Draft for Discussion

Tier 1 Water Budget and Water Quantity Stress Assessment for Trout Lake Sub-watershed

Prepared for
North Bay – Mattawa Conservation Authority

Submitted by
Gartner Lee Limited

August, 2008

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Executive Summary

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The North Bay – Mattawa Conservation Authority completed a Conceptual Water Budget for the North Bay – Mattawa Source Protection Area early in 2008. This present document is the next step and provides a Tier 1 Water Budget and Water Quantity Stress Assessment for the Trout Lake sub-watershed, under the MOE Guidance Module 7, dated March 2007. The City of North Bay obtains all of its drinking water from Delaney Bay, at the west end of Trout Lake. The municipal water supply for the City of North Bay is unique in that it is 100% consumptive, being drawn from one watershed and the treated wastewater returned to another.

The amount of available water in the Trout Lake sub-watershed was based on the volume of streamflow, precipitation and runoff coming into the lake. Streamflow data from gauge station 02JE020 on the Mattawa River below Bouillon Lake was used on a pro-rata basis to determine inflow to Trout Lake, after first considering the city's water taking. Water demand was conservatively calculated by summing up the highest historic water taking at the North Bay Water Treatment Plant (2007) with other water uses reported in the Ministry of Environments Permit To Take Water database. The consumptive uses for the sub-watershed were calculated and compared to the available water to determine the Percent Water Demand for this surface water system. Contrary to the Guidance documents, no allowance was made for stream reserve as the water taking was downstream of the contributing watershed, and the leakage at the Turtle Lake dam is considerable and not susceptible to interception by water taking.

It was found that the Trout Lake water supply varies each month and reaches above 20% water demand during the summer season (June through September) but less than 20% water demand during the spring time (April through May) when streamflow is high. Based on the Guidance module, it has been concluded that the stress assignment for the Trout Lake sub-watershed is **MODERATE** particularly during the summer season when the water demand is high and there is declining inflow to the lake. These findings are consistent between the current and future (25 year) conditions. Based on the **MODERATE** stress level assignment, there is a need to proceed to a more detailed Tier 2 Water Budget and Water Quantity Stress Assessment for the City of North Bay's water supply.

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1. Introduction

The Conceptual Water Budget for the North Bay – Mattawa Source Protection Area (North Bay – Mattawa SPA) provided a quantitative calculation of the various components of the hydrologic cycle (e.g., precipitation, evapotranspiration, runoff) as well as an understanding of the surface and groundwater pathways that water takes through the watershed (Section 5, North Bay – Mattawa SPA Final Report, 2008). That report recommended that Tier 1 Water Budget and Water Quantity Stress Assessments be conducted for a number of municipal water supplies, of which the Trout Lake water taking by the City of North Bay is one.

This Water Quantity Stress Assessment process provides a framework to evaluate the sustainability of drinking water supply systems in the context of the local watershed. The objective of the framework is to help identify drinking water sources that may not be able to meet current or future demands. Those sources which are identified as having potential problems meeting demand will ultimately be subject to further analyses at the Tier 2 or Tier 3 levels.

The Conceptual Water Budget (NBMSPA, 2008) identified that surface water is the major source of drinking water for the urban population and that the amount of water moving through the watershed greatly exceeds present uses. The City of North Bay draws its water supply from Delaney Bay in the western end of Trout Lake. This withdrawal is a completely consumptive use, as the treated effluent generated in North Bay is discharged into a separate watershed (Lake Nipissing).

This report documents the Tier 1 Water Budget and Water Quantity Stress Assessment for the Trout Lake water supply[1] (Map 1). This Tier 1 Water Budget and Water Quantity Stress Assessment is a component of the overall Assessment Report. It is this document where water supply and demand are quantified, where water movement within the sub-watershed is understood, and where the sustainability of the North Bay source is evaluated.

1.1 Trout Lake Sub-watershed Description

The Trout Lake sub-watershed (Map 1) occupies 181.1 km^2 at the headwaters of the Mattawa River (Northland Engineering and Beak Consultants, 1992). Discharge from the watershed is controlled by a dam located on the Mattawa River at the outlet of Turtle Lake. The Trout Lake sub-watershed consists of the contiguous portions of Trout Lake and Turtle Lake (which are joined and

1. *The Tier 1 evaluation for the other three municipal drinking water supplies (Mattawa, Powassan, and South River) will be completed separately.*
3. *Actual Periods of record for the streamflow gauge are from 1971-1998. In order to match the period of record for the meteorological stations, values for the year 1998 through 2000 were calculated on a proportional basis. The calculation involved determining the ratio of streamflow records for the same period of records between the two adjacent watersheds. The ratio was found to be nearly constant for each pair of watersheds. The missing data for the gauge station was then calculated by simply multiplying the ratio with the available measured data of the nearby gauge station.*

act as one water basin having the same elevation) plus the connecting portion of the Mattawa River.

1.2 Water Quantity Stress Assessment Objectives

This Tier 1 Assessment reviews the short and long-term sustainability of the City of North Bay's surface water source. The objective of the Tier 1 analysis is to estimate the hydrologic stress on the water sources in order to determine which are unstressed from a water quantity perspective. Unstressed sources are screened out of future (more detailed) analyses at the Tier 2 or Tier 3 levels, and are subject to monitoring and periodic review to ensure problems do not arise. Water sources under a moderate to significant level of stress will be subject to further water budget evaluation at the Tier 2 level

2. Tier 1 Water Budget and Sub-watershed Stress Assessments

2.1 Overview of the Procedures

In the Conceptual Water Budget, estimates were made of the various components of the hydrologic cycle (or water balance), including precipitation (P), evapotranspiration (ET), and the remaining surplus comprising recharge (R) and runoff (RO). The P and ET were based on long-term meteorological records from stations inside and outside the region. The surplus was distributed between runoff and recharge within the watershed according to land use, surficial geology (soil type) and slope. The MOEE (1995) method was applied in a GIS platform to assist with this process.

For the Trout Lake supply, the Tier 1 Simple Approach from MOE Module 7 is proposed. In the Trout Lake watershed, as with the greater Source Protection Area, water pathways are surface driven. That is, the low permeability bedrock outcrops drive much of the water to runoff to the watercourses. Water that does infiltrate recharges the shallow, more permeable, soil and then follows short groundwater pathways discharging to the watercourses as baseflow. Hence, over a long period of time the change in groundwater storage is essentially zero, and the surface watercourses eventually receive and convey all the water which is not evaporated or transpired. Figure 1 is a conceptual diagram that has been prepared to show these pathways.

Figure 1. Schematic Diagram of Conceptual Water Balance for the Trout Lake Sub-watershed

This Tier 1 Water Quantity Stress Assessment analysis utilizes available data, first collected and analyzed in the Conceptual Understanding phase, to evaluate the cumulative stress within the watershed. The screening assessment for the sub-watershed includes an estimation of the percentage of the consumptive amount of a water supply source that is demanded by water users. In this study, this percentage is referred to as the Percent Water Demand.

The Percent Water Demand calculation requires a quantitative assessment of both the supply and the demand. The surface water supply for Trout Lake includes the water that falls within catchment area feeding both Trout and Turtle Lakes (Figure 1), which comprises 181.1 km^2. However, none of the contributing streams are gauged, nor is the outlet of Trout or Turtle Lakes. Therefore, in order to provide a reliable estimate of the water coming into this catchment, an assessment of the total discharge was made, assuming that the watershed was in balance (i.e. inputs = outputs). Downstream on the Mattawa River, below Bouillon Lake is the nearest long term HYDAT gauging station (Number 02JE020). This station relates to a 951.5 km^2 total catchment area which includes the 181.1 km^2 of the Trout and Turtle Lake watersheds. Assuming that the physiography of these areas is quite similar, a proportional analysis of the 02JE020 data was done to estimate the outflow characteristics of the Trout and Turtle Lake watershed. This calculation incorporated the municipal North Bay water taking, allowing the total water into the smaller watershed to be calculated, as will be discussed in Section 2.1.1.1.

The current demand for the City of North Bay was calculated based on the "actual" takings recorded at the North Bay Water Treatment Plant in the greatest demand year for which data was available, 2007. Typically municipal water use is only about 20% consumptive, the rest being returned through treated sewage to the surface water system. However in this case, water is taken from Trout Lake (in the greater Ottawa River watershed) and discharged to Lake Nipissing (in the greater Lake Huron watershed). Since the water is removed from Trout Lake and ultimately discharged to Lake Nipissing as treated effluent, this represents a 100% consumptive use from Trout Lake's perspective. For the Tier 1 Simple Approach, the current and future (25-Year) demand scenarios were evaluated on a monthly basis, as identified in Table 1.

Table 1. Tier 1 Stress Assessment Scenarios (MOE 2007)

Time Period	Average Annual% Water Demand	Highest Monthly% Water Demand
Current Conditions	Groundwater Sources	Groundwater and Surface water sources
Future Conditions (25 years ahead)	Groundwater Sources	Groundwater and Surface water sources

As Table 1 indicates, surface water conditions are evaluated monthly, whereas groundwater systems are evaluated for both average annual and monthly conditions. The reason for this is that the rate of groundwater flow is so slow that there are only subtle differences between months, whereas monthly flow in surface water varies widely. For the reasons described above, this report deals only with the surface water source.

2.1.1 Water Budget Elements

The Tier 1 Water Budget for Trout Lake used a simple approach (for details see NBMCA, 2008) that estimated the various components of the hydrologic cycle (or water balance), including precipitation (P), and evapotranspiration (ET). These were calculated using available precipitation and temperature data (1971-2000) collected during the North Bay – Mattawa SPA Conceptual Water Budget phase. The calculations were conducted on a monthly basis to allow for monthly Tier 1 water quantity stress assessment. Water surplus (precipitation minus actual evapotranspiration) was calculated according to the methodology of Thornthwaite and Mather (1957). This calculation took into account monthly mean temperature and precipitation for climate stations within or near the North Bay – Mattawa SPA. Figure 2 shows the breakdown of this water balance. A total average annual precipitation over the 30 year period was 984 mm. Actual Evapotranspiration was 596 mm, leaving a surplus of 388 mm available for recharge and runoff, both of which will reach the watercourses.

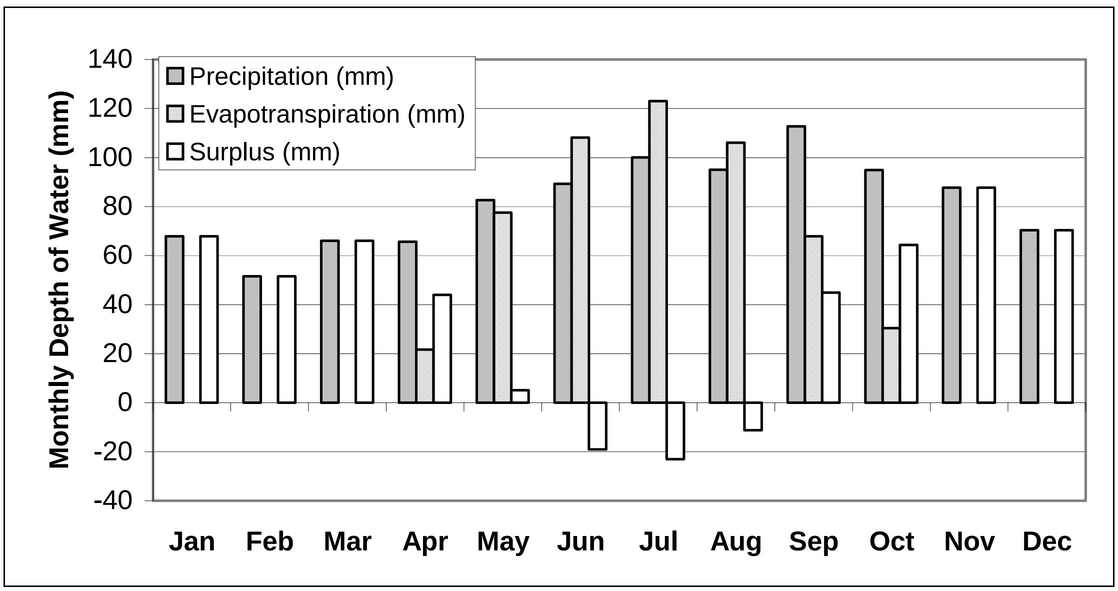

Figure 2. Monthly Water Budget Based on North Bay Meteorological Station (1971-2000)

Mean monthly streamflow at Mattawa River (02JE020) was used to estimate streamflow at the Turtle Lake outlet on a proportional basis described in Section 2.1, using data also from 1971-2000 for consistency with the climatic data.

2.1.1.1 Water Supply Estimation

The source of available drinking water supplies in a surface water system (e.g., river or creek) at any given time is limited to the flow to the system. The surface water quantity stress assessment takes into account the seasonal variability in streamflow, and is therefore evaluated using expected monthly values. However in a system drawing from a lake, the storage of the lake may be used to supplement the supply during low flow periods and, therefore, a modification of the stress assessment protocol is warranted.

As described previously a simple pro-rata of the average monthly discharge at 02JE020 was used to determine the outflow of the Trout/Turtle lake basin. However, before doing that, an account needed to be made for the North Bay water taking which does not go back into that basin. With reference to the conceptual drawing in Figure 1 the pro-rata needs to be applied to the total discharge of the greater watershed. That is, the streamflow at 02JE020 plus the North Bay Water taking is a more realistic measure of the water that contributes to the watershed. The pro-rata is then applied to this sum, to give an estimate of what contributes to the smaller Trout/Turtle watershed.

To do this the typical water taking by North Bay needs to be known for each month. Since the North Bay water taking is not known on a monthly basis for the entire period, it was deemed appropriate to develop an average number based on population. Rees, 1974 reports that the serviced population in 1972 was about 45,400. In 2007, when there are monthly water usage figures, the serviced population was 50,450. Assuming a linear population growth, the population growth was about 144.3 people per year. The average water use figures for the period have been determined for the median year in the period, 1986, when the population (estimated using the above figures) would have been about 47,420 people. The ratio of the 1986 population to the 2007 population is 0.94, which then may be applied to the 2007 water usage figures to determine the average monthly water use for the 30 period.

Table 2 has been prepared to show the results of this work. It is however useful to work through an example, in this case for the month of January. The mean monthly flow at 02EJ020 for January was 8.96 m^3/s for the thirty year period of 1971 to 2000[3]. The 2007 water taking by North Bay for this month was 1,135,743 cubic metres, which is equivalent to an average of 0.424 m^3/s. Applying the 0.94 factor to this, yields an average water taking or 0.399 m^3/s. Therefore the average contribution to the full watershed above 02EJ020, if taken as equal to the total withdrawal, is: $8.96 + 0.399 = 9.36$ m^3/s. By applying the pro-rata of watershed areas, the contribution to the Trout/Turtle sub-watershed is then: $181.1/951.5 \times 9.36 = 1.78$ m^3/s. As mentioned, Table 2 summarizes the monthly water supply to the Trout/Turtle Lake sub-watershed.

Table 2. Monthly Water Supply in the Trout Lake Sub-watershed

Month	Mean monthly Flow at 02JE020 (m^3/s)		2007 Water Takings from NB WTP (m^3/s)		Coefficient 1986:2007		Total Flow at 02JE020 (m^3/s)	Prorated Mean Monthly Flow in Trout Lake (m^3/s)
January	8.96	+	0.42	x	0.94	=	9.36	1.78
February	8.27	+	0.43	x	0.94	=	8.67	1.65
March	14.00	+	0.43	x	0.94	=	14.40	2.74
April	44.50	+	0.42	x	0.94	=	44.89	8.55
May	26.17	+	0.46	x	0.94	=	26.61	5.06
June	11.30	+	0.51	x	0.94	=	11.78	2.24
July	7.77	+	0.48	x	0.94	=	8.23	1.57
August	6.82	+	0.51	x	0.94	=	7.29	1.39
September	8.51	+	0.44	x	0.94	=	8.93	1.70
October	13.65	+	0.40	x	0.94	=	14.03	2.67
November	19.21	+	0.40	x	0.94	=	19.58	3.73
December	14.09	+	0.38	x	0.94	=	14.45	2.75
Annual Summary	**15.27**		**0.44**				**15.68**	**2.99**

Figure 3 depicts the mean monthly inflow distribution for the Trout/Turtle Lakes sub-watershed as derived in Table 2. From Figure 3 it is seen that the highest inflow occurs in April with a value of 8.55 m^3/s, whereas the lowest flow occurs in the late summer, with a mean flow of 1.39 m^3/s for August. The mean annual inflow to the sub-watershed is 2.99 m^3/s. From the flow distribution, it appears that the highest flow into the watershed is associated with snowmelt in the spring. Conversely, the lowest flow occurs either in February when there is little runoff due to low temperatures and zero recharge, or at the end of summer when rainfall is minimal and evaporative uptake is high. It must, however, be noted that low discharge in February/August may not be a limiting factor given the available storage in the lake and interim replenishment in the spring.

One of the limitations of using observed outflow data in any water management assessment as representative of the inflow (assuming zero basin storage changes) is that the outflow is not regulated on available water, but rather on boating depths on the lakes (P. Bullock, personal communication, 2008). That is, some outflows in the summer months will be lower than the corresponding inflow, as managers try to maintain certain boating depths. Therefore the inflow, calculated above to represent water supply to the lakes, will be lower than what is actually coming in. Therefore the above analysis is conservative in nature, that is, the water supply is greater than that estimated here. It is also useful to examine the sensitivity of the lake to water taking. The peak monthly water usage of 1,464,198 m^3 was recorded in July of 2005. Expressed over the 21.6 km^2 lake area (Figure 1), this is equivalent to a depth of 68 mm or about two and a half inches of water. Based on Bullock, 2008, freeboard in the lake is about 2 m, from 201.0 mASL to 203.0 mASL for the 1:100 year low water level and 1:100 year flood, respectively. The average water level is 202.0 mASL. A monthly change of 0.068 m is therefore easily accommodated.

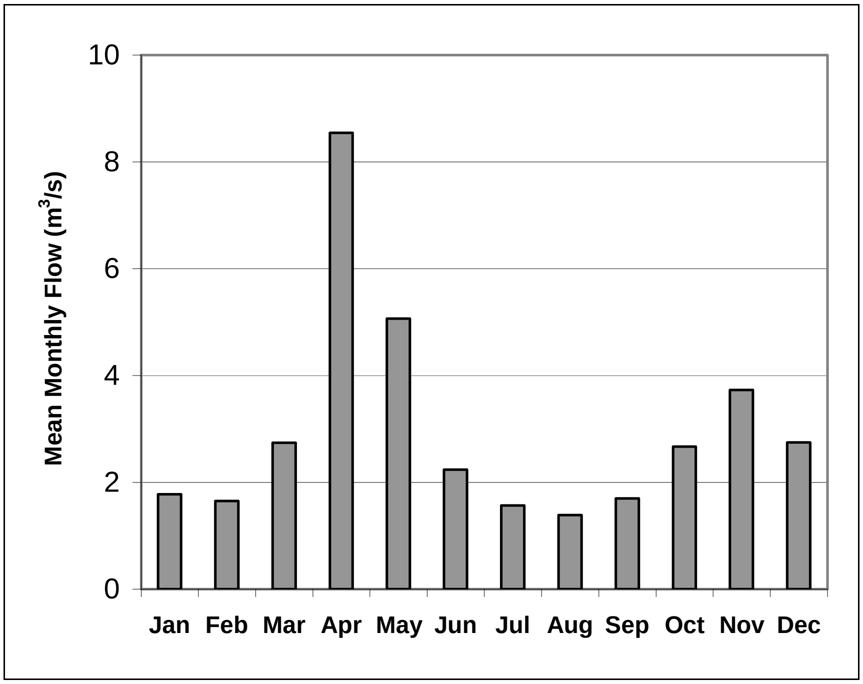

Figure 3. Mean Monthly Flow (Water Supply) to the Trout Lake Sub-watershed Based on the Streamflow Measurement at 02JE020 Located on Mattawa River

Finally, some consideration was given to the use of median monthly flows in this assessment, as specified in the Guidance Module, versus average monthly flows. Median flows are correctly thought to be more representative of normal conditions, as they are not influenced as much by high flow precipitation events. This is particularly true for evaluating a water taking from a watercourse where there is little storage of water. However, the Trout Lake water source is in reality a very large storage reservoir. As such it effectively captures large storm events which contribute to replenishing storage. Based on this, it was deemed more appropriate to use average monthly flows for the purpose of this assessment.

2.1.1.2 Water Demand Estimation

Within the current methodology, water demand only relates to water taken as a result of an anthropogenic activity (e.g., municipal supply water takings, private water well takings as well as other permitted takings), that is, a partial or total consumptive use. In a strict sense, consumptive water demand refers to water taken from surface or groundwater and not returned locally in a reasonable period of time.

The consumptive surface water use/demand was quantified based on the Ministry of Environments Permit to Take Water (PTTW) database for the North Bay - Mattawa SPA (see Table 3). The database revealed three permit holders located within the Trout Lake sub-watershed: the City of North Bay's municipal water supply, the Department of National Defence for industrial cooling water and a small communal water supply, and an agricultural permit for irrigation. The quantities of permitted water taking as reported in the PTTW database are generally presented as maximum allowable takings over a period of time and do not usually reflect the actual taking. As a result, using permitted water takings to estimate water demand typically overestimates the actual demand.

Table 3. Consumptive Surface Water Use in the Trout Lake Sub-watershed

Permit No.	Source Name	Purpose of Taking	Period of Taking	Water Taking (Mm3/yr)	Consumptive Factor	Consumptive Use (Mm3/yr)
4187-6P2HR4	Trout Lake	Industrial (Cooling Water)	365 days	3.90	0.25	0.975
	Trout Lake	Communal Water Supply	365 days	0.02	0.2	0.004
90-P-5838	Trout Lake	Municipal Water Supply	365 days	29.02	1	29.02
00-P-5052	Four Mile Creek	Agriculture (Field and Pasture Crops)	92 days (Jun. 1 - Aug. 30)	0.02	0.8	0.016
		TOTAL		**32.96**		**30.01**

Consequently, actual taking quantities were used in the calculations for the North Bay Water Treatment Plant where they are available. As seen in Figure 4, actual water takings in 2007 from the NBWTP were used in the analysis as being most representative of current water use patterns. 2007 is also the year of heaviest use with 13.9 million cubic metres withdrawn, in comparison to 13.4 million in 2006 and 13.0 million in 2005. No actual water use information is available for the remaining permitted water users. As a conservative approach, the maximum permitted values were used to estimate the water demand.

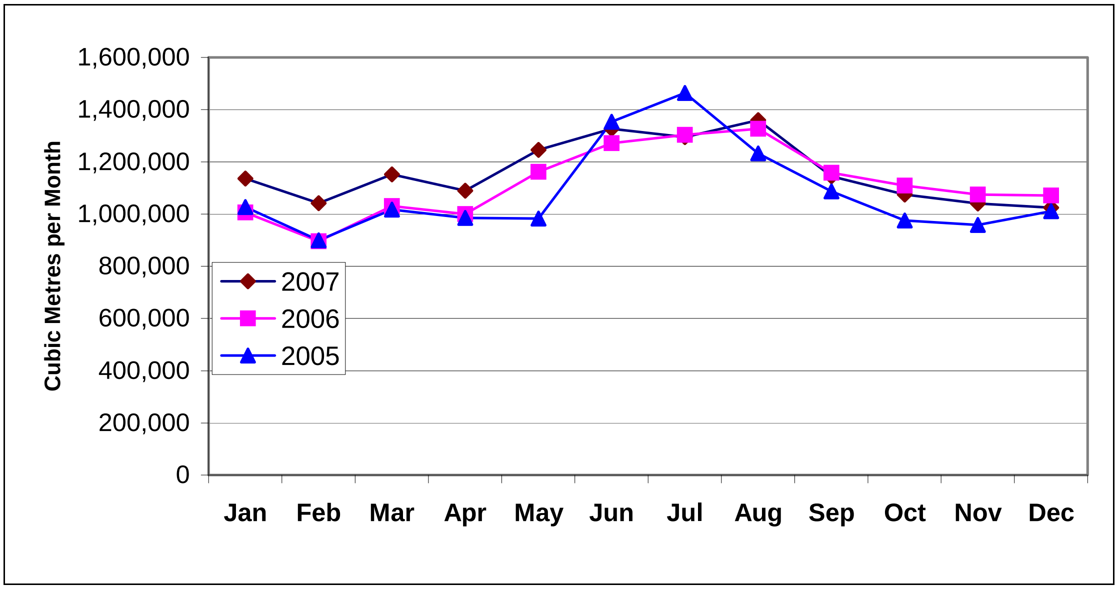

Figure 4. Monthly Water Takings at the North Bay Water Treatment Plant

Table 3 summarizes the current water takings from Trout Lake estimated on a monthly basis. Notice that the highest total water demand occurs in the May to August period, which is about 5 to 14% higher than the average month.

The consumptive water use or demand was computed as:

Consumptive water use = *Actual Demand – Amount returned*
= *CF x Actual Demand*

where *CF* represents the consumptive use factor for each use. For the analysis of the Trout Lake municipal water taking, the CF of 1.0 has been used. This is done instead of a CF = 0.2, recommended by the MOE guidance documents, because the water taken from Trout Lake is not returned to the Trout Lake, but rather to Lake Nipissing. The CF for other water use was taken as the default CF value from Appendix D of the Tier 1 Stress Assessment Module 7 Guidance document (MOE, 2007). The actual values applied here are noted at the bottom of Table 3. Applying these CF values to the quantities listed in Table 3, yields the estimated consumptive water demands listed in Table 4. Notice that the highest monthly total consumptive water demand occurs also in the summer period.

Table 3. Current Total Water Demand (Takings) of the Trout/Turtle Lake Sub-watershed

Month	NB WTP (m^3/s)	Industrial Cooling (m^3/s)	Communal Water Supply (m^3/s)	Agriculture (m^3/s)	Total Demand (m^3/s)
January	0.4240	0.1236	0.0006	0.0000	0.5483
February	0.4306	0.1236	0.0006	0.0000	0.5549
March	0.4300	0.1236	0.0006	0.0000	0.5543
April	0.4200	0.1236	0.0006	0.0000	0.5443
May	0.4650	0.1236	0.0006	0.0000	0.5893
June	0.5117	0.1236	0.0006	0.0075	0.6435
July	0.4836	0.1236	0.0006	0.0075	0.6154
August	0.5078	0.1236	0.0006	0.0075	0.6396
September	0.4414	0.1236	0.0006	0.0000	0.5657
October	0.4013	0.1236	0.0006	0.0000	0.5256
November	0.4013	0.1236	0.0006	0.0000	0.5256
December	0.3826	0.1236	0.0006	0.0000	0.5069
Annual Average	**0.4416**	**0.1236**	**0.0006**	**0.0019**	**0.5678**
Consumptive Factors	**1**	**0.25**	**0.2**	**0.8**	

Table 4. Current Consumptive Water Demand (Takings) of the Trout/Turtle Lake Sub-watershed

Month	NB WTP (m^3/s)	Industrial Cooling (m^3/s)	Communal Water Supply (m^3/s)	Agriculture (m^3/s)	Total Demand (m^3/s)
January	0.424	0.0309	0.0001	0.0000	0.4550
February	0.4306	0.0309	0.0001	0.0000	0.4616
March	0.43	0.0309	0.0001	0.0000	0.4610
April	0.42	0.0309	0.0001	0.0000	0.4510
May	0.465	0.0309	0.0001	0.0000	0.4960
June	0.5117	0.0309	0.0001	0.0060	0.5488
July	0.4836	0.0309	0.0001	0.0060	0.5207
August	0.5078	0.0309	0.0001	0.0060	0.5449
September	0.4414	0.0309	0.0001	0.0000	0.4724
October	0.4013	0.0309	0.0001	0.0000	0.4323
November	0.4013	0.0309	0.0001	0.0000	0.4323
December	0.3826	0.0309	0.0001	0.0000	0.4136
Annual Average	**0.4416**	**0.0309**	**0.0001**	**0.0015**	**0.4742**

Consideration may also be given to the effect of existing and future aggregate extraction on water quantity. Most pits or quarries are located above the water table, and therefore do not extract groundwater. They in fact represent a potential net increase in recharge (based on precipitation with no transpirative uptake by plants, but with increased evaporative losses). Some pits or quarries below the water table require water extraction typically discharged to local streams. The water therefore ends up in the surface water system. There may be some evaporative loss (about 25%) but the size and extent of these operations is minimal in comparison to the very much greater size of the Trout Lake watershed. Based on this, it has been assumed that no significant net changes to the water balance occur from this kind of operation, and therefore it was not included in the consumptive demand calculation.

For the future conditions scenario, the only expected change in the demands listed in Tables 3 and 4 are for the City of North Bay Water Treatment Plant. The future water demand is based on a projected increase in population for the City of North Bay of 4,230 within the next 25 years (Watson and Associates, 2006). The increased demand for the municipal water taking was based on 2007 average consumption of approximately 725 L/capita/day for each North Bay resident. Applying this expected consumption rate to the projected population increase results in an additional water taking rate at the North Bay Water Treatment Plant of only 0.035 m^3/sec.

Table 5 summarizes the water takings from the Trout Lake sub-watershed estimated on a monthly basis for future conditions 25 years from now. Applying the same consumptive use factors as noted at bottom of Table 3, the expected future 25 year consumptive water demands are noted in Table 6.

Table 5. Future Total Water Demand of the Trout/Turtle Lake Sub-watershed

Month	NB WTP (m^3/s)	Industrial Cooling (m3/s)	Communal Water Supply (m3/s)	Agriculture (m3/s)	Total Demand (m3/s)
January	0.4595	0.1236	0.0006	0.0000	0.5838
February	0.4661	0.1236	0.0006	0.0000	0.5904
March	0.4655	0.1236	0.0006	0.0000	0.5898
April	0.4555	0.1236	0.0006	0.0000	0.5798
May	0.5005	0.1236	0.0006	0.0000	0.6248
June	0.5472	0.1236	0.0006	0.0075	0.6790
July	0.5191	0.1236	0.0006	0.0075	0.6509
August	0.5433	0.1236	0.0006	0.0075	0.6751
September	0.4769	0.1236	0.0006	0.0000	0.6012
October	0.4368	0.1236	0.0006	0.0000	0.5611
November	0.4367	0.1236	0.0006	0.0000	0.5610
December	0.4181	0.1236	0.0006	0.0000	0.5424
Annual Summary	**0.4771**	**0.0309**	**0.0001**	**0.0015**	**0.6033**

Note: Future scenario computed as 25 years from now

Table 6. Future Consumptive Water Demand of the Trout/Turtle Lake Sub-watershed

Month	NB WTP (m^3/s)	Industrial Cooling (m^3/s)	Communal Water Supply (m^3/s)	Agriculture (m^3/s)	Total Demand (m^3/s)
January	0.4595	0.0309	0.0001	0.0000	0.4905
February	0.4661	0.0309	0.0001	0.0000	0.4971
March	0.4655	0.0309	0.0001	0.0000	0.4965
April	0.4555	0.0309	0.0001	0.0000	0.4865
May	0.5005	0.0309	0.0001	0.0000	0.5315
June	0.5472	0.0309	0.0001	0.0060	0.5843
July	0.5191	0.0309	0.0001	0.0060	0.5562
August	0.5433	0.0309	0.0001	0.0060	0.5804
September	0.4769	0.0309	0.0001	0.0000	0.5079
October	0.4368	0.0309	0.0001	0.0000	0.4678
November	0.4367	0.0309	0.0001	0.0000	0.4677
December	0.4181	0.0309	0.0001	0.0000	0.4491
Annual Average	**0.4771**	**0.0309**	**0.0001**	**0.0015**	**0.5096**

Note: Future scenario computed as 25 years from now

2.1.1.3 Water Reserve Estimation

Water reserve is an estimate of the amount of streamflow or lake reserve that needs to be reserved to support other uses of water within the watershed: including both ecosystem requirements (instream flow needs) as well as other human uses, both future permitted uses and current and future non-permitted uses. Typically the MOE Guidance documents require a 10% reserve for surface water systems. It has been determined through discussion with the peer review team and NBMCA that no reserve is necessary for the purpose of this Tier 1 assessment. This is based on the unique setting of the Trout/Turtle Lake reserve as the following discussion outlines.

The 10% reserve was originally intended to provide supply to the downstream users of the surface water system. In this case the downstream water flow is governed not by the relatively small water taking, but by the regulation of the lake for water depths. Based on conversations with Mr. Bullock of the City of North Bay, the outlet of Turtle Lake is always observed to be flowing, even when there is no overflow from the dam. That is, the leakage from the dam, through the stop logs, is significant and is driven by the total head behind the dam, and not the incremental change at the crest. The 10% reserve is also applied to water takings from rivers and other watercourses. However the watershed that supplies Trout and Turtle lakes are upstream of the water taking and therefore not affected by it. Some consideration was also given to treating the lakes the same as a groundwater reservoir, like an aquifer, just one with 100% storage. It was deemed inappropriate, as the full storage of the lake could never physically be tapped. Indeed the storage in just the 2 m of freeboard, expressed over the area of the lake is over 43 million cubic metres, or more than 3 times the current or future water taking in 25 years. For these reasons, no reserve is being applied to this analysis.

2.1.1.4 Tier 1 Water Budget

In addition to providing an integrated water budget summary for the entire North Bay - Mattawa SPA, water budgets were calculated for five sub-watersheds under the Conceptual Water Budget (NBMCA, 2008). As the watershed region is composed of numerous lakes and wetlands and its soil structure is mostly of silt, sand and gravel, there is a significant interaction between surface water and groundwater in terms of localized baseflow contribution to the streams. For example, for the Mattawa River Watershed, a total of about 50% of surplus water was identified as baseflow.

Based on the assessment in the Conceptual Water Budget report, a detailed water budget analysis for Trout Lake was conducted for its contributing watershed as a part of this Tier 1 analysis. The total contributing catchment area for Trout Lake is estimated to be 181.1 km^2. The mean monthly and annual components of the water balance were calculated by the method of Thornthwaite and Mather (1957). The possible need to break out the surface area of the lakes (21.6 km^2) which represent just under 12% of the sub-watershed, was considered. This analysis recognized that the lakes likely have a different rate of evaporative loss to the atmosphere in comparison to the evapotranspirative loss from the land surfaces. In fact, Rees, 1974 reported that the evaporative loss for 1972 was about 16" or 425.7 mm. 1972 was a relatively wetter and cooler year, and therefore the average evaporative loss might be higher. In comparison the actual annual evapotranspiration found in this study is 534.9 mm. It was found that incorporating the lake area adjustments made only a 2.5% difference between in the total surplus volumes, and therefore the more simple approach of approximating the evaporation with the actual evapotranspiration rates was used here.

Table 7 summarizes the Tier 1 monthly water budget for the Trout/Turtle lake sub-watershed. In order to allow comparison to measured streamflow and water taking rates, the water depths determined from the water balance were multiplied by the contributing catchment area, and converted to flows expressed as m^3/s. For example the mean monthly precipitation[4] for January of 67.8 mm, multiplied by 181.1 km^2 (justified for units) is:

$$= \frac{67.8 \text{ mm/month} \times 10^{-3} \text{ m/mm} \times 181.1 \text{ km}^2 \times 10^6 \text{ m}^2/\text{km}^2}{31 \text{ days/mo} \times 24 \text{ hr/day} \times 3600 \text{ s/hr}}$$

$$= 4.59 \text{ m}^3/\text{s}$$

As shown in Table 7, the average annual precipitation falling on the Trout Lake watershed is 5.64 m^3/s. Approximately 3.05 m^3/s (or approximately 54% of annual precipitation) is lost through evapotranspiration and 2.59 m^3/s (or approximately 46% of annual precipitation) of water remains

4. The values for the full year are shown graphically on Figure 2.

as surplus. The amount of surplus is assumed to reach the lake more quickly through runoff and more slowly through groundwater pathways. Out of 2.59 m^3/s of surplus water, 0.5483 m^3/s are typically withdrawn from Trout Lake for municipal water supply and for other permitted water uses. As mentioned in Section 4 of the Conceptual Water Budget report, the total streamflow should theoretically be equal to the surplus, given that groundwater storage changes are negligible over longer periods of time. In this watershed, estimated surplus matches with streamflow within about 11%, which is reasonable given the variability of precipitation volumes. A breakdown of water surplus, streamflow, and water takings on a monthly basis is shown on Figure 5 graphically.

Table 7. Monthly and Annual Water Budget for the Trout Lake Sub-watershed

Month	Precipitation (m^3/s)	Actual ET (m^3/s)	Surplus (m^3/s)	Streamflow[1] (m^3/s)	Water Taking [2] (m^3/s)
January	4.59	0.00	4.59	1.78	0.5483
February	3.86	0.00	3.86	1.65	0.5549
March	4.46	0.00	4.46	2.74	0.5543
April	4.59	1.51	3.07	8.55	0.5443
May	5.59	5.24	0.35	5.06	0.5893
June	6.23	7.56	Deficit (-1.33)	2.24	0.6435
July	6.77	8.32	Deficit (-1.56)	1.57	0.6154
August	6.42	7.17	Deficit (-0.75)	1.39	0.6396
September	7.88	4.75	3.14	1.70	0.5657
October	6.41	2.06	4.36	2.67	0.5256
November	6.12	0.00	6.12	3.73	0.5256
December	4.76	0.00	4.76	2.75	0.5069
Annual Average	**5.64**	**3.05**	**2.59**	**2.99**	**0.5678**

Note: 1. *Mean flow into the watershed as reported in Table 2, not including the water taking.*
2. *This includes water takings by the City of North Bay Water Treatment Plant as well as water takings by other permitted users (see also Table 3 in Section 2.1.1.2 for details)*

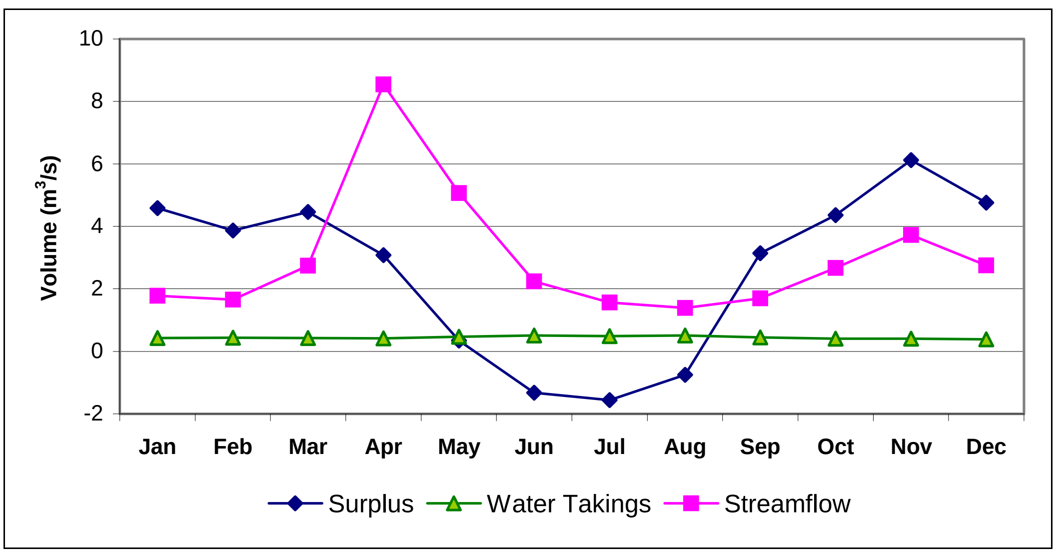

Figure 5. Water Surplus, Streamflow and Water Takings in the Trout Lake Sub-watershed

When comparing water surplus with water takings, it may initially appear that May through August are the months when water taking exceeds the surplus and a deficit condition to the lake may occur. However this is not observed in practice due to the slower groundwater pathways. That is, some of the recharge of the surplus from earlier months will reach the lake as baseflow, supplementing the water supply. More importantly, the lake acts as a large reservoir, effectively buffering the effects of monthly deficits. Figure 5 shows that inflow to the lake always exceeds water taking amounts.

2.1.2 Sub-watershed Stress Assessment

The Tier 1 stress assessment is designed to identify sub-watersheds where the degree of stress warrants refined water budget efforts for stress characterization. The stress assessment as outlined in the MOE Guidance manual evaluates the ratio of the consumptive water demand to the available water supplies, minus water reserves within the sub-watershed as is listed as follows:

$$\textit{\% Water Demand (Surface Water)} \quad \frac{Q_{DEMAND}}{Q_{SUPPLY} - Q_{RESERVE}} \times 100$$

The terms of the equation were determined as follows:

- **Q_{Supply} (*Surface Water Supply)*:**
  Calculated on a monthly basis using the measured streamflow data (1971-2000) of Gauge Station 02JE020 and applying the pro-rata of catchment area of two sub-watersheds, presented in Table 2 .
- **Q_{Demand} (*Surface Water Demand*):**
  Calculated as the actual water takings from the Trout Lake at the North Bay Water Treatment Plant in the latest year 2007 plus the maximum permitted rates of the other takings listed in MOE PTTW database as described in Section 2.1.1.2 ;
- **$Q_{Reserve}$ (*Surface Water Reserve*):**
  Typically calculated as 10% of the total surface water supply, but taken here as 0% as outlined in Section 2.1.1.3;
- *%* ***Surface Water Demand*****:**
  Calculated using the expression mentioned above.

Base on the Percent Water Demand, the Trout Lake sub-watershed is assigned a stress level on the following basis. The thresholds for assigning the degree of stress (low, moderate or significant) for the surface water assessment are given in Table 8 below.

Table 8. Surface Water Stress Thresholds

Surface Water Quantity Stress Level Assignment	Maximum Monthly Percent Water Demand
Significant	> 50%
Moderate	20% - 50%
Low	<20%

At the Tier 1 level for the Trout Lake sub-watershed, two scenarios were evaluated:

a) current conditions; and
b) 25-year future demand.

Using the information given in Tables 2 to 6, the Trout Lake sub-watershed stress level for both current and future conditions was determined. Table 9 summarizes the stress level computations for current conditions, whereas Table 10 gives the stress level results for the future conditions.

Table 9. Current Percent Water Demand and Stress Level

Month	Total Supply (Streamflow) (m^3/s)	Total Demand (takings) (m^3/s)	% Water Demand	Stress Level Assignment
January	1.781	0.5483	30.7931	Moderate
February	1.651	0.5549	33.6090	Moderate
March	2.742	0.5543	20.2174	Moderate
April	8.545	0.5443	6.3696	Low
May	5.063	0.5893	11.6382	Low
June	2.242	0.6435	28.7032	Moderate
July	1.565	0.6154	39.3304	Moderate
August	1.389	0.6396	46.0391	Moderate
September	1.698	0.5657	33.3056	Moderate
October	2.670	0.5256	19.6875	Low
November	3.728	0.5256	14.0987	Low
December	2.750	0.5069	18.4335	Low

Table 10. Future Percent Water Demand and Stress Level

Month	Total Supply (Streamflow) (m^3/s)	Total Demand (takings) (m^3/s)*	% Water Demand	Stress Level Assignment
January	1.781	0.5838	32.7869	Moderate
February	1.651	0.5904	35.7592	Moderate
March	2.742	0.5898	21.5123	Moderate
April	8.545	0.5798	6.7851	Low
May	5.063	0.6248	12.3394	Low
June	2.242	0.6790	30.2867	Moderate
July	1.565	0.6509	41.5992	Moderate
August	1.389	0.6751	48.5944	Moderate
September	1.698	0.6012	35.3957	Moderate
October	2.670	0.5611	21.0173	Moderate
November	3.728	0.5610	15.0483	Low
December	2.750	0.5424	19.7245	Low

*Note: * Total consumptive water demand, Future conditions for 25 years from now.*

Under current conditions, the maximum monthly surface water demand of approximately 46.0% occurs in the month of August. The stress level associated with the percentage water demand is assigned as **"Moderate"** in accordance with the thresholds as listed in Table 8. Other Moderate but less severe months are also in the summer: June, July and September. The summer period is more critical than the spring or autumn because of the great evapotranspirative uptake coupled with declining streamflow into the lakes. January, February and March are also moderate, because of the low streamflow during winter freezing conditions. In total, seven months were assigned a stress level of "moderate", with the remaining five months receiving a "low" stress level assignment.

The future (25-year) scenario is presented in table 10. In general, the future results are about 2% greater than the existing scenario and up to 2.5% greater in the summer months. The monthly ratings for the future scenario are the same as the current conditions with the exception of October, which changed from a current rating of low to a future rating of moderate.

2.1.3 Potential Drought Conditions

It is beyond the scope of this document to examine climate change to provide a prediction of future weather conditions. However, multi-year droughts have occurred in past, most recently in late 1997 to early 1999. For example the average annual streamflow in the Lavase River and Chippewa Creek were a significant fraction of their normal values in 1998 (Table 11)[5].

Table 11. Comparison of 1998 Streamflow (m^3/s) to Average Condition

Water Course	Lavase River (02DD013)	Chipwa Creek (02DD014)
1971 to 2000 average flow	0.960	0.638
1998 average annual flow	0.609	0.495
1998 as% of average	63.4%	77.6%

To provide a basis to compare changes in stress level due to potential drought conditions, a streamflow reduction was arbitrarily set at 70% of normal flow for the existing condition. Table 12 shows the change in stress levels for this simulated drought condition. The peak months of August and July have risen from a moderate designation to a high designation. There are now only 2 months of low stress levels in the spring and early winter, 8 months of moderate stress levels, plus the high level in July and August. It must be emphasized that in the case of the Trout Lake reservoir, the lake storage will be a mitigating factor, as was the case in 1998 for North Bay.

5. *Corresponding values for station 02JE020 on the Mattawa River were not available.*

Table 12. Comparison of Percent Water Demand and Stress Level for Current Conditions and Simulated Drought Conditions

Month	Current Conditions				Simulated Drought Conditions			
	Total Supply (Streamflow) (m^3/s)	Total Demand (takings) (m^3/s)	% Water Demand	Stress Level Assignment	Total Supply (70% of Streamflow) (m^3/s)	Total Demand (takings) (m^3/s)	% Water Demand	Stress Level Assignment
January	1.781	0.5483	30.8	**Moderate**	1.246	0.5483	44.0	**Moderate**
February	1.651	0.5549	33.6	**Moderate**	1.156	0.5549	48.0	**Moderate**
March	2.742	0.5543	20.2	**Moderate**	1.919	0.5543	28.9	**Moderate**
April	8.545	0.5443	6.4	**Low**	5.981	0.5443	9.1	**Low**
May	5.063	0.5893	11.6	**Low**	3.544	0.5893	16.6	**Low**
June	2.242	0.6435	28.7	**Moderate**	1.569	0.6435	41.0	**Moderate**
July	1.565	0.6154	39.3	**Moderate**	1.095	0.6154	56.2	**High**
August	1.389	0.6396	46.0	**Moderate**	0.973	0.6396	65.8	**High**
September	1.6 98	0.5657	33.3	**Moderate**	1.189	0.5657	47.6	**Moderate**
October	2.670	0.5256	19.7	**Low**	1.869	0.5256	28.1	**Moderate**
November	3.728	0.5256	14.1	**Low**	2.609	0.5256	20.1	**Moderate**
December	2.750	0.5069	18.4	**Low**	1.925	0.5069	26.3	**Moderate**
Annual Average	**2.99**	**0.5678**	**25.2**	**Moderate**	**2.090**	**0.5678**	**36.0**	**Moderate**

It is also important to recognize that this is an estimate intended as a sensitivity analysis only. It is considered possible that the surplus may actually rise, due to more intense rainfall events yielding more runoff. For water takings from a watercourse, this water may not be available for withdrawal; however for a reservoir such as Trout Lake, this water can be captured and retained, and the supply value may actual increase. For this reason the above analysis for drought should be considered carefully, and should not be the basis for rating decisions on watershed stresses.

2.1.4 Recommendation for Tier 2

MOE Guidance Module 7 (MOE, 2007) indicates that sub-watersheds assigned a “Moderate” to “Significant” level of stress require a Tier 2 Water Budget and Water Quantity Stress Assessment. The above discussion identifies that the Trout Lake water supply is at a moderate level of stress for seven months of the year. For this reasons it is recommended that a Tier 2 level of study be conducted for the Trout Lake sub-watershed.

3. Uncertainty

Uncertainty is inherent in the water budget estimation process. The accuracy of estimates is reliant on the quality of input data. Observations pertaining to climate, streamflow and hydrology contain uncertainty of measurement. For example, precipitation can vary by as much as 25% between meteorological stations, and in the case of the North Bay Mattawa SPA the stations are very far apart. Each of these factors can lead to uncertainty in the water budget estimates which may then compound the uncertainty when applied to the sub-watershed stress assessment. This uncertainty particularly becomes important if a sub-watershed has been assigned a stress level near the low-moderate threshold.

The Tier 1 stress assessment seeks to determine water quantity stress on a watershed/ sub-watershed basis utilizing existing observed data or simple, ideally conservative, estimates of various elements of the hydrologic cycle. In some cases some of these estimates may be subject to considerable uncertainly. For example, for the Trout Lake Sub-watershed Stress Assessment, surface water supply in the lake was calculated based on a gauge (02JE020 on the Mattawa River some 28 km downstream of Trout Lake) and the streamflow data was pro-rated to calculate water supply in the lake. This estimate may contain considerable uncertainty in the calculation of final percentage water demand.

4. Significant Recharge Areas

As part of the water budgetting exercise completed in the Conceptual Water Budget for the North Bay-Mattawa SPA, recharge rates were determined across the North Bay-Mattawa SPA (NBMCA, 2007). As described in Guidance Module 7 (MOE, 2007), recharge is the process by which water moves from the ground surface, through the unsaturated zone, to arrive at the water table. Given that recharge is an integral part of understanding the flow systems across the watershed, it was important for the Water Quantity Stress Assessment to address the issue of "significant" recharge areas. As identified in Guidance Module 7, the use here of the term "significant" is different than that used to define a level of stress in the source water protection stress assessment process.

Significant recharge areas were delineated (described below) using the more simple methods outlined in Appendix B of Guidance Module 7. The identification of the Significant Recharge Areas for any given watershed is considered a two-step process. The first step is to delineate those areas that provide the most volume over the smallest area of recharge to the watershed. These areas are labelled as "High Recharge Volume Areas". The second step is to consider which of these areas, or other low volume recharge areas might be considered significant within the context of the watershed.

Significant recharge area mapping was conducted using the High Volume Recharge Area Delineation method (# 3) described in Guidance Module 7. In this methodology, high volume recharge areas were delineated based on those areas that have a recharge rate of greater than 1.15 times the average annual recharge rate to the watershed under consideration. The high volume recharge areas for the entire North Bay-Mattawa SPA are found on Map 2.

The High Volume Recharge Areas delineated above are all certainly strong contenders to be identified as Significant Recharge Areas. However, it should be pointed out that even some areas with a lower recharge rate might be considered significant if they are essential in maintaining an important hydrological or ecological function. However, such areas are not identified with the Trout Lake sub-watershed.

The high volume recharge areas in the North Bay-Mattawa SPA (Map 2) provides general recharge to subsurface aquifers in areas with little or no water use or no municipal water demand and are thus not deemed significant in the context of this surface water driven system which is highly regulated[7].

5. Data and Knowledge Gaps

There is no measured water discharge data for the Trout/Turtle Lake reservoir, which limits the ability to do an accurate water balance for the lake. Normally it would be a recommendation of this report that a proper gauge be constructed to measure continuous streamflow at this location. However, the City of North Bay have indicated that management of the reservoir is conveniently done to daily measured water levels and the flow data would only be of secondary use. In addition, the discharge point is not amenable to retrofit, nor is there a power source within any reasonable distance. There is no climate station directly in the sub-watershed. Precipitation and temperature data were obtained from North Bay Airport to calculate water budget components for the Trout Lake sub-watershed. Given the breadth of the watershed under consideration a second station at the east end of the Lake is recommended.

6. Summary

A Tier 1 Water Budget and Water Quantity Stress Assessment has been completed for Trout Lake, source of drinking water supply for the City of North Bay. A water budget was calculated for the Trout Lake sub-watershed. A water quantity stress assessment was conducted on the Trout Lake

7. *This does not say that the ecologic function is insignificant, however evaluation of this important function is beyond the scope of this document.*

water supply. An analysis was performed based on existing conditions and on 25-year future demands.

It has been concluded that the stress assignment for Trout Lake is **MODERATE** especially during the summer season when the water demand is high and there is declining inflow to the lake. Based on the **MODERATE** stress level assignment, there is a need to proceed to a detailed Tier 2 Water Budget and Water Quantity Stress Assessment for the water supply in the North Bay – Mattawa SPA.

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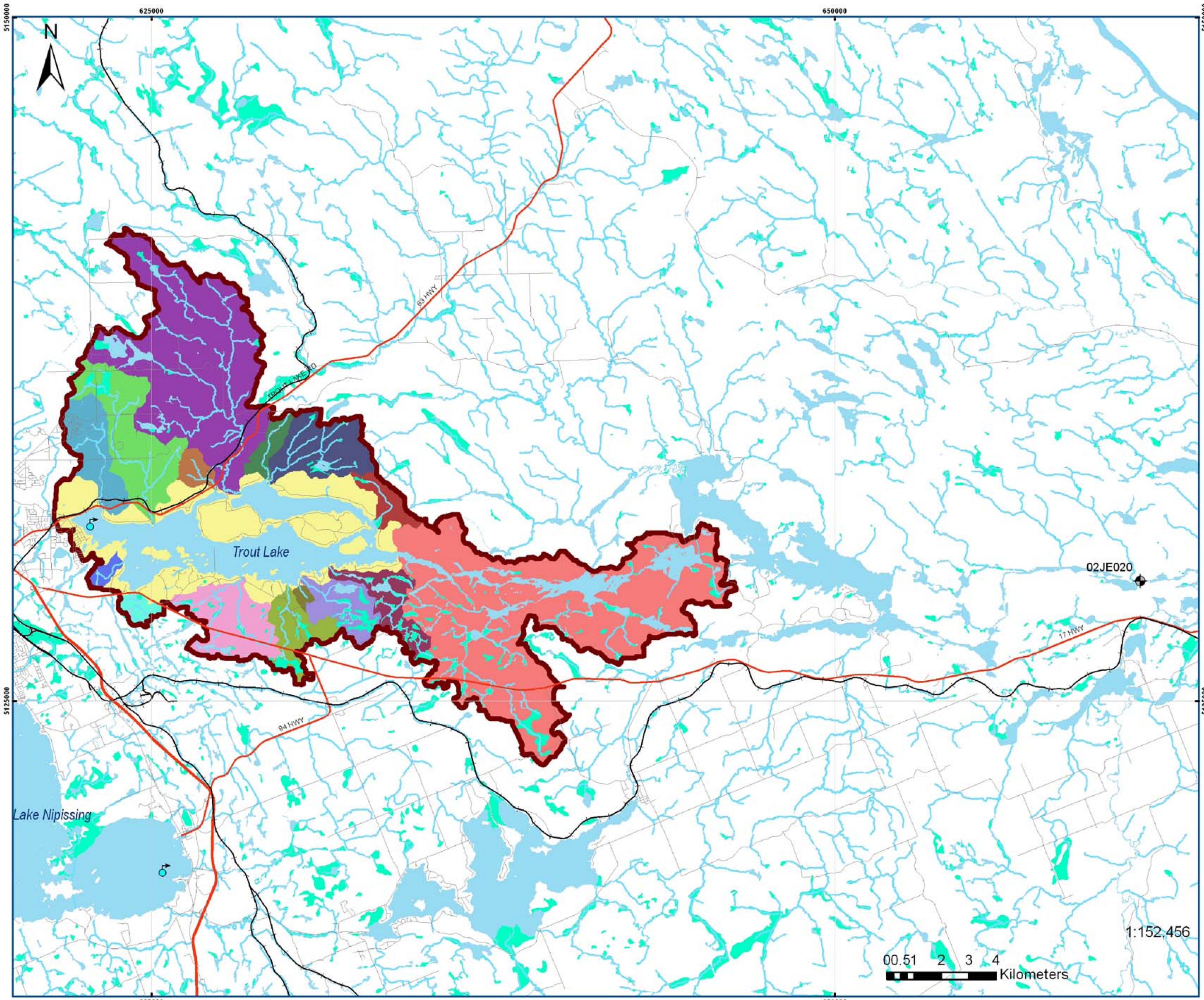
North Bay-Mattawa Source Protection Area - Tier 1
MAP 1 - Trout Lake Subwatersheds

NORTH BAY – MATTAWA

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER



Legend

- Subwatershed Boundary
- HYDAT 02JE020
- Doran Creek
- Four Mile Creek
- Hogan Creek
- Lees Creek
- Local Drainage
- Unnamed Creek
- Unnamed Creek NB-2411
- Unnamed Creek NB-2411a
- Unnamed Creek NB-2427
- Unnamed Creek NB-2431
- Unnamed Creek NB-2433
- Unnamed Creek NB-2433a
- Unnamed Creek NB-2433b
- Unnamed Creek NB-2433c
- Unnamed Creek NB-3141
- Turtle Lake areas
- WaterWithdrawal
- Highway
- Road
- Railway
- River/Creek
- Intermittent Stream
- Waterbody
- Wetland

NORTH BAY-MATTAWA CONSERVATION AUTHORITY

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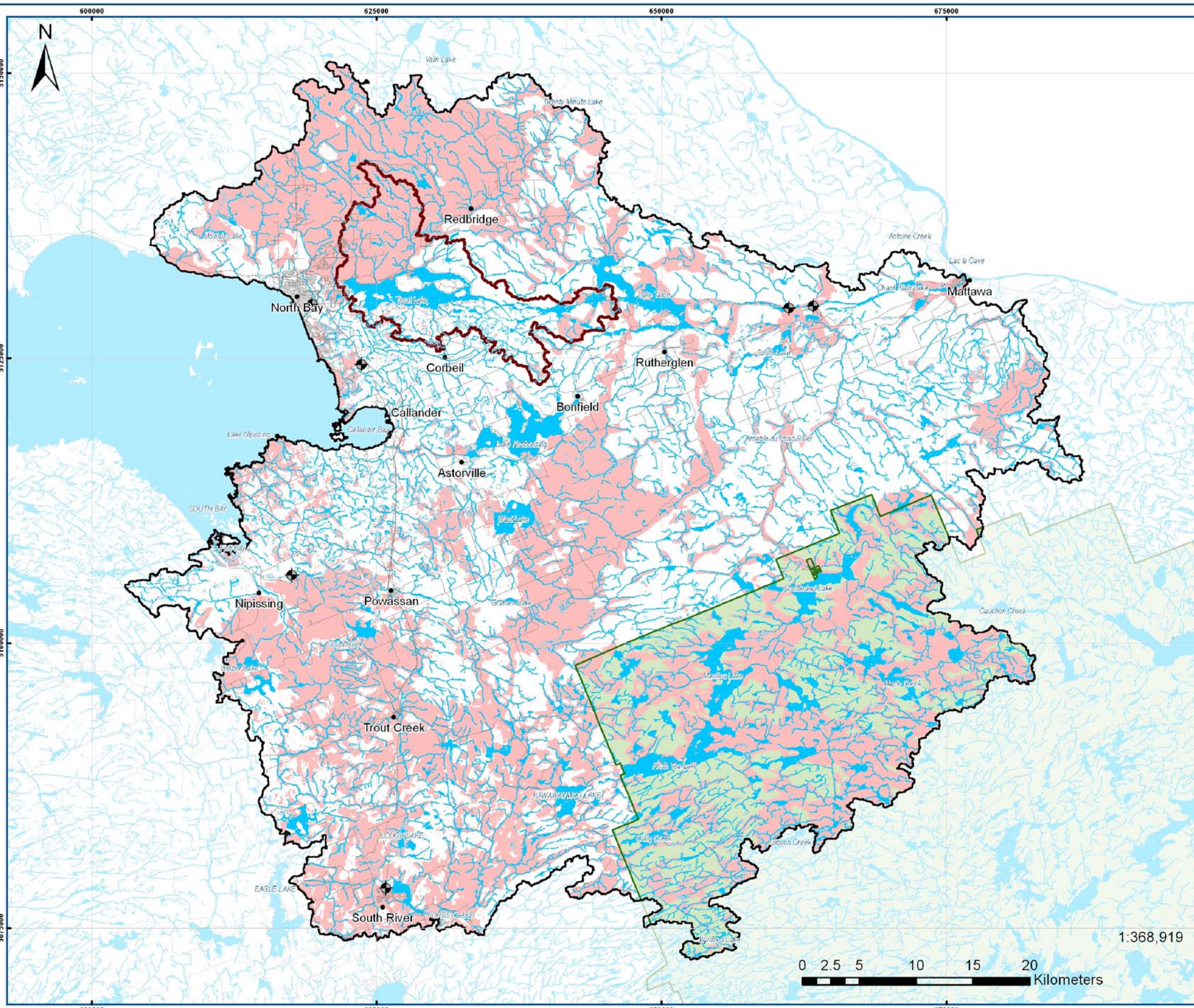
Map Projection & Datum: NAD83 UTM Zone 17N

NORTH BAY – MATTAWA

DRINKING WATER SOURCE PROTECTION
ACT FOR CLEAN WATER



North Bay-Mattawa Source Protection Area - Tier 1
MAP 2 - High Volume Recharge Areas

Legend

- High Volume Recharge Areas
- HYDAT Station
- Trout Lake Subwatershed Boundary
- Source Protection Area
- Communities
- Road
- River/Creek
- Waterbody Area, Permanent
- Wetland Area, Permanent
- Provincial Park

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