LAKE CAPACITY ASSESSMENT: TROUT LAKE

Introduction

Trout Lake

Trout Lake is located on the Precambrian Shield in the District of Nipissing. The lake has an area of 1,887 hectares and is comprised of two basins: Four Mile Bay (north) is 27 meters in depth and Trout Lake (Main Basin – south) is 63 meters in depth (**Figure 1**). The catchment is primarily forested with many wetlands and streams. The lake provides drinking water to the City of North Bay, situated on the western shoreline. Both lake basins have experienced extensive permanent and seasonal shoreline development within the 300 meter buffer due to its close proximity to the City. The remaining shoreline property is Crown owned (**Figure 2**).

Trout Lake lies within the Upper Ottawa – Kipawa watershed. The Jocko, Mattawa, and Amable du Fond Rivers flow through the watershed to Lac La Cave. Four Mile Lake is the main inflow into Trout Lake, flowing into Four Mile Bay which is connected to Trout Lake (Main Basin). Many small streams and wetlands also feed both basins of the lake. Trout Lake's outflow is the Mattawa River which flows southeast to Turtle Lake.

Both basins of Trout Lake support a naturally reproducing Lake Trout population and the lake is designated as a Natural Lake Trout Lake by the Ministry of Natural Resources and Forestry (MNRF) (OMNRF 2015). The lake's fish community is diverse with many cold and warm water species such as Lake Trout, Rainbow Trout, Walleye, Brook Trout, Largemouth Bass, Smallmouth Bass, Muskellunge, White Sucker, and Rock Bass (OMNR 2012).

The Official Plans for both the City of North Bay and the Township of East Ferris include water quality objectives for Trout Lake. Both Official Plans also have policies limiting the number of new shoreline lots. These development restrictions effectively impose a development freeze on the lake (City of North Bay 2012, Township of East Ferris 1999).

Development and Lake Trout

Lake Trout typically occupy deep, cold, well oxygenated lakes. As the thermocline deepens during the summer months, Lake Trout will generally move to deeper waters, making use of warmer, shallower areas during nocturnal foraging. Studies have shown that the survival, growth and reproduction of Lake Trout are impaired in lakes where the dissolved oxygen concentration drops below 7 mg/L (Evans 2005, Evans 2007).

The amount of dissolved oxygen in the water column is influenced by many factors including: temperature, wind, ice conditions, lake morphometry, photosynthetic production, respiratory consumption, and photo-oxidation of dissolved organic carbon (DOC). Dissolved oxygen concentrations typically decrease with depth through the hypolimnion. This is because, with thermal stratification, the hypolimnion is effectively isolated from atmospheric and epilimnetic oxygen supplies. The isolation persists from the time that stratification is established in the spring and summer until the fall turnover, when stratification breaks down and mixing resumes. Oxygen depletion in the hypolimnion due to algal decomposition results in a loss of well oxygenated cold-water habitat that is vital to the growth and survival of Lake Trout (OMOE et al. 2010). In some oligotrophic lakes, dissolved oxygen concentrations will remain high with increasing depth through the hypolimnion. This type of oxygen profile (orthograde) tends to occur in lakes with large hypolimnions and low levels of phosphorus (Wetzel 2001).

Phosphorus is a limiting nutrient that controls the growth of aquatic plants and algae (Wetzel 2001). When the supply of phosphorus is high (>0.02 mg/L), it may promote excess growth of algae and aquatic plants. Throughout the growing season, algae and plant matter die, decompose, and settle to the bottom of lakes, consuming oxygen in the hypolimnion. A major source of anthropogenic phosphorus to inland lakes is from septic systems (OMOE et al. 2010). Additional sources of phosphorus to lake environments include stormwater runoff, agricultural runoff, fertilizers, shoreline clearing and associated soil erosion. By implementing controls on shoreline development, the degree of phosphorus enrichment and resulting impacts to sensitive lake systems can be mitigated.

To help protect lakes from excessive phosphorus loading and resulting oxygen depletion, the Ontario Ministry of the Environment and Climate Change (MOECC) uses several tools to assess the capacity of a lake to support development. This is collectively known as Lakeshore Capacity Assessment.

Lakeshore Capacity Assessment

Lakeshore Capacity Assessment is used as a planning tool to establish shoreline development limits on Precambrian Shield lakes in order to control phosphorus loading to inland lake environments. The Lake Capacity Assessment Handbook (2010) takes a watershed approach and defines shoreline development as being within 300 meters of a lake or any permanently flowing tributary of the lake and includes lakes upstream in the watershed. The goals of lakeshore capacity assessment are to help maintain the quality of water in recreational inland lakes and to protect coldwater fish habitat by keeping changes in the nutrient status of inland lakes within acceptable limits. Phosphorus and dissolved oxygen are commonly used indicators of water quality.

Dissolved Oxygen

The Provincial Water Quality Objectives (PWQOs) set acceptable concentrations of dissolved oxygen (DO) for lakes in Ontario (OMOE 1994). For cold water biota, acceptable DO concentrations are between 5 and 8 mg/L (depending on water temperature). For warm water biota, the acceptable DO concentrations are between 4 and 7 mg/L, depending on temperature. For waters where sensitive biological communities such as Lake Trout exist, or where additional physical or chemical stressors are operating, more stringent criteria may be required.

In Ontario, 7 mg/L (expressed as a Mean Volume Weighted Hypolimnetic Dissolved Oxygen concentration (MVWHDO)) has been adopted as the water quality criterion to protect Lake Trout lakes. This is reflected in the Lakeshore Capacity Assessment

Handbook (LCAH) (OMOE et al. 2010), which is used to inform development decisions on lakes situated on the Precambrian Shield. Specifically, the LCAH recommends:

> "There will be no new municipal land use planning approvals for new or more intense residential, commercial or industrial development within 300m of lake trout lakes where the mean volume-weighted hypolimnetic dissolved oxygen has been measured to be at or below 7 mg/L. This recommendation also applies to lakes where water quality modeling has determined that the development of existing vacant lots, with development approvals, would reduce the MVWHDO to 7 mg/L or less. The preservation of an average of at least 7 mg/L dissolved oxygen in the hypolimnion of Ontario's Lake Trout lakes will help to sustain the province's Lake Trout resources".

For the purpose of managing Lake Trout populations, MNRF recommends that a lake or basin of a lake be classified as 'at capacity' when the MVWHDO value is less than or equal to 7.0 mg/L (OMNR 2009). This value must represent the average of at least 3 dissolved oxygen profiles taken during the target period (August 15-September 15) of separate years.

For lakes that have MVWHDO values above 7.0 mg/L, the Lakeshore Capacity Model (LCM) can be used to predict how much development the lake can support without causing the MVWHDO to drop below the criteria. The LCM takes into account phosphorus in atmospheric deposition, natural inputs from the watershed, and anthropogenic inputs associated with development. The results of the LCM are used to predict the resulting MVWHDO through the use of a steady state model for hypolimnetic dissolved oxygen (Molot et al. 1992).

Phosphorus

Historically, management decisions relating to phosphorus have relied on an Interim Provincial Water Quality Objective (PWQO) (OMOE 1994). The Interim PWQO states:

> "To avoid nuisance algae growth in lakes, average total phosphorus concentrations over the ice-free period should not exceed 20 μg/L. A high level of protection against aesthetic deterioration will be provided by a total phosphorus concentration of < 10 μg/L. This applies to all lakes naturally below this value".

A new PWQO establishes lake-specific objectives for lakes on the Precambrian Shield based on the background phosphorus concentration of the lake (OMOE et al. 2010). The Lakeshore Capacity Model is used to determine the natural (pre-development) background concentration of total phosphorus (TP). The objective is then established as the natural background concentration of phosphorus plus 50%, to a maximum of 20 μg/L. When the phosphorus concentration within the lake exceeds this value, the lake may be considered to be 'at capacity' with respect to phosphorus load.

Where the measured TP concentration within a lake is less than the natural background concentration plus 50%, the Lakeshore Capacity Model can be used to predict how much new development the lake can sustain without causing TP concentrations to exceed the objective.

This report presents an assessment of the potential development capacity of Trout Lake based on the lake's phosphorus levels and dissolved oxygen regime. A discussion of supplementary water quality information is also provided.

Figure 1. Bathymetry of Trout Lake, City of North Bay and Corporation of the Municipality of East Ferris (geographic townships of Widdifield and Ferris). Depth strata are measured in meters. The deep holes in Four Mile Bay (north) and Trout Lake Main Basin (south) are indicated by an 'x'.

Location

District	Nipissing
Township	City of North Bay, East Ferris
Geographic Township	Widdifield, Ferris
Watershed	Upper Ottawa - Kipawa
Zone	17T
Easting	633993
Northing	5130403
Topographic Sheet	North Bay 31 L/6

Morphometry

Surface Area (ha)	1887
Catchment Area (ha)	10201
Shoreline Length (km)	71.6
Maximum Depth (m)	63.0
Total Volume (m^3)	$3.3x10^8$

Shoreline Development (2013)*

Residences	
Permanent	760
Seasonal	259
Vacant Lots of Record	172
Shoreline Crown Land (%)	1.67

*development counts inferred from 2013 Municipal Property Assessment Corporation (MPAC) data and examination of aerial imagery

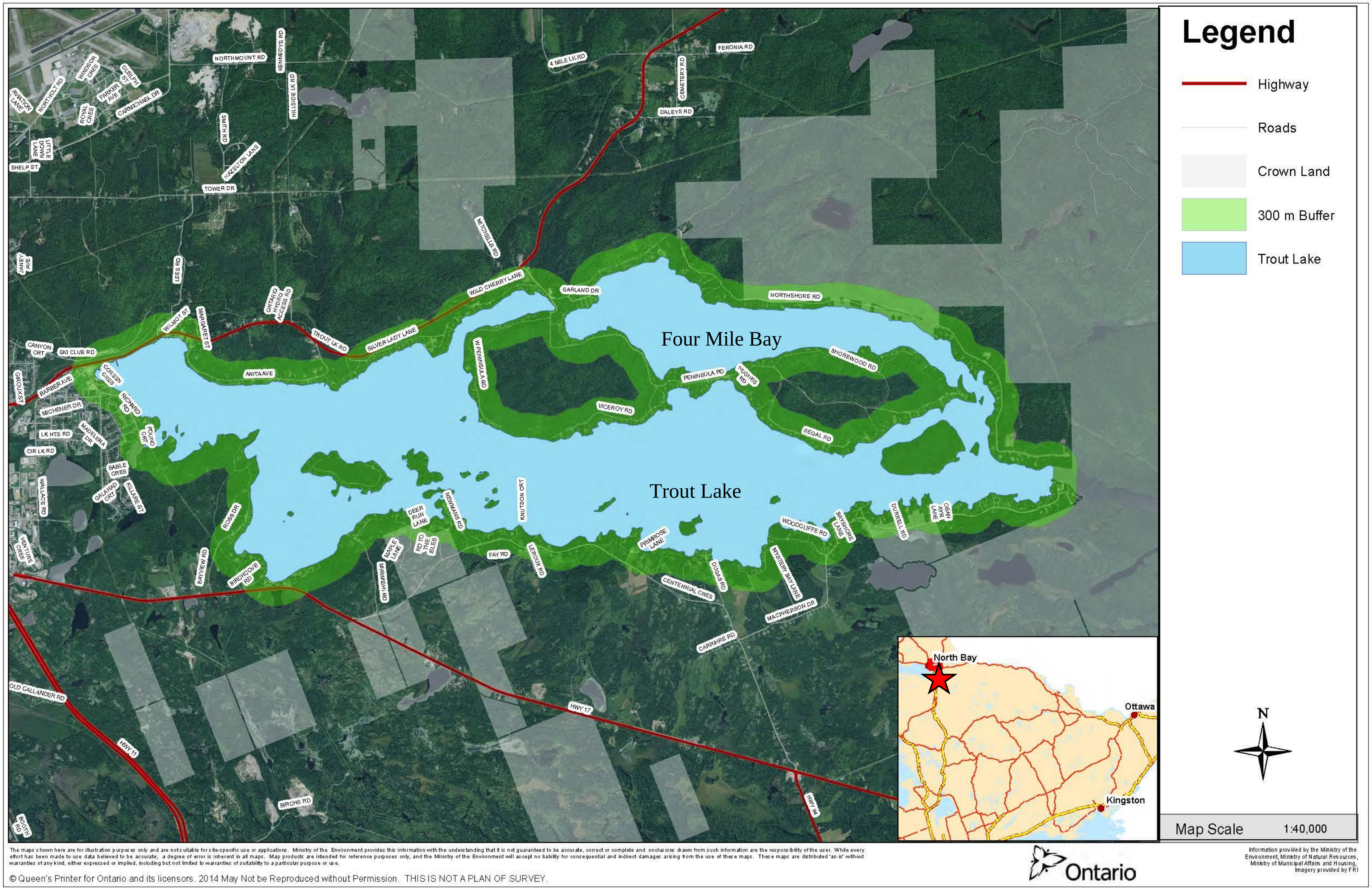

Figure 2. Trout Lake, City of North Bay and Corporation of the Municipality of East Ferris (geographic Townships of Widdifield and Ferris). The green highlighted area represents a 300 meter buffer along the shoreline and grey areas are Crown Land.

Methods

Data

Trout Lake was sampled annually by the MOECC between 1984 to 1996 as part of their Recreational Lakes Program. The most recent water quality information for Trout Lake was collected by the North Bay-Mattawa Conservation Authority (NBMCA) (2004-2007) and the MOECC (2010, 2012, 2013, 2015). The MOECC water quality data includes water chemistry and Secchi depth measurements (**Appendix 1**) and dissolved oxygen and temperature data (**Appendix 2**).

For the purposes of this Lakeshore Capacity Assessment, historical and recent data were used to characterize the lake. This assessment used 5 to 8 years of end-of-summer dissolved oxygen data and 8 years of spring phosphorus data.

Mean Volume Weighted Hypolimnetic Dissolved Oxygen Calculation

The DO regime for Trout Lake was characterized using DO and temperature profiles collected during or near the target sampling window (August 15 through September 15) between 1987 and 2015.

All profiles (temperature and DO) were collected using a YSI meter and these meters were fully calibrated prior to each survey. Values for DO and temperature were considered at one meter depth intervals. The upper limit of the hypolimnion was identified as the lower depth of the first 1 meter depth interval with a temperature change less than 1 °C.

The oxygen content for a given one meter frustum (stratum) was determined by averaging the DO concentration of the top and bottom of the stratum. The MVWHDO was determined by summing the values for each stratum and dividing by the total volume of the hypolimnion. Calculations were done using the following formula (OMNR 2009):

$$MVWHDO = \sum_{s=1}^{n} V_s * DO_s$$

where:
MVWHDO is the Mean Volume Weighted Hypolimnetic Dissolved Oxygen (mg/L);
V_s is the volume fraction of stratum s;
DO_s is the dissolved oxygen concentration (mg/L) in stratum s; and
n is the number of strata in the hypolimnion.

Lakeshore Capacity Model

The Lakeshore Capacity Model (LCM) (MOE 2010) was used to assess the development capacity of Trout Lake. The LCM is a steady-state mass balance model that calculates a phosphorus budget for a lake based on natural and anthropogenic phosphorus loads, lake morphometry, and watershed hydrology (Paterson et al. 2006). The LCM is used to predict a phosphorus concentration of a lake which can then be compared to measured values for model validation. If predicted phosphorus concentrations are within acceptable levels of measured values, the LCM can be used as a planning tool to estimate changes in lake phosphorus concentrations resulting from proposed development applications, conversions of seasonal cottages to permanent homes, or other land use activities that may increase or decrease phosphorus loadings to the lake. A separate oxygen model (Molot et al. 1992) is used to predict changes to hypolimnetic oxygen based on predicted changes in phosphorus concentrations.

The LCM uses input data from a variety of sources such as topographic maps, geological maps, provincial datasets for wetlands, forested areas, and watershed boundaries. Field visits are often used to verify sub-catchment areas and confirm drainage patterns, particularly if concerns are raised regarding the accuracy of any data set. For example, at the southeast end of Trout Lake field work was completed to confirm the flow directions of tributary streams and identify the drainage divide between Trout Lake and the Mattawa River. This work confirmed that the watershed mapping produced using MNRF's Ontario Flow Assessment Tool 3 (OFAT 3) was accurate.

MOECC and MNRF lake files are an important source of bathymetric data, water quality data, and fishery inventories. Shoreline development is an important input parameter and obtaining accurate development counts around a lake can often be challenging. Information can be obtained from the assessment rolls of municipalities, lake associations, aerial imagery or direct field counts. At a cost, the Municipal Property Assessment Corporation (MPAC) can provide assessment data that identify waterfront lots and second-tier development. For Trout Lake, MPAC data provided the main source of development counts. This was supplemented by aerial imagery taken in 2009.

Results and Discussion

Trout Lake Outflow Point

In 1994 the Ministry of the Environment and Energy recognized the outlet of Trout Lake as the line corresponding to Universal Transverse Mercator (UTM) 634,000 metres east (grid zone 18T) (**Figure 3**).

This location is a natural constriction at the east end of Trout Lake. The reach between this location and the Narrows (inlet to Turtle Lake) is more riverine than lacustrine, has a very shallow morphometry (<2 metres) and is considered a flowing system (the Mattawa River). The Ministry of Natural Resources and Forestry, in their publication Data Capture Specification for Hydrographic Features, also identify this location as the outflow of Trout Lake and this reach as the Mattawa River (MNRF 2011).

For the purposes of modelling Trout Lake and delineating the catchment area, UTM 634,000 meters east was used to define the outlet of Trout Lake and the beginning of the Mattawa River. OFAT 3 was used to create a watershed boundary for Trout Lake from this outlet location, and provincial datasets were overlaid over the watershed boundary to calculate model input parameters such as percent wetland, percent forest, and a 300 metre influence area.

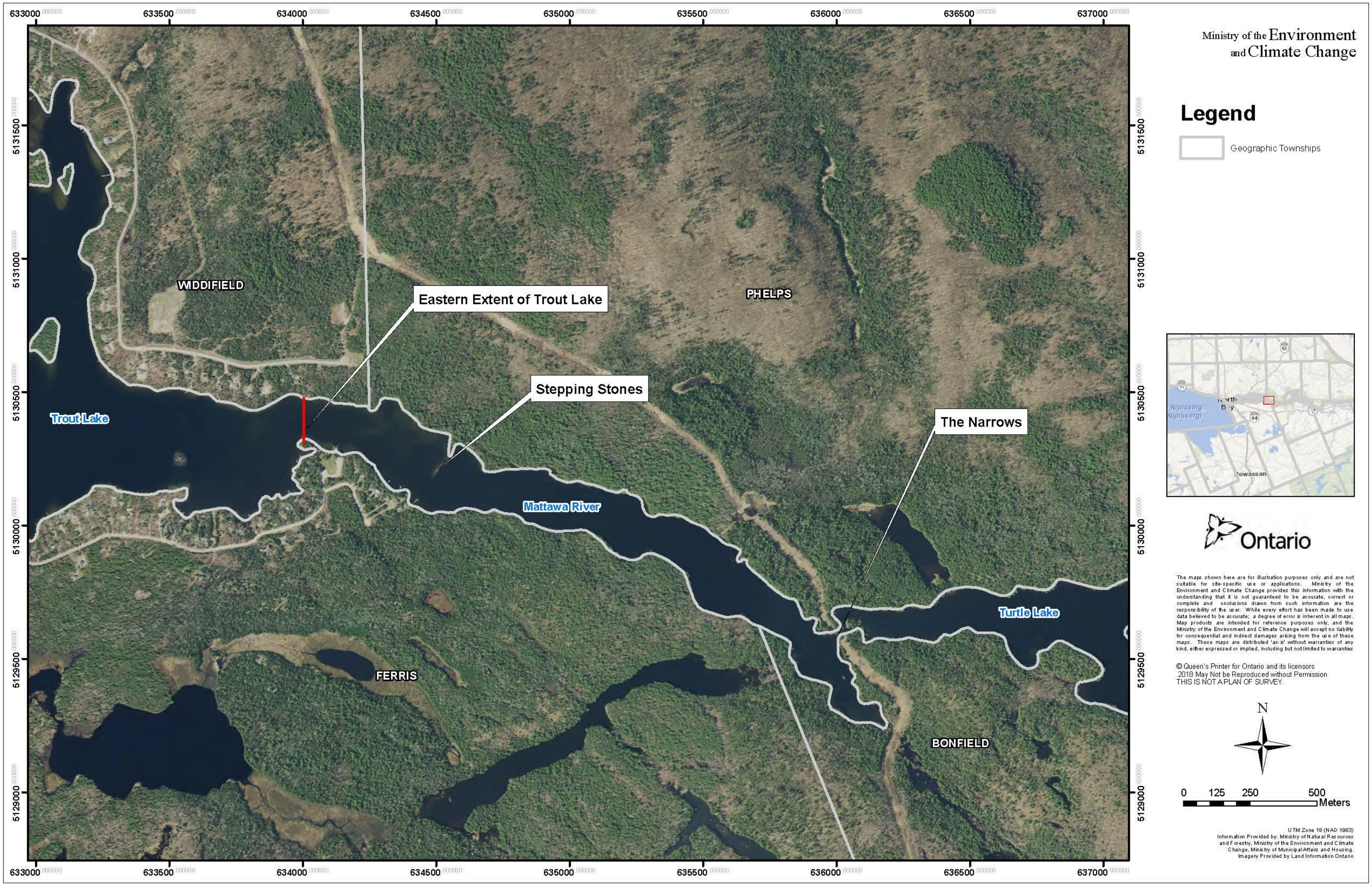

Figure 3. The outflow of Trout Lake is located at UTM easting line 634,000 meters.

Phosphorus and Water Clarity

Recent spring phosphorus data from Trout Lake includes 2004-2007, 2010, 2012, 2013 and 2015 samples from the Lake Partner Program (sampled by NBMCA and MOECC). The LPP uses a low level phosphorus detection method with duplicate samples to quantify phosphorus concentrations.

The recent spring phosphorus data indicates that both basins of Trout Lake are oligotrophic (<10 μg phosphorous per litre). Spring turnover total phosphorus concentrations (TP_{SO}) in the euphotic zone range from 4.04 μg/L to 8.88 μg/L in Four Mile Bay and 2.80 μg/L to 8.00 μg/L in Trout Lake (Main Basin). The average spring turnover phosphorus concentrations for Four Mile Bay and Trout Lake (Main Basin) are 5.88 μg/L and 4.19 μg/L respectively (**Table 1**).

Table 1. Summary of annual average spring turnover total phosphorus (TPso) concentrations (μg/L) in Trout Lake (2004-2007, 2010, 2012, 2013, 2015).

Year	Annual Average TPso (μg/L)	
	Four Mile Bay	Trout Lake (Main Basin)
2004	6.85	4.76
2005	5.29	3.63
2006	6.53	5.60
2007	4.57	3.46
2010	5.56	3.36
2012	4.60	2.90
2013	8.45	5.00
2015	5.70	4.43
Average	**5.88**	**4.19**

Secchi depth is a measure of water clarity which can be influenced by zooplankton biomass, algae biomass, turbidity, dissolved organic carbon, and suspended particulate matter. The average Secchi depths measured by the LPP (2002-2012) are 5.1 meters in Four Mile Bay and 5.8 meters in Trout Lake (Main Basin) which are indicative of excellent water clarity in both basins.

Alkalinity, pH and Hardness

Total alkalinity in Trout Lake is low and ranged from 7.0 to 8.0 mg/L in Four Mile Bay and 13.4 to 13.8 mg/L in Trout Lake (Main Basin). This indicates the lake has low levels of calcium carbonate ions and is therefore moderately sensitivity to acidification. The range in pH in the euphotic zone was 6.83 to 7.20 in Four Mile Bay and 7.24 to 7.52 in Trout Lake (Main Basin).

The hardness level of a waterbody is a function of the concentration of various dissolved salts (most commonly calcium and magnesium ions) and is usually associated with the surficial geology in the watershed. The hardness concentrations in Trout Lake (11 to 19 mg/L) indicate that it is a fairly dilute water body (**Appendix 1**).

Dissolved Organic Carbon

Lakes with high dissolved organic carbon (DOC) concentrations may have naturally high background phosphorus concentrations (OMOE et al. 2010). High levels of DOC may occur naturally in lakes with large areas of wetlands in their catchments. In Trout Lake, DOC concentrations are low to moderate and ranged from 3.3 to 5.3 mg/L in the euphotic zone (**Appendix 1**).

Nitrogen (Ammonia, Nitrate, Nitrite, Total Kjeldahl Nitrogen)

In surface waters, nitrogen may exist as nitrate, nitrite, ammonia or ammonium. The chemical form of nitrogen, which varies with oxygen concentration and pH, has a strong influence on the level of toxicity to fish. Both un-ionized ammonia (NH_3), and to a lesser extent nitrate, are known to be toxic to aquatic life. Un-ionized ammonia may accumulate to toxic levels in the hypolimnion under low oxygen conditions.

In Four Mile Bay, total ammonia concentrations were 0.011 mg/L in the euphotic zone and 0.005 mg/L at a meter off bottom (MOB); in the main basin of Trout Lake concentrations were 0.009 mg/L in the euphotic zone and 0.005 mg/L at MOB (**Appendix 1**). Under the conditions observed in the hypolimnion (temperature $<10\ ^{o}C$ and pH <7.5), this equates to 0.00003 mg/L of un-ionized ammonia which is very low. The Canadian Water Quality Guideline for un-ionized ammonia is 0.019 mg/L and the PWQO for un-ionized ammonia is 0.020 mg/L. Both water quality criteria are established for the protection of aquatic life (CCME 2010, OMOE 1994).

Similarly, nitrate concentrations were relatively low in Trout Lake (0.031 to 0.202 mg/L in Four Mile Bay, 0.033 to 0.194 mg/L in Trout Lake (Main Basin)) (**Appendix 1**). This is well below the Canadian Water Quality Guideline of 3.00 mg/L nitrate-nitrogen (CCME 2012). Nitrite concentrations in Trout Lake were 0.001 mg/L in surface samples and 0.001 mg/L in the MOB samples (**Appendix 1**). There is no PWQO for either nitrate or nitrite.

Dissolved Oxygen and Temperature

Five and eight dissolved oxygen and temperature profiles were available for Four Mile Bay and Trout Lake (Main Basin) respectively. Profiles were collected within the sampling window of August 15th to September 15th (**Figure 4**). Both basins of Trout Lake thermally stratify and the dissolved oxygen profiles display clinograde, positive heterograde, and negative heterograde patterns depending on the year sampled. The top of the hypolimnion ranged between 10 to 12 meters in Four Mile Bay and 11 to 15 meters in Trout Lake (Main Basin). Oxygen concentrations in the hypoliminion suggest the lake bottom is oxic in both basins. Raw dissolved oxygen and temperature data can be found in **Appendix 2**.

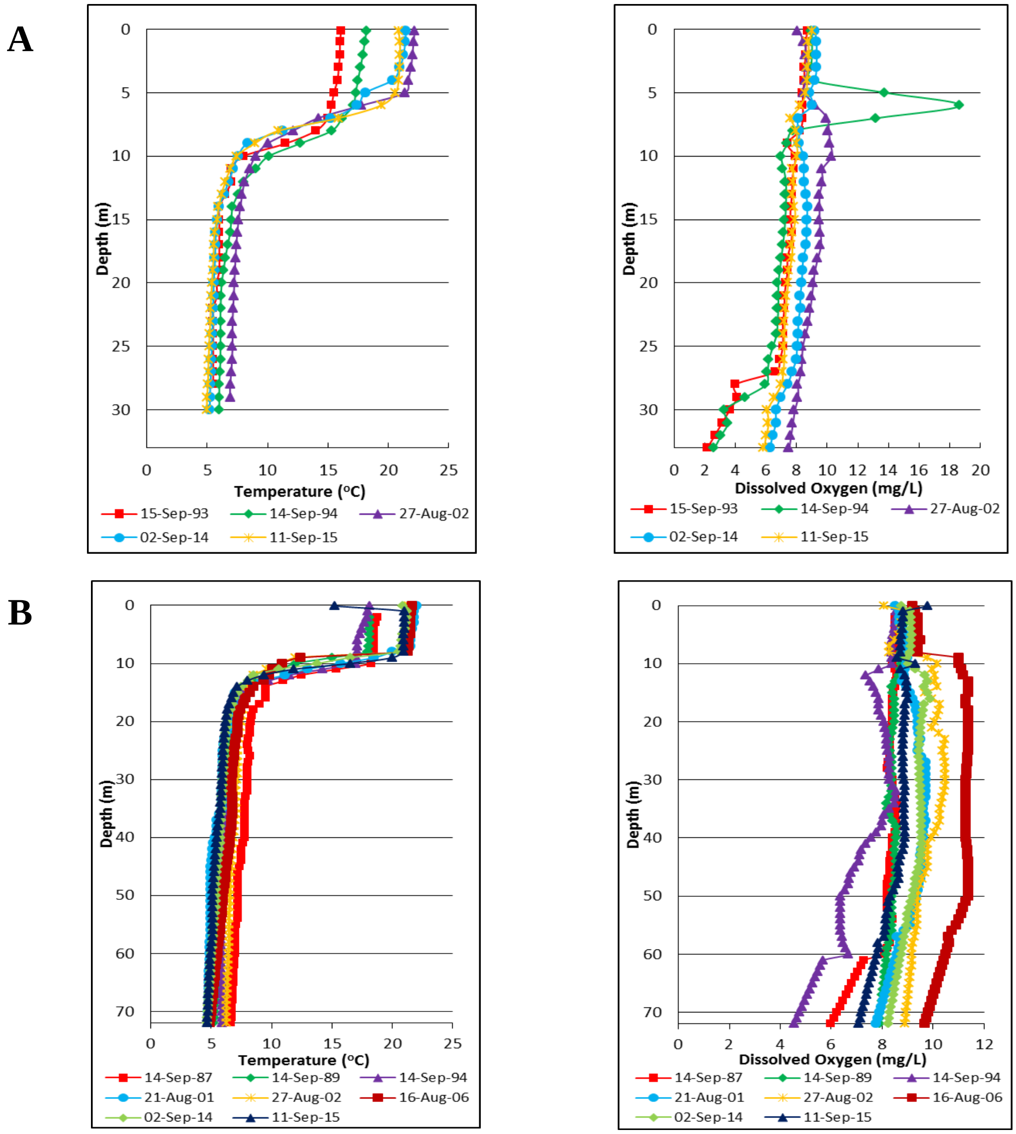

Figure 4. Temperature and dissolved oxygen profiles collected from the deepest point in the two basins of Trout Lake; A = Four Mile Bay, B = Trout Lake (Main Basin).

MVWHDO

Dissolved oxygen and temperature profiles have been collected for both basins of Trout Lake. MNRF (2009) suggests that a lake has discrete basins if they are “separated by submerged sills that are higher than the top of the hypolimnion and maximum depth of a basin is >13 m.” The sill depth between the two Trout Lake basins (< 6 meters) is always less than the average hypolimnetic depth for Four Mile Bay or Trout Lake, and the maximum depth for both basins is >13 meters. Therefore, for the purposes of calculating MVWHDO, Trout Lake is considered a dual-basin lake.

As with other dual or multi-basin Lake Trout lakes, dissolved oxygen and temperature profiles from the deepest hole in each basin is considered in the calculation of MVWHDO.

The average MVWHDO in Four Mile Bay was calculated using five dissolved oxygen and temperature profiles collected between 1993 and 2015. Eight profiles, collected between 1987 and 2015, were used for Trout Lake (Main Basin). As shown in **Table 2**, the MVWHDO was above 7 mg/L for each profile examined except for the 1994 profile from Four Mile Bay. The long-term MVWHDO averages were 8.03 mg/L and 9.15 mg/L for Four Mile Bay and Trout Lake (Main Basin) respectively.

Table 2. Summary of Mean Volume Weighted Hypolimnetic Dissolved Oxygen for Four Mile Bay and Trout Lake Proper of Trout Lake.

Date	MVWHDO (mg/L)	
	Four Mile Bay	Trout Lake (Main)
14-Sep-87	---	8.77
14-Sep-89	---	8.36
15-Sep-93	7.94	---
14-Sep-94	6.94	7.78
21-Aug-01	---	9.25
27-Aug-02	9.30	10.07
16-Aug-06	---	11.12
02-Sep-14	8.40	9.18
11-Sep-15	7.59	8.69
Average	**8.03**	**9.15**

Phosphorus and Oxygen Models

The Lakeshore Capacity Model was used to determine residual development capacity for Trout Lake as the average MVWHDO is > 7 mg/L in both basins.

The phosphorus model for Trout Lake is provided in **Appendix 2**. Trout Lake is considered a second order lake; it is fed by one lake greater than 25 hectares in size (Four Mile Lake) as well as several wetlands, streams, and ponds. The catchment of Trout Lake (Main Basin) is located within the Precambrian Shield. The catchment for Four Mile Bay has approximately 11% cleared land and 5% wetland, while the catchment for Trout Lake (Main Basin) has approximately 21% cleared land and 11% wetland. All waterbodies in the watershed less than 25 hectares in size are assumed to be forested, and are not modeled independently (MOECC 2010). Recent monitoring data indicate that Four Mile Bay and Trout Lake (Main Basin) are oxic at a meter off bottom and thermally stratify during the ice-free period.

The phosphorus model over-predicts measured spring overturn concentrations for both Four Mile Bay and Trout Lake (Main Basin) by greater than 20%, indicating that the model does not predict within acceptable ranges for either basin of this lake (**Table 3**). Therefore, the number of allowable residences to reach capacity based on the background + 50% phosphorus objective cannot be determined by the model and in turn, the dissolved oxygen model cannot be employed.

Table 3. Summary of phosphorus model predictions for Trout Lake.

Phosphorus Concentration (µg/L)	Four Mile Bay		Trout Lake (Main Basin)	
	Predicted	Average Measured	Predicted	Average Measured
TP_{SO}	10.66	5.88	11.42	4.19
TP_{lake}	10.02	N/A	10.77	N/A
$TP_{background}$	5.19	N/A	5.51	N/A
$TP_{background}$ + 50%	7.79	N/A	8.26	N/A

There are several reasons that may explain the over-prediction of measured TP. They include a lag time in the movement of phosphorus from septic systems to lakes due to watershed soils that favour retention; significant groundwater inputs to the lake; the lake being erroneously modeled as anoxic; measured phosphorus data are of poor quality; or the lake falling outside of the calibration and test range of the model.

When the LCM does not predict phosphorus concentrations within acceptable limits, the Lakeshore Capacity Assessment Handbook (MOE 2010) recommends that the Interim PWQO for phosphorus be followed as a guideline. For lakes that are naturally below 10 µg/L phosphorus, such as Trout Lake, the Interim PWQO recommends using 10 µg/L as an upper threshold. We are of the opinion that because the long-term measured phosphorus concentrations in Trout Lake are so low (i.e. < 4 µg/L), the Interim PWQO is not adequately protective of water quality in Trout Lake. Therefore we do not recommend its use.

The Official Plans (OP's) for the City of North Bay and the Township of East Ferris already include water quality objectives for total phosphorus and dissolved oxygen. These policies recommend maintaining a measured average long term ice-free phosphorus concentration below 7 µg/L combined with a late summer volume weighted dissolved oxygen measure of 8 mg/L. Both these water quality objectives are more stringent than the PWQO's. The OP policies for both municipalities have been in place for many years and effectively impose a development cap on new lots.

Trout Lake Development Capacity Summary

Trout Lake is managed by the MNRF as a naturally reproducing Lake Trout lake. It is a relatively large waterbody that has experienced extensive shoreline development due to its proximity to the City of North Bay. Trout Lake is the source of drinking water for the City of North Bay and for numerous individual private water supplies. Its excellent water quality supports many recreational activities and a strong fishery.

The phosphorus model does not predict within acceptable limits for Four Mile Bay or Trout Lake (Main Basin), as it over-predicts the spring overturn concentrations by greater than 20% of measured values. As such the model cannot be used as a planning tool to predict a background concentration (in order to set a background plus 50% objective), and therefore it cannot be used to estimate an upper limit for development.

The City of North Bay and the Township of East Ferris OP's already have policies for Trout Lake which restrict the development of new lots based on water quality objectives for phosphorus and hypolimnetic dissolved oxygen. Given the importance of this lake as a drinking water source for the City, and the at-capacity status of the downstream Lake Trout lakes (Turtle Lake and Talon Lake), the ministry supports the approach taken by the municipalities to limit new development. In the future, the Ministry may be open to considering a very limited release of new development lots for Trout Lake. The decision to allow or not allow new shoreline development lots will be based on a rigorous review of the long-term measured water quality data and a detailed statistical analysis of trends by the ministry.

Prepared By: Eastern Region Technical Support Section
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Appendix 1a. Water Chemistry Summary for Four Mile Bay from the MOECC Lake Monitoring Program (2014).

Parameter	03-Sep-14	
	Euphotic	MOB
Secchi Disk (m)	4.0	
Total Phosphorus	0.005	0.008
Ammonia- Nitrogen	*0.011*	0.005
Nitrite-Nitrogen	0.001	0.001
Nitrate- Nitrogen	*0.031*	0.202
Total Kjeldahl Nitrogen	0.24	0.23
Dissolved Organic Carbon	5.0	4.3
Dissolved Inorganic Carbon	1.9	2.1
pH	7.20	6.83
Total Alkalinity	8.0	7.0
Conductivity (uS/cm)	53.0	51.0
Calcium	3.2	3.19
Magnesium	0.838	0.824
Hardness	11.0	11.0
Total Suspended Solids	*1.2*	0.5
Total Dissolved Solids	*35.0*	*33.0*

Notes:

Results given in italics indicate a measurable trace amount which should be interpreted with caution

Shaded cells indicate the method detection limit (MDL) (i.e. the true value could not be reliably detected and is less than or equal to MDL)

All units in mg/L unless otherwise stated

MOB = meter off bottom

Appendix 1b. Water Chemistry Summary for Trout Lake (Main Basin) from the MOECC Lake Monitoring Program (2014).

Parameter	03-Sep-14	
	Euphotic	MOB
Secchi Disk (m)	4.0	
Total Phosphorus	0.005	0.005
Ammonia- Nitrogen	*0.009*	0.005
Nitrite-Nitrogen	0.001	0.001
Nitrate- Nitrogen	*0.033*	0.194
Total Kjeldahl Nitrogen	0.18	0.25
Dissolved Organic Carbon	3.9	3.3
Dissolved Inorganic Carbon	3.4	3.7
pH	7.52	7.24
Total Alkalinity	13.4	13.8
Conductivity (uS/cm)	98.0	99.0
Calcium	5.43	5.32
Magnesium	1.43	1.46
Hardness	19.0	19.0
Total Suspended Solids	*0.9*	0.5
Total Dissolved Solids	64.0	64.0

Notes:

Results given in italics indicate a measurable trace amount which should be interpreted with caution

Shaded cells indicate the method detection limit (MDL) (i.e. the true value could not be reliably detected and is less than or equal to MDL)

All units in mg/L unless otherwise stated

MOB = meter off bottom

Appendix 2a. Summary of dissolved oxygen and temperature data from Four Mile Bay in 1993, 1994, 2002, 2014, and 2015.

Measured Depth (m)	15-Sep-93		14-Sep-94		27-Aug-02		02-Sep-14		11-Sep-15	
	Temp (ºC)	DO (mg/L)	Temp (ºC)	DO (mg/L)	Temp (ºC)	DO (mg/L)	Temp (ºC)	DO (mg/L)	Temp (ºC)	DO (mg/L)
0.1	16.1	8.7	18.2	9	22.2	8.1	21.47	9.18	20.84	9.04
1	16	8.6	*18.05*	*9*	22.1	8.5	21.41	9.3	20.98	8.79
2	16	8.6	17.9	9	*22*	*8.6*	21.27	9.3	20.98	8.8
3	15.9	8.5	*17.7*	*8.95*	21.9	8.7	20.97	9.3	20.94	8.74
4	15.8	8.5	17.5	8.9	*21.65*	*8.6*	20.37	9.19	20.85	8.69
5	15.5	8.4	*17.3*	*13.8*	21.4	8.5	18.13	8.86	20.61	8.61
6	15.3	8.4	17.1	18.7	*17.8*	*9.25*	17.41	9.02	19.41	8.28
7	15	8.4	*16.2*	*13.25*	14.2	10	15.27	8.1	15.88	7.65
8	14	8.2	15.3	7.8	*12.1*	*10.1*	11.26	8.15	10.91	7.99
9	11.5	7.4	*12.7*	*7.4*	10	10.2	8.36	8.17	8.92	8.01
10	8	7.9	10.1	7	9	10.3	7.57	8.45	7.43	8.04
11	7	7.8	*9.05*	*7.15*	8.5	9.7	7.15	8.47	6.92	7.77
12	7	7.7	8	7.3	8.1	9.7	6.77	8.47	6.5	7.82
13	6.5	7.7	*7.55*	*7.3*	7.9	9.5	6.39	8.61	6.2	7.75
14	6	7.6	7.1	7.3	*7.75*	*9.5*	5.99	8.7	5.95	7.87
15	6	7.6	*7*	*7.25*	7.6	9.5	5.85	8.67	5.82	7.91
16	6	7.7	6.9	7.2	*7.5*	*9.55*	5.72	8.64	5.61	7.77
17	6	7.6	*6.7*	*7.1*	7.4	9.6	5.69	8.63	5.55	7.72
18	6	7.4	6.5	7	*7.35*	*9.4*	5.65	8.44	5.52	7.7
19	6	7.4	*6.35*	*6.9*	7.3	9.2	5.6	8.37	5.46	7.51
20	5.8	7.3	6.2	6.8	*7.25*	*9.1*	5.54	8.34	5.4	7.44
21	5.8	7.2	*6.15*	*6.8*	7.2	9	5.52	8.23	5.33	7.36
22	5.5	7.2	6.1	6.8	*7.15*	*8.9*	5.49	8.24	5.28	7.31
23	5.5	7.1	*6.1*	*6.75*	7.1	8.8	5.46	8.1	5.26	7.23
24	5.5	7.1	6.1	6.7	*7.1*	*8.6*	5.43	8.1	5.2	7.19
25	5.5	7.1	*6.1*	*6.45*	7.1	8.4	5.39	8.02	5.16	7.2
26	5.5	6.9	6.1	6.2	*7.05*	*8.35*	5.36	7.97	5.12	7.2
27	5.5	6.6	*6.05*	*6.1*	7	8.3	5.32	7.7	5.09	7.13
28	5.5	4	6	6	6.9	8.1	5.26	7.41	5.06	6.99
29			*6*	*4.65*	6.9	8.1	5.23	6.96	4.99	6.56
30			6	3.3			5.22	6.65	4.97	6.11

Notes:

Red/Italic text indicates interpolated value.

Appendix 2b. Summary of dissolved oxygen and temperature data from Trout Lake (Main Basin) in 1987, 1989, 1994, 2001, 2006, 2014, and 2015.

Measured Depth (m)	14-Sep-87		14-Sep-89		14-Sep-94		21-Aug-01		27-Aug-02		16-Aug-06		02-Sep-14		11-Sep-15	
	Temp (ºC)	DO (mg/L)	Temp (ºC)	DO (mg/L)	Temp (ºC)	DO (mg/L)	Temp (ºC)	DO (mg/L)	Temp (ºC)	DO (mg/L)	Temp (ºC)	DO (mg/L)	Temp (ºC)	DO (mg/L)	Temp (ºC)	DO (mg/L)
0.1					18.1	8.6	22	8.5	21.4	8.1	21.7	9.2	20.88	8.8	15.25	9.83
1					*18*	*8.6*	21.8	8.7	21.4	8.9	21.6	9.3	21.24	9.14	21.03	8.86
2	18.80	8.50	18.1	9.0	17.9	8.6	*21.8*	*8.7*	*21.45*	*8.85*	21.5	9.4	21.22	9.16	21.04	8.85
3	*18.65*	*8.50*	*18.1*	*8.95*	*17.7*	*8.55*	21.8	8.7	21.5	8.8	21.5	9.4	21.17	9.17	21.01	8.81
4	18.50	8.50	18.1	8.9	17.5	8.5	*21.65*	*8.8*	*21.45*	*8.75*	21.5	9.4	21.1	9.17	21	8.82
5	*18.50*	*8.50*	*18.1*	*8.9*	*17.3*	*8.45*	21.5	8.9	21.4	8.7	21.5	9.4	20.91	9.2	20.96	8.79
6	18.50	8.50	18.1	8.9	17.1	8.4	*21.5*	*8.9*	*21.4*	*8.5*	21.4	9.5	20.78	9.17	20.96	8.76
7	*18.50*	*8.50*	*18.05*	*8.85*	*17.1*	*8.4*	21.5	8.9	21.4	8.3	21.4	9.4	20.73	9.17	20.96	8.75
8	18.50	8.50	18.0	8.8	17.1	8.4	*20*	*8.95*	21.1	8.3	21.3	9.4	20.56	9.14	20.92	8.77
9	*18.40*	*8.45*	*15*	*8.8*	*17.05*	*8.4*	18.5	9	12	9.8	12.4	11	16.52	9	20.02	8.63
10	18.30	8.40	12.0	8.8	17	8.4	*15.75*	*8.95*	10.9	10.2	10.9	11	13.8	9.06	16.56	9.35
11	*15.40*	*8.50*	*10.75*	*8.75*	*14.25*	*7.9*	13	8.9	9.6	10	10.1	11.1	10.58	9.33	11.85	8.75
12	12.50	8.60	9.5	8.7	11.5	7.4	*11.1*	*8.85*	8.5	10.1	9.8	11.2	8.55	9.72	9.36	8.94
13	*11.00*	*8.55*	*8.75*	*8.55*	*9.75*	*7.55*	9.2	8.8	8.4	10.1	9.4	11.4	8.1	9.81	7.99	9
14	9.50	8.50	8.0	8.4	8	7.7	*8.1*	*8.95*	8.1	10.2	8.5	11.4	7.5	9.68	7.18	9
15	*9.50*	*8.45*	*7.6*	*8.45*	*7.75*	*7.8*	7	9.1	8	9.7	8.2	11.4	7.24	9.8	6.86	8.99
16	9.50	8.40	7.2	8.5	7.5	7.9	*6.9*	*9.2*	*7.85*	*10*	7.9	11.3	6.96	9.91	6.68	9.02
17	*9.00*	*8.40*	*7.1*	*8.5*	*7.3*	*7.9*	6.8	9.3	7.7	10.3	7.7	11.3	6.8	9.67	6.51	8.93
18	8.50	8.40	7.0	8.5	7.1	7.9	*6.65*	*9.35*	*7.65*	*10.25*	7.4	11.4	6.66	9.65	6.38	8.92
19	*8.40*	*8.40*	*7*	*8.5*	*7.1*	*8*	6.5	9.4	7.6	10.2	7.3	11.4	6.43	9.61	6.25	8.92
20	8.30	8.40	7.0	8.5	7.1	8.1	*6.5*	*9.4*	*7.5*	*10.1*	7.2	11.4	6.37	9.58	6.21	8.89
21	*8.25*	*8.35*	*6.9*	*8.45*	*7.05*	*8.15*	6.5	9.4	7.4	10	7.2	11.4	6.32	9.55	6.16	8.88
22	8.20	8.30	6.8	8.4	7	8.2	*6.3*	*9.45*	*7.35*	*10.25*	7.2	11.4	6.22	9.53	6.12	8.84
23	*8.10*	*8.30*	*6.7*	*8.35*	*7*	*8.2*	6.1	9.5	7.3	10.5	7.1	11.4	6.18	9.49	6.07	8.87
24	8.00	8.30	6.6	8.3	7	8.2	*6.05*	*9.45*	*7.25*	*10.45*	7	11.4	6.15	9.49	6.04	8.84
25	*8.10*	*8.30*	*6.6*	*8.35*	*7*	*8.25*	6	9.4	7.2	10.4	*6.95*	*11.4*	6.13	9.48	6.02	8.83
26	8.20	8.30	6.6	8.4	7	8.3	*6*	*9.55*	*7.2*	*10.45*	*6.9*	*11.4*	6.11	9.48	6	8.84
27	*8.10*	*8.25*	*6.6*	*8.4*	*6.95*	*8.3*	6	9.7	7.2	10.5	*6.85*	*11.4*	6.09	9.49	5.96	8.86
28	8.00	8.20	6.6	8.4	6.9	8.3	*6*	*9.7*	*7.2*	*10.5*	*6.8*	*11.3*	6.07	9.5	5.93	8.84
29	*8.00*	*8.30*	*6.5*	*8.4*	*6.9*	*8.3*	6	9.7	7.2	10.5	*6.75*	*11.3*	6.04	9.51	5.9	8.87
30	8.00	8.40	6.4	8.4	6.9	8.3	*6*	*9.7*	*7.15*	*10.5*	6.7	11.3	6.02	9.51	5.88	8.89
31	*8.00*	*8.40*	*6.3*	*8.4*	*6.85*	*8.45*	6	9.7	7.1	10.5	*6.72*	*11.3*	5.98	9.54	5.86	8.92
32	8.00	8.40	6.2	8.4	6.8	8.6	*5.95*	*9.7*	*7.1*	*10.45*	*6.74*	*11.3*	5.96	9.54	5.84	8.91
33	*7.90*	*8.50*	*6.15*	*8.3*	*6.65*	*8.55*	5.9	9.7	7.1	10.4	*6.76*	*11.3*	5.93	9.53	5.82	8.9
34	7.80	8.60	6.1	8.2	6.5	8.5	*5.9*	*9.65*	*7.1*	*10.35*	*6.78*	*11.3*	5.91	9.57	5.77	8.88
35	*7.80*	*8.55*	*6.05*	*8.25*	*6.35*	*8.3*	5.9	9.6	7.1	10.3	6.8	11.3	5.9	9.59	5.74	8.88
36	7.80	8.50	6.0	8.3	6.2	8.1	*5.7*	*9.65*	*7.05*	*10.3*	*6.76*	*11.3*	5.87	9.59	5.71	8.89
37	*7.80*	*8.55*	*6*	*8.45*	*6.15*	*8.05*	5.5	9.7	7	10.3	*6.72*	*11.3*	5.86	9.58	5.63	8.9
38	7.80	8.60	6.0	8.6	6.1	8	*5.5*	*9.65*	*6.95*	*10.2*	*6.68*	*11.3*	5.79	9.59	5.56	8.91
39	*7.80*	*8.50*	*6*	*8.6*	*6.05*	*7.8*	5.5	9.6	6.9	10.1	*6.64*	*11.3*	5.79	9.58	5.51	8.94
40	7.80	8.40	6.0	8.6	6	7.6	*5.35*	*9.6*	*6.85*	*9.95*	6.6	11.3	5.77	9.59	5.47	8.92
41	*7.65*	*8.40*	*6*	*8.55*	*5.95*	*7.4*	5.2	9.6	6.8	9.8	*6.54*	*11.32*	5.74	9.58	5.43	8.88
42	7.50	8.40	6.0	8.5	5.9	7.2	*5.15*	*9.55*	*6.75*	*9.8*	*6.48*	*11.34*	5.69	9.57	5.39	8.84
43	*7.50*	*8.35*	*6*	*8.55*	*5.9*	*7.15*	5.1	9.5	6.7	9.8	*6.42*	*11.36*	5.6	9.54	5.36	8.75
44	7.50	8.30	6.0	8.6	5.9	7.1	*5.05*	*9.55*	*6.7*	*9.8*	*6.36*	*11.38*	5.57	9.51	5.35	8.73
45	*7.35*	*8.30*	*5.95*	*8.6*	*5.9*	*6.95*	5	9.6	6.7	9.8	6.3	11.4	5.53	9.46	5.3	8.66
46	7.20	8.30	5.9	8.6	5.9	6.8	*5*	*9.55*	*6.65*	*9.7*	*6.24*	*11.4*	5.51	9.42	5.25	8.69
47	*7.20*	*8.25*	*5.9*	*8.55*	*5.9*	*6.75*	5	9.5	6.6	9.6	*6.18*	*11.4*	5.46	9.33	5.22	8.68
48	7.20	8.20	5.9	8.5	5.9	6.7	*5*	*9.45*	*6.6*	*9.5*	*6.12*	*11.4*	5.44	9.32	5.2	8.58
49	*7.20*	*8.20*	*5.9*	*8.45*	*5.9*	*6.55*	5	9.4	6.6	9.4	*6.06*	*11.4*	5.44	9.26	5.14	8.48
50	7.20	8.20	5.9	8.4	5.9	6.4	*5*	*9.35*	*6.6*	*9.4*	6	11.4	5.43	9.24	5.11	8.35
51	*7.20*	*8.20*	*5.9*	*8.4*	*5.9*	*6.4*	5	9.3	6.6	9.4	*5.96*	*11.3*	5.4	9.18	5.1	8.29
52	7.20	8.20	5.9	8.4	5.9	6.4	*5*	*9.2*	*6.55*	*9.4*	*5.92*	*11.2*	5.4	9.11	5.1	8.27
53	*7.20*	*8.30*	*5.85*	*8.4*	*5.9*	*6.4*	5	9.1	6.5	9.4	*5.88*	*11.1*	5.37	9.02	5.09	8.2
54	7.20	8.40	5.8	8.4	5.9	6.4	*5*	*9.1*	*6.5*	*9.4*	*5.84*	*11*	*5.28*	*9.04*	5.09	8.18
55	*7.10*	*8.30*	*5.75*	*8.4*	*5.9*	*6.4*	5	9.1	6.5	9.4	5.8	10.9	*5.24*	*8.99*	5.09	8.18
56	7.00	8.20	5.7	8.4	5.9	6.4	*5*	*8.85*	*6.5*	*9.35*	*5.75*	*10.75*	*5.21*	*8.95*	5.09	8.15
57	*7.00*	*8.25*	*5.65*	*8.35*	*5.9*	*6.45*	5	8.6	6.5	9.3	5.7	10.6	*5.18*	*8.91*	5.09	8.12
58	7.00	8.30	5.6	8.3	5.9	6.5	*4.92*	*8.73*	*6.5*	*9.25*	*5.63*	*10.65*	*5.14*	*8.86*	5.06	7.88
59	*7.00*	*8.20*	*5.6*	*8.25*	*5.9*	*6.6*	*4.91*	*8.66*	6.5	9.2	*5.58*	*10.58*	*5.11*	*8.82*	*4.97*	*7.89*
60	7.00	8.10	5.6	8.2	5.9	6.7	*4.90*	*8.59*	*6.45*	*9.2*	*5.52*	*10.51*	*5.08*	*8.78*	*4.95*	*7.83*
61	*6.93*	*7.29*	*5.55*	*8.20*	*5.90*	*5.70*	*4.89*	*8.52*	6.4	9.2	*5.47*	*10.44*	*5.04*	*8.74*	*4.93*	*7.77*
62	*6.90*	*7.17*	*5.52*	*8.18*	*5.90*	*5.60*	*4.88*	*8.45*	6.4	9.2	*5.42*	*10.37*	*5.01*	*8.69*	*4.91*	*7.71*
63	*6.88*	*7.06*	*5.48*	*8.15*	*5.90*	*5.49*	*4.87*	*8.38*	*6.39*	*9.14*	*5.37*	*10.30*	*4.98*	*8.65*	*4.88*	*7.65*
64	*6.85*	*6.94*	*5.45*	*8.13*	*5.90*	*5.39*	*4.86*	*8.31*	*6.37*	*9.12*	*5.32*	*10.23*	*4.94*	*8.61*	*4.86*	*7.59*
65	*6.83*	*6.82*	*5.42*	*8.10*	*5.90*	*5.29*	*4.84*	*8.24*	*6.35*	*9.09*	*5.27*	*10.16*	*4.91*	*8.56*	*4.84*	*7.53*
66	*6.80*	*6.70*	*5.39*	*8.08*	*5.90*	*5.18*	*4.83*	*8.17*	*6.34*	*9.07*	*5.22*	*10.09*	*4.88*	*8.52*	*4.82*	*7.47*
67	*6.78*	*6.58*	*5.36*	*8.05*	*5.90*	*5.08*	*4.82*	*8.10*	*6.32*	*9.05*	*5.17*	*10.02*	*4.84*	*8.48*	*4.80*	*7.41*
68	*6.75*	*6.46*	*5.33*	*8.03*	*5.90*	*4.98*	*4.81*	*8.04*	*6.31*	*9.02*	*5.12*	*9.95*	*4.81*	*8.43*	*4.77*	*7.35*
69	*6.73*	*6.35*	*5.30*	*8.00*	*5.90*	*4.87*	*4.80*	*7.97*	*6.29*	*9.00*	*5.06*	*9.88*	*4.78*	*8.39*	*4.75*	*7.29*
70	*6.70*	*6.23*	*5.27*	*7.98*	*5.90*	*4.77*	*4.79*	*7.90*	*6.27*	*8.98*	*5.01*	*9.82*	*4.74*	*8.35*	*4.73*	*7.23*
71	*6.68*	*6.11*	*5.24*	*7.95*	*5.90*	*4.67*	*4.78*	*7.83*	*6.26*	*8.95*	*4.96*	*9.75*	*4.71*	*8.31*	*4.71*	*7.17*
72	*6.65*	*5.99*	*5.21*	*7.93*	*5.90*	*4.56*	*4.77*	*7.76*	*6.24*	*8.93*	*4.91*	*9.68*	*4.68*	*8.26*	*4.68*	*7.11*

Notes:

Red/Italic text indicates interpolated and/or extrapolated value.

Appendix 2: Lakeshore Capacity Model for Trout Lake.

Lakeshore Capacity Model - Info on Version 4.0 (updated November 2011)

1. This model has been updated to reflect the Ontario Ministry of the Environment's Lakeshore Capacity Assessment Handbook released in July 2010.

2. Unless otherwise specified, coefficients are derived from Paterson et al. (2006).

3. The model is calibrated to predict the whole lake ice-free mean total phosphorus concentration of the lake. This is reflected in the final output value TPlake.

4. Lakes that are smaller than 25 ha are not modeled, unless they have significant shoreline development. The surface and catchment area of lakes <25 ha are added to the catchment area of the larger downstream lake.

5. Vacant lots of record refers to lots that are designated as residential, but have not yet been cleared for development. The model assumes that these lots will eventually be developed into extended seasonal cottages, unless otherwise specified. Vacant lots of record are used when calculating future anthropogenic load.

6. Current development is inferred based on examination of topographic maps, aerial photographs, and municipal datasets. Land use schedules used where available.

7. All runoff coefficients determined based on decimal degree coordinates obtained from GeoPortal and converted to degrees/minutes/seconds.

8. Lake stats (catchment, wetlands etc) have been obtained from GIS.

9. Relationships between spreadsheets have been established with respect to lake flow schematics for the Brule Lake Watershed (lakes >25 ha).

10. A lake is considered anoxic where the average late summer DO (August 15 -September 15) is less than 1mg/L at 1 meter off bottom. Where no DO data is available, lakes with a maximum depth of less than 12 m (or average depth of < 4m) are assumed to become anoxic at 1 meter off bottom during the late summer critical period. Where no depth information is available, small lakes < 35 ha are assumed to be anoxic.

Lakeshore Capacity Model – Coefficients

Anthropogenic Supply			
Shoreline Development Type	Usage	Units	
Permanent	2.56	capita years/yr	
Extended Seasonal	1.27	capita years/yr	
Seasonal	0.69	capita years/yr	
Resort	1.18	capita years/yr	
Trailer Parks	0.69	capita years/yr	
Youth Camps	0.125	kg/capita/yr	
Campgrounds/Tent trailers/RV parks	0.37	capita years/yr	
Vacant Lots of Record	1.27	capita years/yr	
Per lot TP load	0.04	kg/lot/yr	
Per capita load	0.66	kg/capita/yr	
Intensive Land Use			
Crop agriculture	30	mg/m2/yr	
Urbanization	50	mg/m2/yr	
Golf course	14	mg/m2/yr	(Winter et al. 2006)
Natural Supply			
P in Precipitation/Atmospheric Dep.	16.7	mg/m2/yr	
Watershed Descriptors			
Default Wetland	15	%	
Forested Watersheds			
< 15% cleared land	5.5	mg/m2/yr	
≥ 15% cleared land	9.8	mg/m2/yr	
Wetland Export Equation			
Natural P load from catchment = Ad * (0.47 * % wetland area + 3.82)			
Slope	0.47		
Constant	3.82		
Sedimentation			
Retention coefficient (Rp) = v / (v + qs)			
Anoxic	7.2	m/yr	
Oxic	12.4	m/yr	
Relationship between Spring Overturn and Mixed Whole Lake TP (based on long-term mean; Clark et al. 2010)			
TP_lake = 0.992 * TP_so - 0.563			
Slope	0.992		
Constant	-0.563		

Lakeshore Capacity Model – Inputs

Lake	Lat	Long	Runoff (m) from Database	Surface area, Ao (ha)	Catchment area, Ad (ha)	% Wetland	% Cleared	Years of spring TP sampling	No. of TP samples	Avg. Measured TPso (µg/L)	Hypolimetic DO (mg/L)	Anoxic?	LT Lake?	Max Depth (m)	Mean Depth (m)	Hydrologic Flow
Four Mile Lake (west)	46 23 08	79 23 11	0.512	48.3	122	12.9	21.49	4	6	6.94	< 1 mg/L	Y	N	8.60	2.70	To Four Mile Lake (east)
Four Mile Lake (east)	46 22 46	79 22 25	0.500	34.76	145.68	3.59	12.41	5	7	8.75	< 1 mg/L	Y	N	5.10	2.70	To Four Mile Bay
Four Mile Bay	46 19 26	79 16 20	0.501	324.66	4289.04	4.81	11.01	8	23	5.88	> 1 mg/L	N	Y	27.00	N/A	To Trout Lake
Trout Lake	46 18 50	79 15 35	0.481	1562.25	5912.39	10.98	21.00	8	60	4.19	>1 mg/L	N	Y	63.00	16.90	TARGET

Lakeshore Capacity Model - Anthropogenic Inputs

Lake	Lat	Long	Permanent	Extended Seasonal	Seasonal	Resort	Trailer Parks	Youth Camps	Campgrounds/ Tent trailers/ RV parks	Vacant Lots of Record	Other (e.g., agriculture, urbanization, golf course)
Four Mile Lake (west)	46 23 08	79 23 11	22		3					6	
Four Mile Lake (east)	46 22 46	79 22 25	20		6					7	
Four Mile Bay	46 19 26	79 16 20	142		73					22	
Trout Lake	46 18 50	79 15 35	618		186				20	150	

Lakeshore Capacity Model — Four Mile Lake (west)

Anthropogenic Supply

Shoreline Development Type	Number	Usage (capita years/yr)	
Permanent	22	2.56	
Extended Seasonal	0	1.27	
Seasonal	3	0.69	
Resort	0	1.18	
Trailer Parks	0	0.69	
Youth Camps	0	0.125	kg/capita/yr
Campgrounds/Tent trailers/RV parks	0	0.37	
Vacant Lots of Record	6	1.27	
Retention by soil (Rs) (0-1)	0		

Catchment — Upstream Lakes

Lake Area (Ao)	48.3	ha
Catchment Area (Ad)	122.4	ha
Wetland	12.9	%
Cleared	21.5	%

Hydrological Flow

Mean annual runoff	0.512	m/yr
Lake outflow discharge (Q)	873735	m3/yr
Areal water loading rate (qs)	1.81	m/yr
Inflow 1		m3/yr

Natural Loading

Atmospheric Load	8.06	kg/yr
Runoff Load	21.79	kg/yr

Upstream Loading

Background Upstream Load 1		kg/yr
Current Total Upstream Load 1		kg/yr
Future Upstream Load 1		kg/yr

Anthropogenic Loading

Current Anthropogenic Load	39.54	kg/yr
Future Anthropogenic Load	44.81	kg/yr

Areal Load Rate

Current Total Areal Loading Rate (LT)	143.81	mg/m2/yr
Future Total Areal Loading Rate (LFT)	154.73	mg/m2/yr

Sedimentation

Is the lake anoxic?	Y	
Settling velocity (v)	7.2	m/yr
In lake retention (Rp)	0.80	

Monitoring Data

Years of spring TP data	4	
Average Measured TPso	6.94	µg/L
Measured vs. Predicted TPso	150.7	%
Is the model applicable?	n	
Over or under predicted?	over	

Modeling Results

TPlake	16.69	µg/L
TPout	15.96	µg/L
TPso	17.39	µg/L
TPfuture	17.96	µg/L

Phosphorus Thresholds

TPbk	7.18	µg/L
TPbk+40	10.05	µg/L
TPbk+50	10.77	µg/L
TPbk+60	11.49	µg/L

*if TPbk+40% < TPlake < TPbk+60% cell is orange
*if TPlake > TPbk+60% cell is red

No. of allowable residences to reach capacity:

# Permanent OR	N/A
# Extended seasonal OR	N/A
# Seasonal cottages OR	N/A

Loads

Natural Load w/no development	29.85	kg/yr
Background + 50% Load	44.78	kg/yr
Current Load	69.39	kg/yr
Future Load	74.66	kg/yr

Outflow Loads

Background Outflow Load	6.00	kg/yr
Current Outflow Load	13.94	kg/yr
Future Outflow Load	15.00	kg/yr

Lakeshore Capacity Model — Four Mile Lake (east)

Anthropogenic Supply

Shoreline Development Type	Number	Usage (capita years/yr)	
Permanent	20	2.56	
Extended Seasonal	0	1.27	
Seasonal	6	0.69	
Resort	0	1.18	
Trailer Parks	0	0.69	
Youth Camps	0	0.125	kg/capita/yr
Campgrounds/Tent trailers/RV parks	0	0.37	
Vacant Lots of Record	7	1.27	
Retention by soil (Rs) (0-1)	0		

Catchment			Upstream Lakes
Lake Area (Ao)	34.8	ha	
Catchment Area (Ad)	145.7	ha	
Wetland	3.6	%	
Cleared	12.4	%	
Hydrological Flow			
Mean annual runoff	0.500	m/yr	
Lake outflow discharge (Q)	1775954	m3/yr	
Areal water loading rate (qs)	5.11	m/yr	
Inflow 1	873735	m3/yr	Four Mile (west)
Natural Loading			
Atmospheric Load	5.81	kg/yr	
Runoff Load	8.02	kg/yr	
Upstream Loading			
Background Upstream Load 1	6.00	kg/yr	Four Mile (west)
Current Total Upstream Load 1	13.94	kg/yr	Four Mile (west)
Future Upstream Load 1	15.00	kg/yr	Four Mile (west)
Anthropogenic Loading			
Current Anthropogenic Load	37.56	kg/yr	
Future Anthropogenic Load	43.71	kg/yr	
Areal Load Rate			
Current Total Areal Loading Rate (LT)	187.95	mg/m2/yr	
Future Total Areal Loading Rate (LFT)	208.68	mg/m2/yr	

Sedimentation		
Is the lake anoxic?	Y	
Settling velocity (v)	7.2	m/yr
In lake retention (Rp)	0.58	
Monitoring Data		
Years of spring TP data	5	
Average Measured TPso	8.75	µg/L
Measured vs. Predicted TPso	90.4	%
Is the model applicable?	n	
Over or under predicted?	over	
Modeling Results		
TPlake	15.97	µg/L
TPout	15.27	µg/L
TPso	16.66	µg/L
TPfuture	17.73	µg/L
Phosphorus Thresholds		
TPbk	4.85	µg/L
TPbk+40	6.79	µg/L
TPbk+50	7.27	µg/L
TPbk+60	7.76	µg/L

*if TPbk+40% < TPlake < TPbk+60% cell is orange
*if TPlake > TPbk+60% cell is red

No. of allowable residences to reach capacity:		
# Permanent OR	N/A	
# Extended seasonal OR	N/A	
# Seasonal cottages OR	N/A	
Loads		
Natural Load w/no development	19.83	kg/yr
Background + 50% Load	29.74	kg/yr
Current Load	65.34	kg/yr
Future Load	72.54	kg/yr
Outflow Loads		
Background Outflow Load	8.23	kg/yr
Current Outflow Load	27.12	kg/yr
Future Outflow Load	30.11	kg/yr

Lakeshore Capacity Model — Four Mile Bay

Anthropogenic Supply			
Shoreline Development Type	Number	Usage (capita years/yr)	
Permanent	142	2.56	
Extended Seasonal	0	1.27	
Seasonal	73	0.69	
Resort	0	1.18	
Trailer Parks	0	0.69	
Youth Camps	0	0.125	kg/capita/yr
Campgrounds/Tent trailers/RV parks	0	0.37	
Vacant Lots of Record	22	1.27	
Retention by soil (Rs) (0-1)	0		

Catchment			Upstream Lakes
Lake Area (Ao)	324.7	ha	
Catchment Area (Ad)	4289.0	ha	
Wetland	4.8	%	
Cleared	11.0	%	

Hydrological Flow			
Mean annual runoff	0.501	m/yr	
Lake outflow discharge (Q)	24890575	m3/yr	
Areal water loading rate (qs)	7.67	m/yr	
Inflow 1	1775954	m3/yr	Four Mile (east)

Natural Loading		
Atmospheric Load	54.22	kg/yr
Runoff Load	260.80	kg/yr

Upstream Loading			
Background Upstream Load 1	8.23	kg/yr	Four Mile (east)
Current Total Upstream Load 1	27.12	kg/yr	Four Mile (east)
Future Upstream Load 1	30.11	kg/yr	Four Mile (east)

Anthropogenic Loading		
Current Anthropogenic Load	281.77	kg/yr
Future Anthropogenic Load	301.09	kg/yr

Areal Load Rate		
Current Total Areal Loading Rate (LT)	192.17	mg/m2/yr
Future Total Areal Loading Rate (LFT)	199.05	mg/m2/yr

Sedimentation		
Is the lake anoxic?	N	
Settling velocity (v)	12.4	m/yr
In lake retention (Rp)	0.62	

Monitoring Data		
Years of spring TP data	8	
Average Measured TPso	5.88	µg/L
Measured vs. Predicted TPso	81.5	%
Is the model applicable?	n	
Over or under predicted?	over	

Modeling Results		
TPlake	10.02	µg/L
TPout	9.58	µg/L
TPso	10.66	µg/L
TPfuture	10.38	µg/L

Phosphorus Thresholds		
TPbk	5.19	µg/L
TPbk+40	7.27	µg/L
TPbk+50	7.79	µg/L
TPbk+60	8.30	µg/L

*if TPbk+40% < TPlake < TPbk+60% cell is orange
*if TPlake > TPbk+60% cell is red

No. of allowable residences to reach capacity:	
# Permanent OR	N/A
# Extended seasonal OR	N/A
# Seasonal cottages OR	N/A

Loads		
Natural Load w/no development	323.25	kg/yr
Background + 50% Load	484.88	kg/yr
Current Load	623.91	kg/yr
Future Load	646.22	kg/yr

Outflow Loads		
Background Outflow Load	123.50	kg/yr
Current Outflow Load	238.37	kg/yr
Future Outflow Load	246.89	kg/yr

Lakeshore Capacity Model Trout Lake (Main Basin)

Anthropogenic Supply

Shoreline Development Type	Number	Usage (capita years/yr)	
Permanent	618	2.56	
Extended Seasonal	0	1.27	
Seasonal	186	0.69	
Resort	0	1.18	
Trailer Parks	0	0.69	
Youth Camps	0	0.125	kg/capita/yr
Campgrounds/Tent trailers/RV parks	20	0.37	
Vacant Lots of Record	7	1.27	
Retention by soil (Rs) (0-1)	0		

Catchment

			Upstream Lakes
Lake Area (Ao)	1562.3	ha	
Catchment Area (Ad)	5912.4	ha	
Wetland	11.0	%	
Cleared	21.0	%	

Hydrological Flow

Mean annual runoff	0.481	m/yr	
Lake outflow discharge (Q)	60843634	m3/yr	
Areal water loading rate (qs)	3.89	m/yr	
Inflow 1	24890575	m3/yr	Four Mile Bay
Inflow 2		m3/yr	

Natural Loading

Atmospheric Load	260.90	kg/yr
Runoff Load	955.74	kg/yr

Upstream Loading

Background Upstream Load 1	123.50	kg/yr	Four Mile Bay
Current Total Upstream Load 1	238.37	kg/yr	Four Mile Bay
Future Upstream Load 1	246.89	kg/yr	Four Mile Bay

Anthropogenic Loading

Current Anthropogenic Load	1166.72	kg/yr
Future Anthropogenic Load	1172.87	kg/yr

Areal Load Rate

Current Total Areal Loading Rate (LT)	167.82	mg/m2/yr
Future Total Areal Loading Rate (LFT)	168.76	mg/m2/yr

Sedimentation

Is the lake anoxic?	N	
Settling velocity (v)	12.4	m/yr
In lake retention (Rp)	0.76	

Monitoring Data

Years of spring TP data	8	
Average Measured TPso	4.19	µg/L
Measured vs. Predicted TPso	172.9	%
Is the model applicable?	n	
Over or under predicted?	over	

Modeling Results

TPlake	10.77	µg/L
TPout	10.30	µg/L
TPso	11.42	µg/L
TPfuture	10.83	µg/L

Phosphorus Thresholds

TPbk	5.51	µg/L
TPbk+40	7.71	µg/L
TPbk+50	8.26	µg/L
TPbk+60	8.81	µg/L

*if TPbk+40% < TPlake < TPbk+60% cell is orange
*if TPlake > TPbk+60% cell is red

No. of allowable residences to reach capacity:

# Permanent OR	N/A
# Extended seasonal OR	N/A
# Seasonal cottages OR	N/A

Loads

Natural Load w/no development	1340.14	kg/yr
Background + 50% Load	2010.21	kg/yr
Current Load	2621.73	kg/yr
Future Load	2636.40	kg/yr

Outflow Loads

Background Outflow Load	320.31	kg/yr
Current Outflow Load	626.63	kg/yr
Future Outflow Load	630.13	kg/yr

Lakeshore Capacity Model - Summary Results

	Model Predictions (µg/L)														Available Capacity			Loads (kg/yr)			
Lake	**TP out**	**TP lake**	**TP so**	**TP future**	**TP bk**	**TP bk+40%**	**TP bk+50%**	**TP bk+60%**	**Measured TPso (µg/L)**	**Measured vs. Predicted TPso (%)**	**Model applicable?**	**Over or under predicted?**	**TPlake vs. TPbk+50%**	**Over capacity?**	**# Permanent OR**	**# Extended seasonal OR**	**# Seasonal cottages OR**	**Bk +50% P load**	**Current P load**	**Allowable P load**	**Future P load**
Four Mile (west)	15.96	16.69	17.39	17.96	7.18	10.05	10.77	11.49	6.94	150.71	n	over	5.92	N/A	N/A	N/A	N/A	44.78	69.39	-24.61	74.66
Four Mile (east)	15.27	15.97	16.66	17.73	4.85	6.79	7.27	7.76	8.75	90.36	n	over	8.70	N/A	N/A	N/A	N/A	29.74	65.34	-35.60	72.54
Four Mile Bay	9.58	10.02	10.66	10.38	5.19	7.27	7.79	8.30	5.88	81.46	n	over	2.23	N/A	N/A	N/A	N/A	484.88	623.91	-139.03	646.22
Trout Lake	10.30	10.77	11.42	10.83	5.51	7.71	8.26	8.81	4.19	172.95	n	over	2.51	N/A	N/A	N/A	N/A	2010.21	2621.73	-611.52	2636.40