadow Lake is often referred to as a 'flow through' lake with a retention time of 12.5 days. The major human land use in the watershed is rural development, which dominates more than 63% of the land portion of the watershed. Development is focussed on the Shadow Lake shoreline areas. Roads occupy less than 1% of the watershed which provides opportunity for natural areas to occupy the landscape such as forests (33.9%) and wetlands (2.23%).

Water quality concerns in the Shadow Lake watershed were negligible in all tributaries and the lake. **Table 5.1** indicates the locations and number of samples taken. Nutrient concentrations, including phosphorus and nitrogen, were well within the PWQO in the tributaries; however hypolimnion (bottom of lake layer of water) (SHL4B & SHL5B) total phosphorus samples were slightly elevated. *Escherichia Coli* (*E.coli*) concentrations in all streams and in the lake were well within the PWQO (100 CFU/100ml). The public beach (Norland swimming area) has been posted twice in 2017 and at least once every year since 2007 due to elevated *E.coli* concentrations. 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.

Table 5.1. Water Quality Monitoring Stations in the Shadow Lake Watershed

Station ID	Location	Number of Samples	Most Recent Sample
SHL1	Norland Dam	69	May 2017
SHL2	Fed from South Beaver Lake	67	May 2017
SHL3	1.1km East of Shadow Lake Rd. 2.	70	May 2017
SHL4S	Mid lake (north end) surface	9	Sept 2017
SHL5S	Mid lake (south end) surface	9	Sept 2017
SHL4B	Mid lake (north end) bottom	7	Sept 2017
SHL5B	Mid lake (south end) bottom	7	Sept 2017
BC5	Outlet of Silver Lake into Balsam Lake	33	May 2017
LPP	Mid Lake (Deep site)	3	July 2006

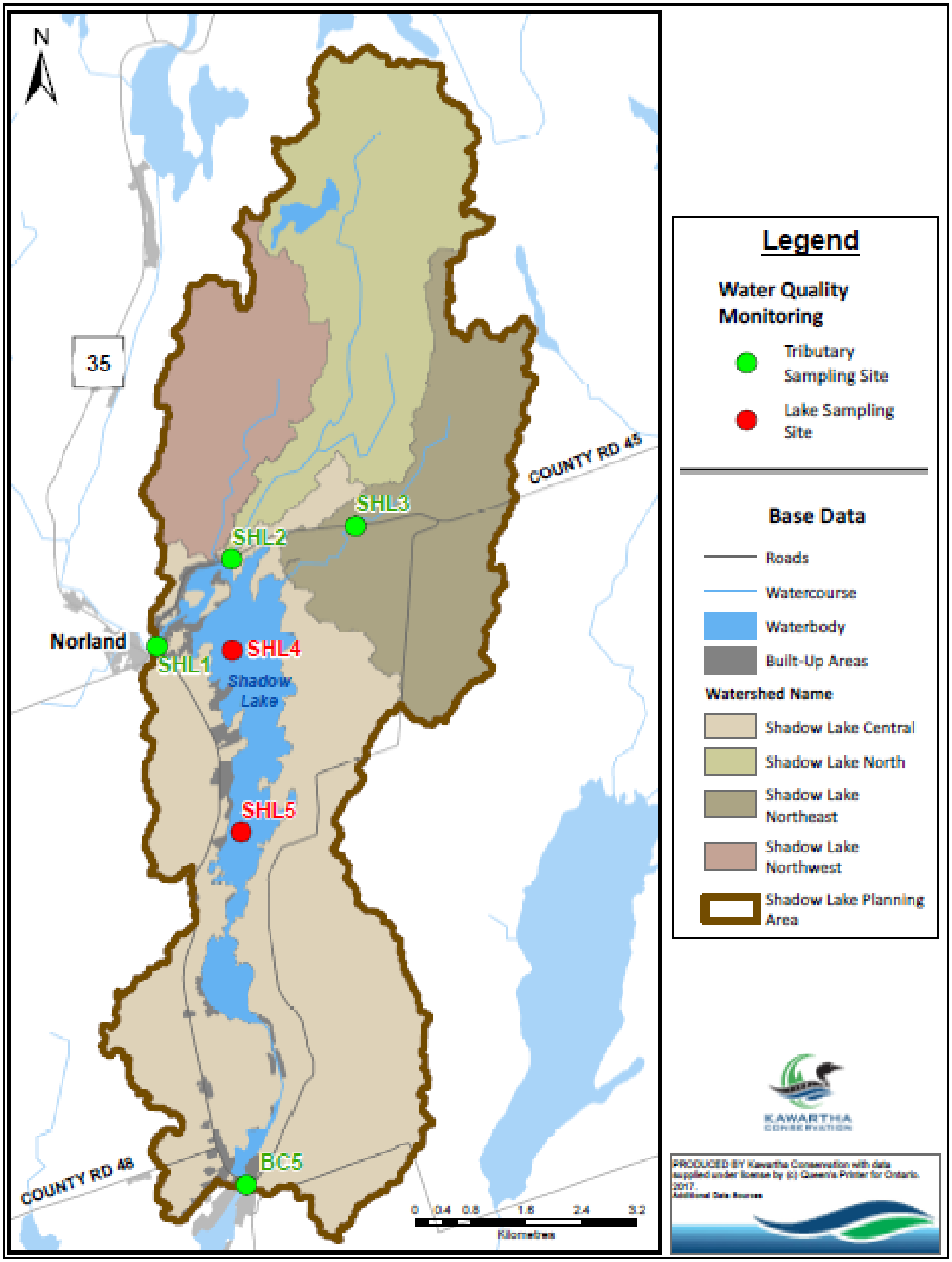


Figure 5.1. Water Quality Monitoring Stations in the Shadow Lake Watershed

Hydrometric Results

Tributary water temperatures followed a seasonal trend throughout the three year study period ranging from a maximum recorded of 26.2 ^{o}C (SHL3) in August 2015 to a minimum of 0.77^{o}C (SHL1) in January 2016 while SHL2 & SHL3 were frozen. The tributary pH values varied significantly (One Way ANOVA $p<0.001$). These variances are mostly due to the local geologic influence of the studies tributaries. Conductivity ranged from 82.7 to 522.9 (mean values) and varied significantly (One Way ANOVA $p<0.001$) following the similar expected pattern observed in pH due to geological influences.

Phosphorus

Phosphorus is one of the two primary nutrients required for the growth of aquatic plants and algae in streams and lakes. Even in elevated levels phosphorus is not considered toxic to plants and animals, but its high concentrations in water can cause the process of eutrophication, which results into excessive algal growth, and a corresponding depletion of dissolved oxygen in the water column. The PWQO for total phosphorus (TP) concentrations in watercourses is set at 30µg/L, in order to prevent nuisance algae and aquatic plant growth **(MOECC, 1994).** The PWQO for TP concentrations in lakes is 20µg/L and/or 10µg/L for those lakes with a natural TP level below this value **(MOECC, 1994)**. As Shadow Lake has historically recorded TP concentrations below 10µg/L, the PWQO of 10µg/L applies to the lake.

Total phosphorus is a measure of both soluble and insoluble phosphorus forms within a water sample. The insoluble component is primarily decaying plant and animal matter or soil particles, which either settles to the bottom or remain 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 and algae, causing increased biological productivity and plant growth. Soluble phosphorus has primarily anthropogenic origins and poses a greater threat to the ecosystem than its insoluble forms.

In the Shadow Lake watershed, average phosphorus concentrations were well within the PWQO. However, there were some exceedances of the PWQO threshold (30µg/L) during the study period. SHL2 experienced exceedances 23% of the time while SHL3 experienced exceedances only 3% of the time. The highest episodes of exceedances occurred in late summer and fall in 2016 at SHL2 and SHL3 measuring (39µg/L) & (32µg/L) respectively. These elevated concentrations are most likely due to seasonal low flow and water levels. Concentrations in the other streams of the watershed are considerably lower and never exceeded the PWQO (SHL1 & BC5) **(Figure 5.2).**

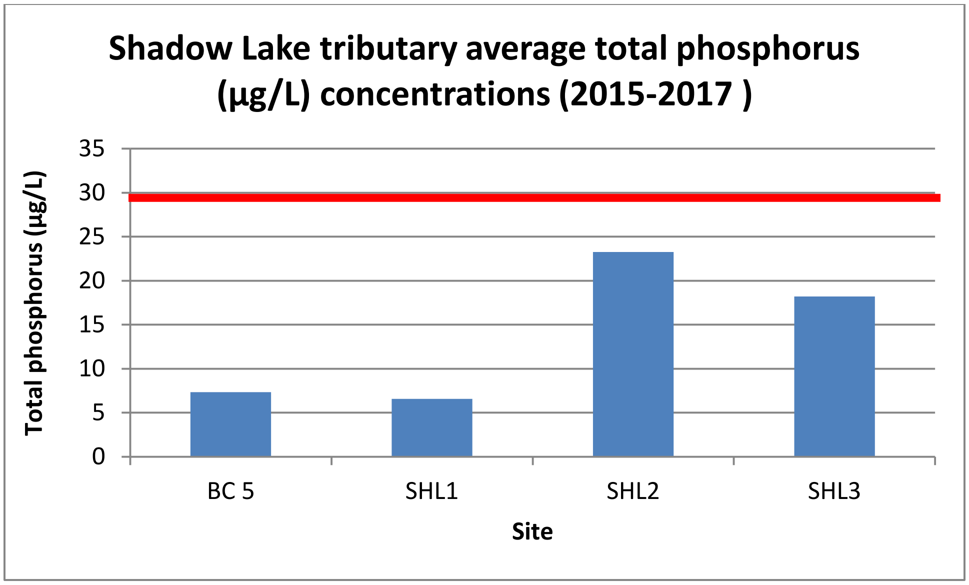


Figure 5.2. Average Phosphorus Concentrations (µg/L) in the Shadow Lake Tributaries in 2014-2017. The red line denotes the Provincial Water Quality Objective (30µg/L).

Shadow Lake Northeast (SHL1) is the lower portion of the Gull River which enters Shadow Lake. The Gull River flows through the rugged landscape of Canadian Shield in a southwesterly direction for more than 120 km before it exits Silver Lake and enters Balsam Lake at the town of Coboconk. Shadow Lake's watershed drains 1356km^2 and includes 17 lakes controlled by 21 dams (See Water Quantity Chapter for details). The sampling site SHL 1 is heavily influenced by the hydrological regime of the Gull River and its water quality further upstream. However, findings included excellent water quality with minimal concentrations of phosphorus ranging from 2µg/L to 15µg/L. The average and median phosphorus concentration measured 6µg/L.

The largest watercourse in the Shadow Lake watershed measures 10.58 km in channel length and extends to a stream network of approximately 38.56km is an unnamed stream identified as site SHL2 located in Shadow Lake North. Its origin is located further north on Precambrian Shield bedrock and includes drainage from Spar and South Beaver Lakes as well as many small wetlands. The water quality in this unnamed stream (SHL2) is considered excellent as it passes through a number of wetlands before it enters Shadow Lake. Phosphorus concentrations ranged from 5µg/L and 39µg/L. The median concentration was 17µg/L and the average phosphorus concentration over the three year study period measured 19.4µg/L which was well within the PWQO.

The northeastern portion of the Shadow Lake consists of another unnamed tributary (SHL3) which also originates from the northern Canadian Shield via a network of wetlands. It measures 6.59km in channel length and is part of a larger stream network consisting of 23.32 km of watercourses. Phosphorus levels ranged from 2µg/L and 35µg/L while the median was calculated at 17µg/L and the average total phosphorus concentration over the three year study period was 18.1µg/L and well within the PWQO. Both of these streams (SHL2 & SHL3) originate in productive healthy wetlands elevations of nutrients as a part of natural processes may occur (i.e. nutrient rich sediment, plant senescence). It is possible to suggest that high phosphorus concentrations in the creeks during dry hot weather are the result of phosphorus input (desorption) from sediments and organic material in the large wetland networks which feed both tributaries the creek.

The Shadow and Silver lakes drain through a single drainage area consisting of limestone parental rock located in Coboconk and drains in to Balsam Lake. The outlet site (BC5) has relatively low phosphorus concentrations and ranged from 4µg/L to 30µg/L. The median concentration was calculated at 6µg/L and the average total phosphorus concentrations measured 6µg/L and are well within the Provincial Water Quality Objectives (30µg/L).

Nitrogen

Nitrogen is another key nutrient vital for the development of algae and aquatic plants. Nitrogen is present in surface water in several chemical forms such as free ammonia and ammonium, nitrite, nitrate and organic nitrogen. For the purpose of analytical and/or statistical analysis, the nitrite values are often combined with the nitrate concentrations, as nitrite-ions are the transitional form of nitrogen from ammonia to nitrate-ions and are usually 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 nitrates and consist typically of 98.0-99.9% of nitrates and 0.1-2.0% of nitrites. 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.

Total Kjeldahl nitrogen (TKN) 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.

Total nitrogen (TN) includes both inorganic and organic forms of nitrogen. There is no provincial or federal guideline for total nitrogen concentrations in surface water. Alberta Environment has established a surface water quality guideline for total nitrogen at 1.0 mg/L **(Alberta Environment, 1999)**. This guideline was used by Environment Canada for reporting on water quality in Lake Winnipeg **(Environment Canada, 2013a, 2013b).** It provides us with an opportunity to use the above-mentioned guideline as a nitrogen interim guideline for streams and lakes in the Kawartha Conservation watershed. As well, the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CWQGs) set the guideline for one of the chemical forms of nitrogen in natural water namely nitrates, at 2.93 mg/L **(CCME, 2007).** This guideline was developed in order to protect freshwater life from direct toxic effects of elevated nitrate levels, which often are the result of anthropogenic contamination. Indirect toxic effects resulting from eutrophication may still occur at nitrate concentrations below the guideline value, depending on the total amount of nitrogen in water **(CCME, 2007).**

Within the Shadow Lake watershed, total nitrogen occasionally exceeded 1.0 mg/L (1% of samples). Over the three year study duration total nitrogen concentrations ranged from 0.11mg/L to 1.81mg/L. Median values ranged from 0.26mg/L to 0.57 mg/L. Average and median nitrogen levels in all streams fall below the interim guideline (Figure 5.6). There were no exceedances in the Gull River (site SHL1) & the southern outlet in Coboconk (site BC1) South, the unnamed Northern tributary (site SHL2) and a few exceedences were found in the north eastern tributary (site SHL3) at a rate of 6% of all samples.

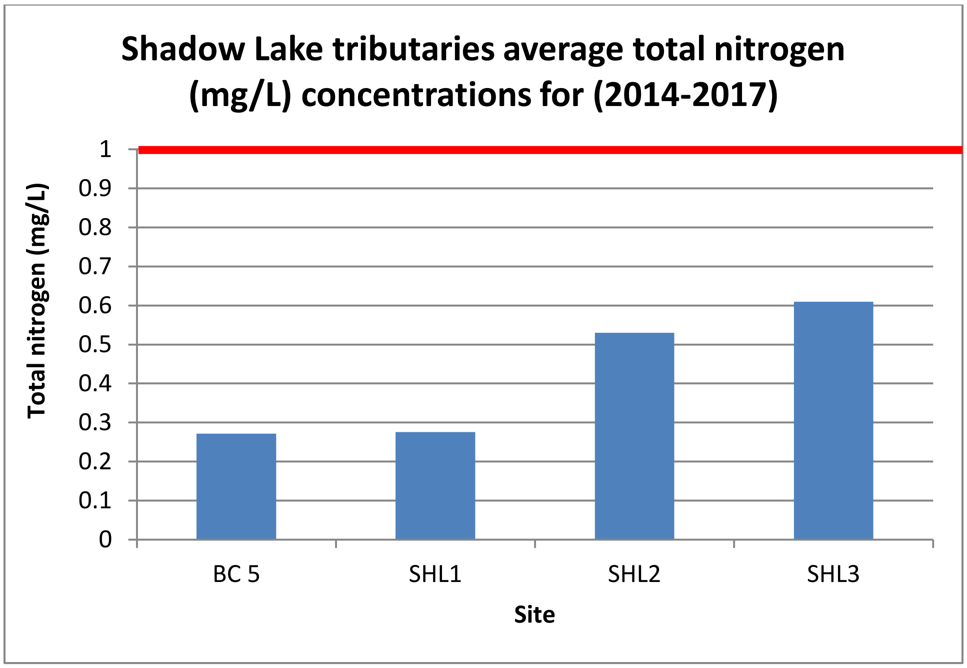


Figure 5.6. Average Total Nitrogen concentrations (mg/L) in the Shadow Lake Tributaries; Silver Lake outlet (BC5), Gull River-Shadow Lake Central (SHL1), Northern unnamed tributary (SHL2) and the unnamed Northeastern tributary (SHL3) in 2014-2017. The red line denotes the interim Provincial Water Quality Objective (1.0mg/L).

The seasonal distribution of total nitrogen in the Northeastern unnamed tributary (site SHL3) is characterized by higher concentrations during summer and fall due to low flow conditions in summer and fall and a heavy organic load as a result of naturally occurring senescence patterns of large wetlands upstream **(Figure 5.6).**

Organic forms of nitrogen as determined by the TKN analysis are higher during spring and summer. TKN values are always higher in summertime as a result of the increased biomass of phytoplankton in water and more organic matter entering streams from wetlands.

Looking at the watershed-wide scale, it appears that nitrogen levels are higher in the Northern and Northeastern unnamed tributaries (SHL2 & SHL3) as opposed to the Gull River. The Gull has a much higher discharge rate than that of the smaller tributaries in addition to originating from deep, mostly oligotrophic Canadian Shield lakes further north. Higher nitrogen concentrations observed in the Northern and Northeastern unnamed tributaries are in contrast to the Gull River and Silver Lake outlet as a result of the flow regime, however the unnamed tributaries share many similarities including originating from large wetland complexes further north. Analysis of the water quality data suggests that the higher concentrations of total nitrogen in the Northern and Northeastern unnamed tributaries is mainly associated with very high organic material from the large wetlands which feed both creeks.

The overall general trend between total nitrogen concentrations and flow over the three year study period shows highest total nitrogen concentrations during the months of August and September and inversely the flow at its lowest values. However, it is interesting to note that the month of March (early-mid) in years 2015 & 2016 also recorded higher values, but may also be a result of low flow just before the freshet.

Total Suspended Solids

Total suspended solids (TSS) may have significant effects on aquatic organisms because of shading, abrasive action, habitat alteration and sedimentation **(CCME, 2002).** 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 natural variation of TSS is so great, it is not desirable to establish a 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 located in the study area usually range from 1.0-4.0 mg/L **(Figure 5.10)** and are quite low in this watershed. Median values were very close to the mean (4mg/L) and there were no exceedances of the PWQO threshold. The maximum TSS concentration was recorded in the Northeastern unnamed tributary (SHL3) measuring 12 mg/L, during May 2016. The TSS concentrations within this stream and the Northern unnamed tributary (SHL2) are relatively slightly higher than the other streams within the study area record (average 3.07mg/L & 3.85mg/L respectively)and may be attributed to the high productivity of the wetlands upstream of the sampling site. The Gull River (SHL1) reported the lowest TSS concentrations averaging 2.14mg/L, while the Silver Lake outlet also showed low concentrations over the three year study period averaging 2.95mg/L. The high volume and flow regime of both the SHL1 and BC5 sites heavily influenced the negligible concentrations through a dilution effect.

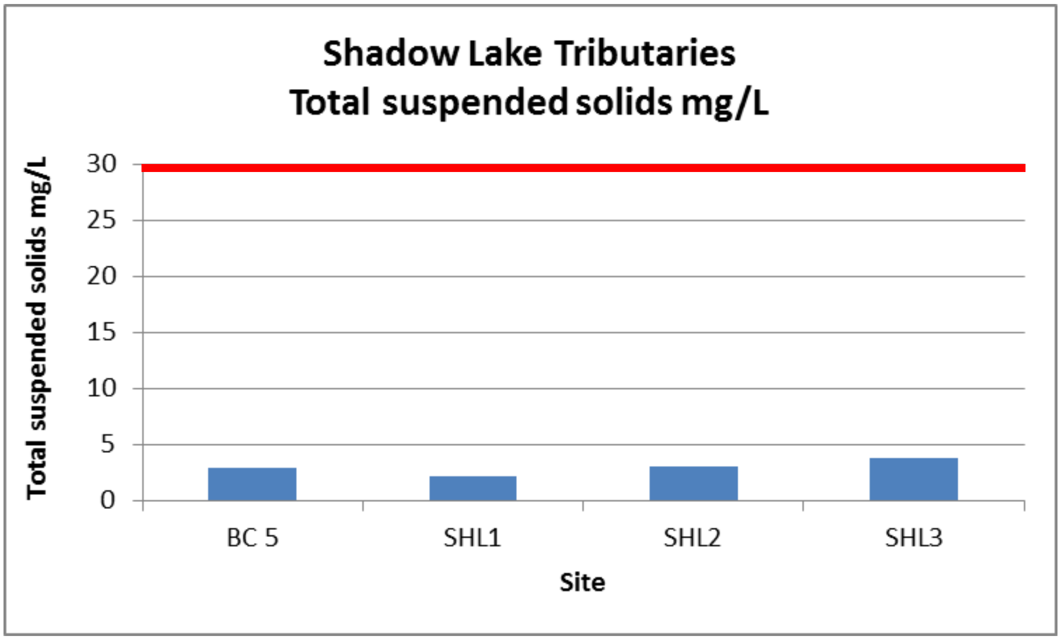


Figure 5.10. Average Total suspended solids concentrations (mg/L) in the Shadow Lake Tributaries; Silver Lake outlet (BC5), Gull River-Shadow Lake Central (SHL1), Northern unnamed tributary (SHL2) and the unnamed Northeastern tributary (SHL3) in 2014-2017. The red line denotes the CCME guideline (30mg/L).

As mentioned above, average and median TSS concentrations in all monitored streams are well below the CCME guideline. The lowest TSS concentrations were detected in the inflow of Gull River (SHL1) and at the outflow of Silver Lake in Coboconk (BC5) **(Figure 5.10).**

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 at beaches **(MOECC, 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 **(MOECC, 1994)**. The PWQO is set at 100 colony forming units per 100 mL (100cfu/100 mL) and based on a geometric mean of at least five samples **(MOECC, 1994)**.

E.coli monitoring results from 2014-2017 have revealed that all of the monitored streams in the Shadow Lake watershed have had *E.coli* levels well within the PWQO with zero exceedances. Although there were not any exceedances there was one occurrence of *E.coli* concentrations approaching the PWQO at the northeastern unnamed tributary (SHL 3). The recorded concentration was 98 cfu/100ml in July 2016. This elevated concentration may be attributed to beaver activity just upstream of the sampling site. However, due to a lack of samples a Geomean *E. coli* concentration was not calculated and the recorded values offer standalone values. *E.coli* exceedances generally followed intensive rain events and can be influenced by natural fauna such as beavers, waterfowl etc. At the same time, dry weather samples can also observe *E.coli* concentrations in excess of the PWQO that may be the result of low water volumes during dry periods and, consequently, increased stream vulnerability to contamination from natural and human-induced sources. The Haliburton, Kawartha, Pine Ridge District Health Unit beach posting data (due to elevated *E. coli* concentrations) show that the public beach on Shadow Lake (Norland Swim Area) has been posted at least once per season during the monitoring years of 2007-2017 (details in *Escherichia Coli* at Public Beaches section).

The Shadow Lake Association also participates in a citizen science *E.coli* monitoring program which samples 4 different sites on Shadow and Silver lakes. The sites are located as follows:

- **Shadow Lake**
    - **SH01 -**approximately 100 metres north of Salter's island
    - **SH02** - midway between where the Gull river enters Shadow lake at the north end and the first island south
- **Silver Lake**
    - **SI01** - approximately 50 metres off Turtle Point (road 22) near the yellow hazard marker.
- **Mill Pond**
    - **MP01** - approximately 20 metres from where the river empties into the mill pond above the dam at Coboconk.

Samples are collected five to six times a year and generally on Mondays or the day after a long weekend during the summer season. Data is disseminated through the Shadow Lake Association's newsletter and on the website. *Escherichia coli* concentrations have been monitored on Shadow and Silver Lakes since 2011 to present. All results have been well within the PWQO and averaged 4.73 cfu/100ml and a median value of 4 cfu/100ml. The maximum concentration was recorded at site SH02 in August 2016 measuring 28 cfu/100ml. The results from the *E. coli* monitoring program demonstrate the excellent water quality of Shadow Lake.

5.4 Lake Water Quality

Water quality in lakes is determined by a number of abiotic and biotic factors. Among abiotic factors it is necessary to mention the hydrological regime, lake water levels, population density and shoreline development. As well, meteorological conditions play an important role in water quality. The amount of precipitation, solar radiation, number of sunny days, wind conditions, and average annual air temperature are factors that have a significant effect on water quality in lakes.

Biotic factors also play an important role in influencing lake water quality factors such as 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 a lake and competition between them for nutrients, light and oxygen. Lake depth can have a considerable effect on the amount of phosphorus and nitrogen in the water and their movement through the water column.

Overall, Shadow Lake can be characterized as an oligotrophic water body based on phosphorus concentrations in the lake water in recent years and Secchi disk depth readings. The phosphorus concentrations are well within the Provincial Water Quality Objectives for lakes (below 10µg/L for naturally low TP lakes) **(Figure 5.11).** Additionally, both bottom and surface samples were analysed for total phosphorus concentrations in the northern and southern sampling sites, SHL4 & SHL5 respectively. Bottom phosphorus concentrations were slightly elevated beyond the naturally low TP lakes (10µg/L PWQO) and will be discussed in greater detail later in the chapter. Secchi disk depth readings usually ranged between 4.0m and 5.6m over the three year study period and averaged a depth of 4.0 confirming the high water quality of the lake and mirroring the average historical Secchi depth of 4.0m, recorded in 1986 **(MOECC 1986).**

Unfortunately, Silver Lake was not sampled during this study and has been identified as a data gap. However it more than likely mirrors the water quality of Shadow Lake.

Phosphorus

Shadow Lake transverses the boundary between the Canadian Shield to the north and the St. Lawrence Lowlands to the south. Shadow Lake is five times larger than Silver Lake and slightly deeper as well having a maximum depth of 22m and mean depth of 7.8m compared to a maximum depth in Silver Lake of 16m, and a mean depth of 6.8m **(OMNRF 2017)**. Lake data (surface samples) collected for this study included representative sites in both the North and South portions of Shadow Lake named SHL4 and SHL5 respectively. The Northern and Southern basins consist of similar hydrographic features, but differ in the intensity of hydrological regimes including the influence of the Gull River discharge volumes. Both basins are also influenced to some degree by abiotic anthropogenic factors including the high density of development including private septic systems along the shores.

Overall total phosphorus concentrations for Shadow Lake were indicative of a non-enriched system (7.30µg/L). Concentrations were similar in both sampling sites (SHL4 and SHL5) representing the comparative depths of the basins measuring. Average concentrations of total phosphorus ranged from 4µg/L to 13µg/L over the three year study period **(Figure 5.11)**.

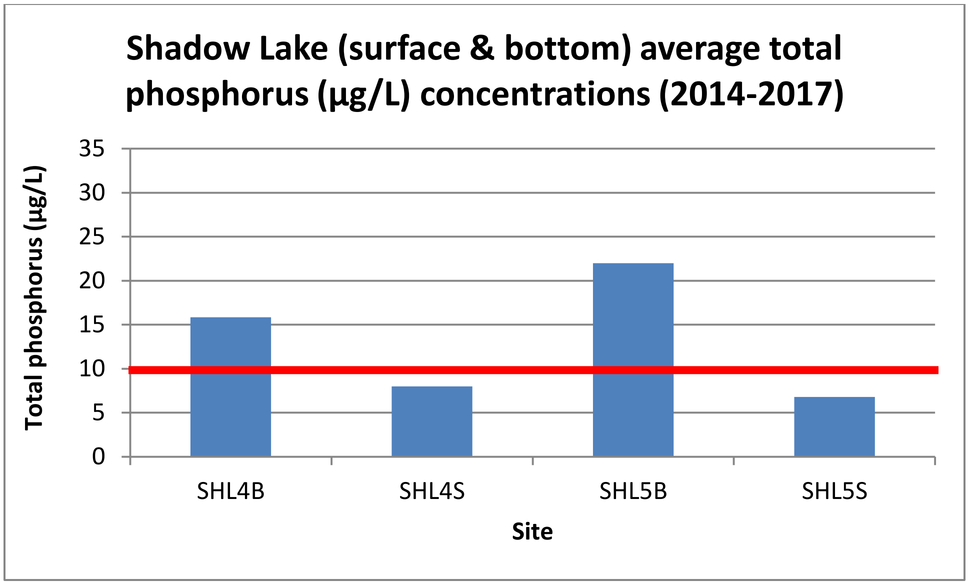


Figure 5.11. Average Phosphorus Concentrations in Shadow Lake during the three year study period (2015-2017). The red line denotes the PWQO (10µg/L).

There was one episode of total phosphorus exceeding the limit of the Provincial guideline limit (10µg/L) in surface samples in August of 2015 (13µg/L). All other results were well within the PWQO. Over the three-year period, phosphorus levels in the northern and southern parts of the lake followed the same low general trend. However, it seems that phosphorus concentrations in 2015 were higher than in 2016 expressing total phosphorus averages of 8.4µg/L and 6.6µg/L respectively, although there was no statistical significant variation between the two years.

The long-term data collected through the Lake Partner Program (LPP) by local lake associations and volunteers since 2003 demonstrate that phosphorus concentrations in the lake are quite stable and well below the Provincial Water Quality Objective **(Figure 5.12**). There is one monitoring station in the framework of the LPP on Shadow Lake. It is located within the deepest spot of the lake which Kawartha Conservations has used as SHL5 for the duration of this study to ensure data collection consistency.

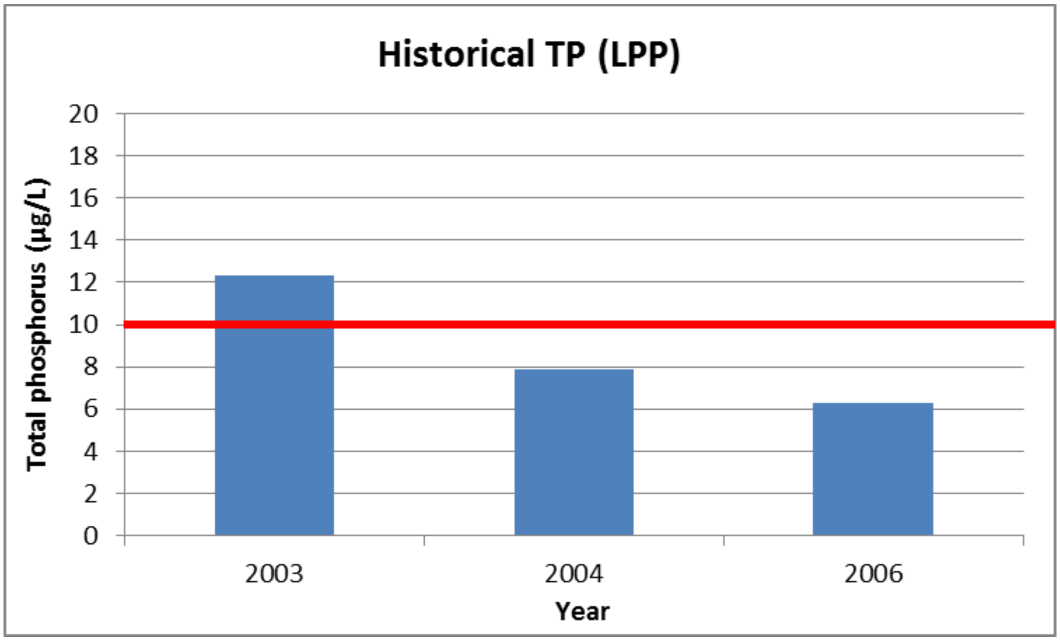


Figure 5.12. Average Annual Phosphorus Concentrations (µg/L) in Shadow Lake for the Period of 2003 – 2006 (Lake Partner Program Data). The red line denotes the PWQO (10µg/L).

Average annual TP concentrations have decreased significantly since 2003 and demonstrates a current low stable concentrations. The 2014-2015 LPP data correlates very well with our own data and follows similar trends **(Figures 5.12).** Mean and median values were practically the same over the twelve year duration measuring 0.006mg/L and 0.005mg/L respectively. There were no exceedences reported. During the period of monitoring the number of samples did not vary significantly between years and can be considered reliable data points to be considered in the context of this report.

In addition to collecting surface water samples Kawartha Conservation also examined bottom water samples (1m above bottom) at both the northern and southern sites (SHL4 & SHL5). The bottom samples were collected at the same interval as the surface samples and analyzed for total phosphorus and nitrogen including the various fractions (NO^2, NO^3, NH^3).

Sediment in lakes can contain much higher phosphorus concentrations than the water, so retrieving hypolimnetic water samples are important to quantify as a possible internal loading mechanism via the release of phosphorus from sediment. In highly oxygenated lake bottoms the inorganic transfer of phosphorus from the water column to the sediment is unidirectional to the sediment, however in low level or no oxygen situations a combination of low/no oxygen levels and a chemical catalyst (Ferrous sulfide precipitation) which results in a removal of iron from the sediment and thus a release of phosphorus to the bottom layer of water (hypolimnion) which then is circulated throughout the water column during periods of low to no dissolved oxygen **(Wetzel 1983).** Although minimal, the role of phospholizing bacteria is also a contributor of internal phosphorus loading from sediment sourcing.

Shadow Lake samples exhibited on average high total phosphorus concentrations in bottom samples of the lake (pooled SHL4 & SHL5 data) ranging from 7µg/L to 44µg/L over the three year study period. The average concentrations at SHL4 and SHL5 measured 16µg/L and 22µg/L respectively. We have applied the PWQO of 10µg/L (for naturally occurring low TP) and recorded that 75% of all bottom samples exceeded the PWQO **(Figure 5.13).**

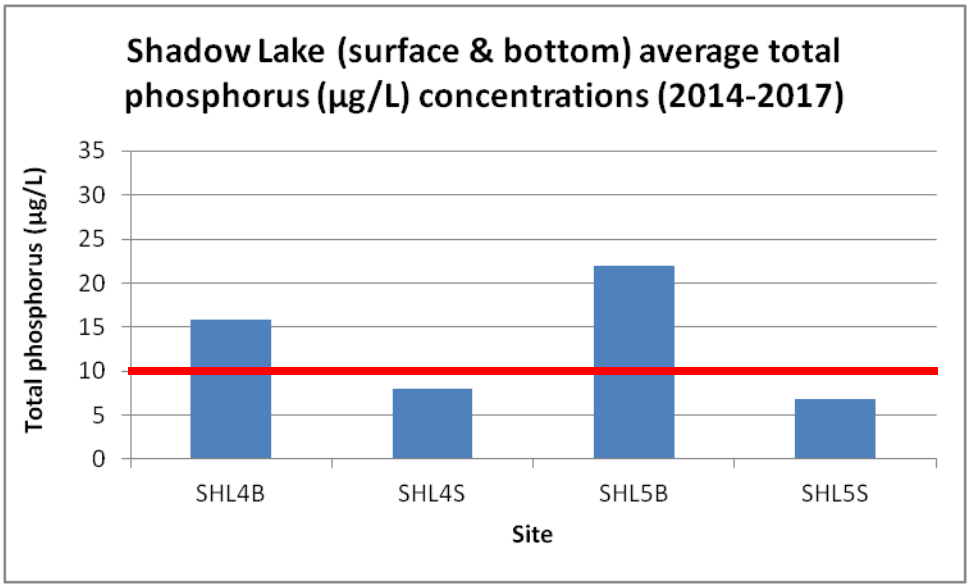


Figure 5.13. Average bottom phosphorus concentrations in Shadow Lake during the year study period (2014-2017). The red line denotes the PWQO (10µg/L).

Coincidently, dissolved oxygen levels were very low at both SHL4 and SHL5 sites and with very low dissolved oxygen concentrations recorded at 0.26 mg/L as end of season values. Unfortunately, these low levels are not optimal for various fish species recruitment or survival (see Aquatic Ecosystems Chapter 6 for details). In order to understand the drivers of the oxygen depletion it is suggested that more comprehensive studies including chlorophyll *a* or phytoplankton community dynamics should be undertaken in the future in addition to more robust bottom sampling.

Silver Lake bottom samples were not collected as part of this study and identified as a data gap.

Nitrogen

The results of nitrogen analysis in surface open water sampling sites (SHL4 & SHL5) in Shadow Lake showed values well within the Provincial Interim Guideline of 1.00mg/L of total nitrogen **(Figure 5.14).** In Shadow Lake overall (pooled site data) total nitrogen concentrations fluctuated over the range of 0.14 – 0.35 mg/L. Both sites (SHL4 & SHL5) exhibited very similar results and had recorded average concentrations of 0.25mg/L and 0.24mg/L respectively. The highest and lowest TN levels were recorded at site SHL5 with a maximum of 0.35mg/L, and a minimum recorded concentration was 0.14mg/L **(Figure 5.14).** The median of both sites were also mirrored each other and was calculated at 0.28mg/L.

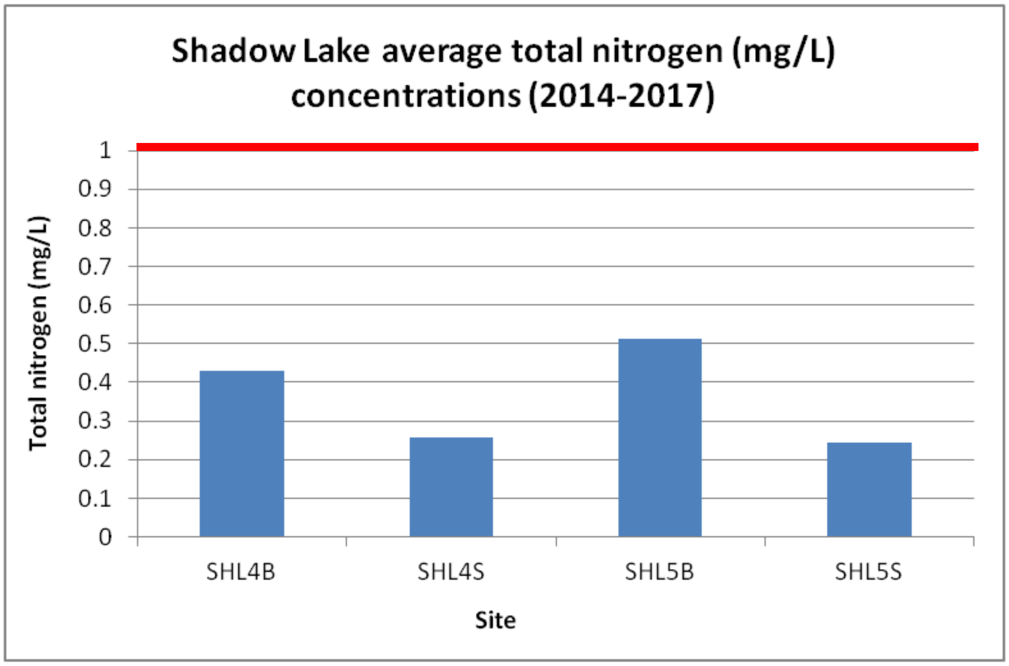


Figure 5.14. Average Total Nitrogen Concentrations (mg/L) in Shadow Lake during the May-September period in 2014-2016.

The low total nitrogen levels may be attributed to the limited amount of agricultural areas as vectors of nitrogen inputs in addition to inputs from well-established wetland complexes further north.

Hypolimnetic samples also showed low nitrogen concentrations, albeit slightly higher than the surface sample sites, but well within the interim PWQO. Total nitrogen concentrations (pooled data- SHL4B & SHL5B) ranged from 0.29mg/L to 0.73mg/L. Total nitrogen concentrations averaged 0.49mg/L **(Figure 5.14).** The maximum concentration was recorded in July 2015 at site SHL5B while the lowest recorded valued was recorded at site SHL4B in June 2016. The influence of flow from the Norland dam influences the hydrology, including the short residence time (12.5 days) and thus the water chemistry of Shadow Lake. A possible correlation between flow and nitrogen concentrations should be examined further and identified as a data gap.

Organic nitrogen (total Kjeldahl nitrogen minus ammonia) constitutes most of the total nitrogen amount in the lake water, ranging from 57% to 99% of total nitrogen amount and averaging at 92%. Nitrate levels tend to be lower in the spring and through most of the summer as a result algal utilization and denitrification by bacteria and concentrations during this period were mostly below the laboratory detection limit (0.02 mg/L) or in the range just above the limit – 0.02-0.03 mg/L. The maximum nitrate concentration was recorded in July 2015 measuring 0.04mg/L and well within the Provincial Water Quality Objectives (2.63 mg/L). Hypolimnetic samples reflected the same trend of low concentrations ranging from 0.02 to 0.35mg/L and were well within the PWQO.

Dissolved Oxygen

Dissolved oxygen (DO) is one of the most important parameters in natural water. It is extremely vital for fish and other forms of aquatic life. Major sources of dissolved oxygen in water are the atmosphere and photosynthesis by aquatic vegetation and algae **(CCME, 1999).** DO in lakes is consumed mainly for oxidation of organic matter at the sediment-water interface and within the water column as well as for bacterial, plant and animal respiration **(CCME, 1999).** Excessive input of phosphorus and nitrogen into lakes can lead to over-abundant development of aquatic vegetation and/or algae. The resulting plant die-off and decomposition causes an accelerated depletion of DO levels in the hypolimnion (bottom deep water layers) affecting the well-being of aquatic organisms.

Extremely low hypolimnetic DO levels have a negative effect on lake ecosystems. When a deficit of dissolved oxygen in the near-bottom layers of lake water occurs, processes of phosphorus desorption from lake sediments can be initiated and can have a significant effect on phosphorus concentrations in water. Acute deficit of dissolved oxygen in combination with low pH values creates a reducing environment (negative Eh values) in both bottom sediments and the water – sediment interface that causes the intensive process of desorption of previously adsorbed phosphorus from sediments. As well, low redox potential can lead to mineral dissolution of iron-phosphorous, manganese-phosphorous and aluminum-iron-phosphorous minerals present in the lake sediments. As a result, elevated concentrations of phosphorus as well as iron and manganese can be observed in the bottom layer of the lake water.

The PWQOs have several numerical limits for the dissolved oxygen, which depend on the type of water biota and temperature of water. For the warm water biota, the objective varies from 4 mg/L at 25 ^{o}C to 7 mg/L at 0 ^{o}C and the percent of DO saturation stays at 47% **(MOECC, 1994).** For the cold water biota the objective varies from 5 mg/L at 25 ^{o}C to 8 mg/L at 0 ^{o}C and the percent of DO saturation varies from 54 to 63% **(MOECC, 1994).** The CWQGs for the Protection of Aquatic Life have somewhat more stringent DO limits. For warm water organisms the lowest acceptable DO concentration is 5.5 mg/L and for the cold water organisms the lowest acceptable concentration is 6.5 mg/L **(CCME, 1999).** (See Aquatic Ecosystems Chapter 6 for more details).

End of Season Dissolved Oxygen

End of season hypolimnetic dissolved oxygen data provides good information in terms of fish recruitment and relationship to algal and macrophyte productivity. Hypolimnion oxygen depletion is a natural occurrence in many stratified lakes such as Shadow Lake as a result of oxygen used to decompose organic material. However, it is important to note that shoreline development and other anthropogenic practices will produce an effect on the lake. All end of season dissolved oxygen concentrations followed unexpected similar trends of a sharp decline in oxygen earlier than anticipated **(Figure 6.18).** In the summer of 2015, within the south basin, dissolved oxygen concentrations throughout the water column follow a similar general trend as water temperatures, with highest values recorded in the epilimnion (7.47 to 6.86 mg/L), rapid declines within the thermocline (6.86 to 2.53 mg/L) and the lowest values within hypolimnion (2.53 to 0.11 mg/L). The northern basin exhibits this same regime only in surface waters to a depth of 9m. From this depth dissolved oxygen steadily increases up to 5.39 mg/L at 13m and then steadily decreases again to 0.26mg/L at the lake bottom. The reasons for the increase in dissolved oxygen are not clear, but could be related to influences from Gull River inflow or in-lake productivity (refer to Aquatic Ecosystems chapter for more details). Further investigation is needed.

Calcium

Calcium (Ca) is an essential building block for all living organisms. Small microscopic animals called zooplankton such as Daphnia spp. (water fleas) use calcium from the water column to build their protective body covering during the moulting process **(MOECC 2016).** Larger animals such as crayfish, amphipods and clams also use calcium to make their shells. Calcium enters our lake via atmospheric deposition & mineral weathering into the soils and enters the lake by leaching from soil. According to the MOECC the two anthropogenic contributors to calcium decline including acidic deposition and forest harvesting practices (2016).

A deficit of calcium entering our lakes began in the early acid rain period (early –mid 1900s) where more calcium was leaving the watershed soils at a faster rate than it could be replenished through weathering processes and atmospheric inputs. At this point in time studies conclude a consequence of accelerated leaching rates calcium levels may have resulted in increased calcium concentrations in some lakes **(Smol et al 2008).** A change in environmental laws was the impetus to a significant decline of acid deposition from rain has declined significantly (approximately 50% less) which translates into decreased calcium leaching to lakes from surrounding watershed soil. According to Smol et al (2008) the impact of little to no calcium replenishment has resulted in decreased concentrations in some lakes within central Ontario.

Additionally, climate change has been identified as potential accelerator to calcium level declines due to the warming of the lakes **(MOECC 2016).** Part of the Ministry of the Environment and Climate Change's citizen science program, the Lake Partner Program includes volunteers collecting calcium samples for analysis on a monthly sample collection **(MOECC 2017)**. The calcium threshold for ecological consequences such as zooplankton community shifts (i.e cladocerans) is 0.5mg Ca/L whereas the threshold for crayfish is a bit higher at 1-2.5mg/L. Unfortunately, Shadow and Silver Lake are data deficient for current calcium concentrations. According to 2009 MNRF Broad Scale Monitoring program calcium concentrations in both lakes measured 10 mg/L **(MNRF 2017).**

Escherichia Coli at Public Beaches

The Haliburton, Kawartha, Pine Ridge (HKPR) District Health Unit monitors bacteriological contamination at one public beach, which is located on Shadow Lake Rd 3 **(Figure 5.15).**

In order to ensure that the lake beaches are safe for swimming, Health Unit inspectors collect water samples for *Escherichia coli* analysis every week from the beginning of June until the end of August.

The Haliburton, Kawartha, Pine Ridge (HKPR) District Health Unit's *E.coli* data for 2011-2017 demonstrate that the beach at Shadow Lake (Norland Swim Area) generally has good bacteriological water quality.

Closures have been limited to approximately one posting per year. However some exceedances have occurred over the past five years. The highest *E. coli* concentrations and subsequent increased frequency of postings occurred during the summer of 2017 **(Figure 5.16**). The beach was posted twice in 2017 and exceeded the geometric mean of 100cfu/100ml 20% of the time (June to August).

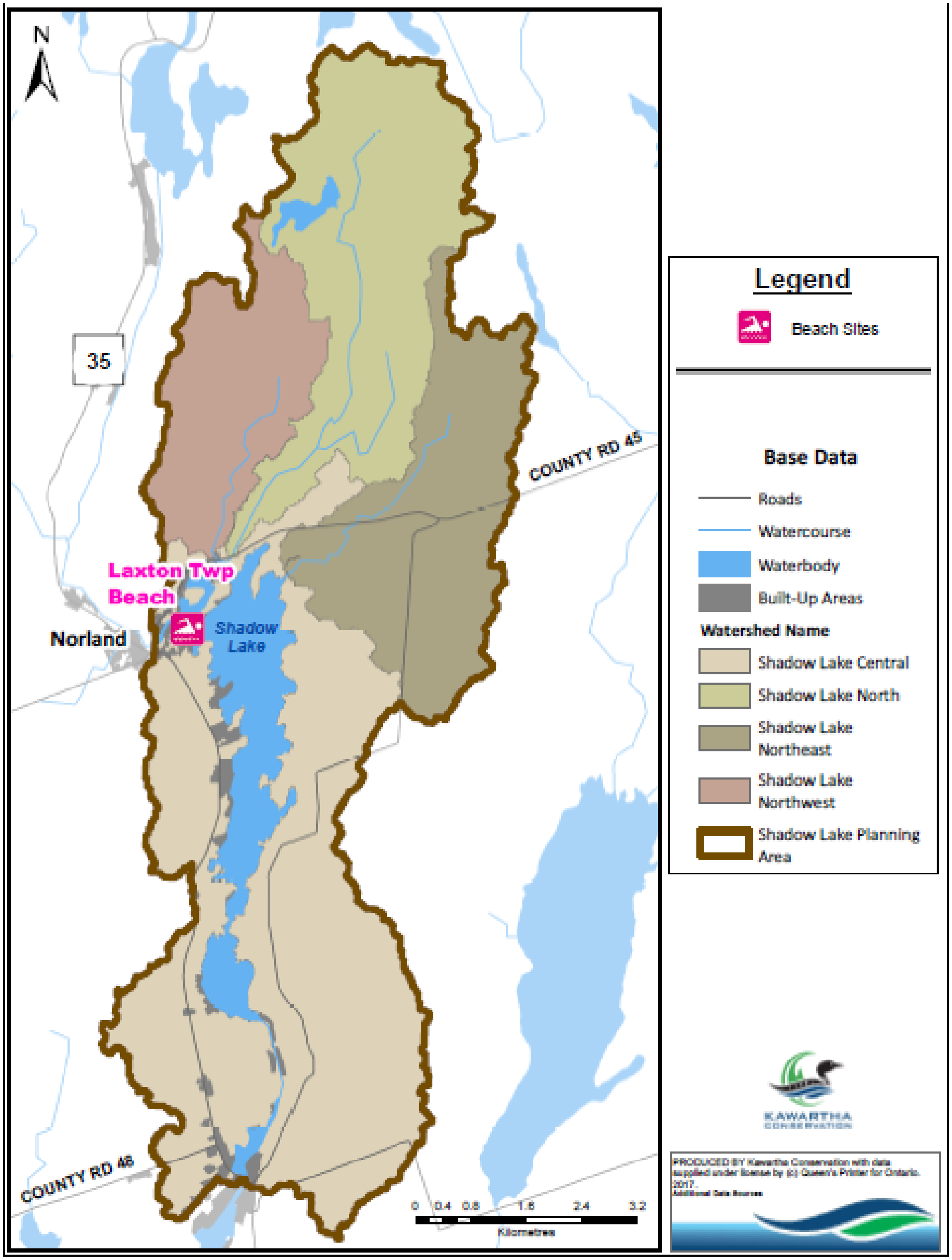


Figure 5.19. Public Beach Location within Shadow Lake Watershed.

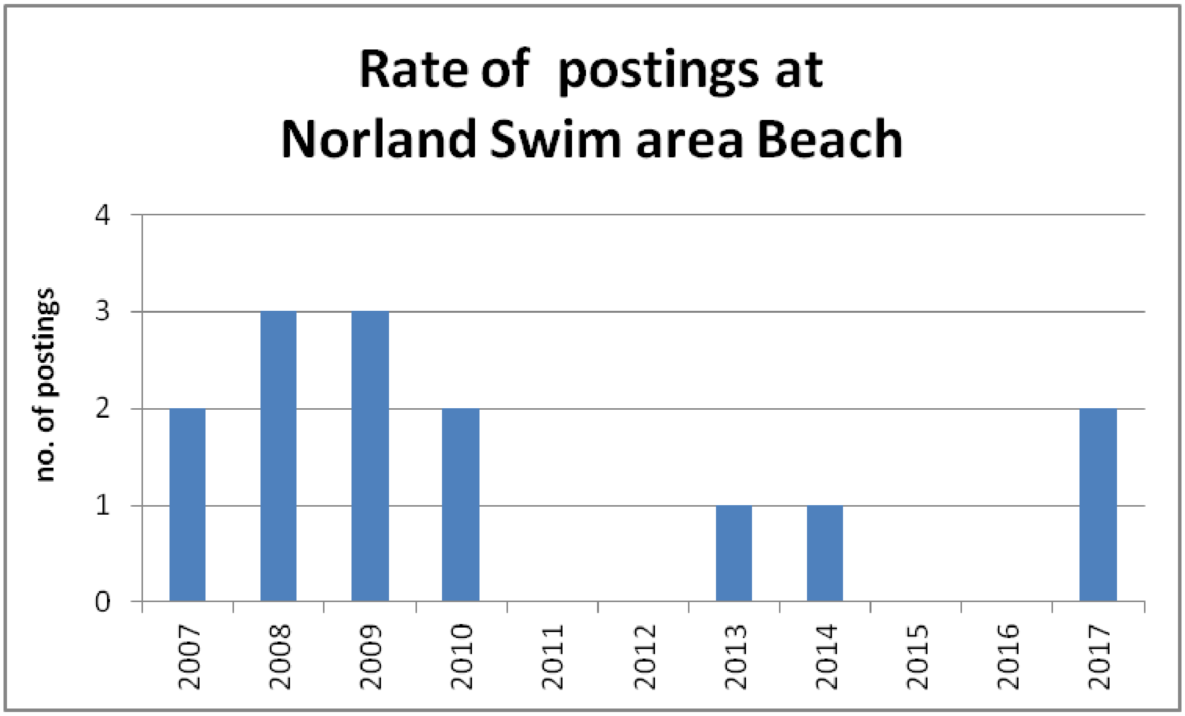


Figure 5.20. Annual Geometric Mean *E.coli* Concentrations (100cfu/100ml) at the Shadow Lake Public Beach (Norland Swim Area).

6.0 Aquatic Ecosystems

6.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- ***Shadow Lake and Silver Lake support diverse fish communities that contribute to a functioning warmwater recreational fishery.*** Approximately 20 fish species have been documented within Shadow Lake and Silver Lake, many of which are important (e.g., walleye, smallmouth bass, muskellunge) in supporting a small recreational fishery. According to the most recent available data (2009), the fish community in Shadow Lake and Silver Lake consists of warm- and cool-water species dominated by yellow perch, smallmouth bass, rock bass, white sucker, walleye, bluegill, muskellunge, and cisco.

- **Shadow Lake supports sensitive, coldwater fishes.** Coldwater native coldwater fish species, including cisco, mottled sculpin, and trout-perch, have also been documented in the lake. These fishes are able to persist likely because of deep basins which thermally stratify during the summer months. No known fish species listed as Special Concern, Threatened or Endangered have been documented. Thermal regime sampling suggests that coldwater stream communities are likely present in the middle reaches of SL_Northeast Subwatershed (in the vicinity of Shadow Lakes Road 10).

- ***Aquatic habitat conditions within the lake, and along the shoreline, are not considered to be impaired to any significant degree.*** According to a recent shoreline survey, approximately 11% of the shore/water interface has been modified by artificial materials, such as concrete, steel, and other non-natural materials. This is a relatively low number given that development exists along approximately 54% of the shoreline within 30m of the lake. According to the most recent survey, nearshore areas of the lake provide ample diversity to aquatic habitat.

- ***Aquatic habitat conditions along the creeks draining directly into Shadow and Silver Lakes are of excellent quality, owing to the lack of human disturbance.*** Subwatersheds that drain directly into the Shadow Lake planning area have exceptional coverage of natural areas, particularly forests and wetlands. Along creek corridors, natural riparian areas comprise over 95% of their entire length, and are within acceptable guidelines for maintaining aquatic ecosystem health. This is substantiated by exiting benthic macroinvertebrate communities.

KEY ISSUES

- ***Establishment of non-native, invasive aquatic species that alter the aquatic ecosystem.*** Shadow Lake and Silver Lake have been exposed to a variety of non-native aquatic species, particularly fishes (common carp, walleye, bluegill, black crappie, rainbow smelt). There is limited data available for the lakes and subwatersheds draining directly into the lake, but yellow iris has been confirmed in 2017. Within the larger Gull River watershed, the following have been reported at present: Chinese mystery snail, rusty crayfish, common reed, and European frog-bit. In addition to these existing non-native species, there are others that are at immediate risk of becoming established (e.g., zebra mussels, round goby). Proliferations of non-native species are considered invasive when they have negative ecological and economic impacts. The hydrological interconnectedness, and close proximity of Shadow Lake to the Gull River and Kawartha Lakes are likely contributing factors in the spread of invasive species.

- ***Climate change has the potential to continue to alter aquatic ecosystem conditions.*** The impacts of climate change will emanate from well beyond the watershed, and could 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 that on a provincial scale 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 and can lead to reduced populations (or elimination) of cisco, trout-perch, and mottled sculpin. Dissolved oxygen and temperature profiles already indicate less than optimal habitat availability for cisco, the reason for which remains poorly understood.

INFORMATION GAPS

- ***Limited understanding of changes to fish community composition and recreational fishing effort.*** Fish communities have only been assessed periodically within the last 45 years, and there has been no standardized approach, making determinations in community shifts and trends unreliable. Fortunately, the Ontario Ministry of Natural Resources and Forestry has initiated its Broad-scale Monitoring Program, through which the fish community and angling activity on Shadow Lake and Silver Lake will be routinely monitored approximately every 5 years. To date there has been one round of surveys under this program, 2009. Tracking trends in top predator fishes, those that contribute to the recreational fishery, sensitive species (e.g., coldwater fishes), and invasive species are particularly important.

- ***Limited understanding of how stressors such as climate change, cumulative development and invasive species will impact the aquatic ecosystem.*** Aquatic communities within the lake have been altered throughout the years in response to various pressures, particularly from the introduction of invasive species. It is important to have a comprehensive understanding of how stressors interact within the lake and its watersheds, for example, by determining lake capacity thresholds. Currently, no known standards exist for determining what constitutes a "healthy aquatic ecosystem" that is specific to Shadow Lake or its tributaries.

- ***Limited understanding of coldwater aquatic habitat and communities.*** Coldwater fishes are present within Shadow Lake (e.g., cisco, trout-perch, mottled sculpin), and likely within certain sections of its tributaries (e.g., SL_Northeast Subwatershed), however there is limited reliable data on important metrics such as species composition, relative abundance, and habitat occupancy. Routine netting programs (aside from the recently implemented Broad-scale Netting program), within the Kawartha Lakes have typically not focused on assessing coldwater fish populations. Coldwater species are sensitive to ecosystem change and as such are useful as indicator organisms in monitoring programs.

- ***Lack of aquatic community data along tributaries, and in Silver Lake.*** Much of the available aquatic community data is only available for fish communities in Shadow Lake. Silver Lake has only been assessed once, in 2009, and there is next to no fish data within streams, in large part due to the remoteness of aquatic habitat (lack of access) within those areas.

6.2 Introduction

This chapter provides an overview of important components of the aquatic ecosystems of Shadow Lake and Silver Lake. An aquatic ecosystem consists of biotic or living things within water bodies and their relationship to, and connection with, other living and non-living components. Maintaining healthy aquatic ecosystems is integral in maintaining healthy lakes.

Below is a characterization of aquatic life (communities of species, particularly fishes) and aquatic habitats (features and functions that maintain life) that exist/interact within the lake and its tributaries.

6.3 Lake Ecosystems

6.3.1 Aquatic Habitat

The lake exists in south-central Ontario within a landscape transitional area between the Canadian Shield and St. Lawrence Lowlands, with the underlying bedrock is the southern parts of the lakes are predominately limestone, while in the north it is predominantly granite. Shadow Lake is five times larger than Silver Lake, and slightly deeper as well having a maximum depth of 22m and mean depth of 7.8m compared to a maximum depth in Silver Lake of 16m, and a mean depth of 6.8m **(OMNRF 2017**). The lakes are hydrologically connected to each other, as well as to the Gull River watershed, and to the Kawartha Lakes through Balsam Lake. Their water levels and major flows through the lake are largely determined by the amount of water entering through Norland dam.

Based on recent water quality sampling (see **Chapter 5: Water Quality**) both lakes are considered oligotrophic low-productive waterbodies. Data indicate water quality within the lakes is considered in a good state, having waters that are relatively clear (4-5m Secchi depth), and unenriched (10 ug/L total phosphorus). This is due in large part to the quality of the water into the lake from the Gull River inputs, which drains from the Canadian Shield as relatively nutrient poor, clean and clear waters. There have been no major changes in water quality according to water clarity records from the 70's and 80's. The lake did not become degraded from acid rain, because limestone bedrock and calcareous shallow soils provide good buffering.

Lake morphology is distinct between the two lakes (**Figure 6.1**). In Shadow Lake the north section contains most of the deepest depths (up to 22m) in the lake, while the south section contains a deep pocket (up to 20m). Most of the shoreline has relatively narrow and steep nearshore areas. In Silver Lake, the deepest depths (up to 16m) occur in the central, south-west section of the lake. The western nearshore areas are relatively narrow and steep while the eastern nearshore areas slope more gradually into the lake. Shallow nearshore areas (less than 3m) are relatively limited in both lakes, occupying only 2.8% of their surface area.

A rapid shoreline survey was conducted by Kawartha Conservation in 2017. Its primary purpose was to delineate shoreline segments of relatively uniformity with respect to artificial, natural vegetated, and natural unvegetated features along the shore-water interface, and their respective lengths **(Figure 6.2 and Figure 6.3).** The number of unique segments was 376. Its secondary purpose was to characterize riparian land use, riparian slope, nearshore substrate, and nearshore aquatic vegetation **(Figure 6.4 – Figure 6.7)** along each delineated segment.

Despite the fact that the shoreline around Shadow Lake and Silver Lake is relatively heavily developed (see **Chapter 3: Land Use**) the water's edge remains in a relatively natural state, with 32.2% consisting of natural unvegetated, 56.4% as natural vegetated, and 11.4% as artificial (**Table 6.1**). The top five categories include Marsh, Forest, Swamp, Cobble, and Bedrock, and comprise over 75% of the Shadow Lake and Silver Lake shorelines. Manicured Lawn is the dominant artificial structure along the shoreline (3.2%).

Table 6.1: Results of rapid shoreline assessment, conducted in summer 2017, expressed as length of shoreline and percentage of total shoreline length.

Category	Length (m)	Length (% of shoreline)
Manicured Lawn	1267	3.2%
Flagstone	855	2.2%
Beach	707	1.8%
Concrete	650	1.7%
Wooden	545	1.4%
Armourstone	396	1.0%
Gabion Baskets	32	0.1%
Steel	8	0.0%
Total Artificial	**4460**	**11.4%**
Cobble	5461	14.0%
Bedrock	3996	10.2%
Boulder	1685	4.3%
Sand	1295	3.3%
Open Water	113	0.3%
Gravel	64	0.2%
Total Natural Unvegetated	**12614**	**32.2%**
Marsh	8160	20.8%
Forest	6263	16.0%
Swamp	5676	14.5%
Meadow	1817	4.6%
Other	150	0.4%
Total Natural Vegetated	**22066**	**56.4%**
Grand Total	**39140m**	**100%**

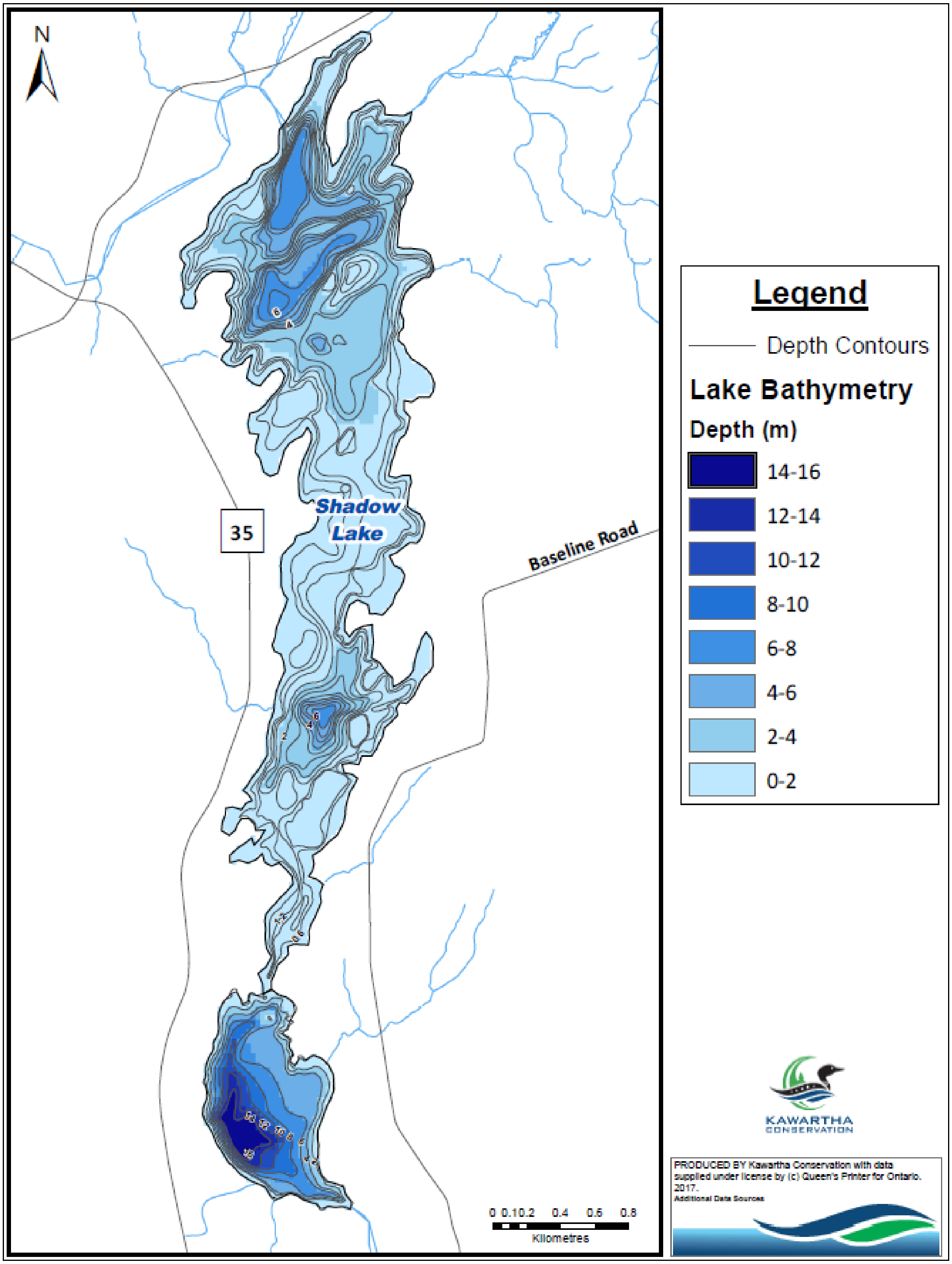


Figure 6.1: Bathymetric map of Shadow Lake and Silver Lake.

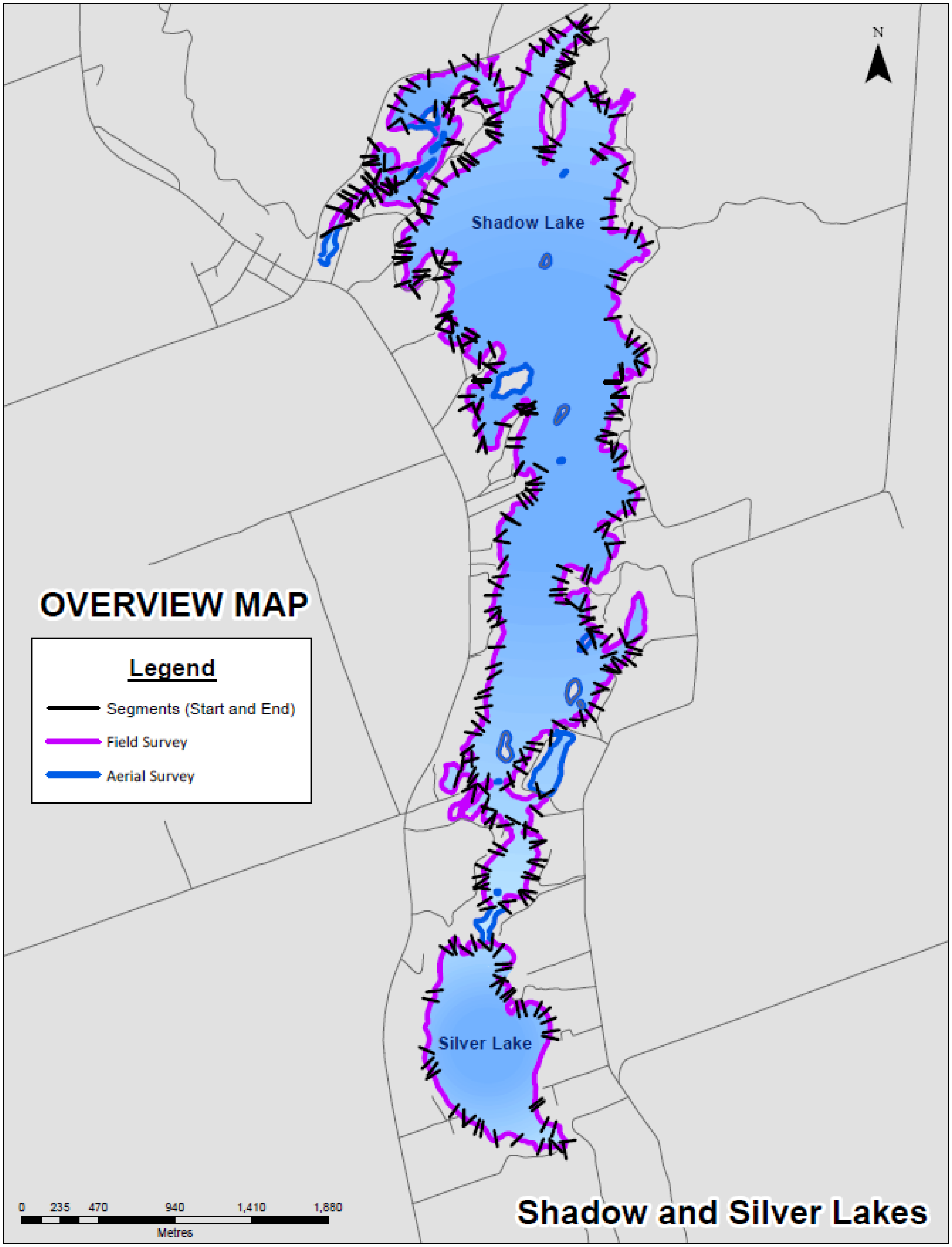


Figure 6.2: Location of segments that deleneated along the shore-water interface.

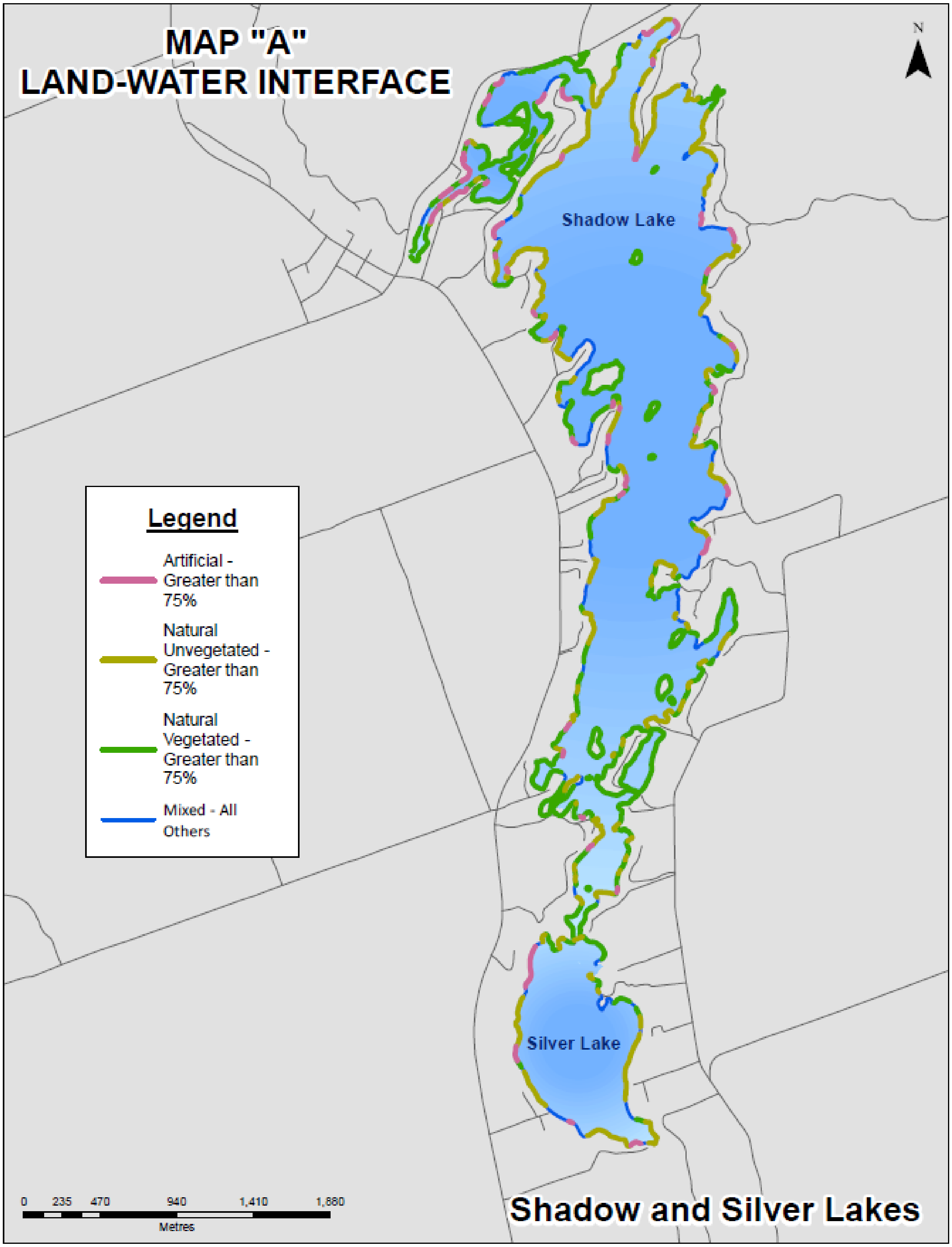


Figure 6.3: Artificial, Natural Unvegetated, and Natural Vegetated shorelines segments.

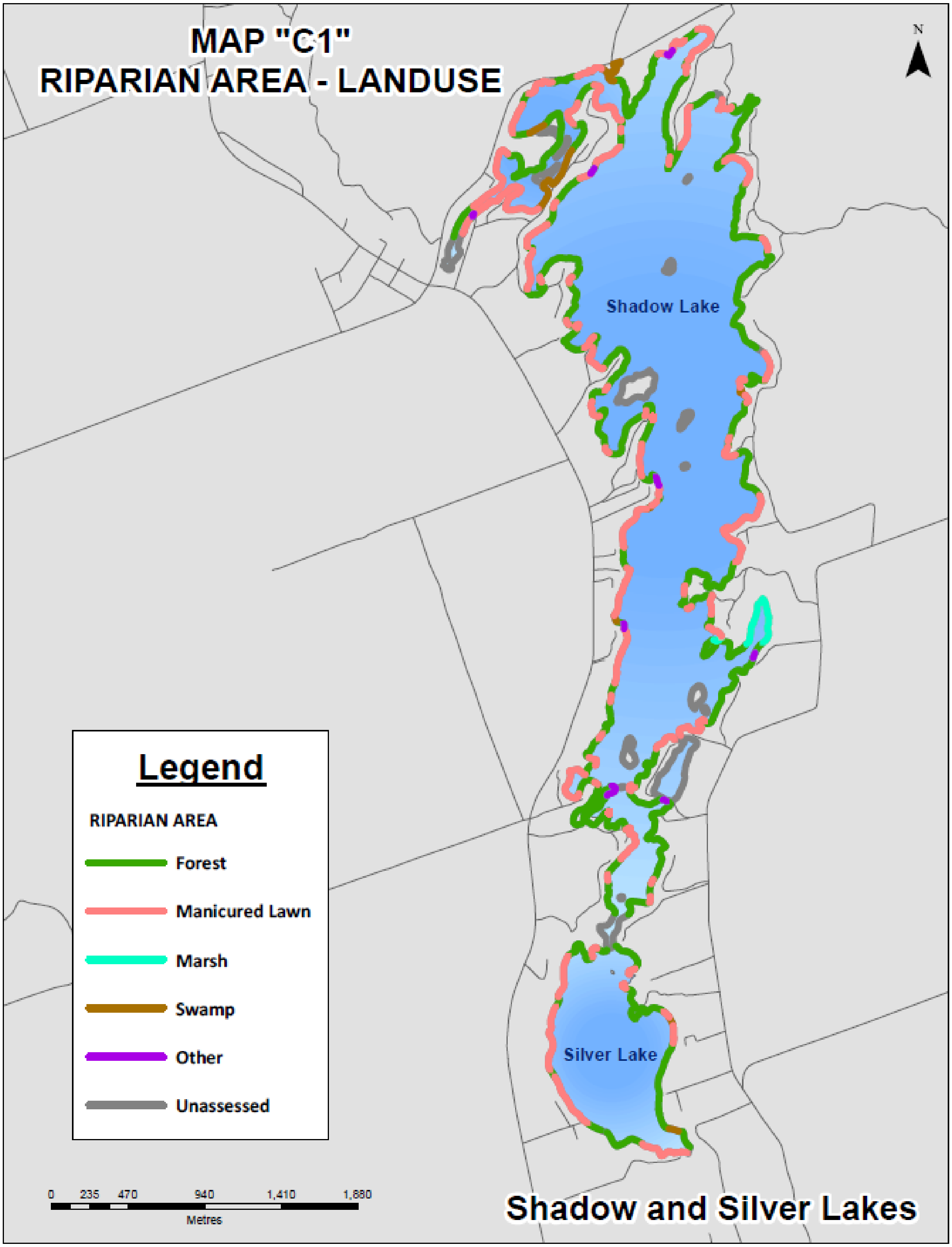


Figure 6.4: Riparian land use along each segment.

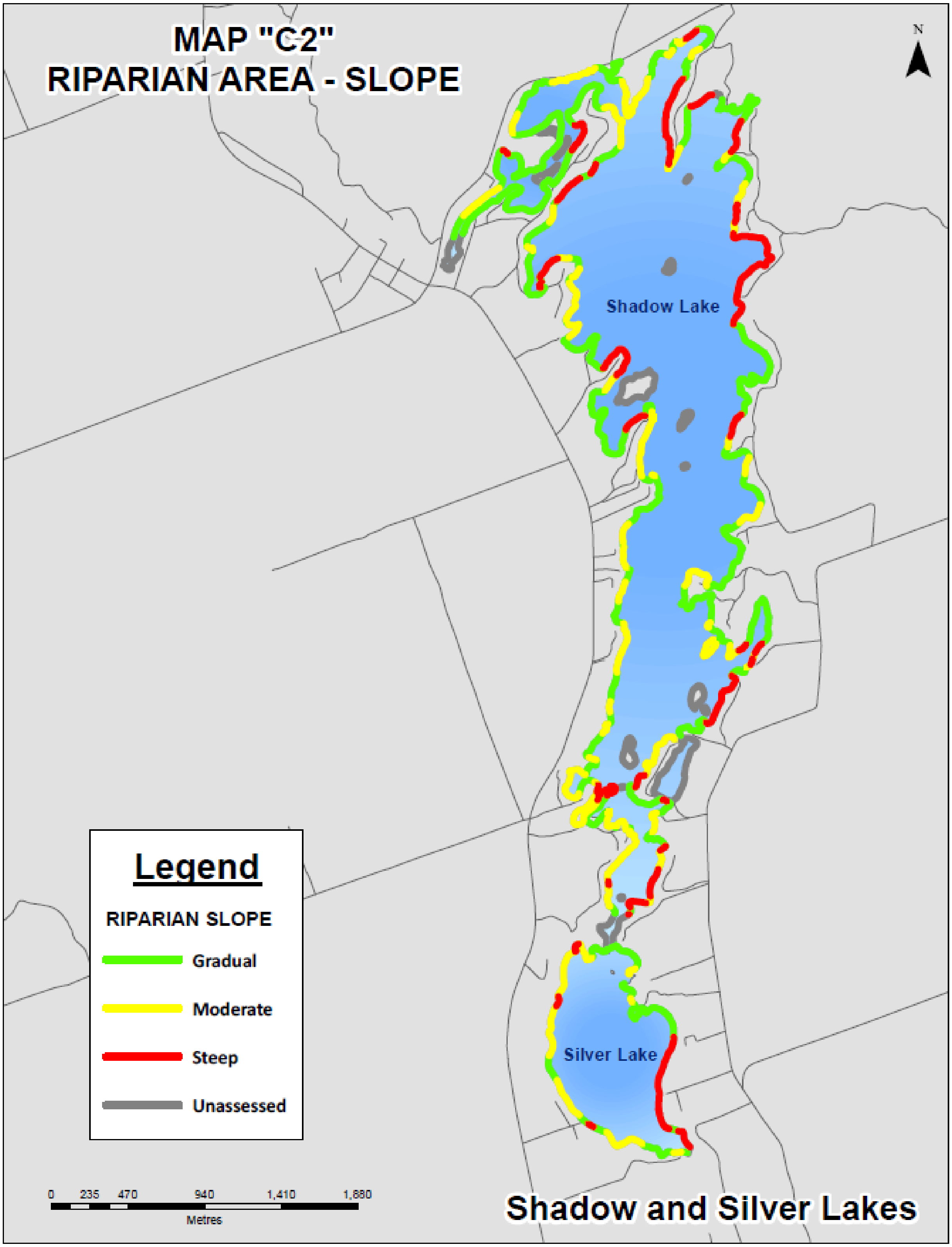


Figure 6.5: Riparian slope along each segment.

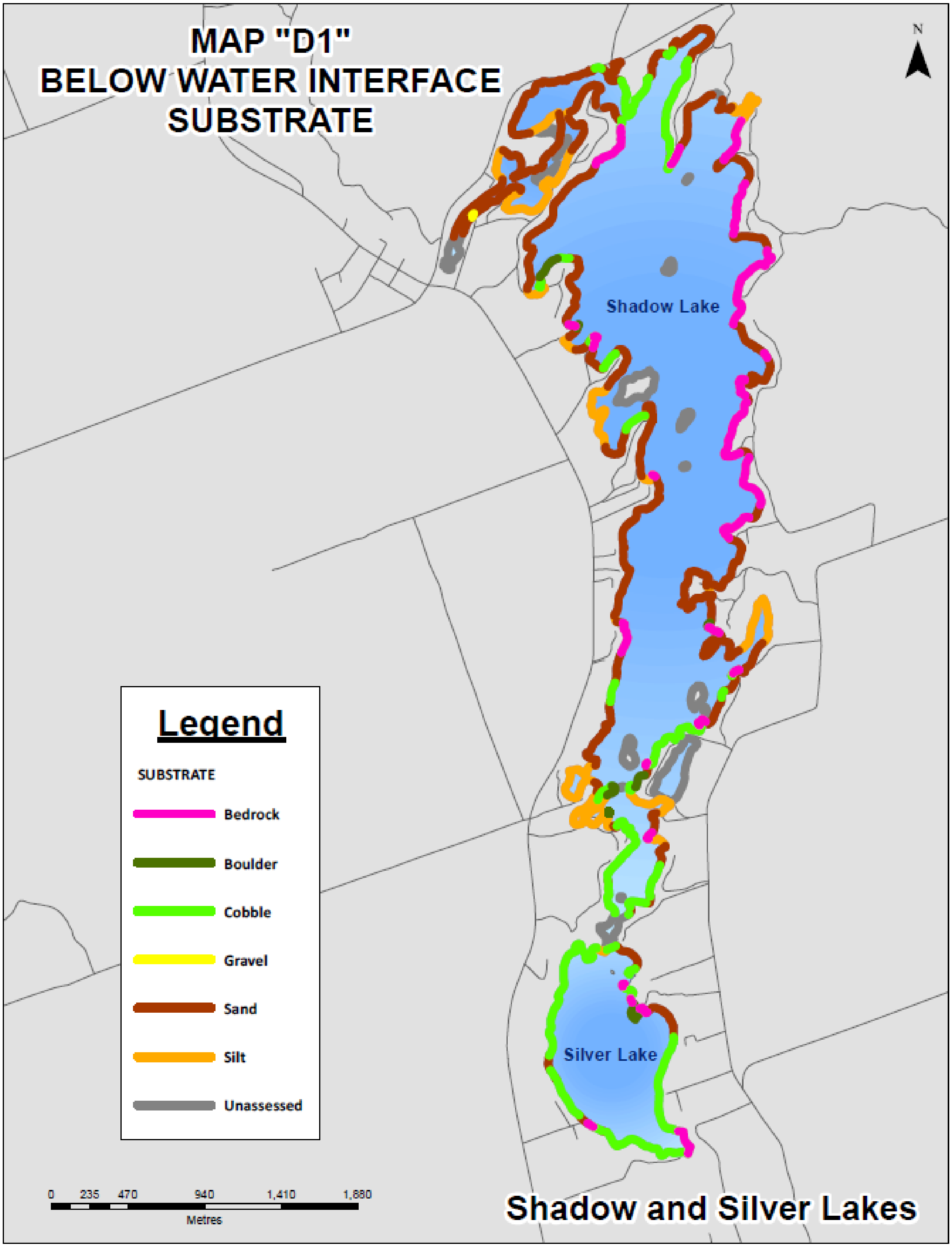


Figure 6.6: Nearshore substrate along each segment.

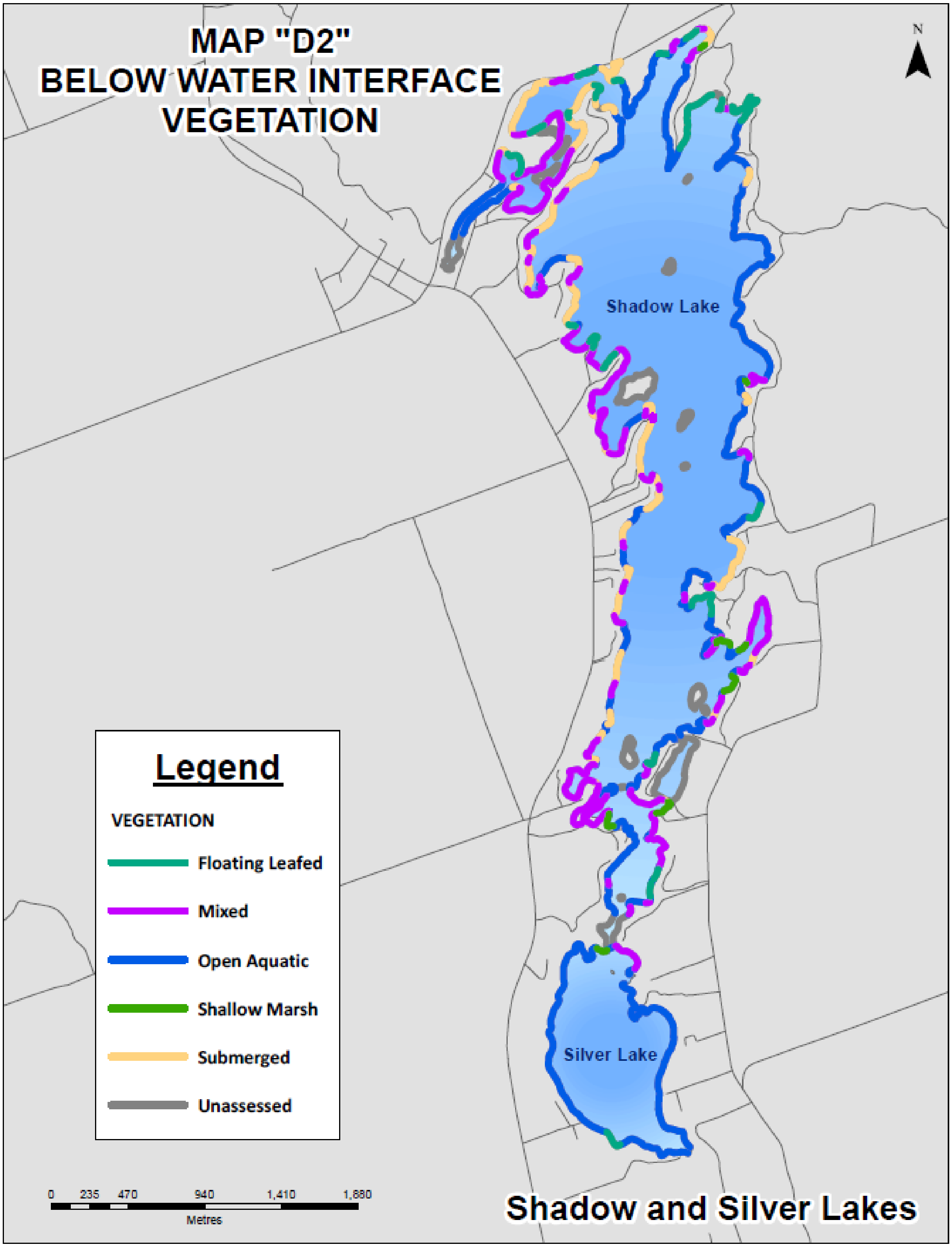


Figure 6.7: Nearshore aquatic vegetation along each segment.

Shadow Lake has been mapped as a warmwater lake, and Silver Lake has been mapped as a coolwater lake. Lake water temperature and dissolved oxygen profiles taken in late summer of 2015 are graphed in **Figure 6.8** for the north basin (to a depth of 20m) and south basin (to a depth of 17.5m). Surface water temperatures remain almost identical in both basins (22.1 to 22.5°C) to a depth of 5m, indicating that the lake is well-mixed at its surface. From this depth, temperatures decline rapidly in both basins within the transition zone known as the thermocline (decrease of >1°C per metre), and indicates lake stratification with a range of more uniform warmer surface water temperatures occurring above this zone (epilimnion) and uniform colder waters below (hypolimnion). The thermocline begins approximately 2m shallower in the south basin than the north basin. In the northern basin, the thermocline extends from 7m (21.7°C) to 10m (11.2°C), and in the southern basin it extends from 5m (22.2°C) to 9m (9.3°C). Temperatures within the south basin are consistently colder than the north basin at equivalent depths. The coldest recorded temperatures (6.6°C at 17.5m in south basin, 7.2°C at 20.0m in north basin) occur in the deepest sections of both basins.

Within the south basin, dissolved oxygen concentrations throughout the water column follow a similar general trend as water temperatures, with the highest values recorded in the epilimnion (7.47 to 6.86 mg/L), rapid declines within the thermocline (6.86 to 2.53 mg/L) and the lowest values within hypolimnion (2.53 to 0.11 mg/L). The northern basin exhibits this same regime only in surface waters to a depth of 9m. From this depth dissolved oxygen steadily increases up to 5.39 mg/L at 13m and then steadily decreases again to 0.26mg/L at the lake bottom. The reasons for the increase in dissolved oxygen is not clear but could be related to influences from Gull River inflow or in-lake productivity.

Lake herring, also known as Cisco, and other small-bodies coldwater fishes (e.g., mottled sculpin, trout-perch) have been documented within the lake. These fishes are more sensitive than others found within the lake and typically only occupy waters having cold, highly oxygenated waters. The preferred water temperatures of Lake Herring is between 7-10°C (**Eakins, 2016**), whereas coldwater fish do not tolerate dissolved oxygen concentrations below 4-7mg/L (**Ministry of the Environment and Energy, 1994**). Temperature and dissolved oxygen profiles taken within the north basin from late spring to late summer indicate that as the year progresses, water temperatures increase which decrease the depth of preferred temperatures, and consequently volume of habitat, from deeper than 7m in June to deeper than 12m in August/September **(Figure 6.9 and Figure 6.10)**. Using a value of 6.5mg/L as a concentration below which is inadequate (**CCME 1999**), dissolved oxygen concentrations are adequate at all depths during June, but by July waters are inadequate between depths of 7 and 11m, and below 15m. By end of August waters are inadequate below 8m. When overlaying temperature and dissolved oxygen requirements, data suggest sub-optimal habitat quality for Lake Herring throughout the summer months. Overlap of preferred conditions exists at depths below 8-9 metres in June, and between 12 and 14m depths at end of July; no overlap in August or September sampling.

There is limited information on aquatic habitat such as substrate, and aquatic vegetation. The only documented important fish spawning area is at the Gull River inlet, its swift waters below Norland Dam known to be Walleye spawning habitat. A comprehensive survey of fish spawning locations has not recently been conducted on the lake, or within its connecting tributaries which also likely support migratory habitat.

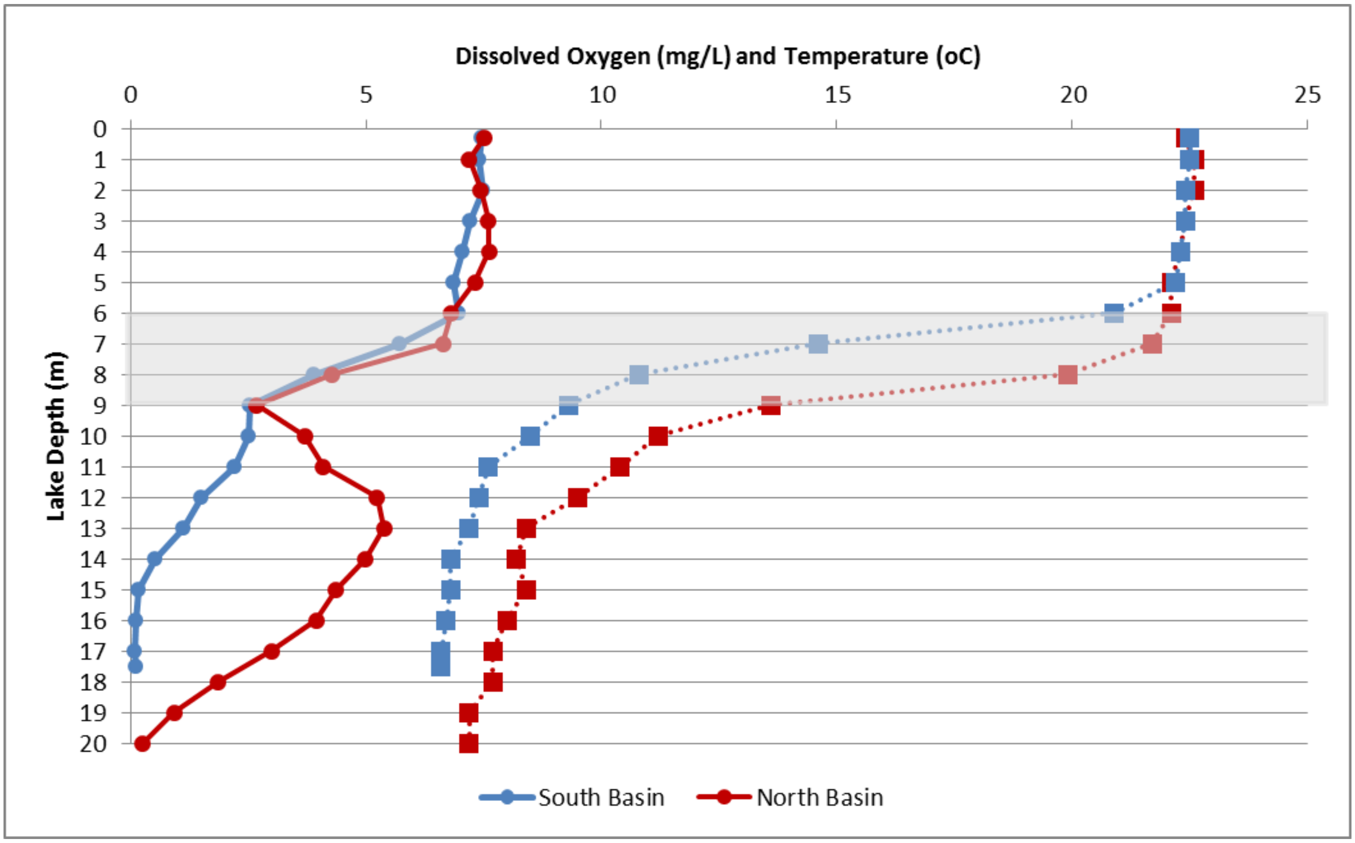


Figure 6.8: Dissolved oxygen (mg/L, solid lines) and water temperature (°C, dotted lines) profiles during late summer (Aug. 31, 2015) in the north basin (red) and south basin (blue). Shaded area represents the thermocline.

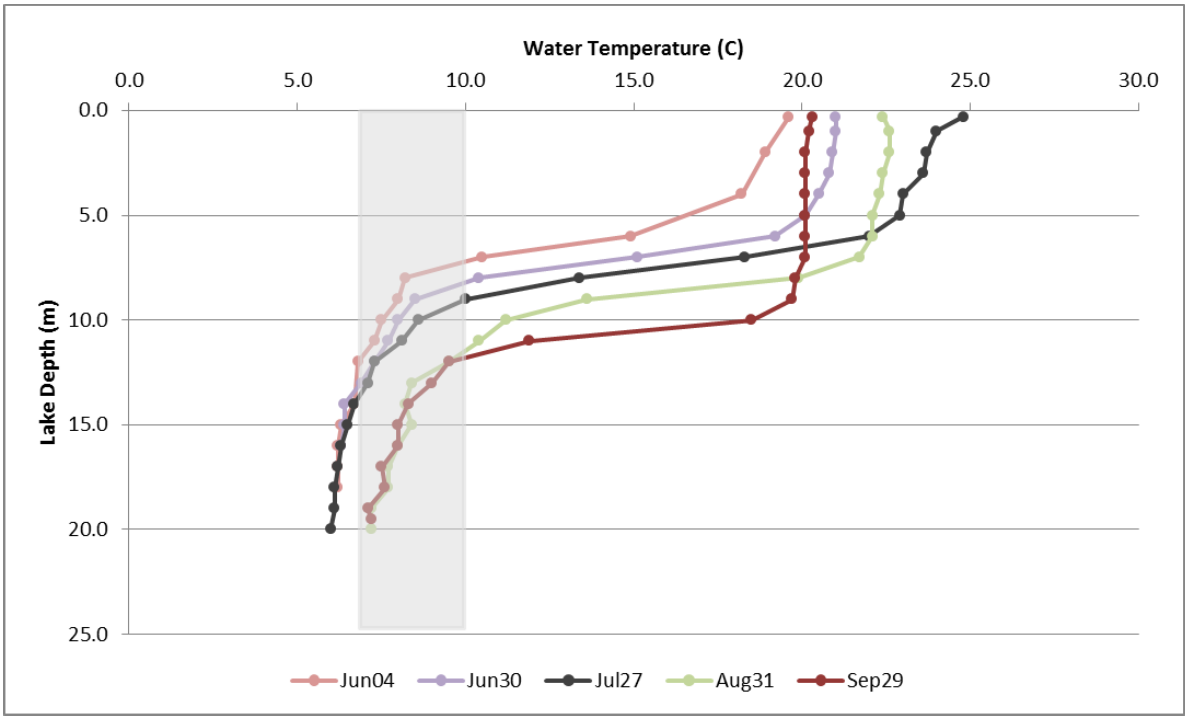


Figure 6.9: Water temperature profiles during late-spring and summer 2015 in the north basin. Shaded area represents zone of optimal temperatures of Lake Herring.

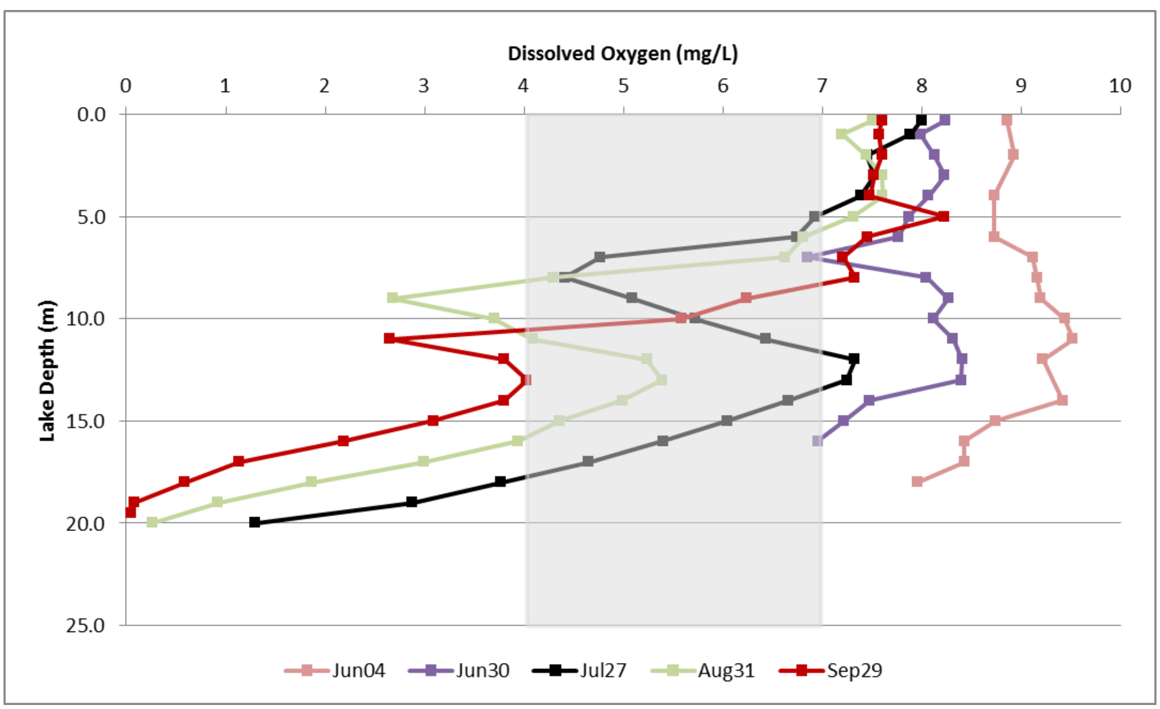


Figure 6.10: Dissolved oxygen profiles during late-spring and summer 2015 in the north basin. Shaded area represents the zone of minimum concentration required for coldwater fishes.

6.3.2 Fish Communities

According to available data, Shadow Lake and Silver Lake support diverse fish communities. Approximately 20 fish species have been confirmed documented in the lakes: 20 in Shadow Lake from three netting records (1960, 1978, 2009), and 12 in Silver Lake from 1 netting record (2009). An additional species (Northern Pike) has been reported as present by the public in 2016. Several of these fishes function as top predators and are important recreational fish species including Smallmouth Bass, Walleye, and Muskellunge.

Lake herring, trout-perch, and mottled sculpin are all native sensitive coldwater fish species that have been documented within Shadow Lake. These fishes are considered intolerant to habitat degradation and require cold, well-oxygenated waters to support their populations. In the summer months, this habitat is limited to the deeper waters of the lakes. There are no species of conservation concern, including mussels, but sampling has been limited.

Several of the documented fishes are not native to the lakes, including: Black Crappie, Bluegill, Common Carp, Rainbow Smelt, and Walleye. Common Carp and Walleye have been documented in the lake since 1960. In 2009 netting recorded several including bluegill, black crappie, and rainbow smelt. Bluegill and black crappie have expanded range in neighbouring Kawartha Lakes where bluegill contribute significantly to biomass of all fish and black crappie have started a new recreational fishery. Northern pike reported most recent, in 2016, has potential to compete with native Muskellunge.

In terms of relative abundance of large-bodied species in the fish community in Shadow Lake, the following represent approx. 95% of total catch per unit effort in 2009 netting: Yellow Perch (70%) Smallmouth Bass (10%), Walleye (4%), Bluegill (4%), Muskellunge (3%), and Cisco (3%). In Silver Lake, the following represent approx. 95% of total catch in 2009 netting: Yellow Perch (63%), Rock Bass (19%), Smallmouth Bass (7%), and White Sucker (6%). Changes over time to fish community are not well understood, no routine and standard netting program over time. Shadow Lake is a fixed lake through the Broad-scale Monitoring program, and will be reoccurring approximately every 5 years thus will be able to track changes over time.

There are limited information related to the status of recreational fishery, such as most-sought after fishes and exploitation pressure statistics including angler effort/harvest/etc. No creel survey data but anecdotal (recent) suggest decrease in angler catches.

Table 6.2. List of documented fishes in Shadow Lake and Silver Lake.

Species	Shadow_MNR1960	ROM_Shadow_MNRJun1978	BSM_Shadow_MNRJul2009	BSM_Silver_MNRSep2009	FishONLINE public reporting
Black Crappie			x	x	
Blacknose Shiner		x	x		
Bluegill			x	x	
Bullhead Sp.	x				
Cisco	x		x		
Common Carp	x	x			
Fathead Minnow		x			
Golden Shiner	x		x	x	
Largemouth Bass	x		x	x	X
Logperch			x	x	
Mottled Sculpin			x		
Muskellunge	x		x		X
Northern Pike					X
Pumpkinseed			x	x	x
Rainbow Smelt			x		
Rock Bass		x	x	x	X
Smallmouth Bass	x		x	x	X
Spottail Shiner		x		x	
Sunfish Sp.	x				
Trout-perch			x		
Walleye	x		x	x	
White Sucker	x		x	x	
Yellow Perch		x	x	x	

Table 6.3: Fish community data from most recent (2009) Broad-scale Monitoring program netting survey.

BSM Shadow Lake (July 2009)				
Fish Species	Total Catch (%)	Maximum Length (cm)	Minimum Length (cm)	Average Length (cm)
Yellow Perch	70	25.6	13.2	18.1
Smallmouth Bass	10	48.4	19.7	27.1
Walleye	4	61.1	35.7	50.8
Bluegill	4	18.1	16.8	17.3
Muskellunge	3	116	110.9	113.5
Cisco	3	39.2	34.5	36.9
Pumpkinseed	1	13.2	13.2	13.2
Black Crappie	1	28.8	28.8	28.8
White Sucker	1	44.1	44.1	44.1
Golden Shiner	1	16.8	16.8	16.8
Rock Bass	1	13.5	13.5	13.5
Largemouth Bass	1	37	37	37
BSM Silver Lake (September 2009)				
Fish Species	Total Catch (%)	Maximum Length	Minimum Length	Average Length
Yellow Perch	63	21.5	14.3	16.7
Rock Bass	19	22.2	10	15
Smallmouth Bass	7	37	22.3	27.1
White Sucker	6	49.5	17.7	36.7
Golden Shiner	2	17	17	17
Pumpkinseed	2	9.6	9.6	9.6
Largemouth Bass	2	34.4	34.4	34.4

6.3.3 Exotic and Invasive Species

An exotic species is one that has been moved from its native habitat to a new area, whereas an invasive species is an exotic species that has proliferated to the extent that it causes widespread negative environmental, social, or economic impacts.

Shadow Lake is hydrologically connected to the Trent-Severn Waterway watershed, a popular recreational and cottage-county destination. These lakes are particularly susceptible to exotic species transfer because they are recreational hotspots (e.g., boating corridor, fishing, watersports, etc.) that are close to large population centres such as the Greater-Toronto-Area. There are several pathways of exotic species introductions, including Intentional introductions (e.g., pest management, fish stocking, etc.), accidental introductions (e.g., dumping aquariums, hitch a ride, etc.), and natural dispersal through connected waterbodies.

Six of documented fishes are considered exotic (includes public report of Northern Pike). No species reported to EDDMAPs for Shadow or Silver Lake water bodies. The following have been reported in the Gull River Watershed **(EDDMAPS, 2017)**: Chinese mystery snail (2015), *Phragmites* (2013), Rainbow Smelt (1969), European Frogbit (2015), Rusty Crayfish (1975).

Through KRCA sampling, yellow iris (2017) was identified in the SL_North Subwatershed along the creek corridor adjacent to Buller Road, upstream of Monck Road.

No confirmed zebra mussels, but calcium concentrations (around 10 mg/L) are below requirements (20 mg/L). The calcium concentrations in Shadow Lake are a clear limiting factor in preventing establishment although they are present in neighbouring Four Mile Lake, a similar geological landscape (transitional area). Close hydrological connection, and geography, with Kawartha Lakes having zebra mussels should have facilitated spread if Shadow Lake and Silver Lakes were vulnerable.

There is concern among local residents of the potential introductions and proliferation of freshwater jellyfish, *Holopedium glacialis*. At present, no documented outbreaks, and lake is likely not vulnerable because calcium levels are relatively high to support native zooplankton (i.e., daphnia).

6.11 Tributary-Based Ecosystems

6.4.1 Aquatic Habitat

Figure 6.11 and Figure 6.12 shows the best-available mapping of the watercourse network within the Shadow Lake Watershed planning area. When combined, the watercourse network totals approximately 100 km in length, all of which can be considered as probable aquatic habitat that directly supports or contributes to aquatic life. Almost all streams (approximately 93% of total length) flow through natural lands, primarily through mixed forest, shallow aquatic marsh, open aquatic, deciduous forest, aquatic floating, and coniferous forest. A small percentage (4%) flows through agricultural areas (mostly pasturelands), and 2% through developed areas (rural development and under roads).

Stream Order

Figure 6.11 shows the watercourse network, and **Table 6.4** lists their respective lengths by stream order. Stream ordering, as introduced by **Strahler (1957**), 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; and so on proceeding in a downstream manner. As outlined in the River Continuum Concept **(Vannote et al., 1980**), stream ordering is a useful approach to help classify watercourse reaches that tend to exhibit similar biological properties. Stream orders within the Shadow Lake planning area range from one to five. The majority of watercourses (over 70% by length), are small first- and second-order streams. These “headwaters” are typically small, ill-defined and inconspicuous ephemeral or intermittent stream corridors that usually dry up during extended dry periods (e.g., during summer and winter). Headwaters are typically far-removed from the lake, but serve an important function by providing seasonal aquatic habitat when flow does occur, as well as conveying food, nutrients, and water flow that are used by aquatic life residing downstream in the larger and more identifiable watercourses. The larger streams sections, of third-, fourth-, and fifth-orders, comprise over 27% of the total length of the stream network. These sections typically flow continuously, thus providing aquatic habitat year-round.

Table 6.4. Length of Streams Within Each Subwatershed by Strahler Order.

Subwatershed	Stream Length (km)	1st order (%)	2nd order (%)	3rd order (%)	4th order (%)	5th order (%)
SL_Central	19	62%	15%		1%	23%
SL_North	39	46%	26%	9%	18%	
SL_Northeast	17	47%	20%	26%	7%	
SL_Northwest	25	60%	14%	23%	3%	
Total	**100**	**53%**	**20%**	**14%**	**9%**	**4%**

There are 15 mapped tributaries that drain directly into Shadow Lake and Silver Lake. Gull River is the largest (draining into the northwest of Shadow Lake through Norland as a 5th-order stream), followed by the Shadow Lake Northwest, North, and Northeast tributaries (draining into the north end of Shadow Lake as 4th order streams), and several other smaller tributaries and surface water drainage features (draining into various sections of the lakes, as 2nd and 1st order streams). Aside from the Gull River, most of the aquatic habitat within these tributaries consist of relatively undisturbed low-gradient wetlands, with organic and silty substrates and extensive vegetation of both treed and marsh type. Although aquatic community data is limited for these tributaries, the outlet sections of these tributaries are likely important habitat of Shadow Lake because they provide transitional areas between the lotic flowing water “stream-like” environments and the lacustrine still-water “lake-like” environments. These transitional areas are biodiversity hot-spots, providing a corridor for the movement of aquatic organisms, water mixing, and food and energy transport which all contribute to the aquatic biodiversity and productivity of the lake. Several important fishes, particularly muskellunge, likely migrate into these tributaries in early spring to reproduce, however this assumption requires further study for confirmation. Likewise, many tributary-dwelling fish species likely migrate to the lake or refuge pools during seasonal dry periods or to avoid stream freeze-up during winter months. Therefore, unimpeded access to-and-from the lake helps maintain healthy fish populations in the lake. The Gull River, below Norland dam, is a known Walleye spawning area.

Riparian Area

The transitional zones between aquatic and terrestrial environmental are called the riparian area. Natural riparian areas encompass a range of vegetation types (i.e., forest, wetland, meadow), and provide similar benefits along tributaries as do natural shorelines around lakes. These include: stabilizing stream banks, reducing erosion, moderating water temperatures, filtering contaminants, providing cover and spawning habitat for fishes, and supplying nutrients and food for the watercourse (**Gregory et al., 1991**). To characterize riparian areas within Shadow Lake planning area, the extent and type of land cover along the watercourse was interpreted from aerial photography taken in 2013. Natural cover (e.g., forest, wetlands, etc.) within the riparian areas was classified according to Ecological Land Classification methodology (**Lee et al., 1998**), whereas non-natural land cover (e.g., agricultural lands, urban areas, aggregate pits, etc.) was classified according to methods developed to complement this protocol (**Credit Valley Conservation, 1998**).

Various studies have investigated the minimum riparian buffer width necessary to maintain the ecological integrity of watercourses, often ranging from 5 metres to 300 metres depending on the functions they provide (**OMAFRA, 2003**) (**Figure 6.13**). 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**). In general, a 30 m width of natural vegetation on both sides of the watercourse is of sufficient size to provide beneficial functions such as aquatic habitat, bank stability, and sediment removal. Studies in southern Ontario have demonstrated that that stream degradation occurs (e.g., loss of sensitive species) when riparian vegetation amounted to less than seventy-five percent of the total stream length (**Environment Canada, 2013**). Thus, as a general guideline, it is recommended that to help maintain the ecological integrity of the aquatic ecosystem, at least 75 % of the total length of watercourses should have natural riparian areas, preferably as wide as 30m, on either side of the top of bank-full stage.

Table 6.5 lists the percentages of 30 m riparian areas by subwatershed. Natural riparian area coverage within three of the four subwatersheds is exceptionally high (97-98%), whereas coverage within SL_Central is just below the minimum recommended guidelines. This is due, in large part, to developments adjacent to the Gull River in Norland and Coboconk.

Table 6.5. Riparian Land Use (30m on Both Sides) in Subwatersheds of the Shadow Lake planning area.

Subwatershed	Riparian Area (ha)	Agriculture	Development	Natural
SL_Central	**146**	**16%**	**12%**	**71%**
SL_North	284	<1%	<1%	98%
SL_Northeast	130	2%	<1%	97%
SL_Northwest	190	<1%	<1%	98%
Grand Total	**751**	**4%**	**2%**	**93%**

Water temperature plays an important role in the overall health of aquatic ecosystems, affecting rates of productivity, timing of reproduction and movement of aquatic organisms (**Caissie, 2006**). Fish 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**). Thermal habitat is often categorized into three broad types: warmwater, coolwater and coldwater. Warmwater designations imply that the watercourse is known to contain, or is likely to support, warmwater fishes (e.g., bluntnose minnow, fathead minnow, largemouth bass, etc.). Coolwater 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. This 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.).

In the summer of 2016 the thermal regime of watercourses was assessed at all third-order and fourth-order stream-road crossings to identify any potentially sensitive areas. In total, 9 sites were sampled by taking spot-measurements of water temperature following the module outlined in the Ontario Stream Assessment Protocol (**Stanfield, 2010**) with slight modifications to the time of collection as per **Chu et al. (2009**). The data from these surveys were used to assign a thermal regime status of coldwater, coolwater, or warmwater 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 (**Stoneman and Jones, 1996**). According to available data prior to this survey, the thermal regime status of most of the creeks within the planning area was unknown. As shown in **Figure 6.14**, 3 of the sample sites were dry, 4 sites have a warmwater thermal regime, 1 site has a coolwater regime, and 1 site is coldwater. During these assessments, it was noted that perched culverts exists along 3 of the sites: 1 along the tributary at the outlet of Shadow Lake North Subwatershed (Buller Rd.), 1 at the tributary within Shadow Lake Central Subwatershed (Monck Rd., west of Baseline Rd.), and 1 along a different tributary within Shadow Lake Central Subwatershed (Shadow Lake Road #4). Perched culverts have the potential to act as barriers to the movement of aquatic life, preventing access to habitats along the tributary-lake connections.

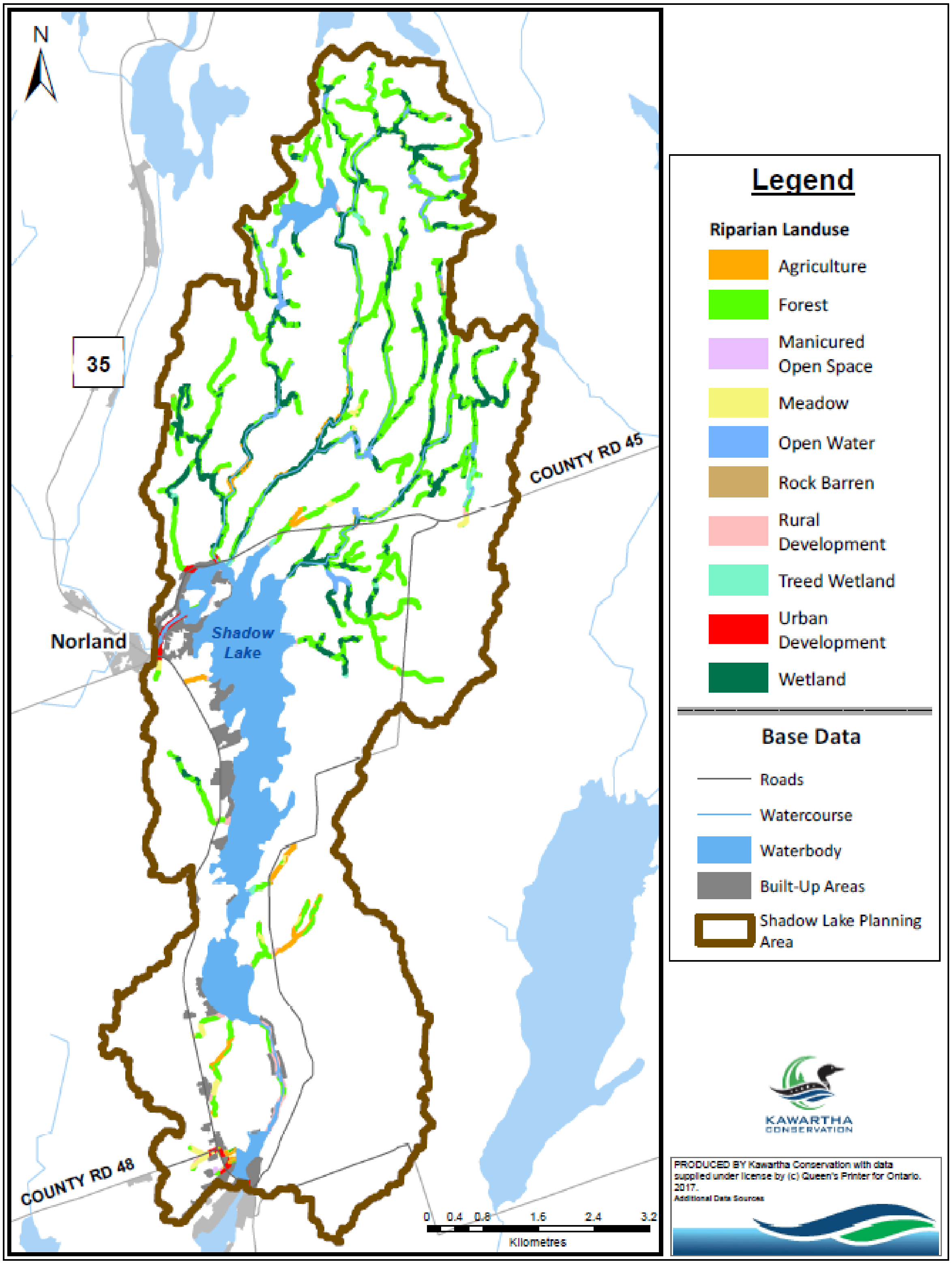


Figure 6.11. Land Use Along Stream Corridors in the Shadow Lake planning area.

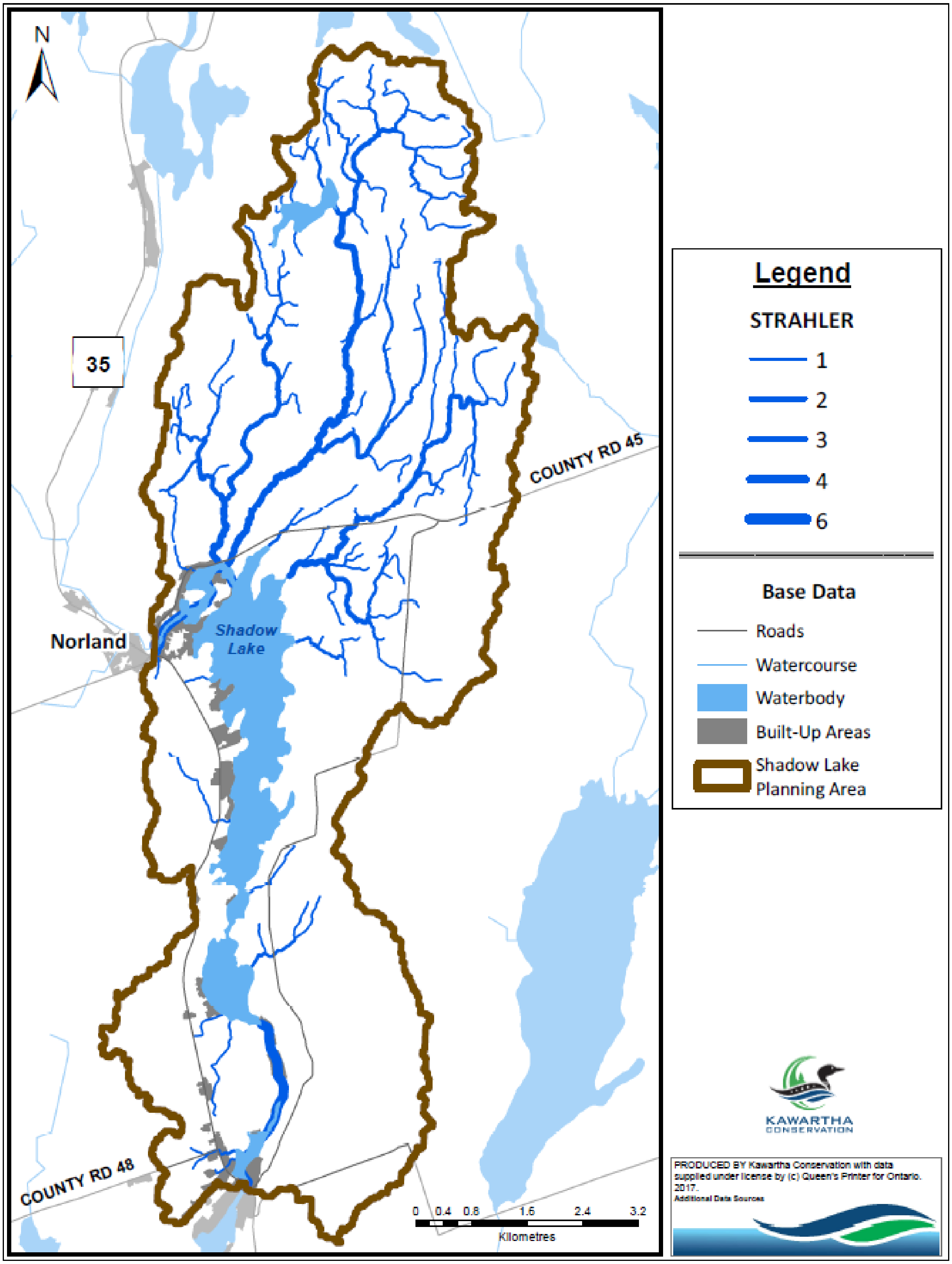


Figure 6.12. Watercourse Network by Strahler Order.

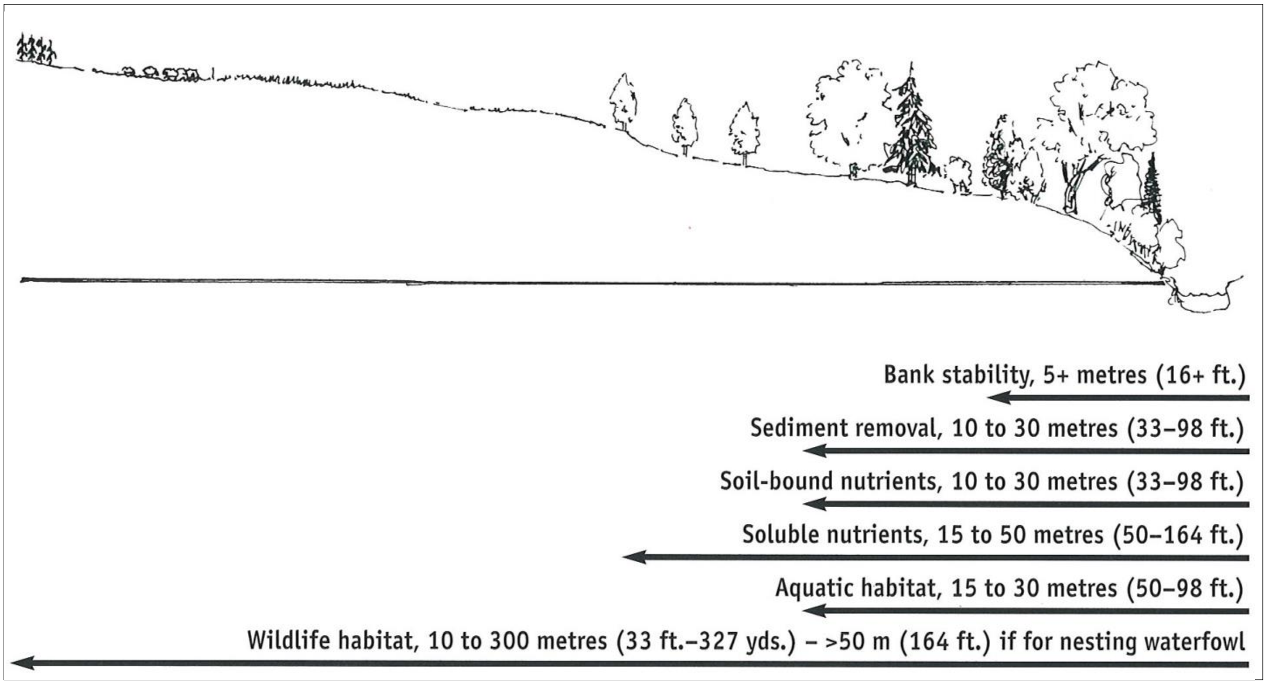


Figure 6.13. Summary of Important Functions of Natural Riparian Areas by Width.

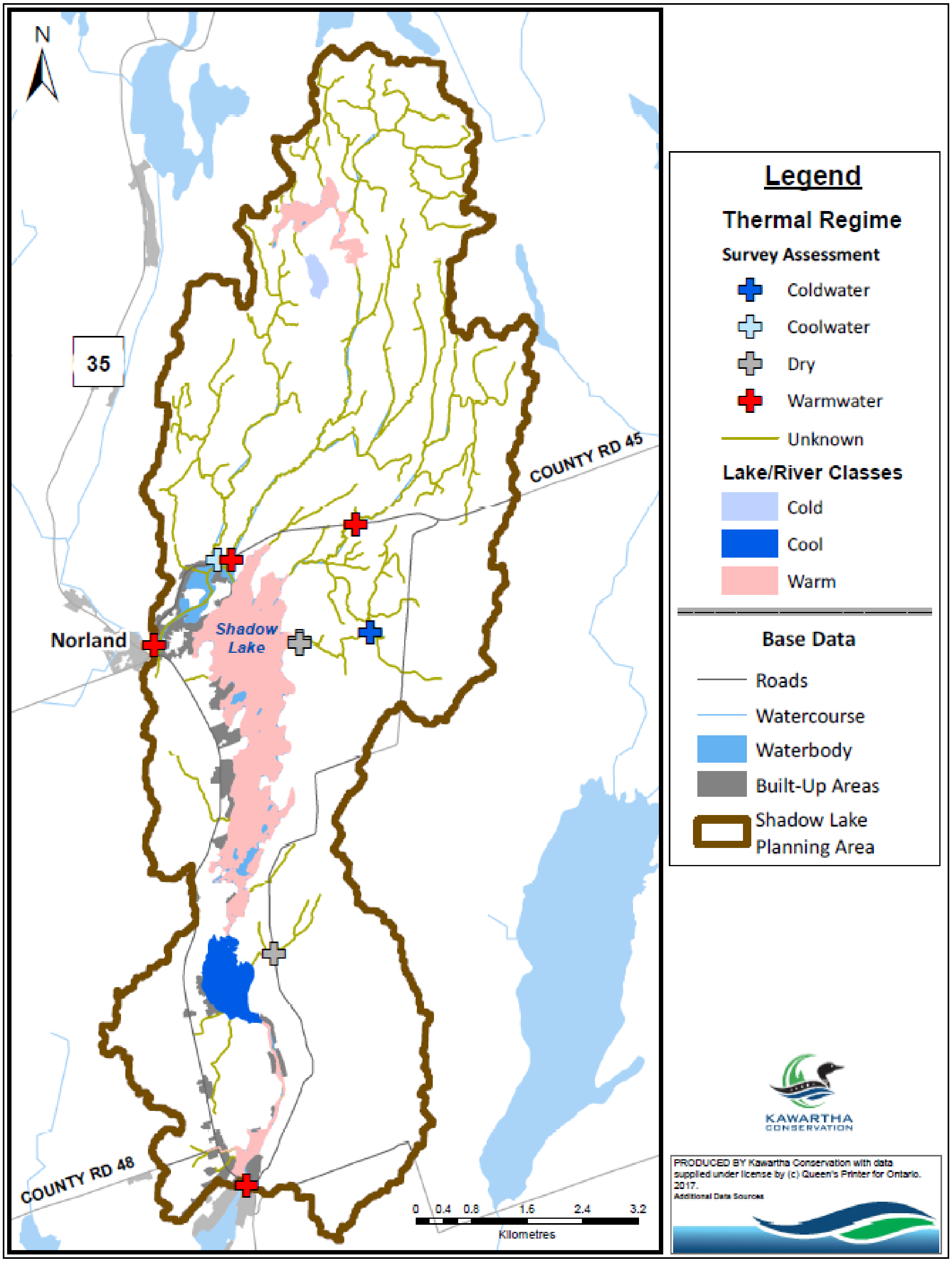


Figure 6.14. Watercourse Thermal Regime.

6.4.2 Fish Communities

There are no fish community data for watercourses directly flowing into Shadow Lake or Silver Lake.

6.4.3 Benthic Macroinvertebrates

Benthic Macroinvertebrates (benthos) have been widely used in biological assessments to characterize water quality and aquatic ecosystem health. Sampling for benthos is advantageous because they are abundant in most streams, serve as primary food source for fish, respond to ecosystem stress and are relatively inexpensive to collect (**Barbour et al., 1999**).

Sampling methods and Sites

In summer of 2016 and 2017, Kawartha Conservation conducted a bioassessment using benthic macroinvertebrates to gain insight into the status of the current condition of the aquatic ecosystem within the subwatersheds of Shadow Lake. Well-defined, wadeable steams that exist near road-crossings within subwatersheds that directly drain into Shadow Lake and Silver Lake were targeted for assessment. In total, 2 sites were sampled. Sampling was conducted following the transect kick-and-sweep methodology outlined in the 'Streams' module of the Ontario Benthos Biomonitoring Network (OBBN) protocol (Jones et al., 2005). All benthos collected were preserved in alcohol and identified under a microscope to the 27-group taxonomic resolution. **Table 6.6** provides a summary of the major habitat characteristics at all bioassessment sites. All sites were sampled when water temperatures ranged from 11-17^{o}C. Stream sizes sampled were small-to-medium, having wetted widths ranging from 1.1 to 6.8m and maximum depths ranging from 120 to 790 mm. Substrates encountered exhibited cobble, sand, and silt. The watercourses are relatively slow moving, having water velocities with 0 to 5 hydraulic head.

Table 6.6. Site and Habitat Characteristics at Bioassessment Sites

Site ID	Sub-watershed	Date	Water Temp (^{o}C)	Substrate (dom+subdom)	Depth (mm)	Hydraulic Head (mm)	Width (m)
HSLMP-01	SL_Central	2016/07/04	11	Cobble and Sand	120-240	0-5	1.1-3.9
HSLMP-05	SL_North	2017/06/22	17	Silt and Sand	490-790	0	6.0-6.8

Benthos Community

Benthos communities as summarized by OBBN taxa groups are shown in **Figure 6.15**. All raw benthos taxa data are found in Appendix 6A. Data indicate a marked difference in benthos communities between the two sample sites. At site HSLLMP-01 (Shadow Lake Road #4), the relative composition of benthos were dominated by the following three taxa: Chironomidae (25.6%), Plecoptera (23.1%), and

Trichoptera (19.8%), whereas the benthos at site HSLLMP-05 (Buller Rd.) was dominated by the following two taxa: Amphipoda (55.5%) and Isopoda (26.7%).

Benthos data can be used to make inferences into the condition of the local aquatic ecosystem, through summarizing data within the context of certain metrics that are known to be indicative of stream condition (**Barbour et al., 1999)**. One approach is to summarize the relative composition of taxa within the orders Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies). These taxa are considered sensitive organisms that are intolerant to disturbance and sites with higher numbers of these taxa tend to be in better ecological condition. Another approach is to summarize the taxa within the order Isopoda (Aquatic Sowbugs), a relatively tolerant organism. Sites with higher numbers of Isopoda tend to be in poorer ecological condition. These metrics tend to perform most accurate when applied to streams with fast flowing water (i.e., riffles) and coarse substrates (i.e., gravel, cobble). Currently, no known scientifically-defensible bio-criteria standards exist for all types of streams in the Shadow Lake watershed. Both sites exhibited varying substrates and flows thus determinations based on the selected metrics likely remain meaningful but should be considered preliminary, particularly given these are rapid assessment surveys.

The site at Shadow Lake Road #4 is considered in a better state in large part because its benthos community contains relatively more mayflies, stoneflies and caddisflies within the sample (47.0%, compared to 3.1%). Further, the site at Buller Rd. contains a benthos community that has relatively more isopods within the sample (26.7%, compared to 0.7%). It is not clear what factors are specifically contributing to Buller Rd. site being in a worse state, particularly given that water chemistry data indicate that these waters are not nutrient enriched and there are minimal land use stressors identified. However, potential influences include the fact that habitat is more favourable to tolerant organisms, degradation of habitat from being in close proximity to a county road (e.g., inputs of road salt and sediments), and/or the index not performing well in terms of accurately determining aquatic health at this location.

When comparing community composition of sensitive organisms (i.e., mayflies, stoneflies, and caddisflies) as an average of both sites (i.e., Shadow Lake tributaries), to data on tributaries of neighbouring lakes (**Table 6.7**), Shadow Lake tributaries are considered relatively average. However, there substantially lower number of sample sites in Shadow Lake tributaries (2 sites), than in neighbouring tributaries (5-18 sites), therefore comparison results should be interpreted with some caution. However, due to the lack of human disturbance within the subwatersheds of Shadow Lake, aquatic community conditions are expected to be relatively healthy.

Table 6.7. Comparison of Bioassessment Results from Shadow Lake Tributaries to those from other local tributaries.

	Shadow Lake Tributaries (2016-2017)	Four Mile Lake Tributaries (2015)	Pigeon Lake Tributaries (2014)	Balsam/Cameron Lake Tributaries (2013)	Sturgeon Lake Tributaries (2012)
Number of Sites	**2 (roadside)**	5 (roadside)	16 (random)	16 (random)	18 (random)
Sensitive Taxa (%EPT)	**25.1**	44.0	25.1	26.9	11.4

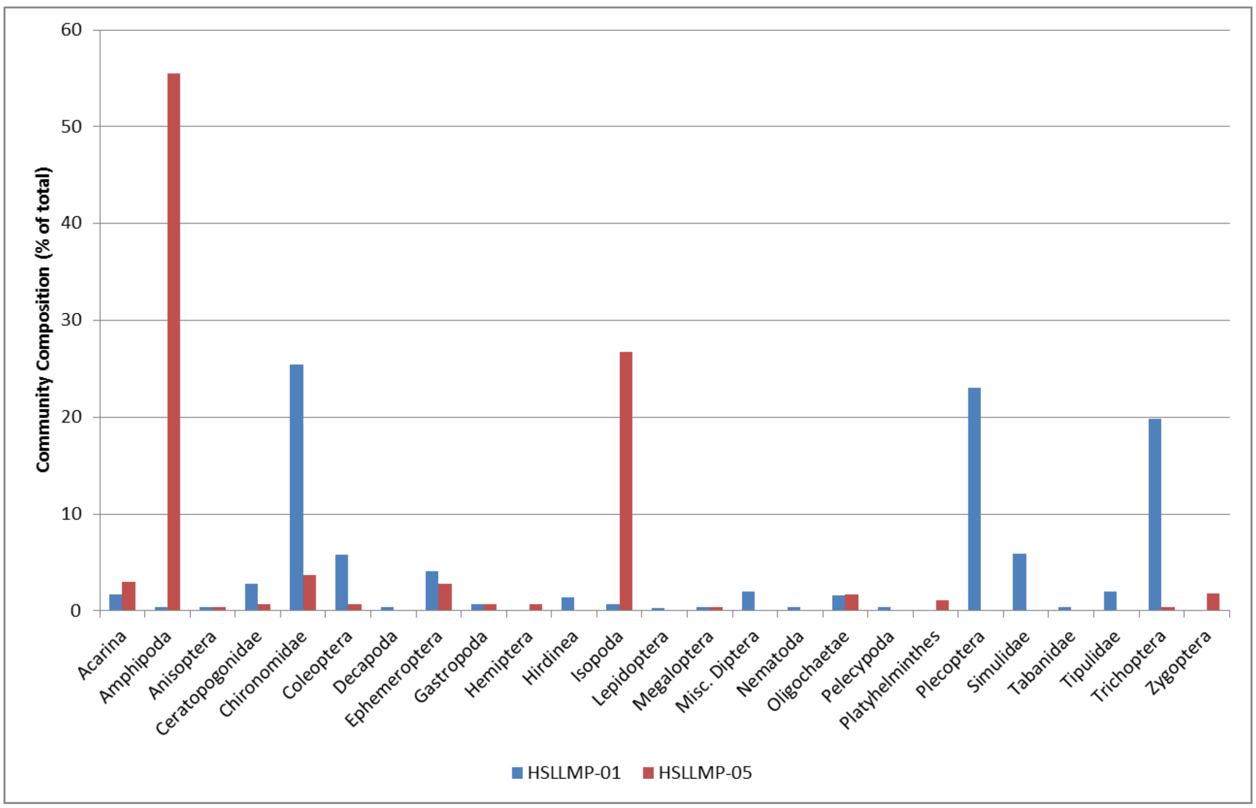


Figure 6.15. Major Benthos Taxa Found in the Tributaries

7.0 Terrestrial Ecology

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

7.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- ***Natural Heritage conditions can be considered very good.*** The area surrounding Shadow Lake contains large tracts of forests and some areas of wetlands, providing not only habitat for many species, but also helping to maintain good water quality through mitigating runoff, providing filtering and uptake of nutrients and solids, and creating connections between the lake and the natural areas to the north, particularly the unique features of the Land Between.

- ***The Shadow Lake watershed has an abundance of forests.*** Forests serve a number of functions within a watershed, not the least of which is functioning to improve water quality. Forests act to slow runoff, uptake and transpire water into the atmosphere, allow water to permeate into the ground, help to reduce erosion around lakes while providing habitat for numerous flora and fauna species

KEY ISSUES

- ***A number of natural heritage features exist in the Shadow Lake watershed that may be considered locally significant; however they are not afforded any legislative protection.*** ANSI's and Provincially Significant Wetlands are the only areas that are afforded protection due to their provincial significance, yet none are identified in the Shadow Lake Watershed. There are a number of other natural heritage features that are important locally that have not yet been identified or set aside for protection.

- ***Natural heritage features need increased study in order to determine their health.*** Much of the Shadow Lake watershed possesses areas where very little is known about the state of the flora and fauna. Better information through natural heritage studies would help with the sustainable management of this area.

- ***The existing natural heritage features are experiencing some fragmentation around the lake.*** The fragmentation of natural heritage features makes the movement of species more difficult and therefore ecosystems are less resilient due to limited diversity. A healthy natural heritage system with strong connections indicates a healthy and resilient watershed.

- ***Eight Species at risk have been identified in the Shadow Lake study area.*** Of the 8 species, 2 are dependent on the lake and/or its tributaries for survival; Blanding's Turtle (threatened) and Snapping Turtle (special concern)

- ***Development Intensification adjacent to and in natural features.*** Development around the lake is increasing the amount of pressure on natural areas as portions of forests and wetlands continue to be removed to make room for houses and cottages.

- ***Climate change has the potential to continue to alter terrestrial ecosystem conditions***. The impacts of climate change will emanate from well beyond the watershed, but they can affect physical and biotic attributes and ecological functions within the watershed. Forests, already stressed by invasive plant and insect species, will continue to degrade due to climate change pressures. Without healthy natural heritage systems, diversity will decline species will be less resilient to the changes that are upon them.

INFORMATION GAPS

- ***Limited understanding of the health and quality of terrestrial ecosystems.*** The terrestrial ecosystems have not been inventoried recently in any detailed manner to determine their health. No comprehensive and updated list of species, including species at risk exist for the Shadow Lake watershed.

- ***Lack of information to determine the impacts of climate change on terrestrial ecosystems.*** Much like a complete inventory, no assessment of the resiliency of the terrestrial ecosystem to climate change has been completed.

7.2 Natural Cover

An area of natural cover refers 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 generation;
- 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 headwaters, wetlands, large forest tracts and riparian buffer areas, may affect any or all of the above functions.

The entire Shadow Lake watershed contains 50 km^2 of natural cover, representing 80% of the total terrestrial area. This includes only areas classified as forest, wetland, rock barren and open water. There is a further 6% cover found in meadows, thickets, woodlots and plantations. **Figure 7.1** demonstrates the cover types existing within the 5 watersheds that drain into Shadow Lake. Meadows and cultural plantations are separated out from natural cover because they do not represent natural cover areas, but rather areas that are under recent human influence. **Table 7.1** illustrates the percentage of each land use type within the watershed.

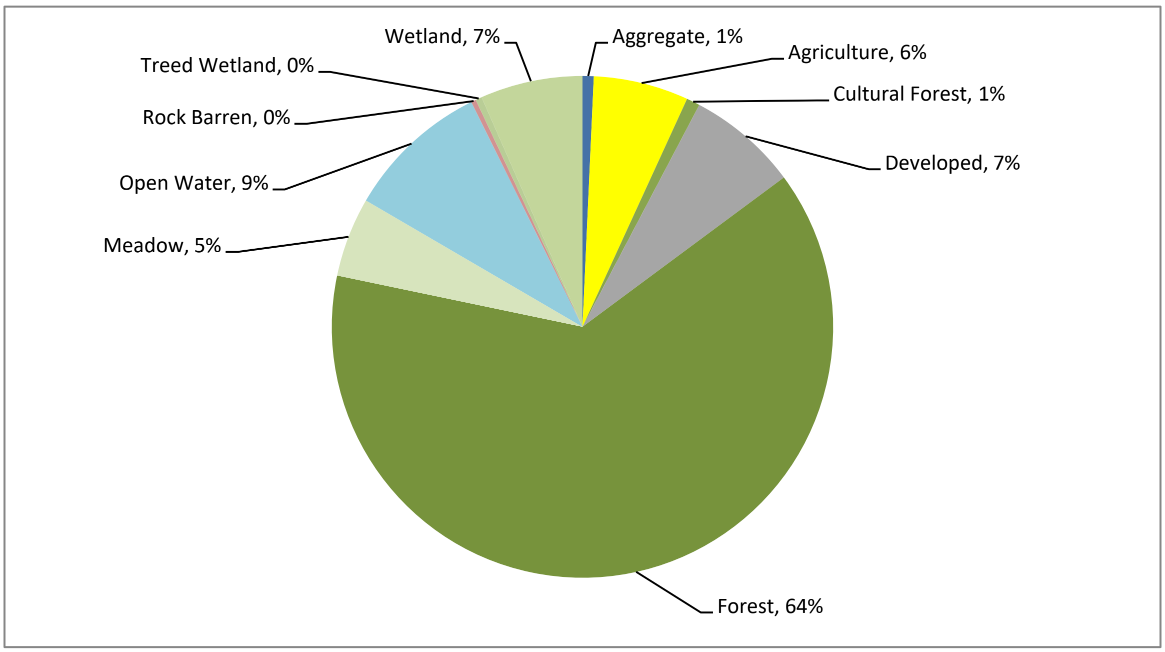


Figure 7.1. Shadow Lake Watershed Land Cover Based on Ecological Land Classification

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 Shadow 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-9 represents the Shadow Lake watershed, while Eco-district 5E-11 includes the area of the Shadow Lake Watershed that is north of the Lake (Henson and Brodribb, 2005). Ecodistrict 6E-9's northern boundary follows the southern edge of the Canadian Shield and includes the limestone Carden Plains in the west, the Napanee Plain in the east and the till plains of the Dummer Moraine.   Eco-district 6E-9 is primarily deciduous and mixed forests as well as swamp wetlands. The Great Lake Conservation Blueprint would require that 23% of the remaining natural cover, and over 40% of all species and vegetation community targets be set aside in order meet conservation targets. Ecodistrict 5E-11 is mostly underlain by undifferentiated igneous and metamorphic rock (the Canadian Shield) exposed at the surface or covered by thin soils. Eco-district 5E-11 has an equal cover of coniferous and hardwood forests, while 9% of the area is wetland consisting of deciduous swamp and some open muskeg. The Great Lake Conservation Blueprint would require that 10% of the remaining natural cover, and over 30% of all species and vegetation community targets be set aside in order meet conservation targets for 5E-11.

Table 7.1. Area and Percentage of Cover Types in the Shadow Lake Watershed

Land Use	Watershed Area km2	Watershed Area(%)
Watershed	62.9	100
Forest	39.93	63.4
Forested Wetland	0.25	0.41
Non-Forested Wetland	4.15	6.60
Meadow	3.23	5.12
Total Cover (including plantations, meadows, rock barrens and thickets)	54.16	86.02

Forests

Forests covered more than 90% of Southern Ontario prior to European settlement ***(*Larson et al, 1999*)*** and naturally occurring forests currently account for 64% of the terrestrial portion of the Shadow Lake watershed (a combination of upland forests (63%) and forested/treed wetlands (0.5%). 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 forests that are found in the Shadow Lake watershed are mostly regrowth 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 or on the Canadian Shield, where granite bedrock is unsuitable for cropland. This is reflected in the Shadow Lake watershed by the fact that the dominant natural area type is forest, specifically mixed forest and that coniferous, mixed and deciduous forests account for over 60% of the Shadow Lake landscape.

The entire Shadow Lake watershed is currently 33% higher than the target of 30% forest cover for Areas of Concern watersheds within the great lakes basin **(Environment Canada, 2004),** and Shadow Lake is 28% higher than the Conservation Ontario target **(Conservation Ontario, 2011)** of 35% forest cover for watersheds in Ontario. No watershed in the Shadow Lake study area falls below 60% forest cover.

Comparing the amount of forest cover with target levels suggests that conservation of forest and efforts to monitor and maintain forest health would be beneficial for overall watershed health. The areas of the watershed available for forest restoration are fairly minimal with much of the watershed already under natural cover.

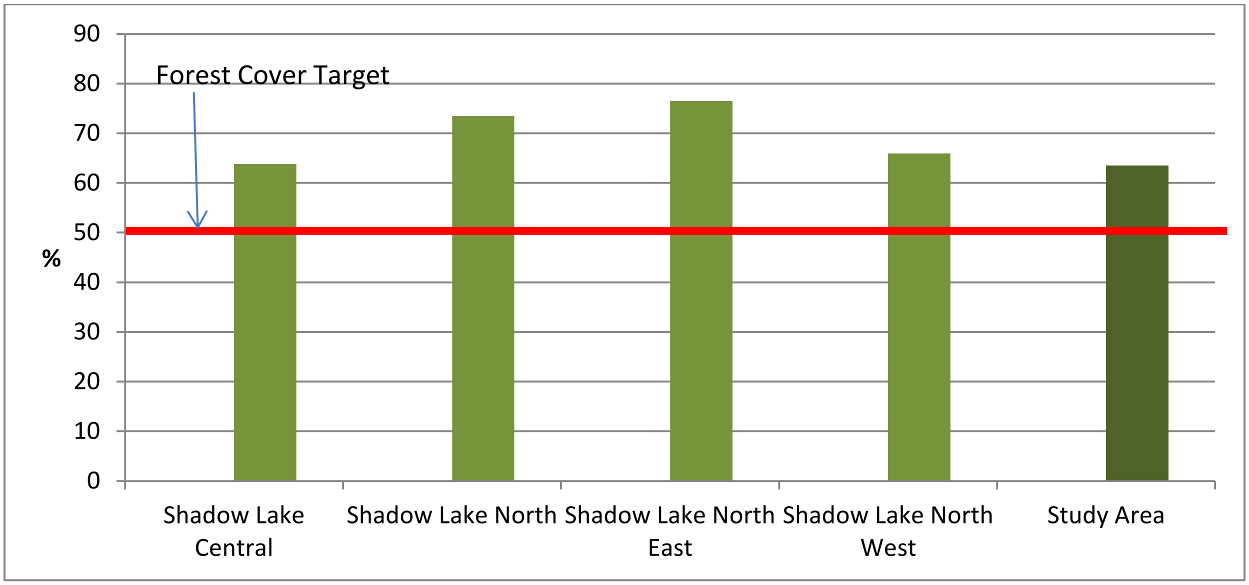


Figure 7.2. Forest Cover in the Shadow Lake Watershed

7.3 Ecological Land Classification

Ecological Land Classification (ELC) is a method to further classify natural cover types into vegetation community types within the Shadow Lake watershed. Vegetation communities for the watersheds were classified and mapped in 2011-2013 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, 5 unique types of cultural areas, 12 unique types of developed areas and 16 unique types of natural areas, based on the community series level of detail, were identified for the Shadow Lake 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. Developed areas are in active and continuous use for purposes that do not support or are in direct conflict with naturally occurring ecosystems. 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 resource in supporting healthy ecosystems. Vegetation community types are described in Appendix 7A, and mapped in **Figure 7.3**.

The ELC assessment shows that the Shadow Lake watershed contains 6% cultural community types, 14% developed areas and 80% natural community types. Mixed forest in the Shadow Lake watershed, at 29%, encompasses the greatest area of the natural cover community types, with coniferous forest and deciduous forest being the next two most dominant community types. Eight wetland types have been identified within the Shadow Lake watershed and account for 7% of the total study area. The watersheds contain mostly coniferous swamp, deciduous swamp and shallow marsh and the rest is made up of fens, thicket swamps and marshes. Only minimal areas of aquatic wetland communities are found within the lake area as Shadow Lake is mostly open water.

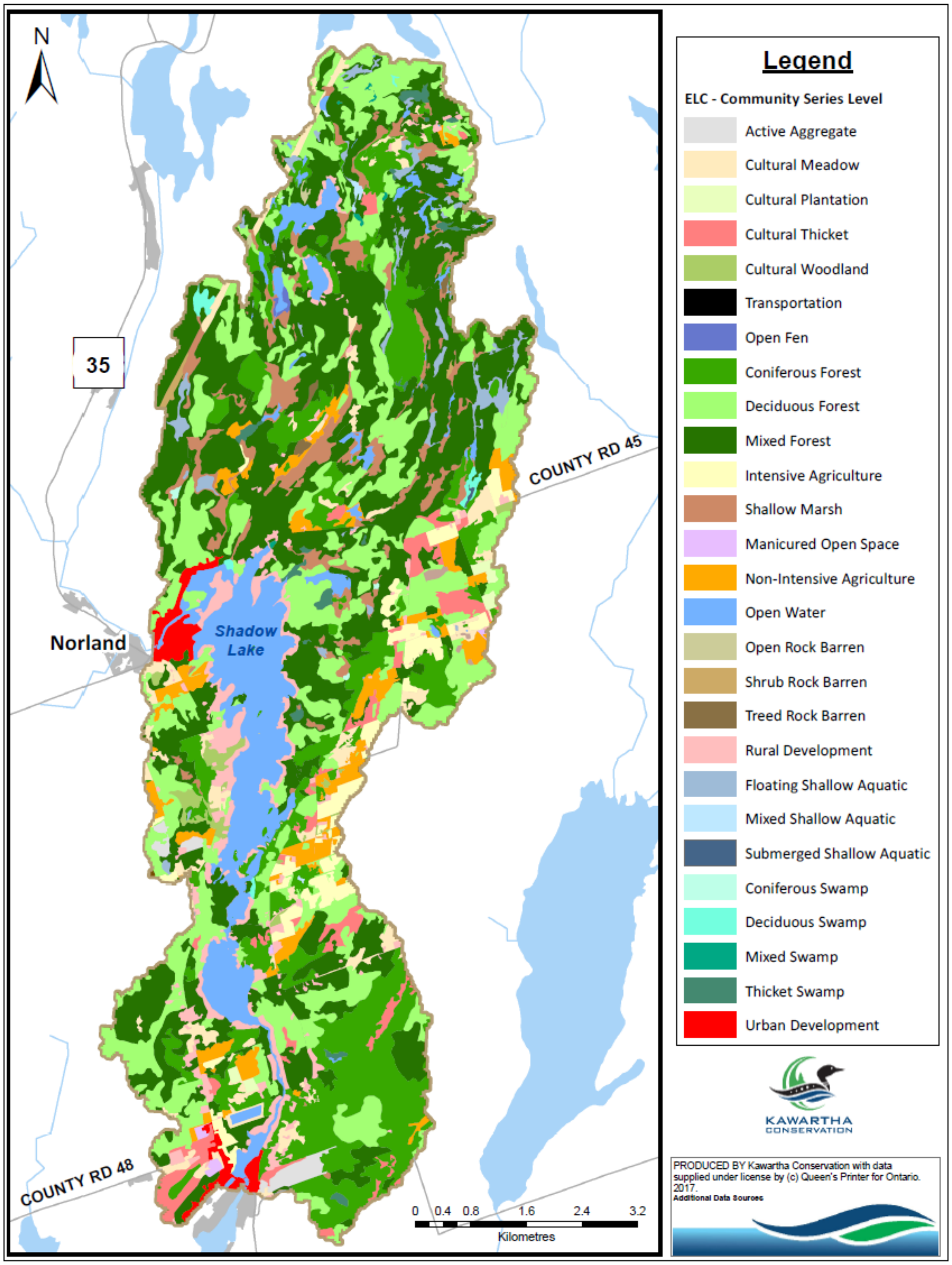


Figure 7.3. Ecological Land Classification of the Shadow Lake Watershed

7.4 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 Conservation Blueprint for Biodiversity has identified 20 species at risk as conservation targets within ecodistricts 6E-9 and 21 species in 5E-11 **(Henson and Brodribb, 2005).**

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 Shadow 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 Shadow Lake watershed level.

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 woodlands 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 7.2** 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 interior 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%. Shadow Lake watershed has 7 % interior (>100m) and 1 % deep interior (>200m). Therefore the Shadow Lake watershed is below he targets for both interior and deep interior forest cover. **Figure 7.4** shows the distribution of interior forest areas within the watershed.

Table 7.2. 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.

Source: Environment Canada (2004)

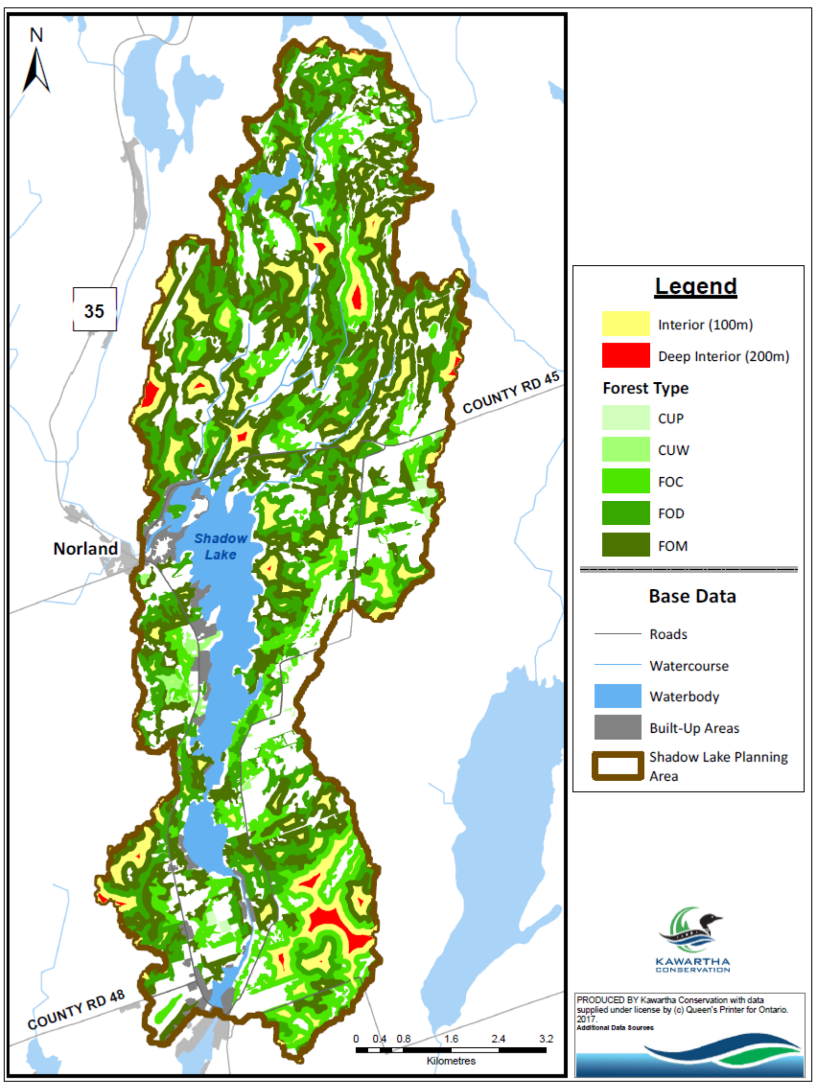


Figure 7.4. Areas of Interior Forest in the Shadow Lake Watershed

7.5 Species and Habitats at Risk

Endangered, rare and threatened species

Blandings Turtle (*Emydoidea blandingii*), threatened,
Butternut (*Juglans cinerea*), endangered
Common Five-lined Skink, (*Plestiodon fasciatus*), special concern
Eastern Hog-nosed Snake (*Heterodon platirhinos*), threatened,
Eastern Meadowlark (*Sturnella magna*), threatened
Milk Snake (*Lampropeltis Triangulum*), special concern,
Rusty-patched Bumble Bee, (*Bombus afinis*), endangered
and Snapping Turtle (*Chelydra serpentina*), special concern

The above are species at risk that have been identified in the Shadow Lake study area. A full list of species, occurrences and detailed information about their life history, status and recovery plans is available on the OMNRF Natural Heritage Information Centre web site.

7.6 Herpetofaunal Species

The Ontario Reptile and Amphibian Atlas has identified the following species in the Shadow Lake Watershed:
American Toad (*Bufo [Anaxyrus] americanus*),
Blandings Turtle (*Emydoidea blandingii*),
Blue-spotted Salamander(*Ambystoma laterale)*,
Eastern Garternsnake (*Thamnophis sirtalis*),
Common Five-Lined Skink (*Plestiodon fasciatus*)
Green Frog (*Rana clamitans)*,
Midland Painted Turtle (*Chrysemys picta*),
Northern Leopard Frog (*Lithobates pipiens*),
Snapping Turtle (*Chelydra serpentina*),
Spring Peeper (*Pseudacris crucifer*),
and Wood Frog (*Lithobates sylvaticus*).

7.7 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 no ANSI sites within the Shadow Lake watershed.

There are a number of locally significant areas of natural and scientific interest located in the Shadow Lake watershed that have not been classified or identified by the province or Kawartha Conservation as regionally or provincially significant. 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 MNR.

SWH is defined 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).**

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 are 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.

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 Shadow Lake watershed that are natural heritage features such as wetlands and forests, are composed of 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 found widely throughout the Shadow Lake watershed. The natural areas within the Shadow Lake watershed tend to be only minimally fragmented; maintaining core areas should 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 7.7**.

Wetlands

Wetlands are key natural heritage and hydro logically sensitive features that 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 and protection under the Ontario Provincial Policy Statement. **Figure 7.6** illustrates the location of wetlands within the watershed. **Figure 7.3** also illustrates wetland classification by indicating the vegetation community series.

Environment Canada 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.

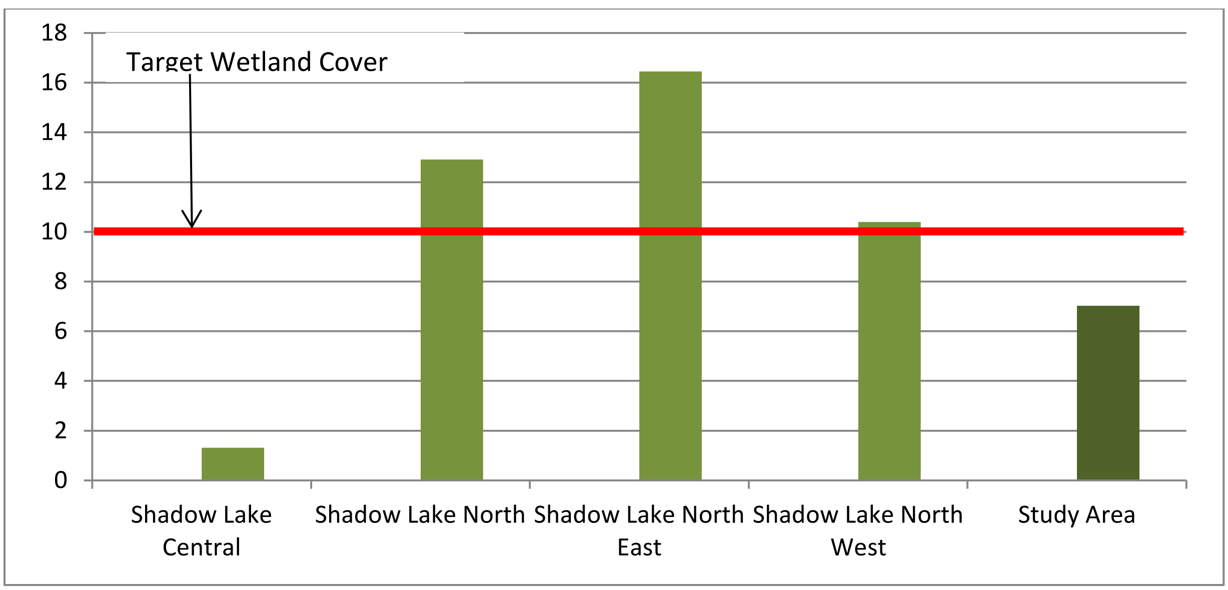


Figure 7.6. Wetland Cover in the Shadow Lake Watershed

The Shadow Lake watershed contains approximately 4km^2 of wetland representing 7% of the terrestrial area; this is below the 10% minimum recommended percentage of wetland cover, however it does match the Great Lakes Conservation Blueprint for Biodiversity for Eco-district 5E-11, which indicates that 9% of the area is wetland. There are no areas designated as provincially significant wetlands in the Shadow Lake study area. All wetlands are illustrated in **Figure 7.7**.

Wetlands have also been classified through air photo interpretation to a community series level using the ELC System for southern Ontario, first approximation **(Lee et al., 1998).** The wetland types identified are further described in **Appendix 7A**.

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 provide a critical function by maintaining stream flow during periods of drought.

Ecological Goods and Services

Natural areas such as wetlands and forests are a critical part of any terrestrial ecosystem. 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 and Bagstad, 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 et al., 2011).**

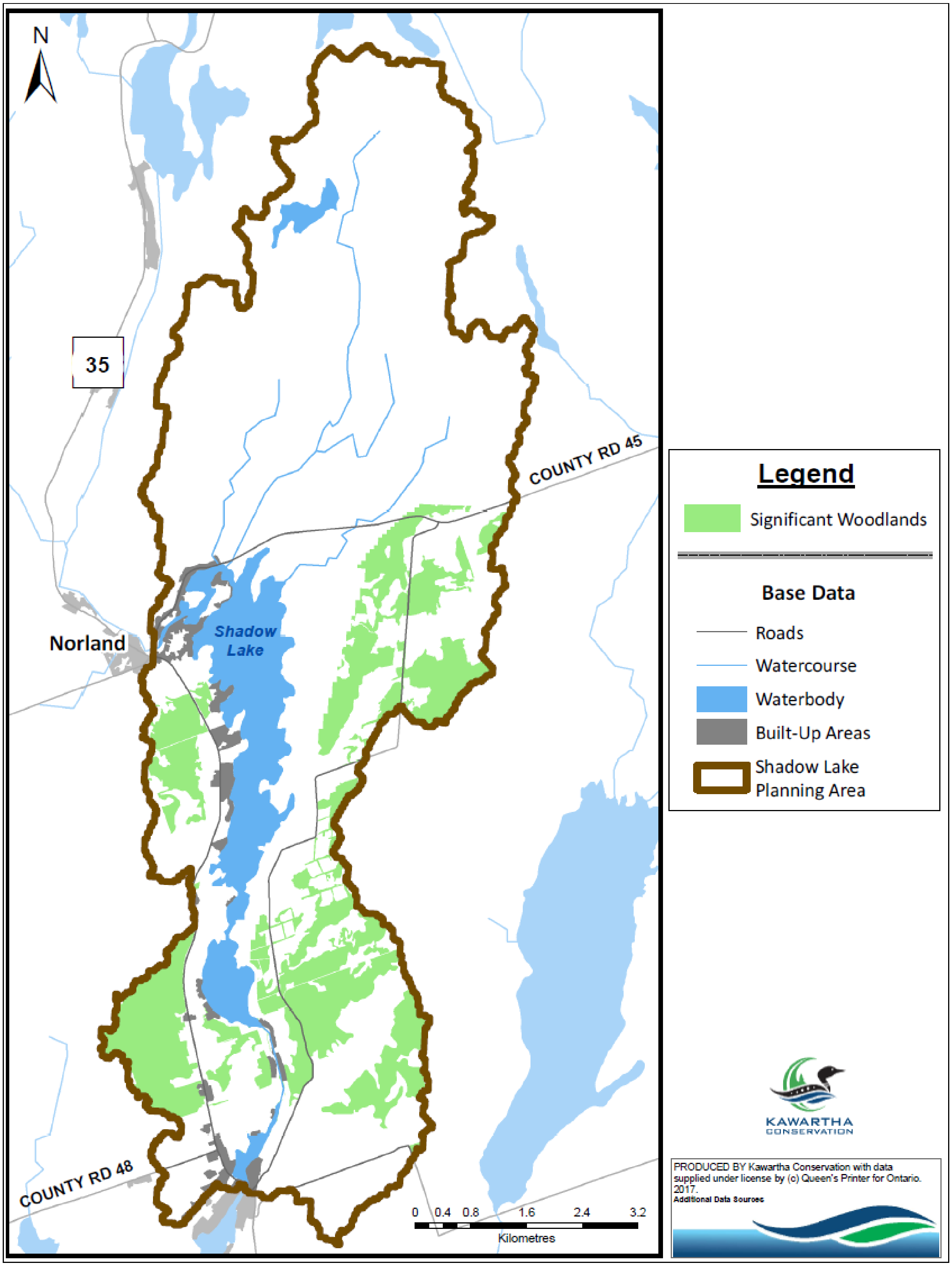


Figure 7.7. Significant Natural Features in the Shadow Lake Watershed

7.8 Kawarthas, Naturally Connected Natural Heritage System

The Kawarthas, Naturally Connected project is a collaborative engagement process in which community members, practitioners, and other stakeholders in the Kawartha Lakes region developed a natural heritage system (NHS) using the best available data and tools **(Figure 7.8).**

Kawarthas, Naturally Connected is a multi-partner initiative established in 2011 by community members, practitioners, and other stakeholders in the City of Kawartha Lakes, Peterborough County, and the City of Peterborough, to ensure the protection of the cultural, social, ecological and economic attributes of the area.

Natural Heritage Systems (NHS) are networks made of natural features and areas such as wetlands, forests, river corridors, lakes and meadows. They can also include areas that have the potential to be restored. These natural areas provide "ecosystem services" that support life and the health of people, plants and wildlife. Some of the services provided by our natural systems include clean air and clean water, pollination and food production, habitat for fish and wildlife species, resiliency to environmental stressors (climate change, invasive species, flooding, soil erosion), production of medicines, biofuels and other products and recreational opportunities.

Kawarthas, Naturally Connected provides support for Lake Management Plan implementation through identification and prioritization of areas for stewardship activities. The Natural Heritage System has included natural features that are the highest priority for protection and restoration in order to achieve or sustain a healthy ecosystem that supports sustainable use of the land. Currently the Kawarthas, Naturally Connected system consists of a map of the system. There is work being done towards establishing the role that the system will have in municipal planning, additionally the system can be applied to stewardship prioritization and land acquisition for long term protection of natural features.

For more information or how to become involved in developing the Naturally Connected system you can visit http://www.kawarthasnaturally.ca/

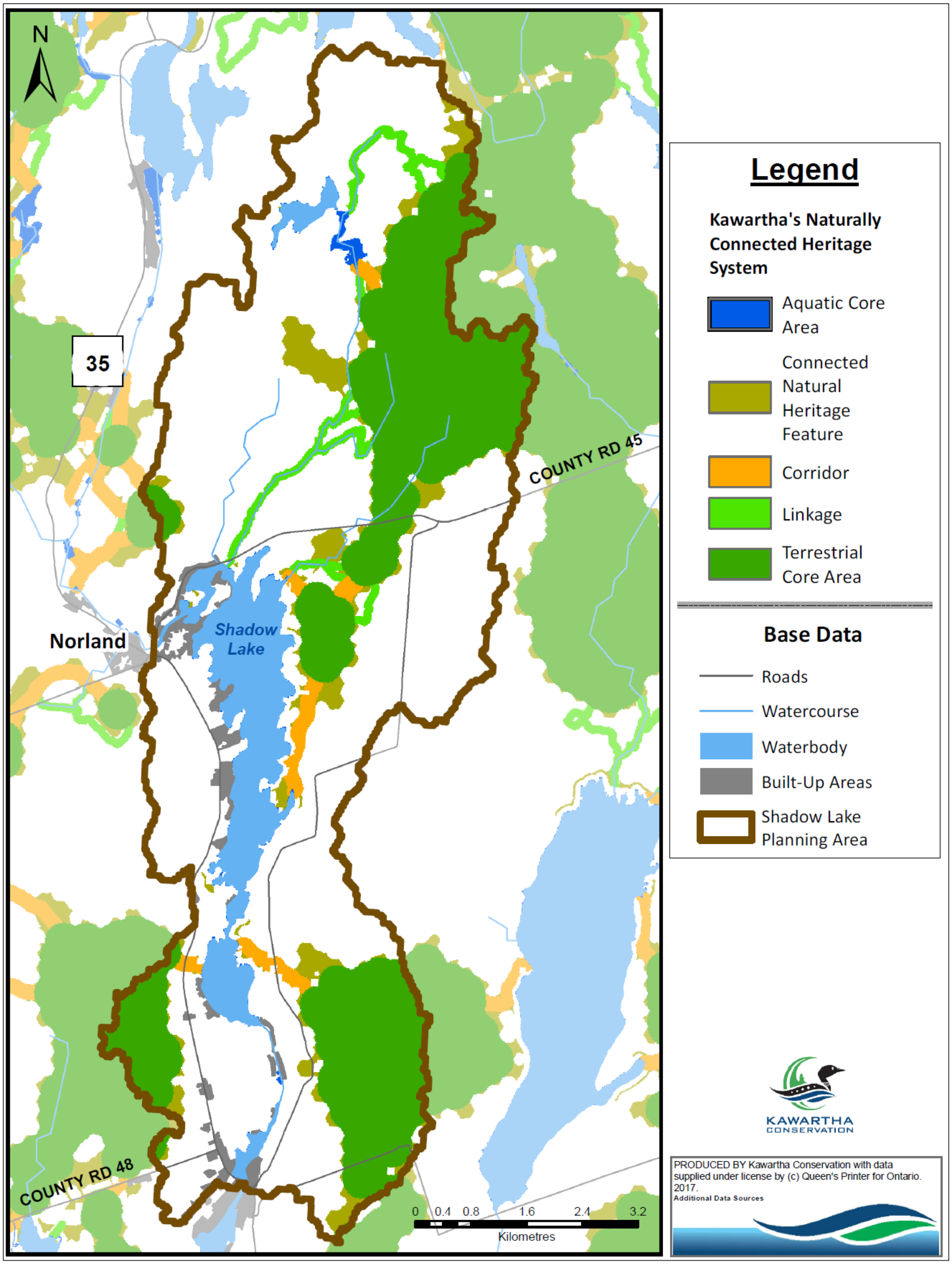


Figure 7.8. Kawarthas Naturally Connected Natural Heritage System in the Shadow Lake Watershed

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Appendix 7A

Community Series Description

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Pigeon Lake Watershed	
		km²	%
AA - Active Aggregate	Barren, heavily disturbed open pit or quarry	0.4	0.61
AI - Inactive Aggregate	Surface cover ≥ 25% or barren, currently unused open pit or quarry	0.07	0.11
BBO – Open Beach/Bar	Areas of openness maintained by active shoreline processes such as ice scour, wave energy, erosion and deposition. Substrate of coarse parent mineral material, rock or bedrock. Above the seasonal high-water mark; subject to extremes in moisture and temperature. Vegetation cover varies from patchy and barren to more closed and treed, tree cover ≤ 25%, shrub cover ≤ 25%	0	0
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).	0	0
BOO – Open Bog	Bog with tree cover ≤ 10%, shrub cover ≤ 25%	0	0
BOT – Treed Bog	Bog with 10% < tree cover ≤ 25%	0	0
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%.	1.74	2.78
CUP – Cultural Plantation	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by tree cover > 60%.	0.17	0.27
CUS – Cultural	Areas that have resulted from or are	0	0

[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	Pigeon Lake Watershed	
		km^2	%
Savanna	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%.		
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%.	1.48	2.34
CUW – Cultural Woodland	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by tree cover between 35% and 60%,	0.37	0.59
CVI - Canadian Vehicle Infrastructure	Roads and highways	1.39	2.21
DIS – Disturbed Areas	No natural cover, areas that have been disturbed by human influences, e.g. trails	0	0
FEO	Areas with an organic substrate and > 40cm of brown moss or sedge peat, rarely flooded but always saturated and pH is slightly alkaline to mildly acidic. Tree cover ≤ 10%, shrub cover ≤ 25%	0.04	0.06
FES	Areas with an organic substrate and > 40cm of brown moss or sedge peat, rarely flooded but always saturated and pH is slightly alkaline to mildly acidic. Tree cover ≤ 10%, shrub cover > 25%	0	0
FET	Areas with an organic substrate and > 40cm of brown moss or sedge peat, rarely flooded but always saturated and pH is slightly alkaline to mildly acidic. 10% < Tree cover≤ 25%	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	9.31	14.79
FOD – Deciduous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% deciduous tree species	11.91	18.92
FOM – Mixed Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 25% deciduous tree species	18.71	29.72

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Pigeon Lake Watershed	
		km²	%
	and greater than 25% coniferous tree species		
IAG – Intensive Agriculture	Annually cultivated, crop fields, gardens, nurseries, tree farms. Variable	1.53	2.44
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.	0	0
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%.	2.77	4.39
***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	0.08	0.13
***NAG** – Non Intensive Agriculture	No cultivation, grasses, hay, pasture, grazing. Variable	2.32	3.69
OAO – Open Aquatic	Areas with water >2m deep. Plankton dominated with no macrophyte vegetation and no tree or shrub cover.	5.82	9.26
RBO – Open Rock Barren	Found where conditions are most extreme; bare rock surfaces or small patches of very shallow substrate. Tree cover ≤25%, shrub cover ≤ 25%	0.04	0.06
RBS – Shrub Rock Barren	Found where conditions may be less extreme; where rock is broken and cracked or where limited substrates have accumulated. Tree cover ≤ 25%, shrub cover > 25%	0.08	0.13
RBT – Treed Rock Barren	Found where bedrock is broken and cracked or where shallow substrates have accumulated. 25% < tree cover ≤ 60%	0.08	0.13
***RD** – Rural Development	Variable. 0.2 ha < area < 2.0 ha containing development not associated with agriculture	2.39	3.80
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.	0.92	1.47

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Pigeon Lake Watershed	
		km^2	%
	Greater than 25% cover of floating-leaved macrophytes. Often influenced by shoreline energy.		
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.	0.05	0.07
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.	0.02	0.03
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) Tree cover ≤25%, shrub cover > 25%	0	0
SBO – Open Sand Barren	Tree cover ≤25%, shrub cover ≤ 25%	0	0
SWC – Coniferous Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is >25%, canopy height is greater than 5m, and conifer tree species make up >75% of the canopy. Hydrophytic shrubs and herbs present.	0.03	0.04
SWD – Deciduous Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is >25%, canopy height is greater than 5m, and deciduous tree species make up >75% of the canopy. Hydrophytic shrubs and herbs present.	0.19	0.30
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.	0.04	0.06

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Pigeon Lake Watershed	
		km²	%
	Hydrophytic shrubs and herbs present.		
SWT – Thicket Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is ≤ 25% and hydrophytic shrub cover is >25%.	0.37	0.59
URB – Urban Development	Variable. > 5 residential units in an area > 2 ha, generally residential	0.63	0.99
Cultural Areas		12.58	19.97
Natural Areas		50.39	80.03
Developed Areas		3.02	4.79
Combined Areas of Cover*		54.16	86.02
Roads		1.39	2.21

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