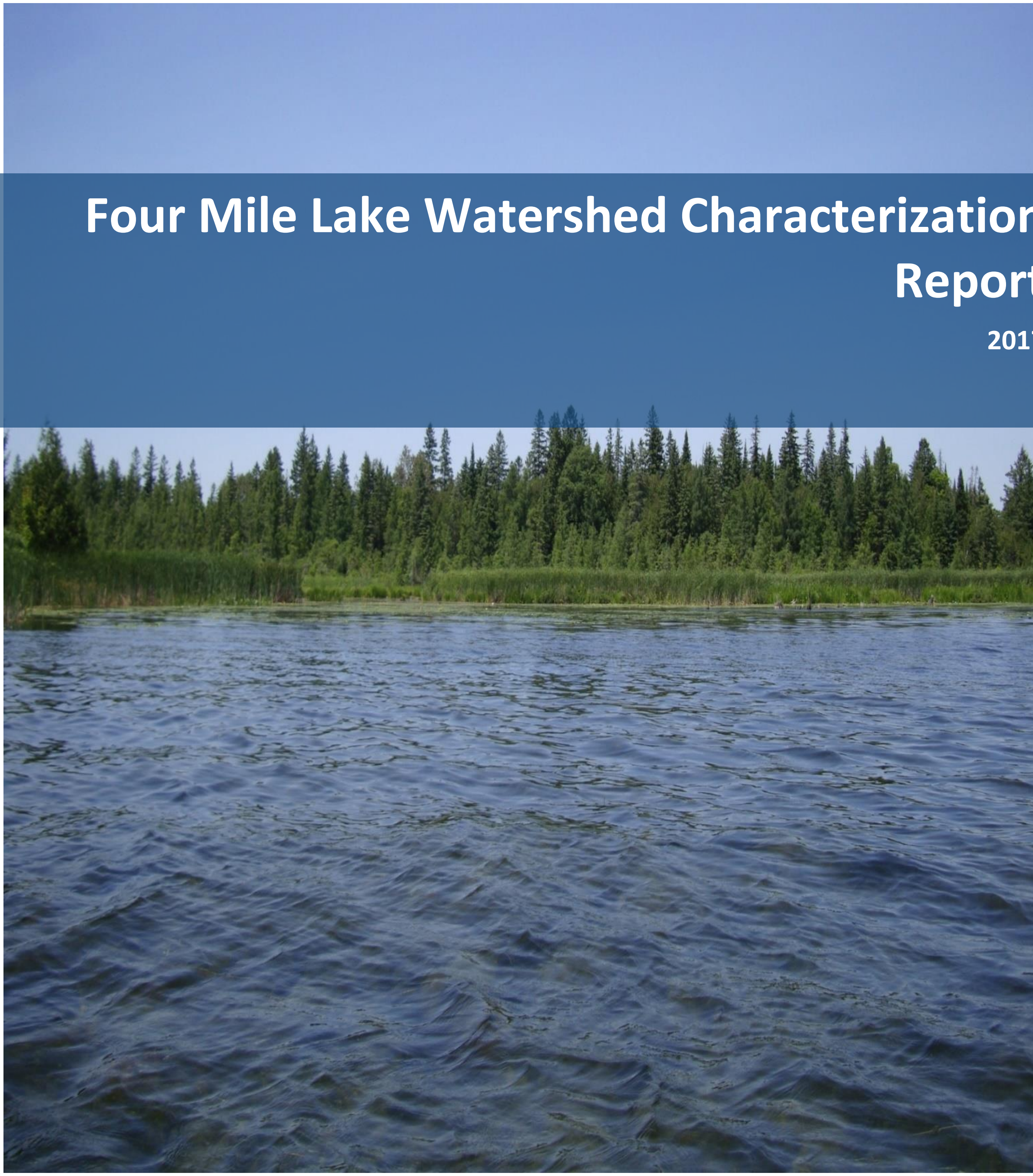
Four Mile Lake Watershed Characterization Report

2017



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

Scugog Lake Stewards

Four Mile 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

FML: Four Mile Lake

FMLSP: Four Mile Lake 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 Four Mile Lake Watershed Characterization Report is to provide a technical, comprehensive report on the current state of Four Mile Lake and its subwatersheds that supports the development of a Four Mile Lake Stewardship Plan. Emphasis has been placed on characterizing the immediate drainage area around Four Mile 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.

Introduction

The Four Mile Lake watershed occupies a small area (78.96 km^2) within the north-east portion of the Kawartha Conservation watershed. The study area for the Four Mile Lake Stewardship Plan includes areas adjacent to the lake from the north including the Corben Creek subwatershed.

Socio-economics

The Four Mile Watershed has an estimated year round population of approximately 380. 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 Four Mile Lake that support the tourist 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.

Land Use

The major human land use in the watershed is represented by built up areas (along the Four Mile Lake Shoreline) in addition to agricultural areas comprising of 4% and 9% of the watershed, respectively. The remainder of the watershed is dominated by natural areas such as forest, 48%, wetlands 18% and meadows at 8%. Open water comprises 13% of the entire watershed.

The Four Mile Lake 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. Four Mile 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 Four Mile 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

The water level and flow data confirm that the lake, as well as its monitored tributary have well-defined seasonal pattern, reflecting seasonal variations of water inflow. During the period of monitoring, the highest flows and water levels at the FML outlet have been observed in April in response to the spring freshet, often coupled with rain events. After peaking, lake's water level recedes through the summer and fall's months, reaching its lowest marks in September-October. The flushing rate is 2.76 times per year. Therefore, on average, the water mass in Four Mile Lake changes every ~130 days. Small, unregulated tributaries of Four Mile Lake exhibit a natural flow regime with well-defined seasonal flow patterns. High flows typically occur in spring, associated with snowmelt, and throughout the year following high volume precipitation events. Low flows are typically observed in the summer and winter months.

Four Mile Lake, on average, receives 25.58 million m^3 of water inflow every year. The water inputs include Corben Creek subwatershed (42.56%), Merrett Creek subwatershed (15.19%), Four Mile Lake Central-the Western Tributary subwatershed (16.21%), and direct precipitation (26.04%). Water exits Four Mile Lake through Corben Creek S. and traverses through meadows, forest and agricultural land before exiting into Balsam Lake. Karst topography, that is very common in central and lower portions of the Corben Creek subwatershed, causes intermittent flow in the main channel and creek's tributaries when watercourses disappear under the ground and reappear back to surface.

Water Quality

Four Mile Lake can be characterized as an oligotrophic (low productivity) water body with excellent water quality. Water quality concerns in the Four Mile Lake watershed include elevated concentrations of phosphorus in its northern tributary, namely Merrett Creek as well as high *Escherichia Coli* concentrations in some streams and at the public beach in addition to high nitrogen concentrations in the Western Tributary and Merrett Creek. Total (inorganic and organic nitrogen) and Total Kjeldahl forms of nitrogen have exceeded the guideline threshold in Western Tributary (2013-2014) and have shown elevated concentrations in Merrett Creek over the entire monitoring period (2013-2016). 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. 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. Four Mile Lake Central (including the Western Tributary) accounts for 39% (181.84 kg) of the total phosphorus inputs into the lake, local subwatersheds account for 38% (178.49 kg), and Atmospheric deposition accounts for 23% (107.4 kg).The Haliburton, Kawartha, Pine Ridge District Health Unit beach posting data (due to elevated *E. coli* concentrations) shows that the public beach on Four Mile Lake has been posted at least once per season during the monitoring years of 2011-2015.

Aquatic Ecosystems

Lake morphology is distinct between the northern and southern sections (Figure 8.1). The south basin of the lake contains the deepest depths (up to 20m) and has relatively narrow and steep nearshore areas adjacent to shore. The north basin of the lake, in contrast, contains relatively shallower waters that more gradually slope into the lake. Shallow nearshore areas (less than 2m) are relatively limited in the lake, occupying only 13% of the lake surface area. The distribution of bottom substrate within the littoral zone (the nearshore area extending to a depth at which vascular plant growth ceases). Weedy substrates characterized the greatest length of shoreline (5375m), followed by rock conditions (4025m), submerged shoals (3975m), sand and stones (3825m), rocky cliffs (2375m), and sand (1000m) and gravel (725m).

The most large-bodied fish species found in four Mile Lake, in terms of relative abundance, are yellow perch, smallmouth bass, rock bass, walleye, pumpkinseed, white sucker, largemouth bass, and muskellunge. Lake herring, lake whitefish, and burbot are all coldwater fish species that have been documented within the lake. These fishes require cold, well-oxygenated waters to support their populations.

The southern basin of Four Mile Lake is the deepest part of the lake and has been observed to stratify during the summer months, trapping cold water in the deeper water that provides habitat of suboptimal quality to sustain these fishes during the hot periods. 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 entire Four Mile Lake watershed contains 55 km^2 of natural cover, representing 78% of the total terrestrial area. This includes only areas classified as forest, wetland, and open water. There is a further 10% cover found in meadows, thickets, woodlots and plantations. Three areas of forest that represent a significant amount of the Four Mile Lake watershed are a portion of the Somerville Tract (3420 Ha), a portion of the Victoria County Forest (3743 Ha), and the Altberg Nature Reserve (470 Ha), all located in the North Eastern portion of the watershed. The combined area of these three forested areas is 7633 Ha or 76 km^2, which is greater than the entire area of the Four Mile Lake Watershed. The existing natural heritage features are experiencing some fragmentation in the Southern portion of the watershed. 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. Six Species at Risk have been identified in the Four Mile Lake study area and include the Blandings Turtle, Chimney Swift, Crested Arrowhead, Eastern Meadowlark, Snapping Turtle and Woodland Pinedrops. Of the 6 species, 2 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

Four Mile Lake is located just north of Balsam Lake and east of the town of Coboconk 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 served 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 future management of Four Mile Lake, including best management practice recommendations, the City of Kawartha Lakes (CKL) initiated the development of the Four Mile Lake Stewardship Plan (FLSP) 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 and projected to be accepted by Council the middle of 2016.

The Watershed Characterization Report is an overview of the current state of the aquatic and terrestrial ecosystems within the Four Mile Lake core planning area. The core planning area includes all of the subwatersheds that drain directly into Four Mile 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 2013 to June 2016. Additionally, it includes information and data from previous studies dating back to the 1980s and early 2000s.

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

1.2 Study Area

The Four Mile Lake watershed occupies a small area (78.96 km^2) located just outside the Kawartha Conservation watershed jurisdiction. The study area for the Four Mile Lake Stewardship Plan includes areas adjacent to the lake from the north including the Corben Creek subwatershed. The major human land use in the approximately 3% of the watershed which provides opportunity for natural areas to occupy the landscape such as forest, which dominates more than 48% of the land portion of the watershed. Roads occupy approximately 1% of the watershed which provides opportunity for natural areas to occupy the landscape such as forests (24%).

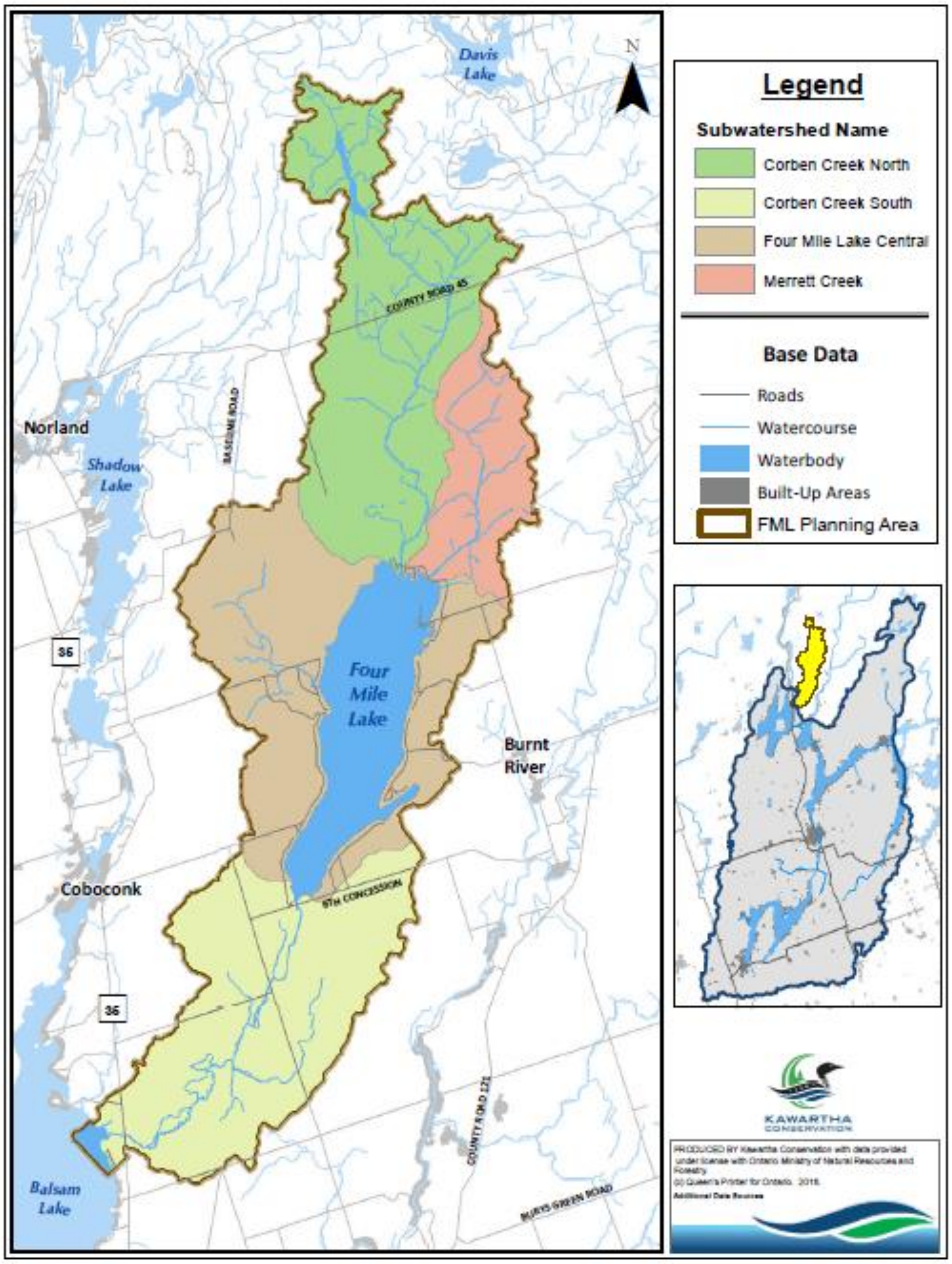

Figure 1.1. Four Mile Lake Stewardship Plan Study Area.

Headwaters of the Corben Creek, including Corben Creek North and Merrett Creek subwatersheds are situated within the Precambrian bedrock formation, with shallow soils and many rock outcrops. Small lakes, such as Corben Lake, Goodoar Lake and Lower Goodoar Lake are located at the upper portion of Corben Creek North subwatershed. Numerous wetlands are located within this area, which is typical for the Canadian Shield settings. Overall, the natural cover at the headwaters of the Four Mile Lake (Corben Creek North and Merrett Creek) reaches 95%. This includes forest, wetlands and meadow. Different types of wetlands occupy prevailing portion of the headwaters area, more than 75%. From a hydrological point of view the Four Mile Lake watershed includes all areas that supply water to the lake. This means that the Four Mile Lake watershed is comprised of small local subwatersheds (Corben Creeks, North and South, Merrett Creek, and Western Tributary) as seen in Figure 1.1.

The overall characteristics of the Four Mile Lake study area and its subwatersheds, including Four Mile Lake are shown in Table 1.1

Table 1.1. Four Mile Lake Subwatershed Characteristics.

Sub watershed	Total Surface Area (km^2)	Stream Network Length (km)	Natural Cover (%)	Agriculture (%)	Rural / Urban Development (%)
Corben Creek North	0.68	29.98	93.5	2.45	0.75
Merrett Creek	0.21	10.79	96.8	0.001	0.75
Four Mile Lake Central	0.05	7.14	86.1	4.82	8.79
Four Mile Lake	7.58	45.91	91.2	3.05	4.00
Corben Creek South	0.46	17.62	76.3	15.2	5.76

2.0 Socio-Economic Characterization

2.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- **The Four Mile Lake shoreline is comprised of a seasonal heavy population.** The shoreline area (500m buffer) includes 409 buildings in which 83% are seasonal residences and 17% are year round permanent homes.

- **Seasonal population is expected to increase by 2031.** The affordability of the Kawartha Lakes area in comparison to the driving prices of cottages to the North will positively influence population growth within the CKL and by extension affect the FML community.

- **Shared community lake values.** These include the following: good water quality; unique alvar areas, fish and wildlife habitat; peaceful and quiet ambience; lack of commercial, industrial, residential cluster and backlot development; good fishing and recreational opportunities and a safe living environment.

KEY ISSUES

- **The reduction of services to smaller communities such as Burnt River.** The Burnt River community lost library services as a result of CKL budget constraints in 2016. A growing trend in smaller communities is a sharing of resources (i.e., Emergency Response, Fire Fighters).

- **Shared community lake concerns.** These include; poorly functioning septic systems; shoreline alterations; boating disturbance and potential pollution; nuisance aquatic plants; public swimming safety; and invasive species.

INFORMATION GAPS

- **There is a lack of data on the number of visitors to the City of Kawartha Lakes area during the winter months**. Current City of Kawartha Lakes data supports summer tourism contributions to the economy, but little to no data exists for winter tourism. The City of Kawartha Lakes area is full of winter recreational opportunities such as snowmobiling, winter hiking and ice fishing.

- **There is a lack of data on seasonal and duration of seasonal residents during the year.** This data would help support a greater understanding of when and how long seasonal use of the Four Mile Lake area occurs.

2.2 Brief History

First Nation Peoples have lived in the Kawartha Lakes area for thousands years before Europeans arrived in the beginning of the 19th century. The area we know as the City of Kawartha Lakes (formally known as Victoria County) was settled by Europeans when the Government of Canada put forward the land for sale in 1821. It was one of the first municipalities in the province to be established, in 1863. The County of Victoria was composed of the Town of Lindsay, the Villages of Bobcaygeon, Fenelon Falls, Omemee, Sturgeon Point, Woodville, the Townships of Bexley, Carden, Dalton, Eldon, Emily, Fenelon, Manvers, Mariposa, Ops, Somerville, Verulam and the United Townships of Laxton, Digby and Longford (CKL, 2010). This collection of towns and villages remained physically unchanged until 1974 when the Regional Municipality of Durham was established and Manvers Township was added to the County of Victoria. The City of Kawartha Lakes was created on January 1, 2001 by the amalgamation of municipalities formed within the County of Victoria (CKL, 2010).

The small hamlet of Burnt River is the closest hamlet adjacent to the north eastern portion of Four Mile Lake. It was settled in 1864 and was originally named Rettie's Bridge named after the first settler of the area, Alexander Rettie. The Burnt River was an effective transit system for the logging industry and was used as part of the log drive down to Cameron Lake during the mid-1800s. The Burnt River area was also home to a quarry which was the main source of employment for its residents. The stone processed from this quarry was used to build the Lindsay jail and the main Post Office in Toronto (Burnt River 2000 Committee, 2000). In 1876 the Victoria Railway began and finished in 1878. It was at the onset of the railway that the name of the Burnt River Station replaced Rettie's Station. From that point on the Burnt River hamlet grew into a small town that consisted of many small businesses such as the Burnt River Telephone Company, The Burnt River Women's Institute, the Union Creek Post Office and a school.

The opening of the first 'summer hotel,' Holliday's Hideaway, in 1939 first attracted visitors to the region. Four Mile Lake was and remains a highly sought recreational destination for its residents and visitors (Burnt River 2000 Committee, 2000). Four Mile Lake's shoreline has changed since the early days of its first cabins and has become a community of year round and seasonal residences all enjoying and protecting Four Mile Lake.

2.3 Population and Housing

According to the Canadian Business Analyst which is based on the most recent Canadian Census numbers, the permanent population of the City of Kawartha Lakes was 88,158, which was a small decrease of 1.0% from the 2008 population of 88,615 (ESRI 2013) (Table 2.1). The CKL has an aging population that is similar to many other areas in Ontario. The median age was 48.4 in 2011, while the median age for the province was only 40.4. There were 35,044 private households in 2013, with an average household size of 2.2. The City of Kawartha Lakes has a low population density with only 23.7 persons per square kilometre as a result of the predominantly rural area. Approximately 65% of the population lives in rural areas (CKL, 2009) with the remainder living in the larger towns of Lindsay, Bobcaygeon and Fenelon Falls (Richard Fortin Associates, 2012). The City's Growth Management Strategy predicts a fairly moderate increase in population households through 2031 (MHBC Planning Inc., 2011).

Table 2.1. Population and Housing Statistics for the City of Kawartha Lakes

Variable	Census Year	
	2008	2013
Population (year round)	88,615	88,158
Households (Permanent Residences)	34,393	35,044

Source: ESRI Canada 2013

The Four Mile Watershed has an estimated year round population of 380 (Table 2.2) (ESRI 2013). 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.

Table 2.2. Residential Demographics of Four Mile Lake

2013 Total Population	380
2013 Households	193
Owned Dwellings	178
Rented Dwellings	15
Band Dwelling	0
Average Household Income (2013)	$63,713
Median Age (2013)	54.60

Source: ESRI Canada, 2013.

Seasonal Population

The CKL has a significant seasonal population due to its many cottages and vacation properties. In 2011, the seasonal population was estimated at 32,000 (MHBC Planning Inc., 2011). Current projections of the seasonal population could reach approximately 37,000 by 2031 (Table 2.3). As a significant number of the cottager population retire a growing trend has emerged of converting seasonal properties, such as cottages, to larger permanent residences. This observed trend is expected to increase as the large portion of the CKL population reaches the age of retirement. It is predicted that 17.9% of the seasonal residents will convert seasonal properties to permanent residency by 2031 (Tim Welsh Consulting and Lapoint Consulting, 2013). This boost in year round population will increase pressures to the lakes. A higher population means higher lake use with a greater impact to the lake from increased pleasure crafts, fishing, waterfront property construction, and road expansions etc. An increase in waterfront homes also means a higher installation and use of septic systems which are known to contribute large amounts of excess nutrients to lakes if not managed properly (Whitehead et al., 2011).

Table 2.3. CKL Projections for Seasonal Population and Conversions of Seasonal Residences to Permanent Residences (2001-2031)

Variable	2001	2006	2011	2021	2026	2031
Seasonal Population	29,000	31,000	32,000	35,000	36,000	37,000
Seasonal Conversions	NA	NA	480	1,580	2,030	2,330

Source: Reprinted from Tim Welsh Consulting and Lapoint Consulting, 2013.

Real Estate

It is estimated that 16,437 single detached homes (not including seasonal dwellings) face onto (i.e. have frontage on) waterway areas in the Trent Severn Waterway corridor communities. A large portion of these properties are located in the area from Lakefield to Lake Simcoe, accounting for 6,871 properties of which over half are located within the Kawartha Lakes area (TCI Management Consulting and EDP Consulting, 2007).

According to Royal LePage's Recreational Property Report (2013), in the Kawartha Lakes, a standard waterfront property, with land-access, is priced at approximately $325,000. This price is low compared to neighbouring cottage country, Muskoka, where average cottage prices are $700,000. Due to affordable list prices, waterfront property is in high demand in the Kawartha Lakes and is expected to increase. The main buyers moving to the area are families who plan to use the property, rather than investors (Royal LePage, 2013). An increase in the development in the area would instigate an increase in property across the City of Kawartha Lakes (CKL, 2014). The average value of waterfront properties depends on the water quality of the local lakes and overall watershed. The development around Four Mile Lake has focused on the shoreline areas and supports approximately 180 dwellings with a density of 2.62 buildings within a hectare distance (Table 2.4).

Table 2.4. Building Parameters for Four Mile Lake

Lake	Building Count	Lake Area (ha)	Shoreline (km)	Density (Bldgs/ha)
Four Mile Lake	180	758	21.3	2.62

Source: Garter Lee 2002 & ESRI 2013.

In order to accommodate the projected population growth by 2031 to 100,000 people, the City of Kawartha Lakes has designated land to be developed within their growth plan. There are a total of 1,216 units in Draft Approved and Registered Plans in the Designated Greenfield Areas of Lindsay (730), Bobcaygeon (427), and Fenelon Falls (65 units) as of 2010. The housing demand analysis indicates a need for 10,681 new units from 2006 to 2031 averaging 428 units per year (Table 2.5). CKL staff indicates that there has been an average of approximately 338 new units built per year over the last 10 years (1999-2008). This slower growth approach allows for careful planning and better management strategies to ensure the highest protection of Kawartha Lakes including Four Mile Lake.

Table 2.5. Estimated Total Residence Type (Projected for 2031)

	Single Detached	Semi Detached	Townhouses	Apartments	Seniors	TOTAL
Lindsay	13,171	194	3,815	1,951	442	19,572
Fenelon Falls	1,451	21	486	83	66	2,107
Bobcaygeon	5,395	52	539	781	N/A	6,767
Omemee	1,533	N/A	183	N/A	N/A	1,716
Sub-total	21,550	267	5,023	2,815	508	30,162
Hamlets	3,285	N/A	N/A	N/A	N/A	3,285
Conversions	6,105	0	0	0	0	6,105
TOTAL	30,940	267	5,023	2,815	508	39,552
Average persons per unit (in 2031)	2.62	2.62	1.78	1.51	1.2	

Source: City of Kawartha Lakes

2.4 Industry and Employment

The main industries in the CKL include retail, manufacturing, agriculture, and tourism, as shown in Table 2.6 below.

Table 2.6. CKL Economic Contributions by Industry in 2007

Industry	Economic Contribution (2007)
Manufacturing	$340 million
Agriculture	$243 million
Retail	$600 million
Tourism	$100 million

Source: Reprinted from the CKL, 2010.

Agriculture

Agriculture is one of the largest economic contributors to the City of Kawartha Lakes (Table 2.6). This industry supports a number of year round and seasonal jobs and businesses while contributing largely to the economic development of the CKL (CKL, 2010). The total number of people employed within the agricultural sector is approximately 15,558 (OMAFRA, 2013).The agricultural sector is the largest land user within the city boundaries, however it comprises a very small percentage (6% of land use) within the Four Mile Watershed study area (ESRI 2013). The total land area used for farming within the CKL is 53,446 ha and is composed of approximately 1366 individual farms (OMAFRA, 2013). Approximately 69% (26,645 ha) of the total farmland area is cropland and the additional 31% (11, 828 ha) represents natural lands used for pasture (Figure 2.1). Table 2.7 demonstrates the economic contribution of agricultural income derived from the land and its usage and indicates the highest gross income farming activities are oilseed and grain farming. Dairy and cattle farms also demonstrated significant economic returns, and similar to cropland farming, they have the ability to contribute substantial amounts of nutrients to water bodies if not managed properly.

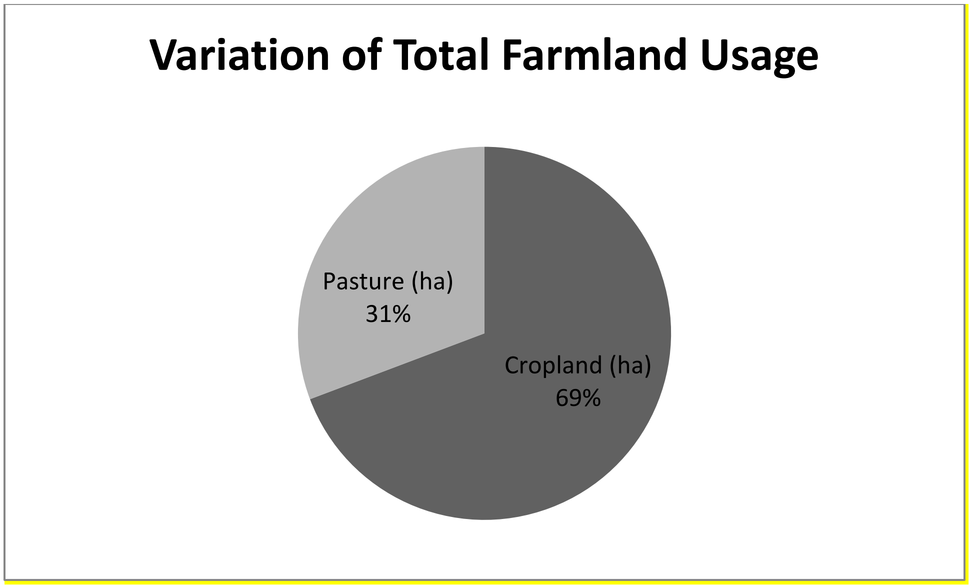

Figure 2.1. Farmland area (ha) delineated by usage for the City of Kawartha Lakes (OMAFRA, 2013)

Table 2.7. The Number of Farms by Industry in the CKL according to Gross Income

Farms by Industry Group	Number of Farms	Gross Income, $
Oilseed and grain farming	146	29,000,000
Dairy cattle and milk	64	21,400,000
Beef cattle ranching	411	20,400,000
Hog and pig production	3	2,700,000
Greenhouse, nursery and floriculture	31	4,500,000
Vegetable and melon farming	19	2,700,000
Sheep and goat farming	56	-
Poultry and egg production	14	-
Other animal production	246	-
Fruit and tree nut farming	10	-
Other crop farming	366	-

Source: OMAFRA 2013.

Recreation and Tourism

The CKL, including areas around Four Mile Lake, offers a wide variety of recreational opportunities. Healthy local lakes encourage tourism, which in turn strengthen the job market within tourism industry. Seasonal and permanent residences around the lakes have resulted in the growth of property management businesses, food services, and other support industries. Due to the large number of navigable lakes and waterways, the main recreation attractions tend to be seasonal outdoor activities. Some of the key recreation activities available around Four Mile Lake include:

2 Seasonally used areas such as private cottages, campsites and trailer parks,
3 Local boating regattas and social activities in and beyond Four Mile Lake
4 Fishing (ice fishing included), including leisure, and competitive tournaments, and
5 Local parks and beaches (The Tourism Company and CKL, 2008).

Tourism is extremely important to the regional economy of the CKL, contributing $100 million in 2012. The projected industrial growth in CKL will be in the commercial sector with the focus on tourists and seasonal and permanent residents (Dillon Consulting, 2012).

In 2012, it was estimated that there were close to 1 million visits to CKL which generated $101,841,825 dollars in visitor spending (CKL 2016). Figure 2.2 illustrates the percentage of person visits to various recreational activities. The highest person visits corresponded with Outdoor and Sports Activities category (Figure 2.2). Most visitors to the area were travelling for pleasure or to visit friends or relatives. The most popular times of the year for people to visit the area were between January - March and July - September.

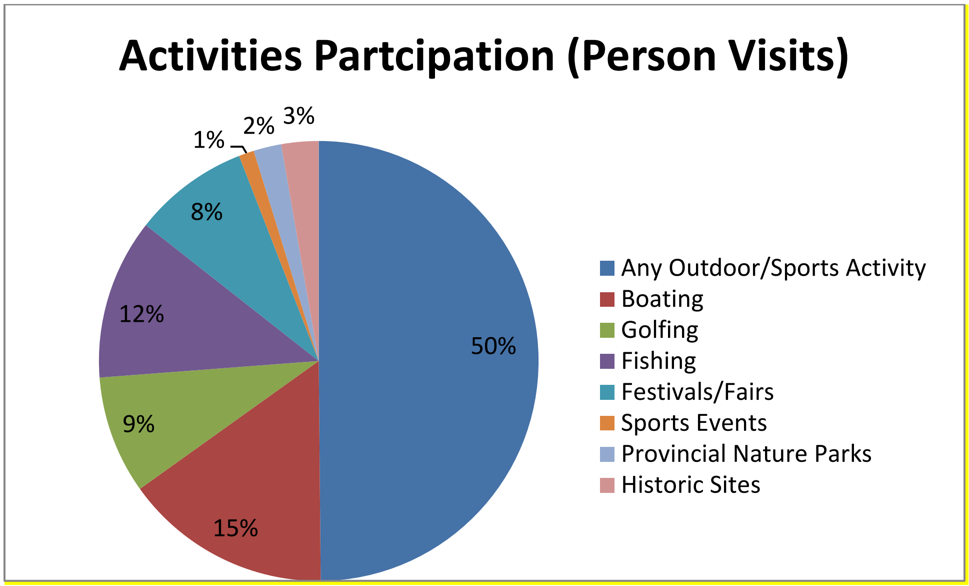

Figure 2.2. The distribution of person visits varies among several categories of activities. Participation in Outdoor/Sports Activities comprised 50% or person visits during 2012 (CKL 2016)

Four Mile Lake supports excellent recreational fishing in winter and summer months. The Four Mile Lake Association has worked very hard to actively assist in the management of fishing through petitioning and implementation of a restrictive boat launch municipal by-law. The by-law denotes various times of the day that the boat launch may be used which results in restricted times and is suspected of creating limited accessibility to the lake by outside angler visits. The Ministry of Natural Resources and Forestry dedicates a weekend in February and July as Ontario Family Fishing Weekends which are license free events meant to encourage new members to the angler community and coincides with the most popular times of the year for visitors to the CKL area.

There are many private businesses in the vicinity of Four Mile Lake that support the tourist industry and water-based recreation. Boating and fishing accounted for 15% and 12%, respectively of the total person visits to the Kawartha Lakes Region (Figure 2.2). These businesses benefit from the recreation opportunities the lakes provide, and help re-circulate money into the local economy.

Key Values of the Four Mile Lake Community

Results from a previous survey (Michalski & Associates 1986) indicated that the Four Mile Lake Community had shared key values about their lake. These values included:

- Good Water Quality
- Unique Alvar Areas, Fish and Wildlife Habitat
- Peaceful and Quiet Ambience
- Lack of Commercial, Industrial, and Residential Cluster and Backlot Development
- Good Fishing and Recreational Opportunities
- Safe Living Environment

The residents around Four Mile Lake highly value the protection of their lake.

Key Concerns of the Four Mile Lake Community

The Four Mile Lake community has some concerns surrounding the lake and the protection of it. These concerns included:

- Poorly Functioning Septic Systems
- Shoreline Alterations
- Boating Disturbance and Potential Pollution
- Nuisance Aquatic Plants
- Public Swimming Safety
- Invasive Species
- New, Large-scale Developments

This lake management plan serves to address these concerns and provide recommendations in order to support the values of the community and the health of Four Mile Lake.

3.0 Land Use

3.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- **The geology of Four Mile Lake lies within a geological transition area.** This area is 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).
- **Four Mile Lake is comprised of three dominant physiographic landforms**. These features influence the planning area: Limestone Plains, Bare Rock Ridges and Shallow Till, and Spillways.
- **Karst Topography is an important and unique characteristic of the southern Four Mile Lake planning area.** This feature affects the surface and subsurface drainage of the study area.

KEY ISSUES

- **Ensuring the protection of the Carden Alvar region with the study area.**

INFORMATION GAPS

- **Gaps in unconfirmed Karst topography exist within the study area.** Further examination of the study area could lead to the verification of these formations, and will lead to a better understanding of the role they play within the Four Mile Lake watershed.

3.2 Physical Geography

The Four Mile Lake 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). As shown in Figure 3.1, Chapman and Putnam (1984) describe three dominant physiographic landforms as driving the landscape of the planning area: 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. Four Mile 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).

An important and unique feature of the limestone bedrock in this area is the presence of karst physiography, characterized by underground crevices, hollows, and fissures underground that formed over geologic time as soft sections of the bedrock were worn away. This landform directly affects surface and sub-surface drainage within the watershed, particularly in Corben Creek South where a section of the main channel disappears and later reappears kilometres down slope (see Chapter 5: Water Quantity).

Bare Rock Ridges and Shallow Till occupy the northern section of the planning area. This terrain is also referred to as the Georgian Bay Fringe physiographic region, and is considered as existing within the southern Canadian Shield. Soils are extremely thin or non-existent within this region and as such rock-outcroppings are dominant landscape features. Precambrian rocks are particularly exposed along the northern shoreline of Four Mile Lake. On and adjacent to the Canadian Shield, the soils are frequently too thin to support successful agricultural activities and as a result, large areas of land once cleared have reverted back to modified forest cover (Helleiner et al., 2009).

A glacial spillway has been recorded in the northeastern section of Four Mile Lake. This area consists of sands that were deposited during the recession of the most-recent glacial activity, at which time the Four Mile Lake watershed was hydrologically connected to a much larger spillway now occupied by the Burnt River watershed.

For more information on the geology, physiography, and topography of the Four Mile Lake Planning area please refer to Michalski Associates (1986).

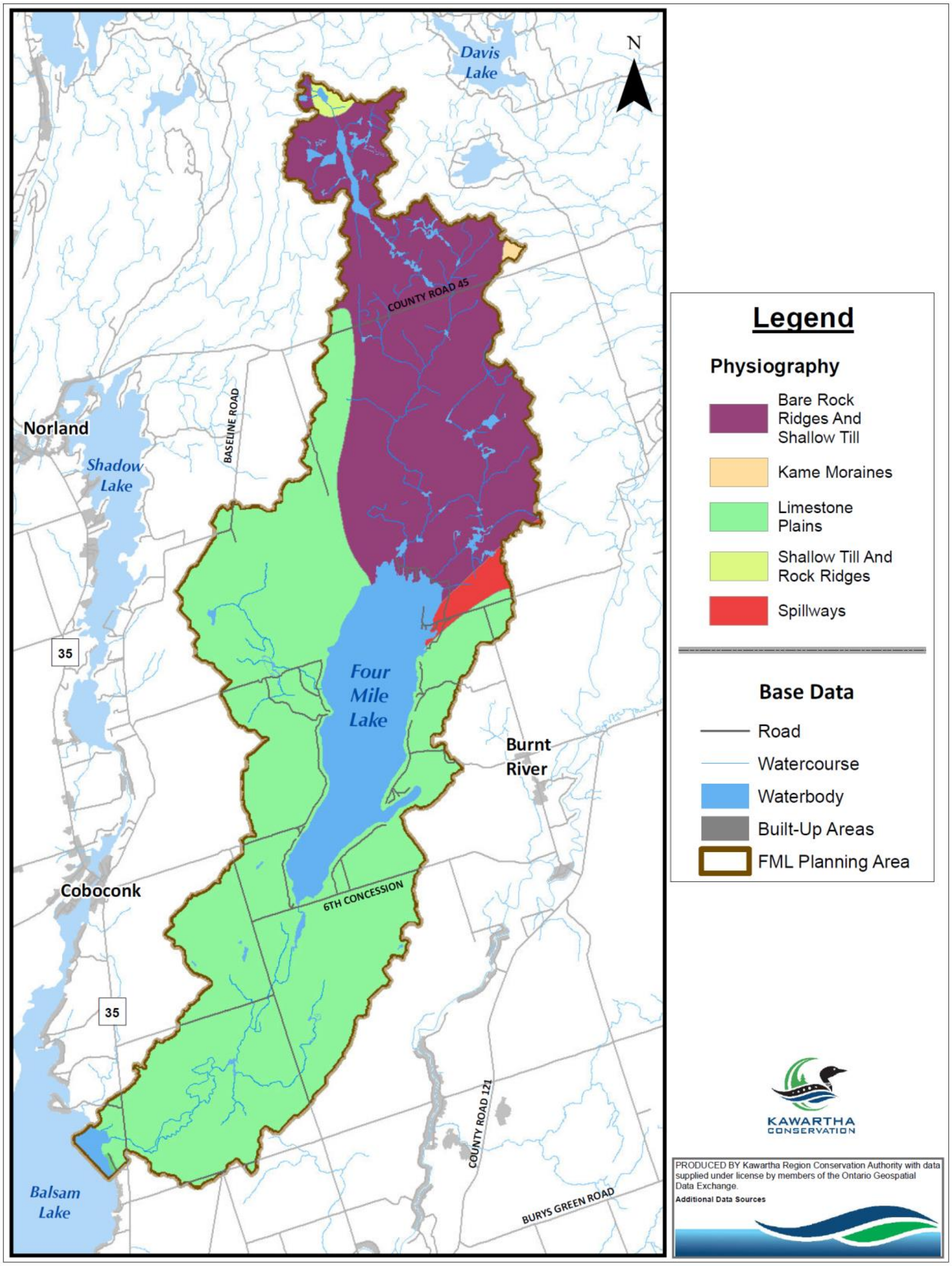

Figure 3.1. Physiographic features within the Four Mile Lake planning area.

4.0 Climate

4.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- **Climate within the Four Mile 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.** Identified climate change trends can be a factor influencing the productive capacity of fisheries. For example, increases of water temperature can influence factors such as year-class strength, recruitment, growth and survival of fishes. It is generally predicted that increases in water temperatures will promote the production of warm-water fishes, while reducing production of cool/coldwater fishes. Coldwater fishes in particular are sensitive to increasing water temperatures and it can lead to reduced populations of some species.

INFORMATION GAPS

- **Current data on evaporation and evapotranspiration for the study area is not available.** Accurate evaporation / evapotranspiration data will allow improving calculations of water budget and, consequently, nutrient loads in the lake.

4.2 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 Four Mile 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, using all qualified monitoring stations. The current 30-year normals are determined from the weather data obtained during the 30-year period of 1981-2010.

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 4.1).

The climate monitoring station in Minden (Minden, Environment Canada 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 Four Mile Lake watershed 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.

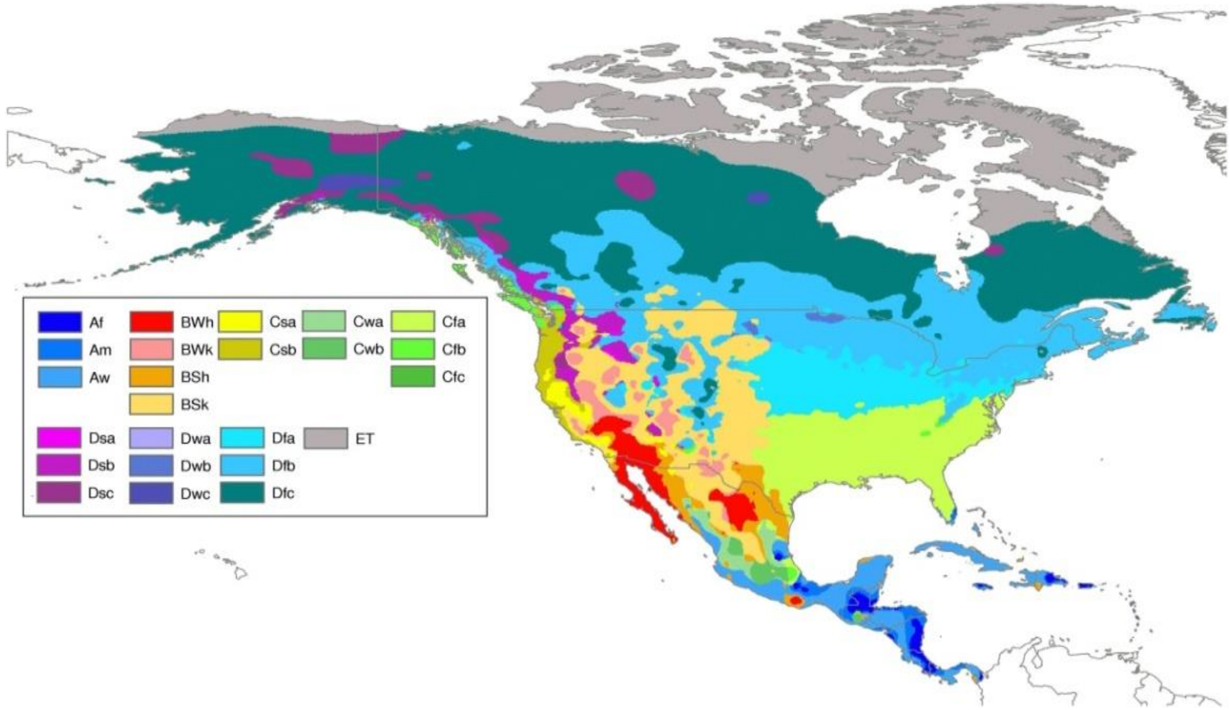

Figure 4.1. The Köppen Climate Classification System for North America
Source: http://people.eng.unimelb.edu.au/mpeel/Koppen/North_America.jpg

Average monthly temperatures and precipitation values from the Minden climate monitoring station are shown in Table 4.1 and Table 4.2, and graphed at Figure 4.2 and Figure 4.3. These data confirm the study area as belonging to the moist continental mid-latitude climate category.

4.3 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 and -7.8^{o}C in February with January averaging as the coldest month of the year (Table 4.1).

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.

4.4 Precipitation

Precipitation is fairly evenly distributed throughout the year, with January-April being slightly drier than the rest of the year (Figure 4.4). 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.

Long-term observations confirm that snow may occur from October to May (Table 4.1, Figure 4.4). January and December are months with the highest snowfall, up to 60 cm. On average, about 2.3 m of snow falls throughout the year. Snow usually accumulates from November to March; however snowpack may melt or decrease as a result of the short-term periods of warmer weather (thaws). The highest daily snowfall of 33 cm was recorded in March of 1943.

Currently, there is one active precipitation monitoring location within the Four Mile Lake watershed that was installed and maintained by Kawartha Conservation. It is located at the lake's outlet where Concession Rd.6 crosses the lake. The gauge was installed in 2013 for the purposes of the Four Mile Lake Management Plan monitoring and consists of manual accumulative gauges that collect and store precipitation until a reading is taken. Precipitation amounts for this monitoring location are shown in Table 4.2.

Recorded precipitation amounts demonstrate that the 2013-2014 and 2014-2015 hydrologic years were lower in precipitation comparing to average values. For example, precipitation observed during period of January - March 2015 was only 79.6 mm, representing only 35% of long-term amount for this period (246 mm) recorded at Minden climate monitoring station. Furthermore, records show that hydrological year 2014-2015 was the driest during the observation period. Amount of precipitation recorded that hydrological year was only seventy five percent of long-term average value.

Table 4.1. Average Monthly and Daily Extreme Values of Air Temperature and Precipitation for the Environment Canada Climate Monitoring Station Minden (6165195)

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

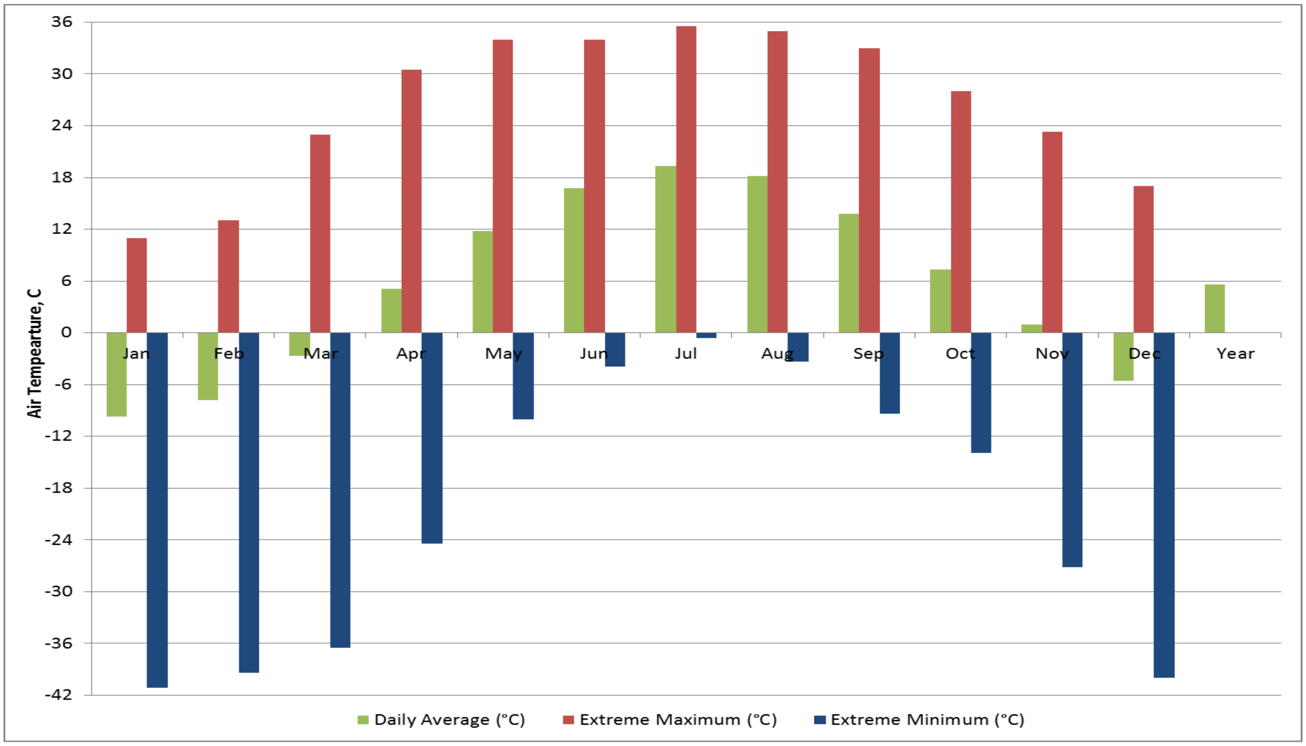

Figure 4.2. Monthly Air Temperature for the Minden Climate Monitoring Stations (Environment Canada, 6165195): Daily Average, Extreme Maximum and Extreme Minimum

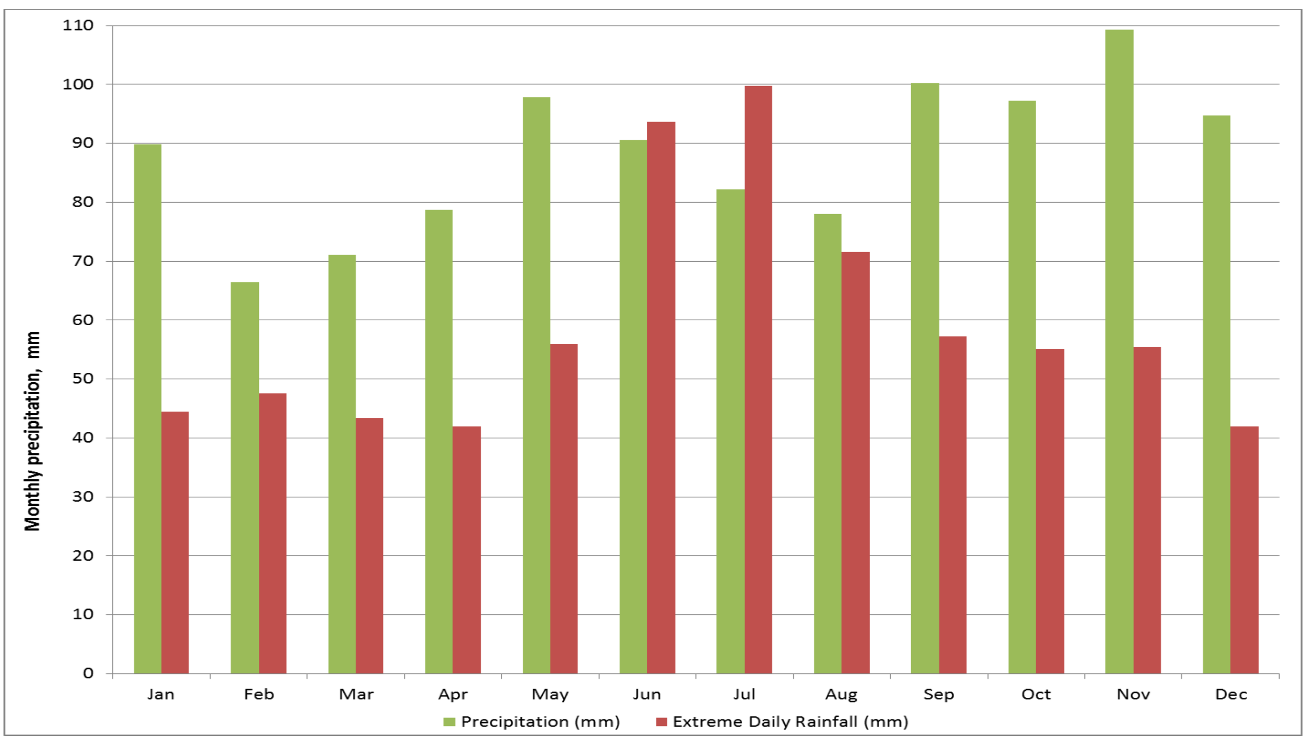

Figure 4.3. Monthly Precipitation Normals and Extreme Rainfall Values for the Minden Climate Monitoring Station (Environment Canada, 6165195)

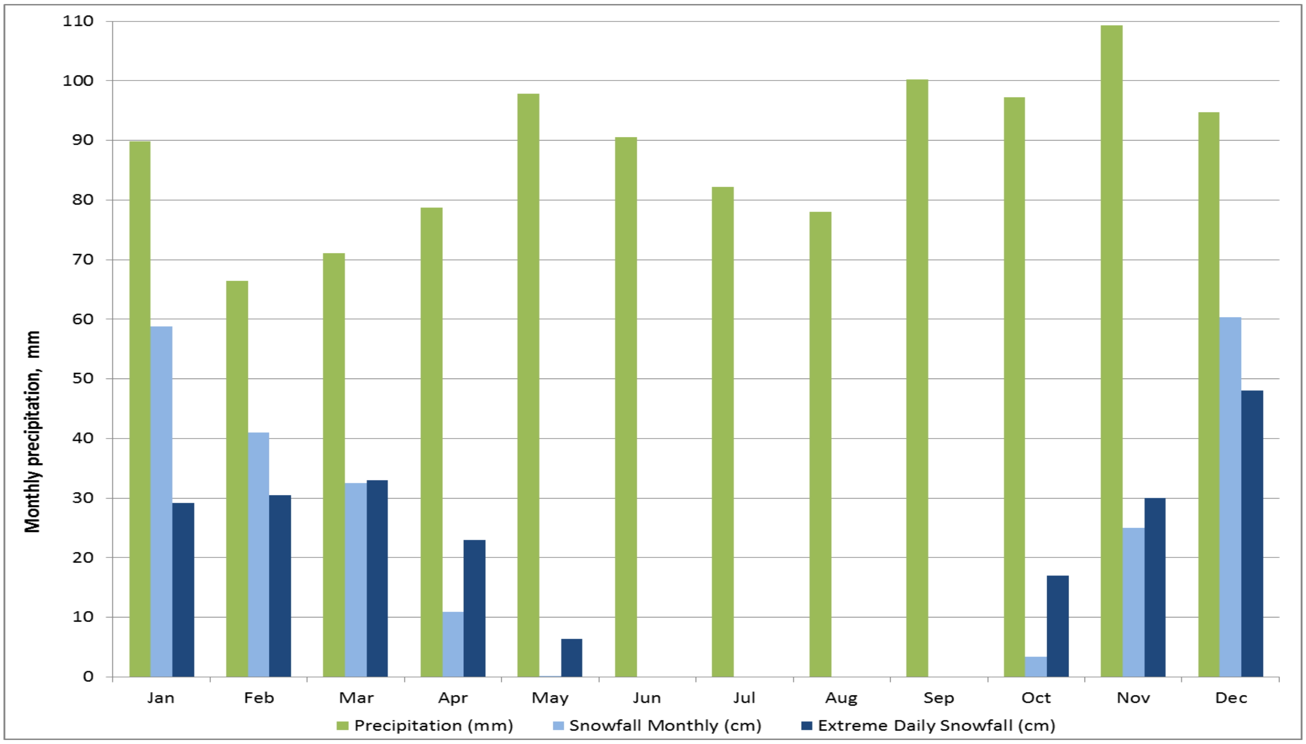

Figure 4.4. Monthly Precipitation Normals for the Environment Canada Climate Monitoring Stations: Minden (6165195)

Table 4.2. Precipitation Amounts for Four Mile Lake Precipitation Monitoring Stations Presented by Hydrologic Year

Year, hydrologic	2013-2014	2014-2015	2015-2016
June	82.2	98.9	151.2
July	48.7	86.4	86.7
August	171.4	74.5	95.8
September	81.7	88.4	78.4
October	142.3	112.0	93.8
November	59.9	83.8	66.7
December	59.1	59.5	99.4
January	61	36.2	62.0
February	32.5	23.7	63.8
March	47.1	19.7	183.9
April	95.1	69.2	59.7
May	58.1	45.0	56.7
Total	**939.1**	**797.3**	**1098.1**

4.5 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 physical process that moves water through the air. It is the major component of the water balance and water budget. 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 of plants evaporates from the plant's leaves (Figure 4.5).

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.

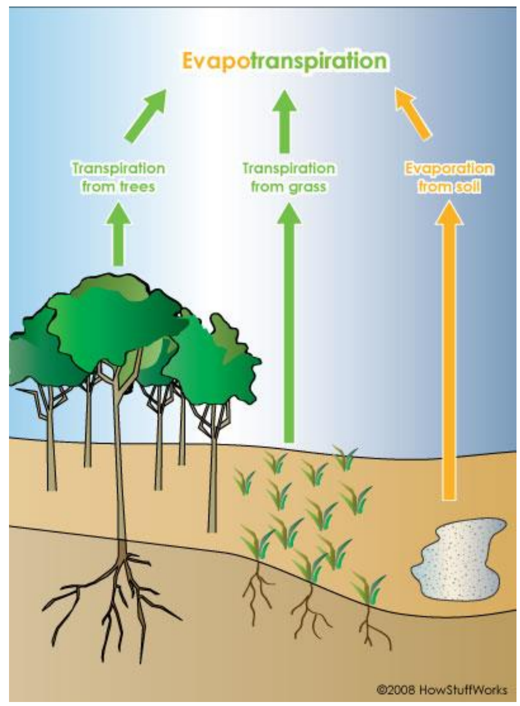

Figure 4.5. Process of Evapotranspiration
Source: http://science.howstuffworks.com

Measuring evapotranspiration is a complex and costly process. Because of that, ET is commonly computed from weather data. A large number of empirical or semi-empirical equations and methods 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. Currently, the Penman-Monteith method is recommended by United Nations Food and Agriculture Organization as the standard method for the computation of the evapotranspiration (Allen, R.G., Pereira L.S., Raes D., and M. Smith. 1998). The method uses meteorological data such as daily mean temperature, wind speed, relative humidity and solar radiation.

The National Atlas of Canada, published in 1974 includes a coarse-scale map of the potential evapotranspiration (PET) for Canada (Figure 4.6). According to that map, PET value is about 560 mm (22 inches) per year for the Four Mile Lake watershed area.

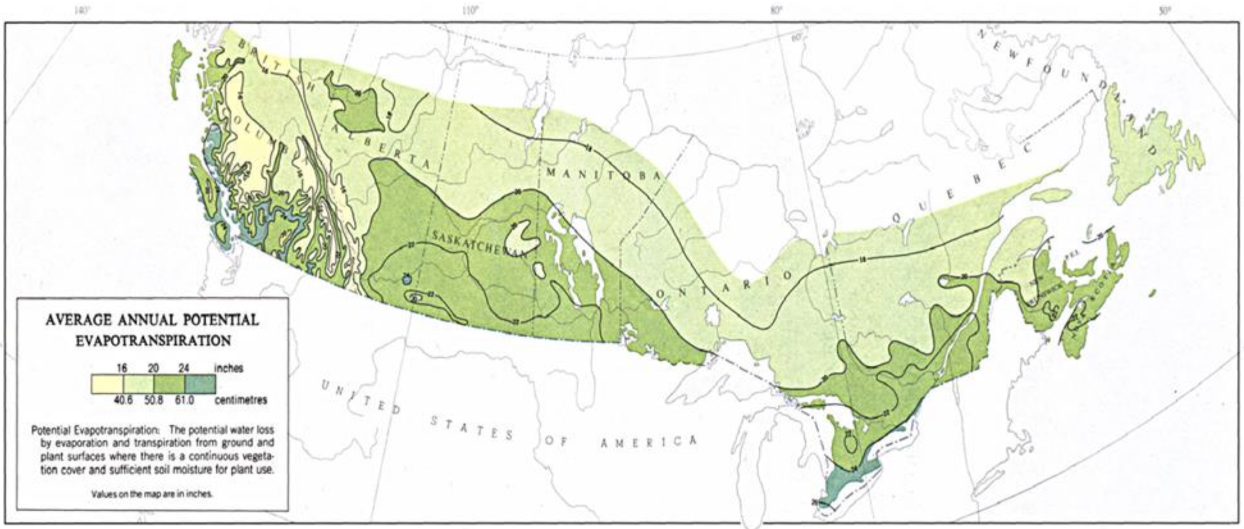

Figure 4.6. Average Annual Potential Evapotranspiration

Source: The National Atlas of Canada, 1974

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, soil texture 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 northern portion of the Four Mile Lake watershed located within the Algonquin Lake-Nipissing Ecoregion, Boreal Shield Ecozone (Ecodistrict 413). The central and southern portions of the FML watershed belong to the Manitoulin-Lake Simcoe Mixwood Plains Ecoregion within Mixed Plains Ecozone (Ecodistricts 552-554). Estimated values of the potential evapotranspiration for those ecoregions are shown in Table 4.3.

Table 4.3. Average Monthly and Annual Potential Evapotranspiration (mm)

Eco Districts	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
413	0	0	11.6	63.0	97.6	115	129	103	64.7	30.5	8.2	0	612.8
552	0	0	9.4	65.0	103	117	132	103	64.2	29.7	7.3	0	630.6

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 12 mm, declining to 0 mm in the winter season. The average annual evapotranspiration between the two ecoregions is 622 mm.

4.6 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, 2016). 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 we head towards an increasing atmospheric concentration of both carbon dioxide and methane, we can expect that increasing impacts of climate change will create both negative and positive results for communities everywhere: in our watershed and our communities, in our province, in our country and around the world.

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

Under all scenarios, it is expected that mean annual temperature will increase for the study area (Table 4.4, Figure 4.7). The highest increase in temperature will be observed during winter (5.1^{o}C increase according to the High Emission Scenario) compared to current normals.

An increase of annual mean precipitation is expected under all scenarios, with winter and spring experiencing the highest rise with up to 30 mm per season under the Medium Emission Scenario (Table 4.5, Figure 4.8). It is important to note that with winter being milder, winter precipitation will fall as rain, affecting the hydrological cycle, monthly stream flows, lake levels, and water resources overall.

Table 4.4. Mean Air Temperature Predictions Under Different Emission Scenarios

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

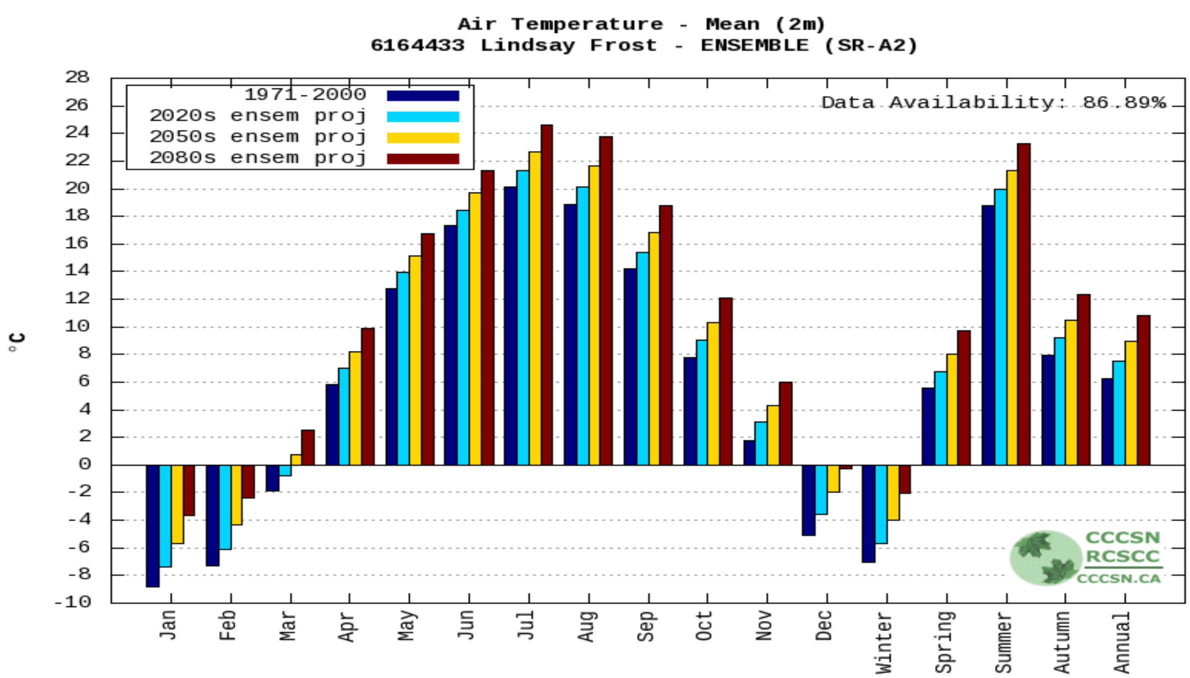

Figure 4.7. Mean Air Temperature - High Emissions Scenario (CCCSN, 2016)

Table 4.5. Total Precipitation Predictions Under Different Emission Scenarios

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

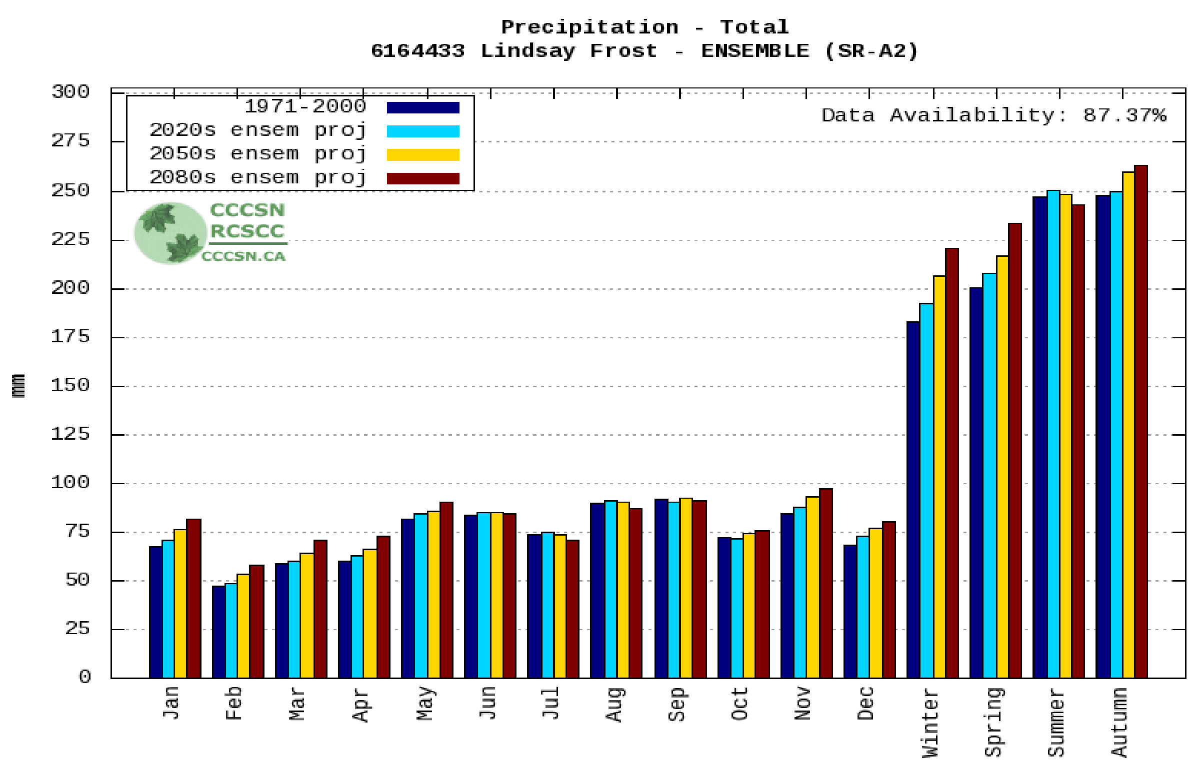

Figure 4.8. Total Precipitation - High Emissions Scenario (CCCSN, 2016)

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 6, 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 Four Mile Lake watershed residents.

5.0 Water Quantity

5.1 Summary of Observations, Issues and Information Gaps

OBSERVATIONS

- **As Four Mile Lake is a natural, unregulated water body, its water level regime follows well-defined seasonal pattern, reflecting seasonal variations of water inflow.** The water levels are observed in April in response to a spring freshet, often combined with rain events. After peaking, FML's water level recedes through the summer and fall months, reaching its lowest marks in September-October. Low water levels are also observed in winter months.

- **The western tributary of Four Mile Lake that was studied for the purpose of the Four Mile Lake Management Plan has exhibited similar 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.

- **Karst topography that is present at the central and lower portion of the Corben Creek watershed.** Karst topography explains the intermittent pattern of Corben Creek that is observed within the 5-km reach downstream of Four Mile Lake.

- **Wetlands and forested areas that are abundant in the Four Mile Lake watershed provide significant benefits for the surface water, moderating stream flow, providing high and low-flow mitigation and assisting in groundwater recharge.**

- **No water withdrawal subject to the regulation under the "Permit To Take Water Program" (PTTW) (more than 50,000 L/day) from Four Mile Lake or within its watershed is registered.**

KEY ISSUES

- **The groundwater discharge to the Corben Creek, Four Mile Lake and their tributaries that supports baseflow and is a main component of the stream flow during the dry periods is low or non-existent in the prevailing portion of the watershed.** This causes small and medium southern watercourses to flow very low or to go stagnant or dry during periods of limited precipitation due to limited capacity of the shallow aquifers in the study area that provide groundwater input to the stream flow.

- **Climate change has the potential to impact the flow regime of local watercourses.** Climate change could cause impact to local watercourses by reducing the duration and intensity of spring runoff and aquifer recharge, and by increasing the potential for dry conditions and/or extreme high-flow events during summer.

INFORMATION GAPS

- **Further investigation of karst features that are present within the watershed will improve understanding of groundwater and baseflow at the region.**

- **Flow monitoring data within the Corben Creek watershed are limited to three years of monitoring in the framework of the FMLSP.** Monitoring data are a key source of information on the water resources' conditions and trends. Water level and flow monitoring should be continued, at least at the Four Mile Lake outlet location.

- **Cumulative effect of water taking that does not require permitting cannot be evaluated accurately because of absence of data.** Unpermitted water taking may cause significant effect on the lake, especially during low water/drought conditions

- **Annual monitoring data on lake evaporation are not available.** This adds uncertainty to the calculations of a water budget.

5.2 Drainage Network

Four Mile Lake is a relatively small lake with a surface area of 7.58 km^2 located at the middle portion of Corben Creek (Figure 5.1). Corben Creek is a tributary of Balsam Lake, flowing from north to south and entering Balsam Lake at the lake's northern end. Corben Creek is situated between much larger Gull and Burnt Rivers and overall makes the headwaters of the Trent River.

Overall characteristics of the Corben Creek watershed as a planning area and its subwatersheds, including the Four Mile Lake subwatershed are shown in Table 5.1.

Headwaters of the Corben Creek, including Corben Creek North and Merrett Creek subwatersheds are situated within the Precambrian bedrock formation, with shallow soils and many rock outcrops. Small lakes, such as Corben Lake, Goodoar Lake and Lower Goodoar Lake are located at the upper portion of Corben Creek North subwatershed. Numerous wetlands are located within this area, what is typical for the Canadian Shield settings. Overall, the natural cover at the headwaters of the Four Mile Lake (Corben reek North and Merrett Creek) reaches 95%. This includes forest, wetlands and meadow. Different types of wetlands occupy prevailing portion of the headwaters area, more than 75%.

Table 5.1. Stream and Subwatershed Characteristics, the Corben Creek Watershed

Sub watershed	Drainage area (km^2)	Stream Network Length (km)	Main Channel Length (km)	Main Channel Gradient (m/km)	Natural Cover (%)	Agriculture (%)	Rural / Urban Development (%)	Stream Density (km/km^2)	Average Watershed Slope, (%)
Corben Creek North	19.1	29.98	7.45	4.689	93.5	2.45	0.75	1.524	3.54
Merrett Creek	6.78	10.79	4.3	3.977	96.8	0.001	0.75	1.591	3.41
Four Mile Lake Central	17.5	7.14	3.14	3.019	86.1	4.82	8.79	0.408	2.78
Four Mile Lake	43.3	45.91	14.89	2.308	91.2	3.05	4.00	1.06	2.94
Corben Creek South	19.11	17.62	6.7	2.047	76.3	15.2	5.76	0.922	2.45
Corben Creek (planning area)	69.98*	64.53	21.59	2.212	77.3	6.02	4.09	0.922	2.781

*Area of Four Mile Lake (7.58 km^2) included

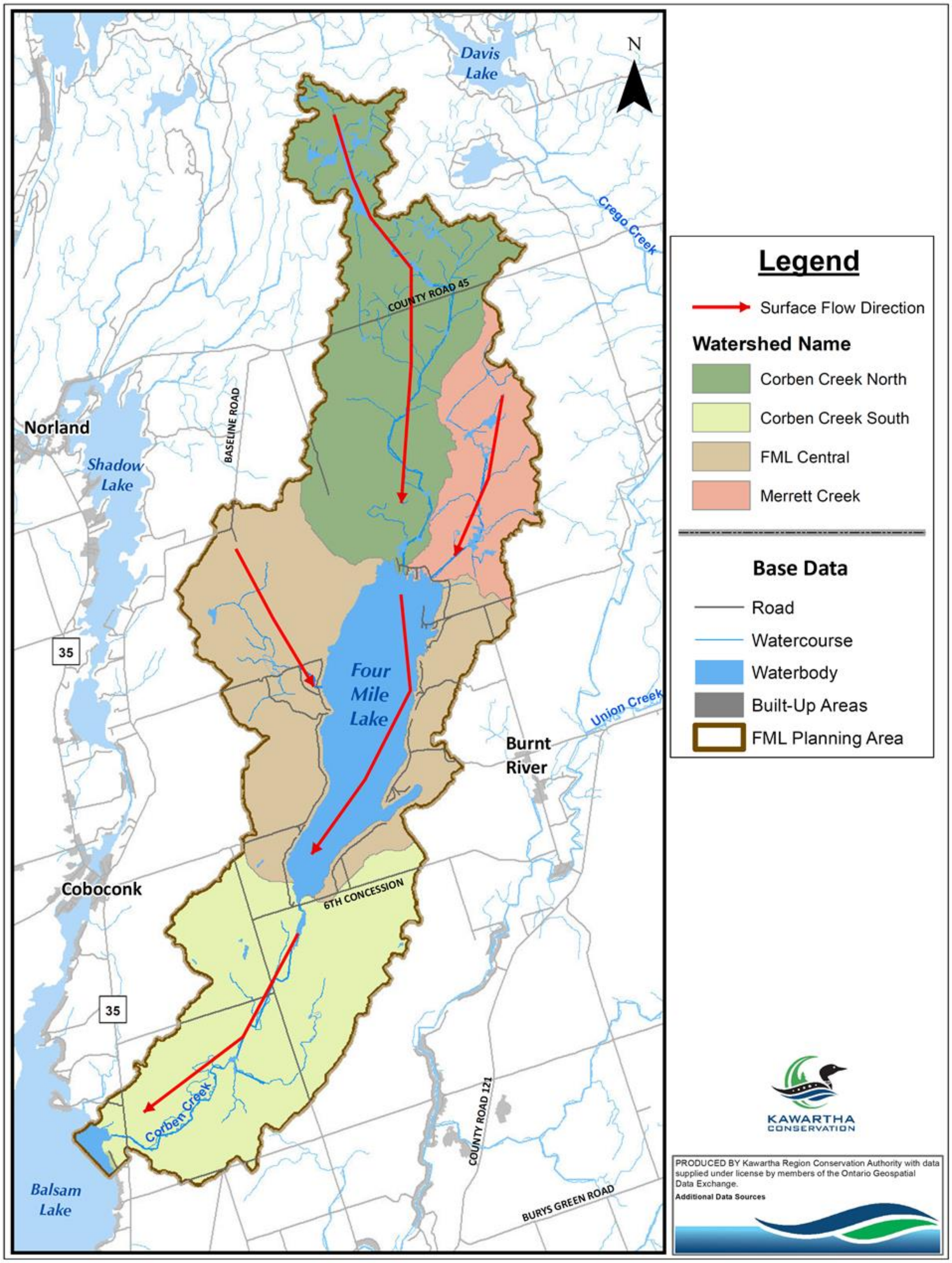

Figure 5.1. Drainage Network and Flow Directions within the Corben Creek Watershed

The rest of the drainage basin (Four Mile Lake Central and Corben Creek South subwatersheds) extents over the limestone plateau represented by Paleozoic bedrock. Overall, stream density within the Four Mile Lake Central portion of the Corben Creek subwatershed is low, only 0.408 km/km^2, while it reaches 1.591 km/km^2 at creek's headwaters. The only permanent drainage channel that is situated in the central portion of the Corben Creek watershed is a short creek located on the west-side of the Four Mile Lake. This creek drains Soap Lake and a few local wetlands scattered along the channel. Similar to the northern portion of the Corben Creek watershed, the central and southern parts are characterized by the high percentage of the natural areas, up to 86%, and numerous wetlands.

As limestone formation, that forms the majority of the FML watershed, is water soluble, landscape features such as fissures, sinkholes, underground caverns have been created over the millions of years, forming a landscape that is known as karst topography in the region (Figure 5.2). As karst topography is very common at the Four Mile Lake Central subwatershed, it is most likely the leading cause for the low stream network density within this subwatershed. The most prominent occurrence of karst structures are observed downstream of Four Mile Lake, between Somerville Concession 6 Road and Somerville Concession 5 Road. At the lake outlet, while the majority of flow exits the lake through the main channel, a significant amount of water escapes through the openings and cracks in rock formation on the upstream (north) side of the bridge, by-passing the main channel. In about ~50 m water re-enters Corben Creek downstream of the bridge.

Further south Corben Creek disappears completely, going underground, as shown on the Figure 5.3. It resurfaces just upstream of the crossing with Somerville Concession 5 Road, demonstrating good flow characteristics. After that, Corben Creek continues flowing in south westerly direction before it enters Balsam Lake.

5.3 Water Levels and Flow Regime

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 calculation 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.

Continuous water level monitoring for the Four Mile Lake management planning project has been performed by two gauge stations (Figure 5.4). One set of monitoring equipment was installed at the outlet of the lake, at Somerville Concession 6 Road. Another monitoring location was established on a lake's western tributary, in order to investigate amount of runoff produced by the Four Mile Lake Central subwatershed. Both monitoring locations consist of a sensor that measures the water level at pre-set intervals and a data logger that records measured values. Details on the flow monitoring locations are shown in Table 5.2.

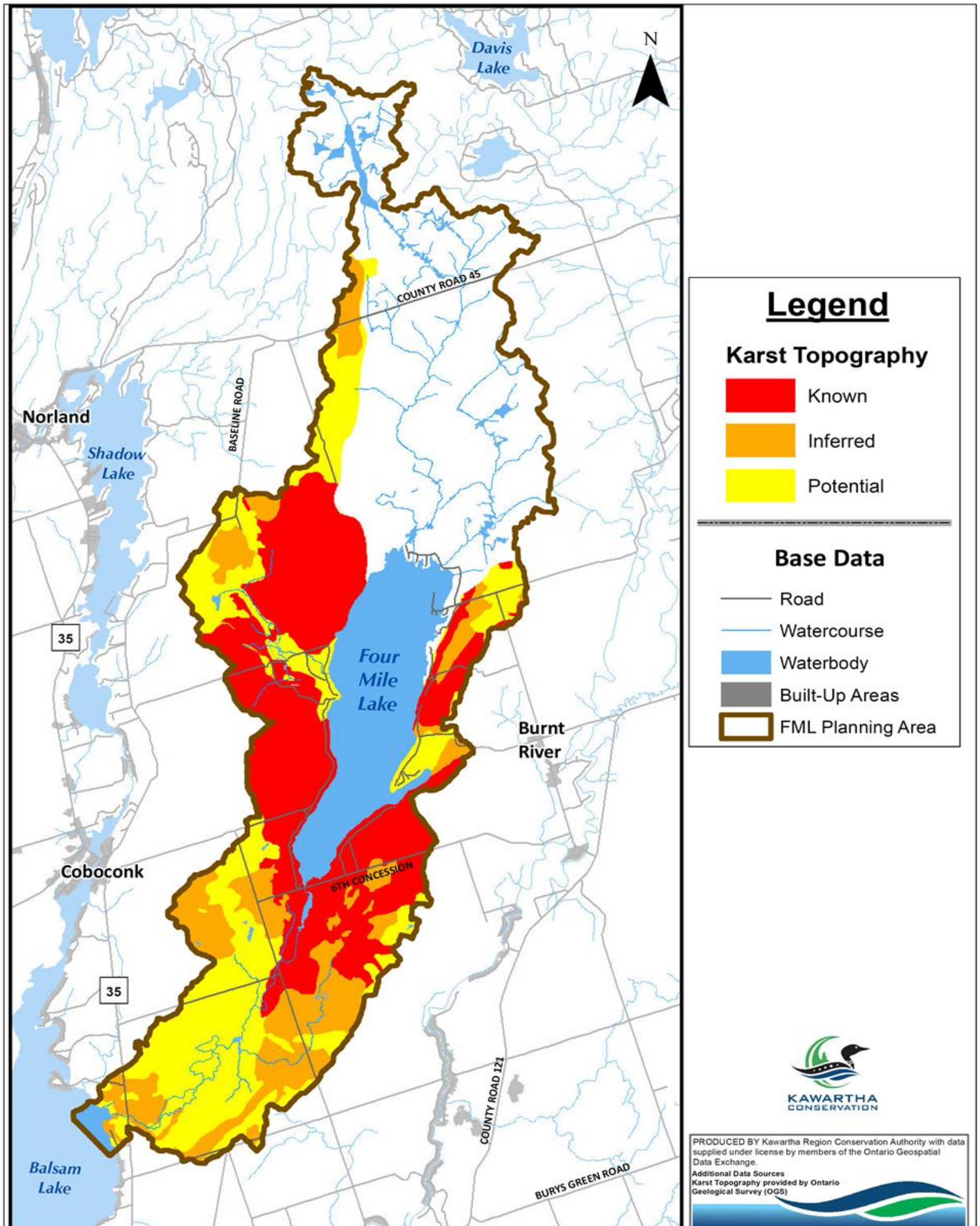

Figure 5.2. Karst Topography within the Corben Creek Watershed

Figure 5.3. Verified Kast Appearance at the Corben Creek South Subwatershed (2016)

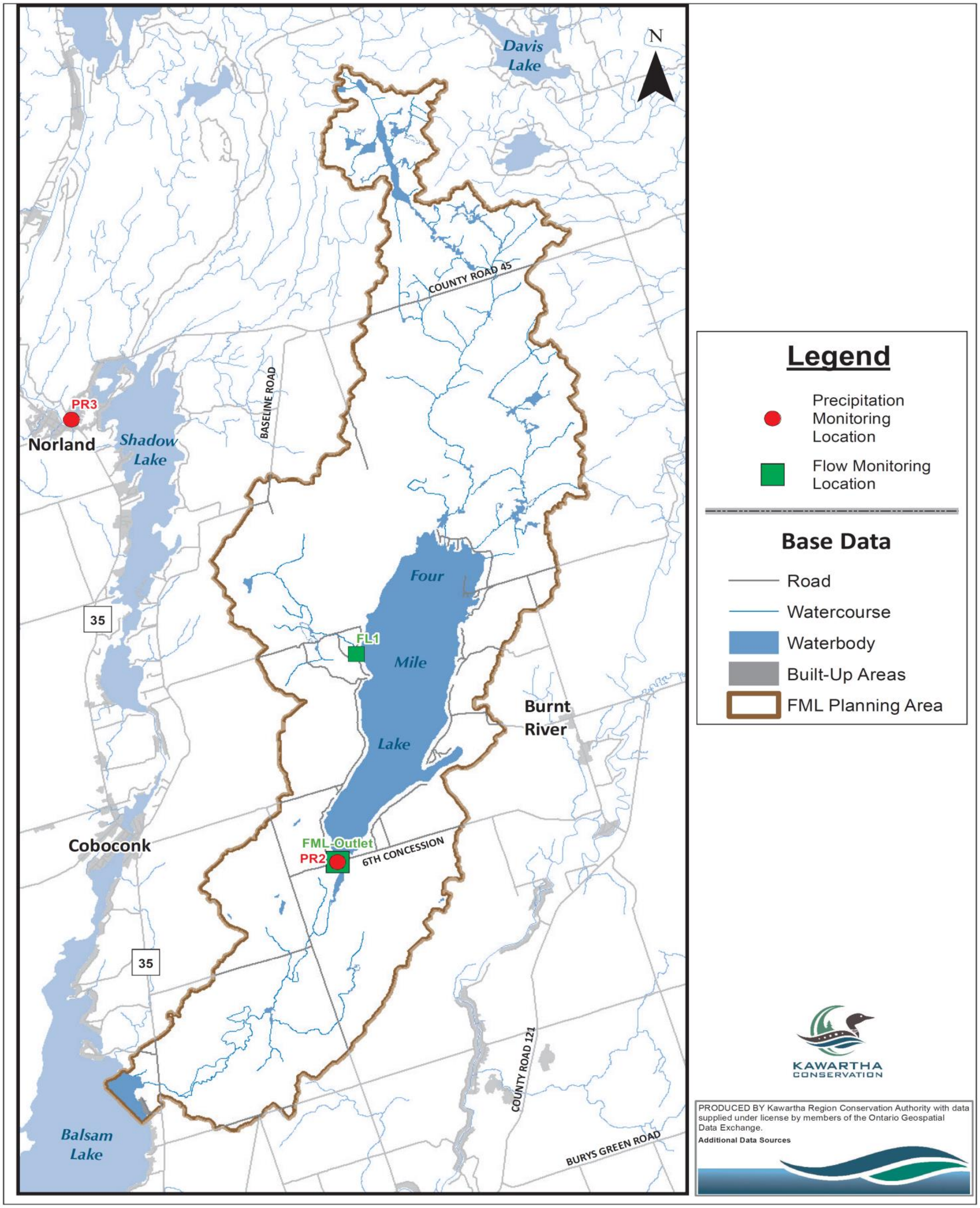

Figure 5.4. Flow Monitoring Locations within the Corben Creek subwatershed

Table 5.2 Continuous Water Level and Stream Flow Monitoring Locations within Corben Creek Watershed

Water course	Location	Drainage Area, km^2	% of total subwatershed area	Measuring Interval	Data Record	Type
Corben Creek	Outlet of Four Mile Lake	43.3	61.9	30 min	2013-2016	Temporary, pressure transducer
Western Tributary	West portion of the FML Central subwatershed	6.84	99	30 min	2015-2016	Temporary, acoustic doppler

Water levels represent heights of water above the sensor. Information on water levels is very important for flood forecasting and emergency management, floodplain development and other applications. In order to develop a water budget or calculate the amount of pollutants carried with water into a lake, data on the volume of water that flows through the watercourse is required. In order to convert observed water level data into flow information, a rating curve has to be developed. Discharge (volume of water that flows through a cross section of a watercourse in one second) and corresponding water levels are measured numerous times at the monitoring location and graphed to develop a relationship. A wide range of water levels and flow (from the highest to the lowest) are targeted in order to establish reliable relationship. Once a rating curve and an equation that describes it are developed, water level values are converted to discharges that characterize water quantity at the gauging location.

The monitoring station at the Four Mile Lake outlet (Somerville Concession 6 Rd.) has provided data on volume of water that exits the lake at any given moment. This information is extremely important for development of water budget, that in turn is a base for nutrient loads calculation. Flows into and out of Four Mile lake is not regulated, as a result, the lake's water level fluctuates considerably during the seasons.

The water level and flow data confirm that the lake, as well as its monitored tributary have well-defined seasonal pattern, reflecting seasonal variations of water inflow. During the period of monitoring, the highest flows and water levels at the FML outlet have been observed in April in response to the spring freshet, often coupled with rain events (Figure 5.5). After peaking, lake's water level recedes through the summer and fall's months, reaching its lowest marks in September-October. Despite the fact that existing dataset is not satisfactory for statistical analysis, preliminarily data review confirms that precipitation plays major role in lake's hydrological regime. Table 5.3 compares observed water levels to the amount of precipitation recorded during the monitoring period. The highest and yearly average water levels correspond well to the yearly amount of precipitation. However, the lowest yearly water level was observed during 2015-2016 hydrologic year, the year with the highest observed precipitation. This is because not only the amount, but timing of precipitation is extremely important as well. During 2015-2016 hydrologic year precipitation distribution was very inconsistent: exceptionally wet March (183.9 mm of precipitation recorded) was followed by very dry April, May and June, when only ~50% of normal amount of rain was recorded. As a result of those abnormal conditions, in August 2016 water level of Four Mile Lake has reached the lowest values recorded over the monitoring period.

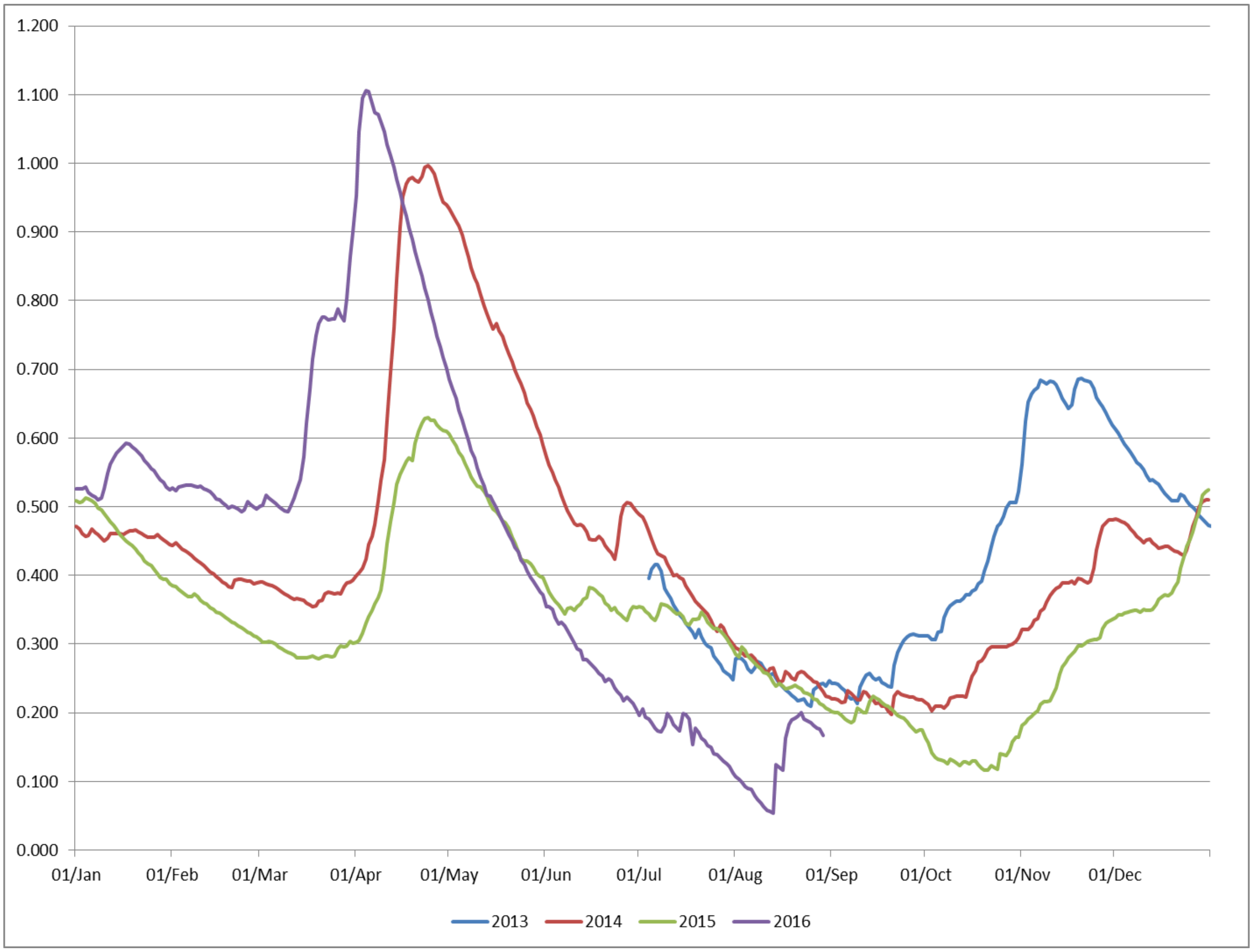

Figure 5.5. Daily Water Levels, Corben Creek (FML Outlet), monitoring location

Table 5.3. Average, Maximum and Minimum Water Levels and yearly amount of precipitation observed at the outlet of Four Mile Lake

Hydrological year	Water Level at the outlet, m			Precipitation amount
	Average	Max	Min	
2013-2014	0.474	0.997	0.209	939.1
2014-2015	0.368	0.630	0.198	797.3
2015-2016	0.428	1.106	0.117	1098.1

Land use within a watershed affects the hydrological regime of a watercourse. Naturally covered areas provide significant benefits in keeping water resources abundant and clean. Forest cover helps to moderate stream flow, providing high and low flow mitigation and assisting in groundwater recharge. Similar to forest cover, wetlands provide peak flow mitigation and flood storage capacity as well as assist in improving water quality by sediment trapping and nutrient retention and removal.

Comparatively development areas have greater areas of impervious surfaces which alter the spatial and temporal distribution of flow, increasing the flood peaks and volumes, and decreasing groundwater recharge, storage and discharge.

While agricultural activities impact water quality more than quantity, they can also change some aspects of the stream flow regime, including higher velocity run-off over tilled soils that can alter peak flows.

As described in Chapter 3 – Land Use and Physical Geography, a very small portion of the Corben Creek watershed lands are used for agriculture and almost 77% of the watershed area is occupied by forests (57%), wetlands (17%) and meadows (3%) that are collectively classified as natural cover. Agricultural lands are not evenly distributed throughout the drainage area around Four Mile Lake. The majority of agricultural lands are located in the southern portion of the watershed where soils and drainage are more suitable for agriculture.

Four Mile Lake Morphometry Characteristics

The major morphometric and hydrologic characteristics of Four Mile Lake are as following:

Surface Area:	7.58 km^2
Lake Volume:	70,494,000 m^3
Mean Depth*:	9.3 m
Maximum Depth*:	19.1 m

*Michael Michalski, 1986.

Lake flushing rate is a rate at which water (or some dissolved substance) enters and leaves a lake relative to lake volume. It is usually expressed as time needed to replace the lake volume with inflowing water. Using inflow volumes, calculated as part of the lake water budget (refer to the chapter 5.6 Water Budget) the flushing rate is 2.76 times per year. Therefore, on average, the water mass in Four Mile Lake changes every ~130 days.

5.4 Baseflow

Baseflow is the portion of flow in a watercourse that comes from groundwater discharge, rather than direct runoff related to rain or snowmelt events. During most of the year, stream flow is composed of both groundwater contribution and surface runoff. Baseflow conditions are deemed to exist when groundwater provides the entire flow of a stream. Ultimately, sustained groundwater inflow into the tributaries means sustained water levels and healthy conditions for the lakes.

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

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

Methodology

Baseflow monitoring involves measuring the discharge at designated locations during prolonged periods of dry weather. In general, the sample sites were located at every stream-road crossing throughout the watershed.
Criteria for the site selection include:

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

Baseflow sampling was conducted following standardized procedures described in Hinton, 2005. In order to collect comparable and reliable data, the stream flow measurements are to be performed under consistent groundwater inflow conditions; meaning the volume of groundwater storage should not experience significant change. Therefore, the survey is to be conducted under dry conditions when no significant precipitation has occurred during the previous two weeks, in the shortest possible period of time. Data analysis involves calculation and mapping of discharge and net discharge at every measured point and net discharges per a square kilometer (Figure 5.6).

The baseflow data within the Corben Creek watershed were collected during the summer of 2016. Based on the watershed size and sites accessibility, only 10 sites throughout the study area were visited. Four sites were found flowing and were measured. Two sites were visibly flowing, but not suitable for measurements (too deep to measure). Four sites were dry or with standing water.

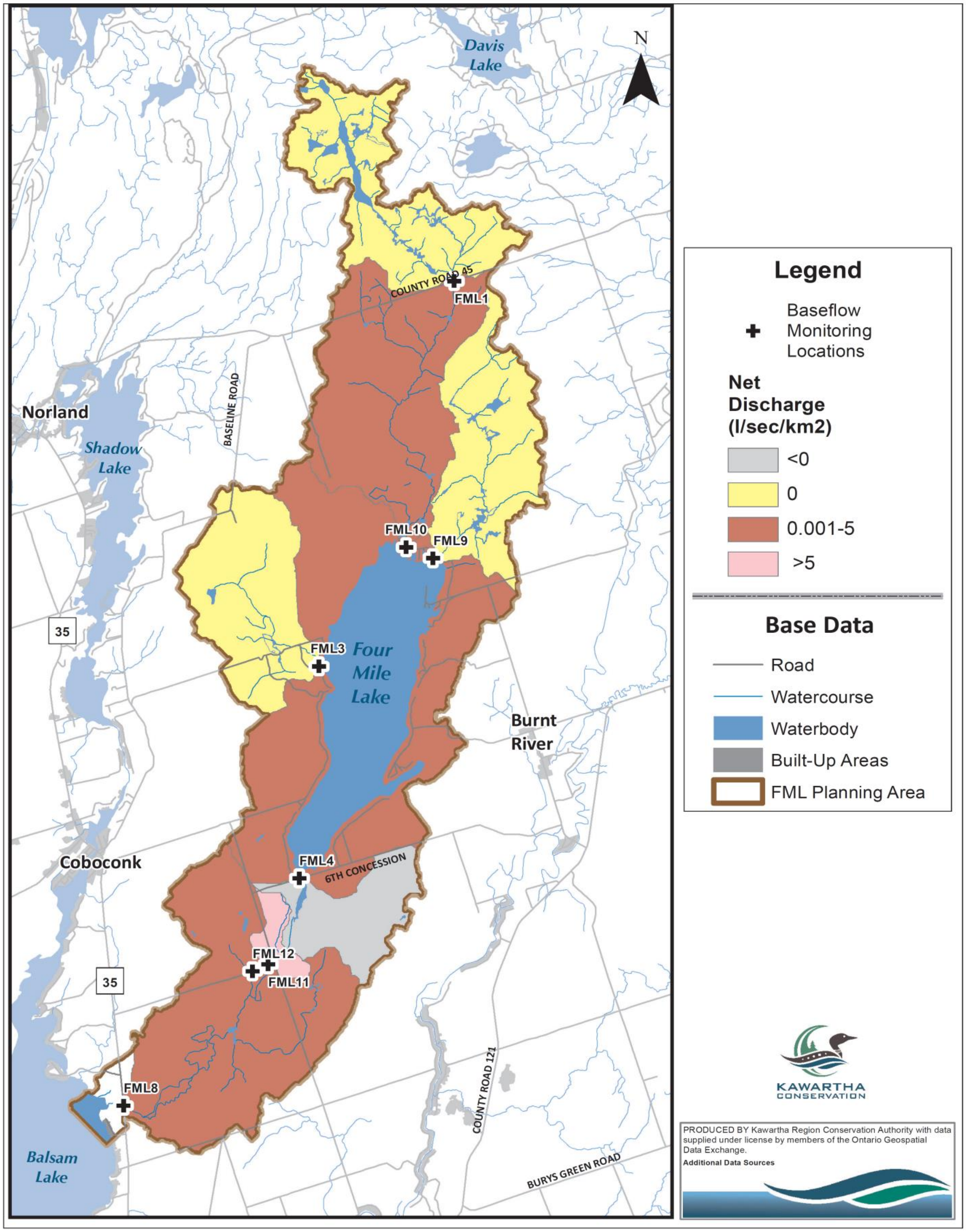

Figure 5.6. Baseflow Distribution within the Corben Creek Watershed

Overall, analysis has revealed that:

- The groundwater inflow into the tributaries of Corben Creek and Four Mile Lake (baseflow) is generally limited.
- Tributaries that drain headwaters as well as a central portion of the watershed (about 30% of the watershed in total) were found dry, what indicates absence of the groundwater inflow.
- Majority of the watershed, ~64% of its drainage area, produces baseflow that is below 5 L/sec/km^2.
- As it was mentioned before, Corben Creek disappears under the ground downstream of the Four Mile Lake outlet to reappear ~ 1 km downstream, demonstrating good flow characteristics.

5.5 Water Taking

According to the Ministry of the Environment and Climate Change database, no water taking activities that require a registered Permit To Take Water occur within the Corben Creek watershed, including Four Mile Lake. The "Permit To Take Water Program" requires obtaining a permission from the MOECC to withdraw more than 50,000 L/day.

For the private water supply it is assumed that local residents withdraw water from the ground water or directly from the lake for properties with access to lake fronts. Figure 6.7 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 and withdrawal volumes are not known.

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

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

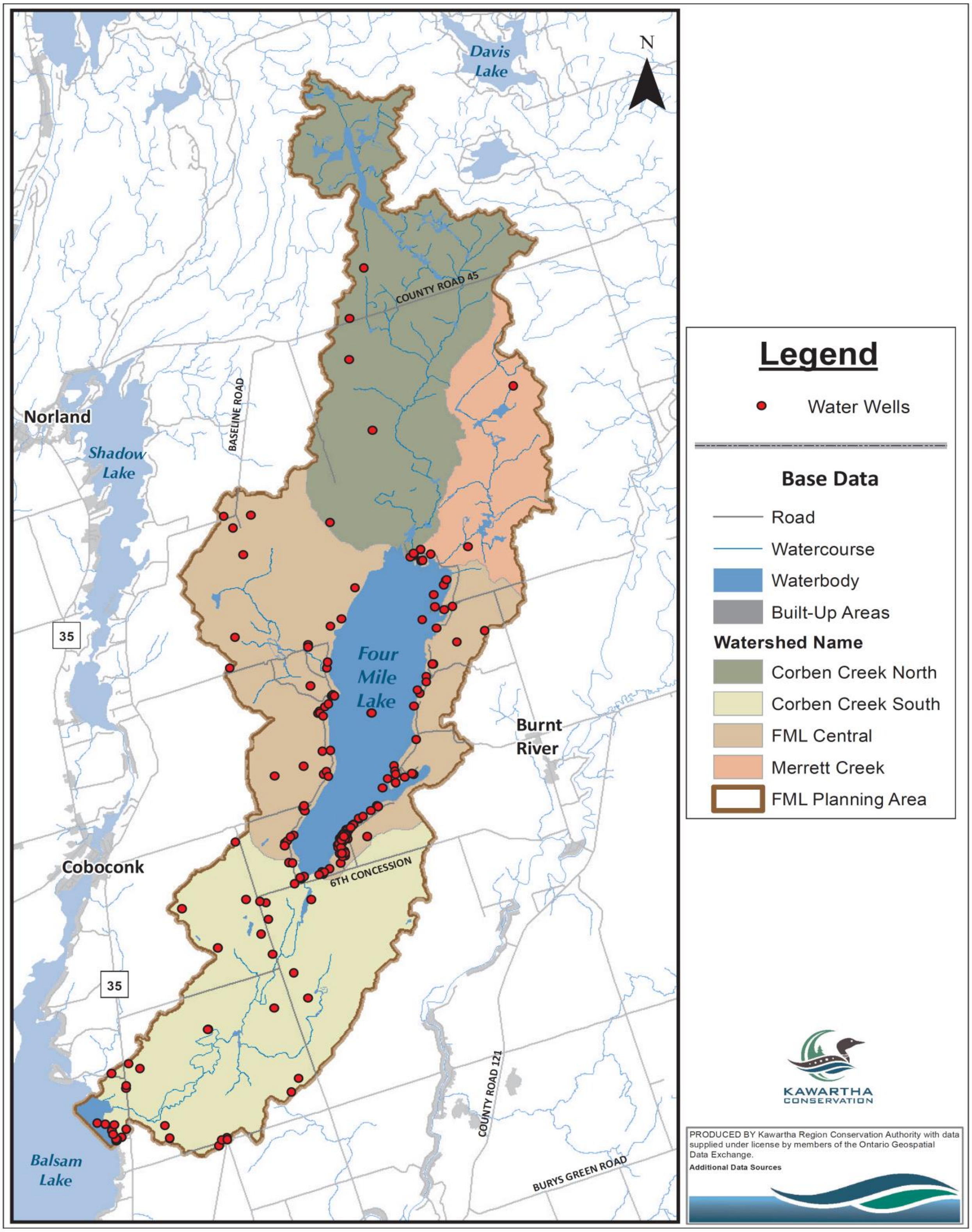

Figure 5.7. Water Wells within the Corben Creek Watershed (as per Water Well Record Database, MOECC)

5.6 Water Budget

A water budget is an essential component of any hydrological and water quality study. In the framework of the Four Mile 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 Four Mile 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,
±Δ – imbalance.

The Four Mile Lake water budget for the 2011–2012, 2012–2013 and 2013–2014 hydrologic years is shown in Table 5.4. 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 5.8 presents average water budget for Four Mile Lake over period of study.

The total amount of precipitation for the lake has been measured at the outlet of the lake by means of simple precipitation gauge established specifically for the lake management project. The amount of precipitation over period of monitoring varied significantly. Only 793.7 mm of precipitation were recorded in 2014-2015, while during the next hydrological year, 2015-2016 almost 1100 mm were registered at this monitoring location. Although the precipitation amount is usually expressed in millimetres, it was converted into cubic meters for the purposes of convenient comparison with flow components.

Table 5.4 Four Mile Lake Annual Water Budget in the 2013-2014, 2014-2015 and 2015-2016 Hydrologic Years

	2013 – 2014		2014 – 2015		2015 – 2016		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:	***27.34***	**100**	***21.55***	**100**	***27.86***	**100**	***25.58***	**100**
Precipitation (P)	7.12	26.04	6.04	28.05	8.32	29.88	7.16	28.00
Corben Creek North	11.64	42.56	8.92	41.41	11.30	40.56	10.62	41.51
Merrett Creek	4.15	15.19	3.18	14.78	4.03	14.48	3.79	14.81
Corben Creek Central	4.43	16.21	3.40	15.77	4.20	15.08	4.01	15.68
Total water outflow:	***30.73***	**100**	***20.34***	**100**	***27.10***	**100**	***26.06***	**100**
Four Mile Lake Outlet	26.03	84.71	14.31	70.34	22.01	81.20	20.78	79.76
Evaporation (E)	4.70	15.29	4.70	23.11	4.70	18.80	4.70	18.04
Change in lake storage (ΔS)	0.23	0.01	1.33	6.56	0.38	0.01	0.65	2.19
Imbalance (±Δ)	*-2.21*	*-7.69*	*1.20*	*5.59*	*0.76*	*0.03*	*-0.08*	-0.69

Evaporation from the water surface of the lakes is the least studied component of the water budget. As it has been mentioned before, evaporation depends on many weather factors such as daily air temperature, relative humidity, solar radiation, wind speed and direction as well as on such physiographic factors as local elevation, topography, vegetation and distance to the large water bodies (Great Lakes, oceans). There are no meteorological stations that monitor evaporation and evapotranspiration within the Kawartha watershed or nearby. That's why evaporation and/or evapotranspiration value can be determined only theoretically taking into consideration available information found in scientific literature. After an extensive research of a variety of scientific sources, the long-term average amount of 625 mm per year was taken from the National Soil Database as the most accurate and appropriate potential evaporation/evapotranspiration value for Four Mile Lake (Agriculture and Agri-Food Canada, 1997). This number was also converted into cubic meters for the convenient comparison.

As it was described before, two flow monitoring stations have being located within Four Mile Lake watershed: at the outlet of the lake and on a small tributary that inflow into the lake at its west side.

Dataset from the outlet location was used to calculate an annual yearly outflow from the lake. The tributary monitoring location provided means to better estimate inflow from the central portion of the watershed. Flow for the lake's upstream tributaries (Corben Creek and Merrett Creek) was estimated using the unit area discharge ($L/sec/km^2$) from the gauged watersheds.

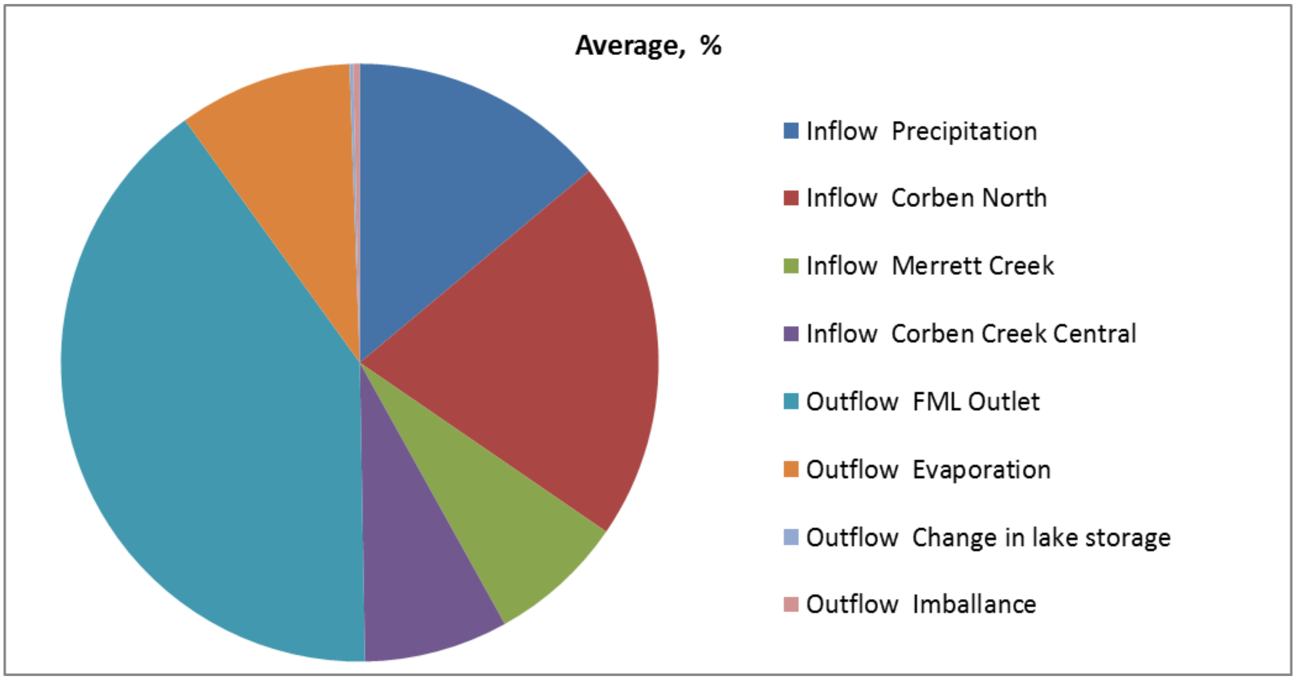

Figure 5.8. Water Balance of Four Mile Lake, Average for the Period of Study, 2013-2016

Changes in lake storage (ΔS) have been calculated as a difference in the lake levels on June 1, 2013 and May 31, 2014; on June 1, 2014 and May 31, 2015; and on June 1, 2015 and May 31, 2016 multiplied by the lake water surface area based on water level data recorded by the monitoring equipment at the lakes outlet. The change in lake storage can be positive or negative depending on difference in the lake water levels from year to year.

During the period of observation, the Four Mile Lake water budget had a positive imbalance (5.59% or 1.20 million m^3) in 2014-2015, and again in 2015-2016 (0.03% or 0.76 million m^3). A negative imbalance of 2.21 million m^3 or -7.69% was observed in 2013-2014 (Table 5.4). A positive imbalance means that according to the calculations more water entered the lake than left it. A negative imbalance indicates that more water left the lake than entered. Calculated imbalance values are well within the acceptable limit of 10% for the water balance calculation (Scott et al., 2001) thus providing a high level of confidence in phosphorus and nitrogen load calculations.

6.0 Water Quality

6.1 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 2013 and ended in 2016. The water quality monitoring network in the Four Mile Lake watershed included 4 stations on the lake's tributaries across the study area, including Western Tributary, Corben Creek, Merrett Creek and one station at the Four Mile Lake outlet, two monitoring stations on Four Mile Lake and one precipitation sampler situated at the Four Mile Lake outlet. Previously collected data (2011-2013) for Corben Creek S (@ Highway 35) was included in this study.

OBSERVATIONS

- ***Four Mile Lake can be characterized as oligotrophic water body with excellent water quality.*** While the water quality is excellent, there are times when nutrient levels in the surrounding tributaries, specifically Merrett Creek approach high concentration levels as outlined by the Provincial Water Quality Objectives. Though these higher nutrient levels originate from a natural upstream source (various types of wetlands) they can create problematic algal growth, and contribute to the growth of macrophytes reducing recreational enjoyment of the lake and impacting the natural communities that live in and around the lake.

- ***Average phosphorus concentrations in Four Mile Lake are well within the Provincial Water Quality Objectives for lakes (below 0.10mg/L for naturally low TP lakes).*** Long term trends indicate stable low phosphorus concentrations for Four Mile Lake which are well within the Provincial Water Quality Objectives.

- ***Nitrogen concentrations are well within the Provincial Water Quality Objectives in Four Mile Lake.*** However, 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 E. coli monitoring results indicate that concentrations have exceeded the Provincial Water Quality Objective at Merrett Creek & Corben Creek N in June 2015 and also the Western Tributary in August of 2015.*** The Haliburton, Kawartha, Pine Ridge District Health Unit beach posting data (due to elevated *E. coli* concentrations) show that the public beach on Four Mile Lake has been posted at least once per season during the monitoring years of 2011-2015.

KEY ISSUES

- ***Higher concentrations of nutrients in Four Mile Lake via Merrett Creek.*** There are significantly higher concentrations of the nutrients phosphorus and nitrogen in Merrett Creek in comparison to the other tributaries (Western Tributary and Corben Creeks). There is limited data on the upstream of Merrett Creek and it is suggested that a more intensive upstream study be undertaken in order to understand the source of the nutrients better.

- ***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 (0.010mg/L). Further investigation is suggested to quantify internal TP inputs.

- ***Higher levels of total suspended solids (TSS) in Merrett Creek compared to the other tributaries.*** Although the TSS values are below the Provincial Water Quality Objective, the average TSS value at Merrett Creek was almost twice as high as the TSS values in the other Four Mile tributaries. This may be attributed to the natural processes of the upstream wetlands which dominant this subwatershed, but further investigation is needed to rule out any anthropogenic causes.

- ***Frequency of Public Beach closures.*** According to *E.coli* posting data (2011-2014) provided by The Haliburton, Kawartha, Pine Ridge District Health Unit indicates that the beach has been posted at least once per swimming season since 2011. Results show that the highest number of exceedances of the Provincial Water Quality Objective was in 2013 (20% of samples) while in 2014 only 9% of samples exceeded the Provincial Water Quality Objectives.

- ***Steep slopes >25% encompassing Four Mile 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

- ***No information on nearshore water quality data***. Water sampling on Four Mile Lake has taken place in the pelagic zone (mid lake area), currently 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 Four Mile Lake.

- ***No data collected to determine if Four Mile Lake contains any emerging contaminants.*** Emerging contaminants includes, but are not limited to, 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.

6.2 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.

6.3 Methodology

Water quality monitoring plays an important role in meeting the objectives of the Four Mile 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 Four Mile Lake Management Plan development was undertaken in 2013-2016 at four tributary/inlet sites and also two open water sampling sites on the lake (Figure 6.1). Historical water quality information from 2011-2014 for Corben Creek at Hwy #35 has been also been included for a comparison of water quality data across the entire watershed.

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, Mississauga, Ontario) 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 2016). Total phosphorus & calcium grab samples are collected at the south 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 along with temperature.

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) 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), 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 (2013-2016). 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 on a variation of nutrient concentration data between tributaries to determine if streams were statistically significantly different from one another. Table 6.1 shows the site ID, location, and number of samples.

6.4 Four Mile Lake Tributaries

From a hydrological point of view the Four Mile Lake watershed includes all areas that supply water to the lake. This means that the Four Mile Lake watershed is comprised of small local subwatersheds (Corben Creeks, North and South, Merrett Creek, and Western Tributary) as seen in Figure 1.1.

The Four Mile Lake watershed occupies a small area (78.96 km^2) within the north-east portion of the Kawartha Conservation watershed. The study area for the Four Mile Lake Stewardship Plan includes areas adjacent to the lake from the north including the Corben Creek subwatershed. The major human land use in the approximately 10% of the watershed which provides opportunity for natural areas to occupy the landscape such as forest, which dominates more than 48% of the land portion of the watershed. Roads occupy approximately 1% of the watershed which provides opportunity for natural areas to occupy the landscape such as forests (24%).

Water quality concerns in the Four Mile Lake watershed include elevated concentrations of phosphorus in its northern tributary, namely Merrett Creek, high nitrogen concentrations in the Western Tributary and Merrett Creek, as well as high *Escherichia Coli* concentrations in some streams and at the public beach. Total Nitrogen (inorganic and organic) and Total Kjeldahl forms of nitrogen have exceeded the guideline threshold in Western Tributary (2013-2014) and have shown elevated concentrations in Merrett Creek over the entire monitoring period (2013-2016). 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 6.1. Water Quality Monitoring Stations in the Four Mile Lake Watershed

Station ID	*Location*	Number of Samples	Most Recent Sample
FL1	Western Tributary @ Beaver Drive	71	May 2016
FL2	Merrett Creek @ Woodworth Drive	62	May-2016
FL3	Corben Creek @ Woodworth Drive	64	May-2016
FL4	Corben Creek (Four Mile Lake outlet @ 6th Concession)	75	May-2016
BC7	Corben Creek @ Hwy #35	74	June-2014
FML1	Four Mile Lake (North)	12	Sept-2016
FML2	Four Mile Lake (South)	12	Sept-2016
LPP (FML2)	Mid Lake (Deep site)	30	Sept-2015

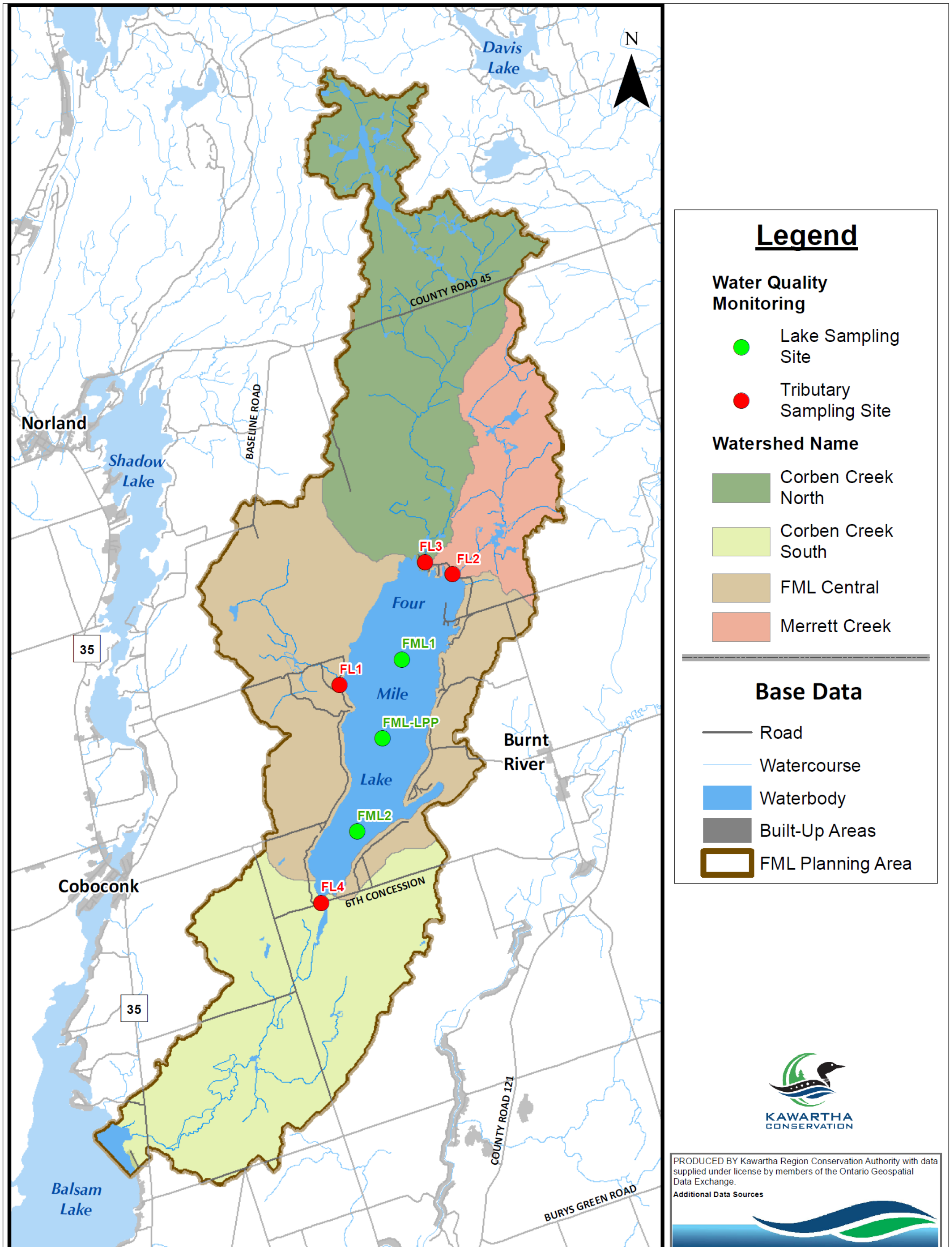

Figure 6.1. Water Quality Monitoring Stations in the Four Lake Watershed

Hydrometric Results

Tributary water temperatures followed a seasonal trend throughout the three year study period ranging from a maximum recorded of 27.6 ^{o}C (FL 3) in June 2014 to a minimum of 0.12^{o}C (FL2) in February 2016. The tributary pH values varied significantly across the 4 tributaries (One Way ANOVA p<0.001). However, pairwise analysis (Dunn's Method) showed that Merrett and Corben Creeks did not differ significantly, and that the Four Mile lake outlet and Western Creek varied significantly (p<0.001). These variances are mostly due to the local geologic influence of the studies tributaries. Conductivity ranged from 69.75 to 405.37 (mean values) and varied significantly (One Way ANOVA p<0.001) following the similar expected pattern observed in pH due to geological influences. The pairwise analysis showed that Merrett and Corben Creeks did not differ significantly, and that the Four Mile lake outlet and Western Creek varied significantly (p<0.001).

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.

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.

The PWQO for total phosphorus (TP) concentrations in watercourses is set at 0.030 mg/L, in order to prevent nuisance algae and aquatic plant growth (MOECC, 1994). The PWQO for TP concentrations in lakes is 0.020 mg/L and/or 0.010 mg/L for those lakes with a natural TP level below this value (MOECC, 1994). As Four Mile Lake has historically recorded TP concentrations below 0.010 mg/L, the PWQO of 0.010 mg/L applies to the lake.

In the Four Mile Lake watershed, average phosphorus concentrations approach the PWQO in the northern tributary, Merrett Creek (0.028mg/L) throughout the study period of 2013 to 2016 with many exceedances beyond the PWQO 40% of the time. Concentrations in the other streams of the watershed are considerably lower and very seldom exceed the PWQO. As a result, phosphorus averages in Western Tributary, as well as Corben Creek North and South and at Highway 35 have always been well below the PWQO threshold of 0.030 mg/L (Figure 6.2). Total phosphorus concentrations between the Four Mile tributaries varied greatly during the time period of the study.

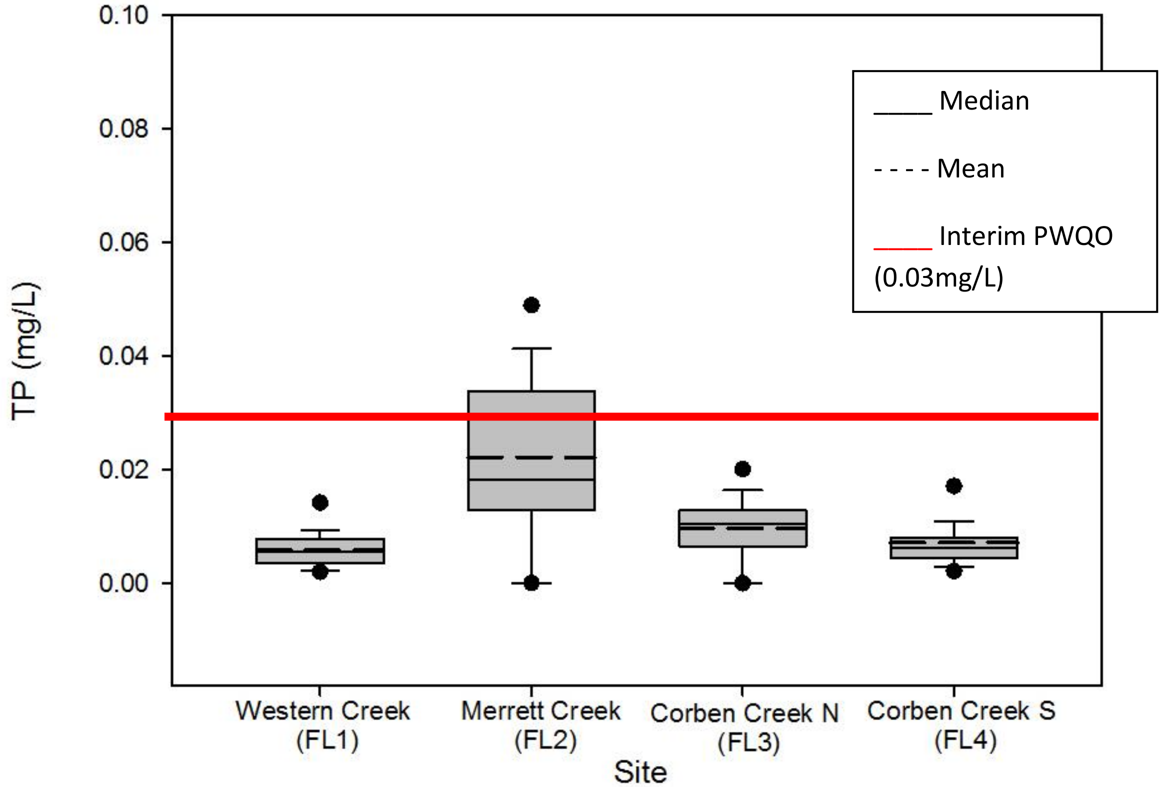

Figure 6.2. Average Phosphorus Concentrations (mg/L) in the Four Mile Lake Tributaries in 2013-2016. The red line denotes the Provincial Water Quality Objective (0.03mg/L).

Note: the box encapsulates the middle 50% of the data (with median drawn halfway through each box); the mean (average) is represented by the dashed line; the whiskers represent the maximum and minimum values without the more extreme outliers of the dataset; the points above and below the whiskers represent data at the 5th and 95th percentiles.

Corben Creek is the largest watercourse in the Four Mile watershed measuring 28.98 km in channel length (including north and south portions). Its origin is located further north on Precambrian Shield bedrock and includes drainage from Goodoar and Lower Goodoar and Corben Lakes as well as many small wetlands. Corben Creek South continues as the only outlet of Four Mile Lake and is unregulated meandering through forested area and Karst formations (see Chapter 5- Water Quantity for more details) to Highway 35 just north west of the village of Baddow (Figure 1.1). The western portion of Four Mile Lake (Central subwatershed) consists of a single drainage area composed of limestone parental rock through the inflow tributary referred to as the Western Tributary. The Western Tributary is a small unnamed tributary (17.5km^2) and measuring 7.14 km in channel length, located within the Four Mile Lake Central subwatershed. The Western Tributary has relatively low phosphorus concentrations and is well within the Provincial Water Quality Objectives (0.03mg/L). Total phosphorus concentrations between the Four Mile tributaries varied greatly during the time period of the study. Corben Creek North experienced total phosphorus concentrations between 0.002mg/L to 0.03mg/L. There were two occurrences when concentrations reached the PWQO limit (Figure 6.2). Both concentration limits (0.03mg/L) occurred during the summer months (August and the end of June).

As mentioned Corben Creek South (19.11 km) is the only outlet of Four Mile Lake and exits under Concession 6 and travels further South to Highway #35 where it enters Balsam Lake. Phosphorus levels in Corben Creek South ranged from 0.002 mg/L to 0.043 mg/L over the study period. The creek exhibited a maximum value of 0.043mg/L which was the single exceedance over the entire duration of the study (2013-2016) and occurred in November 2015; however Corben Creek South's average TP concentration over the three-year period is 0.007 mg/L, which is well below the PWQO.

Merrett Creek TP values vary significantly from the other streams ($P>0.05$) and is a much different stream from the 3 others and thus exhibits varied water quality information. It is a relatively small subwatershed (6.78km^2) and is the most natural watercourse within this study consisting of 58% wetland. The creek originates from a vast wetland upstream and is part of protected areas such as the Somerville Tract, Victoria County Forest and the Altberg Wildlife Reserve. There is very little direct anthropogenic influence along this water course. However, it may be assumed that the natural functions of healthy wetlands are contributing slightly elevated levels of nutrients (TP & TN) to Merrett Creek.

The annual averages ranged from 0.012 mg/L to 0.83 mg/L (Figure 6.2). Median concentrations were almost identical during the first two years of monitoring, recorded as 0.02 mg/L over in 2013 & 2014, however in 2015/16 the median concentration increased slightly to 0.03mg/L. Exceedances above the PWQO of 0.03 mg/L were detected in the stream and observed during the growing season of each study year ranging with exceedances from 0.03mg/L to 0.083mg/L and occurring 40% of the time. The highest phosphorus readings were observed mainly under low flow conditions. It is possible to suggest that high phosphorus concentrations in the creek during dry hot weather are the result of phosphorus input (desorption) from sediments and organic material in a large wetland which feeds the creek. The slight increases observed during higher flow events may be attributed to land runoff and release of organic material. Phosphorus levels are lower during the other three seasons (0.001-0.03 mg/L). The lowest TP concentrations are usually observed throughout late autumn, winter and into early spring.

Western Tributary is a small unnamed tributary (17.5km^2) located within the Four Mile Lake Central subwatershed (Figure 6.1). This creek is encompassed by a natural area surrounding Four Mile Lake (65% forest cover and 7% wetland). The Western Tributary exhibited overall low TP concentrations throughout the three year study period measuring with minimum and maximum recorded values at 0.003mg/L and 0.009mg/L respectively. Highest values were observed during the summer months (July & August) in 2013-2014 and 2015-2016 and during the spring freshet (April/May) in 2014-2015 (Figure 6.3). Average TP concentrations (over the study period) measured 0.006mg/L which is well within the Provincial Water Quality Objective (PWQO= 0.03mg/L). The median concentration, over the three year period was the same as the average value of 0.005mg/L. None of the samples taken on the Western Tributary exceeded the PWQO over the three year study period. The natural heritage values and lack of a heavy residential presence have aided in the health of this stream. The northern portion of the Western Tributary, at the stream crossing at Beaver Drive experiences a high occurrence of beaver dam building which blocks the culvert and is addressed often by way of dismantling. This dismantling creates a flushing and may have some effect on water quality (Figures 6.3, 6.4, 6.5).

In regards to the relationship between water quality and water quantity and in particular TP loading there is an observation of higher TP loading concentrations occurring during the winter months (Figure 6.5). This may be an indication of winter loading as a result of frost free days and should be monitored regularly as a climate change strategy.

Total Phosphorus concentrations show an inverse relationship to water quantity and in particular flow regimes. In periods of low flow the TP values seem to increase in concentrations (Figure 6.3).

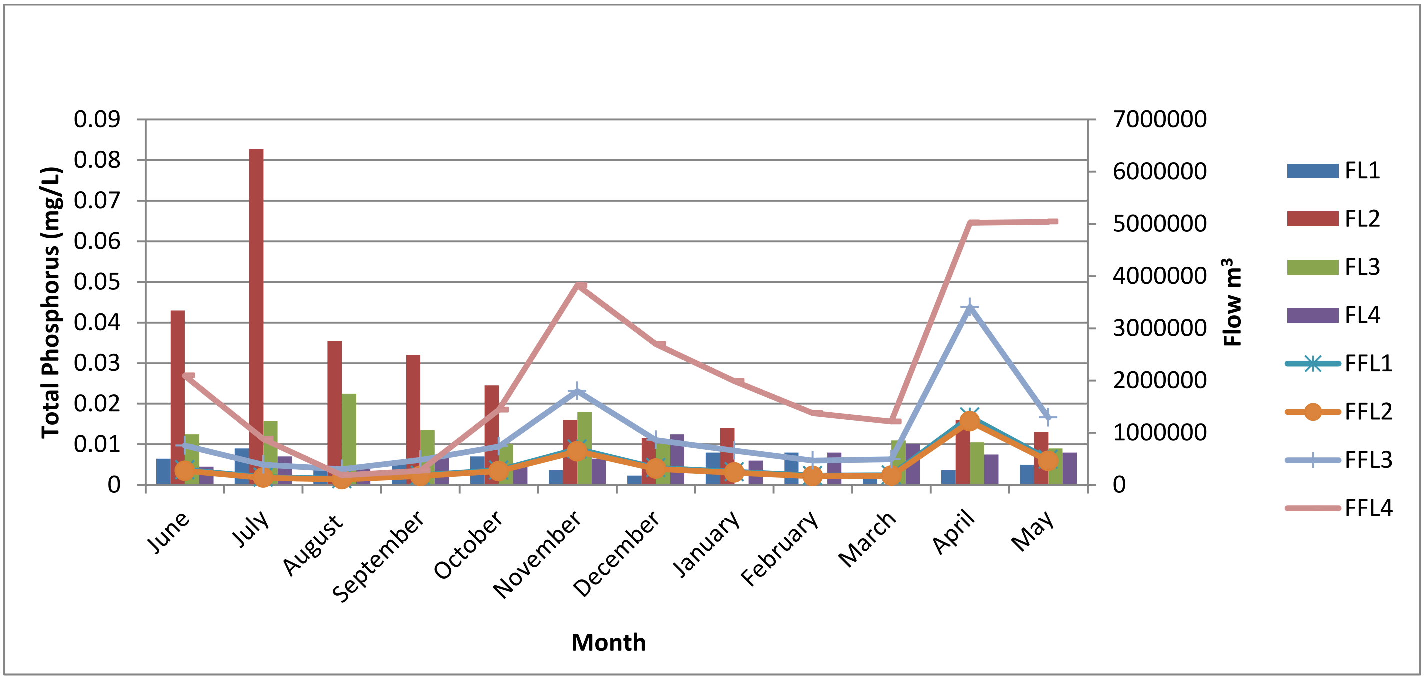

Figure 6.3. Relationship of flow (FFL) and TP concentrations (FL) by month for Western Tributary (1), Merrett Creek (2), Corben Creek N (3) and Corben Creek S. (4) during the hydrologic year 2013-2014.

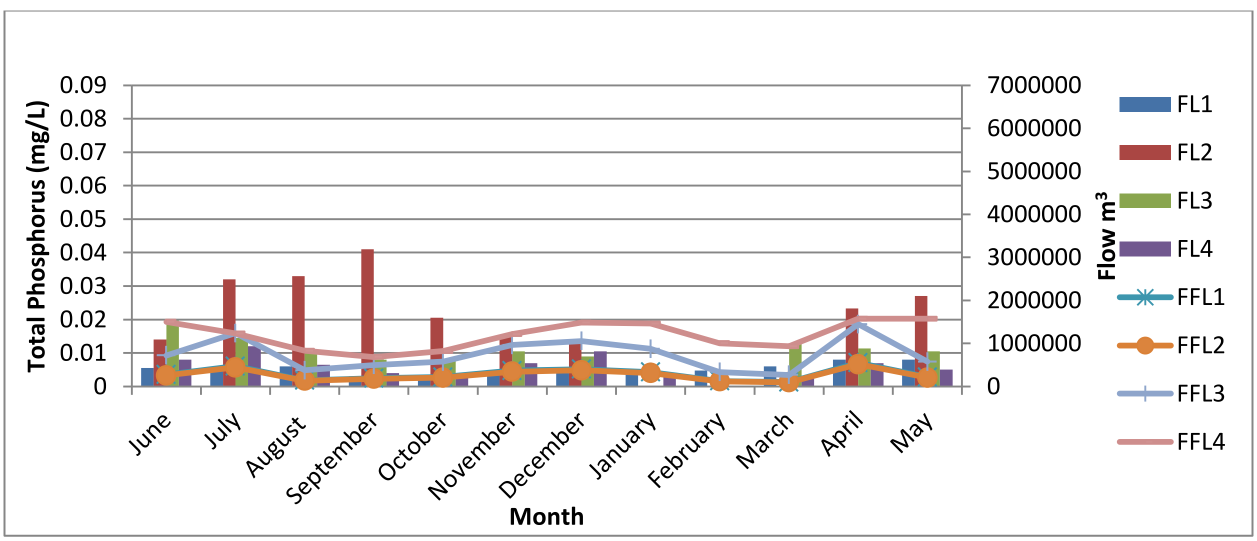

Figure 6.4. Relationship of flow (FFL)and TP concentrations by month for Western Tributary (FL1), Merrett Creek (FL2), Corben Creek N (FL3) and Corben Creek S. (FL4) during the hydrologic year 2014-2015.

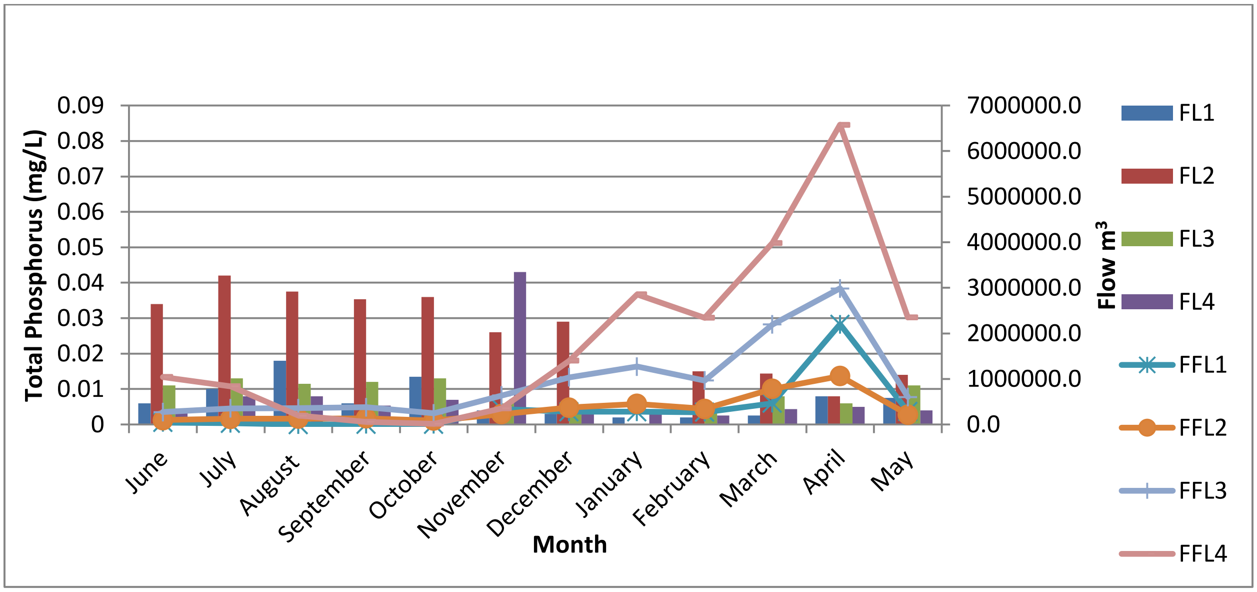

Figure 6.5. Relationship of flow (FFL) and TP concentrations by month for Western Tributary (FL1), Merrett Creek (FL2), Corben Creek N (FL3) and Corben Creek S. (FL4) during the hydrologic year 2015-2016.

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. Within a short time, all nitrites in lake or river water are transformed into nitrates. 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 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 Four Mile Lake watershed, total nitrogen occasionally exceeded 1.0 mg/L (10% of samples). Over the three year study duration total nitrogen concentrations ranged from 0.114mg/L to 2.198mg/L. Average and median nitrogen levels in all streams fall below the interim guideline (Figure 6.6). There were no exceedances in Corben Creek North & South and most exceedances were found in Merrett Creek at a rate of 37% of all samples, but one exceedance was recorded at Western Tributary. Furthermore, exceedances were highest in Merrett Creek during the sampling year of 2015 to 2016 where 45% of all samples at this creek exceeded the 1.0mg interim provincial guideline.

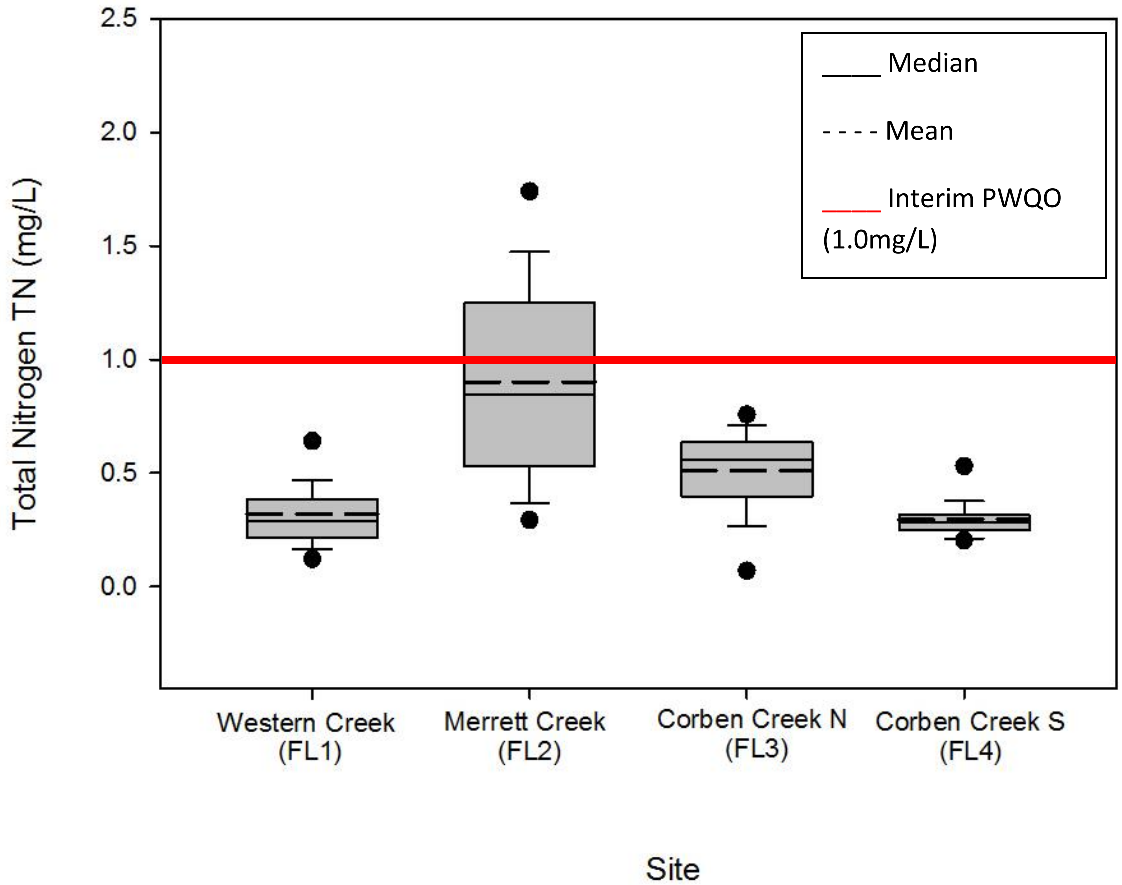

Figure 6.6. Average Total Nitrogen concentrations (mg/L) in the Four Mile Lake Tributaries; Western Tributary (FL1), Merrett Creek (FL2), Corben Creek N (FL3) and Corben Creek S. (FL4) in 2013-2016. The red line denotes the interim Provincial Water Quality Objective (1.0mg/L).

Note: the box encapsulates the middle 50% of the data (with median drawn halfway through each box); the mean (average) is represented by the dashed line; the whiskers represent the maximum and minimum values without the more extreme outliers of the dataset; the points above and below the whiskers represent data at the 5th and 95th percentiles.

Seasonal distribution of total nitrogen Merrett Creek is characterized by higher concentrations during summer and fall due to low flow conditions during these months and a heavy organic load as a result of naturally occurring senescence patterns of large wetlands upstream (Figure 6.6).

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, one can see that nitrogen levels are higher in Merrett Creek as opposed to Corben Creek, situated to the northern portion of Four Mile Lake, which has the lowest concentrations of all nitrogen forms and has similar flow patterns to Merrett Creek, but originates from shield lakes further north. Extremely high nitrogen concentrations in Merrett Creek are in contrast to

Corben Creeks North and South, however very similar to Western Tributary which also originates from a large wetland. Analysis of the water quality data suggests that an increase in total nitrogen levels in the Merrett and Western Tributary Creeks is mainly associated with very high organic material from the large wetlands which feed both creeks.

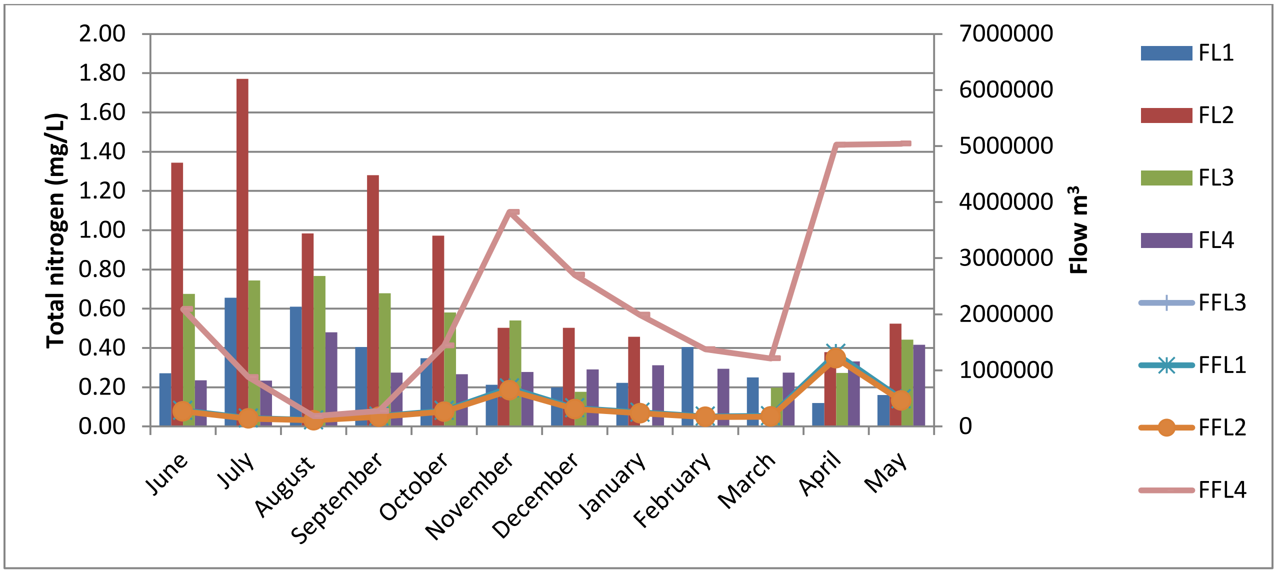

Figure 6.7. Relationship of flow (FFL) and total nitrogen concentrations by month for Western Tributary (FL1), Merrett Creek (FL2), Corben Creek N (FL3) and Corben Creek S. (FL4) during the hydrologic year 2013-2014.

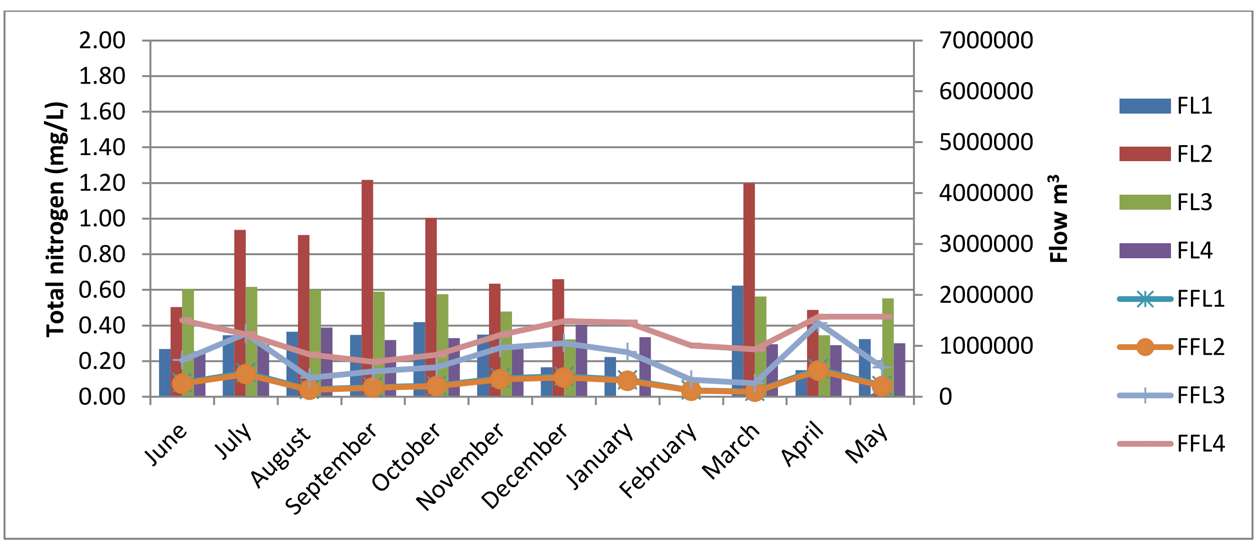

Figure 6.8. Relationship of flow (FFL) and total nitrogen concentrations by month for Western Tributary (FL1), Merrett Creek (FL2), Corben Creek N (FL3) and Corben Creek S. (FL4) during the hydrologic year 2014-2015.

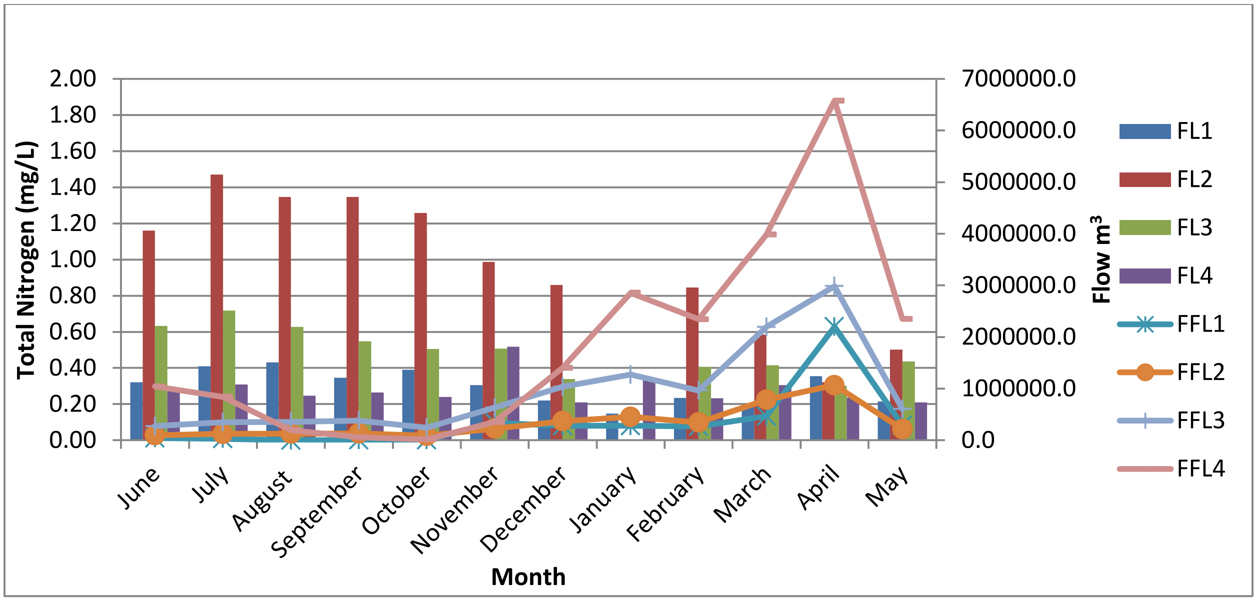

Figure 6.9. Relationship of flow (FFL) and total nitrogen concentrations by month for Western Tributary (FL1), Merrett Creek (FL2), Corben Creek N (FL3) and Corben Creek S. (FL4) during the hydrologic year 2015-2016.

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 June to October and inversely the flow at its lowest values.

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 increase 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 are usually 1.0-4.0 mg/L (Figure 6.10). The maximum TSS concentration was recorded in Merrett Creek measuring 33 mg/L, during July 2013. The TSS concentrations within this stream are higher than the other streams within the study area (average 4.47 mg/L) and may be attributed to the high productivity of the stream and wetlands upstream of the sampling site on Merrett Creek. The remaining tributaries, Western Tributary (FL1), Corben Creek N (FL3), and Corben Creek S. (FL4) within this study area had average TSS concentrations of 1.39mg/L, 2.89mg/L, and 1.39mg/L respectively over the three year study period.

Figure 6.10 shows that the average and median TSS concentrations in all monitored streams are well below the CCME guideline. The lowest TSS concentrations were detected in the outflow of Four Mile Lake in Corben Creek S (Figure 6.10)

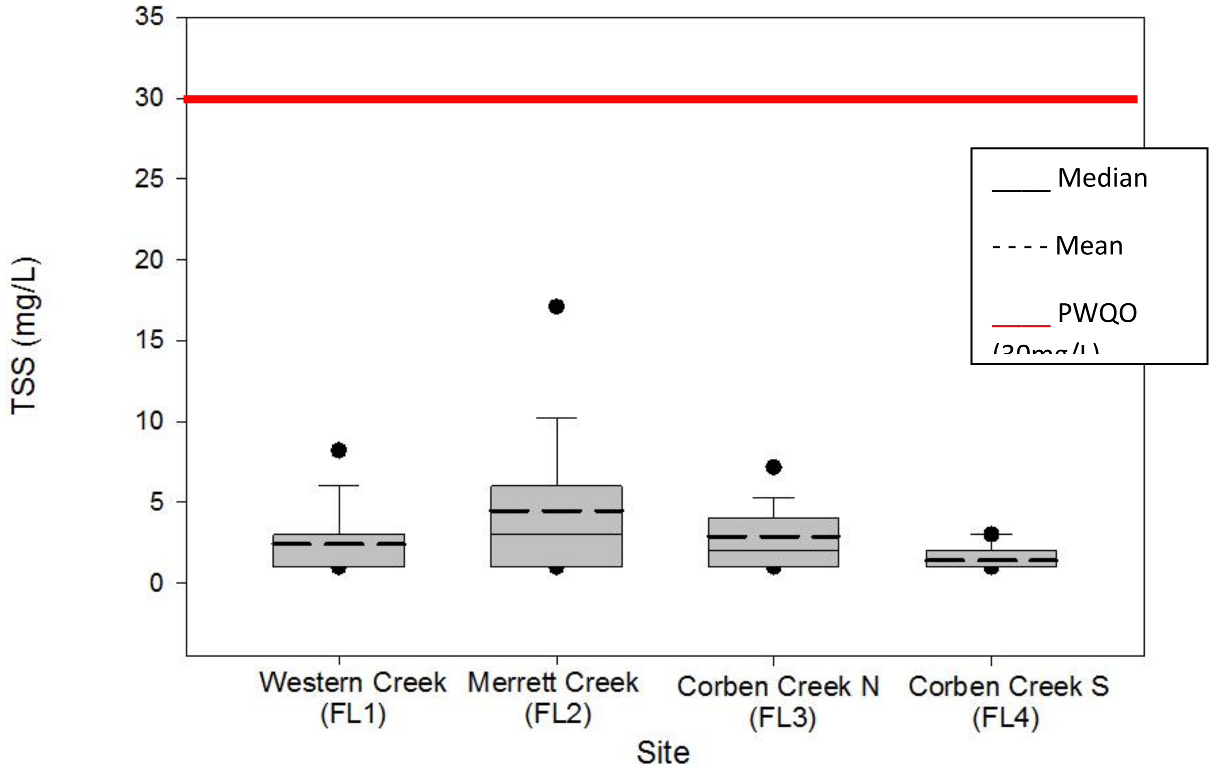

Figure 6.10. Average Total suspended solids concentrations (mg/L) in in 2013-2016 including, Western Tributary (FL1), Merrett Creek (FL2), Corben Creek N (FL3) and Corben Creek S (FL4). All fell well within the CCME guideline (30mg/L). The red line denotes the CCME guideline (30mg/L).

Note: the box encapsulates the middle 50% of the data (with median drawn halfway through each box); the mean (average) is represented by the dashed line; the whiskers represent the maximum and minimum values without the more extreme outliers of the dataset; the points above and below the whiskers represent data at the 5th and 95th percentiles.

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 (Geomean) of at least five samples (MOECC, 1994).

E.coli monitoring results from 2013-2016 have revealed that majority of monitored streams in the watershed have had *E.coli* levels below the PWQO. However, Tributary *E. coli* monitoring results indicate that concentrations have exceeded the Provincial Water Quality Objective at Merrett Creek and Corben Creek North in June 2015 and the Western Tributary in August of 2015. 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. 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 Four Mile Lake has been posted at least once per season during the monitoring years of 2011-2015 (details in *Escherichia Coli* at Public Beaches section).

6.5 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, Four Mile 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 PWQO for lakes (below 0.10mg/L for naturally low TP lakes (Figure 6.11). Additionally, both bottom and surface samples were analysed for total phosphorus concentrations in the northern and southern sampling sites, FML1 & FML2 respectively. Secchi disk depth readings usually ranged between 5.8m and 7.9m over the three year study period and averaged a depth of 6.5m confirming the high water quality of the lake.

Phosphorus

Four Mile Lake is composed of one basin sharing relatively similar sized portions of sedimentary and Precambrian rock. Shallower depths of 6m are observed in the northern end of the lake while deeper depths to a maximum of 18m are found in the southern end. Lake data (surface samples) collected for this study included representative sites in both the north and south sites, FML1 and FML 2 respectively. The Northern and Southern portions of Four Mile Lake consist of similar hydrographic features and hydrological regimes and are influenced to some degree by abiotic anthropogenic factors such as the high density of development including private septic systems along the shores.

Overall total phosphorus concentrations for Four Mile Lake were indicative of a non-enriched system (0.006mg/L) recording results lower than historical results from the 1970s which measured 0.012mg/L (Dillon and Rigler, 1974: Michalski 1986). Concentrations were similar in both sampling sites (FML1 and FML2) representing the more shallow northern and deeper southern areas of the lakes measuring 0.006mg/L and 0.005mg/L respectively (Figure 6.11).

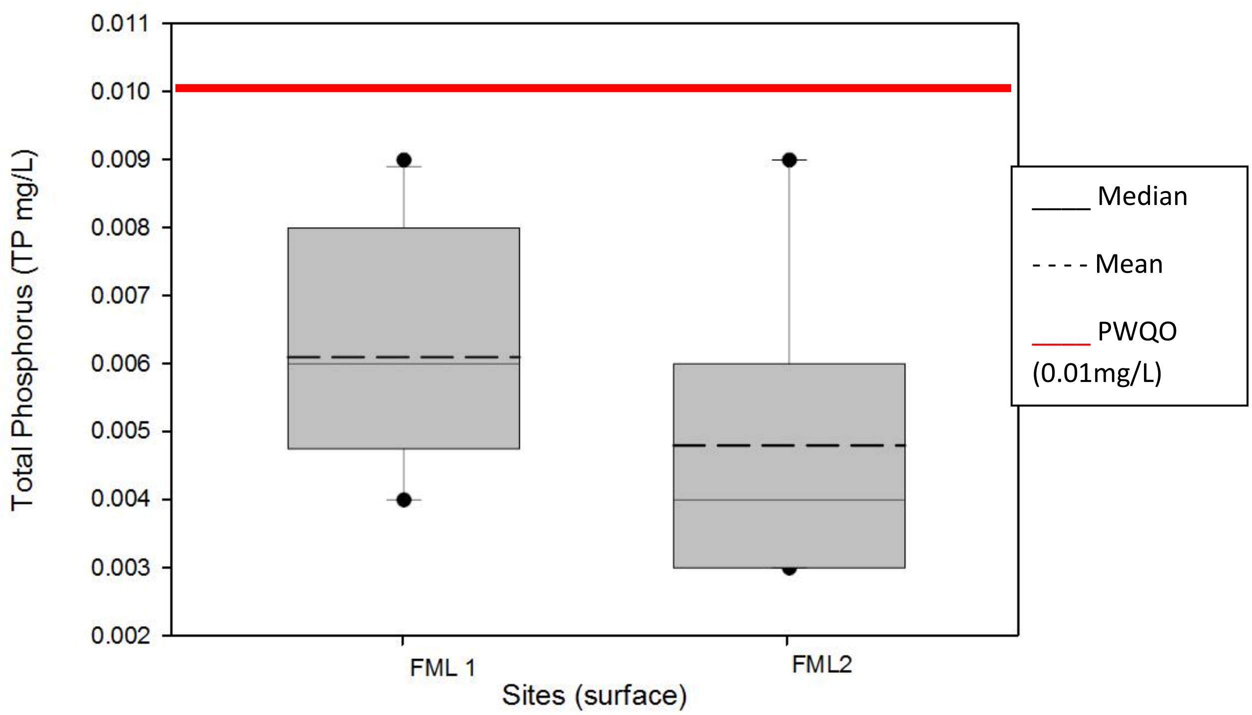

Figure 6.11. Average Phosphorus Concentrations in Four Mile Lake during the three year study period (2014-2016). The red line denotes the PWQO (0.01mg/L).

Note: the box encapsulates the middle 50% of the data (with median drawn halfway through each box); the mean (average) is represented by the dashed line; the whiskers represent the maximum and minimum values without the more extreme outliers of the dataset; the points above and below the whiskers represent data at the 5th and 95th percentiles.

There was one episode of total phosphorus approaching the Provincial guideline limit which coincided with a high flooding event during the spring of 2014. It appears that high spring inflow from overland runoff, saturated wetlands upstream and other smaller overfilled tributaries resulted into a small influx of phosphorus into the lake during April – May and caused elevated TP levels during the summer of 2014.

Monthly average concentrations of total phosphorus ranged from 0.003mg/L to 0.01mg/L over the three year study period (Figure 6.12). Further analysis revealed that the variation of total phosphorus concentrations did not vary significantly temporally (*p*>0.05, T Test).

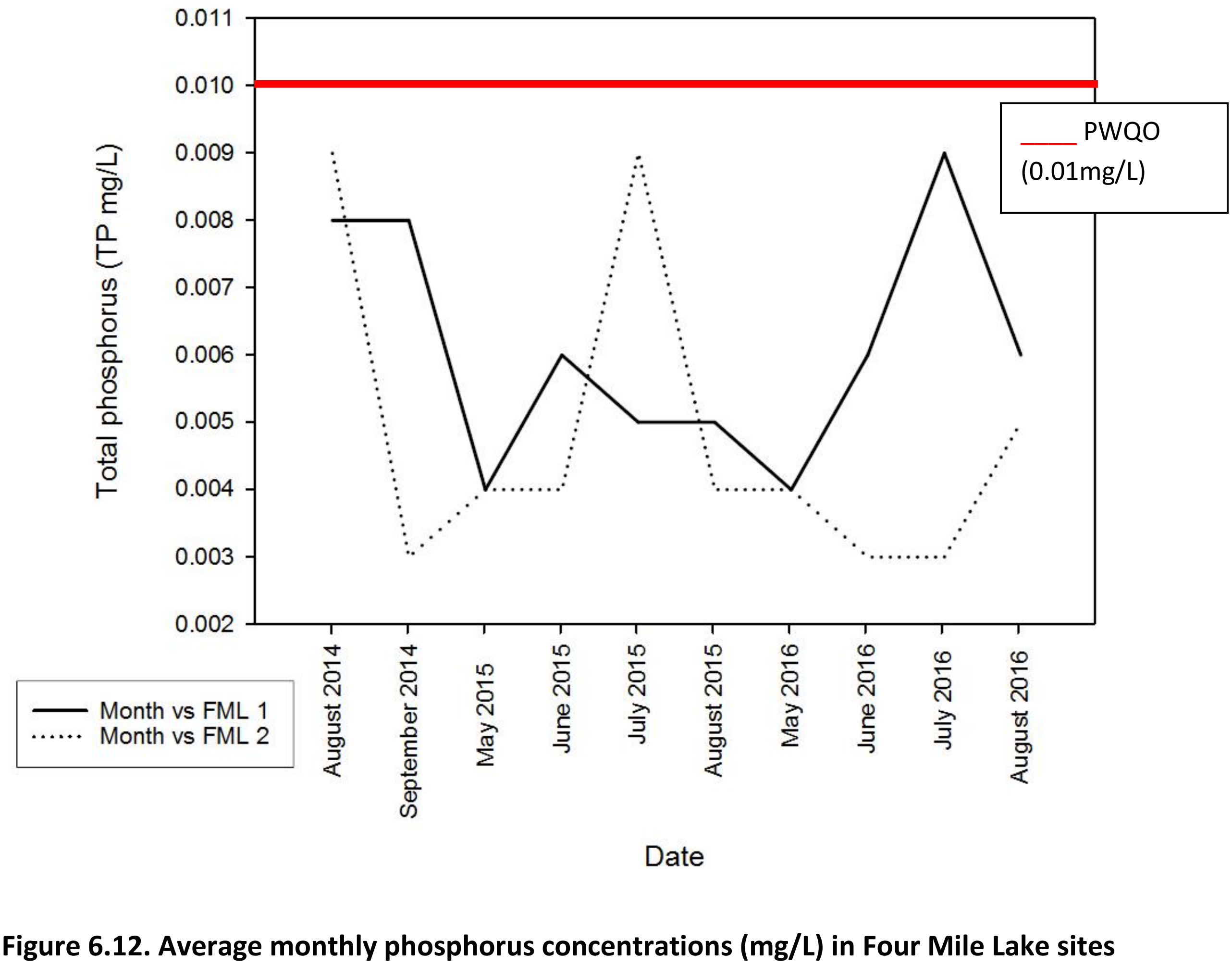

Figure 6.12. Average monthly phosphorus concentrations (mg/L) in Four Mile Lake sites (FML1 and FML2) during the three year study period (2014-2016). The red line denotes the PWQO (0.01mg/L).

Over the three-year sampling period, phosphorus levels in the northern and southern parts of the lake followed the same general trend, except for the 2016 sampling field season. Data suggests there is an inverse relationship between the two sites where the highest concentration of phosphorus (0.09 mg/L) was observed at the northern sampling station while the southern site FML2 exhibited much lower concentrations. These results may be contributed to the shallow depth at FML1 (max 6m) and could be attributed to non-stratification occurring compared to stratified FML2 depth (Max depth 18m). However, both sampling sites experienced overall higher phosphorus concentrations during the summer months (July-August). This may reflect increasing algal populations in summer time, though phytoplankton and chlorophyll *a* analysis were beyond the scope of this study. The lowest TP concentrations were usually observed in May – June, just before or during the spring turnover. The available data demonstrate that the lowest phosphorus concentrations in Four Mile Lake overall were usually observed in May and/or June, just before or after the spring turnover (Figure 6.6). After that, TP levels increase and reach the highest values in July -August, depending on the weather conditions in each given year.

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 PWQO (0.01mg/L) since the beginning of monitoring (Figure 6.13). There is one monitoring station in the framework of the LPP on Four Mile Lake. It is located within the deepest spot of the lake which Kawartha Conservations has used as FML2 for the duration of this study to ensure data collection consistency.

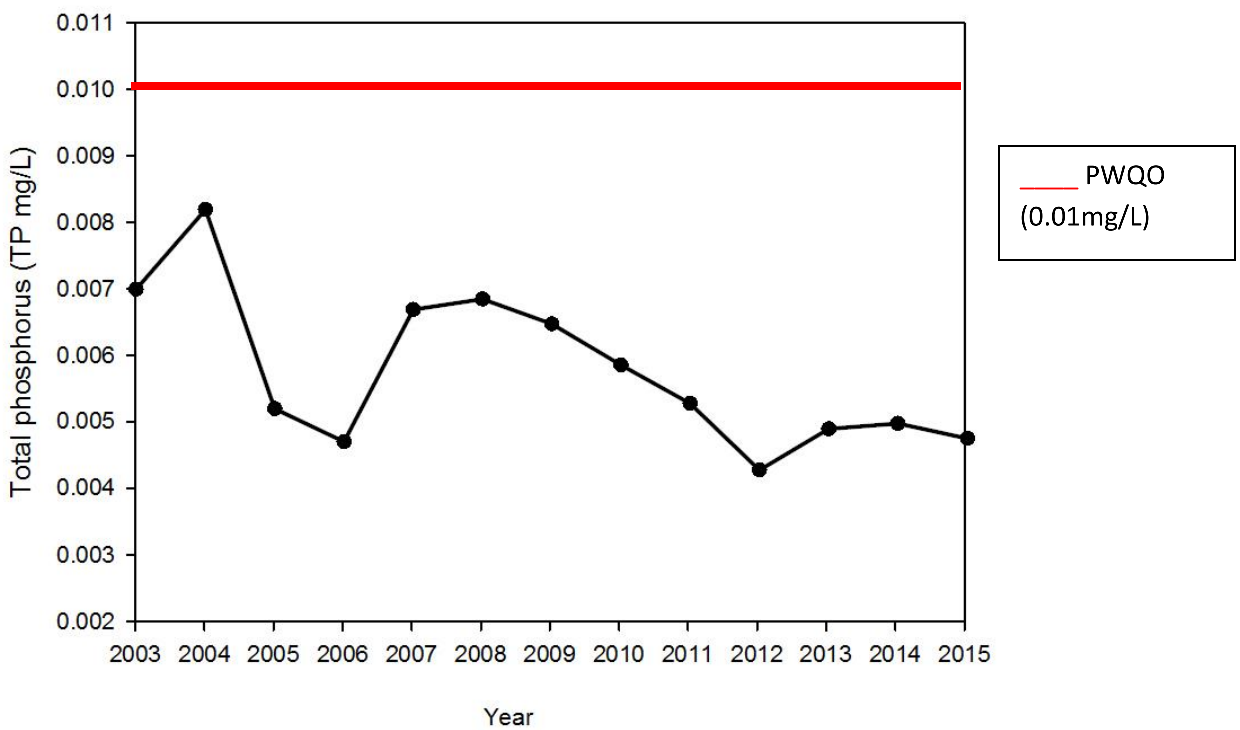

Figure 6.13. Average Annual Phosphorus Concentrations (mg/L) in Four Mile Lake for the Period of 2003 – 2015 (Lake Partner Program Data). The red line denotes the PWQO (0.01mg/L).

Since the early 2000s the average annual TP concentrations fluctuated from 0.004 to 0.008 mg/L. The 2014-2015 LPP data correlates very well with our own data and follows similar trends (Figures 6.14). A basic statistical analysis performed has shown that phosphorus concentrations do not indicate much change between the years. 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 exceedances 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.

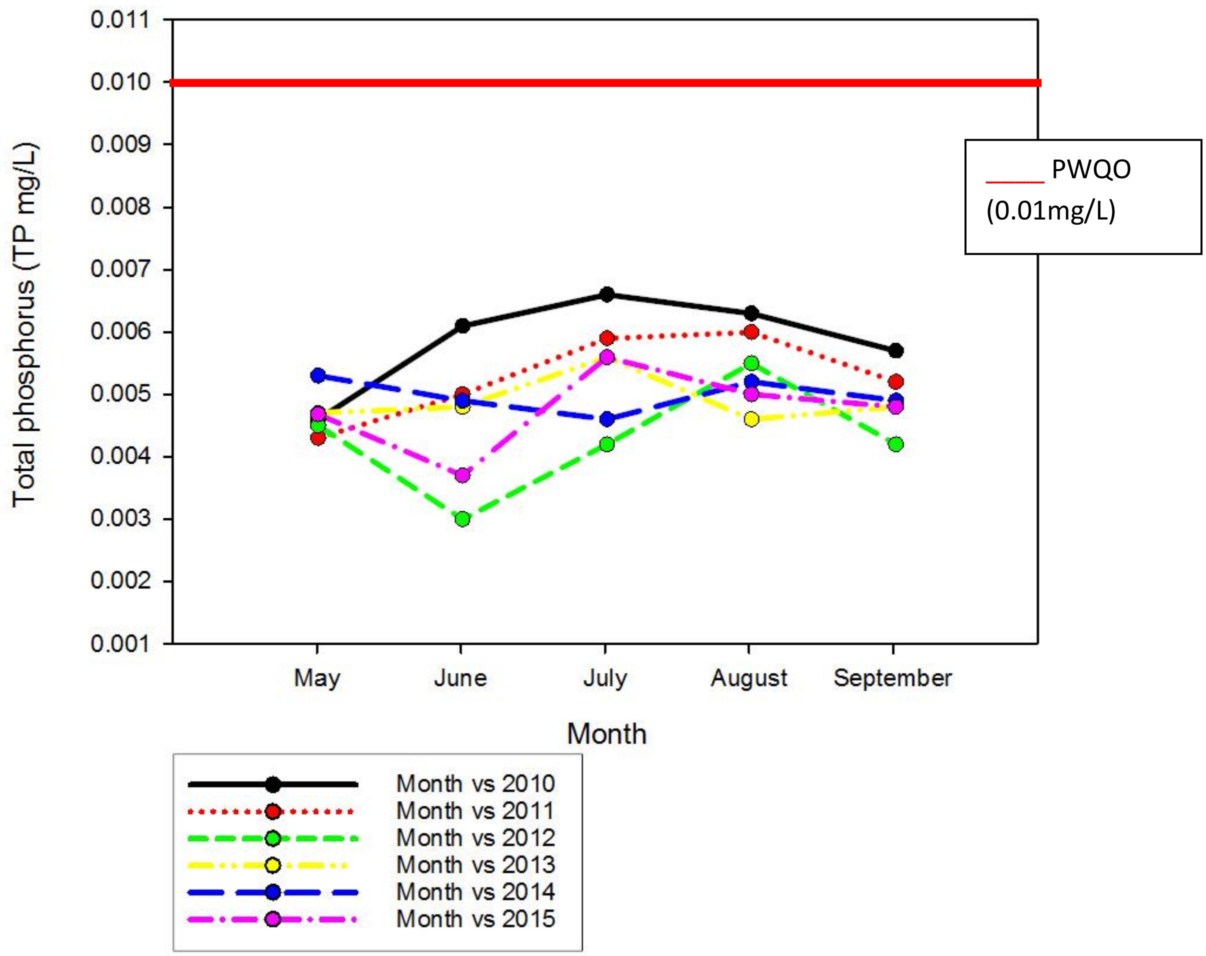

Figure 6.14. Monthly average phosphorus concentrations (mg/L) in Four Mile Lake for the Period of 2010 – 2015 (Lake Partner Program Data).

Upon further analysis of the Lake Partner Program total phosphorus data it appears that similar seasonal trends are followed over the past five years (Figure 6.14). However, it seems that in 2010 and 2011 there was a constant increase in TP over the summer season then returned to the general decreasing trend in September. The other years (2012-2015) generally followed a trend of lower levels of TP during

May and June and an observable incline during the summer months of July and August then returning to a decrease of concentrations in September at the onset of fall.

In addition to collecting surface water samples Kawartha Conservation also examined bottom water samples (1m above bottom) at both the northern and southern sites (FML1 & FML2). The bottom samples were collected at the same interval as the surface samples and analyzed for total phosphorus and nitrogen including the various fractions.

Sediment in lakes can contain much higher phosphorus concentrations than the water, thus retrieving lake bottom 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) 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 fall turnover (Wetzel 1983). Although minimal, the role of phospholizing bacteria is also a contributor of internal phosphorus loading from sediment sourcing.

Overall Four Mile Lake exhibited on average low total phosphorus concentrations in bottom samples of the lake (pooled FML1 & FML2 data) ranging from 0.003mg/L to 0.016mg/L over the three year study period. The average concentration was well within the PWQO measuring 0.007mg/L however, there were two occurrences of PWQO exceedances which occurred on the August 30th sampling event where concentrations were recorded as 0.016 mg/L and 0.014 mg/L at sites FML1 and FML2, respectively (Figure 6.15).

Coincidently, dissolved oxygen levels were very low at FML2 and recorded at 1.43 mg/L. The more northern site (FML1) exhibited higher dissolved oxygen levels (6.19 mg/L), however this value falls at the cusp of healthy oxygen levels for various fish species recruitment (see Aquatic Ecosystem Chapter 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.

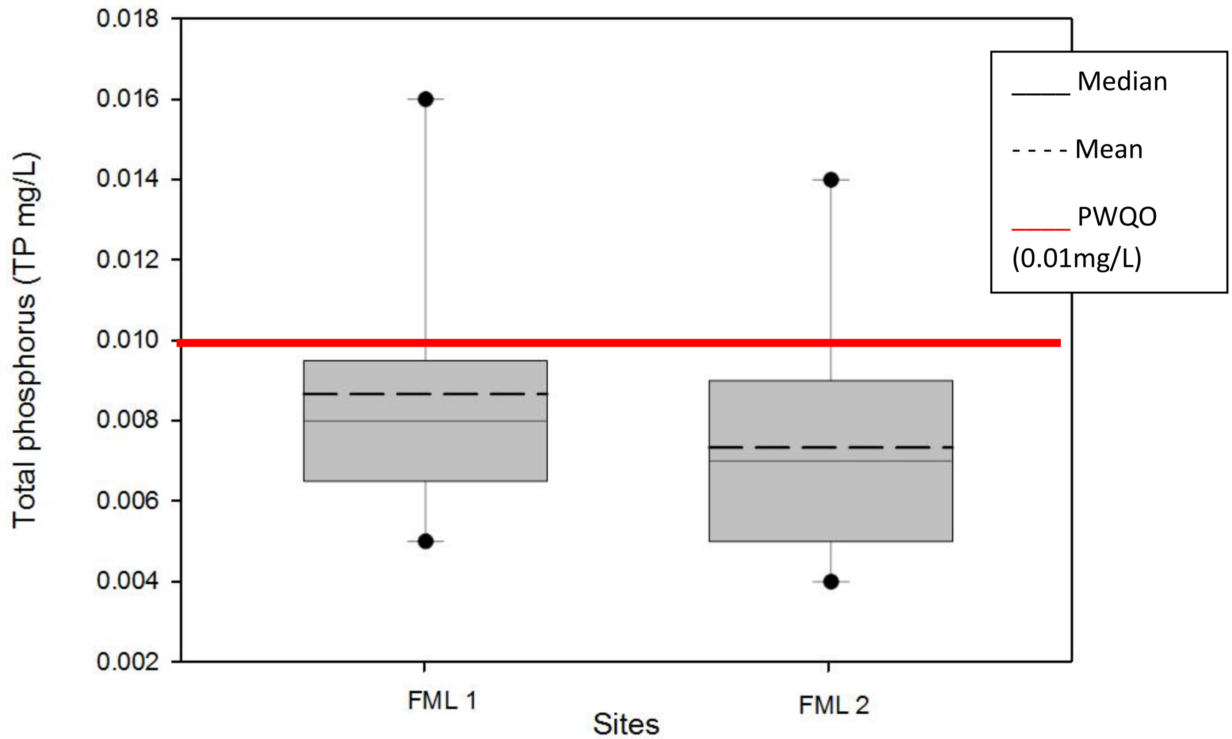

Figure 6.15. Average bottom Phosphorus Concentrations in Four Mile Lake during the three year study period (2014-2016). The red line denotes the PWQO (0.01mg/L).

Note: the box encapsulates the middle 50% of the data (with median drawn halfway through each box); the mean (average) is represented by the dashed line; the whiskers represent the maximum and minimum values without the more extreme outliers of the dataset; the points above and below the whiskers represent data at the 5th and 95th percentiles.

Nitrogen

The results of nitrogen analysis in open water sampling sites (FML1 & FML2) in Four Mile showed values well within the Provincial Interim Guideline of 1.00mg/L of total nitrogen (Figure7.16). In Four Mile Lake overall (pooled site data) total nitrogen concentrations fluctuated in the range of 0.29 – 0.43 mg/L . Both sites (FML1 & FML2) exhibited very similar results and had recorded average concentrations of 0.27mg/L and 0.29mg/L respectively. The highest TN levels was recorded at site FML 2 with a maximum of 0.43mg/L, while the minimum recorded concentrations was 0.24mg/L was recorded at site FML1. (Figure 6.16). The median of both sites were also very similar and calculated at 0.27mg/L & 0.28 mg/L at FML1 and FML2 respectively.

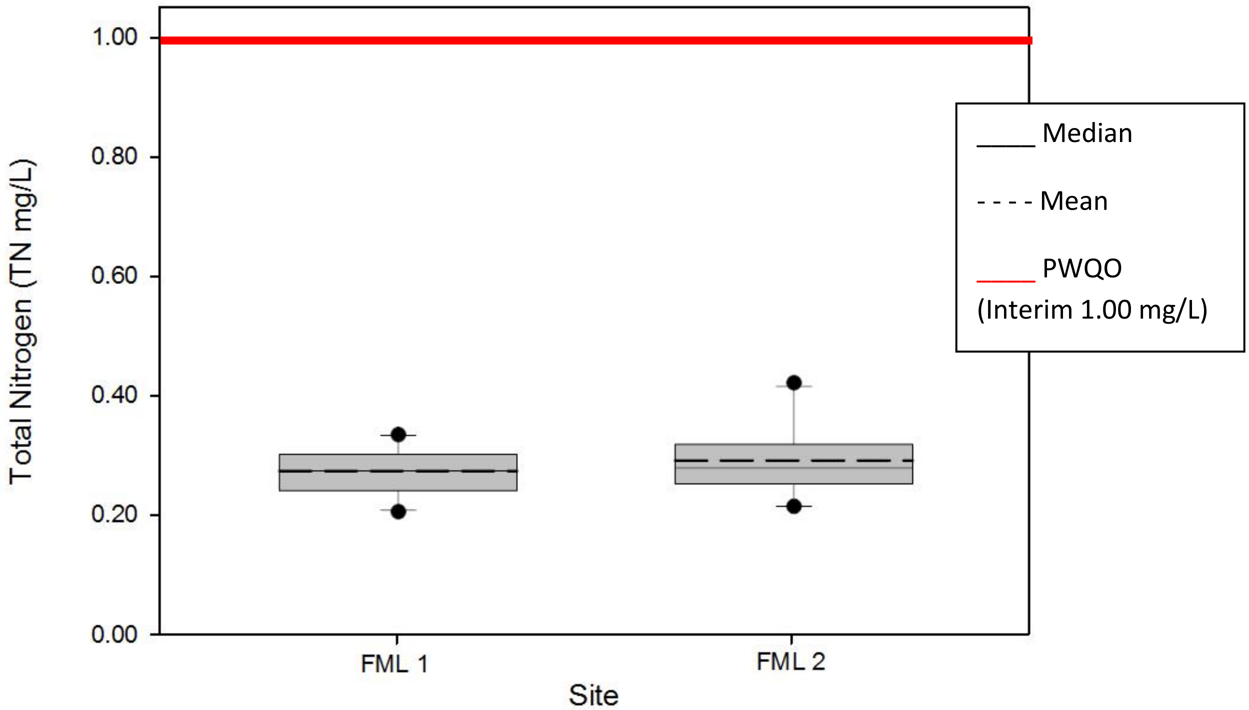

Figure 6.16. Average Total Nitrogen Concentrations (mg/L) in Four Mile Lake during the May-September period in 2013-2016.

Note: the box encapsulates the middle 50% of the data (with median drawn halfway through each box); the mean (average) is represented by the dashed line; the whiskers represent the maximum and minimum values without the more extreme outliers of the dataset; the points above and below the whiskers represent data at the 5th and 95th percentiles.

There was not a significant difference in TN concentrations spatially or temporally in comparison of year to year data (*p*>0.05, T Test). The low nitrogen levels may be attributed to the limited amount of agricultural areas as vectors of nitrogen inputs in addition to the vast protected areas surrounding the lakes such as the Altberg Reserve, Victoria County Forest and the central and eastern wetlands.

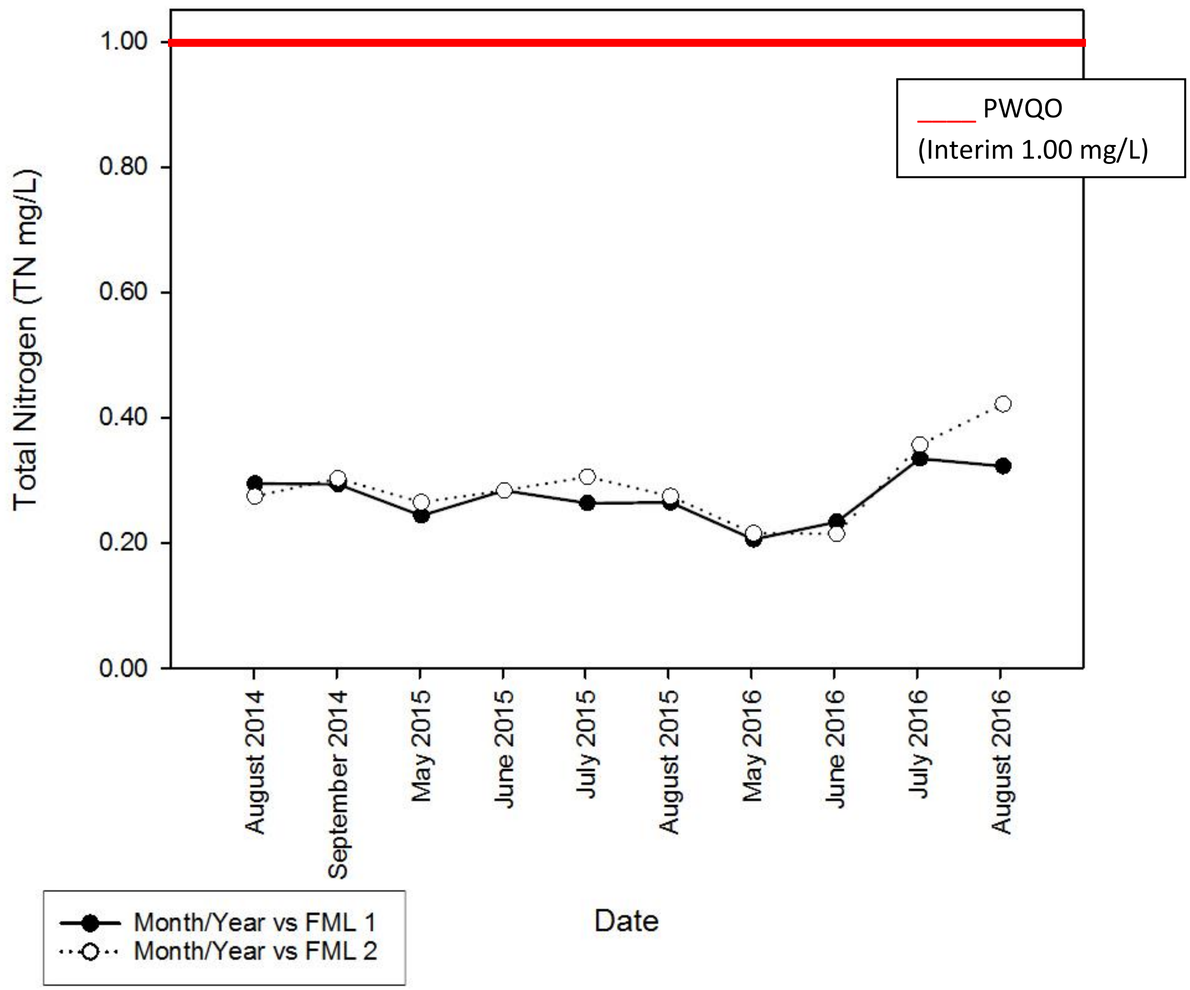

Figure 6.17. Average Monthly Total Nitrogen Concentrations (mg/L) in Four Mile Lake during the May-September period in 2013-2016.

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 concentrations were recorded in August and September 2016 measuring 0.04mg/L (Figure 6.17) and well within the PWQO (2.63 mg/L).

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 Ecosystem Chapter for more details).

End of Season Dissolved Oxygen

End of season hypolimnetic dissolved oxygen provides good information in terms of fish recruitment and relationship to algal and plant productivity. End of season dissolved oxygen concentrations did not vary significantly between years (One-way ANOVA $p<0.05$). All end of season dissolved oxygen concentrations followed expected similar trends of a sharp decline in oxygen by the end of the September (Figure 6.18). Hypolimnion oxygen depletion is a natural occurrence in many stratified lakes such as Four Mile 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. In comparison to the 1975 & 1985 dissolved oxygen results concentrations are still below the 5mg/L level (Michalski 1986). These low concentrations will have a direct impact on species composition of the lake (see Aquatic Ecosystem Chapter).

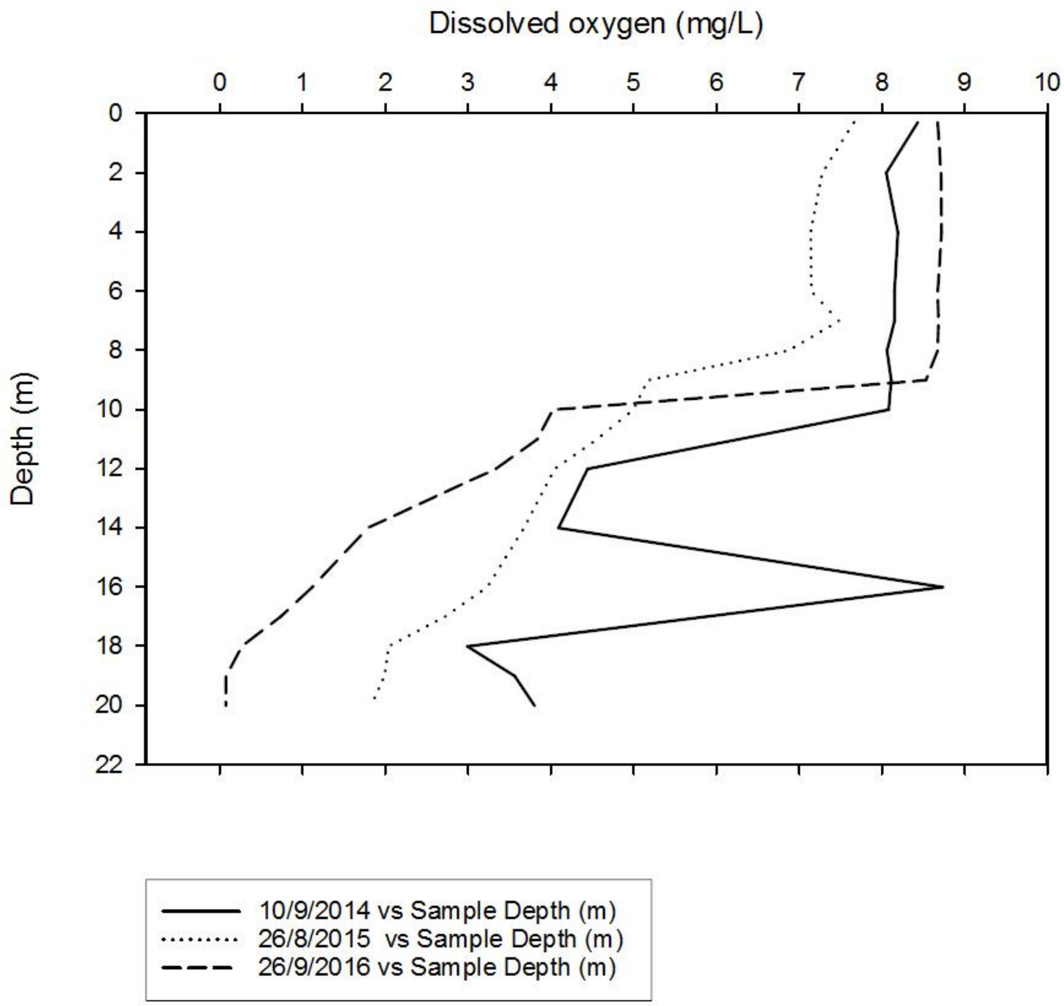

Figure 6.18. Average annual end of season dissolved oxygen concentrations (mg/L) in Four Mile Lake from 2014-2016.

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 include 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. Consequently current studies conclude accelerated leaching rates of 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 (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 2016). 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. Four Mile Lake is well above this threshold and has calcium levels measuring 30.6mg/L on average over the last 11 years (MOECC 2016).
However, it is essential to maintain good forestry practices and monitoring to maintain the current levels to create resiliency as a strategy against climate change.

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 Hillside Drive (Figure 6.19). Additionally, the public beach also serves as a public boat launch with regulated hours of use to accommodate all stakeholders.

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.

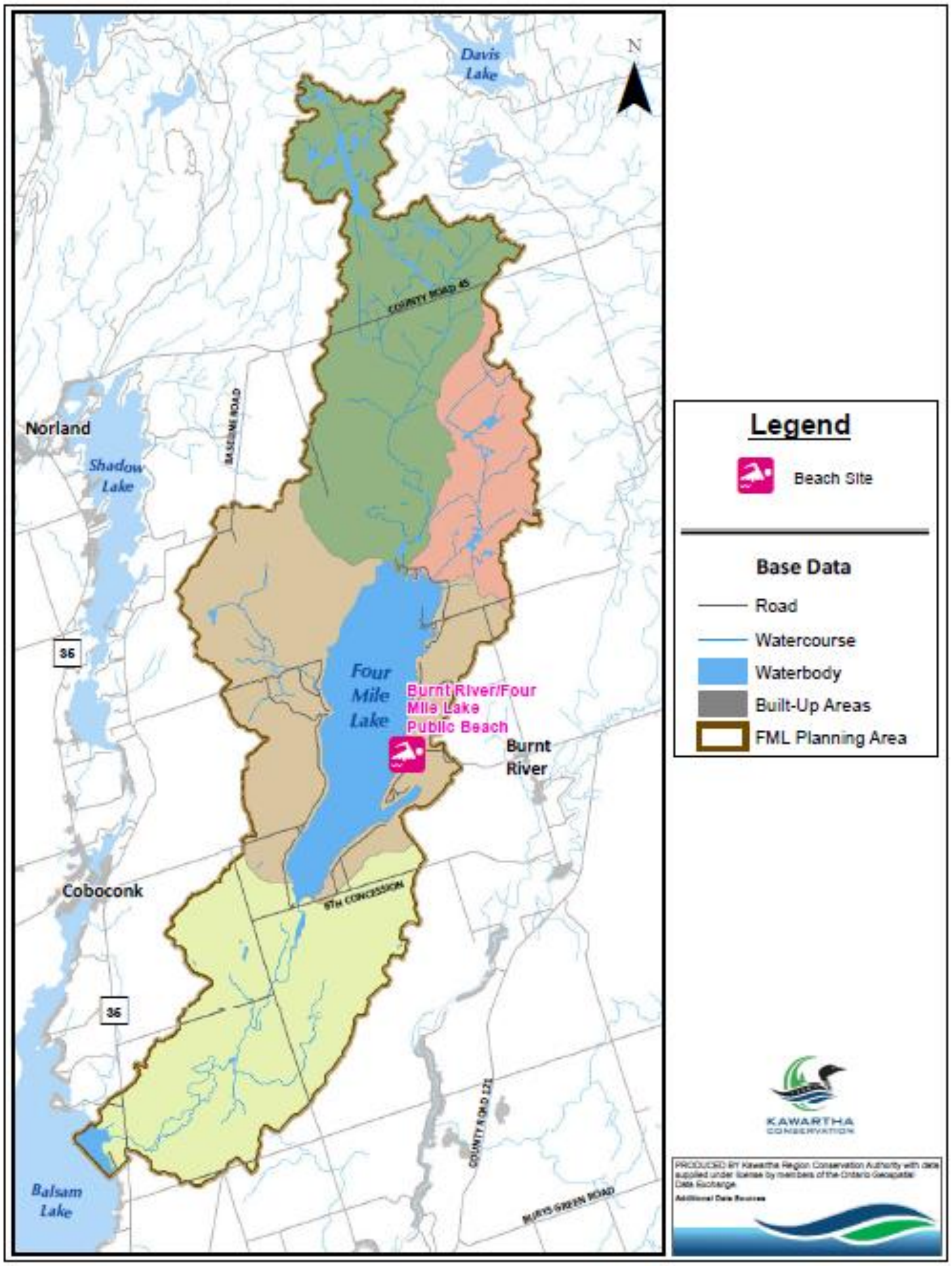

Figure 6.19. Public Beach Location within Four Mile Lake Watershed

The Haliburton, Kawartha, Pine Ridge (HKPR) District Health Unit's *E.coli* data for 2011-2015 demonstrate that the beach at Four Mile 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 year of 2013 (Figure 6.20). The beach was posted twice in 2013 and exceeded the geometric mean of 100cfu/100ml 20% of the time (June to August). Future studies may include the identification and mitigation of *E.coli* sources.

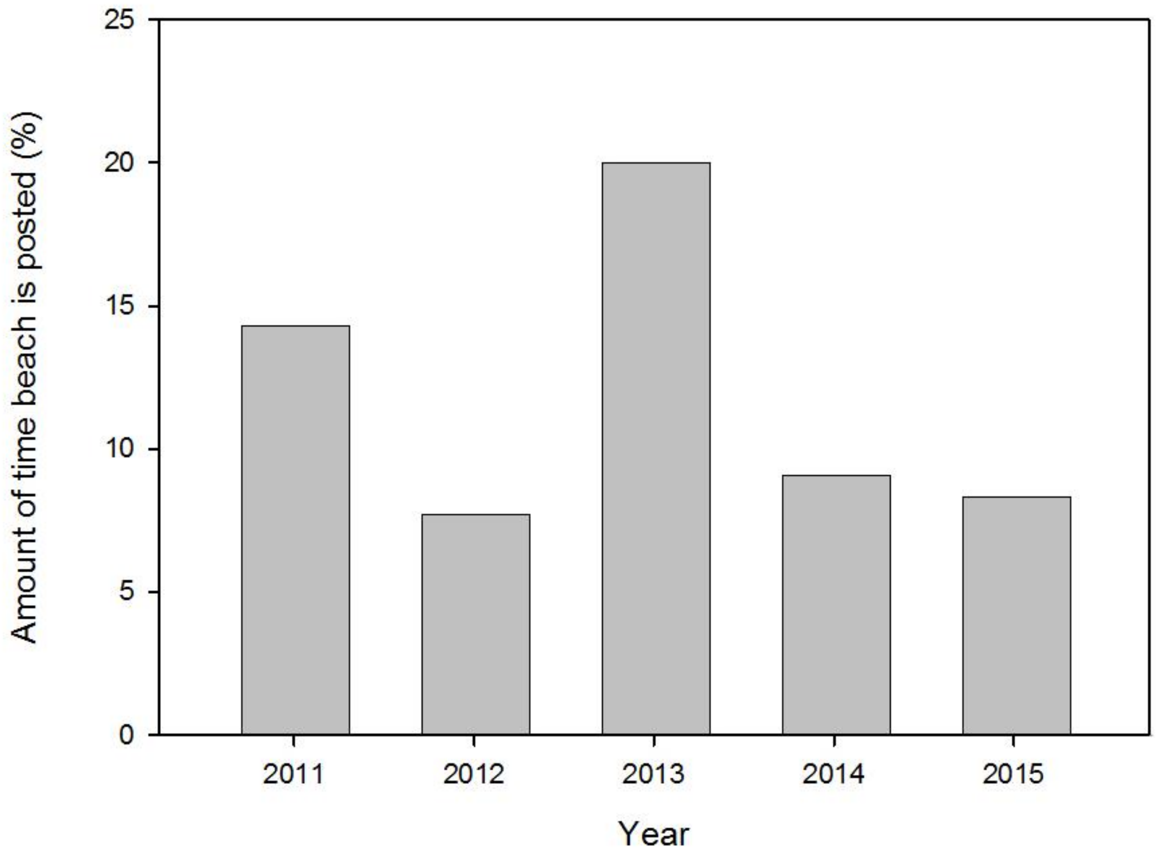

Figure 6.20. Annual Geometric Mean *E.coli* Concentrations (100cfu/100ml) at the Four Mile Lake Public Beach

7.0 Aquatic Ecosystems

7.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- **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 8% 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 73% of the shoreline within 30m of the lake. Nearshore areas of the lake provide ample diversity of aquatic habitat, and the eastern shore in particular provides an abundance of walleye spawning habitat.

- **Four Mile Lake supports diverse fish communities that contribute to a functioning recreational fishery.** Approximately 21 fish species have been documented within the lake over a 45-year period, many of which are important (e.g., walleye, muskellunge, largemouth bass) in supporting a recreational fishery. According to the most recent available data (2009), the fish community in Four Mile Lake consists of warm- and cool-water species dominated by yellow perch, smallmouth bass, rock bass, walleye, and pumpkinseed. Sensitive coldwater fish species have been documented in the deeper southern basin of Four Mile Lake (lake whitefish and lake herring), which thermally stratifies during the summer months. No known fish species listed as Special Concern, Threatened or Endangered have been documented.

- **Aquatic habitat conditions along the creeks within the watershed are of excellent quality, owing to the lack of human disturbance.** Subwatersheds within the Four Mile 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 that have relatively high compositions of sensitive taxa, and bioassessment results that indicate a status of fair or better at all sampled sites.

KEY ISSUES

Establishment of non-native, invasive aquatic species that alter the aquatic ecosystem. Four Mile Lake has been exposed to a variety of non-native aquatic species, particularly invertebrates (e.g., zebra mussels, rusty crayfish, banded mystery snail), and aquatic plants (e.g., common reed, Eurasian water milfoil). In addition to these existing non-native species, there are others that are at immediate risk of becoming established (e.g., 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 Four Mile Lake to the 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 lake herring, lake whitefish, and burbot. Dissolved oxygen and temperature profiles already indicate less than optimal habitat availability for these species, the reason for which remains poorly understood.

INFORMATION GAPS

- **Limited understanding of changes to fish community composition and recreational fishing effort.** Although fish communities have been assessed periodically within the last 45 years, 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 Four Mile Lake will be routinely monitored approximately every 5 years. To date there have been two rounds of surveys under this program, 2009 and 2016 (the results of which are not available at the time of report publication). 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 Four Mile Lake or its tributaries.

- **Limited understanding of coldwater aquatic habitat and communities.** Coldwater fishes are present within Four Mile Lake (e.g., lake herring, trout-perch, and burbot), and its tributaries (brook trout, and sculpin species), 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.** Much of the available aquatic community data is only available for fish communities in the lake, and benthic invertebrate communities in the subwatersheds of Four Mile Lake Central and Corben Creek South. There are significant aquatic community data gaps in Corben Creek North and Merrett Creek, in part due to the remoteness of aquatic habitat within those areas.

7.2 Introduction

This chapter provides an overview of important components of the aquatic ecosystems of Four Mile 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.

7.3 Lake Ecosystems

7.3.1 Aquatic Habitat

The lake exists in south-central Ontario within a landscape transitional area between the Canadian Shield and St. Lawrence Lowlands, therefore the lake has characteristics of lakes within the region. Underlying bedrock is predominately limestone, therefore calcareous shallow soils provide good buffering and lake not sensitive to acid rain. Four Mile Lake is hydrologically connected to the Kawartha Lakes through Corben Creek from its outlet to Balsam Lake, its water levels and flows are not manipulated and it follows a natural hydrological regime.

Based on recent water quality sampling (see Chapter 6: Water Quality) Four Mile Lake is considered an oligotrophic, unenriched waterbody. Data indicate water quality within the lake is considered in a good state, having waters that are relatively clear (6m Secchi depth), and unenriched (5 ug/L total phosphorus).

Lake morphology is distinct between the northern and southern sections (Figure 7.1). The south basin of the lake contains the deepest depths and has relatively narrow and steep nearshore areas. The north basin of the lake, in contrast, contains relatively shallower waters that more gradually slope into the lake. Shallow nearshore areas (less than 2m) are relatively limited in the lake, occupying only 13% of the lake surface area. The distribution of bottom substrate within the littoral zone (the nearshore area extending to a depth at which vascular plant growth ceases) as reported by Michalski Associates (1986) is shown in Figure 7.2. Weedy substrates characterized the greatest length of shoreline (5375m), followed by rock conditions (4025m), submerged shoals (3975m), sand and stones (3825m), rocky cliffs (2375m), sand (1000m) and gravel (725m). No recent data on littoral conditions are available.

A rapid shoreline survey was conducted by Kawartha Conservation in 2016 to characterize features along the shore-water interface. Despite the fact that the shoreline around Four Mile Lake is heavily developed (see Chapter 3: Land Use and Physical Characteristics) the water's edge remains in a relatively natural state, with 71% consisting of natural unvegetated, 21% as natural vegetated, and 8% as artificial (Table 7.1). The top five categories, including cobble, bedrock, marsh, boulder, and gravel comprise over

80% of the Four Mile Lake shoreline. Concrete is the dominant artificial structure along the shoreline (3.5%).

Table 7.1: Results of rapid shoreline assessment, conducted in summer 2016, expressed as length of shoreline and percentage of total shoreline length.

Category	Length (m)	Length (% of shoreline)
Concrete	800.2	3.5%
Gabion Baskets	190.5	0.8%
Flagstone	183.6	0.8%
Manicured	143.8	0.6%
Wooden	142.5	0.6%
Riprap	136.6	0.6%
Beach	101.8	0.4%
Armourstone	85.9	0.4%
Steel	24.1	0.1%
Rubber	5.5	<0.1%
Total Artificial	1814.5	7.9%
Cobble	7142.6	31.2%
Bedrock	5666.0	24.8%
Boulder	1742.8	7.6%
Gravel	1227.5	5.4%
Sand	407.2	1.8%
Open Water	42.3	0.2%
Total Natural Unvegetated	16228.4	70.9%
Marsh	2594.4	11.3%
Forest	1063.3	4.6%
Swamp	981.0	4.3%
Meadow	192.4	0.8%
Total Natural Vegetated	4831.1	21.1%

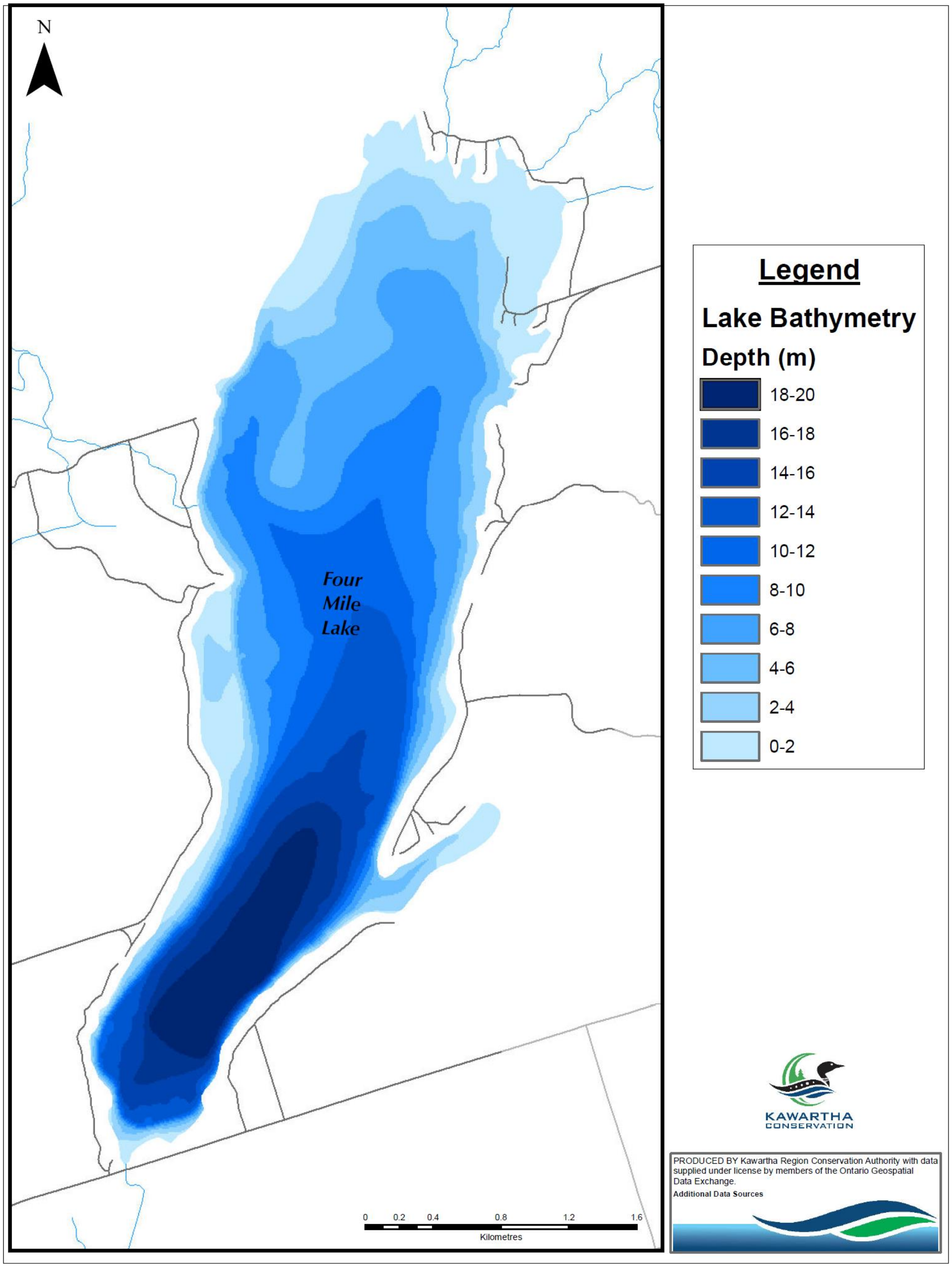

Figure 7.1: Bathymetric map of Four Mile Lake, showing three sections of the lake with varying aquatic habitat conditions.

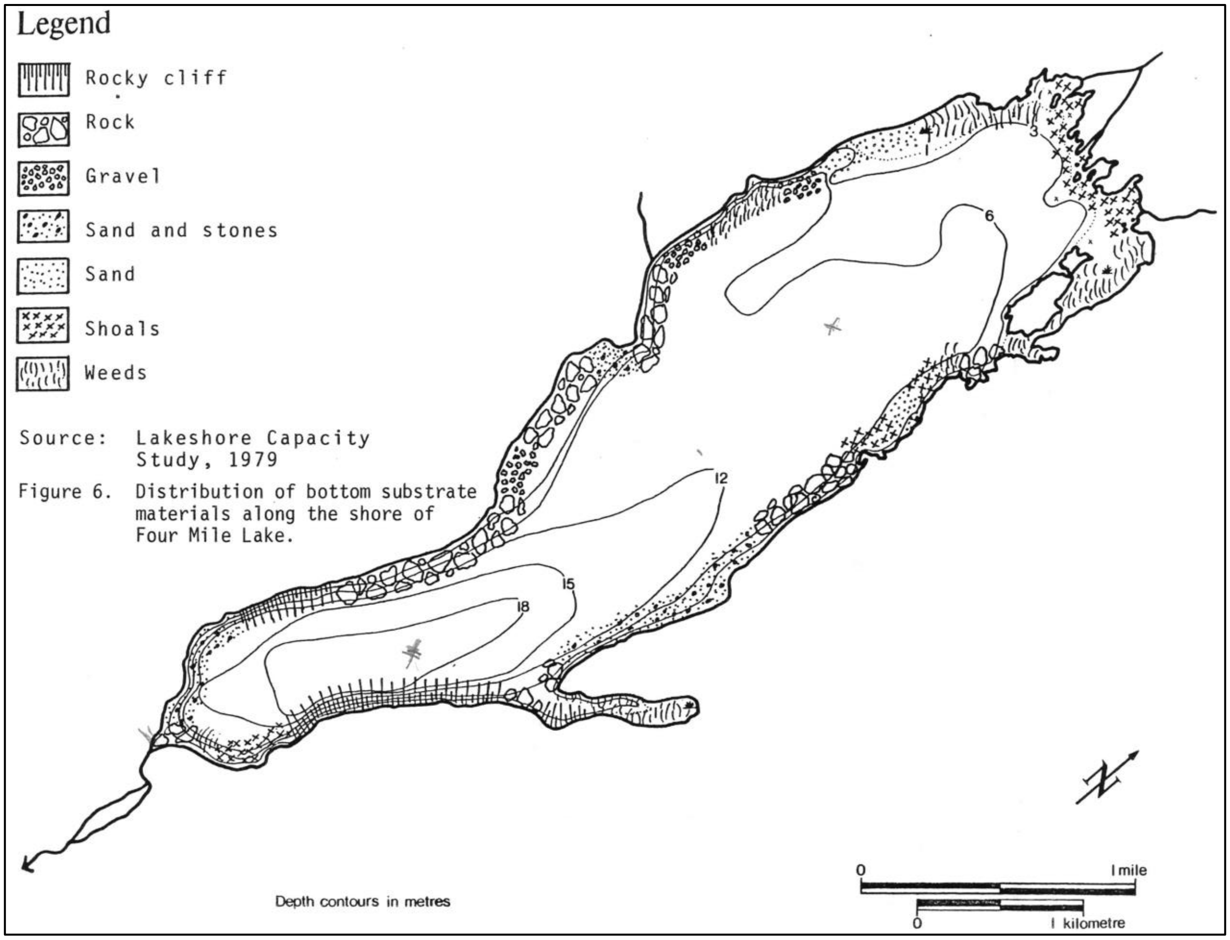

Figure 7.2: Distribution of bottom substrate materials along the shore of Four Mile Lake.

Lake water temperature and dissolved oxygen profiles taken in late summer of 2015 are graphed in Figure 7.3 for the north basin (to a depth of 9m) and south basin (to a depth of 20m). Surface water temperatures remain almost identical in both basins, indicating that the lake is well-mixed. Rapid declines in temperature occur in both basins starting from 22°C at 8m in depth, and continues to the bottom of the lake in the north basin (16°C at 9m), and to 8.8°C at 14m in depth within the south basin. This zone of rapid temperature declines is the thermocline, and is indicative of lake stratification with a range of more uniform warmer surface water temperatures occurring above this zone (epilimnion) and colder waters below (hypolimnion). Dissolved oxygen concentrations show a similar pattern, with comparable and higher values recorded in the epilimnion (6.84 to 7.67mg/L), rapid declines within the metalimnion and the lowest values within hypolimnion (3.65 – 1.81mg/L). Low dissolved oxygen within the hypolimnion could be limiting the productivity of resident coldwater fish communities.

Several coldwater fishes (lake whitefish, lake herring, and burbot) have been documented within the lake. These fishes are more sensitive than others found within the lake and typically only occupy waters having their preferred water temperatures between 7-14°C (Eakins, 2016) and 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 south basin from late spring to late summer indicate that there is sub-optimal quality for these species (Figure 7.4 and Figure 7.5), particularly as the summer season progresses and water temperature increase and dissolved oxygen decreases. Data indicate that deep waters (below 9m in depth during late summer) have cold-enough temperatures to support coldwater life. However, dissolved oxygen concentrations are below the threshold within these depths to support coldwater life.

Figure 7.6 shows the locations of known spawning habitat for two important recreational fish within the lake, walleye and muskellunge (Land Information Ontario, 2016). Most of the east shore of the lake is documented as providing spawning habitat for walleye, which is dominated by coarse substrates (e.g., cobble, gravel) along wind swept nearshore areas. Muskellunge spawning habitat has been documented in the northwest shore and near the lake outlet. It is important to note that 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.

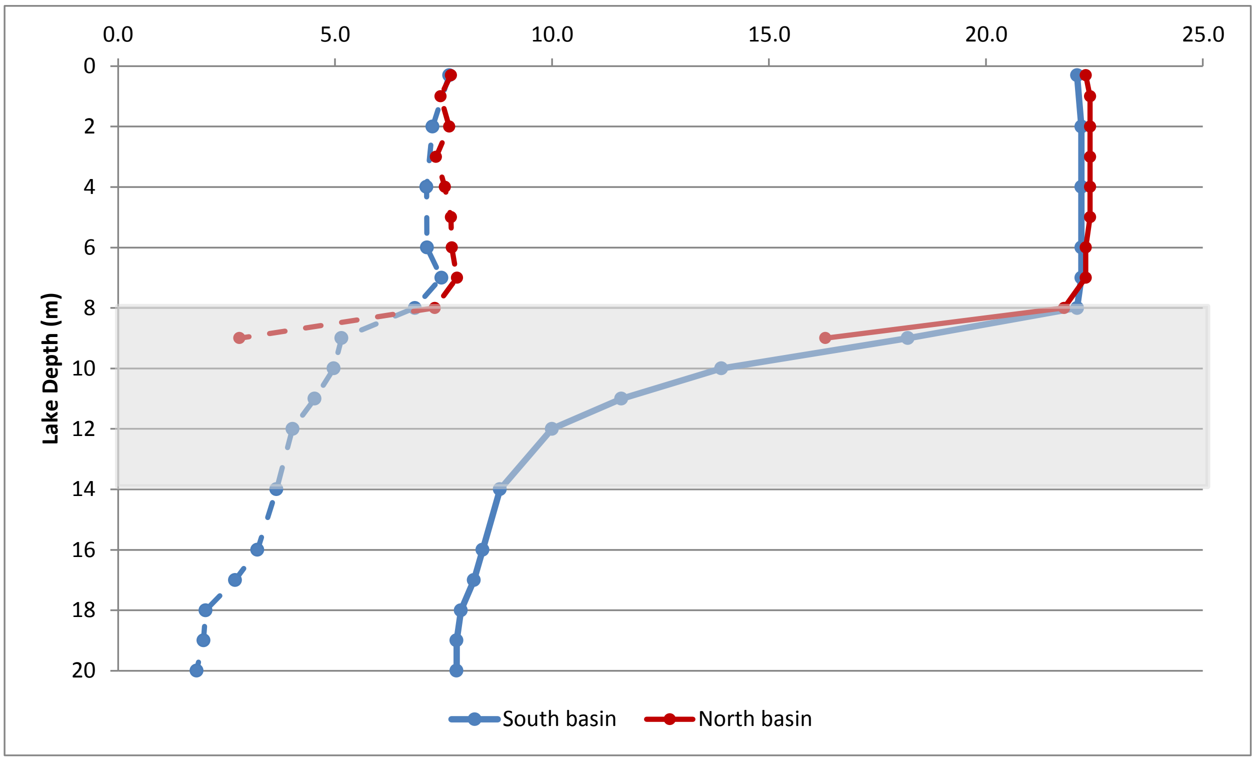

Figure 7.3: Water Temperature (°C, solid lines) and dissolved oxygen (mg/L, dashed lines) profiles during late summer (Aug. 26, 2015) in the north basin (red) and south basin (blue). Shaded area represents the thermocline.

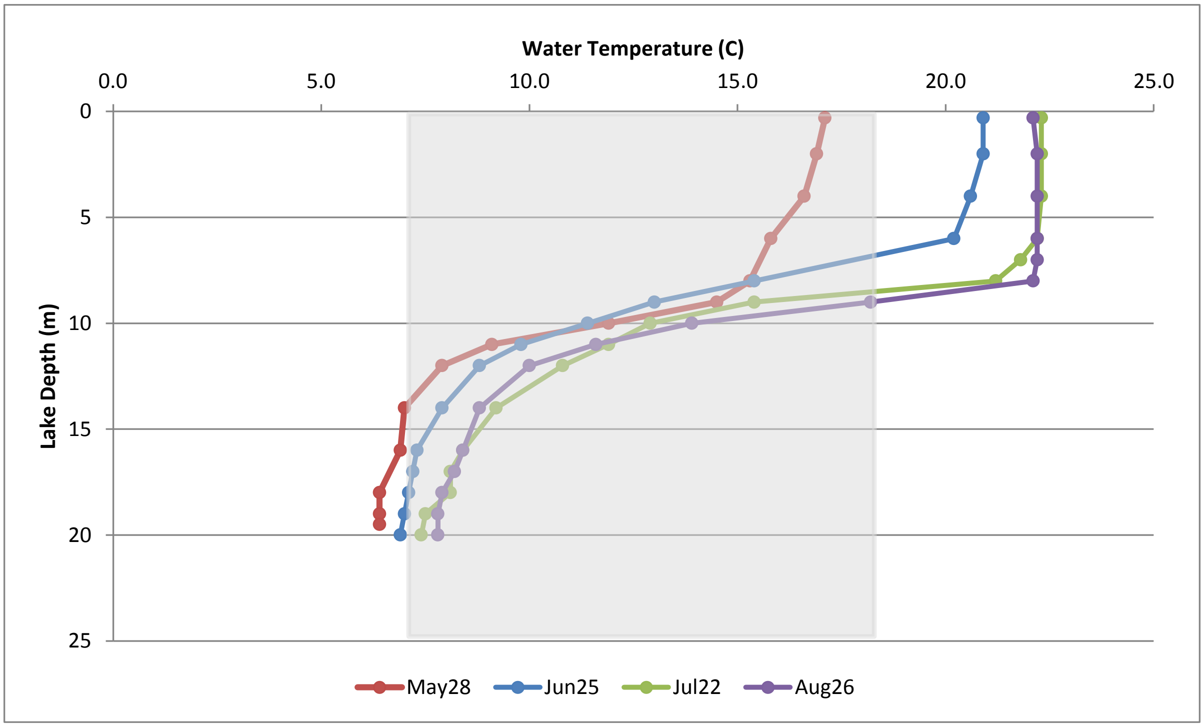

Figure 7.4: Water temperature profiles during late-spring and summer 2015 in the south basin. Shaded area represents zone of optimal temperatures of documented coldwater fishes.

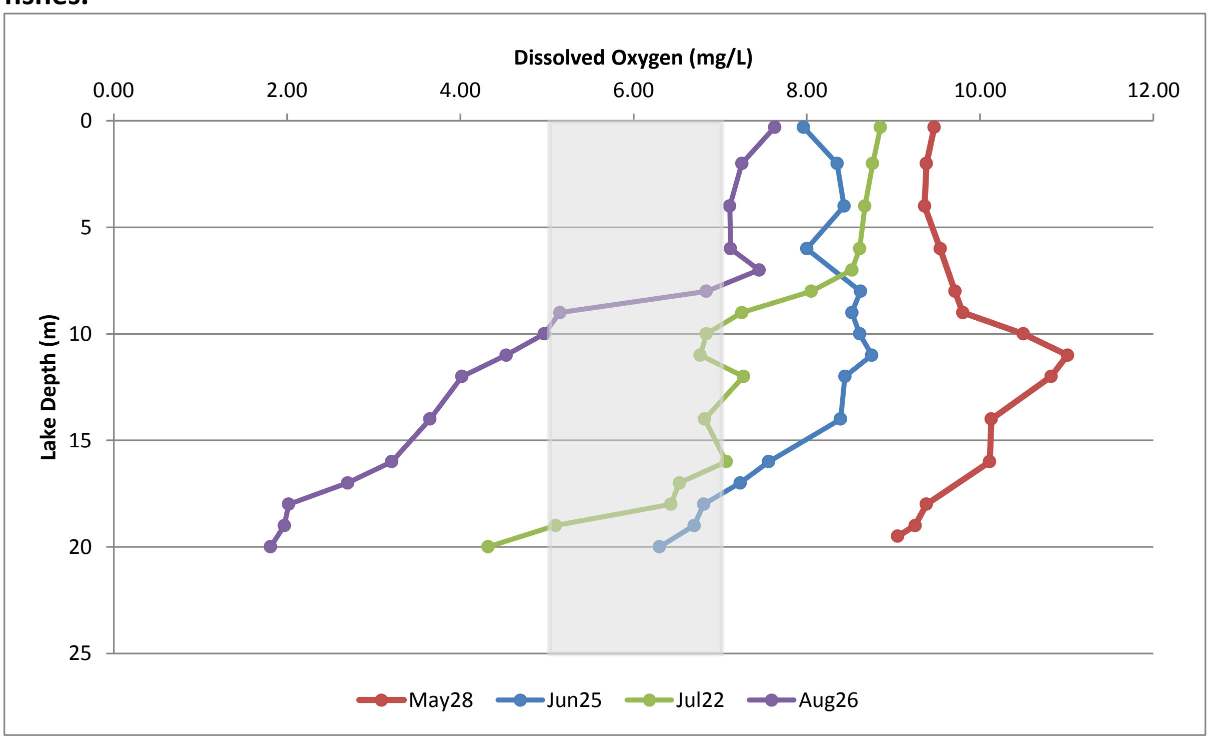

Figure 7.5: Dissolved oxygen profiles during late-spring and summer 2015 in the south basin. Shaded area represents the zone of minimum concentration required for coldwater fishes.

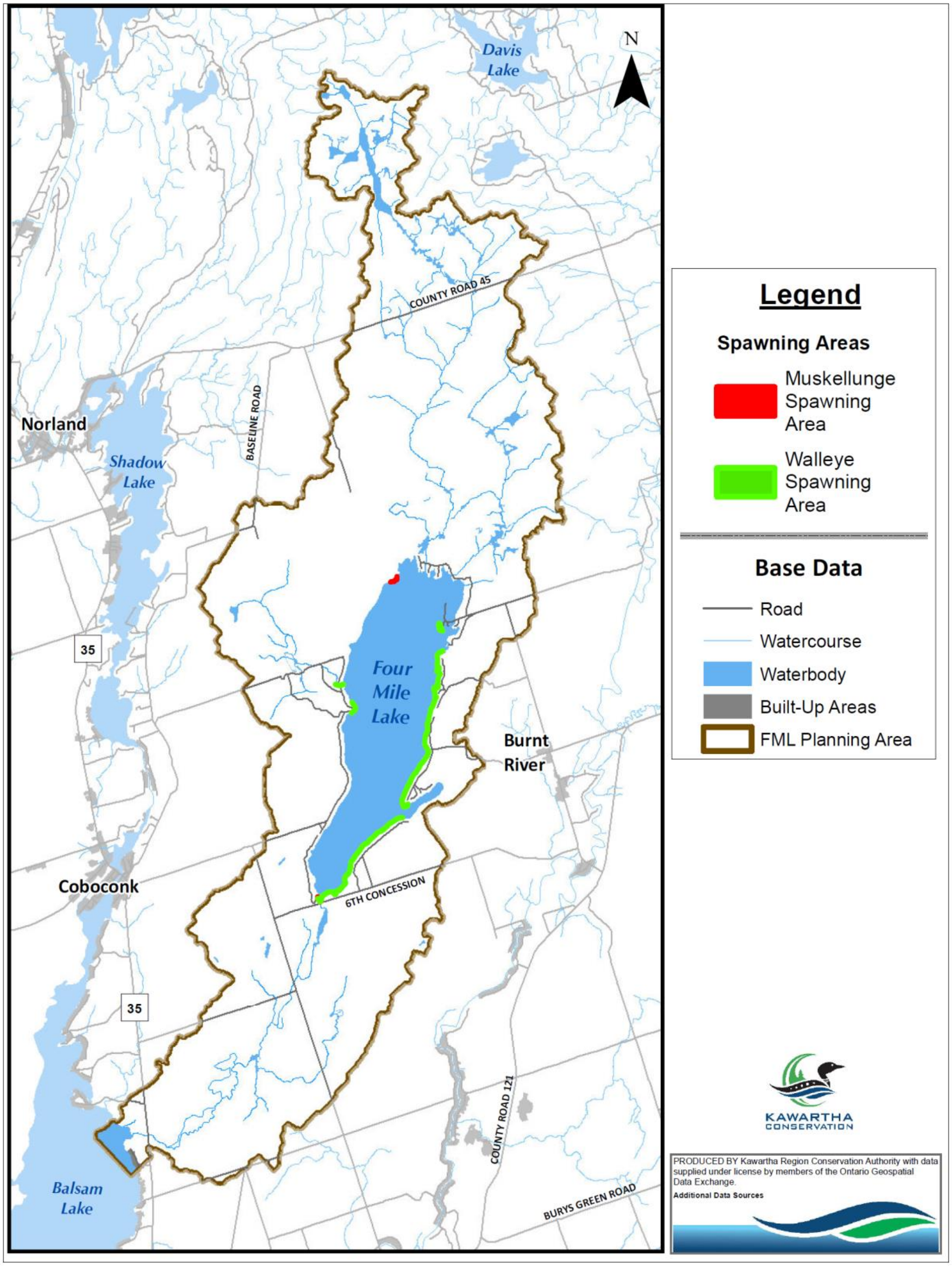

Figure 7.6. Muskellunge and Walleye Spawning Areas within Four Mile Lake

7.3.2 Fish Communities

There are limited long-term aquatic community data available for Four Mile Lake. Available fisheries data comes from five main sources: OMNRF sampling in the early-to-mid 1970's, Michalski Associates sampling in the mid 1980's, Briones and Kelly sampling in early 2000's, Kawartha Conservation sampling in mid 2010's, and sporadic records submitted to OMNRF over the years. This information helps to characterize the fish community and aquatic habitat conditions in the lake but does not permit the characterization of long-term changes.

Routine aquatic community sampling was initiated in 2008 by the OMNRF, through its Broad-scale Monitoring program. This method uses a combination of two types of gillnets: "large mesh" that target fish larger than 20 cm in length, the size range of interest to anglers; and, "small mesh" that target smaller fish (size range of interest to large fish). Surveys are conducted when surface water temperature is greater than 18 degrees Celsius, and concluded when temperature drops below 18 degrees Celsius. Ideally, it is recommended that sampling take place during the four to six week period of maximum summer water temperature. All Small mesh sets must fish overnight (target duration is 18 hours) and include both crepuscular periods (i.e., set no later than one hour before sunset and lifted no earlier than one hour after sunrise). Four Mile Lake is considered a fixed lake, and as such is scheduled for sampling approximately every 5 years. Two surveys have been undertaken to date, 2009 and 2016. Data is not yet available for the 2016 survey.

According to available data, Four Mile Lake and its tributaries support diverse coolwater and warmwater fish communities. Approximately 21 fish species have been documented in the lake (Table 7.2). According to the most recent lake-netting programs (2009), the most large-bodied fish species found in four Mile Lake, in terms of relative abundance, are yellow perch, smallmouth bass, rock bass, walleye, pumpkinseed, white sucker, largemouth bass, and muskellunge (Table 7.3). Lake herring, lake whitefish, and burbot are all coldwater fish species that have been documented within the lake. These fishes require cold, well-oxygenated waters to support their populations. The southern basin of Four Mile Lake is the deepest part of the lake and has been observed to stratify during the summer months, trapping cold water in deep waters that provides habitat of suboptimal quality to sustain these fishes during the hot periods. Michalski (1986) speculated that resident individuals might survive poor quality conditions for short periods by seeking out warmer better oxygenated waters in the lake's upper strata. No known fish species listed as Special Concern, Threatened, or Endangered have been documented.

The lake has an active recreational fishery supported particularly by smallmouth bass and walleye. Angling effort, harvest, and targeted species have not been recently quantified. According to OMNRF (2009), in the Kawartha Lakes the most sought-after species for anglers has shifted within the past 30 years, from predominately walleye to bass and walleye. Additionally, fish harvested by anglers has shifted from walleye to bass, panfish and Muskellunge. It is reasonable to infer that these generalizations likely hold true for the fishery of Four Mile Lake.

Table 7.2: Fish species found in Four Mile Lake based on records from all known fish surveys.

Fish Species	OMNRF Records 2016 (Hogg,June2016)	OMNRF Lake Inventory (July 1970)	OMNRF inventory (ROM, September 1975)	Michael Michalski Associates Lake Evaluation (1986)	Kelly Trent University Thesis Sampling (Summer 1998)	OMNRF BsM (July 2009)
Muskellunge	x	x	x	x		x
Smallmouth Bass	x	x	x	x	x	x
Largemouth Bass	x	x	x	x	x	x
Walleye	x	x	x	x		x
Lake Herring		x	x	x		
Pumpkinseed	x	x	x	x	x	x
Rock Bass	x	x	x	x	x	x
Yellow Perch	x	x	x	x	x	x
Brown Bullhead	x	x	x	x		
White Sucker	x	x	x	x	x	x
Lake Whitefish				x		
Burbot	x				x	
Emerald Shiner	x			x		
Common Shiner	x			x		
Blacknose Shiner	x			x		
Bluntnose Minnow	x			x	x	
Spottail Shiner	x					x
Iowa Darter	x					
Fathead Minnow	x					
Creek Chub	x					
Central Mudminnow	x					
Minnows		x				

Table 7.3: Fish community data from 2009 Broad-scale Monitoring program netting survey.

Fish species	Total catch %	Maximum length (cm)	Minimum length (cm)	Average length (cm)
Yellow Perch	33	28.7	14.3	19.5
Smallmouth Bass	30	47.7	19.1	28.9
Rock Bass	16	24.7	10.4	17.1
Walleye	15	53.3	22.1	37.2
Pumpkinseed	4	27.8	10.9	20.0
White Sucker	< 1	53.0	39.0	46.0
Largemouth Bass	< 1	32.2	32.2	32.2
Muskellunge	< 1	81.9	81.9	81.9

7.3.3 Exotic and Invasive Species

In the Four Mile Lake ecosystem, several types (e.g., plants, invertebrates, fish, etc.) of aquatic invasive species are now well established that have altered, or are altering these natural communities. 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.

Four Mile 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.

Within Four Mile Lake, there are several exotic and invasive species that are now part of the aquatic ecosystem. According to an exotic species tracking project (EDDMAPS, 2015), three aquatic exotic species have been documented, and are also all invertebrates. These include the banded mystery snail, zebra mussel, and rusty crayfish.

7.4 Tributary-Based Ecosystems

7.4.1 Aquatic Habitat

Figure 7.7 shows the best-available mapping of the watercourse network within the Four Mile Lake Watershed planning area. When combined, the watercourse network totals approximately 65 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 98% of total length) flow through natural lands, primarily through coniferous forest, shallow aquatic marsh, coniferous swamp, mixed forest, thicket swamp, deciduous forest, and open water. A small percentage (2%) flows through agricultural areas (evenly split between croplands and pasturelands), and developed areas (rural development and under roads).

Stream Order

Figure 7.8 shows the watercourse network, and Table 7.4 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 Four Mile Lake planning area range from one to four. 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-, and fourth-orders, comprise over 25% of the total length of the stream network. These sections typically flow continuously, thus providing aquatic habitat year-round.

Table 7.4. Length of Streams Within Each Subwatershed by Strahler Order

Subwatershed	Stream Length	1st order	2nd order	3rd order	4th order
Corben Creek North	29	59%	14%	12%	15%
Corben Creek South	18	59%	3%	-	38%
Merrett Creek	11	65%	13%	22%	-
FML Central	7	63%	21%	16%	-
Stream Order Total	**65 km**	**60%**	**12%**	**21%**	**7%**

There are 3 identifiable tributaries that drain directly into Four Mile Lake. Corben Creek North is the largest (draining into the north end of the lake as a 4^{th} order stream), followed by Merrett Creek (draining into the northeast end of the lake as a 3rd-order stream), and an unnamed tributary referred to as the Western Tributary (draining into the west end of the lake as a 3rd-order stream). Aquatic habitat within these tributaries consist of undisturbed low-gradient wetlands, with organic and silty substrates and extensive vegetation of both treed and marsh type. The outlet sections of these tributaries are particularly important aquatic habitat of Four Mile 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.

Corben Creek South drains all of Four Mile Lake at its south end and flows south into the north east shore of Balsam Lake. This creek drains Four Mile Lake as a 4th-order stream with a moderate gradient into a large man-made pond. It then flows south through mostly-forested areas within a channel of fractured limestone bedrock and coarse substrates and then into large tracts of wetlands before draining into the Corben Creek Provincially Significant Wetland along the shore of Balsam Lake. This wetland outlet area has been documented as providing spawning habitat for Balsam Lake muskellunge (Garter Lee and French Planning, 2002).

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 Four Mile Lake planning area, the extent and type of land cover along the watercourse was interpreted from aerial photography taken in 2008. Natural cover (e.g., forest, wetlands, etc.) within the riparian areas was classified according to Ecological Land Classification methodology (Lee et al., 1998), whereas non-natural land cover (e.g., agricultural lands, urban areas, aggregate pits, 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 7.9). 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 7.5 lists the percentages of 30 m riparian areas by subwatershed. Natural riparian area coverage within each subwatershed is exceptionally high (92-96%, and even higher when including open water) and is well-above minimum ecological requirements.

Table 7.5. Riparian Land Use (30m on Both Sides) in Subwatersheds of the Four Mile Lake Watershed

Subwatershed	Riparian Area Size (ha)	Natural (%)	Agriculture (%)	Development (%)	Open Water (%)
Corben Creek North	93	96	0	0	3
Corben Creek South	53	95	2	1	2
FML Central	22	92	1	4	3
Merrett Creek	35	94	0	1	5
All Combined	**203 ha**	**95%**	**1%**	**1%**	**3%**

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 summer of 2015 and 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, 7 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 7.10, all of the sample sites were either classified as dry or having a warmwater thermal regime. All of the tributaries draining into Corben Creek were sampled at their outlet, and within Corben Creek North and Merrett Creek there remains gaps in knowledge within their upper and middle reaches.

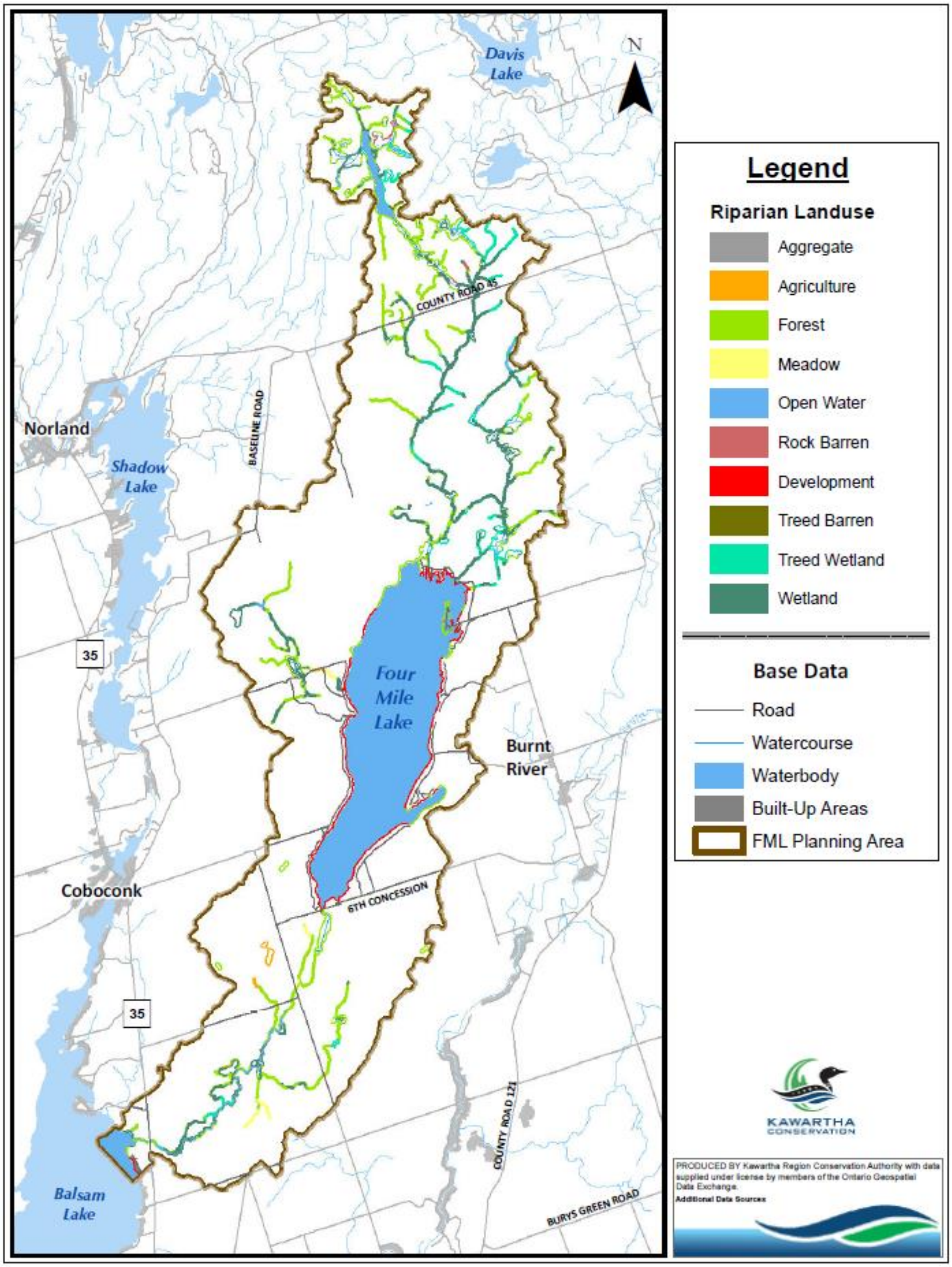

Figure 7.7. Land Use Along Stream Corridors and Lake Shoreline in the Four Mile Lake Planning Area

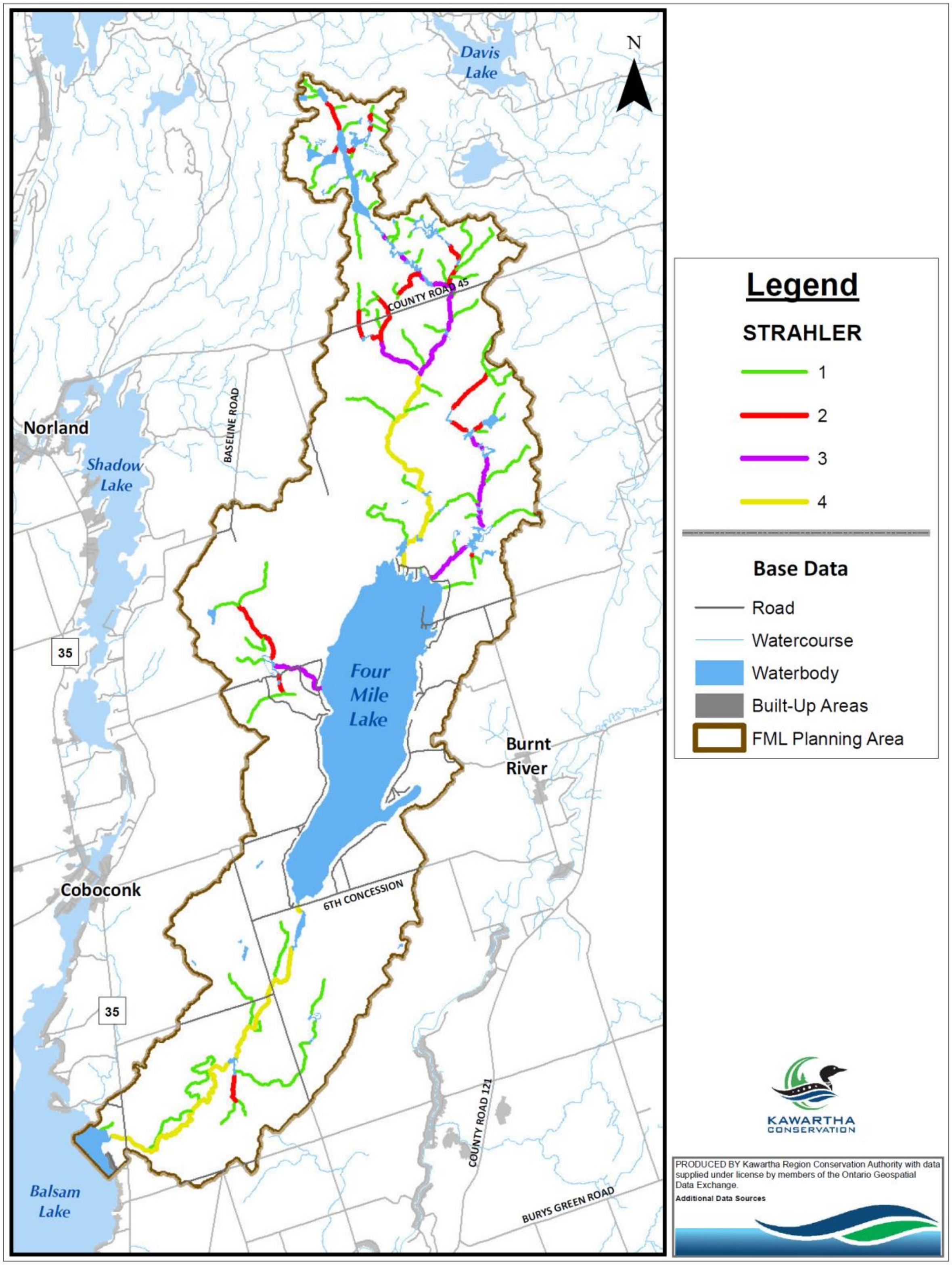

Figure 7.8. Watercourse Network by Strahler Order

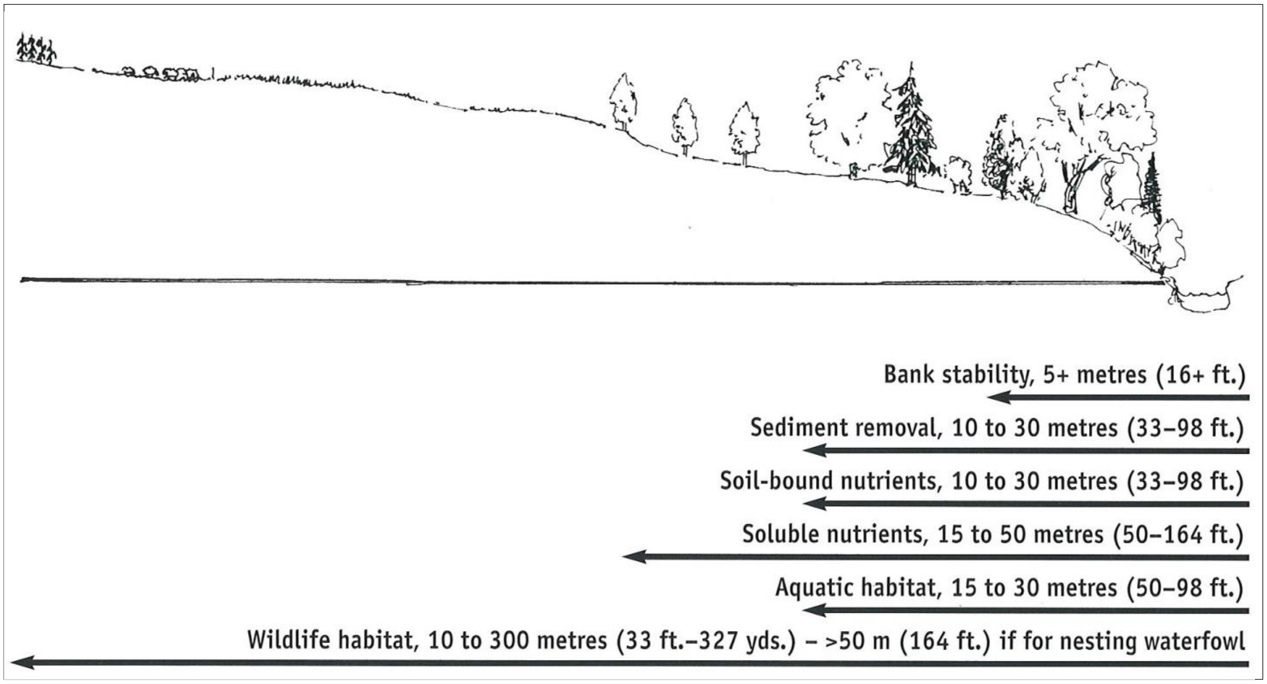

Figure 7.9. Summary of Important Functions of Natural Riparian Areas by Width

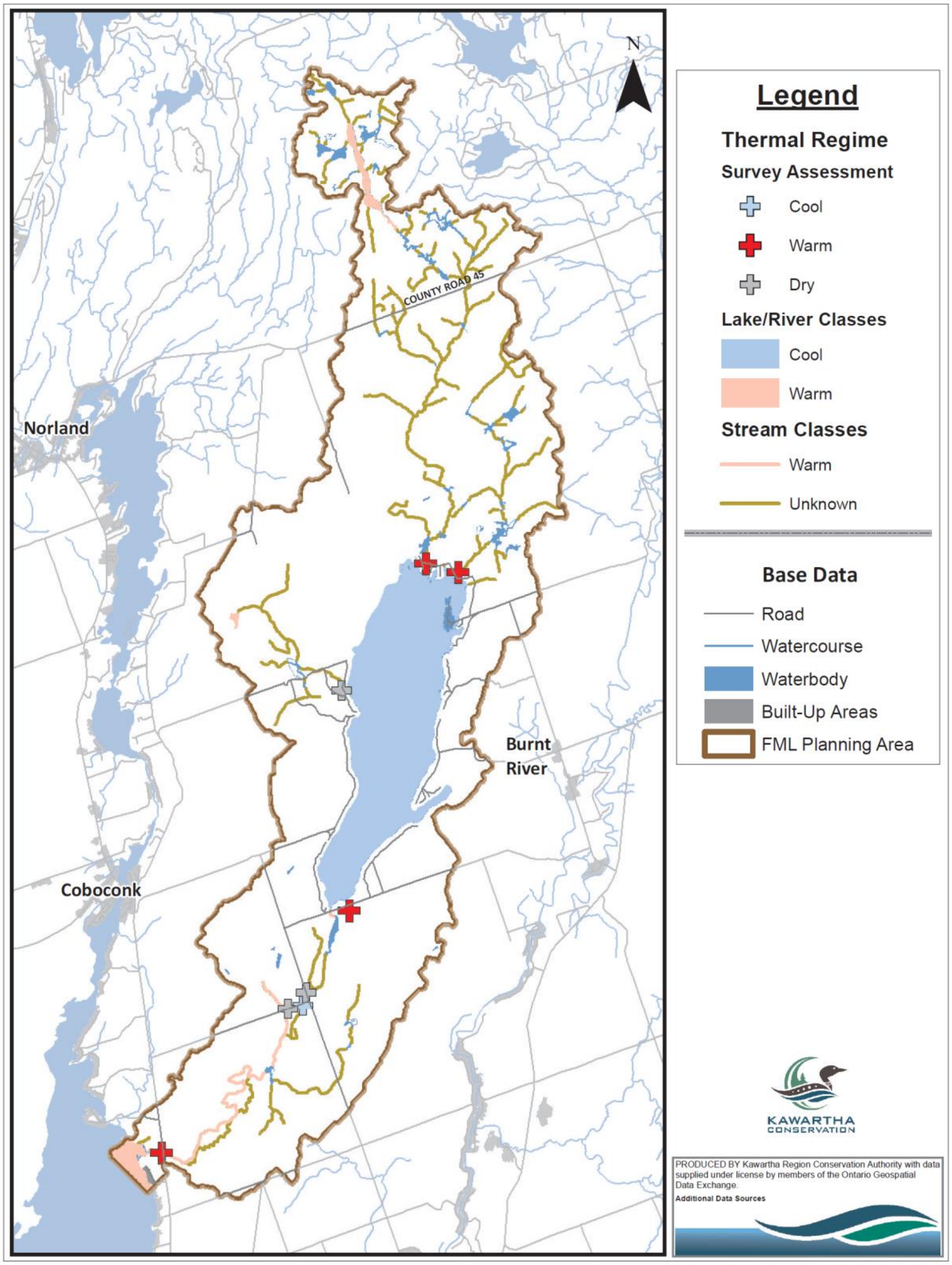

Figure 7.10. Watercourse Thermal Regime

7.4.2 Fish Communities

Within the tributaries of the Four Mile Lake planning area, there is limited fish community data available. Kawartha Conservation seine-netted the outlets of Corben Creek North and Merrett Creek in the summer of 2016 and documented seven unique fish species, including: bluntnose minnow, brook stickleback, central mudminnow, largemouth bass, pumpkinseed, rock bass, and yellow perch.

All of the documented fishes are considered to be native and common within the Four Mile Lake watershed area and are indicative of a warmwater thermal regime, as substantiated by water temperature classifications. There are no known sensitive fish species, or those that are considered to be at risk, meaning classified as Special Concern, Threatened or Endangered.

7.4.3 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 spring of 2015, 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 Four Mile Lake. Well-defined, wadeable steams that exist near road-crossings within subwatersheds that directly drain into Four Mile Lake were targeted for assessment. In total, 5 sites were sampled, excluding Corben Creek North and Merrett Creek because the water near the road crossing was considered unwadable at the time of survey. 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 family-level taxonomic resolution wherever possible. Table 7.6 provides a summary of the major habitat characteristics at all bioassessment sites. All sites were sampled in May with water temperatures ranging from 12.4 to 20.9°C. Stream sizes sampled were small-to-large, having wetted widths ranging from 1.3 to 21.0 m and maximum depths ranging from 105 to 700 mm. Substrates encountered exhibited coarse substrates typically dominated by gravel and cobble. Most watercourses are relatively fast flowing, having water velocities ranging from 0 to 100 mm hydraulic head.

Benthos Community

All raw benthos taxa data are found in Appendix A. Approximately 53 unique taxa were found within the planning area. In terms of major OBBN groupings when all sites are combined, Chironomidae, Trichoptera, Plecoptera, and Ephemeroptera collectively contribute to the community over twice as much as all other taxa combined (Figure 7.12). In terms of benthos families, the top five taxa within the planning area are Chironomidae (19%), Hydropsychidae (12%), Heptageniidae (7%), Perlodidae (6%), and Simuliidae (5%), which collectively comprise approximately 50% of all taxa. In terms of common benthos found at most sites, Chironomidae and Hydropsychidae were found at 100% of sites; Cambaridae, Empididae, Simuliidae, Tipulidae, unknown Ephemeroptera, and unknown Oligochaetae at 80%; and Hyalellidae, Pisidiidae, Ceratopogonidae, Elmidae, Heptageniidae, Planorbidae, Asellidae, Corydalidae, Nemouridae, and Polycentropodidae at 50% of sites.

Table 7.6. Site and Habitat Characteristics at Bioassessment Sites

Site ID	Sub-watershed	Date	Water Temp (oC)	Substrate (dom+subdom)	Depth (mm)	Hydraulic Head (mm)	Width (m)
FML-01	Corben Creek South	2015/05/27	20.9	Gravel and Cobble	310-430	5-100	6.3-21.0
FML-04	Corben Creek South	2015/05/21	14.8	Sand and Cobble	165-315	5-50	6.0-10.0
FML-05	Corben Creek South	2015/05/20	15.1	Cobble and Boulder	400-700	5-95	4.0-12.9
FML-08	FML Central	2015/05/20	13.9	Sand and Cobble	130-325	0-25	1.9-3.9
FML-15	Corben Creek South	2015/05/21	12.4	Gravel and Sand	105-170	5-20	1.3-1.8

Benthos Biotic Index

To characterize aquatic ecosystem health within the subwatersheds, benthos data are summarized for each site using the Hilsenhoff Family Biotic Index (Hilsenhoff, 1988). In this approach, taxa identified down to the family-level are assigned a value between 0 (least tolerant) to 10 (most tolerant) based on their tolerances to nutrient enrichment according to values in Conservation Ontario (2011). An index value is calculated by summarizing the number of benthos in a given taxa, multiplied by their tolerance value, and divided by the number of total organisms in the sample. This approach is similar to the methodology used by conservation authorities for Watershed Reporting (Conservation Ontario, 2011). It should be noted that this biotic index performs most accurate when applied to streams with fast flowing water (i.e., riffles) and coarse substrates (i.e., gravel, cobble). Since many of the sites exhibited relatively fast velocities and coarse substrates, biotic index determinations are meaningful. Currently, no known scientifically-defensible bio-criteria standards exist for all types of streams in the Four Mile Lake watershed.

Benthos Results

As shown in Table 7.7, compared to the Hilsenhoff Family Biotic Index, sites were classified as Excellent (20%), Good (20%), and Fair (60%), and Fairly Poor (19%). In terms of Watershed Reporting grade-values, sites were classified as grade: A (13%), B (38%), C (31%), D (19%), and F (0%). All of the sites were determined to be in a state that was Fair (C-grade) or better. All sites had high representations of mayflies, stoneflies and caddisflies within the sample. Mayflies, stoneflies, and caddisflies are considered sensitive taxa, and abundances of benthos within these orders are known to decrease in response to increasing perturbation (Barbour et al., 1999). These taxa represent 44% of all taxa counts within the Four Mile Lake tributaries, and at least one family within these taxa were found at 100% of the sites.

Table 7.7. Family Biotic Index and Watershed Report Card Results

Family Biotic Index	Watershed Report Card Grade	FMLSP Sites (#)	FMLSP Sites (%)
0.00-3.75 (Excellent)	A	1	20%
3.76-4.25 (Very Good)	A	0	0%
4.26-5.00 (Good)	B	1	20%
5.01-5.75 (Fair)	C	3	60%
5.75-6.50 (Fairly Poor)	D	0	0%
6.51-7.25 (Poor)	F	0	0%
7.26-10.00 (Very Poor)	F	0	0%

When comparing benthos communities found in Four Mile Lake streams to comparable bioassessments in the tributaries of Sturgeon Lake, Balsam Lake and Cameron Lake, and Pigeon Lake, the tributaries of Four Mile Lake appear to be in better aquatic ecological condition than those streams, as indicated by the best Family Biotic Index and Watershed Report Card Grade, and highest average composition of sensitive taxa at each site (Table 7.8). These results are only based on a limited number of non-random sites (5), so should be interpreted with some caution. However, due to the lack of human disturbance within the subwatersheds of Four Mile Lake, aquatic community conditions are expected to be relatively healthy.

Table7.8. Comparison of Bioassessment Results From Four Mile Lake Tributaries to Pigeon Lake, Balsam Lake and Cameron Lake, and Sturgeon Lake Tributaries.

	Four Mile Lake Tributaries (2015)	Pigeon Lake Tributaries (2014)	Balsam/Cameron Lake Tributaries (2013)	Sturgeon Lake Tributaries (2012)
Number of Sites	5 (roadside)	16 (random)	16 (random)	18 (random)
Family Biotic Index	4.90 (Good)	5.06 (Fair)	5.17 (Fair)	6.06 (Fairly Poor)
Watershed Report Card Grade	B	C	C	D
Taxa Richness	17.0 (53 in total)	19.8 (52 in total)	15.9 (52 in total)	17.0 (63 in total)
Sensitive Taxa (%EPT)	44.0	25.1	26.9	11.4

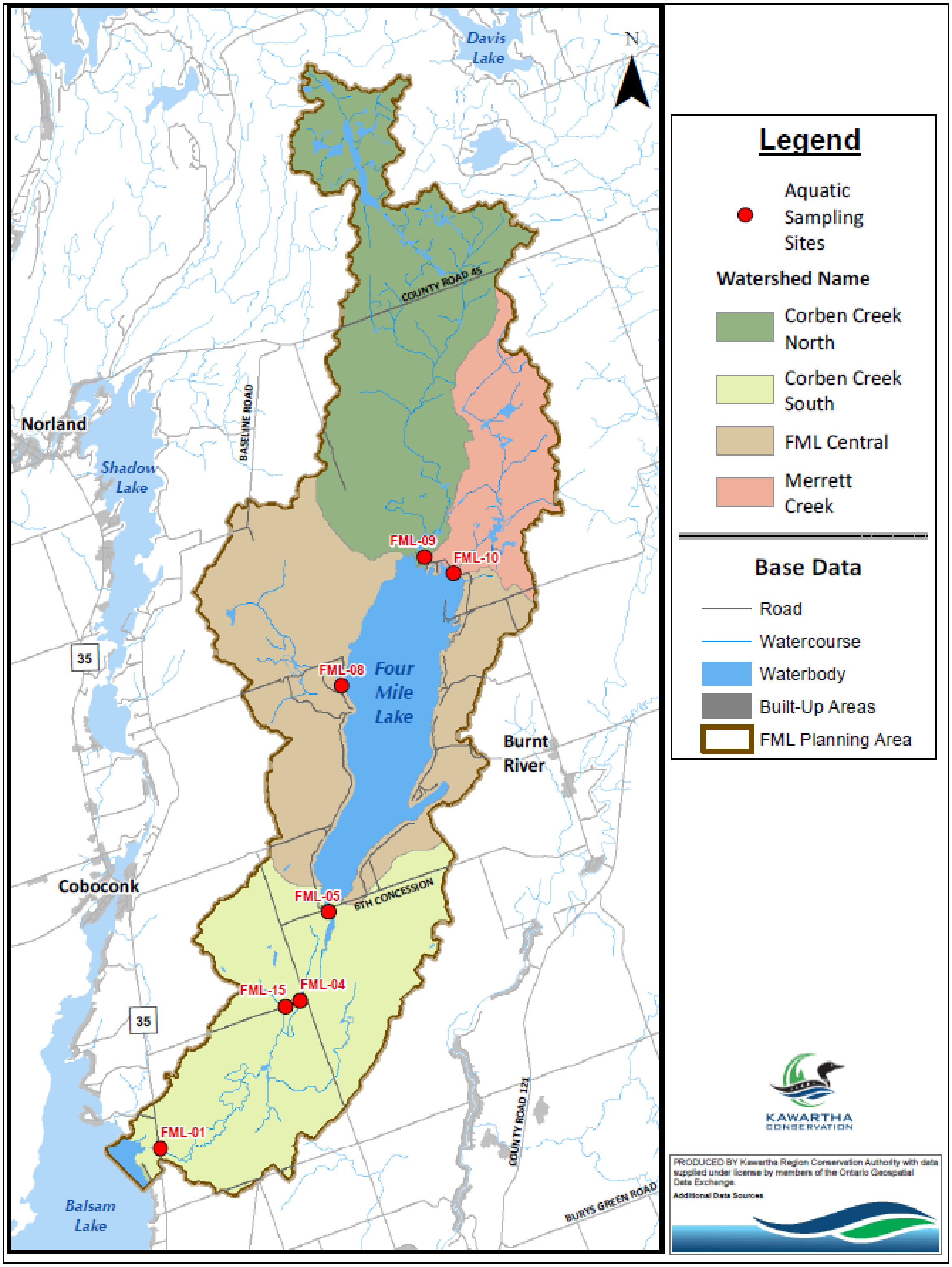

Figure 7.11. Aquatic Community Sample Sites

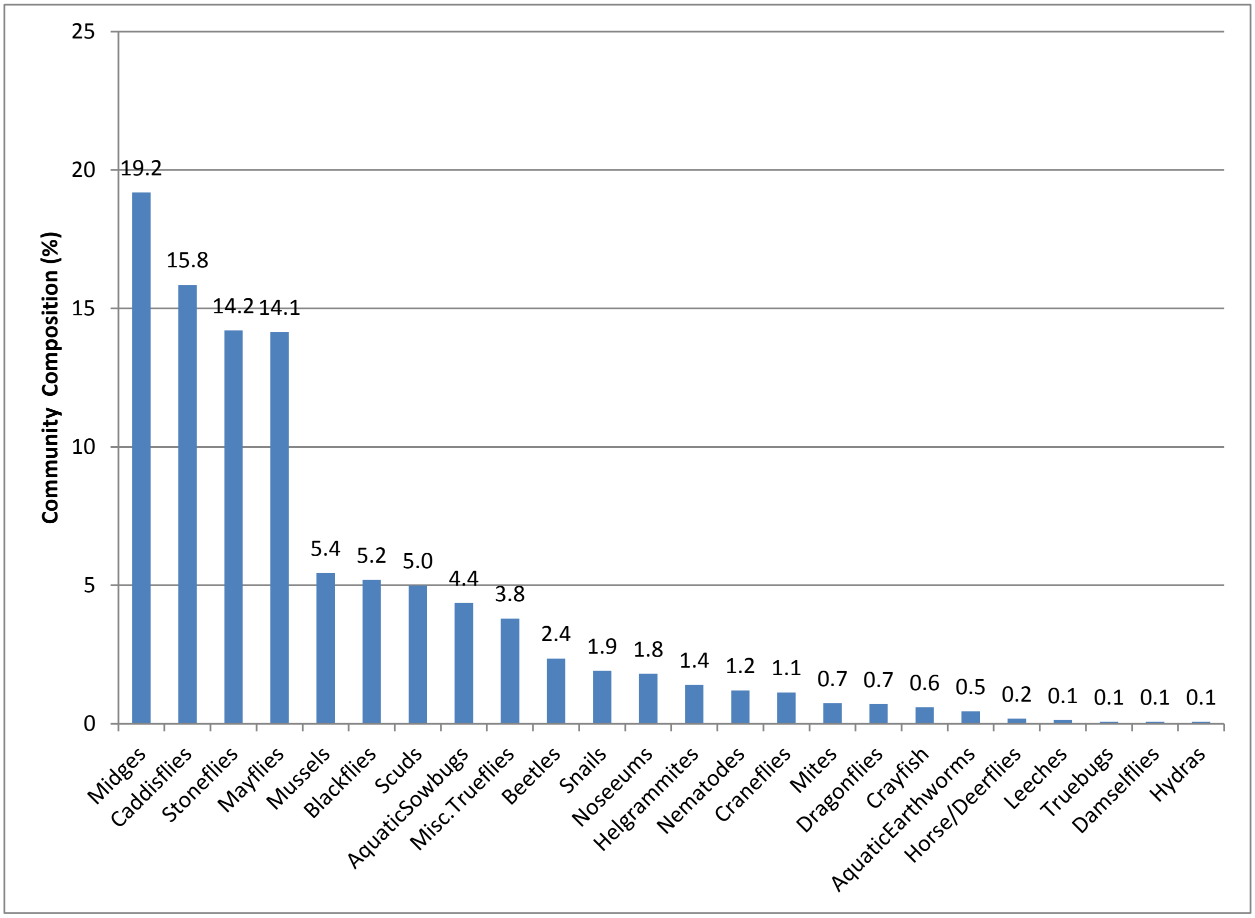

Figure 7.12. Major Benthos Taxa Found in the Tributaries

8.0 Terrestrial Ecology

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

8.1 Summary of Observations, Key Issues, and Information Gaps

OBSERVATIONS

- **Natural Heritage conditions are fairly healthy in the Four Mile Lake watershed.** This is due in part to less urban development and less intensive and non-intensive agriculture than in watersheds further south. The area to the north, east and west of Four Mile Lake contains large tracts of forests and wetlands providing habitat for wildlife, and maintenance of good water quality through: mitigating runoff, providing filtration 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 Four Mile Lake watershed has an abundance of wetlands, the majority being swamp type wetlands.** Wetlands serve a number of functions within a watershed, not the least of which is functioning to improve water quality. Swamp type wetlands often contain dense forests, which act to slow the movement of water through watersheds, and acting as groundwater recharge areas. Due to this Swamp type wetlands are particularly important to the headwaters of cold water streams. Marsh type wetlands help to reduce erosion around lakes and provide habitat for numerous fish, bird and mammal species.

- **Interior forest is above guidelines for all watersheds and deep interior forest is slightly below guidelines for Merrett Creek and Corben Creek South Watersheds.** Interior forest is an important part of a healthy forested ecosystem as they provide habitat for a variety of species that can only live in this ecosystem type.. Interior forest is also a measure of the health of forests overall and can indicate that state of forests within a watershed.

KEY ISSUES

- **A number of natural heritage features exist in the Four Mile Lake watershed that may be considered locally significant; however they are not afforded any legislative protection.** Areas of Natural Scientific Interest (ANSI's) are the only areas that are afforded protection due to their provincial significance, yet none are identified in the Four Mile 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 existing natural heritage features are experiencing some fragmentation in the Southern portion of the watershed.** The fragmentation of natural heritage features makes the movement of species more difficult and cause ecosystems to become less resilient due to limited diversity. A healthy natural heritage system with strong connections indicates a healthy and resilient watershed.

- **Six Species at risk have been identified in the Four Mile Lake study area.** Of the six species, two are dependent on the lake and/or its tributaries for survival; Blanding's Turtle and Snapping Turtle.

- **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. Lakeshore areas continue to be developed and less desirable areas such as swamps are targeted.

- **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 and species will be less resilient to the changes that occur to them.

INFORMATION GAPS

- **Limited understanding of the health and quality of terrestrial ecosystems.** The terrestrial ecosystems have not been inventoried recently in detailed to determine their health. No comprehensive and updated list of species, including species at risk, exists for the Four Mile 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.

8.2 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:

1. filtering nutrients, sediments and pollutants from surface water runoff;
2. improving air quality through filtration and oxygen generation;
3. improving the natural aesthetic of communities thus contributing to the wellbeing of local citizens;
4. maintaining aquatic and terrestrial wildlife habitat;
5. performing flood attenuation;
6. providing opportunities for recreation and for people to connect with the natural world through activities such as hiking, nature viewing, biking, fishing, and hunting;
7. providing wildlife habitat & preserving biodiversity;
8. reducing shoreline erosion by slowing and reducing surface water runoff;
9. sequestering carbon to reduce atmospheric carbon dioxide levels, thus contributing to the mitigation of the effects of climate change; and,
10. 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 Four Mile Lake watershed contains 55 km^2 of natural cover, representing 78% of the total terrestrial area. This includes only areas classified as forest, wetland, and open water. There is a further 10% cover found in meadows, thickets, woodlots and plantations however meadows, thickets 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. Figure 8.1 demonstrates the cover types existing within the 4 subwatersheds and perimeter of the lake that drain into Four Mile Lake. Table 8.1 illustrates the percentage of each land use type within the watershed.

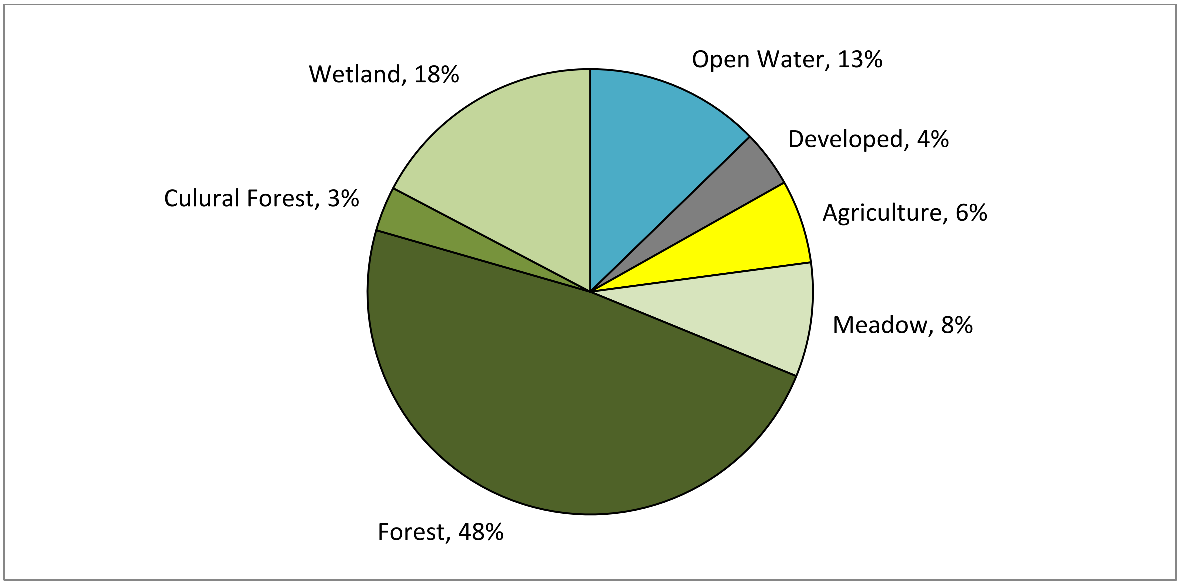

Figure 8.1. Four Mile Lake Watershed Land Cover Based on Ecological Land Classification

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 Four Mile 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 Four Mile Lake watershed. 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. Ecodistrict 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.

Table 8.1. Area and Percentage of Cover Types in the Four Mile Lake Watershed

Land Use	Watershed Area km2	Watershed Area(%)
Watershed (terrestrial portion)	**70.05**	**100**
Forest	35.91	51.3
Forested Wetland	6.5	9.3
Non-Forested Wetland	5.5	7.9
Meadow	5.8	8.3
Total Cover (including plantations, meadows, rock barrens and thickets)	**63**	**90**

Forests

Forests covered more than 90% of Southern Ontario prior to European settlement *(*Larson et al, 1999*)* and naturally occurring forests currently account for 57% of the terrestrial portion of the Four Mile Lake watershed (a combination of upland forests (48%) and forested/treed wetlands (9%)). 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 Four Mile 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 the Canadian Shield, where granite bedrock is unsuitable for cropland. Due to the intermittent nature of some of these landscapes forests are often quite fragmented. This is reflected in the Four Mile Lake watershed by the fact that the dominant natural area type is forest, specifically coniferous forest and that coniferous, mixed and deciduous swamps account for almost 60% of the Four Mile Lake landscape.

The entire Four Mile Lake watershed is currently 27% higher than the target of 30% forest cover for Areas of Concern watersheds within the great lakes basin (Environment Canada, 2004). Four Mile Lake is 22% higher than the Conservation Ontario target (Conservation Ontario, 2011) of 35% forest cover for watersheds in Ontario and only the Corben Creek South watershed falls below 50% 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.

Three areas of forest that represent a significant amount of the Four Mile Lake watershed are a portion of the Somerville Tract (3420 Ha), a portion of the Victoria County Forest (3743 Ha), and the Altberg Nature Reserve (470 Ha), all located in the North Eastern portion of the watershed. The combined area of these three forested areas is 7633 Ha or 76 km2, which is greater than the entire area of the Four Mile Lake Watershed.

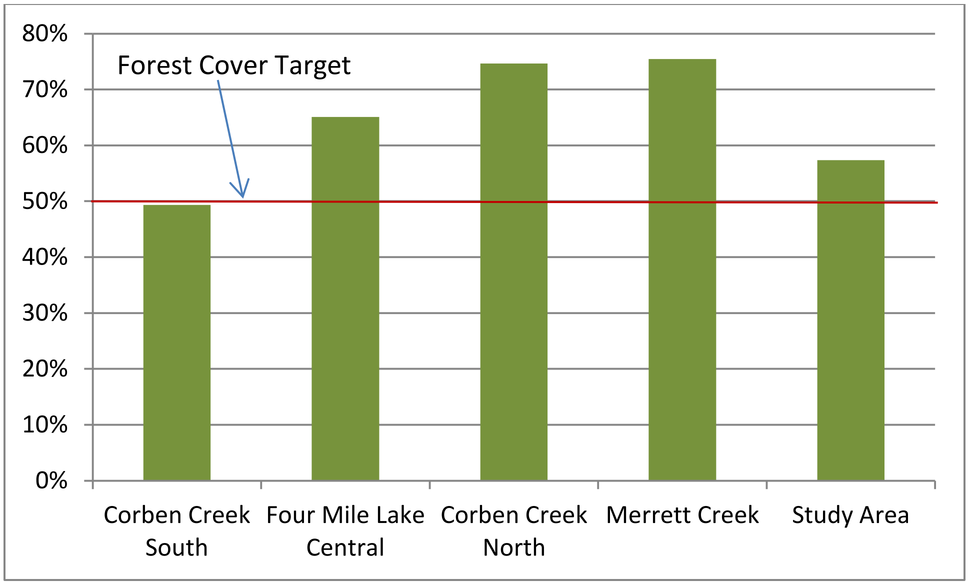

Figure 8.2. Forest Cover in the Four Mile Lake Watershed; target is 50% for Kawartha Conservation's watershed plans.

8.3 Ecological Land Classification

Ecological Land Classification (ELC) is a method to further classify natural cover types into vegetation community types within the Four Mile 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, 5 unique types of developed areas and 19 unique types of natural areas, based on the community series level of detail, were identified for the Four Mile 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 B, and mapped in Figure 8.3.

The ELC assessment shows that the Four Mile Lake watershed contains 11% cultural community types, 10% developed areas and 78% natural community types. Coniferous forest in the Four Mile Lake watershed, at 25%, encompasses the greatest area of the natural cover community types, with mixed forest and deciduous forest being the next two most dominant community types. Eleven wetland types have been identified within both the Four Mile Lake and account for 17% of the total study area. The watersheds contain mostly coniferous swamp, deciduous swamp and shallow marsh. The remaining parts of the watershed are composed of mainly fens, thicket swamps and marshes. Only minimal areas of aquatic wetland communities are found within the lake area as Four Mile Lake is mostly open water.

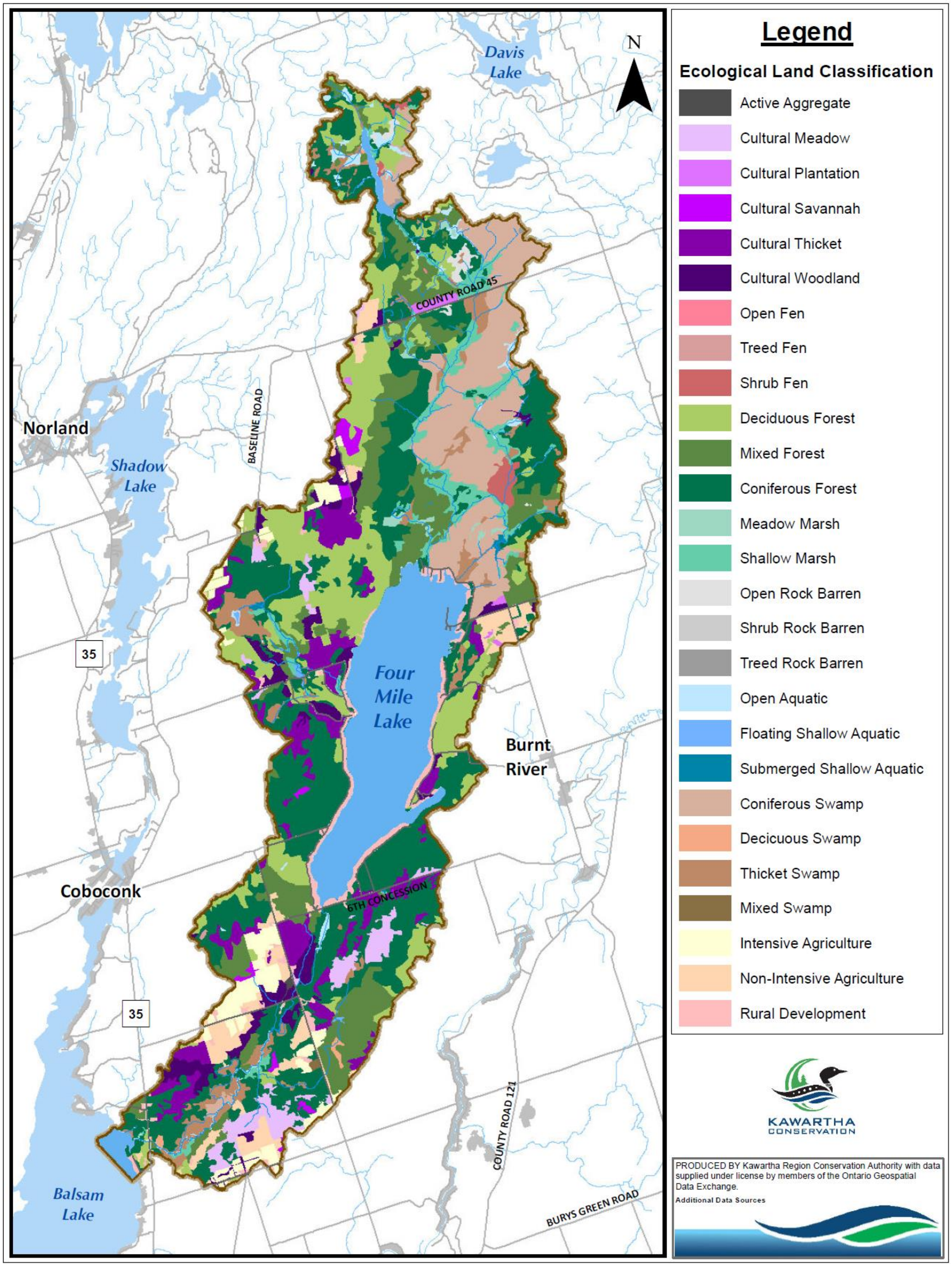

Figure 8.3. Ecological Land Classification of the Four Mile Lake Watershed

8.4 Terrestrial Biodiversity

The diversity of terrestrial flora and fauna species that are supported by the available habitat within the watershed can provide an insight into the overall ecological health and condition of the watershed. The existence of significant species, such as designated species at risk or species populations known to be in decline, can assist with prioritization of conservation work within the watershed.

The Great Lakes Blueprint for Biodiversity has identified 20 species at risk as conservation targets within Ecodistricts 6E-9 (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 bound by watersheds. Thus we should consider how the watershed contributes to the overall health of the Ecodistrict and how this supports the larger picture, The Great Lakes Blueprint for Biodiversity. Therefore, when developing a terrestrial natural heritage system, it makes sense to follow an established blueprint for biodiversity rather than creating one at the Four Mile 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 "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 8.2 lists the general response of species to varying sizes of forest patches.

Table 8.2. 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.

(Environment Canada, 2004)
*The forest patches are assumed to be roughly squared when considering the amount of forest interior.

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%. Four Mile Lake watershed has 20 % interior (>100m) and 8 % deep interior (>200m). Therefore the Four Mile Lake watershed is above the targets for both interior and deep interior forest cover. Figure 8.4 shows the distribution of interior forest areas within the watershed.

8.5 Species and Habitats at Risk

Endangered, rare and threatened species and their habitat

Significant portions of endangered, rare and threatened species and their habitat exist within several areas of the Four Mile Lake watershed. A full list of species, occurrences and their habitats is available on the OMNRF Natural Heritage Information Centre web site. Species that have been historically present within the FML watershed are listed in Table 3.

Table 8.3: List of species at risk within the FML watershed.

SPECIES	SRANK	COSEWIC	SARO
Blandings Turtle	S3B	THR	THR
Chimney Swift	S4B, S4N	THR	THR
Crested Arrowhead	N/A	N/A	N/A
Eastern Meadowlark	S4B	THR	THR
Snapping Turtle	S3	SC	SC
Woodland Pinedrops	N/A	N/A	N/A

THR – Threatened, END – Endangered, NAR – Not at Risk, SC – Special Concern

SX – Presumed Extirpated, SH – Possibly Extirpated, S1 – Critically Imperiled, S2 – Imperiled, S3 – Vulnerable, S4 – Apparently Secure, S5 – Secure (B – Breeding, N – Nonbreeding, M – Migrant, ? – Inexact/Uncertain)

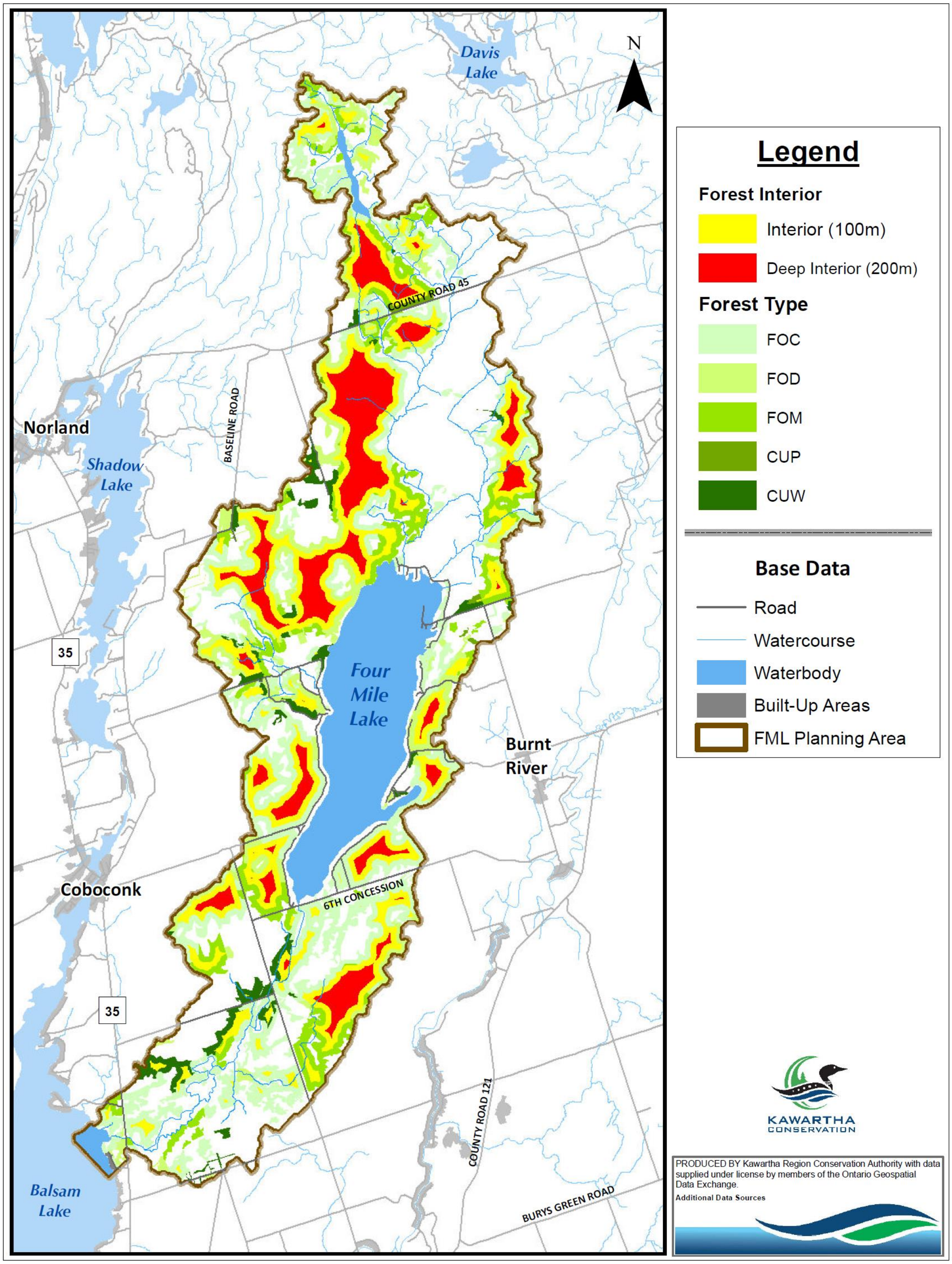

Figure 8.4. Areas of Interior Forest in the Four Mile Lake Watershed

8.6 Significant Natural Heritage Features

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

8.6.1 Areas of Natural and Scientific Interest (ANSI)

Areas of Natural and Scientific Interest 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 Four Mile Lake watershed.

There are a number of locally significant areas of natural and scientific interest located in the Four Mile 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.

8.6.2 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 OMNRF.

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.

8.6.3 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.

8.6.4 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 Four Mile 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 Four Mile Lake watershed. The natural areas within the Four Mile Lake watershed tend to be only minimally fragmented; maintaining core areas should be a planning priority.

8.6.5 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 (Key Natural Heritage Features), or act as an ecological linkage between KNHFs. Significant woodlands within the watershed are illustrated in Figure 9.7.

8.6.6 Wetlands

Wetlands are key natural heritage and hydrologically 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 9.6 illustrates the location of wetlands within the watershed. Figure 9.3 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.

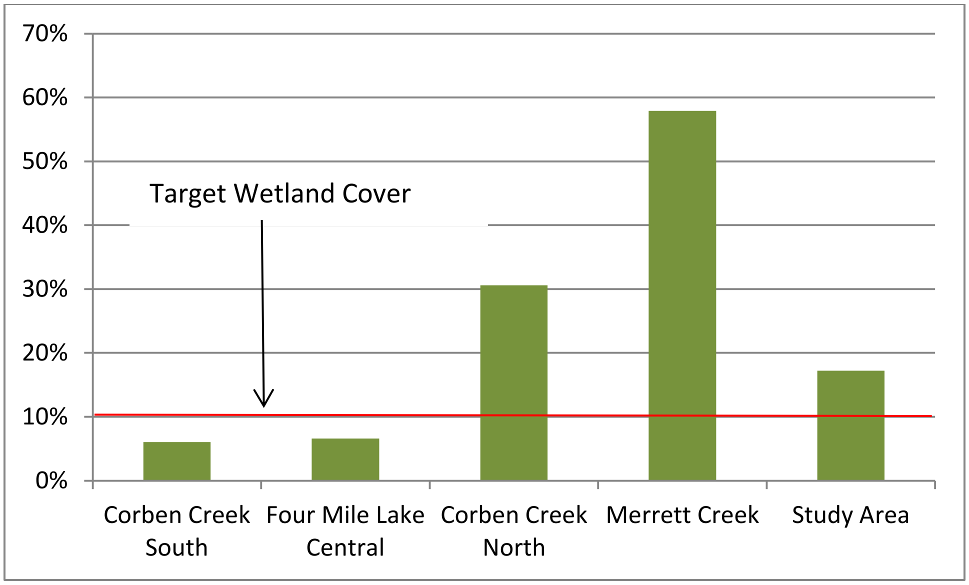

Figure 8.6. Wetland Cover in the Four Mile Lake Watershed; study area includes shorelines (terrestrial land) of FML not included in any of the four subwatersheds.

The Four Mile Lake watershed contains approximately 12 km^2 of wetland representing 17% of the terrestrial area; this exceeds the 10% minimum recommended percentage of wetland cover. There is a small area of wetland that is designated as provincially significant wetland, located at the outlet of Corben Creek. All evaluated wetlands including provincially significant wetlands (PSWs) are illustrated in Figure 8.7.

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 B.

Forested wetlands, including headwater wetlands, have high species diversity and are 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 in water filtration, having the capacity to remove harmful impurities, bacteria and excess nutrients. 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 in water (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.

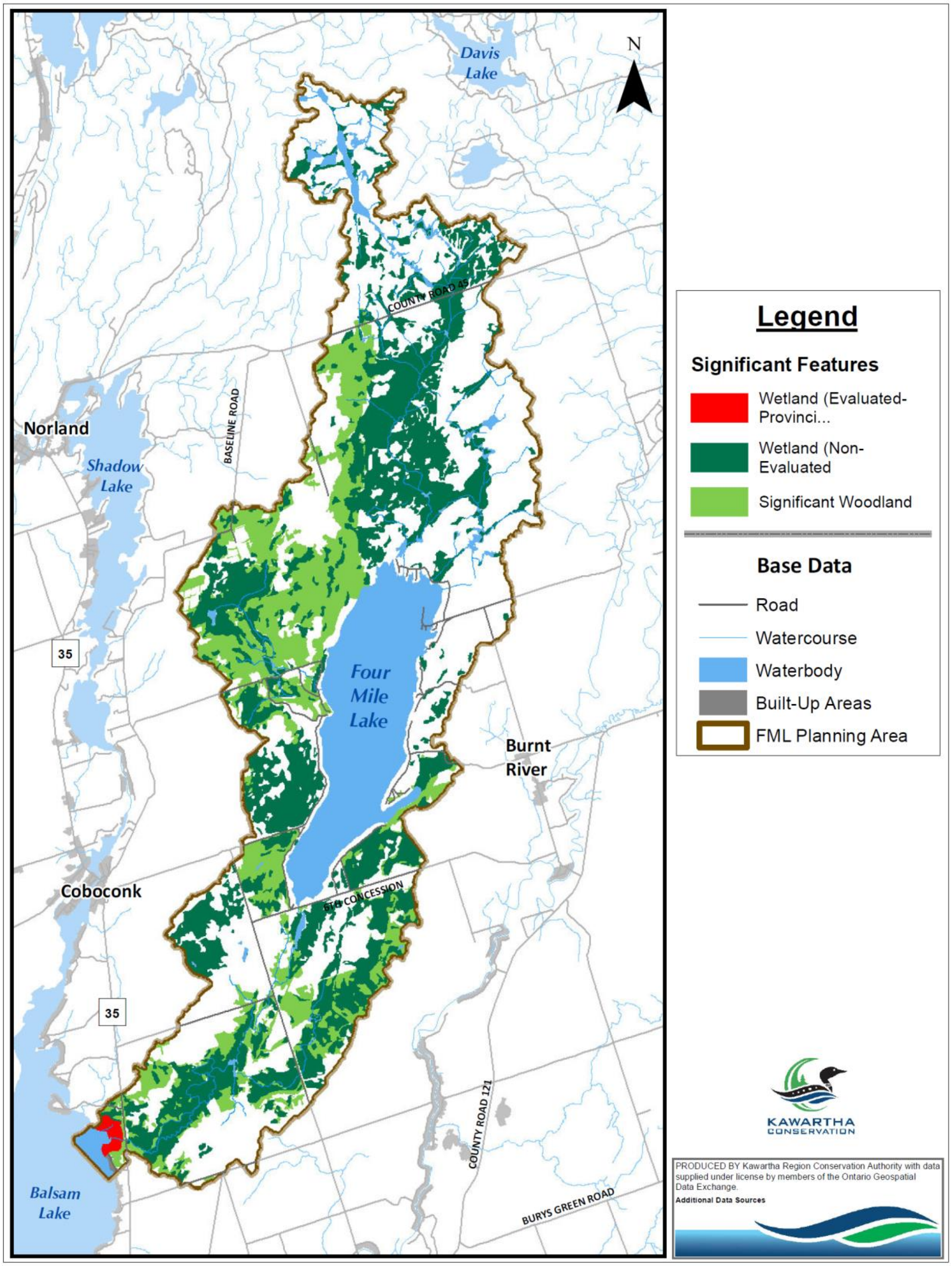

Figure 8.7. Significant Natural Features in the Four Mile Lake Watershed

8.6.7 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).

8.7 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 9.8).

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 this system that is being worked on to establish for use with municipal planning. In addition to municipal planning 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/

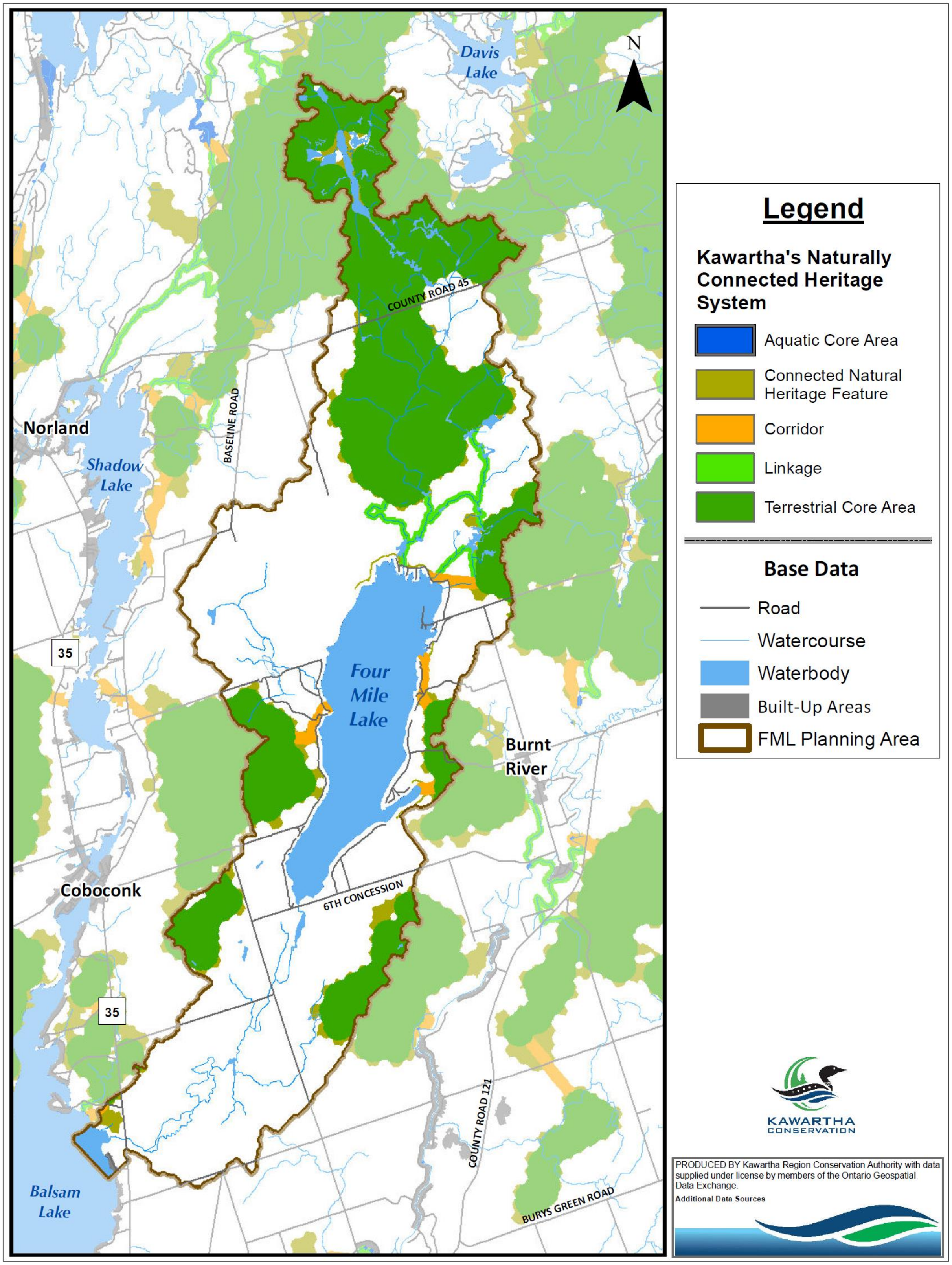

Figure 8.8. Kawarthas Naturally Connected Natural Heritage System in the Four Mile Lake Watershed

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Glossary

Agricultural Area:	A portion of the watershed where the predominant land use is agriculture or agriculture related
Agricultural activities:	Refers to any actions related to farm operations. This includes but is not limited to: growing crops, raising livestock, spreading manure, irrigation and clearing fields
Anthropogenic:	Effects, processes or materials that are derived from or as a result of human activities
Aquatic system:	An ecosystem located within a water body (Also see: Ecosystem)
Aquatic vegetation:	Refers to plants and algae that grow within an aquatic environment
Aquifer:	Layer of permeable rocks or loose materials (gravel, sand) that is saturated with water and through which groundwater moves and can be extracted using water well
Baseflow:	The portion of stream flow that is entirely attributed to groundwater inputs
Benthics:	Organisms that live in the benthic zone at the bottom of a water body
Best management practice (BMP):	A term used to describe the preferred method of management that has proven to reliably lead to a desired result. Usually associated with stormwater management or agricultural practices
Biodiversity:	The variability among living organisms and the ecological complexes of which they are part. A healthy ecosystem is traditionally one with a high level of biodiversity.
Biota:	The total collection of organisms of a geographic region.
Coldwater fish:	Fish species such as brook trout that prefer colder water temperatures (usually below 15˚C).
Conductivity:	In regards to water, conductivity measures the ability of a water sample to conduct electricity. This is dependent on the concentration of dissolved salts and other ionizing chemicals.
Dissolved oxygen (DO):	An amount of oxygen that is being dissolved in the water column.
Ecological functions:	The natural processes, products or services that living and non-living environments provide or perform within or between species, ecosystems and landscapes.
Ecosystem:	A recognizable ecological unit such as a group of plant and animal species living together in a particular area.
Erosion:	The removal of soil sediment and rock in the natural environment. This may be as a result of natural processes such as weathering or through anthropogenic processes such as deforestation and poor farm management practices.
Eutrophication:	A natural or human-caused process whereby water bodies receive excess nutrients (phosphorus and nitrogen specifically) that stimulate

excessive aquatic plant and/or algae growth. Nutrients can come from natural sources such as erosion of soils or stream banks, or human sources (fertilizers, urban runoff, sewage treatment plant discharges, etc.).

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

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

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

Farming activities: (See agricultural activities)

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

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

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

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

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

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

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

Marsh: A marsh is an area 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%.

Heavy metals: In regards to water quality, this refers to metals located within the water column as a result of natural or anthropogenic processes. Heavy metals are usually toxic for aquatic organisms and humans, e.g., lead, cadmium, thallium and mercury.

Moraine: A geographic feature consisting of a mound of earth and rock pushed up in front of an advancing glacier.

Native species: A species that is indigenous to an ecosystem in that it occurs there naturally without any human intervention.

Nutrients: In terms of water quality, this refers to the chemicals that aquatic vegetation requires for vital functions. Nutrients include phosphorus, nitrogen, potassium and some other chemical elements.

Oligotrophic water body: A lake, stream or any other natural or man-made water body that has very low levels of nutrients, such as phosphorus and nitrogen, in its water and, as a result, low productivity with few aquatic plants.

Precipitation: The transfer of water from the atmosphere to the earth's surface in

	the form of rain, snow, hail, dew, etc.
Provincially significant wetland (PSW):	Based on the guidelines for wetland management (MNR, 1984), these are wetlands classed as 1 through 3 in the wetlands policy (Section 3 of the Planning Act).
Recharge:	In regards to groundwater, recharge refers to water being added to a groundwater system such as an aquifer.
Restoration:	Returning an altered landscape back to its original form through physical restructuring and the reintroduction of native species. For example, shoreline restoration or naturalization refers to the removal of non-natural features such as lawns and break walls and the addition of native plant species.
Riparian zone/area:	The interface between land and a stream or lake.
Secchi disk:	White and black disk 20 centimeters in diameter used to measure water transparency in lakes. The disc is lowered into the water on the line. The depth at which the pattern on the disk is no longer visible is taken as a measure of the transparency of the water. This measure is known as the Secchi depth and is related to water turbidity in the lake.
Sediments:	Any particulate matter that can be transported by flowing water, and eventually deposited on the bottom of a water body.
Stormwater:	A term used to describe water that originates during a precipitation event. Usually used to define water that flows through storm sewer systems in urban areas.
Subwatershed:	A subsection of a watershed. (Also see: watershed)
Surface water:	Precipitation that does not soak into the ground or return to the atmosphere but instead flows through streams, rivers, lakes and wetlands.
Suspended sediments:	Sediments that are still situated within a water column. (Also see: Sediments)
Swamp:	A treed wetland consisting of greater than 25% living tree cover or 70% dead tree cover
Total phosphorus (TP):	A measure of both soluble and insoluble phosphorus forms within a water column. The insoluble component is primarily decaying plant and animal matter or soil particles. Soluble phosphorus (e.g., orthophosphates) is dissolved in water column in molecular form. It is readily available to aquatic plants and algae.
Transpiration:	Evaporation from aerial parts of a plant such as the leaves. (Also see: Evaporation, Evapotranspiration)
Urban area:	An area with an increased density of human-created structures and population when compared to surrounding areas. In Canada, an urban area is defined as having more than 400 people per square kilometer and has more than 1,000 people in total.
Warmwater fish:	Fish species that prefer warmer water temperatures such as muskellunge and smallmouth bass.
Water budget:	A summary of the quantity of water in the atmosphere, ground and surface water systems within a watershed.

Water quality: An integrated index of chemical, physical and microbiological characteristics of natural water that determines suitability of water for the aquatic life and various human uses.

Watershed: The total area of land that drains to a river or other large body of water.

Wetland: Lands that are seasonally or permanently covered by shallow water as well as lands where the water table is close to or at the surface. The four major types of wetlands are swamps, marshes, bogs and fens.

Woodland: Treed areas that provide environmental and economic benefits such as erosion prevention, water retention, provision of habitat, recreation and the sustainable harvest of woodland products.

Appendix A:

Benthic macroinvertebrate raw counts (pooled for each site) and summary data for 5 bioassessment sites.

CommonName_OBBN	ScientificName_Family	Tolerance Value	FML-01	FML-04	FML-05	FML-08	FML-15
AquaticEarthworms	UnknownOligochaeta	8	1	0	2	3	1
AquaticSowbugs	Asellidae	8	14	0	0	50	4
Beetles	Dytiscidae	5	0	0	0	0	10
Beetles	Elmidae	5	11	0	13	1	0
Beetles	Psephenidae	4	0	1	1	0	0
Blackflies	Simuliidae	5	11	3	0	4	66
Caddisflies	Brachycentridae	2	0	1	0	0	0
Caddisflies	Glossosomatidae	1	0	1	0	0	0
Caddisflies	Helicopsychidae	3	0	12	0	0	0
Caddisflies	Hydropsychidae	5	38	21	68	47	2
Caddisflies	Limnephilidae	4	0	3	0	6	0
Caddisflies	Odontoceridae	0	0	1	0	0	1
Caddisflies	Philopotamidae	4	20	0	0	0	0
Caddisflies	Polycentropodidae	6	0	1	8	0	6
Caddisflies	UnknownTrichoptera		0	2	0	0	1
Craneflies	Tipulidae	4	2	10	0	1	3
Crayfish	Cambaridae	6	1	1	1	6	0
Damselflies	UnknownZygoptera		0	0	1	0	0
Dragonflies	Corduliidae	2	0	0	1	0	0
Dragonflies	Gomphidae	4	0	6	0	0	0
Dragonflies	Libellulidae	2	2	0	1	0	0
Helgrammites	Corydalidae	4	2	12	1	0	0
Helgrammites	Sialidae	4	0	4	0	0	0
Horse/Deerflies	Tabanidae	5	0	0	0	0	3
Hydras	Hydridae	5	0	0	1	0	0
Leeches	Erpobdellidae	8	0	0	0	1	0
Leeches	Hirudinidae	8	0	0	0	1	0
Mayflies	Baetidae	6	36	5	0	0	0
Mayflies	Caenidae	6	9	0	0	0	0
Mayflies	Ephemerellidae	2	0	2	19	0	0
Mayflies	Heptageniidae	3	48	39	38	0	0
Mayflies	Leptophlebiidae	4	2	0	2	0	0

Mayflies	UnknownEphemeroptera		0	3	1	10	2
Midges	Chironomidae	6	121	65	45	36	28
Misc.Trueflies	Empididae	6	11	33	1	6	0
Misc.Trueflies	Psychodidae	10	0	0	0	1	2
Mites	UnknownHydrachnida	6	0	0	0	0	12
Mussels	Dreissenidae	8	0	0	71	0	0
Mussels	Pisidiidae	6	3	0	0	6	1
Nematodes	Nematoda/Nemata	5	0	15	0	1	0
Noseeums	Ceratopogonidae	6	2	0	0	7	20
Scuds	Crangonyctidae	6	0	0	0	35	7
Scuds	Hyalellidae	8	6	9	18	0	0
Snails	Lymnaeidae	6	0	0	0	5	0
Snails	Physidae	8	0	0	0	1	3
Snails	Planorbidae	6	0	1	0	8	7
Snails	Viviparidae	6	0	4	0	0	0
Stoneflies	Leuctridae	0	0	0	0	0	83
Stoneflies	Nemouridae	2	0	7	0	5	40
Stoneflies	Perlidae	3	0	1	2	0	0
Stoneflies	Perlodidae	2	0	0	0	62	23
Stoneflies	UnknownPlecoptera		0	0	0	1	0
Truebugs	Corixidae	5	0	1	0	0	0
Other_Ant	Unknown		0	0	0	1	0
Other_Spider	Unknown		0	0	0	2	1
Other_Fish	Unknown		1	16	7	2	0
Other_WaterStriders	Veliidae		0	1	0	0	0
SUM(Richness)			17	20	12	18	18
SUM_AllTaxa			341	281	302	309	326
SUM_AllBenthosTaxa			340	264	295	304	325
SUM_#TaxaToleranceValues			340	259	293	293	322
SUM_%TaxaToleranceValues			100	92	97	95	99
EPT%			45	38	47	43	49
Hilsenhoff Family Biotic Index_Value			5.35	4.84	5.62	5.25	3.46
Hilsenhoff Family Biotic Index_Grade			Fair	Good	Fair	Fair	Excellent

Appendix B

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	0.03	0.04
AI - Inactive Aggregate	Surface cover ≥ 25% or barren, currently unused open pit or quarry	0	0
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%.	1.62	2.32
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	0.20	0.29

[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	
		km²	%
	characterized by tree cover > 60%.		
CUS – Cultural Savanna	Areas that have resulted from or are maintained by cultural or anthropogenic-based disturbances and often have a large proportion of non-native plant species. These areas are characterized by 25%< tree cover ≤ 35%.	0.40	0.56
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%.	3.76	5.37
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%,	2.06	2.94
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%	0.009	0.01
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%	0.37	0.54
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%	0.002	0.03
FOC – Coniferous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of	17.79	25.39

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Pigeon Lake Watershed	
		km²	%
	greater than 75% coniferous tree species		
FOD – Deciduous Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 75% deciduous tree species	8.91	12.72
FOM – Mixed Forest	Areas where tree cover is greater than 60%, and the canopy is comprised of greater than 25% deciduous tree species and greater than 25% coniferous tree species	6.95	9.93
IAG – Intensive Agriculture	Annually cultivated, crop fields, gardens, nurseries, tree farms. Variable	2.04	2.91
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.	0.21	0.30
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%.	2.43	3.47
***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	0
***NAG** – Non Intensive Agriculture	No cultivation, grasses, hay, pasture, grazing. Variable	2.18	3.11
OAO – Open Aquatic	Areas with water >2m deep. Plankton dominated with no macrophyte vegetation and no tree or shrub cover.	8.43	12.04
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%	0.25	0.36
RBS – Shrub Rock Barren	Found where conditions may be less extreme; where rock is broken and	0	0

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Pigeon Lake Watershed	
		km²	%
	cracked or where limited substrates have accumulated. Tree cover ≤ 25%, shrub cover > 25%		
RBT – Treed Rock Barren	Found where bedrock is broken and cracked or where shallow substrates have accumulated. 25% < tree cover ≤ 60%	0.09	0.13
R**oads**		0.69	1.00
***RD** – Rural Development	Variable. 0.2 ha < area < 2.0 ha containing development not associated with agriculture	2.14	3.05
SAF – Floating-leaved Shallow Aquatic	Area with standing water <2m deep. No tree or shrub cover, and if emergent vegetation is present is not dominant. Greater than 25% cover of floating-leaved macrophytes. Often influenced by shoreline energy.	0.09	0.13
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.	0.07	0.10
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.	0.37	0.53
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	6.38	9.11

Community Series (Code -Descriptive Name)[1]	Description of Community Series	Pigeon Lake Watershed	
		km²	%
	herbs present.		
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.	0.09	0.013
SWM – Mixed Swamp	Areas with variable flooding where water depth is <2m and standing water or vernal pooling makes up >20% of the ground coverage. Tree cover is >25%, canopy height is greater than 5m, deciduous tree species make up >25% of the canopy, and coniferous tree species make up >25% of the canopy. Hydrophytic shrubs and herbs present.	0.04	0.05
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%.	2.40	3.44
URB – Urban Development	Variable. > 5 residential units in an area > 2 ha, generally residential	0	0
Cultural Areas		8.04	11.48
Natural Areas		54.92	78.41
Developed Areas		7.08	10.11
Combined Areas of Cover*		62.97	89.9
Roads		0.69	1.0

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