Trout/Turtle Lake Tier Two Subwatershed Stress Assessment and Tier Three Local Area Risk Assessment

FINAL REPORT

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Prepared for:
North Bay – Mattawa Conservation Authority

NORTH BAY-MATTAWA CONSERVATION AUTHORITY

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Executive Summary

The Clean Water Act (2006) was introduced by the Province of Ontario to ensure communities are able to protect their municipal drinking water supplies through the development of collaborative, locally driven, science-based Source Water Protection plans. Communities are in the process of identifying potential water quality and quantity risks to local sources and will take action to reduce or eliminate these risks. Municipalities, conservation authorities, property owners, farmers, industry, community groups, and the public are working together to meet these common goals.

For the purposes of Source Water Protection, the North Bay-Mattawa Source Protection Region was formed, and includes the North Bay-Mattawa Conservation Authority (NBMCA), as well as the South River watershed. A number of water resource studies are currently being completed within the Source Protection Region in support of the Clean Water Act (2006). These include vulnerable area delineation, threats identification / classification, and subwatershed-based water budgets. This report focuses on the latter.

As part of the water budget assessment process, the Clean Water Act (2006) requires all subwatersheds to be assessed under the Province's Water Budget Framework. The overall objective of the Water Budget Framework is to evaluate the reliability of municipal water supplies, and if necessary identify threats to water quantity.

The initial step of the Framework is the Subwatershed Water Quantity Stress Assessment. The Subwatershed Water Quantity Stress Assessment is a structured means of evaluating the degree of potential stress within a subwatershed. This assessment estimates a Percent Water Demand for each subwatershed by comparing the water demands to the available surface water and groundwater supply for that subwatershed. The Stress Assessment is a tiered process whereby subwatershed areas identified to have higher percent water demands are studied in greater detail than those subwatersheds that have lower percent water demand.

Municipal water supply systems, located within subwatersheds that are found to have a Moderate or Significant potential for stress, at both the Tier One and Tier Two level, are required to complete a Tier Three Local Area Risk Assessment. The objective of a Tier Three Local Area Risk Assessment is to estimate the potential that a municipal water supply will not be able to meet its planned pumping rates. Where the supply is not able to meet its planned pumping rates, the municipality will identify and make plans to deal with significant threats to water quantity.

The Trout/Turtle Lake subwatershed, which is the headwaters of the Mattawa River, is the source of drinking water for the City of North Bay. The subwatershed is approximately 176 km^2 in area, with Trout and Turtle Lakes comprising approximately 19 km^2 of the total drainage area. Water levels within Trout/Turtle Lake are controlled by the operation of Turtle Dam, which is maintained and operated by the Ministry of Natural Resources.

A Tier One Subwatershed Stress Assessment (Gartner Lee, 2008b) identified the subwatershed as having a Moderate potential for stress, thus requiring a Tier Two Subwatershed Stress Assessment. The Tier Two Subwatershed Stress Assessment is meant to be a confirmation of

Tier One Subwatershed Stress Assessment results, using better information and numerical models.

Tier Two Subwatershed Stress Assessment

The Tier Two Stress Assessment described herein was completed using a numerical surface water flow model and a reservoir routing model. The surface water model provides estimates of inflow to Trout/Turtle Lake, which are used to complete the Stress Assessment. The reservoir routing model was developed to assist in ensuring simulated Trout/Turtle Lake inflows would result in reasonable lake levels. These modelling tools provide a physical means of quantifying flow through the Trout/Turtle Lake subwatershed for use in the Stress Assessment calculations. The Stress Assessment includes consideration of the following conditions:

- Current Conditions - Percent Water Demand calculations;
- Planned System Conditions - Percent Water Demand calculations;
- Future Conditions - Percent Water Demand calculations; and
- Drought Conditions.

All of the above conditions are required to be considered in determining the stress classification for a subwatershed. Any one of the conditions that determines the subwatershed to be at a Moderate or Significant degree of stress is sufficient to identify that subwatershed as requiring a Tier Three Risk Assessment. As such, consideration of additional conditions is not required where a subwatershed has already been classified as potentially stressed.

Utilizing simulated inflows, reporting water withdrawal rates from the municipality, and the methodology outlined in the Technical Rules (MOE, 2009), the Trout/Turtle Lake subwatershed was assessed to have a Significant potential for stress under current conditions. An uncertainty assessment was completed on the Stress Assessment results, which resulted in a Low uncertainty classification.

Significant Groundwater Recharge Areas

In addition to the Subwatershed Stress Assessment, the Province's Water Budget Framework requires the delineation of Significant Groundwater Recharge Areas (SGRAs). The Water Budget Guidance Module (MOE, 2007) states that SGRAs should be delineated and mapped to identify and protect the drinking water across the broader landscape. This study follows a straightforward and reproducible procedure for delineating SGRAs as described in the Technical Rules. This report identifies areas having an estimated groundwater recharge rate equal to or greater than 115% of the average rate in the surrounding landscape, and defines these areas as SGRAs.

Tier Three Local Area Risk Assessment

The Tier Three Local Area Risk Assessment is meant to investigate whether the municipal water supply can meet its existing and planned demands. As the Tier Two Subwatershed Stress Assessment found the Trout/Turtle Lake subwatershed to have a Significant potential for stress, a Tier Three Local Area Risk Assessment is required for the City of North Bay municipal intake.

The Tier Three Local Area Risk Assessment considers four scenarios when evaluating the level of risk for the municipal supply. They are as follows:

- Existing Land Use, Existing Pumping, Average Climate Conditions;
- Existing Land Use, Existing Pumping, Drought Conditions;
- Planned Land Use, Planned Pumping, Average Climate Conditions; and
- Planned Land Use, Planned pumping, Drought Conditions.

Using the numerical tools generated for the Tier Two Subwatershed Stress Assessment, lake levels for Trout/Turtle Lake were estimated for each scenario. Simulated lake levels were compared against minimum operational lake levels documented in the Turtle Dam Operating Plan and the elevation of the City of North Bay's municipal intake. Simulated water levels for all four scenarios remained above critical lake level thresholds, resulting in the North Bay municipal supply being assigned a risk level of **Low**. Due to the Low risk level, no significant or moderate water quantity threats were identified within the Trout/Turtle Lake subwatershed.

No additional investigation is required for water quantity issues within the Trout/Turtle Lake under the Clean Water Act (2006).

Municipal Water Demand

In an effort to reduce water withdrawals from Trout/Turtle Lake, the City of North Bay has implemented, or is implementing, a number of water conservation measures. These water conservation measures include: a bylaw restricting outdoor water use; the installation of water meters on all connections to the water distribution system; and the adoption of a volumetric approach for water billing. The analysis described herein has shown that the full adoption of all water conservation measures would increase summer/fall lake levels by approximately 10 cm during years with low water.

The City of North Bay is strongly encouraged to continue implementing water conservation measures, in an effort to reduce water level fluctuations within Trout/Turtle Lake.

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1.0 Introduction

The *Clean Water Act* (2006) was introduced to Ontario Legislature for its First Reading on December 5, 2005 and received Royal Assent on October 19, 2006. The *Act* and five regulations came into effect on July 3, 2007. The intent of the legislation is to ensure that communities are able to protect their municipal drinking water supplies through the development of collaborative, locally driven, science-based Source Protection Plans. Communities will identify potential risks to local water sources and take action to reduce or eliminate these risks. Municipalities, Conservation Authorities, property owners, farmers, industry, community groups, First Nations, and the public will work together to meet these common goals.

The *Clean Water Act* is designed to protect drinking water quality and drinking quantity. The Water Budget Framework, developed to protect drinking water quantity, includes a three tiered process. As required under this Provincial Water Budget Framework, this report documents the development and application of a Tier Two Subwatershed Stress Assessment for Trout/Turtle Lake subwatershed; a subwatershed within the jurisdiction of the North Bay - Mattawa Conservation Authority. Should the Tier Two Subwatershed Stress Assessment indicate that the Trout/Turtle Lake subwatershed has a Moderate or Significant potential for stress, a Tier Three Local Area Risk Assessment for the City of North Bay water intake will be completed as part of this study.

1.1 NORTH BAY – MATTAWA SOURCE PROTECTION REGION

Under the *Clean Water Act* (2006), the Province has delineated Source Protection Regions across the Province. The boundaries of the North Bay – Mattawa Source Protection Region extend beyond the boundaries of the North Bay - Mattawa Conservation Authority (NBMCA) to include the drainage areas of South River, Reserve-Beatty Creek and Bear-Boileau Creek. This area forms the North Bay – Mattawa Source Protection Region and is approximately 4,000 km^2, as shown on Map 1. Significant hydrologic and physiographic features within the area include: Lake Nipissing, Trout and Turtle Lakes, Wasi Lake, Mattawa River, the North Bay Escarpment, and portions of Algonquin Park.

The population of the North Bay – Mattawa Source Protection Region is approximately 76,000 people, with approximately 56,000 living within the City of North Bay. Other communities include Mattawa, Callander, Corbeil, Bonfield, Astorville, Powassan, Trout Creek, South River, and Nipissing. The land cover in the Source Protection Region is comprised of 80% forest; 7% lakes; 6% agriculture or pastures; 2% urban or settlement areas; and 5% being minor land covers (e.g. burns/cutovers, bogs, or unclassified areas. Surficial geology is predominantly exposed bedrock, or bedrock with thin drift, associated with the Canadian Shield.

1.2 TROUT/TURTLE LAKE SUBWATERSHED

This study focuses on the Trout/Turtle Lake subwatershed shown on Map 1. The subwatershed is located east of the City of North Bay, and forms the headwaters of the Mattawa River. The drainage area of the subwatershed is 176 km^2, of which approximately 20 km^2 is Trout/Turtle Lake. Turtle Dam, a stop-log structure at the outlet of Turtle Lake, controls lake elevations in both Trout and Turtle Lake. The dam is operated to maintain water levels for upstream recreational and navigation purposes. At the western end of the lake system, Delaney Bay in

Trout Lake serves as the water supply for the City of North Bay. The Trout/Turtle Lake subwatershed and the locations of the municipal intake and Turtle Dam are shown on Map 2.

1.3 WATER BUDGET FRAMEWORK

Under Ontario's *Clean Water Act*, Source Protection Regions are required to work through the Water Budget Framework to identify drinking water sources that may not be able to meet current or future water demands. Each successive tier in the framework increases in complexity, requiring a higher level of detail and understanding. The final step in this framework includes the identification, classification and ranking of land use activities that are deemed to be water quantity threats to municipal supplies. The four main steps in the Water Budget Framework are listed below:

- Conceptual Water Budget
- Tier One Subwatershed Stress Assessment
- Tier Two Subwatershed Stress Assessment
- Tier Three Local Area Risk Assessment

The methodology followed in this report is consistent with the Technical Rules prepared by the Ontario Ministry of Environment (MOE, 2009) for the preparation of Assessment Reports under the *Clean Water Act*. The relevant section in the Technical Rules can be found in Part III.4 – Subwatershed Stress Levels – Tier Two Water Budgets. The Province developed the Provincial Guidance Module #7 Water Budget and Water Quantity Risk Assessment (MOE, 2007) which provides further instructions on how to complete a Subwatershed Stress Assessment.

In addition to a Water Budget and Stress Assessment, the Province's Framework requires that Significant Groundwater Recharge Areas (SGRAs) are delineated at each Tier. Guidance Module #7 (MOE, 2007) outlines that SGRAs should be delineated and mapped to identify and to protect drinking water sources across the broader landscape. SGRAs are refined and updated at each successive Tier.

An overview of the tiered studies prescribed within the Guidance Module #7 (MOE, 2007) and the Technical Rules (MOE, 2009) is provided in the following sections.

1.3.1 Conceptual Water Budget

The Technical Rules (MOE, 2009) and Guidance Module #7 (MOE, 2007) require a Conceptual Water Budget for each watershed in the Province of Ontario. The Conceptual Water Budget addresses baseline data collection, mapping, and analysis of the compiled information. A conceptual understanding of the study area builds on the watershed characterization to describe the functions of the groundwater and surface water flow systems in the study area. Four questions are emphasized at this stage:

- Where is the water?
- How does the water move between the various watershed elements (soils, aquifers, lakes, rivers)?

- What and where are the surface water and groundwater takings?
- What are the trends?

In addressing the above questions, the Conceptual Water Budget includes an initial understanding of the various storage elements (e.g. soils, aquifers, rivers, lakes) and fluxes (e.g. precipitation, recharge, runoff, evapotranspiration) in a watershed. It also requires an understanding of the geologic system and a consideration of surficial features, such as wetlands and large impervious areas, which must be incorporated into any water budget analysis. A preliminary inventory of all water takings is also undertaken at this stage.

A Conceptual Water Budget Report (Gartner Lee, 2008a) was completed by the North Bay - Mattawa Source Protection Region.

1.3.2 Tier One Subwatershed Stress Assessment

The goal of the Tier One Subwatershed Stress Assessment is to estimate cumulative stresses placed on a subwatershed. The study team estimates the Percent Water Demand, which is the percentage of water flowing through the subwatershed that is demanded by water users. Subwatersheds where the Percent Water Demand is estimated to be above a benchmark threshold value are classified as having a Moderate or Significant potential for stress. A more detailed Tier Two Subwatershed Stress Assessment is completed if a subwatershed has a Moderate or Significant potential for stress and contains a municipal water supply. Subwatersheds classified as having a low Percent Water Demand are classified as having a Low potential for stress and are not subject to additional water budget requirements.

A Tier One Subwatershed Stress Assessment for the Trout/Turtle Lake subwatershed (Gartner Lee, 2008b) was completed by the North Bay - Mattawa Source Protection Region. The Tier One Assessment concluded that the Trout/Turtle Lake subwatershed has a Moderate potential for stress, and identified the need for study at the Tier Two level.

1.3.3 Tier Two Subwatershed Stress Assessment

The Tier Two Subwatershed Stress Assessment uses more refined water demand estimates and a more advanced water budget model than those used for the Tier One Assessment. The Percent Water Demand calculations are the same as those used in a Tier One Assessment and use the same threshold values for stress assessment. Tier Two Subwatershed Stress Assessments are developed at the subwatershed scale, similar to the Tier One, and use a continuous surface water model and, where necessary, a groundwater flow model, in their development.

Municipal water supplies located within subwatersheds that are confirmed to have a Moderate or Significant potential for stress, proceed to a locally-focused, Tier Three Local Area Risk Assessment.

Since the Tier One Assessment of the Trout/Turtle Lake subwatershed identified a Moderate potential for stress, the North Bay - Mattawa Source Protection Region proceeded with a Tier Two Assessment.

1.3.4 Tier Three Local Area Risk Assessment

The objective of the Tier Three Local Area Risk Assessment is to estimate the potential that municipalities will meet their existing and their planned water quantity requirements while also meeting the requirements of other water uses. A Tier Three Local Area Risk Assessment is carried out for all municipal water supplies located in subwatersheds classified as having a Moderate or Significant potential for stress in the Tier Two Subwatershed Stress Assessment. A Tier Three Local Area Risk Assessment involves a detailed study of the available groundwater and/or surface water sources, requiring additional data collection and refinement of surface and/or groundwater flow models where necessary.

1.4 STUDY OBJECTIVE

The Tier One Assessment (Gartner Lee, 2008b) concluded that the Trout/Turtle Lake subwatershed has a Moderate potential for surface water stress. The goal of the current Tier Two investigation is to confirm the Tier One results through a more detailed analysis. If the subwatershed is found to have a Moderate or Significant potential for stress following the Tier Two Subwatershed Stress Assessment, a Tier Three Local Area Risk Assessment must be completed as part of this study.

1.5 TIER TWO METHODOLOGY

The approach for conducting a Tier Two Subwatershed Stress Assessment is outlined in Guidance Module #7 (MOE, 2007) and the Technical Rules (MOE, 2009) *Part III.4 – Subwatershed Stress Levels – Tier Two Water Budgets*. These documents prescribe an approach for estimating subwatershed stress based on estimates for water supply, water reserve, and water demand within a subwatershed.

As the sole municipal water supply in the subwatershed is from Trout/Turtle Lake and as there are no permitted groundwater takings within the subwatershed, this Tier Two Assessment focuses only on the surface water system.

The Tier Two Subwatershed Stress Assessment consists of two components, a Water Budget, and a Subwatershed Stress Assessment. The following sections describe both components.

1.5.1 Water Budget

The Tier Two Water Budget begins with the collection and interpretation of maps and data relating to the hydrological system. These data include geologic mapping, land use and vegetation mapping, topographic data, and surface water drainage maps. The next step involves using this information to develop and calibrate the hydrologic model. Continuous hydrologic flow models are typically used to describe and quantify water budget components including: evapotranspiration, overland runoff, groundwater recharge, and total streamflow.

As part of this project, the Guelph All-Weather-Sequential-Events Runoff (GAWSER) model (Schroeter, 2004) was chosen to simulate the hydrology of the Trout/Turtle Lake subwatershed. As there are no surface water stream gauges within the Trout/Turtle Lake subwatershed, the hydrologic model also included the adjacent La Vase River and Chippewa Creek subwatersheds. Observed streamflows from Water Survey of Canada stream gauges on La Vase River and Chippewa Creek were used to calibrate and verify the hydrologic model.

Following model calibration, hydrologic parameters for these watercourses were transferred to hydrologically similar areas in the Trout/Turtle Lake subwatershed, allowing the representation of the Trout/Turtle Lake subwatershed hydrology using physical parameters that represent local conditions as well as possible. As an additional measure of model performance, inflows to Trout/Turtle Lake generated from the hydrologic model were used to estimate lake levels, which allowed comparison against MNR observed lake levels. Verifying model results to a secondary dataset increases the confidence associated with model results.

1.5.2 Tier Two Subwatershed Stress Assessment

A subwatershed's potential for stress is estimated by comparing the amount of water consumed to the amount of water flowing through the subwatershed. Estimated consumptive water demand, when divided by the available water supply, minus a reserve term, and expressed as a percentage, results in a value known as Percent Water Demand. Subwatersheds with a Percent Water Demand greater the specified Provincial thresholds are classified as either having a Moderate or a Significant potential for stress. The Percent Water Demand equation and Provincial Thresholds are included in Section 5.1.2.

The purpose of classifying subwatersheds as having a Significant or a Moderate potential for stress is to identify subwatersheds that have a higher probability of experiencing water quantity related impacts. Identified subwatersheds, which contain municipal water supplies, are then required to undergo a Tier Three Local Area Risk Assessment. Tier Three studies are more detailed to improve the local understanding of the potential impacts on municipal drinking water sources from various drinking water threats. Subwatersheds identified as having a Low potential for stress are less likely to be affected by water takings under the current water demands; in these cases a more detailed level of study is unnecessary, unless increased or additional water takings move the subwatershed into a higher stress category (i.e. Moderate or Significant potential for hydrologic stress).

The Technical Rules (MOE, 2009) require that the subwatershed stress be estimated for current, future (25-year) and planned water demands (Section 5.2.2). If the Percent Water Demand for a subwatershed is above the Provincial thresholds for any of the three demand scenarios, the subwatershed is classified as having a Significant or Moderate potential for stress.

Drought conditions also need to be considered for both surface water and groundwater sources. For surface water sources, drought conditions are represented by a two-year period with the lowest recorded precipitation (see Section 5.2.3). Should the normal operation of the intake be affected by the two-year drought period, the subwatershed is classified as having a Moderate potential for stress.

Furthermore, the Technical Rules require that the influence of uncertainty be considered with a sensitivity analysis if the estimated Percent Water Demand is within two percent of a threshold value (see Section 5.2.4).

1.6 TIER THREE METHODOLOGY

The approach for completing a Tier Three Local Area Risk Assessment is outlined in the Technical Rules, *Part IX.1 – Risk level, local area*. The Risk level for the municipal water source is determined by assigning an Exposure level to the water source and a Tolerance level to the municipal system.

Tolerance is assigned by comparing the capacity of the municipal system to accommodate the peak demands experienced by the municipal system. Should the municipal system have sufficient capacity to meet the peak demands, a “High” Tolerance is assigned; otherwise a “Low” Tolerance is assigned.

Exposure is assigned by determining if the water source is able to provide sufficient water to the municipal system, as well as other water uses. Other water uses include other water takers, wastewater assimilative capacity, recreational uses, navigational uses, aquatic habitat, and electric power generation. Should the water source be sufficient to supply both the municipal supply, as well as other uses, a” Low” Exposure is assigned; otherwise a “High” Exposure is assigned. Numeric tools, developed within the Tier Two Subwatershed Stress Assessment will be used to assess Exposure.

As per the Technical Rules (MOE, 2009), both Tolerance and Exposure are considered when assigning the Risk level to the water source and municipal system. A Risk level of “Low”, “Moderate” or “Significant” can be assigned, depending on the specific combination of Tolerance and Exposure levels.

2.0 Watershed Description

This section describes watershed characteristics that are relevant to the Trout/Turtle Lake Tier Two Subwatershed Stress Assessment. Summaries of previous studies related to the characterization of Trout/Turtle Lake subwatershed, including descriptions of climate, land cover, and geology within Trout/Turtle Lake subwatershed, and specifications of Trout/Turtle Lake and Turtle Dam are included. As mentioned in Section 1, the Chippewa Creek and La Vase River subwatersheds were included in the modelled area. As such, the present characterization includes these two subwatersheds.

2.1 PREVIOUS STUDIES

Several studies outside of the Source Water Protection Framework have been completed for Trout/Turtle Lake. These studies provide insight on Trout/Turtle Lake subwatershed, as well as the historic conditions, operations, and levels of the Lake. The studies are listed below:

- North Bay-Mattawa Source Protection Region Conceptual Water Budget (Gartner Lee Ltd. 2008a). This report describes the climate, geology, land cover, water use and hydrology of the North-Bay Mattawa Source Protection Region.
- Tier One Water Budget and Water Quantity Stress Assessment for Trout Lake Subwatershed (Gartner Lee Ltd. 2008b). This report, using observed streamflow data, calculated the Tier One Percent Water Demand for the Trout/Turtle Lake subwatershed. A stress level of Moderate was assigned to the subwatershed, requiring the need for a Tier Two Subwatershed Stress Assessment.
- The Trout Lake Reservoir – A Water Balance Study (Rees, 1974). A water balance of Trout Lake was calculated for 1972 based on readily available data and empirical formulas. The results of the study were considered reasonable estimates of the water balance parameters and corresponded reasonably well with regional values. The study also found that the reservoir is capable of servicing the municipal water demands of the City of North Bay.
- Trout Lake Watershed Management Study – Watershed Hydrology and Shoreline Development (CRA and Ecoplans, 1988). This report evaluated the effects of shoreline development on the water quality of Trout Lake and Four Mile Bay using a hydrologic model. The model was also used to evaluate alternative development scenarios, watershed hydrology and water management concerns.
- Trout Lake Pollution Control Planning Study – Limnology and Hydrology Analysis (Northland Engineering and Beak Consultants, 1992). In this report, a water balance for the Trout Lake was calculated using a mass balance approach. Reservoir inflows were estimated by pro-rating flow records from the La Vase River and Chippewa Creek WSC streamflow gauges. Water levels showed good agreement with MNR recorded levels. This report also described the water quality of Trout Lake and its contributing streams, the trophic status of the Lake, and modelling of phosphorus loadings in the watershed.

- NBMCA Groundwater Study Report (WHI, 2006). This report documents local and regional groundwater and aquifer characterization, intrinsic susceptibility, groundwater use, potential contaminant sources, and wellhead protection areas. It also included a number of groundwater mapping objectives and a groundwater protection strategy.
- Turtle Lake Dam Documentation. There are a number of documents available on Turtle Lake Dam including the Dam Safety Assessment Report (Acres International, 2001a.); the Emergency Preparedness Plan (Acres International, 2001b.); the Data Collection and Site Inspections (Acres International, 2000.); and the Turtle Lake Dam Operating Plan (MNR, 1996).

2.2 CLIMATE

The annual and mean annual precipitation from 1950-2005, as recorded at the North Bay Airport station, is shown in Figure 2-1. The North Bay Airport climate station is located in the Chippewa Creek subwatershed, adjacent to the Trout Lake subwatershed. An upward trend in precipitation is evident, with a mean annual precipitation of 1,070 mm over the last 30 years (1975-2005). The mean monthly snowfall and rainfall are shown in Figure 2-2. Typical of Canadian climate, snowfall dominates during the winter months, and rainfall dominates during summer months; spring and fall experience a mix of rain and snow.

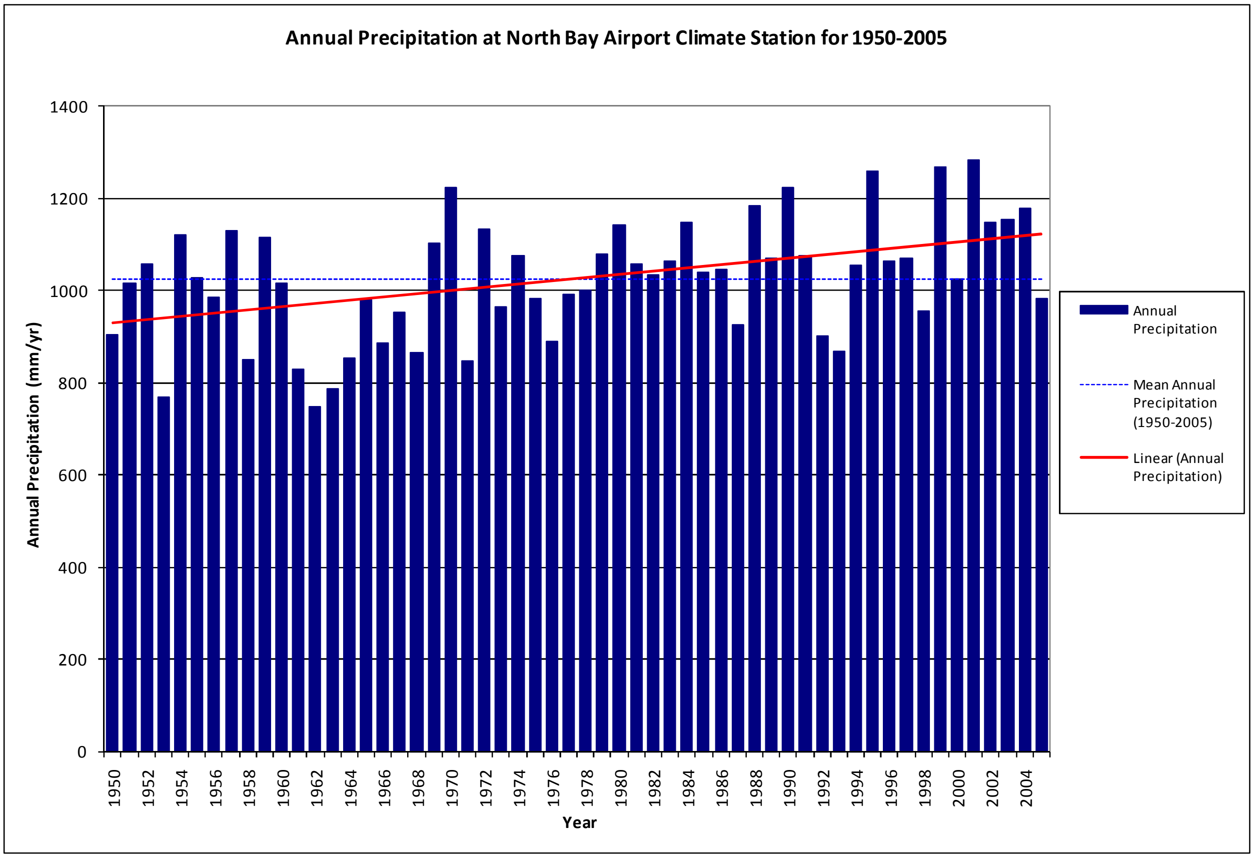

Figure 2-1: Annual Precipitation Recorded at North Bay Airport Meteorological Station for 1950-2005

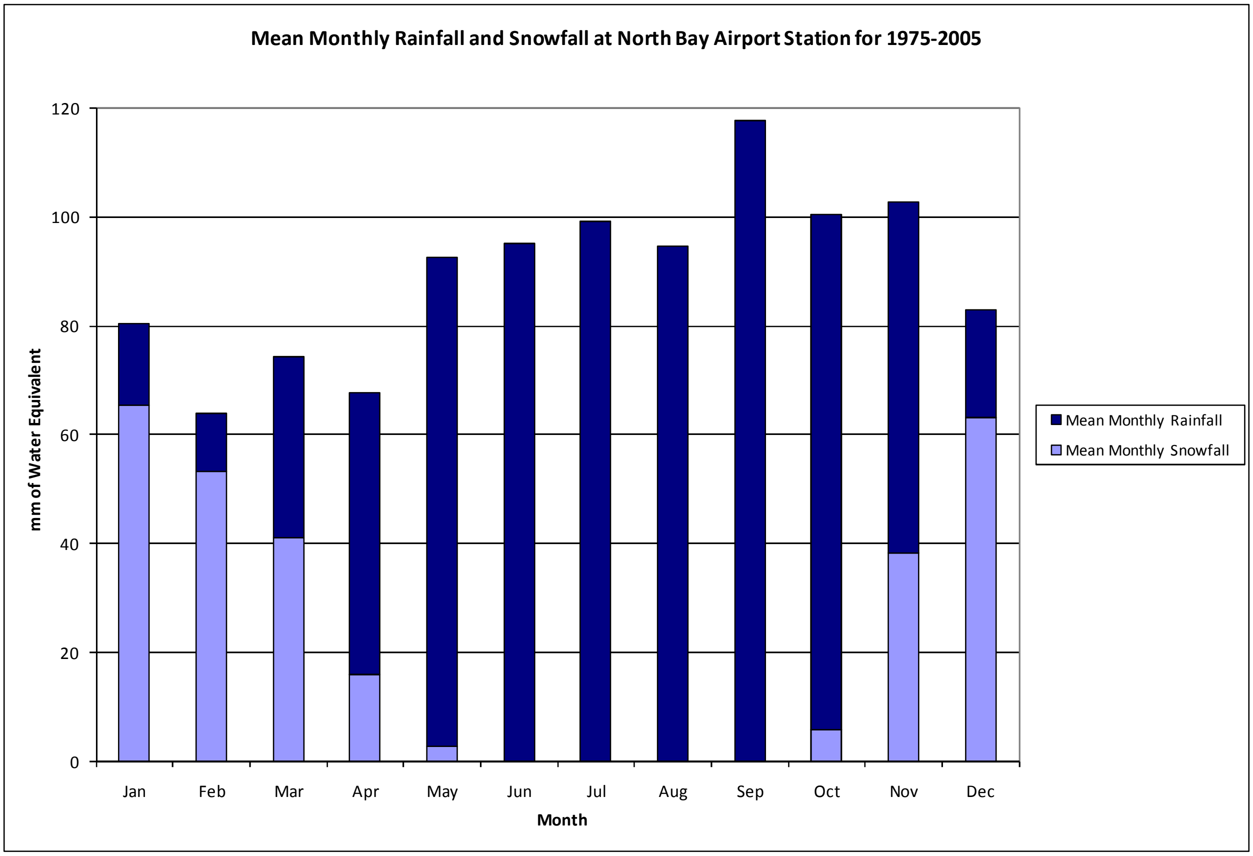

Figure 2-2: Mean Monthly Rainfall and Snowfall at North Bay Airport Station for 1975-2005

2.3 GEOLOGIC / LAND COVER DESCRIPTION

The Trout/Turtle Lake subwatershed covers an area of 176 km^2. As seen on Map 2, the Chippewa Creek subwatershed is west of Trout/Turtle Lake subwatershed and covers approximately 40 km^2. The La Vase River subwatershed is south of Trout/Turtle Lake subwatershed and covers approximately 90 km^2.

Land cover is one of the primary factors that influences how a subwatershed will respond to a precipitation event. Land cover for the study area is shown on Map 3, and is taken from the 2000 Edition of the Ontario Provincial Land Cover Database. As there have been no significant land use changes over the last nine years, it is assumed this data is representative of current land use. Table 2-1 lists the distribution of land cover type over each subwatershed. Approximately 70% of the Trout/Turtle Lake and the La Vase River subwatersheds are forested. These subwatersheds also contain numerous small lakes and wetlands. Approximately half of Chippewa Creek subwatershed is forested with the remaining half being urban lands associated with the City of North Bay.

Table 2-1: Land Cover as a Percentage of Total Area for Trout/Turtle Lake, Chippewa Creek and La Vase River Subwatersheds

Land Cover	Trout/Turtle Lake	Chippewa Creek	La Vase River
Water	17%	1%	1%
Settlement/Infrastructure	4%	49%	6%
Bedrock	0%	1%	0%
Forest Sparse	6%	5%	14%
Forest Dense Deciduous	27%	14%	15%
Forest Dense Mixed	30%	24%	37%
Forest Dense Coniferous	6%	5%	5%
Bog - Treed	2%	0%	3%
Agriculture - Pasture	6%	1%	12%
Cloud/Unknown	2%	0%	7%

(Based on 2000 Ontario Provincial Land Cover Database (Spectranalysis, 2004))

Surficial geology is a crucial component of the watershed characterization, as it determines the rate and volume of water that penetrates the soil surface. Surficial geology is characterized by think deposits of overburden material lain during the last glacial event, with large areas of outcropping bedrock. Areas with similar surficial geology will respond in a similar manner to a precipitation event; this is discussed further in Section 4 and Appendix B.

The surficial geology (OGS, 2005), as shown on Map 4, illustrates two main geologic regions within the study area. The regions are separated by the North Bay Escarpment, which runs along the north shore of Trout/Turtle Lake. The area above the Escarpment, the northern half of Chippewa Creek subwatershed and the area northwest of Trout/Turtle Lake, has a thicker overburden that is characterized by coarser grained materials, such as sands and gravels, deposited as till and glaciofluvial outwash. The area below the Escarpment, the area south and east of Trout/Turtle Lake, consists of bedrock with very thin overburden. There are pockets of glaciolacustrine deposits and organic deposits throughout the study area, which are comprised of finely grained materials, such as clays. The City of North Bay lies over glaciolacustrine deposits and bedrock, with some organic deposits throughout.

2.4 TROUT/TURTLE LAKES

Located to the east of North Bay, Trout and Turtle Lakes form the headwaters of the Mattawa River, which is a tributary of the Ottawa River. Water levels in both lakes are controlled by a water control structure known as Turtle Dam. While Trout and Turtle are considered to be separate lakes, they are connected by a channel enlarged by blasting. This channel accommodates navigation between the lakes. It is assumed both that this channel does not significantly restrict flow from Trout Lake into Turtle Lake, and that the water levels are similar in both lakes. Comparison of Trout and Turtle Lake levels is investigated further in Section 2.5.1.

2.4.1 Trout Lake

The surface area of Trout Lake is reported to range from 16.8 km^2 (Turtle Lake Operating Plan, MNR) to 18.9 km^2 (NBMCA GIS water polygon layer). The maximum depth is approximately 65

m. A bathymetric map of Trout Lake (MNR, 1972) is included on Map 5. The drainage area to Trout Lake, including the Lake's islands, is 106 km^2.

2.4.2 Turtle Lake

The reported surface area for Turtle Lake ranges from 2.5 km^2 (Turtle Lake Operation Plan, MNR) to 3.0 km^2 (NBMCA GIS water polygon layer). The maximum depth of Turtle Lake is approximately 55 m. A bathymetric map of Turtle Lake (MNR, 1972) is included on Map 6. The direct drainage area to Turtle Lake (not including Trout Lake drainage) is 49 km^2.

2.5 TURTLE DAM

Turtle Dam is located at the outlet of Turtle Lake and controls levels in both Trout and Turtle Lakes. The dam was originally built as a wood structure in approximately 1880 for navigation purposes related to the lumber industry. The structure was not maintained, and burned in 1910. The dam, originally rebuilt in 1920 by Booth Lumber Company (TLCA, 2009), has been rebuilt twice since then; once in 1948, and lastly in 1956. Discharge from the dam enters the small lakes of Werewolf, Moosegrass, Bigfish and Tillard, before entering the larger Talon Lake. All lakes are part of the larger Mattawa River system.

Several documents are available that describe the structure and operation of the dam: the Turtle Dam Operating Plan (MNR, 1996); Data Collection and Site Inspections (Acres, 2000); Dam Safety Assessment Report (Acres, 2001a); and the Emergency Preparedness Plan (Acres, 2001b). The structure and operation of Turtle Dam is summarized below:

- The primary purpose of Turtle Dam is to maintain lake levels for upstream recreational and navigational purposes. The Operating Plan does not consider any downstream flow targets. The operating range for the dam is a maximum water level of 202.24 masl, a summer optimum of 202.22 masl and a minimum level of 201.78 masl. The minimum water level was set based on the historical location and elevation of the City of North Bay intake
- Turtle Dam is a reinforced concrete structure, approximately 2.5 m high and 40 m in length, with three 4.27 m sluiceway openings. Lake elevations are controlled by stop logs, with each sluiceway having a maximum of four stop logs; each stop log is 0.305 m (12 in) in height. The sill elevation is 201.06 masl and with all four stop logs installed, the spillway crest is 202.28 masl.
- Turtle Dam has no low-flow bypass. This causes discharge to stop once lake levels drop below the elevation of the stop logs, other than the leakage around the stop logs. Discussions with MNR staff responsible for operating Turtle Dam indicated that the stop logs are jacked down each summer to reduce leakage. (Hall, pers. comm. Sept. 2009).
- There is no emergency spillway for Turtle Dam, although additional flow capacity is provided by wing walls on either side of the structure. Both wing walls have a crest elevation of 202.73 masl. The deck elevation of the dam is 203.63 masl.

Schematics and photos of Turtle Dam are included in Appendix A.

2.5.1 Monitoring

MNR staff manually record reservoir levels and stop log settings as part of normal Turtle Dam operations. Lake levels are usually recorded from the MNR dock, located in Trout Lake's Delaney Bay, but are also less frequently monitored at the upstream face of Turtle Dam. Included in Figure 2-3 is a summary of observed monthly lake elevations. Lake level monitoring is not carried out in January or February.

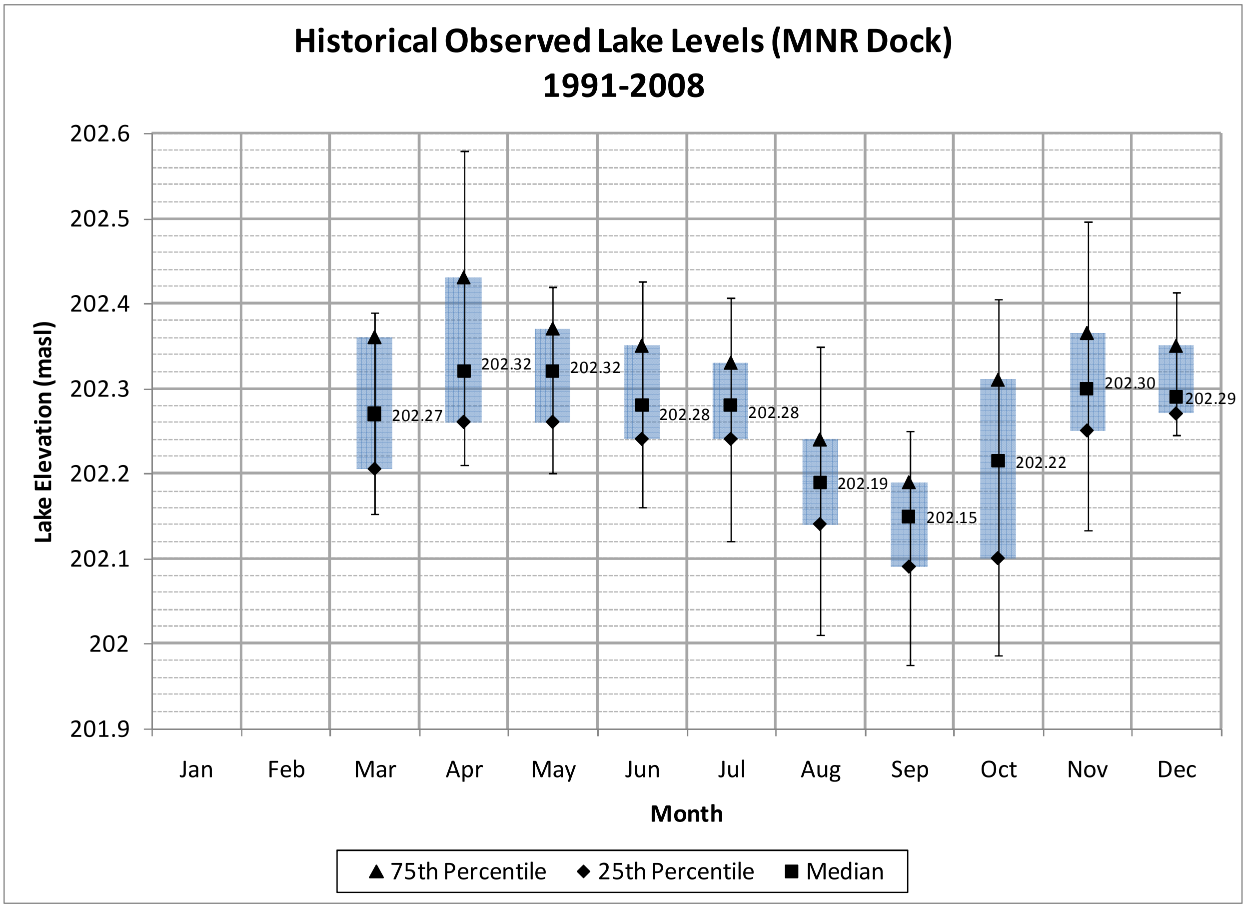

Figure 2-3: Monthly Statistics of Historically Observed Lake Levels at the MNR Dock

Analysis of the observed lake levels show that for the majority of months, lake level elevations are very stable, with monthly median levels deviating from 202.30 masl by only ±3 cm. The month of April, typically the spring freshet, has the highest 75th (202.43 masl) and 95th (202.58 masl) percentile elevations. While the spring freshet does seem to have an impact on the upper range of April's lake elevations, it has a minimal impact on April median lake elevations; April median elevations increase by only 5 cm from the March median lake elevation. May median lake elevations remain steady from April's, at 202.32 masl, before slightly falling to the summer holding level of 202.28 masl in June. The fact that pre-freshet levels (March) are similar to those in June suggests that little volume produced by the freshet is retained by the reservoir into the early summer period.

Lake levels deviate from 202.28 masl during the months of August and September, typically falling below 202.20 masl. Lake levels begin to recover during the month of October, with median elevations in the months of November and December reaching 202.3 masl.

MNR monitoring records also include several instances of lake levels observed both at the MNR dock in Delaney Bay (Trout Lake) and at Turtle Dam. These occurrences are shown on Figure 2-4, and show that Delaney Bay water levels are on average 5 cm higher than levels at Turtle Dam. Given that the outlet of the lake system is at Turtle Dam, 20 km to the east of Delany Bay, a slight gradient from Trout Lake towards Turtle Lake is not unexpected; however, this gradient is extremely small, equal to a slope of 0.00025% over the combined length of Trout and Turtle Lake. This supports the assumption that Turtle Dam controls the lake elevations within Trout Lake.

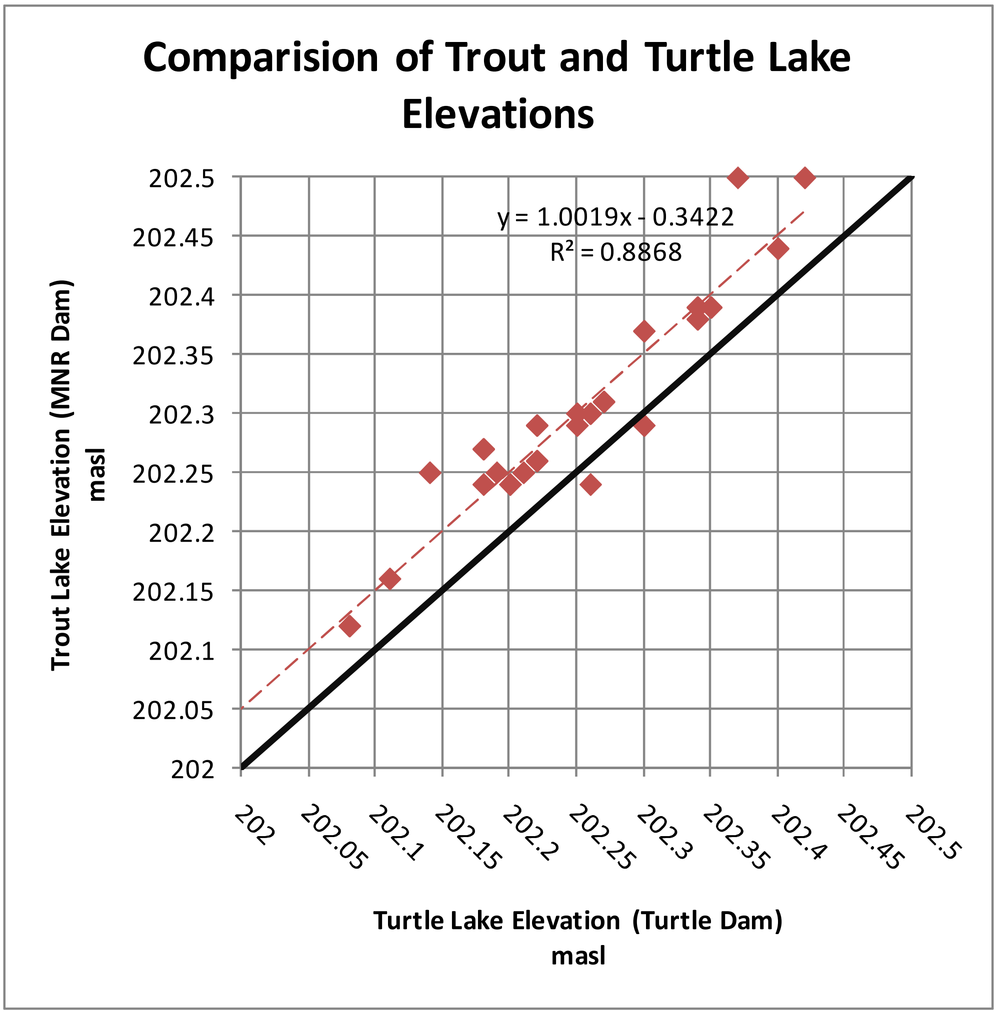

Figure 2-4: Comparison of Lake Elevations at Trout Lake (MNR Dock) and Turtle Lake (Turtle Dam)

No continuous monitoring exists for Trout/Turtle Lake level, inflow, or discharge. In the summer of 2008, NBMCA initiated a field program designed to capture spot flow measurements at major tributaries to the Lake. While this data can be used to determine the resiliency of the tributary flow into Trout/Turtle Lake, it is not a complete representation of the total inflow as not all tributaries were measured. Due to the many tributaries entering the Lakes, it is unlikely that total inflow could be continuously accurately monitored; however, a flow gauge downstream of Turtle Dam, and/or a continuous water level gauge at the dam, would greatly assist in determining the total discharge and storage changes.

2.5.2 Dam Operations

The Turtle Dam Operating Plan outlines a standard operating procedure to remove one log from each sluiceway in the fall prior to freeze-up. In March, an additional log is removed from each gate, with additional logs removed in April, on an as-needed basis to control high lake levels. Following the spring freshet, all four logs are typically installed to maintain lake levels close to 202.24 masl.

Included on Figure 2-5 is the operating procedure described in the Turtle Lake Operating Plan, along with critical lake levels. The upper/lower stop log setting represents the spillway crest elevation.

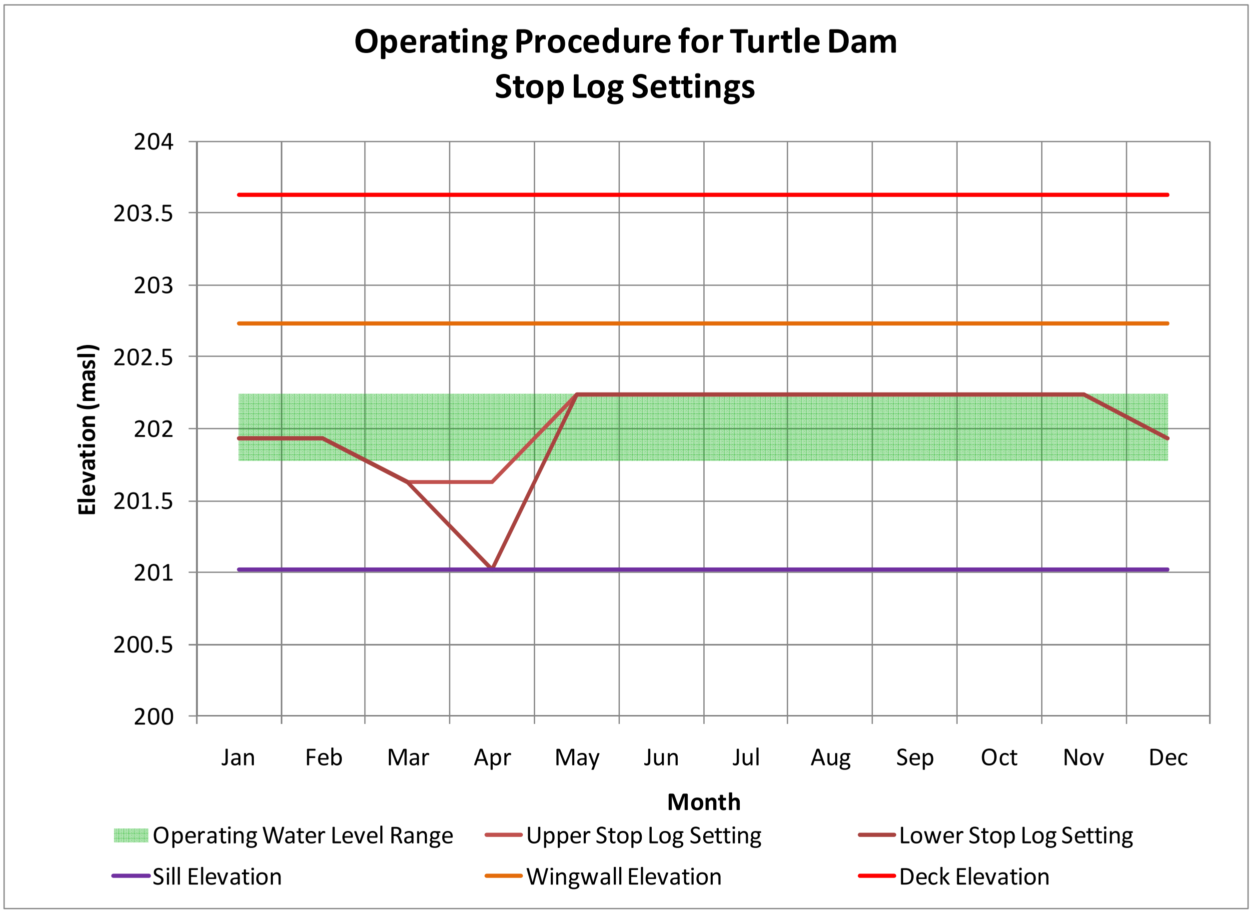

Figure 2-5: Stop Log Settings for Turtle Dam Based on Operational Procedures

This operating plan has been closely followed, as evident in the Turtle Lake water level and dam operation documentation. This documentation was digitized to better understand how Turtle Dam has historically been operated, and is summarized on Figure 2-6. Figure 2-6 displays the median stop log setting that has occurred each month in the 1991-2008 time period.

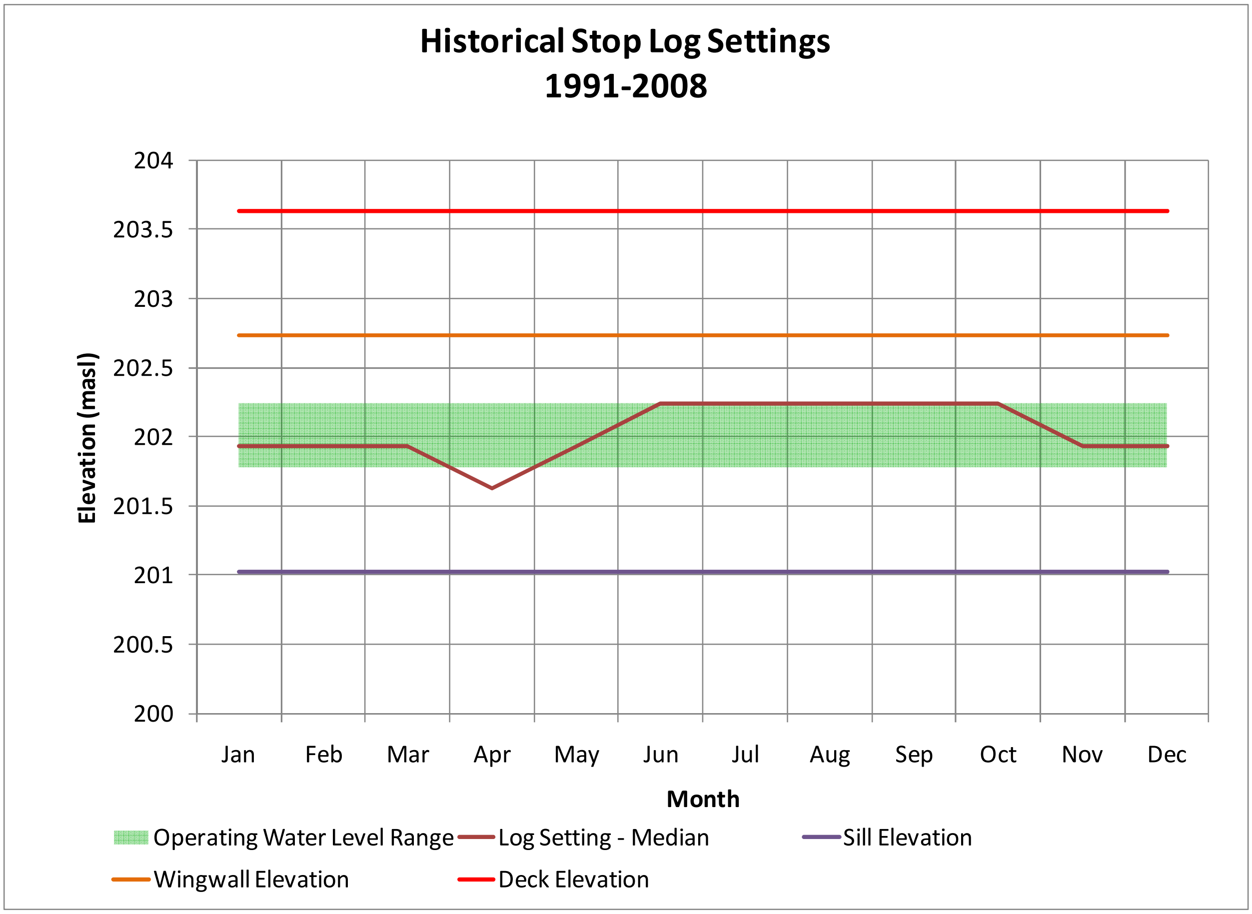

Figure 2-6: Stop Log Settings for Turtle Dam Based Historical Data

2.5.3 Stage-Storage-Discharge Relationship

A stage-storage-discharge curve relates the water elevation (stage) of a reservoir to the volume of water stored (storage), and to the quantity of water released from the reservoir to downstream water bodies (discharge). These relationships are critical to understanding the impact of water takings on reservoir storage, water levels, and discharge.

An existing stage-storage relationship was taken from Data Collection and Site Inspections (Acres 2000). This stage-storage relationship was developed for the active component of reservoir storage (storage above the sill elevation), and therefore does not include volume below 201.06 masl. The permanent pool storage (reservoir volume below 201.06 masl) was estimated by the Trout Lake Pollution Control Planning Study (Northland & Beak, 1992) to be approximately 350,000 ML.

Discharge was added to this relationship by calculating sluiceway flow using the discharge equation derived by the Trout Lake Watershed Management Study (Conestoga Rovers & Associates, 1988). Discharges for wing wall flow were taken from Data Collection and Site Inspections (Acres, 2000). The stage-storage-discharge relationship is presented below on Figure 2-7 and in Table 2-2.

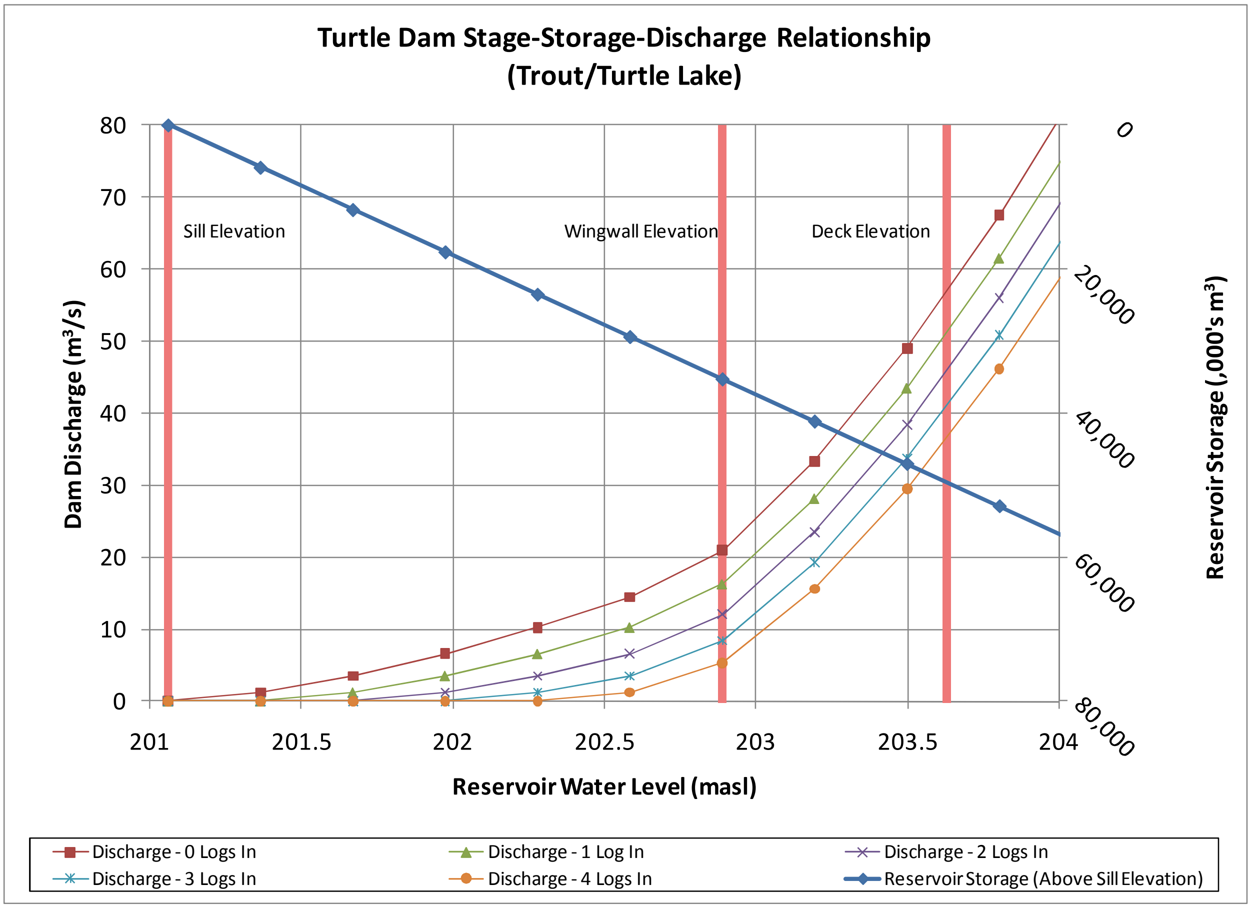

Figure 2-7: Turtle Dam Stage-Storage-Discharge Relationship

Table 2-2: Turtle Dam Stage-Storage-Discharge Relationship Table

Lake Elevation	Lake Storage	Wing wall Discharge	Stop Log Setting (# of Stop Logs In)				
			4	3	2	1	0
masl	1,000 m^3	m^3/s	Discharge (m^3/s) per sluiceway				
201.06	0	0	0	0	0	0	0
201.36	5,884	0	0	0	0	0	1.21
201.67	11,768	0	0	0	0	1.21	3.53
201.97	17,652	0	0	0	1.21	3.53	6.58
202.28	23,537	0	0	1.21	3.53	6.58	10.26
202.58	29,421	0	1.21	3.53	6.58	10.26	14.46
202.89	35,305	1.81	3.53	6.58	10.26	14.46	19.15
203.19	41,189	9.01	6.58	10.26	14.46	19.15	24.28
203.50	47,073	19.21	10.26	14.46	19.15	24.28	29.82
203.80	52,957	31.71	14.46	19.15	24.28	29.82	35.75
204.11	58,841	46.13	19.15	24.28	29.82	35.75	42.05
204.41	64,726	62.25	24.28	29.82	35.75	42.05	48.70

3.0 Water Demand

This section summarizes the surface water demand estimates for the Trout/Turtle Lake subwatershed. The water demand assessment is an important step in the development of a water budget framework; it is critical to the classification of potential stress.

As per the Technical Rules (MOE, 2009) and Guidance Module #7 (MOE, 2007), the consumptive water demand will be estimated using the following definition:

> *"the net amount of water that is taken from a source, and not locally returned to the same source in a reasonable time"*
> *Guidance Module #7 (MOE,2007)*

The Provincial Permit-To-Take-Water (PTTW) database is used for estimating consumptive water demand and is discussed in the following section.

3.1 PERMITS TO TAKE WATER

The Ministry of Environment's PTTW Program began in the early 1960's. It requires any person (or organization) taking more than 50,000 L/d of water to have an active PTTW. Exceptions are granted for domestic water use (non-municipal), livestock watering, and water taken for firefighting purposes. The Province's PTTW database stores information on permits, including the location, the maximum permitted rates, and the general and specific purpose of the water taking.

Historically, the PTTW program has not required PTTW holders to report their actual pumping rates, only the maximum potential water taking is maintained within the PTTW database. This has led to challenges in accurately estimating water use from this information. As actual water use is typically less than the maximum permitted rate, water use estimates generated using maximum permitted rates can be conservatively high. Obtaining more detailed water taking information, including actual pumping rates, can reduce this error and produce more accurate water use estimates.

Map 7 illustrates both surface water and groundwater PTTWs within the Trout/Turtle Lake subwatershed. The PTTW information is current as of May 2008. As is shown on Map 7, there are no permitted groundwater takings and only two surface water permits within the Trout/Turtle Lake subwatershed. These two permits, for industrial cooling and a municipal water supply, draw water from Trout Lake.

Table 3-1 lists the permits and associated characteristics. Permit ID 4187-6P2HR4, the industrial cooling permit, has two taking locations associated with the permit.

Table 3-1: Permits To Take Water within the Trout/Turtle Lake Subwatershed

Permit ID	Major Category	Specific Purpose	Easting	Northing	Permitted Taking (L/d)	Days of Active Taking	Source Name
4187-6P2HR4	Industrial	Cooling Water	622826	5132009	10,682,784	365	Trout Lake
	Industrial	Cooling Water	622826	5132009	54,504	365	Trout Lake
90-P-5838	Water Supply	Municipal	622300	5131250	79,500,000	365	Trout Lake

Over 90 ML/d, or just over 1 m^3/s, is permitted to be withdrawn from Trout Lake. Both takings are permitted to take their maximum rate 365 days per year.

3.2 MUNICIPAL SYSTEM DESCRIPTION

The MOE has granted the City of North Bay a Permit-To-Take-Water for a maximum taking of 79.5 ML/d from Trout Lake for its municipal water supply. Lake water is supplied to the water treatment plant through a 1.2 m diameter intake pipe extending into Delaney Bay of Trout Lake. The 300 m long inlet pipe terminates at an intake crib, which is placed at an elevation of 180.3 masl (21.5 m below the low lake level).

The City of North Bay has a population of 56,000, which includes 1,000 un-serviced residents (Bullock pers. comm., Oct, 2009). A new water treatment facility, completed in October 2009, has capacity to supply water to over 80,000 people, with a maximum water supply capacity of 115.9 ML/d (Veritec, 2008a). The water treatment facility consists of membrane filtration combined with ultraviolet light disinfection and chlorination.

The City's water distribution system has 14,800 connections, servicing residential and industrial/commercial/institutional (ICI) water users. Approximately 9% of the connections (predominantly ICI water users) are metered and are charged on a volumetric basis. The remaining unmetered connections, mostly residential, are charged a flat rate.

Municipal water use can be divided in the following categories: residential water demand, ICI water demand, distribution system losses, distribution system flushing, and water meter under-reporting. This breakdown, as estimated by Veritec (2008a) is included in Table 3-2.

Table 3-2: Estimated Breakdown of Water Use for City of North Bay for 2006

	Estimated Water Volume (ML/yr)	Per Capita Rate (L/d/cap) based on 54,000 pop.	Percent of Total (%)
ICI	3,582	182	27%
Residential	4,569	232	34%
System Flushing	1,468	74	11%
Leakage & Losses	3,661	186	27%
Water Meter Under-Reporting	126	6	1%

	Estimated Water Volume (ML/yr)	Per Capita Rate (L/d/cap) based on 54,000 pop.	Percent of Total (%)
Total	**13,406**	**680**	**100%**

Adapted from Universal Water Metering Strategy: Phase 1 – Universal Water Metering Overview Technical Report (Veritec, 2008a)

The estimated breakdown of water use for the City of North Bay, as presented above, may contain uncertainties. To estimate the water use, Veritec relied upon empirical relationships because of limited availability of metering data. To estimate the residential portion of water use, meters were installed on a small number (10) of residential connections. These meters were monitored and the results were scaled up to estimate the total City residential water demand. Due to this extrapolation, the values reported in Table 3-2 may have significant uncertainties associated with them, and should be considered estimates.

Veritec estimated that residential and ICI water demand comprises approximately 34% and 27%, respectively, of the total pumped water. The remaining 39% is considered “Non-Revenue Water”, as it is not provided to a customer. This Non-Revenue Water is comprised of water meter under-reporting (1%), flushing required for distribution system maintenance (11%), and distribution system losses (27%).

The 4,569 ML/yr of estimated residential demand represents a per capita rate of 232 L/d. This residential per capita rate is comparable to other Ontario municipal systems, as shown in Table 3-3 (2004 Environment Canada Municipal Water Use Database).

Table 3-3: Residential Water Use in Ontario Municipalities

Municipality	Residential Per Capita Rate (L/d/cap)	Metering (% of all Connections)
Barrie	191	100%
Guelph	216	100%
Kitchener	234	100%
Niagara Region	239	58%
Ottawa	235	100%
Peterborough	268	15%
Regional Municipality of Peel	229	100%
Sudbury	259	100%
Toronto	218	97%

Source: 2004 Environment Canada Municipal Water Use Database

3.2.1 Existing Municipal Pumping

The average pumping rate, downloaded from the City’s website, for the June 2002 to December 2008 time period is 404 L/s (35 ML/d). Pumping data for the period prior to June 2002 was not made available for this study.

Significant variability in daily pumping rates exist both seasonally and monthly. The highest variability occurs during the summer months of June, July, August and September, suggesting this variability is due to outdoor water use.

The monthly distribution of daily pumping rates is presented on Figure 3-1. This figure displays the median, 25th percentile, 75th percentile, maximum, and minimum daily pumping rates for each month.

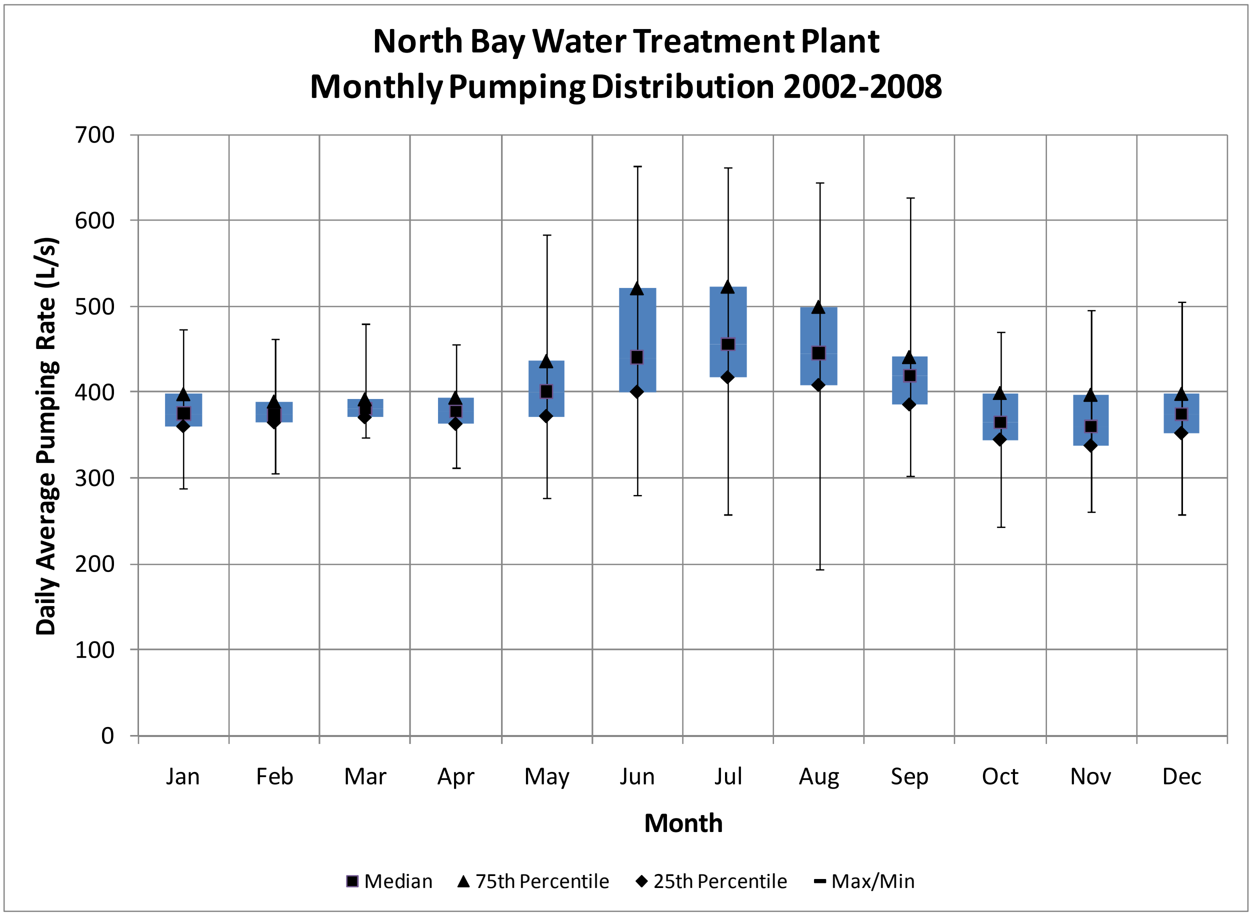

Figure 3-1: North Bay Water Treatment Plant Monthly Pumping Distribution

For the non-summer months, the median, 25th and 75th percentile pumping rates are clustered in the 350-380 L/s range. The maximum pumping rate for the non-summer months is approximately 500 L/s. Demand during the non-summer months is typically seen as the baseline water demand from residential, industrial, commercial, and institutional users.

Variability in daily pumping rates shows a significant increase for summer months. The 25th and 75th percentile range is 400-520 L/s, with the maximum pumping rates exceeding 650 L/s. The increase in demand during summer months, over the baseline demand, is typically related to outdoor water use.

3.2.2 Water Use Reduction Strategies

During the particularly hot and dry summer of 2001, the North Bay municipal system experienced a peak day water demand that approached 90% of the City's water taking permit

(City of North Bay, 2003). The City, therefore, began investigating options to reduce water demand.

To develop recommendations regarding water conservation, City Council authorized the formation of the Water Conservation Advisory Committee in May 2002. The Water Conservation Advisory Committee focused on two main aspects of water consumption: 1) addressing the issue of peak water demands temporarily exceeding water supply; and 2) reducing the annual average per capita water consumption.

3.2.2.1 Peak Demand Reduction

To address peak water demands, the North Bay City Council passed By-Law 2002-52 on June 17, 2002 restricting lawn watering to every other day for the months of June, July and August. This by-law has been well accepted by the community resulting in a reduction in peak water demand.

This reduction in peak demands is illustrated on Figure 3-2. Figure 3-2 shows the annual average and the maximum 3-day average pumping rate for each year in the 2002-2008 time period.

Also included on Figure 3-2 is the peaking factor. The peaking factor is calculated by dividing the maximum 3-day average pumping rate by the average demand. The peaking factor is a metric often used to infer the magnitude of seasonal variation in water demand patterns. A peaking factor of 2 indicates that the maximum demand experienced by the municipality is twice that of the average annual demand; that outdoor water use during the peak months is equal to the annual average demand. A peaking factor of 1 indicates that there is no seasonal variation in water demand; that outdoor water use is close to, if not, zero.

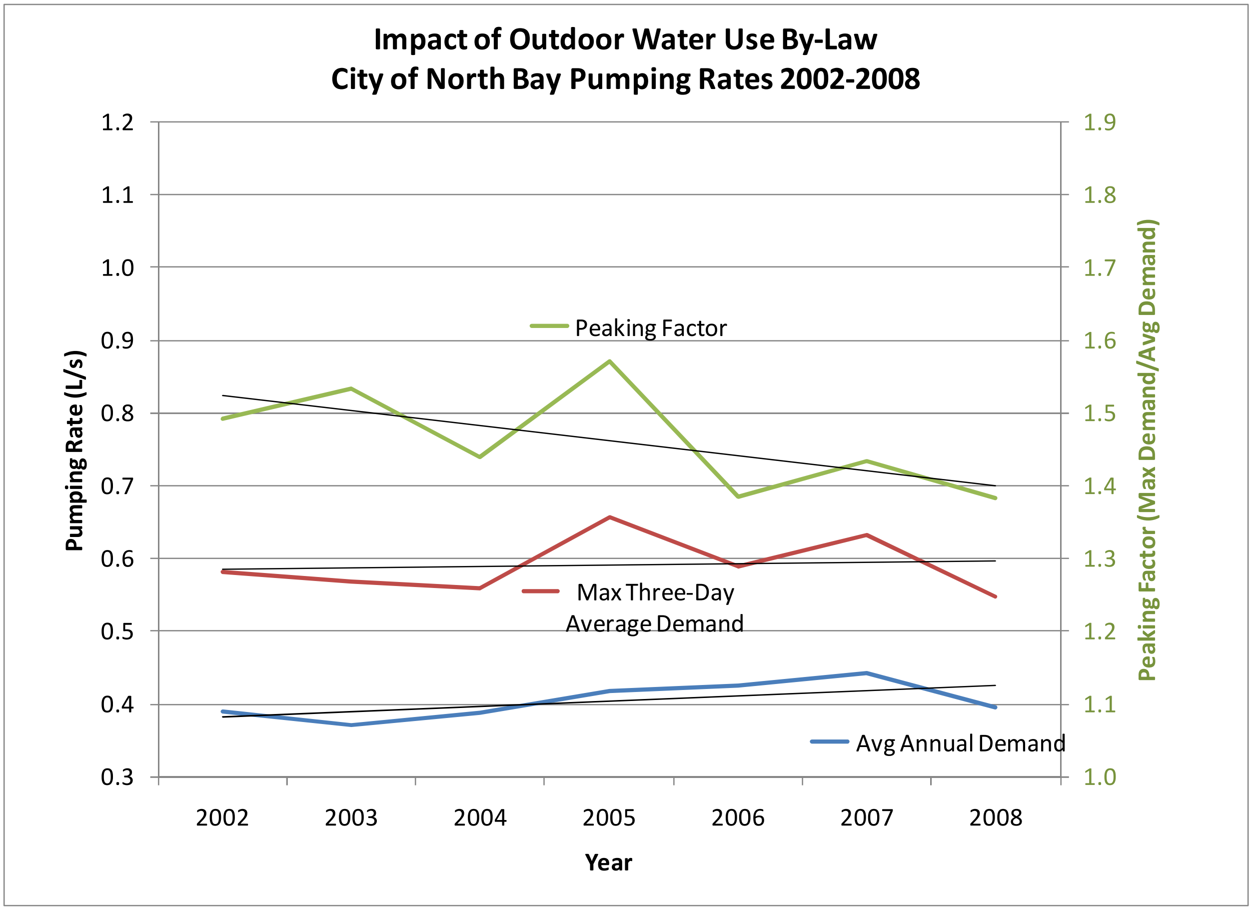

Figure 3-2: City of North Bay Pumping Rates and Peaking Factor

Figure 3-2 shows a reduction in the peaking factor from 1.5 in 2002 to 1.4 in 2008. This suggests that outdoor water use has become a smaller proportion of total water demand. While the average annual demand has continued to increase with population growth over this time frame, the 3-day maximum demand has remained constant.

3.2.2.2 Average Demand Reduction

To address the increase in average annual water demand, the City contracted Veritec to develop a business plan for water meter installation. Installing water meters, and adopting a volumetric billing approach, has long been seen as an effective method for reducing water demand. The three phase project, adopted by City Council in the Fall of 2008 (Resolution 2008-702), included the following reports: Phase 1 – Universal Water Metering Overview Technical Report; Phase 2 – Evaluation of Metering and AMR Technologies Technical Report; and Phase 3 – Universal Water Metering Implementation Strategies and Costs.

The City of North Bay tendered the water meter installation project with completion scheduled for 2010 and with the pricing structure to be in place by 2011. As a result of this project, all water distribution system connections will be metered and charged on a volumetric basis. The short-term and long-term reduction in residential water consumption is estimated to be 30% and

20%, respectively (Veritec 2008a). A long term reduction of 20% in the consumption rate results in a future residential per capita rate of 185 L/d/cap.

While the impact of city-wide water metering on residential water consumption will be significant, the largest reduction in water demand will come from the City's newfound ability to detect and fix distribution system leaks. Veritec (2008a) estimated that once metering is in place, the City should be able to reduce the current Non-Revenue Water volume from 39% of total pumped water, to 20% of total pumped water over a 10-year period, an approximate reduction of 50%.

By both reducing the residential water demand and having an effective leak detection system, the per capita water demand for North Bay will be reduced from 680 L/d/cap (2006) to 458 L/d/cap.

3.2.3 Future Municipal Demand

The population of North Bay is expected to reach 58,600 by 2031 (Watson, 2009). Without the water conservation measures currently being implemented by the City, this would result in an annual average withdrawal of 461 L/s from Trout/Turtle Lake

Table 3-4 contains future water use estimates for three water conservation scenarios. The scenarios include: 1) no conservation; 2) a 20% reduction in residential demand; and 3) a 20% reduction in residential demand and 50% reduction in Non-Revenue water. The 2006 water use breakdown is also included.

Table 3-4: Future Water Use & Water Conservation Scenarios

		2006 (54,000) (No Conservation)			**2031** (58,600) (No Conservation)			**2031** (58,600) (20% Residential Reduction)			**2031** (58,600) (20% Residential and 50% Non-Revenue Water Reduction)		
		ML / year	L/ d/ cap	% of Total	ML / year	L/ d/ cap	% of Total	ML / year	L/ d/ cap	% of Total	ML / year	L/ d/ cap	% of Total
Revenue Water	ICI	3,582	182	27	3,887	182	27	3,887	182	29	3,887	182	40
	Residential	4,569	232	34	4,958	232	34	3,967	185	29	3,967	185	41
Non Revenue Water	System Flushing	1,468	74	11	1,593	74	11	1,414	66	11	542	25	6
	Leakage	3,661	186	27	3,973	186	27	3,527	165	27	1,351	63	14
	Other Losses	126	6	1	137	6	1	121	6	1	46	2	0
Total		**13,406**	**680**	**100**	**14,548**	**680**	**100**	**12,917**	**604**	**100**	**9,793**	**458**	**100**
Average Withdrawal from Trout Lake (L/s)		425			461			410			311		

Implementing water metering and volumetric billing alone will reduce the 2031 annual average withdrawal from Trout Lake from 461 L/s (14,548 ML/yr) to 410 L/s (12,917 ML/yr). By reducing the Non-Revenue Water component by half, the annual average withdrawal will be further reduced to 311 L/s (9,793 ML/yr). This is an overall reduction of 27% from 2008 pumping rates.

3.3 CONSUMPTIVE DEMAND

As described above, both Guidance Module #7 (MOE, 2007) and the Technical Rules (MOE, 2009) require the consideration of consumptive water demand when completing the Subwatershed Stress Assessment.

Consumptive demand estimates associated with a water taking requires two pieces of information: (1) the proportion of pumped water that is not returned to the original source (consumptive use factor); and (2) the amount of water pumped. These are discussed in the following sections.

3.3.1 Consumptive Use Factors

Consumptive use factors are specific characteristics of individual water takings. They depend on a variety of factors, including the purpose of the water use, the source of water, and the point of discharge. This section documents the consumptive use factors applied to the two surface water permits in the Trout/Turtle Lake subwatershed.

The industrial cooling permit (ID 4187-6P2HR4, related to the SAGE (Semi-Automatic Ground Environment) facility at the Canadian Forces Base North Bay) withdraws water from Trout Lake. After use, this water is discharged to Lees Creek, a tributary of Trout Lake. As the discharge point is approximately 3-4 km upstream of Trout Lake, it is assumed that the water returns to Trout Lake in less than two days. This water is therefore assumed to be returned to its original source within “a reasonable amount of time”, and therefore largely non-consumptive. However, the consumptive demand associated with this water taking must also consider evaporation due to the permitted water use. Consumptive losses for once-through cooling are typically small but are associated with increased evaporation occurring from the discharge of warmed water. Previous studies have found consumptive factors for once-through cooling to be approximately 2% (AquaResource, 2009). As such, a consumptive factor of 2% is assigned to this taking.

The North Bay municipal water supply permit (ID 90-P-5838) also withdraws water from Trout Lake. Raw water is treated and distributed to North Bay residents, businesses, and industries. Wastewater is then collected, treated and discharged into Lake Nipissing. As the source of water (Trout Lake) is within the Ottawa River basin and the wastewater discharge point (Lake Nipissing) is within the Lake Huron basin, no withdrawn water is returned to the original source; a consumptive factor of 100% is assigned to this taking.

Table 3-5 summarizes the consumptive use factors applied to both PTTWs.

Table 3-5: Consumptive Use Factors for Permits within Trout/Turtle Lake Subwatershed

Permit ID	Purpose of Water Use	Consumptive Use Factor
4187-6P2HR4	Industrial Cooling	2%
90-P-5838	Municipal Water Supply	100%

3.3.2 Pumped Water

The volume of water pumped from the Trout/Turtle Lake subwatershed was determined using the PTTW database and actual pumping records. Table 3-6 summarizes the monthly average water withdrawal rates from the Trout/Turtle Lake subwatershed.

Table 3-6: Reported and Permitted Pumping Rates for Trout/Turtle Lake Subwatershed

Permit ID	Reported/ Permitted Value	Jan (L/s)	Feb (L/s)	Mar (L/s)	Apr (L/s)	May (L/s)	Jun (L/s)	Jul (L/s)	Aug (L/s)	Sep (L/s)	Oct (L/s)	Nov (L/s)	Dec (L/s)	Annual Average (L/s)
4187-6P2HR4	Permitted	124	124	124	124	124	124	124	124	124	124	124	124	124
90-P-5838	Reported*	390	386	376	376	388	403	420	414	442	389	378	389	396
Total		**514**	**510**	**500**	**500**	**512**	**527**	**544**	**538**	**566**	**513**	**502**	**513**	**520**

*Mean Monthly Rates for 2008

3.3.3 Consumptive Demand Estimates

Applying the consumptive use factors in Table 3-5, to the pumped rates in Table 3-6, yields the consumptive water demand estimates for the Trout/Turtle Lake subwatershed shown in Table 3-7. This is the amount of water withdrawn from the subwatershed and not returned to the same source.

Table 3-7: Consumptive Water Demand Estimates for Trout/Turtle Lake Subwatershed

Permit ID	Reported/ Permitted Value	Jan (L/s)	Feb (L/s)	Mar (L/s)	Apr (L/s)	May (L/s)	Jun (L/s)	Jul (L/s)	Aug (L/s)	Sep (L/s)	Oct (L/s)	Nov (L/s)	Dec (L/s)	Annual Average (L/s)
4187-6P2HR4	Permitted Value	2	2	2	2	2	2	2	2	2	2	2	2	2
90-P-5838	Reported	390	386	376	376	388	403	420	414	442	389	378	389	396
Total		**392**	**388**	**378**	**378**	**390**	**405**	**422**	**416**	**444**	**391**	**380**	**391**	**398**

3.4 OTHER WATER USE CONSIDERATIONS

The water use analysis described in the previous section focuses only on permitted surface water takings. There are no permitted groundwater takings within the subwatershed. Additional, relatively minor, water withdrawals may also contribute to the consumptive water demand. Such takings include lake intakes servicing homes and cottages surrounding Trout and Turtle Lake, withdrawals for small scale non-permitted agricultural demands or livestock watering. In addition to surface water takings, some groundwater takings may occur in the form of unrecorded dug wells and owner-constructed wells. The impact of omitting these water takings from the consumptive demand estimate is considered minimal; agricultural activities are minor (6% of land area) and domestic uses return water to the Trout/Turtle Lake subwatershed through septic systems.

3.5 WATER USE SUMMARY

As previously indicated, two surface water permits are located within the Trout/Turtle Lake subwatershed: the City of North Bay permit with a maximum rate of 79.5 ML/d (920 L/s); and the Canadian Forces Base industrial cooling permit with a maximum rate of 10.7 ML/d (124 L/s). There are no permitted groundwater takings within the subwatershed.

These two water takings result in an annual average rate of water withdrawal from Trout/Turtle Lake subwatershed of 44.9 ML/d (520 L/s); representing about half of the maximum permitted water withdrawal rate. Applying a consumptive factor of 2% to the cooling taking, and 100% to the municipal supply, yields a consumptive withdrawal of 34.6 ML/d (398 L/s) from the subwatershed.

Water demand estimates typically have a high degree of uncertainty, particularly for water demand estimates derived from the PTTW database. Often the maximum permitted rate is significantly higher than the actual withdrawal rate; therefore, when the permitted rate is used, the water demand estimates can be conservatively high.

Due to the availability of reported pumping rates from the City of North Bay, errors introduced into the water demand estimates due to use of maximum permitted rates are minimal. Because of this the uncertainty associated with the Trout/Turtle Lake subwatershed water demand estimates is low.

4.0 Water Budget Modelling

Hydrologic modelling is required to estimate streamflow, reservoir water levels, and major water budget components such as evapotranspiration, direct overland runoff and groundwater recharge. Hydrologic models represent underlying hydrologic processes within a watershed, and when combined with climate data, can generate annual, monthly or daily estimates of the predominant hydrologic cycle components. A hydrologic model is calibrated by adjusting model parameters until the model's predicted streamflow is representative of observed conditions.

Two models were developed and calibrated to characterize the hydrology of the Trout/Turtle lake subwatershed. A hydrologic model was developed to estimate streamflow, evapotranspiration, direct overland runoff, and recharge on a daily basis. A reservoir routing model was developed to use these daily streamflow estimates into Trout/Turtle Lake to predict lake water levels and outflow. Model performance was verified with two data sets including Water Survey of Canada streamflow estimates, and MNR lake levels, resulting in greater certainty in model results.

As outlined in the Technical Rules (MOE, 2009), the scope of a Tier Two Subwatershed Stress Assessment includes the development and application of both a computer-based continuous surface water flow model and a computer-based three dimensional groundwater flow model. Since the Trout/Turtle Lake subwatershed does not have any groundwater takings, the development of a three dimensional groundwater flow model was not necessary.

The following sections are an overview of the development, calibration, and application of the hydrologic flow model and the reservoir routing model. Further details of the models, calibration, and sensitivity analysis are located in Appendix B

4.1 HYDROLOGIC MODELLING

The Guelph All-Weather Sequential-Events Runoff (GAWSER) model (Version 6.9.10, 2008) was used for the Trout/Turtle Lake Tier Two Subwatershed Stress Assessment.

The GAWSER model (Schroeter & Associates, 2004) is a physically-based, deterministic hydrologic model and can be used to simulate major hydrologic processes and streamflow hydrographs, resulting from inputs of rainfall and/or snowmelt. The GAWSER model has been applied widely in Ontario for planning, design, real-time flood forecasting, and evaluating the effects of physical changes in the drainage basin (Schroeter & Associates, 2004).

4.1.1 Model Construction

There are no stream gauges in Trout/Turtle Lake subwatershed; consequently, the model boundaries were extended to include the La Vase River and Chippewa Creek subwatersheds. These adjacent subwatersheds have watercourses with long-term Water Survey Canada (WSC) stream gauges. The hydrologic model was calibrated to the observed flow from these gauges. The modelled area and catchments is shown on Map 8. The model schematics are included in Appendix C.

The model was run using rainfall, snowfall, and air temperature data from the North Bay Airport Climate Station for 1975-2005. Observed streamflow data from the La Vase River at North Bay

(2DD013) and Chippewa Creek at North Bay (2DD014) WSC stream gauging stations were used to gauge the performance of the model in predicting streamflow. The locations of the climate station and streamflow gauges are shown on Map 8.

The GAWSER model uses catchments as the smallest spatial area for which the model can output a hydrograph. The model catchments representing the Trout/Turtle Lake, the La Vase River, and the Chippewa Creek subwatersheds are shown on Map 8. Catchment and channel characteristics were determined using a GIS platform and channel cross sections were approximated using published geomorphic relationships and simplified trapezoidal geometry.

Surficial geology and land cover were combined to generate Hydrologic Response Units. Land areas with the same Hydrologic Response Unit classification are assumed to respond similarly to a precipitation event. The various Hydrologic Response Units found within a given catchment determines how that catchment, as a whole, will respond to precipitation events. The Hydrologic Response Units are shown on Map 9.

4.1.2 Model Calibration and Verification

Model calibration involves adjusting hydrologic parameters to best reflect the observed hydrologic conditions. Following calibration, the model is then tested to confirm that the parameter adjustments are representative of major hydrologic processes; this modelling procedure is called verification.

In calibration, simulated and observed flow is compared for a specific time period, with model parameters adjusted to minimize differences between the two datasets. Following model calibration, simulated and observed flow are again compared, but using a different time period, with no adjustments made to model parameters. This exercise is known as model verification. Good agreement between simulated and observed flow for the verification period indicates that the calibrated model parameters are appropriate for time periods other than the calibration period.

Calibration exercises for continuous hydrologic models are typically approached in a structured hierarchical manner. Models are calibrated to a longer temporal scale, and then sequentially moved to a shorter temporal scale. By initially calibrating to annual volumes, moving to monthly volumes, then finally to daily flows, regional processes, such as climate/evapotranspiration, are considered before local processes, such as groundwater contributions. This allows calibration to better isolate individual processes, and achieve a better fit between simulated and observed streamflow.

The Chippewa Creek and La Vase River calibration and verification phases focused on the agreement between simulated and observed streamflow. The model calibration period was 1995-2005, where the model parameters were adjusted to best replicate hydrologic processes and observed flows. The model verification period was 1985-1994, where the model parameterization, completed during the calibration phase, was tested against a different set of inputs (climate data) and observations (observed flow). A reasonable fit in the verification period increases certainty in the model's ability to reasonably represent hydrologic processes.

Several metrics were used to analyze the model's ability to simulate streamflow. However, only the mean monthly streamflow calibration and verification plots are shown on Figures 4-1 through Figure 4-4. Figures 4-1 through 4-4 display simulated and observed monthly mean streamflow, expressed in units of mm of flow over the upstream drainage area. Expressing flow in this manner allows for hydrologic responses between differing gauges to be directly compared, and is also directly relatable to precipitation depths. The remaining calibration and verification plots are included in Appendix B.

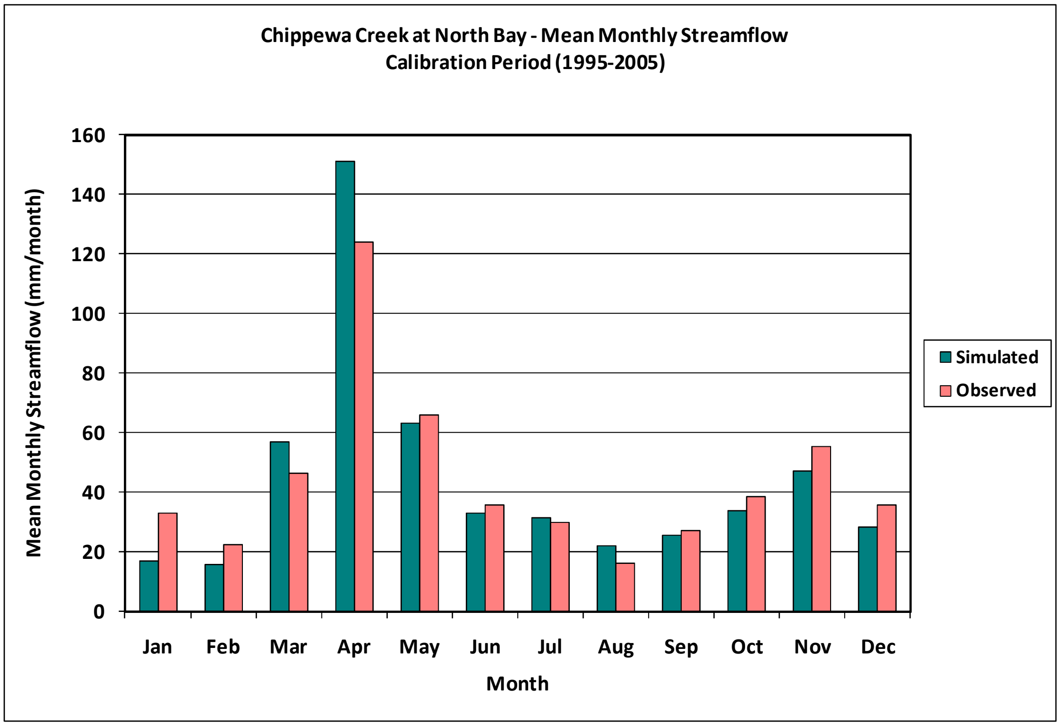

Figure 4-1: Chippewa Creek Gauge Mean Monthly Streamflow – Calibration Period

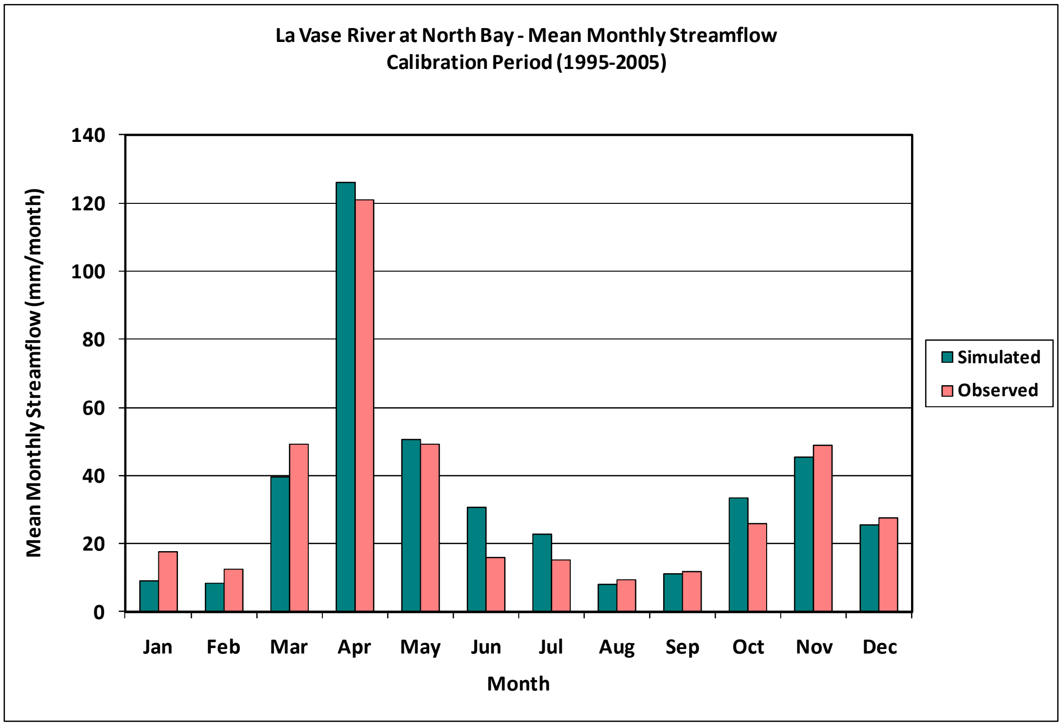

Figure 4-2: La Vase River Gauge Mean Monthly Streamflow – Calibration Period

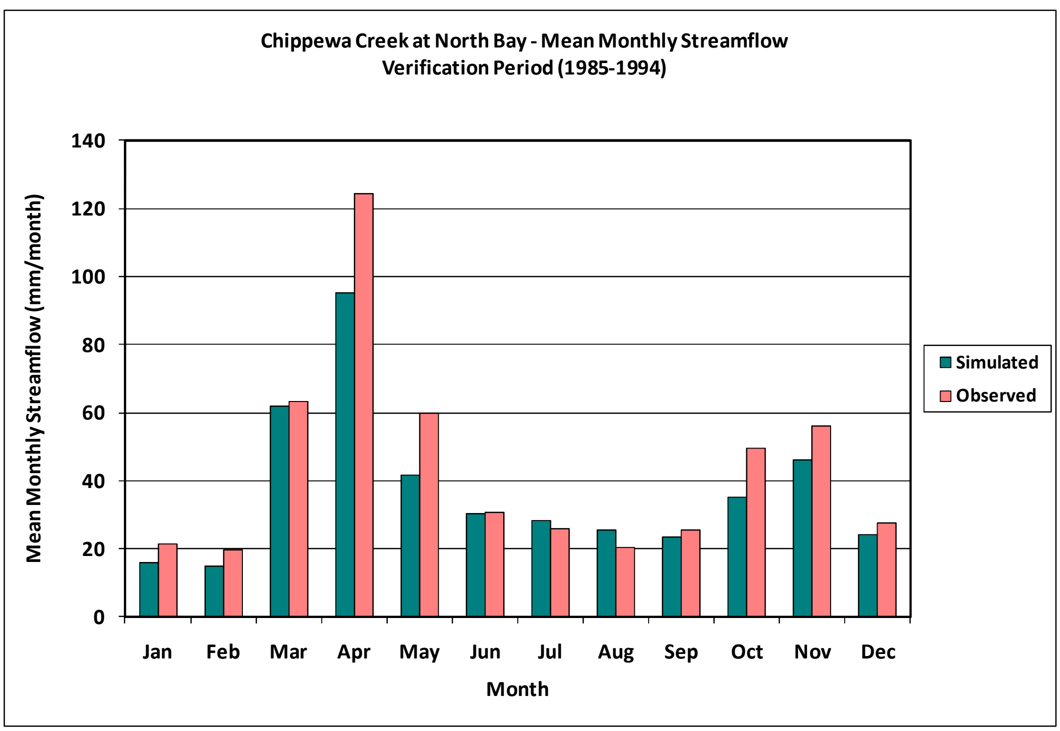

Figure 4-3: Chippewa Creek Gauge Mean Monthly Streamflow – Verification Period

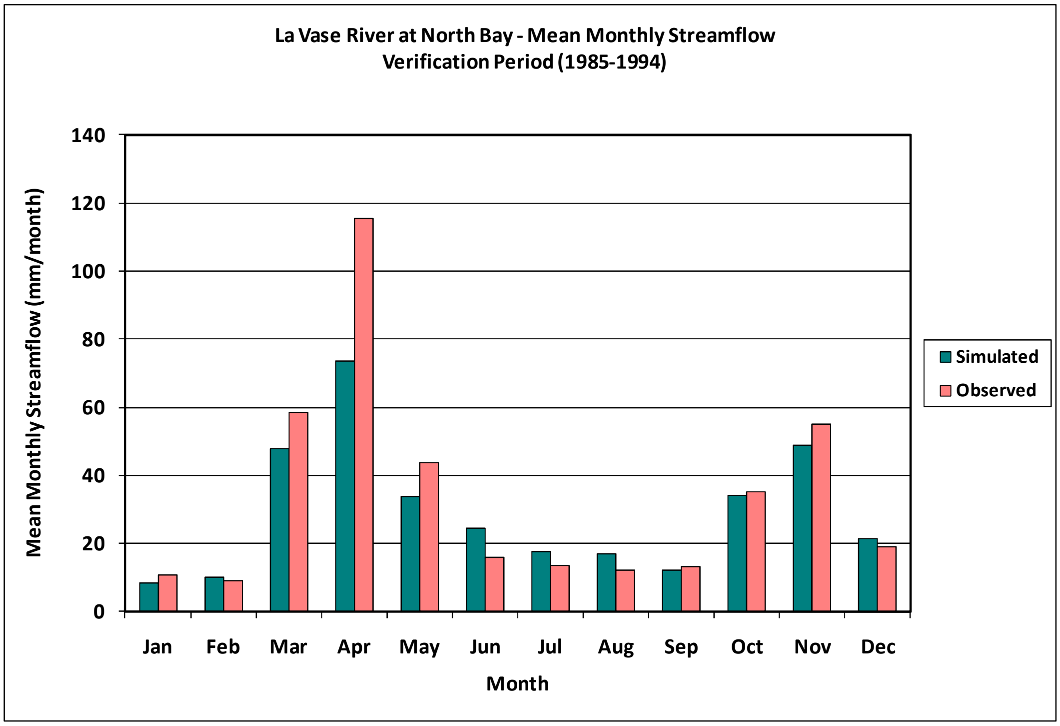

Figure 4-4: La Vase River Gauge Mean Monthly Streamflow – Verification Period

The results of the calibration and verification phase demonstrated that the model reasonably replicates the major hydrologic processes in the Chippewa Creek and the La Vase River subwatersheds. As such, the model parameters for Chippewa Creek and the La Vase were transferred to the Trout/Turtle Lake subwatershed with confidence that natural conditions were being reasonably replicated.

The model parameters applied to Trout/Turtle Lake subwatershed were validated by comparing simulated streamflow at five locations in Trout/Turtle Lake subwatershed against observed spot flow measurements. Spot flow measurements were taken by NBMCA in May, June, July, and August 2008. The spot flow locations are shown on Map 8.

As spot flow measurements were not taken during the modelling time period (1975-2005), a direct comparison between simulated and observed spot flows was not possible. Rather, mean monthly simulated streamflow from 1975-2005 was compared to the range of measured spot flow measurements. Since 2008 was a wetter than average year, it is considered likely that streamflow would be higher than average. Due to this, it is expected that the average flow predicted by the model would be near the bottom range of the 2008 spotflow measurements.

Figure 4-5 compares the simulated mean flow against the range of measured spotflows for Lees Creek. As shown on Figure 4-5, the spotflow ranges were being significantly under-represented by the model until the industrial cooling permit (described in Water Demand Section 3) discharges were included. Additional flow comparisons are included in Appendix B. The favourable results of the spot flow comparison increases model certainty, specifically within the Trout/Turtle Lake subwatershed.

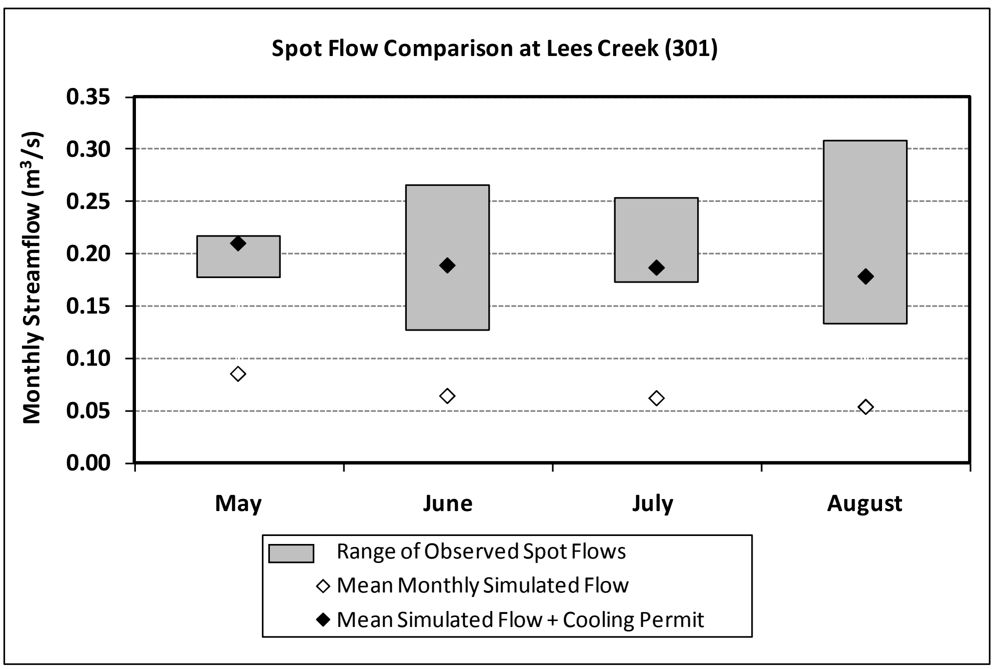

Figure 4-5: Comparison of Mean Monthly Simulated Flows (1975-2005) to Observed Spot Flows (2008) at Lees Creek

4.2 RESERVOIR ROUTING

A reservoir routing model was created to validate estimated inflows to Trout/Turtle Lake. This routing model considers inflows, withdrawals, evaporative losses, and level-storage-discharge relationships to generate a daily time series of Trout/Turtle Lake water levels. The 1995-2005 time period used for this analysis, coincides with the calibration period used for the hydrologic model. The reservoir routing model replicates observed water levels very well for most years, as shown in the comparison of simulated water levels and observed water levels presented in Figure 4-6.

Sources of uncertainty associated with the reservoir routing model include level-storage-discharge relationships, the quantity of stop-log leakage, and the effect of ice conditions on the level-discharge relationship. Despite these uncertainties, the reservoir routing model produced simulated reservoir levels generally consistent with observations; this can also be considered a secondary validation of the simulated Trout/Turtle Lake inflows.

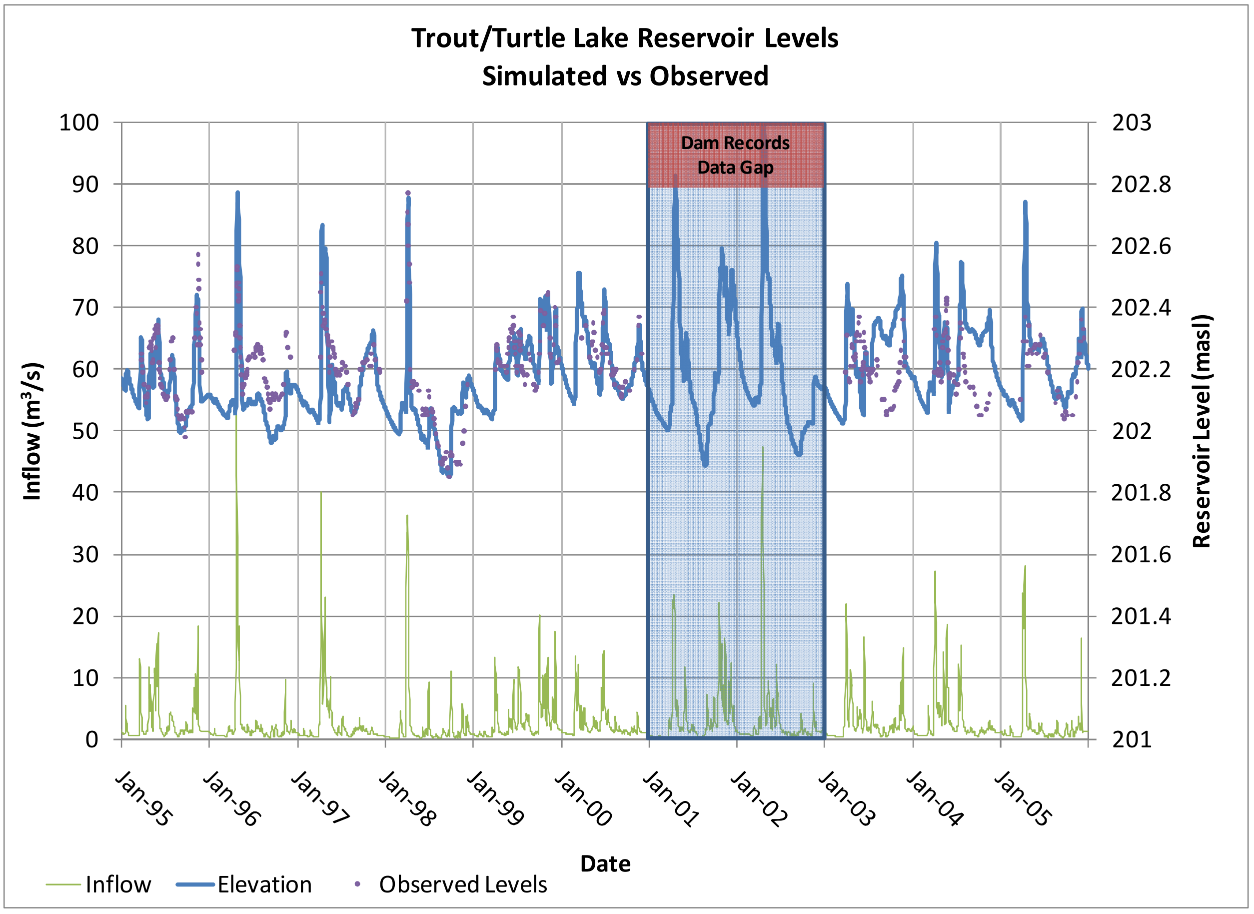

Figure 4-6: Trout/Turtle Lake Inflows and Simulated and Observed Lake Levels

4.3 SENSITIVITY ANALYSIS

As all models require the use of assumptions to simplify the hydrologic system, modelled results contain uncertainties. These uncertainties are due to the inability of a hydrologic model to replicate all individual of the physical processes that may influence the bulk hydrologic response (streamflow) from a catchment. These uncertainties can be managed or reduced by undertaking detailed calibration/verification exercises, and validating model output to additional observed datasets; however, they cannot be removed.

A sensitivity analysis can be used to determine the significance of this uncertainty on model results. For the Trout/Turtle Lake GAWSER model, four uncertainty scenarios were investigated. These scenarios each varied infiltration parameters (±25%), and varied the potential evapotranspiration rates (±10%), independently. The scenarios did not result in significantly different model outcomes; the Trout/Turtle Lake inflows varied by a maximum of 4 mm/month, and the Trout/Turtle Lake water levels varied by a maximum of 4 cm. Additional details are provided in Appendix B.

The results of the sensitivity analysis indicate that the uncertainty associated with infiltration and evapotranspiration parameters do not significantly impact simulated Trout/Turtle Lake inflows or lake levels. This result increases the level of confidence associated with the hydrologic model for estimating lake inflows or levels.

4.4 WATER BUDGET

The GAWSER model outputs several daily water balance parameters at the catchment and at the Hydrologic Response Unit level. Some of these parameters include mean daily streamflow, precipitation, rainfall, evapotranspiration, overland runoff, infiltration, seepage, baseflow, depression storage, and soil water content.

The mean annual water budget (precipitation, evapotranspiration, runoff, and recharge) was calculated on a subwatershed basis for the 1975-2005 study period, as summarized in Table 4-1. The four water budget components are described below:

- Precipitation – Depth of water that reaches the ground surface via rainfall or snowmelt, based on reported climate data.
- Evapotranspiration – Depth of water that leaves the subwatershed via evaporation, transpiration, and sublimation.
- Direct Overland Runoff – Depth of water that does not infiltrate the soil, but reaches the surface water system via overland flow.
- Groundwater Recharge – Depth of water that infiltrates into and past the evaporative root zone and enters the groundwater flow system. This water is returned to the surface water system via groundwater discharge, and sustains dry weather streamflow (baseflow).

Table 4-1: Mean Annual Water Budget on a Subwatershed Basis

	Mean Annual Water Budget for 1975-2005 in mm/yr and (% of Precipitation)			
Subwatershed	**Precipitation**	**Evapotranspiration**	**Overland Runoff**	**Groundwater Recharge**
Trout/Turtle Lake	953	568 (60%)	246 (26%)	139 (15%)
Chippewa Creek	1,027	523 (51%)	316 (31%)	188 (18%)
La Vase River	924	549 (59%)	282 (31%)	93 (10%)

As seen in Table 4-1, the estimated annual water budget values vary between subwatersheds. Evapotranspiration estimates are highest in Trout/Turtle Lake subwatershed, due to evaporation from the surface of Trout and Turtle Lakes. Overland runoff is lowest in Trout/Turtle Lake subwatershed and highest in Chippewa Creek subwatershed, due to developed lands. Recharge is lowest in the La Vase River subwatershed, where low permeable bedrock dominates the area. The Chippewa Creek subwatershed has the highest recharge rates due to high portions of sand and gravel.

In the Trout/Turtle Lake subwatershed, evapotranspiration accounts for 60% of the mean annual water budget, 26% is surface runoff, and the remaining 15% recharges into the ground and returns as baseflow.

The 1975-2005 mean annual water budget was also calculated on a Hydrologic Response Unit basis. These results are presented on Map 10 (Mean Annual Evapotranspiration), Map 11 (Mean Annual Overland Runoff) and Map 12 (Mean Annual Groundwater Recharge).

Included on Map 13 is the breakdown of inflow to Trout/Turtle Lake by subwatershed. Inflow is presented for each subwatershed, expressed in units of million m^3 per year, as well as a percentage of total inflow. Outflows (evapotranspiration from the lake surface, consumptive withdrawals and Turtle Dam discharge) are similarly displayed.

5.0 Tier Two Subwatershed Stress Assessment

The approach for conducting a Tier Two Subwatershed Stress Assessment is outlined in both the Province's Guidance Module 7 (MOE, 2007) and the Technical Rules (MOE, 2009). The Stress Assessment is intended to be performed separately for surface water systems and groundwater systems. As there are no municipal groundwater supplies or permitted groundwater takings within the Trout/Turtle Lake subwatershed, this Tier Two Subwatershed Stress Assessment is completed only for surface water demands.

Estimated values for water supply and water reserve are calculated using numeric water budget models; water demand is estimated using the Permit-To-Take-Water (PTTW) database. For the Trout/Turtle Lake subwatershed, information from Section 3 (Water Demand) and Section 4 (Water Budget Modelling) were used to complete the Tier Two Subwatershed Stress Assessment.

5.1 STRESS ASSESSMENT METHODOLOGY

The Technical Rules (MOE, 2009) describes three scenarios used to determine a subwatershed's potential for stress. The scenarios are as follows:

1. Historical Conditions;
2. Percent Water Demand Scenarios; and
3. Drought Assessment Scenario.

If a subwatershed meets the criteria for having a Moderate or Significant potential for stress under any one of these three scenarios, then the subwatershed is identified as having either a Moderate or Significant potential for stress. Under the direction of the Technical Rules, when a subwatershed is designated as having a Moderate or Significant potential for stress, municipal systems located in the subwatershed are required to complete a Tier Three Local Area Risk Assessment.

The above scenarios are described in the following sub-sections.

5.1.1 Historical Conditions

According to Rule 34.2 (c) of the Technical Rules (MOE, 2009), if either of the below conditions are met, any time after January 1, 1990, the subwatershed is classified as having a Moderate potential for stress:

> *(i) any part of a surface water intake was not below the water's surface during normal operation of the intake, or*
>
> *(ii) the operation of a surface water intake pump was terminated because of an insufficient quantity of water being supplied to the intake.*

5.1.2 Percent Water Demand Scenarios

As outlined in the Guidance Module #7 (MOE, 2007) and the Technical Rules (MOE, 2009), the Percent Water Demand is calculated using the following formula:

$$\textit{Percent Water Demand} = \frac{Q_{DEMAND}}{Q_{SUPPLY} - Q_{RESERVE}} \times 100\%$$

The terms are defined below:

- Q_{DEMAND} is the consumptive demand calculated as the estimated rate of locally consumptive takings.
- Q_{SUPPLY} is the water supply term, calculated for surface water as the monthly median inflow for the area to be assessed.
- $Q_{RESERVE}$ is the water reserve, defined as the specified amount of water that does not contribute to the available water supply. For surface water supplies, reserve is estimated using the 90th percentile monthly flow, at a minimum (i.e. the flow that is exceeded 90% of the time).

For surface water systems, the Technical Rules for a Tier Two Subwatershed Stress Assessment require that the above equation be calculated on a monthly basis. Monthly estimates of demand, supply and reserve are used to determine the Percent Water Demand for each month. The maximum Percent Water Demand for all months is then used to categorize the potential for stress into one of three levels: Significant, Moderate or Low, as shown in Table 5-1.

Table 5-1: Surface Water Potential Stress Thresholds

Surface Water Potential Stress Level Assignment	Maximum Monthly % Water Demand
Significant	≥ 50%
Moderate	>20% and < 50%
Low	≤ 20 %

Percent Water Demand is calculated for three different water demand scenarios: (1) Current Water Demand; (2) Planned Water Demand; and (3) Future Demand. Under each scenario, a subwatershed's potential for stress is evaluated by comparing the consumptive water demand with the amount of water flowing through the subwatershed (water supply). Only those subwatersheds identified as having a Low potential for stress under the Current Demand scenario require assessment for the Planned and Future Demand scenarios.

The Technical Rules (MOE, 2009) require further consideration of subwatersheds with a Low potential for stress AND a Percent Water Demand close to the Moderate threshold in Table 5-1. Thus, subwatersheds with a maximum monthly surface water Percent Water Demand between 18% and 20% require an uncertainty assessment. If uncertainty associated with the water supply and demand terms can result in a Percent Water Demand greater than 20%, the subwatershed in question is assigned a Moderate potential for stress.

5.1.3 Drought Assessment Scenario

Upon review of the Historical Conditions and completion of the Current, Planned, and Future Demand Scenarios, subwatersheds still classified as having a Low potential for stress are subject to the Drought Scenario. The Drought Scenario consists of comparing modelled results of available surface water supply for a two-year drought period to current demand and future demand.

According to the Technical Rules (MOE, 2009), for a municipal surface water intake, if either of the below conditions are met during a modelled two year drought, the subwatershed would be classified as having a Moderate potential for stress:

> *(i) any part of a surface water intake was not below the water's surface during normal operation of the intake, or*
>
> *(ii) the operation of a surface water intake pump was terminated because of an insufficient quantity of water being supplied to the intake.*

Whereas the Percent Water Demand Scenarios were based on subwatershed-wide demand and supply, the Drought Assessment Scenario is based on the available water supply at an intake location. If one municipal intake is found to meet the criteria listed above, the entire subwatershed is identified as having Moderate potential for stress.

5.2 STRESS ASSESSMENT

The following sections document the Tier Two Subwatershed Stress Assessment for the Trout/Turtle Lake subwatershed according to Technical Rules (MOE, 2009).

5.2.1 Historical Conditions

As described in Section 5.1.1, the first test for determining a subwatershed's potential for stress is whether the operation of a municipal well/intake has been affected due to an insufficient supply of water.

The minimum lake level for Trout/Turtle Lake, documented in the MNR Turtle Dam operation records, occurred on September 23 1998, was 201.85 masl. The municipal intake is at an elevation of 180.30 masl, which is 21.55 m below the minimum recorded lake level; therefore there is no historical occurrence of either the lake level dropping below the surface water intake, or an insufficient quantity of water causing termination of normal operation of the intake.

5.2.2 Percent Water Demand

5.2.2.1 Existing Conditions

The GAWSER model (Section 4.0) generates a daily time series of Trout/Turtle Lake inflows, which includes direct precipitation falling on the lake surface. The time period selected for this analysis is 1975 to 2005. Selecting a 30-year period is consistent with climate studies, which typically use a 30-year period to describe average climate (e.g. Climate normals published by Environment Canada).

Mean monthly inflows and monthly 90th percentile exceedance flows, derived from the daily time series of inflow, are included in Table 5-2. The estimated consumptive demand for the Trout/Turtle Lake (Section 3.0) is also included.

Using the Percent Water Demand equation presented in Section 5.1.2, the water supply, water reserve, and water demand values are used to calculate the Percent Water Demand for each month. The result of this calculation is shown in the last row of Table 5-2.

Table 5-2: Existing Conditions Stress Assessment

Term	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Consumptive Water Demand [1] (m^3/s)	0.39	0.39	0.38	0.38	0.39	0.41	0.42	0.42	0.44	0.39	0.38	0.39
Water Supply [2] (m^3/s)	0.74	0.64	2.39	5.97	2.81	1.95	1.65	1.37	1.81	2.09	2.48	1.47
Water Reserve [3] (m^3/s)	0.43	0.33	0.38	1.12	0.92	0.78	0.43	0.42	0.51	0.62	0.85	0.84
Water Supply - Reserve (m^3/s)	0.31	0.30	2.01	4.85	1.89	1.17	1.21	0.95	1.31	1.47	1.63	0.63
Percent Water Demand [4]	**128%**	**129%**	19%	8%	**21%**	**35%**	**35%**	**44%**	**34%**	**27%**	**23%**	**62%**

Definitions:

[1]- *2008 Mean Monthly Municipal Water Demand + Permitted Industrial Cooling Consumptive Demand*

[2]- *Median Monthly Streamflow (1975-2005)*

[3]- *90th Percentile Exceedance Streamflow (1975-2005)*

[4]- *Percent Water Demand = Consumptive Demand / (Supply-Reserve) x 100%*

Comparing the results of Table 5-2 to the Percent Water Demand thresholds presented in Table 5-1, the Percent Water Demand for the months of December, January, and February exceed the threshold for a Significant potential for stress (≥50%). The Percent Water Demand calculated for May through September exceeds the threshold for a Moderate potential for stress (20-50%).

Based on the Percent Water Demand calculations and thresholds described in Rule 34.1 of the Technical Rules (MOE, 2009), the Trout/Turtle Lake subwatershed is assigned a **Significant** potential for stress.

5.2.2.2 Planned and Future Demand

As the Trout/Turtle Lake subwatershed is classified as having a **Significant** potential for stress under existing conditions (Section 5.2.2.1), the Percent Water Demand for planned or future demand conditions did not need to be calculated.

5.2.3 Drought Scenario

As the Trout/Turtle Lake subwatershed is classified as having a **Significant** potential for stress under existing conditions (Section 5.2.2.1), a drought assessment for the North Bay municipal intake is not necessary.

5.2.4 Uncertainty Classification

Rule 36 of the Technical Rules (MOE, 2009) requires that an uncertainty classification of either “High” or “Low” be assigned for each subwatershed that is assessed. This qualitative assignment considers four factors: (1) the available input data; (2) the ability of the model to replicate major hydrologic processes; (3) the quality assurance and quality control procedures; and (4) the extent and level of model calibration achieved.

As climate is the primary input to the hydrologic system, proper representation is critical to accurately represent the hydrology of a watershed. A long-term, high quality meteorological station at the North Bay Airport, located within the Trout/Turtle Lake subwatershed, provides a reasonable representation of the main climate drivers (temperature and precipitation). As such, uncertainty associated with the available input data is low.

Consumptive water use estimates, often a source of uncertainty, are predominantly comprised of reported actual pumping rates from the City of North Bay’s municipal intake. The high proportion of water demand associated with reported pumping rates, rather than permitted rates, reduces uncertainty associated with consumptive demand estimates.

The hydrologic model reasonably replicates the major hydrologic processes. This is evident by comparing the simulated streamflow to the observed streamflow for La Vase River and Chippewa Creek streamflow gauges; comparing the spot flow measurements for Trout Lake tributaries; and comparing the reported and simulated Trout/Turtle lake water elevations. The ability of the model to replicate continuous and spot flow observations, as well as lake levels, suggests that the model is a reasonable predictor of streamflow within the Trout/Turtle Lake subwatershed. As such, the uncertainty associated with the model and level of calibration is low.

High levels of quality assurance and quality control were maintained throughout the completion of the Trout/Turtle Lake Tier Two Subwatershed Stress Assessment. Efforts included thoroughly checking all calculations, replicating model output, and internally reviewing documentation. Uncertainty associated with quality assurance and quality control is low.

With these factors in mind, the Trout/Turtle Lake Tier Two Subwatershed Stress Assessment is assigned a **Low** uncertainty classification.

5.3 DISCUSSION

The Trout/Turtle Lake subwatershed is classified as having a **Significant** potential for stress. This classification indicates that the Percent Water Demand for this subwatershed is higher than Provincial thresholds, and that the subwatershed has a higher probability of experiencing water quantity-related impacts, when compared to a subwatershed with a Low potential for stress. It does not necessarily indicate that a subwatershed is experiencing local hydrologic or ecologic stress or that water takings are unsustainable.

As per the Technical Rules (MOE, 2009), municipal water supply systems within subwatersheds identified at the Tier Two level as having a Moderate or Significant potential for stress, meet the requirement for a Tier Three Local Area Risk Assessment. A Tier Three Local Area Risk Assessment evaluates the risk that a municipal system will not be able to meet existing or planned pumping requirements.

Based on the outcome of the Tier Two Subwatershed Stress Assessment, a Tier Three Local Area Risk Assessment for the North Bay municipal intake is required under the *Clean Water Act*. Tools developed as part of the current Tier Two Subwatershed Stress Assessment (hydrologic and reservoir routing model) were used to support the Tier Three Local Area Risk Assessment, and provided a scientific basis for evaluating the risk, in accordance with the Technical Rules (MOE, 2009).

5.4 SIGNIFICANT GROUNDWATER RECHARGE AREAS

The Technical Rules (MOE, 2009) require the identification of Significant Groundwater Recharge Areas (SGRAs) as a specific type of vulnerable area that will be protected under the *Clean Water Act* (2006). The role of SGRAs is to support the protection of drinking water across the broader landscape. SGRAs delineated using the water budget tools are further scored as areas of high, moderate, or low groundwater vulnerability based on their mapped intrinsic susceptibility (or alternate vulnerability mapping) as part of the Water Quality Threats Assessment process.

Recharge is the process whereby water moves from the ground surface through the unsaturated zone to the underlying water table. Groundwater recharge occurs across a watershed at a range of rates depending on soil type, land use, slope, and climate. The GAWSER model output provides an estimate of groundwater recharge from the Hydrological Response Units within the Trout/Turtle Lake, Chippewa Creek and La Vase River subwatersheds (Map 12). The Technical Rules (MOE, 2009) provide a straightforward methodology to delineate SGRAs from the GAWSER model simulation results.

5.4.1 Methodology

The Technical Rules (MOE, 2009) provide the following instructions for the delineation of SGRAs;

Part V.2 - Delineation of significant groundwater recharge areas

44. Subject to rule 45, an area is a significant groundwater recharge area if,

(1) the area annually recharges water to the underlying aquifer at a rate that is greater than the rate of recharge across the whole of the related groundwater recharge area by a factor of 1.15 or more; or

(2) the area annually recharges a volume of water to the underlying aquifer that is 55% or more of the volume determined by subtracting the annual evapotranspiration for the whole of the related groundwater recharge area from the annual precipitation for the whole of the related groundwater recharge area.

45. Despite rule 44, an area shall not be delineated as a significant groundwater recharge area unless the area has a hydrological connection to a surface water body or aquifer that is a source of drinking water for a drinking water system.

46. The areas described in rule 44 shall be delineated using the models developed for the purposes of Part III of these rules and with consideration of the topography, surficial geology, and how land cover affects groundwater and surface water.

This assessment delineates SGRAs for both methods outlined in Rule 44(1) and 44(2) for the entirety of the modelled area. The "*related groundwater recharge area*" is taken as the entire domain for the GAWSER model: Trout/Turtle Lake, Chippewa Creek and La Vase River subwatersheds. This is consistent with Provincial guidance which recommends that this assessment be performed at the watershed scale.

Map 12 illustrates the 1975-2005 average annual groundwater recharge rates estimated by the GAWSER model at the Hydrologic Response Unit scale and will be used for the delineation of the SGRAs. Section 4.0 and Appendix B describe the modelling process used to generate this coverage.

5.4.2 Results

Rule 44.1 specifies the threshold for SGRAs to be 115% of the average groundwater recharge rate. Areas with recharge above this threshold are classified as a SGRA. The spatially averaged recharge rate for the Trout/Turtle Lake, La Vase River, and Chippewa Creek subwatersheds is 131 mm/yr, and results in a SGRA threshold of 151 mm/yr (131mm/yr*1.15). The SGRAs delineated according to this method are shown on Map 14, and comprise approximately 27% of the modelled area. Areas less than 0.1 km^2 were removed from the SGRA coverage, as these areas are at a scale finer than the original datasets (1:50K OGS quaternary geology mapping) can support.

Rule 44.2 specifies the threshold for SGRAs to be 55% of the net precipitation (precipitation-evapotranspiration). The net precipitation across the modelled area is 921 mm/yr - 539 mm/yr, or 382 mm/yr. Applying the 55% factor to the net precipitation yields a SGRA threshold of 210 mm/yr. The SGRAs delineated according to this method are shown on Map 15, and comprise approximately 15% of the modelled area. As with Map 14, areas less than 0.1 km^2 were removed from the SGRA coverage, as these areas are at a scale finer than the original datasets (1:50K OGS quaternary geology mapping).

The predominant difference between the SGRAs identified by Rule 44.1 (115% of average recharge) and those identified by Rule 44.2 (55% of net precipitation) is the inclusion of the till deposits North of Trout Lake. Due to a lower SGRA threshold, the 115% methodology captures a large portion of the Four Mile Creek and Doran Creek drainage areas, which is not captured by the 55% methodology. The lower threshold associated with the 115% methodology is caused by the inclusion of Trout/Turtle Lake recharge (assumed to be zero) lowering the spatial average.

In addition to the delineated areas, Maps 14 and 15 also include domestic wells (as reported in the Ministry of the Environment's water well information system) and the North Bay municipal intake. Delineated areas must have a hydrological connection to a drinking water system to be considered a SGRA. It is recognized that many dwellings surrounding Trout/Turtle Lake take drinking water directly from the lake, but are not shown on Maps 14 and 15 as a drinking water system. As well, owner-constructed dug wells are underrepresented in the water well database system.

5.4.3 Discussion

As outlined by the Technical Rules (MOE, 2009), either one of the two methodologies, 115% of average recharge (Map 14) or 55% of surplus precipitation (Map 15), can be used to identify SGRAs. Upon consultation with the Water Budget Peer Review Committee, the first methodology (115% of average recharge) was selected to delineate SGRAs.

The SGRAs delineated in this section reflect those areas within the Trout/Turtle Lake, Chippewa and La Vase River subwatersheds that are considered to be important groundwater recharge areas. These areas include the sand and gravel deposits found above the Escarpment as well as localized deposits throughout the study area. Large portions of Four Mile Creek and Doran Creek are also be identified as being an SGRA.

When relying on the SGRA map to support water quantity or water quality protection activities there is a need to consider some of the assumptions and limitations associated with the delineated SGRAs. They are as follows:

1. Significant volumes of groundwater recharge may occur in areas that are not classified as SGRAs. Estimated groundwater recharge rates in some areas may be high, but just below the SGRA threshold.
2. The hydrologic model is calibrated to achieve the best overall fit to measured streamflow. Within a specific watershed, there is a wide range of estimated groundwater recharge rates depending on local geologic type and land cover. While the calibration process addresses the confidence of the hydrologic simulation within a subwatershed, the water budget parameters for a specific Hydrologic Response Unit are not calibrated and the results should only be considered as a relative measure of hydrologic processes.

The Province's objectives for incorporating SGRAs into the Water Quality Threats Assessment process are clearly defined within the Technical Rules (MOE, 2009). SGRAs are used in coordination with intrinsic susceptibility mapping to determine a vulnerability score outside of wellhead protection areas. SGRAs are one of the three types of vulnerable areas identified by the Province.

Conversely, the role of protecting SGRAs from a water quantity perspective is not prescribed in the Technical Rules (MOE, 2009). SGRA mapping may be adopted by individual municipality and county planning offices as a "designated vulnerable area" through the Provincial Policy Statement (PPS), to improve or restore the quality and quantity of water, particularly in areas pertinent to significant hydrologic processes (as per the guidance in section 2.2.1 of the PPS). However, such initiatives are undertaken as each jurisdiction sees fit and may not provide a uniform approach to water quantity protection throughout the watershed, including the potential cumulative impacts of development.

The Source Protection Planning Process also provides a good opportunity to address the need to protect groundwater quantity across a watershed / subwatershed. A groundwater quantity protection initiative for SGRAs would need to include consideration of the total recharge volume, the hydrologic function of recharge from any given area and also the uncertainty of estimated recharge rates.

5.5 TIER TWO SUBWATESHED STRESS ASSESSMENT SUMMARY

A Tier Two Subwatershed Stress Assessment, which follows the Technical Rules (MOE, 2009) and Guidance Module #7 (MOE, 2007) has been completed for the Trout/Turtle Lake subwatershed.

Consumptive water demand, calculated in Section 3.0, and water supply terms (monthly median and 90th percentile exceedance flows), calculated from tools documented within Section 4.0, were used to calculate Percent Water Demand as per the Technical Rules (MOE, 2009). Based on the monthly maximum Percent Water Demand, and thresholds prescribed by the Technical Rules (MOE, 2009), Trout/Turtle Lake subwatershed is classified as having a **Significant** potential for stress. The uncertainty assigned to this classification is **Low**.

Based on the outcome of the Tier Two Subwatershed Stress Assessment and the requirements under the *Clean Water Act* (2006), a Tier Three Local Area Risk Assessment is required for the North Bay municipal intake. The Tier Three Local Area Risk Assessment will evaluate the ability of the municipal intake to meet existing and future demands.

SGRAs have been delineated using both methodologies prescribed by the Technical Rules (MOE, 2009). Upon consultation with the Water Budget Peer Review Committee the methodology of 115% of average groundwater recharge was selected to delineate SGRAs.

6.0 Tier Three Local Area Risk Assessment

The objective of the Tier Three Local Area Risk Assessment (Tier Three Assessment) is to estimate the likelihood that municipalities will be able to meet current and future water quantity requirements. The Tier Three Assessment is carried out on all municipal water supplies located in subwatersheds that were classified in the Tier Two Subwatershed Stress Assessment as having a Moderate or Significant potential for hydrologic stress. The Tier Three Assessment is a more detailed study than the Tier Two Assessment, and examines the municipality's ability to meet water demands while meeting the demands of other water uses. Water quantity threats located within vulnerable areas identified as having a Moderate or Significant Risk level, are ranked or prioritized in a Threats Ranking Assessment (after the completion of the Tier Three Assessment). The goal of this ranking is to prioritize the risk management measures that should be applied to reduce the level of risk associated with the municipal water supply system not being able to meet current or future water demands.

The tasks required to assess the Risk level of each Local Area are listed below, and the following sections discuss each task in greater detail.

1. Local Area Delineation. The Local Area for a surface water intake is referred to as an *intake protection zone for water quantity*, abbreviated as "IPZ-Q". IPZ-Qs are delineated by determining the total drainage area that provides water to the municipal intake. Typically, this corresponds to the watershed boundary of the surface water body where the intake is located. See Section 6.1 for additional detail.

2. Assign Tolerance Level. Tolerance is defined as the municipal system's ability to meet peak water demands. If the municipal system is able to meet peak water demands, a Tolerance level of "High" is assigned. If the municipal system is not able to meet the peak water demands, a Tolerance level of "Low" is assigned. See Section 6.2 for additional detail.

3. Assign Exposure Level. Exposure evaluates whether a Local Area can supply sufficient water to meet the demands of the municipal system, and other water uses. Four scenarios are tested to determine the resiliency of the Local Area to drought conditions, increased municipal takings and potential future changes in land use. If the Local Area can supply sufficient water to the municipal system, without causing adverse effects on other water uses, an Exposure level of "Low" is assigned. If the Local Area cannot supply sufficient water, without causing adverse effects to other water uses, an Exposure level of "High" is assigned. See Section 6.3 for additional detail.

4. Assign Risk Level. Based on the classification of Tolerance and Exposure, the Risk level is assigned to the Local Area. The Risk level for the Local Area may be classified as "Low", "Moderate" or "Significant". See Section 6.4 for additional detail.

6.1 LOCAL AREA DELINEATION; IPZ-Q

The Technical Rules (MOE, 2009) require that a surface water intake protection zone must be delineated for all municipal surface water intakes located within subwatersheds identified by Tier Two Subwatershed Stress Assessments as having a Moderate or Significant potential for stress. Surface water intake protection zones (IPZ-Qs) are defined as the entire drainage area that may supply water to a municipal water supply intake. In the case of the North Bay Trout Lake intake, the drainage area contributing to the intake includes the entire Trout/Turtle Lake subwatershed (Map 16). This zone will be delineated as the Local Area (IPZ-Q), within which the Tolerance, Exposure and Risk levels will be assigned.

6.2 TOLERANCE

The Tolerance level of a municipal drinking water supply system is defined as its ability to meet peak demands. A municipal system within a Local Area (IPZ-Q) is classified as having either a Low or High tolerance level depending on the municipal water supply system's ability to supply water to users during peak demand periods. Specifically, Part IX.3 Rule 107 of the Technical Rules (MOE, 2009) outlines how Tolerance is assigned to a municipal drinking water system, and is included below.

> *107. An existing type I, II or III system has the following tolerance level,*
>
> *(1) High, if the system obtains water from a surface water intake relating to a local area assessed in accordance with the circumstances described in 101(1) and at all times during that assessment, the system would have been capable of meeting the peak demands of users of the system.*
>
> *(2) High, if the system obtains water from a well relating to a local area assessed in accordance with the circumstances described in 101(2) and at all times during that assessment, the system would have been capable of meeting the peak demands of users of the system.*
>
> *(3) Low, if a tolerance level is not assigned in accordance with either of subrules (1) or (2).*

The ability of a municipal drinking water system to meet peak water demands is constrained by the ability of the source to provide a sufficient quantity of water to meet the peak demand, and the ability of the municipality to legally withdraw water at a rate that would meet the peak demands.

As described in Section 3.2, the North Bay intake is located 23 m below the observed Trout Lake low water level elevation (201.8 masl). Only considering Trout Lake alone, it is estimated that the volume of water contained between the intake elevation and the standard operating level is 270,000 ML. Conservatively, assuming no inflow to the lake at all, this volume of water would sustain the City of North Bay's 2008 average withdrawal (~425 L/s, or 37ML/d) for approximately 20 years.

While the storage held in the lake below the standard operating level is sufficient to sustain the municipal taking for a significant period of time with zero inflow, the severe impacts of such a situation occurring should be recognized. In addition to discharge from Turtle Dam ceasing and affecting downstream lakes and rivers, recreational use, aquatic and wetland habitats within Trout/Turtle Lake would be significantly impacted as lake levels are drawn down. It is recommended that the City of North Bay continue to manage municipal water demand with the aim to maintain lake levels within historical ranges.

To assess the City's ability to withdraw sufficient water to meet peak demands, while remaining within PTTW restrictions, peak municipal demands were compared to the maximum permitted withdrawal rate associated with the water treatment plant. As described in Section 3.2.2, the City of North Bay experienced a peak day demand in the summer of 2001 that was approximately 90% of the City's maximum permitted withdrawal rate (North Bay, 2003). As a result of this event, the City instituted an outdoor water use by-law to restrict outdoor water use to every other day. Water withdrawal reports from the City of North Bay indicate that following implementation of the outdoor water use bylaw, 2002-2008, the maximum daily demand between 2002 and 2008 has been less than 70% of the permitted withdrawal rate. This indicates that the water treatment plant is able to withdraw sufficient water from Trout Lake to meet peak demands, while remaining in compliance with the PTTW.

Due to the volume of water stored within Trout/Turtle Lake, and the ability of this storage to supply sufficient water to the municipal intake to meet peak demands, as well as the ability of the City to withdraw peak demands within their current PTTW, a Tolerance classification of "**High**" is assigned to the North Bay municipal drinking water system.

6.3 EXPOSURE

A Local Area is assigned an Exposure level of "High" if the water supply source is insufficient to meet the needs of the system without impacting other water uses. To evaluate whether other water uses are impacted, simulated Trout/Turtle Lake water levels will be assessed. Where water levels drop below a specific threshold, an Exposure level of "High" will be assigned to the Local Area. Where water levels remain above the threshold, an Exposure level of "Low" will be assigned.

Due to MNR operation of Turtle Dam being the primary determinant of flows downstream of Trout/Turtle Lake, selection of an Exposure threshold will focus on water uses upstream of Turtle Dam. The Exposure threshold is discussed in the following sections.

6.3.1 Exposure Thresholds

The Technical Rules require that differing thresholds be used for average climate conditions and drought conditions. Thresholds for each scenario are discussed in the following sections.

6.3.1.1 Threshold for Average Climate Conditions

Water levels within Trout and Turtle Lakes have been controlled by Turtle Dam for over 100 years. Recreational water uses, as well as aquatic and wetland habitat, have adapted to the controlled water level regime, and are now reliant on the water levels being within the historical range of levels experienced by the lakes. The current Turtle Dam Operating Plan (MNR, 1996) states that the primary purpose of the dam is to maintain upstream water levels for recreational purposes, and specifies a lower elevation that dam operators maintain. This lower elevation is specified as 201.78 masl. This elevation was selected as the Exposure threshold for average climate conditions; if water takings drop the lake water level elevation below this level, the operating plan would be violated, and a "High" Exposure classification would be assigned to the Local Area.

It should be noted that a detailed assessment of water level fluctuations and their impact on wetland or aquatic habitat was not completed as part of this study. It is assumed that the water requirements for the existing ecology of Trout/Turtle Lake are accommodated by the Turtle Dam

Operating Plan. As the Turtle Dam Operating Plan was formalized in 1996, it can be assumed that the current ecology has adapted to the range of water levels specified in the Operating Plan.

6.3.1.2 Threshold for Drought Conditions

Through the Peer Review process, the MNR has clarified the Technical Rules, and provided direction to the Study Team that other water uses are **not** to be considered when evaluating Exposure under drought conditions. This recognizes that all water uses must endure lower water levels/flows induced by the drought, and that water level fluctuations caused by drought alone, may cause average thresholds to be violated.

Rather, the Exposure threshold for drought conditions is related to the ability of the municipal drinking water system to withdraw water from the water source. Should the drinking water system be able to withdraw water from Trout Lake during a drought, an Exposure classification of “Low” will be assigned to the Local Area. Should water levels be insufficient for the municipal water system to withdraw water, an Exposure classification of “High” will be assigned.

To evaluate whether the municipal water system is able to withdraw water, the minimum lake elevation in which the municipality is able to withdraw water must be determined. As described in Section 3.2, the elevation of the North Bay water supply intake is 180.3 masl. Applying a 10 m factor of safety to this elevation, yields an elevation of 190.3 masl, and is assumed to be the minimum lake level in which the North Bay municipal intake could function. Should simulated lake levels drop below 190.3 masl, at any time during the drought period, for either the existing or planned scenarios, an Exposure classification of “High” will be assigned to the Local Area.

6.3.2 Exposure Scenarios

When assessing the Exposure level, the Technical Rules (MOE, 2009) require that four scenarios be considered. These scenarios are as follows:

1. Long term average climate, current land use, existing pumping;
2. Drought conditions, current land use, existing pumping;
3. Long term average climate, future land use, planned pumping; and,
4. Drought conditions, future land use, planned pumping.

The following sections document each of the components of the above four scenarios. Assumptions related to each component are also documented.

6.3.2.1 Long Term Average Climate Conditions

Similar to the Water Budget and Tier Two Subwatershed Stress Assessment, (Section 4.4, and Section 5.2), the Tier Three Assessment used a 30-y period from 1975-2005. Simulated streamflow into Trout/Turtle Lake, estimated by the GAWSER model over this time period, was used when determining lake levels.

6.3.2.2 Drought Climate Conditions

The Tier Three Assessment requires consideration of a drought scenario. The drought scenario is meant to evaluate the possibility of short-term climate variability triggering an Exposure exceedance. The Technical Rules specify that the drought period considered for surface water systems is the continuous ten-year period with the lowest mean annual precipitation; however, MNR has provided direction that a shorter two-year period is more appropriate to evaluate drought impacts on surface water bodies. As such, a two-year period will be used to evaluate drought impacts.

As described in Section 2.2, an in-filled dataset for the North Bay Airport, distributed by the MNR was used for this Assessment. The period of record associated with this station is 1950-2005, and through this period there were two major drought periods (as seen on Figure 2-1); one in the 1960’s, and the second during the late 1990’s/early 2000’s. A two year running average was applied to the North Bay climate dataset to determine the period for use in the drought scenario. The lowest continuous two-year period within the 1950-2005 period was 1962-1963, with an average total precipitation of 654 mm/yr, which represents 64% of the long term (1970-2005) average precipitation. Inflows to Trout/Turtle Lake estimated by the GAWSER model for this time period were used to determine corresponding lake levels.

6.3.2.3 Existing Pumping

Consistent with the Tier Two Subwatershed Stress Analysis, reported withdrawal rates from 2008 were used in the Tier Three Assessment for the existing pumping scenario. These values are included in Section 3.2.1 above.

6.3.2.4 Planned System Pumping

Planned system rates are defined as the groundwater or surface water pumping rates used for a drinking water system that is established, or is planned to be established, with one of the following approvals: an individual Environmental Assessment (EA) approval; or if the system has been identified as the preferred solution within a completed planning process with an approved Class EA; or the system would serve a First Nation Community as defined in the Indian Act; Canada (MOE, 2006). According to this definition, and through consultation with the City of North Bay, there are no planned systems associated with the North Bay municipal system. The current drinking water treatment plant and permit to take water have sufficient capacity to provide drinking water to the City of North Bay now, and into the foreseeable future.

The planned system may also represent the committed water demand associated with planned or approved developments which will be serviced by the municipal drinking water supply. The City of North Bay has estimated the number of building lots which have been approved for development to be approximately 1400 (Bullock pers. comm., 2010). It should be noted that this may include lots within developments already under construction, which would be already accounted for in the 2008 population estimate. As such, 1400 additional building lots is considered a conservatively high estimate. Statistics Canada has reported an average of 2.4 people per dwelling for the City of North Bay (Statistics Canada, 2006), resulting in an committed population increase of 3360 people.

To evaluate the impacts of planned population growth on Trout/Turtle Lake water levels, and determine if lake levels will remain above the Exposure threshold, the approved population increase, along with the future per capita rate (Section 3.2.3) was used. As the City of North Bay is currently implementing a number of conservation measures that will reduce water consumption, future estimates evaluated in the Exposure scenarios included the effects of these measures. A second scenario, not considering the impact of the infrastructure upgrades was also included. The pumping rates for the two scenarios in included in Table 6-1.

Table 6-1: Planned Pumping Scenarios

	Per Capita Rate without Conservation (680 L/d)	Per Capita Rate with Conservation (458 L/d)
	Average Taking MLD(L/s)	
Planned Serviced Population (58,360)	40 (459)	27 (309)

6.3.2.5 Planned Land Use

When evaluating Exposure, the Technical Rules (MOE, 2009) require consideration of future land use developments, as well as planned pumping. Land use changes, particularly urban development, have the potential to impact the hydrologic cycle, and will often result in changes to available water, both in terms of total volume of streamflow, as well as the seasonal distribution of streamflow.

The North Bay Official Plan (North Bay, 2003) describes and outlines how and where future development will be accommodated. The City of North Bay recognized the importance of Trout Lake, both for recreational and water supply aspects, and incorporated policies into the Official Plan that aimed to protect the Lake. The following text was taken from Section 2.1.15 of the Official Plan, and describes the development controls placed on lands within the Trout/Turtle Lake subwatershed.

> *"This Official Plan recognizes that Trout Lake is a valuable community resource in that it is the sole source of drinking water for the City of North Bay as well as for private systems which draw their water directly from the lake; that this water body is a significant recreational resource at the fringe of the urban area which offers unique opportunities not found in such close proximity to most Canadian communities; that the shoreline of this water body has a special aesthetic appeal for the development of seasonal and permanent residential uses; and that the general population of North Bay wishes to see that special care is taken through strict lake and watershed development controls to maintain or improve its existing level of water, aesthetic and fishery quality.*
> *...*
> *This Plan recognizes that all lands located within the Trout Lake watershed are connected to Trout Lake by surface and ground water drainage, and that all uses in the watershed directly or indirectly influence Trout Lake.* ***It is the intent of this Plan to strictly control or limit the nature and extent of development*** *along the*

shoreline of Trout Lake, including second tier or back lot development, development on islands in Trout Lake, development along streams flowing into Trout Lake, and development in the Trout Lake watershed in general."

This intent by the City to limit development within the Trout Lake watershed is evident by the land area where urban services are provided. Serviced land is typically required for urban development. Included on Map 17 is a land use map taken from the City of North Bay Official Plan, as well as the Trout/Turtle Lake subwatershed boundary. Only a small portion of the urban serviced area lies within the Trout/Turtle Lake Watershed. This area is located in the easternmost portion of the City, adjacent to Delany Bay, and is 0.9 km^2 in area. As this area is currently fully developed, and no other lands within the Trout/Turtle Lake watershed are serviced, it is expected there will be negligible land use change within the City of North Bay portion of Trout/Turtle Lake watershed.

Municipalities lying adjacent to Trout or Turtle Lakes include the Township of East Ferris, Township of Bonfield and Phelps Township, are predominantly rural townships, with no urban areas within the Trout/Turtle Lake subwatershed. Due to the lack of urban centres, it is expected that there will be no significant land use change within these municipalities.

Despite the measures outlined above, some minor land use change is expected within the Trout/Turtle Lake subwatershed. These anticipated land use changes include a 45 ha (112 acres) industrial development within Lees Creek (Bullock, pers. comm., 2009), as well as a 0.2 ha (0.5 acres) peat extraction site, and a 6.5 ha (16 acres) aggregate extraction site and aggregate extraction site, both of which are within Doran Creek (Scott, pers. comm., 2009). These developments represent approximately 0.3% of the Trout/Turtle Lake drainage area.

These developments were considered within the GAWSER model by modifying the HRU classification for the affected subwatersheds (Lees and Doran Creek). The industrial development was represented by assuming a typical impervious percentage for industrial developments (90%) and increasing the impervious HRU class by the corresponding area. The peat extraction site was represented by transferring land area from the wetland class to the open water class. The aggregate extraction site was simulated by utilizing a high infiltration, low storage, low evapotranspiration HRU class, which supplies infiltrated water quickly to the watercourse. As the Technical Rules require no mitigative measures to be considered when assessing the level of Risk, no best management measures, such as maintaining recharge volumes, were considered during this analysis.

Included in Figure 6-1 and Figure 6-2 is the mean monthly flow under pre-development and post-development conditions for Lees and Doran Creek, respectively.

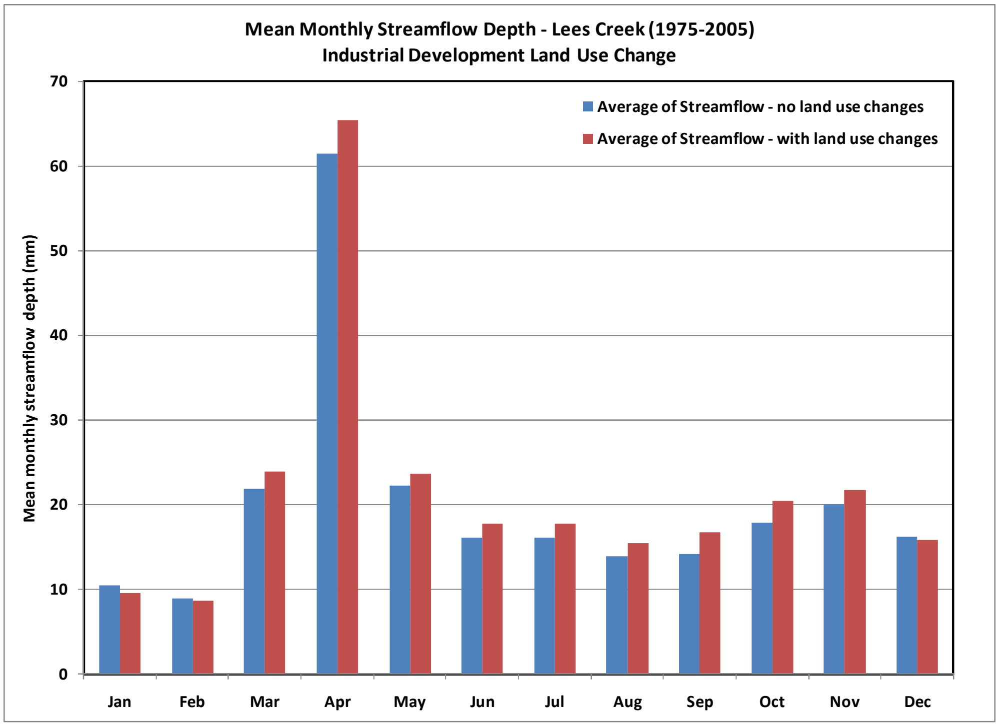

Figure 6-1: Planned Land Use Scenario - Lees Creek

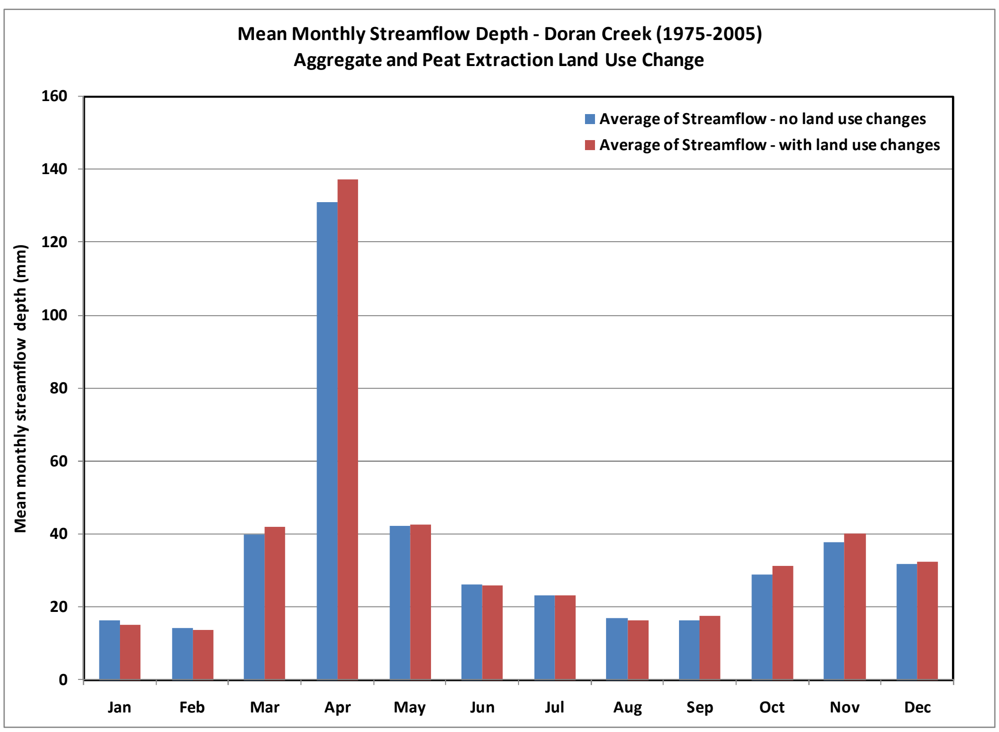

Figure 6-2: Planned Land Use Scenario - Doran Creek

As shown on Figure 6-1, the industrial development in Lees Creek results in increases in streamflow for most months. This is due to the impervious area added by the industrial development causing the majority of rainfall or snowmelt to become overland runoff, reducing the amount of infiltration, and subsequently reducing evapotranspiration. The industrial development also reduces the amount of groundwater recharge generated, and therefore lowers streamflow during months that experience limited overland runoff (e.g. December-February). The industrial development would also impact streamflow during drought periods, where the majority of streamflow would be derived from groundwater discharge. As the volume of groundwater recharge is reduced by impervious land cover, groundwater discharge would be reduced.

The impact of the aggregate and peat extraction land use scenario on Doran Creek (Figure 6-2) generally results in a quicker responding system. Streamflow during the spring months is generally higher as water is routed through to the watercourse faster, with lower summertime streamflow. Streamflow recovers quicker in the fall from the traditional summertime lows; however, streamflow during the months of January and February will be lower.

Land use policies contained within the City of North Bay Official Plan, will limit or control land development within the Trout/Turtle Lake subwatershed. Despite these controls, a small number of developments have previously been approved. To maintain Trout/Turtle Lake levels, these developments should be required to implement best management practices such as maintaining groundwater recharge volumes and managing storm runoff to maintain, or even enhance, dry weather streamflow.

Trout/Turtle Lake simulated inflow hydrographs from the planned land use scenario were used to represent the changes in hydrology that could be expected given approved developments.

6.3.3 Results

Using the reservoir routing model (Section 4.2), lake levels for each of the four Exposure scenarios were estimated using pumping records from City of North Bay, and simulated inflows calculated by the GAWSER model. Recorded stop log settings for Turtle Dam were used to specify dam operations where records existed (1991-2005). Stop log settings for years prior to 1991 were specified by the median stop log settings presented in Figure 2-6 (median stop log setting).

6.3.3.1 Scenario 1: Average climate, existing pumping

Figure 6-3 illustrates the simulated average daily water levels for the 1975-2005 period. Also included in the figure is the operating range of Turtle Dam, as well as the median stoplog setting for Turtle Dam.

Average water levels, with municipal pumping, remain the Exposure threshold of 201.78 masl. As a result, an Exposure classification of “Low” was assigned to the Local Area for Scenario 1.

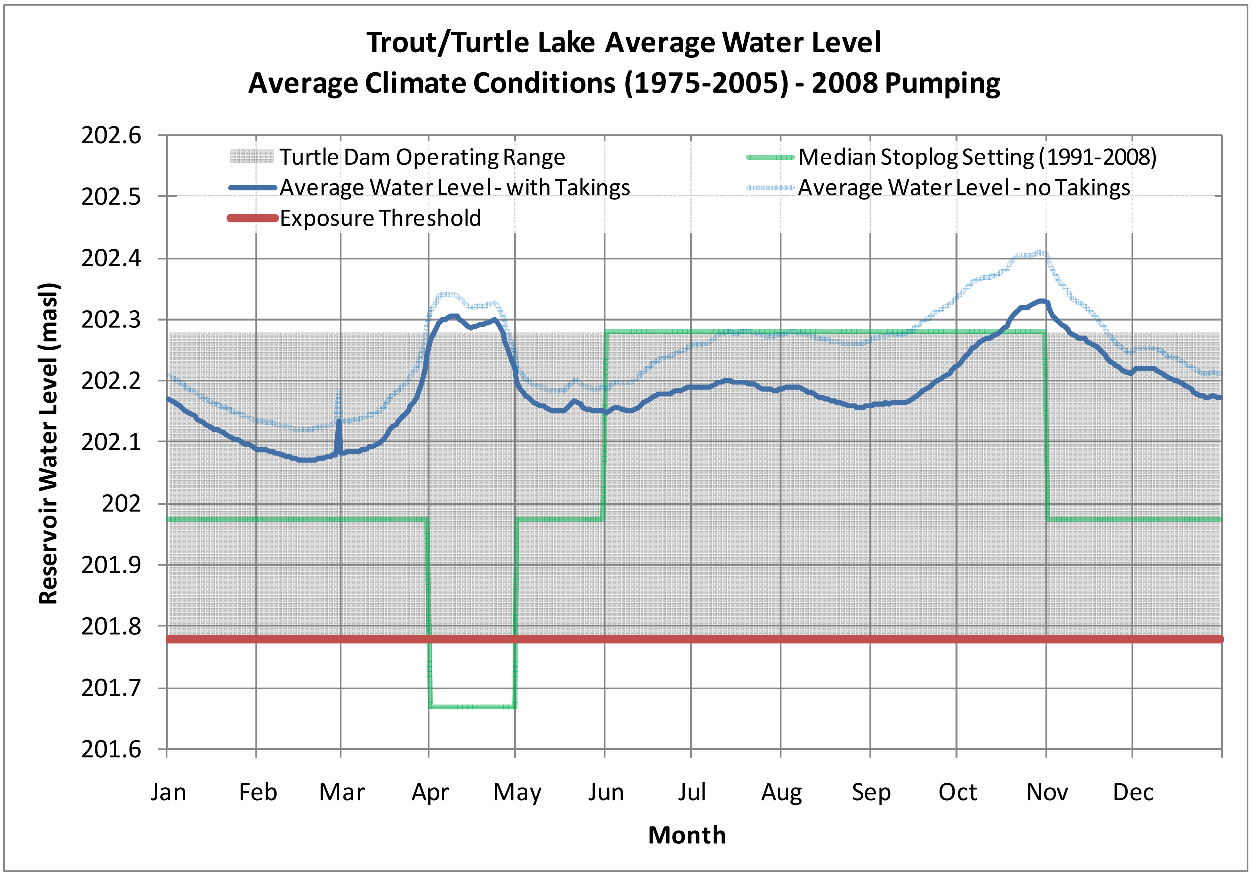

Figure 6-3: Exposure Scenario #1 Results

To assess the impact of municipal pumping on lake levels, another scenario was investigated with water withdrawals turned off. Comparison of the simulated water levels for the two series on Figure 6-3 shows the maximum impact of the water withdrawal is approximately 10 cm, and is seen in the summer/late fall months. This difference is largely reduced through the late fall and winter months as higher inflows replenish reservoir storage.

6.3.3.2 Scenario 2: Drought climate conditions, existing pumping

Figure 6-4 illustrates the minimum simulated daily water level over the 1962-1963 drought period. Minimum, rather than the average, lake levels are considered for the drought scenarios. This is due to the threshold for drought scenarios being the ability of the North Bay intake to withdraw water. Should the intake, at any time in the two year drought period, be exposed, or otherwise unable to withdraw water, an Exposure classification of High would be assigned.

Using inflows simulated to occur using climate data from 1962-1963, minimum lake levels are predicted to drop to approximately 201.78 masl, approximately 11 m above the drought Exposure threshold of 190.3 masl. Based on this analysis, an Exposure level of “Low” was assigned to the Local Area for Scenario 2.

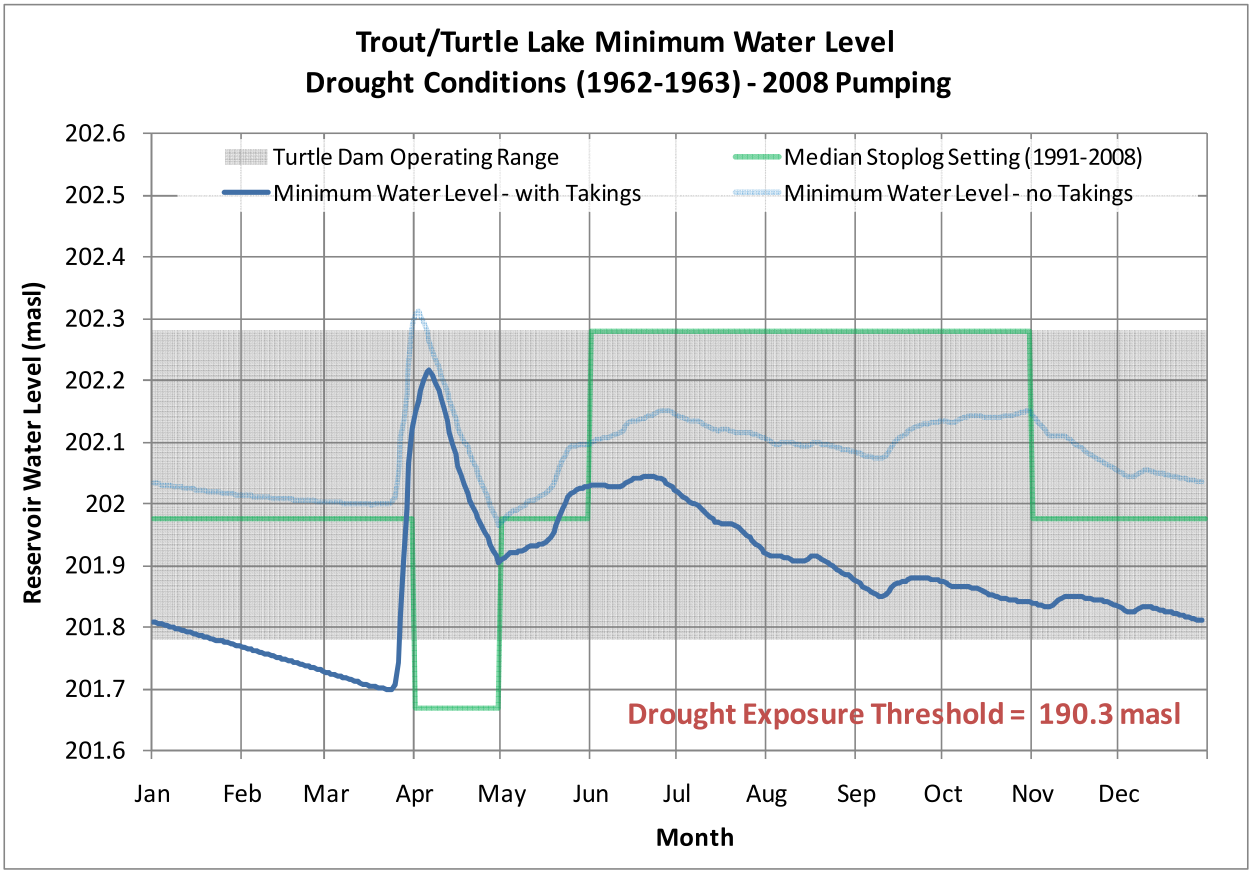

Figure 6-4: Exposure Scenario #2 Results

Similar to Scenario 1, a separate analysis was conducted to determine the impact of municipal takings during a drought period. In the absence of municipal pumping, the minimum water level generally remains above 202.0 masl. A difference of up to 30 cm is noted in the fall months between the simulated water levels with and without municipal pumping. When compared to the impact as shown in Figure 6-3, this indicates that the municipal water taking has a larger impact on water levels during a drought year than an average year.

6.3.3.3 Scenario 3: Average climate, planned pumping and land use

Figure 6-5 illustrates the results of Scenario 3. Simulated water levels for existing pumping, planned land use, as well as the planned pumping (with and without conservation measures as described in Section 3.2.2) are included. Simulated water levels under both planned pumping scenarios are comparable to water levels with existing municipal pumping; the maximum difference is approximately three centimetres, and all water levels remain above 201.78 masl during all months. Based on results of this analysis, an Exposure classification of “Low” was assigned to the Local Area for Scenario 3.

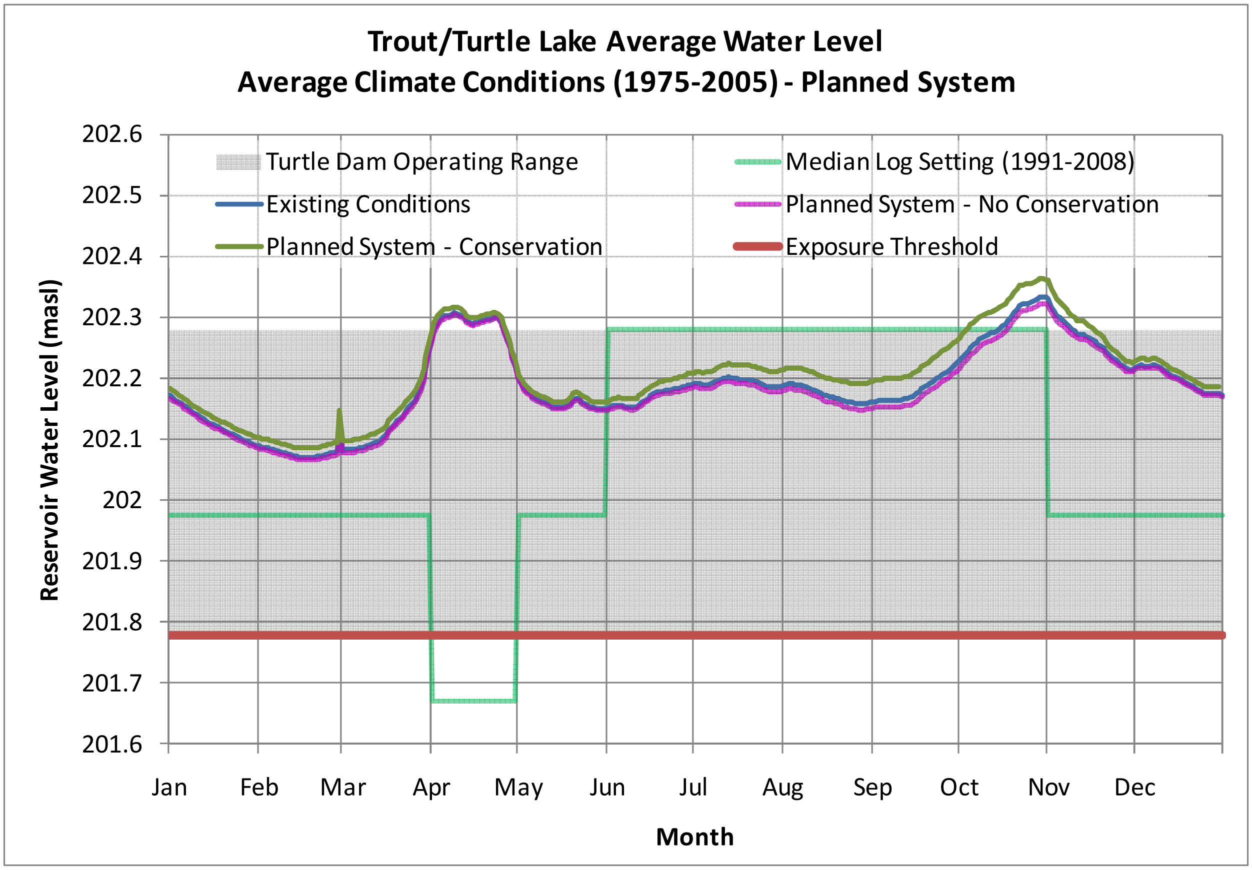

Figure 6-5: Exposure Scenario #3 Results

For long term average conditions, it is estimated that the conservation measures currently being implemented by the City of North Bay will result in Trout/Turtle Lake water levels being up to five centimetres higher than future water levels without the planned upgrades. This increase in water levels would occur primarily during the late summer/fall months, and would be a benefit to the recreational use of Trout/Turtle Lake. It is recommended that the City of North Bay continue to implement aggressive water conservation measures, as reducing water withdrawals from Trout Lake will result in higher and more stable Trout/Turtle Lake water levels.

6.3.3.4 Scenario 4: Drought climate, planned pumping and planed land use

Simulated water levels for planned pumping under drought conditions are illustrated on Figure 6-6. Water levels for existing pumping, planned land use, and planned pumping with and without conservation measures are presented (Figure 6-6). As with the drought scenario for existing pumping, water levels remain well above the drought Exposure threshold of 190.3 masl. Consequently, an Exposure classification of “Low” was assigned to the Local Area for Scenario 4.

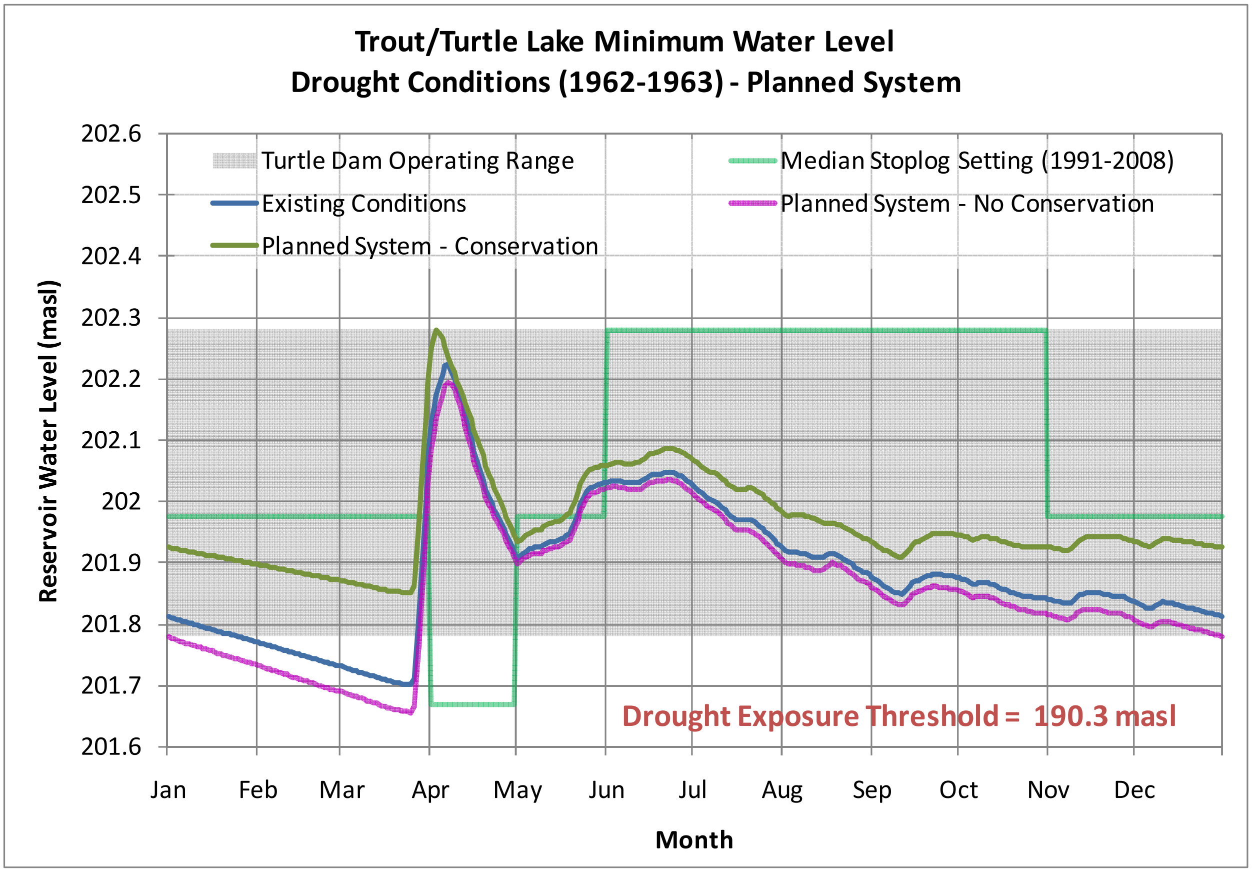

Figure 6-6: Exposure Scenario #4 Results

For drought conditions, the impact of reduced pumping caused by the conservation measures is more pronounced than for average annual conditions; simulated water levels under planned pumping (with conservation) are approximately 10 cm higher than water levels under existing pumping. The higher water levels caused by water conservation measures would typically be observed in the late summer, fall and winter months.

6.3.4 Exposure Summary

All four scenarios, required by the Technical Rules (MOE, 2009), result in an Exposure classification of "Low". These results are due to the large volume of water held in storage by Turtle Dam, and the ability of this storage to buffer the impacts of municipal withdrawals, as well as extreme droughts. Based on the results of all four scenarios, the Exposure classification assigned to the City of North Bay municipal intake is **Low**.

6.4 RISK DETERMINATION

The Risk Level of the Local Area is a combination of the Tolerance and Exposure levels. The Technical Rules (MOE, 2009), outlines how Tolerance and Exposure are used to assign risk.

As per Part IX.1 Rule 98, a Local Area related to a surface water intake is assigned a risk level in accordance with the following:

1. Significant, if the local area has an Exposure level of High and the system has a Tolerance of Low;
2. Moderate, if the local area has an Exposure level of High and the system has a Tolerance of High;
3. Moderate, if the local area has an Exposure level of Low and the system has a Tolerance of Low; or
4. Low, if the local area has an Exposure level of Low and the system has a Tolerance level of High.

The Local Area for the City of North Bay municipal system has a High Tolerance, and a Low Exposure, and as such, the Risk level associated with the Local Area for this municipal system is **Low**.

6.5 UNCERTAINTY ANALYSIS

Similar to the Tier Two Subwatershed Stress Assessment, the Technical Rules require that the Tier Three Assessment results be examined with regard to uncertainty. This qualitative assessment considers four factors: (1) the available input data; (2) the ability of the model to replicate major hydrologic processes; (3) the quality assurance and quality control procedures; and (4) the extent and level of model calibration achieved.

Section 5.2.4 discussed uncertainty associated with each of the four factors with respect to the Tier Two Assessment and tools. Since the tools developed for the Tier Two Subwatershed Stress Assessment were applied in the Tier Three Assessment, the text included in Section 5.2.4 is applicable to the uncertainty associated with the Tier Three Assessment.

An additional source of uncertainty associated with the Tier Three Assessment that is not described in Section 5.2.4, is the selection of the Exposure threshold. The Technical Rules prescribes the methodology for determining the Exposure threshold as the amount of water used by other water uses within the time period of 2003-2007. Water level records for Trout/Turtle Lake, facilitated the Exposure threshold to be estimated, and are directly related to water surface elevation. The availability of historical water levels reduces the uncertainty associated with the Exposure threshold, and subsequently the Exposure analysis. Due to the above considerations, the uncertainty associated with the Tier Three Assessment is **Low**.

6.6 TIER THREE LOCAL AREA RISK ASSESSMENT SUMMARY

To meet the requirements of the Technical Rules (MOE, 2009), the Risk Level for the Local Area that supplies the City of North Bay with raw water was assessed. This assessment was completed by assigning a Tolerance level to the water system, and an Exposure level to the Local Area. Exposure was evaluated for both average and drought climates. The Exposure threshold for average climate was the minimum water level specified in the Turtle Dam Operating Plan, while the threshold for drought conditions was the elevation of the North Bay intake, plus a 10 m factor of safety. Tolerance and Exposure were combined to generate the Risk level for the Local Area.

Due to the ability of Trout/Turtle Lake to meet the peak demands placed on the municipal system a **High** Tolerance was assigned to the City of North Bay municipal system. Simulated water levels within Trout/Turtle Lake were analyzed for all four scenarios required by the Technical Rules and were all above the Exposure thresholds described in Section 6.3.1. Based on the results of the four scenarios, an Exposure level of **Low** was assigned to the Local Area. The **High** Tolerance and **Low** Exposure levels result in a **Low** Risk level for the Local Area, and the City of North Bay municipal system. The uncertainty associated with this classification is considered **Low**.

Due to the Local Area having a Low Risk Level, there are no Moderate or Significant water quantity threats identified within the Local Area.

7.0 Conclusions & Recommendations

To meet the requirements of the *Clean Water Act* (2006), a Tier Two Subwatershed Stress Assessment, and a Tier Three Local Area Risk Assessment was completed for the Trout/Turtle Lake subwatershed. The Trout/Turtle Lake subwatershed, which contains the City of North Bay municipal water intake, was identified as having a Moderate potential for stress the Trout/Turtle Lake Tier 1 Subwatershed Stress Assessment (Gartner Lee, 2008b).

The methodology followed in this report is consistent with the Technical Rules prepared by the Ministry of Environment (MOE, 2009) for the preparation of Assessment Reports under the Clean Water Act. The relevant sections in the Technical Rules can be found in *Part III.4 – Subwatershed Stress Levels – Tier Two Water Budgets*, and *Part IX.1 – Risk level, local area*.

The specific objectives of this study are as follows:

- Complete a Tier Two Subwatershed Stress Assessment for the Trout/Turtle Lake subwatershed;
- Delineate Significant Groundwater Recharge Areas; and
- Complete a Tier Three Local Area Risk Assessment for Trout/Turtle Lake and the City of North Bay municipal drinking water system.

7.1 TIER TWO SUBWATERSHED STRESS ASSESSMENT

To complete the Tier Two Subwatershed Stress Assessment, hydrologic and reservoir routing models were developed, calibrated, and verified. Results from the models were compared to gauged streamflow, spot flow measurements as well as lake levels. This comparison indicated that both the hydrologic model and the reservoir routing model reasonably replicate the major hydrologic processes. Using the hydrologic model, estimates of evapotranspiration, overland runoff, groundwater recharge, and total streamflow were estimated for the 1975-2005 period.

Using output from the hydrologic model, and reported water withdrawals from the City of North Bay, the Tier Two Subwatershed Stress Assessment was completed. This assessment was completed by comparing the consumptive water demand within the subwatershed to the total streamflow entering the subwatershed, on a monthly basis. This comparison results in a value termed “Percent Water Demand”, which when compared to Provincial thresholds, determines if the subwatershed has a Low, Moderate or Significant potential for stress. Tier Two results for the Trout/Turtle Lake subwatershed indicated that the subwatershed has a **Significant** potential for stress. The *Clean Water Act* Technical Rules (MOE, 2009), requires any municipal system located within a subwatershed that has a Moderate or a Significant potential for stress to undergo a Tier Three Local Area Risk Assessment.

7.2 SIGNIFICANT GROUNDWATER RECHARGE AREAS

As part of the Tier Two Subwatershed Stress Assessment and Tier Three Local Area Risk Assessment, the Technical Rules (MOE, 2009) specifies that Significant Groundwater Recharge Areas (SGRAs) be delineated. The Water Budget Guidance Module (MOE, 2007) states that SGRAs should be delineated and mapped, to identify and protect drinking water across the broader landscape. This study follows a straightforward and reproducible procedure for delineating SGRAs as described in the Technical Rules (MOE, 2009). The Technical Rules allow two methodologies for identifying SGRAs. Both methodologies have been considered as part of this report. Based upon consultation with the Water Budget Peer Review Committee, the 115% of average groundwater recharge was selected for delineating SGRAs.

The Province's objectives for incorporating SGRAs into the Water Quality Threats Assessment process are clear. However, the role of protecting SGRAs from a water quantity perspective is not prescribed in the Technical Rules. There is a good opportunity to address the need to protect groundwater quantity within the Source Protection Planning Process, but this opportunity needs to address both the value of total groundwater recharge across a subwatershed as well as those areas having higher than average values. Furthermore, the process needs to address the uncertainty in terms of the magnitude and distribution of recharge rates.

7.3 TIER THREE LOCAL AREA RISK ASSESSMENT

A Tier Three Local Area Risk Assessment is a refined investigation meant to assess the risk of a water source not being able to meet the demands of the municipal system, as well as other water uses. Using the tools generated as part of the Tier Two Subwatershed Stress Assessment, a Tier Three Local Area Risk Assessment was completed for the City of North Bay municipal water intake. The assessment involved determining if water takings cause Trout/Turtle Lake water levels to drop below water level thresholds. As per the requirements of the Clean *Water Act* Technical Rules, four scenarios were investigated. Each scenario indicated that the North Bay municipal intake does not cause water levels to drop below critical water levels. The scenarios investigated included: existing pumping under average climate conditions and current land use; existing pumping under drought conditions and current land use; planned pumping under average climate conditions and planned land use; and planned pumping under drought conditions and planned land use.

Two planned pumping scenarios were considered population increases associated with approved developments within the City of North Bay, for both average climate conditions as well as drought conditions. The first scenario considered current per capita rates. The second scenario considered the impact of installing water meters on all connections to the water distribution, which is currently being implemented by the City of North Bay. As a result of lowered water consumption due to the installation of water meters and adopting a volumetric billing approach, it is anticipated that water levels within Trout/Turtle Lake would be five centimeters higher during an average year, and up to 10 cm higher during a drought, compared to water levels under current per capita rates.

All four scenarios indicated that Trout/Turtle Lake has sufficient storage volume to meet the current demands and planned demands of the North Bay municipal system, while maintaining critical lake levels. As a result of this analysis, the Trout/Turtle Lake subwatershed, and the City of North Bay municipal intake has a Water Quantity Risk level of **Low**. As such, there are no Moderate or Significant water quantity threats within the Trout/Turtle Lake subwatershed.

7.4 DATA GAPS

The primary data gaps identified through the Trout/Turtle Lake Tier Two and Tier Three investigation was the lack of continuous records for both flow (lake inflow and outflow) and lake level. Through use of data collected from adjacent watersheds, and measurements collected as part of the NBMCA's spot flow program as well as the MNR's operational records for Turtle Dam, this data gap was managed. Specific recommendations for addressing this data gap are included below in Section 7.5.2.

7.5 RECOMMENDATIONS

The following sections summarize recommendations developed from the analyses completed and presented in this report.

7.5.1 Continued Use and Improvement of Numeric Models

As part of this study, numeric models have been created that are able to quantify water budget components for the Trout/Turtle Lake subwatershed, as well as estimate changes to lake levels given changes in inflow, water withdrawals, or land use change. These numeric models can, and should, be used for a variety of other water management investigations. Such investigations include, but are not limited to: impact assessment and analysis; support for permit to take water applications; subwatershed studies; lake studies; and supporting water quality investigations.

As additional data is collected through current, or expanded, monitoring programs, the numeric models should be verified/validated and if necessary, revised. These additional verification/validation exercises would improve the model over time, and result in an overall increase confidence in simulated results

7.5.2 Additional Monitoring

Model calibration within the Trout/Turtle Lake subwatershed was limited due to the lack of observed water level and flow data. Due to the importance of Trout and Turtle Lakes to the City of North Bay, both for water supply and recreational purposes, it is recommended that existing data collection programs be continued or expanded into the future. Specific recommendations are included below.

1. Continuous water levels should be collected for Trout/Turtle Lake. This recommendation could be met by the installation of a low cost level logger on the upstream face of Turtle Dam.
2. The NBMCA should continue, and if possible expand, the spot flow monitoring program for Trout/Turtle Lake tributaries. This monitoring program is currently the sole source of information on inflow characteristics to Trout/Turtle Lake, and is critical to understanding the volume and spatial distribution of inflow to Trout/Turtle Lake.
3. Should site conditions allow, it is recommended that a stream gauge station be constructed downstream of Turtle Dam. Having continuous time series for both lake levels and dam discharge would greatly assist water managers in making effective water management decisions.

7.5.3 Water Conservation Measures

The municipal drinking water system for the City of North Bay is responsible for 99.5% of all consumptive withdrawals from Trout/Turtle Lake. This analysis has indicated that reducing the per capita water consumption rate to 450 L/d from the current 680 L/d can result in significant increases in lake levels, particularly during drought periods. It is expected that this reduction can be obtained by fully implementing the following conservation measures;

1. Outdoor water use restrictions;
2. Installation of water meters on all connections; and
3. Adoption of a volumetric billing approach.

It is strongly recommended that the City of North Bay continue to implement these water conservation measures. Furthermore, it is recommended that the City of North Bay investigate the feasibility of additional measures to further reduce water withdrawals from Trout Lake, such as an aggressive leak detection and water fixture retrofit (e.g. toilet) programs.

7.5.4 Land Development within Trout/Turtle Lake Subwatershed

Land use policies contained within the City of North Bay Official Plan, will strictly limit or control land development within the Trout/Turtle Lake subwatershed. Despite these controls, a small number of developments have previously been approved. These developments include an industrial subdivision and peat/aggregate extraction sites. To maintain lake levels within Trout/Turtle Lake, it is recommended that these developments be required to implement best management practices such as maintaining groundwater recharge volumes and managing storm runoff to maintain, or even enhance, dry weather streamflow.

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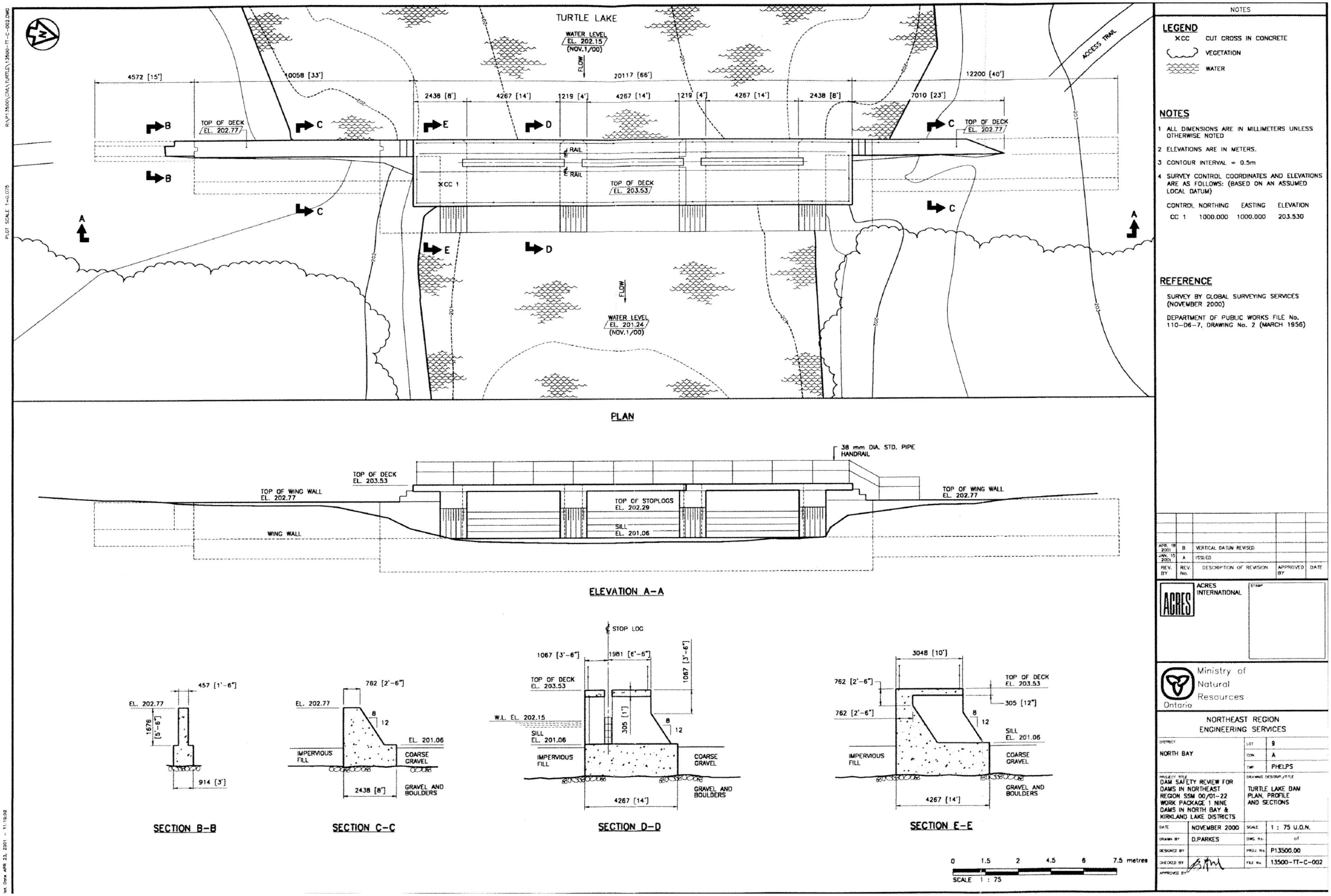
Appendix A – Turtle Dam Schematics and Photos



Taken from Acres International (2000). Data Collections and Site Inspections Work Package 1: 9 Dams in North Bay and Kirkland Lake District. A report to the Ontario Ministry of Natural Resources

Photo #1 – Picture taken looking downstream from upstream of Turtle Dam

Photo #2 – Picture taken looking upstream from downstream of Turtle Dam

Taken from Acres International (2000). Data Collections and Site Inspections Work Package 1: 9 Dams in North Bay and Kirkland Lake District. A report to the Ontario Ministry of Natural Resources

Appendix B – Water Budget Modelling

Water Budget Modelling Technical Appendix

Prepared for:
North Bay – Mattawa Conservation Authority

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AquaResource Inc.

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1.0 Water Budget Modelling

Hydrologic modelling is required to accurately quantify streamflow volumes, reservoir water levels, and major water budget components (evapotranspiration, direct overland runoff and groundwater recharge). Hydrologic models replicate the underlying hydrologic processes within a watershed, and when combined with climate data can generate annual, monthly or daily estimates of the predominant hydrologic cycle components. Model parameters are calibrated to observed conditions to ensure adequate model performance.

To characterize the hydrology of the Trout/Turtle Lake subwatershed, two modelling components were completed.

The first component is the development and application of a continuous hydrologic model. A continuous hydrologic model uses long-term climate datasets to generate a time series of streamflow, evapotranspiration, direct overland runoff, and recharge. Since the Trout/Turtle Lake subwatershed does not have any stream gauges, the model boundary was extended to include the La Vase River and Chippewa Creek subwatersheds. These two adjacent subwatersheds have watercourses with long-term Water Survey of Canada stream gauges. The hydrologic model was calibrated to the observed flow from these gauges; these calibrated parameters were then transferred to hydrologically similar areas within the Trout/Turtle Lake subwatershed.

The second component is the development of a reservoir routing model for Trout/Turtle Lake. To predict water levels within Trout/Turtle Lake, the reservoir routing model considers: (1) simulated inflow to the reservoir (estimated by the hydrologic model); (2) dam discharge (based on historical stop log settings, and existing stage-storage-discharge relationships); and (3) other outflows (evaporation, water withdrawals). The objective of this component is to verify the performance of the hydrologic model by comparing simulated lake levels to observed levels from the MNR.

Verifying model performance as outlined above, with two separate data sets (MNR lake levels and Water Survey of Canada streamflow estimates) results in greater certainty in modelled estimates of streamflow and water budget components.

As outlined in the Technical Rules (MOE, 2008), the scope of a Tier Two Subwatershed Stress Assessment includes the development and application of both a computer based continuous surface water flow model and a computer based three dimensional groundwater flow model. Since the Trout/Turtle Lake subwatershed does not have any municipal or other groundwater takings, the development of a three dimensional groundwater flow model was not considered necessary as it would not add value to the Assessment.

The following sections document the development and application of the hydrologic flow model and the reservoir routing model.

1.1 HYDROLOGIC MODELLING

A hydrologic model is used to estimate key hydrologic components within the Trout/Turtle Lake subwatershed. Although any model is a simplification of the movement of water through the environment, the appropriate model should be able to make valid inferences regarding the key hydrologic processes within a watershed. The Guelph All-Weather Sequential-Events Runoff (GAWSER) model was selected for this Assessment.

The following subsections provide an overview of the model platform and the construction, the calibration and the verification of the Trout/Turtle Lake subwatershed model.

1.1.1 GAWSER

The Guelph All-Weather Storm-Events Runoff (GAWSER) software (Version 6.9.10, 2008) was used to simulate watershed hydrology for the study area. The GAWSER model (Schroeter and Associates, 2004) is a physically-based, deterministic hydrologic model which can be used to simulate major hydrologic processes and streamflow hydrographs, resulting from inputs of rainfall and/or snowmelt. GAWSER has been applied widely in Ontario for planning, design, real-time flood forecasting, and evaluating the effects of physical changes in the drainage basin (Schroeter & Associates, 2004).

There are eight main hydrologic processes represented in the GAWSER continuous streamflow-generation model:

1. Accumulation and ablation of snow;
2. Filling and emptying of interception storage and depression storage;
3. Infiltration;
4. Evapotranspiration;
5. Generation and routing of overland flow;
6. Generation and routing of subsurface storm runoff (interflow);
7. Filling and emptying of groundwater storage (recharge and baseflow); and
8. Routing of flow in channels.

The above processes are documented in the GAWSER Training Guide and Reference Manual (Schroeter and Associates, 2004).

In the GAWSER model, precipitation inputs are defined in terms of rainfall, snowmelt, or a combination of both. Drainage basins are divided into a series of linked elements representing watersheds, channels, and reservoirs. The physical effects of each element are simulated using efficient numerical algorithms representing tested hydrologic models. An hourly computation time step is used for this study.

Seasonal changes in model parameters (e.g. soil hydraulic conductivity) can be specified on a monthly basis or automatically shifted based on air temperature. Evapotranspiration is calculated by either specifying monthly potential evapotranspiration rates or allowing the model to generate potential evapotranspiration rates using the Linacre equation. The Linacre equation is a simplification of Penman's equation. Actual evapotranspiration is calculated as a proportion of potential evapotranspiration, which is dependent on the storage status and the type of storage (interception, depression, soil water).

Catchments are smaller land areas within subwatersheds that have drainage areas contributing to smaller streams or river reaches. GAWSER accounts for variability in infiltration characteristics by conducting separate calculations within each catchment for one impervious unit and up to eight pervious units with different combinations of soil type and land use. The Green-Ampt equation is used in the infiltration calculations allowing for the recovery of infiltration between precipitation events, and reductions in infiltration caused by high soil water conditions.

Overland runoff routing uses area/time versus time relationships, with travel time relationships based on channel rating tables developed from stream cross-section measurements. In-channel routing is completed using the Muskingum-Cunge method. Reservoir routing is handled using the Puls method with controlled releases. Diversions of water flow from channels and reservoirs can be directed to other channels or to groundwater storage. The routing method is stable over a range of channel slopes; this allows the application of the GAWSER continuous streamflow-generation model in watersheds with large variations in both channel slope and geometry.

The GAWSER model has widely been applied throughout Ontario for Source Water Protection purposes, including the following Conservation Authorities: Mattagami Region Conservation Authority, Saugeen River Conservation Authority, Grey Bruce Conservation Authority, Grand River Conservation Authority, Long Point Region Conservation Authority, Kettle Creek Conservation Authority, and Catfish Creek Conservation Authority.

For further information on the GAWSER continuous streamflow-generation model and its application as a water management tool see GAWSER: A Versatile Tool for Water Management Planning (Schroeter et al., 2000b).

1.1.2 Model Construction

1.1.2.1 Modelled Area

The modelled area includes the Trout/Turtle Lake subwatershed and the Chippewa Creek and the La Vase River subwatersheds. The model boundaries were extended to include the Chippewa Creek and the La Vase River subwatersheds to calibrate and to verify the model to stream gauges located in watercourses in these two subwatersheds. Map 8 illustrates the modelled area.

1.1.2.2 Study Period

The selected study period is from 1975 to 2005, as it reflects the most recent 30-year period for which continuous climate data are available (discussed in Section 1.1.2.3). The 30-year period is consistent with climate normals and includes both significant droughts and wet periods necessary to develop representative long-term average conditions.

The 1975-2005 time period was divided into a calibration period (1995-2005) and a verification period (1985-1994); these smaller time periods were selected because of observed flow data availability and the land cover representation incorporated in the model.

1.1.2.3 Climate

Climate data is the predominant input to a hydrologic model. For accurate estimates of streamflow and other water budget components, climate data input into the model must be typical of climatic conditions experienced through the watershed. Climate observations taken from a meteorological station are typically used to represent climate over a watershed, whether or not the climate station is located in the study area. The presence of the North Bay Airport meteorological station within the modelled area increases the confidence that collected climate data is typical of the modelled area; accordingly the climate data collected at this station are used to represent climate within the hydrologic model. The North Bay Airport station is shown on Map 8.

The climate datasets utilized for this study include: daily rainfall, daily snowfall, daily minimum and maximum temperature, and hourly rainfall.

Continuous hydrologic models require complete climate datasets, free of data gaps and errors. Raw climate datasets typically include data gaps and errors due to temporary closure of stations or equipment malfunction. Previous studies found that most raw hourly datasets have a 30% gap in data (Schroeter et al., 2000a). Recognizing this, MNR commissioned Schroeter and Associates (2007) to “fill-in” climate datasets for 400 meteorological stations in the Province of Ontario for the 1950-2005 time period. The North Bay Airport meteorological station was one of the 400 stations included in this study. Schroeter and Associates used a documented methodology (Schroeter et al., 2000a) to infill the data gaps by adjusting data from adjacent stations.

Although the North Bay Airport climate station is within the modelled area and likely broadly represents the climate experienced over the watershed, it remains a singular point measurement of climate data. Representing climate over a broad area by observations from a single point introduces a level of uncertainty into the analysis. This uncertainty is highest during the summer months, when extremely localized thunderstorms are typical. During these times, climate observations at a single station are not likely representative of the climate experienced across the watershed. This uncertainty is lower during the fall, winter and spring months, where slower moving, more regionally based precipitation events occur.

1.1.2.4 Streamflow Information

Observed streamflow information is required both to provide the modeller with insight into the hydrologic response of the watershed, and for gauging the level of model performance in predicting streamflow. Based on observed data, hydrologic models are adjusted to better reflect the observed hydrologic conditions, and tested to confirm the model adjustments are representative of major hydrologic processes. These modelling procedures are known as calibration and verification, respectively.

Care should be taken when using observed streamflow estimates for calibration and verification. Streamflow estimates are affected by gauging inaccuracies and are not absolute; accordingly, observed streamflow estimates are commonly given a ±5 to 15% range of uncertainty (Winter, 1981). Uncertainties associated with flow estimates are often higher under ice conditions, and at high or low flow extremes. Measurement of very low flows is challenging due to difficulties quantifying the rate of flow that is flowing through the channel substrate. These uncertainties are transferred to the hydrologic model because the streamflow estimates are the primary calibration and verification targets.

The observed streamflow data at the Water Survey of Canada stream gauging stations used for this model are summarized in Table 1-1 and shown on Map 8.

Table 1-1: Summary of Observed Streamflow Data

Station Name	Station ID	Date of Records	Latitude	Longitude	Drainage Area (km^2)
LA VASE RIVER AT NORTH BAY	02DD013	1974 - 2005	46°15'48" N	79°23'42" W	70
CHIPPEWA CREEK AT NORTH BAY	02DD014	1974 - 2005	46°18'42" N	79°26'54" W	37

1.1.2.5 Catchments

For modelling purposes, the Trout/Turtle Lake, Chippewa Creek and La Vase River subwatersheds were divided into catchments. These catchments are the smallest spatial area for which the model can output a hydrograph. Geology and land cover were summarized at the catchment scale and were used to generate the hydrologic response of each subwatershed. Table 1-2 summarizes the catchments used in the Trout/Turtle Lake model and Map 8 illustrates the three subwatersheds and their respective catchments. In total, 47 catchments were delineated for the modelled area; 7 for Chippewa Creek subwatershed, 9 for La Vase River subwatershed, and 31 for Trout/Turtle Lake subwatershed.

In Chippewa Creek and La Vase River subwatersheds, the catchments were delineated to ensure that they represent small areas or streams of interest. The delineation was carried out by using the Provincial 10 m Digital Elevation Model (DEM) within a GIS platform. Catchment outlets were placed at streamflow gauging stations and at road crossings where possible. As seen in Table 1-2, the average size of catchments in the Chippewa Creek and the La Vase River subwatersheds are 6 km^2 and 10 km^2, respectively.

To obtain the Trout/Turtle Lake catchment boundaries, the North Bay - Mattawa Tier 1 Subwatersheds (Gartner Lee, 2008b) were more finely delineated to separate major tributaries using the Provincial 10 m DEM. As seen in Table 1-2, the average size of catchments in Trout/Turtle Lake subwatershed is 6 km^2.

Characteristic catchment lengths and widths were determined using a GIS platform; an approach similar to the Long Point Region, the Kettle Creek, and the Catfish Creek watershed models (Schroeter and Associates, 2006a, b, c).

Model schematics for the three modelled areas are included in Appendix B.

Table 1-2: Summary of Model Catchments in Chippewa Creek, La Vase River and Trout/Turtle Lake Subwatersheds

Modelled Area	Number of Catchments	Catchment Size (km²)			Total Size (km²)
		Minimum	Maximum	Average	
Chippewa Creek subwatershed	7	2.6	10.0	5.6	38.9
La Vase River subwatershed	9	5.7	16.1	9.9	89.4
Trout/Turtle Lake subwatershed	31	0.1	18.9	5.7	176.8
Total Area	**47**	**0.1**	**18.9**	**6.5**	**305.1**

1.1.2.6 Routing Reaches

GAWSER uses the Single Linear Reservoir plus the Lag-and-Route method to route the hydrographs downstream and to simulate peak flow attenuation. Detailed information on this can be found in the GAWSER manual (Schroeter and Associates, 2004). While routing has a lesser impact on the hydrograph volumes which are the main calibration targets for continuous surface water models, it does play a key role in the timing of streamflow.

Channel cross-sections were approximated using published geomorphic relationships and simplified trapezoidal channel geometry, as shown in Figure 1-1. Annable (1996) developed a relationship for bankfull discharge as a function of drainage area using data from more than 40 streams in Ontario. The relationships listed in Table 1-3 were used to develop synthetic channel cross-sections; an approach that was also used in the Long Point Region, the Kettle Creek, and the Catfish Creek watershed models (Schroeter and Associates, 2006a, b, c); and the Saugeen Valley, the Grey Sauble, and the Northern Bruce Peninsula models (AquaResource, 2008c).

Channel lengths and bed slopes were estimated from the Provincial virtual drainage layer and the 10 m DEM. Main channel geometries were generated for each routing reach in the model; whereas, generalized cross-sections were created for off-channel routing. Manning's roughness coefficients were estimated for main channels and off-channels, including both the bankfull portion and the floodplain of the channels.

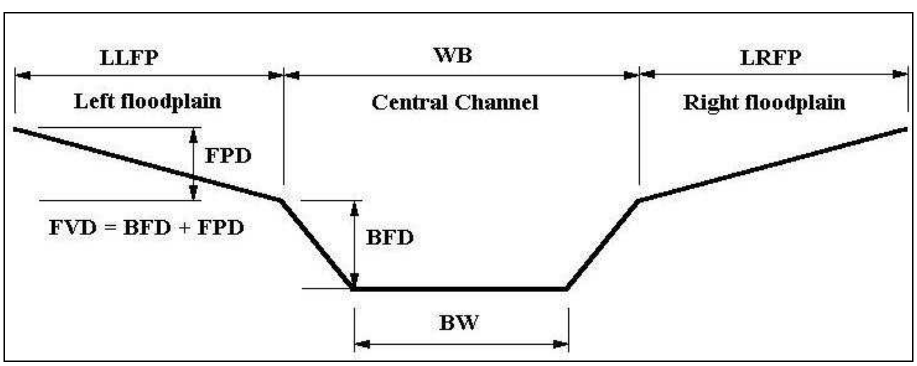

Figure 1-1: Simplified Channel Cross-Section

Table 1-3: Channel Cross-Section Relationships

Equations	Definitions and Units	
$Q_B = 0.52\ A_D^{0.75}$	Q_B = Bankfull Discharge (m^3/s)	W_B = Bankfull Top Width (m)
$A_B = 0.282(A_D^{0.851})$	A_D = Drainage Area (km^2)	TW = Top Width (m)
$W_B = TW = 2.69(A_D^{0.37})$	A_B = Bankfull Area (m^2)	BW = Bottom Width (m)
$BFD = 10A_B / 9TW$	BFD = Bankfull Depth (m)	LFP = Length of Floodplain (m)

(Source: Schroeter and Associates (2006 a, b, c))

A significant amount of routing storage is present within the Trout/Turtle Lake subwatershed; this storage exists in beaver dams, small lakes, and wetlands. These small scale features were not incorporated into the model because they are difficult to represent in the model and the modelling focus is on streamflow volume, not peak flow. As such, routing impacts may be underestimated by the model. Underestimating channel routing would not affect water budget estimates (evapotranspiration, overland runoff, or groundwater recharge), nor the total streamflow volume; however, it would impact the distribution of streamflow volume, particularly at the hourly time scale. This omission would be primarily of concern for flood flow studies, as the peak flows would be over-estimated.

Both the empirically developed channel cross-sections and the lack of consideration for smaller features represent sources of uncertainty. These sources of uncertainty are predominantly related to peak flows, not monthly volumes. As such, this uncertainty is not expected to significantly impact the Assessment results. It is, however, recommended that the NBMCA not utilize this hydrologic model for flood flow estimation, without first revisiting the information within channel routing routines.

1.1.2.7 Hydrologic Response Units

To simulate how a particular catchment would respond to a precipitation event, the physical makeup of the catchment in terms of soils/geologic materials and land cover must be represented in the model. The type of surficial materials and land cover largely determines the soil permeability and soil water content characteristics of a catchment. Land areas with a low permeability and/or high soil water content promote the generation of overland runoff rather than groundwater recharge. Land areas with a high permeability and/or low soil water content promote groundwater recharge rather than overland runoff.

Surficial geology and land cover are grouped to create Hydrologic Response Units (HRUs). Land areas with the same Hydrologic Response Unit classification are assumed to respond to precipitation events in a similar manner. A synthesis of all Hydrologic Response Units within a catchment determines how the catchment as a whole will respond to precipitation events.

Surficial Geology

The procedure for delineating response units for the Trout/Turtle Lake subwatershed model closely follows the methodology used in the GRCA Integrated Water Budget Study (AquaResource, 2008b). Surficial geology mapping was used to define the soil types within the model providing a consistent dataset across the subwatershed. Surficial geology is representative of those overburden materials found within one to two metres below ground surface.

To reduce the number of surficial geology types requiring simulation, the surficial geology types were grouped based on how they react to a precipitation event in a hydrologic sense. This classification scheme broadly assigns, from a hydrologic modelling point of view, all surficial geology types to one of four groupings including: wetlands, thin soil over bedrock, clay and silt tills, and sands and gravels. The geology types assigned to each grouping can be found in Table 1-4. Please note that this grouping was done on a hydrologic basis, and as such may differ from the geologic definition of the materials.

Table 1-4: Surficial Geology Grouping and Description

Model Geologic Grouping	Surficial Geology Description
Wetlands	Organic deposits
Thin Soil on Bedrock	Bedrock, Bedrock-drift complex
Clay and Silt Tills	Glaciolacustrine deposits, Till, Alluvium*
Sands and Gravels	Glaciofluvial outwash, Ice-contact deposits

* *Pervious deposits immediately adjacent to rivers and streams were assumed to have low infiltration due to high water tables and therefore lumped with the poorly drained clays.*

Land Cover

Land cover also affects the hydrologic response of a catchment by modifying the infiltration characteristics. Urban lands typically have some impervious areas that will not generate recharge. Agricultural lands have smaller amounts of depression storage than natural (forested) areas, and also tend to have lower infiltration rates. To represent land cover throughout the subwatersheds, Ontario Provincial Land Cover 2000 was provided by the NBMCA.

More discrete information related to lakes and wetlands was provided by the NBMCA and was used to supplement the Ontario Provincial Land Cover data.

Table 1-5 lists the land cover groupings which were summarized from the above datasets.

Table 1-5: Land Cover Groupings

Model Land Cover Grouping	Ontario Provincial Land Cover Grouping and NBMCA Datasets
Wetlands	Wetland; Bog – Treed; Permanent Wetland
Open Water	Deep Water; Water Body Segment
Urban – High Density	Settlement/Infrastructure with orthoimagery
Urban – Low Density	Settlement/Infrastructure with orthoimagery
Agricultural	Agriculture – Pasture; Bedrock
Forest	Forest Sparse; Forest Dense Deciduous; Forest Dense Mixed; Forest Dense Coniferous; Cloud/Unknown

Hydrologic Response Unit Coverage

The simplified surficial geology and land cover datasets (Table 1-4 and Table 1-5, respectively) were combined to generate a total of 15 HRUs over the modelled area. These 15 HRUs (ID 1 to 15) are listed in Table 1-6 and presented in Map 9. This detailed overlay of datasets defines the hydrologic response of each individual catchment within the model.

Table 1-6: Hydrologic Response Units

ID	Original Hydrologic Response Unit Description
1	Impervious
2	Open water (lakes)
3	Wetlands
4	Low vegetation – thin soil on bedrock
5	Low vegetation – clays and silts
6	Low vegetation – sands and gravels
7	High vegetation – thin soil on bedrock
8	High vegetation – clays and silts
9	High vegetation – sands and gravels
10	Urban Development – thin soil on bedrock
11	Urban Development – clays and silts
12	Urban Development – sands and gravels
13	Rural Development – thin soil on bedrock
14	Rural Development – clays and silts
15	Rural Development – sands and gravels

For modelling purposes, the Urban Development HRUs (10-12) and Rural Development HRUs (ID 13-15) were distributed between the Impervious HRU and the appropriate ‘Low Vegetation’ HRU (ID 4-6), according to their surficial geology. Urban Development HRUs were assumed to be 35% impervious, with Rural Development HRUs assumed to be 10% impervious. For example, if a catchment contained 1 km^2 of ‘Urban Development – sands and gravels’, 0.35 km^2 would be added to the ‘Impervious’ HRU and 0.65 km^2 would be added to the ‘Low Vegetation – sands and gravels’ HRU. Water budget results for ‘Urban Development – sands and gravels’ are then generated by combining water budget results from the ‘Impervious’ HRU and the ‘Low Vegetation – sands and gravels’ HRU, using the same 35/65 ratio.

In GAWSER, it is assumed that land areas defined as a specific Hydrologic Response Unit has similar hydrologic characteristics, including parameters such as infiltration rates, depression storage depths, wilting point, and field capacity. Water that percolates through the modelled soil column past the evaporative root zone is considered groundwater recharge. Groundwater recharge is routed to either a fast-responding groundwater reservoir, or a slow-responding groundwater reservoir. The fast-responding reservoir is intended to represent a shallow groundwater flow system that responds quickly to rainfall events, typically seen in less permeable materials. The slow-responding reservoir represents the deeper groundwater flow system typically associated with more pervious materials, and is responsible for streamflow contributions during baseflow conditions. In the study area, only the ‘High Vegetation – Sand

and Gravels' response unit contributes to the slow-responding groundwater system. All other response units contribute to the fast-responding groundwater system.

GAWSER generalizes the groundwater flow component by only allowing recharge from each Hydrologic Response Unit to supply either the slow or the fast responding groundwater reservoir, not both. Recharge rate estimates from GAWSER include recharge to both reservoirs. Streamflow hydrographs are generated by combining the outflows from both reservoirs and from overland runoff.

Initial Hydrologic Response Unit Parameterization

Hydrologic characteristics assigned to each Hydrologic Response Unit are similar to those used in other GAWSER modelling studies in Ontario (AquaResource 2008b, c; Schroeter and Associates 2006a, b, c; Mattagami, 2007). The modelled Hydrologic Response Units were initially parameterized similarly to the Mattagami GAWSER model and then modified during calibration.

1.1.2.8 Evapotranspiration

Evapotranspiration is an inclusive term for the amount or rate of transfer of liquid or solid water into atmospheric water vapour at the watershed surface. Evapotranspiration is the sum of sublimation of snow or ice, evaporation of water in surface depressions (streams, ponds or lakes), evaporation of water in leaf stomata (transpiration), evaporation of water in soil water pores exposed to the atmosphere, and evaporation from groundwater in locations where the water table is exposed to the atmosphere. Transpired water is the main contribution to evapotranspiration for vegetated surfaces and for summer months.

Evapotranspiration is one of the most dominant hydrological processes in Ontario, and is often the least understood water budget component since it cannot be accurately measured with conventional monitoring techniques. Instead, evapotranspiration rates are commonly estimated through the use of simplified empirical relationships combined with commonly collected climate data (daily temperatures). More detailed empirical relationships are available; however, data requirements (relative humidity, wind speed, solar radiation) are often beyond what is readily available.

Evapotranspiration is calculated within GAWSER by applying a specified potential evapotranspiration rate to the land surface. Water that is held within interception or depression storage is first available for evapotranspiration. When this water is reduced to zero, the evapotranspiration routines begin to remove soil water from the first modelled soil layer. Water is removed from the second soil layer when the first soil layer reaches half of its water holding capacity. After both soil layers reach wilting point, no additional water can be evaporated or transpired until the soil water is replenished. This approach of removing the most readily available water first, progressing to deeper soil water, and then having evapotranspiration stop altogether when soil water reaches wilting point, closely matches the physical process of evapotranspiration. This approach to handling evapotranspiration within a water budget is shared by other hydrologic models such as HSPF (Bicknell et al., 1997).

In Ontario, annual evapotranspiration is dependent on the amount of water that is available to be evaporated during that year. Areas with an unlimited supply of water will evaporate at the potential evapotranspiration rate; this is also known as lake evaporation. Areas that have a limited supply of water and rely on precipitation events to replenish the soil water will evaporate water at the actual evapotranspiration rate.

There are currently two methods for specifying potential evapotranspiration rates within GAWSER. A simplified method, where average monthly lake evaporation rates for the area are input into GAWSER; these rates are assumed to be representative of potential evapotranspiration rates. Through linear interpolation, these average monthly rates are used to generate daily estimates of potential evapotranspiration.

GAWSER also has the capability of using the more detailed Linacre evapotranspiration model, a derivative of Penman's equation. The Linacre model relates maximum and minimum temperatures to solar radiation and dew point temperatures, and uses an empirical relationship to calculate potential evapotranspiration. The calculated potential evapotranspiration can be modified to account for local complexities. For a detailed explanation of the Linacre evapotranspiration model see Linacre (1977). The GAWSER model developed for the Trout/Turtle Lake subwatershed model uses this method.

1.1.2.9 Snow Processes

In Ontario, snow processes drive a large portion of the local hydrology. The North Bay Airport meteorological station records almost 30% of annual precipitation in the form of snowfall. The means by which the snowfall melts, refreezes, compacts, accumulates, erodes, and redistributes all determine the amount of water available to infiltrate, runoff, or sublimate from a land surface.

The snowmelt subroutine within GAWSER computes snow compaction, accumulation, ablation, and redistribution by dividing the modelled area into six 'blocks' of equal snow accumulation; each with their own snow erosion and deposition characteristics. The snowmelt blocks used within the Mattagami Region model (Mattagami, 2007) are used within the Trout/Turtle Lake model, and are as follows:

- Open fields;
- Forest with low snow depth (sparse forests);
- Forest with medium snow depth (dense deciduous forests);
- Forest with high snow depth (dense coniferous/mixed forests);
- Fence lines and roadway ditches; and
- Forest edges.

During drifting snow conditions, snow is eroded (removed) and deposited depending on the snow holding characteristics of the land area. As snow is removed from open spaces, and deposited in forest edges or fence lines, the snowmelt characteristics are modified.

Generally, forested areas do not exhibit erosion or deposition of snow; open fields exhibit erosion but not deposition of snow; and fence lines and forest edges exhibit both erosion and deposition of snow.

GAWSER computes snowmelt / refreeze using a temperature index approach, which is based on a model developed by Schroeter (1988). If air temperature is above 0℃, the snowpack is assumed to be melting, and if air temperature is less than 0℃, the snowpack is freezing. Water is released from the snowpack according to the liquid water holding capacity of the pack.

1.1.2.10 Seasonal Variation

The large seasonal changes in temperature in Canada dramatically affect several hydrologic characteristics and must be represented in the surface water model.

Seasonal shifts are particularly noticeable in infiltration parameters. The difference in infiltration rates between a frozen and a thawed soil can be significant. Areas dominated by soils with normally high infiltration rates, may produce a large proportion of runoff when frozen.

To account for this, GAWSER was developed with the ability to vary parameters with seasons. Monthly adjustment factors are used to continuously modify the base infiltration rate as the model progresses through the year. These factors have been determined through Dr. Harold Schroeter's modelling experience in Ontario watersheds. Included in Table 1-7 are the monthly adjustment factors for seasonal parameters used in the Trout/Turtle Lake model. The factors are representative of typical average monthly conditions, and do not represent conditions that deviate from normal mid-winter thaw.

Table 1-7: Monthly Adjustment Factors of Seasonal Parameters in GAWSER

Description of Factor	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hydraulic Conductivity	0.02	0.02	0.02	0.1	0.4	0.65	0.75	0.9	0.65	0.5	0.1	0.02
Seepage Rate	0.03	0.02	0.02	0.09	0.4	0.5	0.6	0.75	0.35	0.3	0.13	0.06
Percolation Rate	0.04	0.04	0.03	0.05	0.06	0.06	0.1	0.11	0.09	0.08	0.08	0.08
Overland Runoff Lag	5	6	5.5	4.5	4.1	4.5	5.5	6	5	4	3.5	4
Subsurface / Groundwater Flow Recession	2	2	2.25	2.25	2.75	2.5	3.5	3.5	3.25	3	2.75	2.5
Snowmelt / Refreeze	0.25	0.33	0.45	0.8	1.15	1.4	2	2	1.5	1	0.25	0.15
New Snow Density	1.0	1.0	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.1	1.1
Interception Storage	0.2	0.2	0.2	0.5	0.7	1.2	1.5	1.5	1.2	0.7	0.2	0.2

1.1.3 Model Calibration and Verification

A hydrologic model is developed as a representation of a physical hydrologic system. To use model output to assist in decision-making, one must have confidence in the model's performance in replicating observed streamflow conditions. Should streamflow be reasonably replicated, there is a higher degree of certainty that the underlying hydrologic processes are properly represented by the model.

Model calibration is the process of adjusting model parameters, variables, and other inputs in order to reduce the differences between simulated and observed conditions (usually streamflow). As any hydrologic model is a simplification of reality, the simulated and observed streamflow are not expected to match identically. Precipitation events not captured by the climate monitoring network, or a condition that deviates from average (mid-winter melt) can cause differences between simulated and observed conditions. When evaluating a model's performance the focus should be how well the model generally fits the seasonal and annual trends.

Following calibration, a verification exercise is carried out, by applying the model to a time period outside the original calibration time period. This section summarizes the calibration and verification procedure and metrics, lists the calibrated parameters, and discusses the calibration and verification plots for Chippewa Creek and La Vase River.

1.1.3.1 Overview of Calibration and Verification Procedure

Continuous hydrologic models are initially calibrated to a large temporal scale (annual), and then sequentially moved to a more discrete temporal scale (monthly, daily). Calibrating to mean annual flows is an important first step, as it ensures that the total available water budget and climate dataset are reflective of observed conditions. Thus, the large-scale processes such as snowmelt and evapotranspiration are calibrated before the smaller-scale processes, such as channel routing and infiltration rates.

As calibration targets are only available for Chippewa Creek and La Vase River, the calibration / verification procedure has been completed for these watercourses only. Once the model showed a reasonable fit between simulated and observed streamflows and realistic hydrologic parameters, the model parameterization was transferred to the Trout/Turtle Lake subwatershed. Simulated flows within the Trout/Turtle Lake subwatershed were validated using spot flow measurements taken by NBMCA in 2008.

1.1.3.2 Calibration and Verification Metrics

The Chippewa Creek and La Vase River calibration exercise focused on the agreement between simulated and observed streamflows and on obtaining reasonable water balance values. Streamflow is often expressed in one of two forms; 1) as per unit area streamflow, expressed in mm of water over the upstream area; or 2) a flow rate at the measured location, expressed in m^3/s. Both forms are used in the calibration and verification exercise.

During model calibration and verification, a variety of metrics are used to analyze the model's ability to replicate observed flows. The metrics are as follows:

- Annual mean streamflow (mm/year);
- Monthly mean streamflow (mm/month);
- Log Nash-Sutcliffe coefficient for monthly mean streamflow;
- Daily hydrograph (m^3/s); and
- Ranked duration daily streamflow (m^3/s).

The Nash-Sutcliffe coefficient quantifies the difference between simulated and observed streamflow data. According to Chiew and McMahon (1993) and Nash and Sutcliffe (1970), a Nash-Sutcliffe coefficient:

- Equal to 1 is a perfect fit;
- Greater than 0.8 is considered good;
- Greater than 0.6 is considered reasonable; and
- Less than zero is when the observed mean is a better predictor than the model.

Due to the log-normal distribution of streamflow, a normal Nash-Sutcliffe coefficient is heavily weighted towards higher flows. To provide a more accurate assessment of the overall model performance, the log Nash-Sutcliffe coefficient was calculated for this modelling exercise.

It is important for the reader to understand that calibration metrics for continuous models differ from metrics for event-based models. Metrics for continuous models often focus on monthly statistics comparing simulated and observed streamflow, with limited consideration for daily comparisons. This is due to differences in how meteorological data is applied in continuous and event-based modelling. Event-based modelling focuses on understanding rainfall, initial snowpack conditions, and air temperature specific to a particular event. Climate related information, supplemental to published data recorded at a meteorological station, may be used to better represent the event-specific distribution (both spatial and temporal) of precipitation. The modeller can, therefore, achieve a better match of streamflow with respect to timing and volume, as compared to relying on published meteorological data alone, as is done in continuous modelling. The level of model performance for event-based modelling is difficult to achieve for continuous modelling, due to the impracticality of adjusting published meteorological data for every event in the continuous record. As such, in continuous models, the timing and/or magnitude of the simulated hydrograph may differ from the observed hydrograph. These differences are not due to an issue with the model itself, but rather due to the input climate data's inability to accurately represent each specific event's temporal and spatial characteristics. For this reason, calibration metrics for continuous models often focus on monthly statistics, with limited consideration for daily statistics.

1.1.3.3 Calibration and Verification Periods

The model period is 1975-2005 study period and includes the calibration and verification periods, as outlined below:

- *Calibration Period -- 1995-2005*
  Model parameters are adjusted to best replicate hydrologic processes and observed flows.

- *Verification Period -- 1985-1994*
  The model parameterization completed during the calibration phase is tested against a different set of inputs (climate data), and observations (observed flow). A reasonable fit in the verification period increases certainty in the model's ability to reasonably represent hydrologic processes.

1.1.3.4 Calibrated Model Parameters

The focus of the calibration exercise was on processes that affect annual streamflow, seasonal variation in streamflow, and annual water balance estimates (i.e., evapotranspiration, recharge, and runoff). As the primary goal of this study is to support a Water Quantity Stress Assessment, particular attention was paid to low flow months. Limited attention was paid to parameters associated with channel routing, resulting in hydrograph characteristics (e.g. rise, peak flow) that may not represent actual conditions.

The hydrologic parameters assigned to the nine Hydrologic Response Units were modified during calibration to achieve acceptable streamflow and water balance estimates from the model. The final calibrated parameters are listed in Table 1-8. The sensitivity of the model output to changes in the infiltration parameters (i.e., hydraulic conductivity, seepage and percolation rates) and evapotranspiration is included in the sensitivity analysis in Section 4.2.3.

Table 1-8: Final Calibrated Hydrologic Response Unit Parameters

Parameter	Units	Impervious	Open Water	Wetlands	Low Vegetation Soil over Bedrock	Low Vegetation Clay and Silt Tills	Low Vegetation Sands and Gravels	High Vegetation Soil over Bedrock	High Vegetation Clay and Silt Tills	High Vegetation Sands and Gravels
Depression Storage	mm	3	300	300	5	5	5	10	10	10
Hydraulic Conductivity	mm/h	0	0	0.2	0.5	4	7.5	1.5	12	20
Seepage Rate	mm/h	0	0.1	0.2	0.3	3	6	0.9	9	12
Percolation Rate	mm/h	0	0.1	0.01	0.1	0.2	0.5	0.3	0.6	1.2
Average Suction at Wetting Front	mm/h	0	200	200	200	200	250	200	200	250
Height of Soil Layer 1	mm	0	1	1	75	75	75	150	200	200
Saturated Moisture Content of Soil Layer 1	Fraction	0	0.56	0.56	0.56	0.54	0.40	0.56	0.54	0.40
Initial Soil Moisture Content of Soil Layer 1	Fraction	0	0.46	0.46	0.46	0.40	0.10	0.46	0.40	0.10
Field Capacity of Soil Layer 1	Fraction	0	0.46	0.46	0.46	0.40	0.10	0.46	0.40	0.10
Wilting Point of Soil Layer 1	Fraction	0	0.27	0.27	0.27	0.19	0.04	0.27	0.19	0.04
Height of Soil Layer 2	mm	0	1	1	300	300	300	375	500	500
Saturated Moisture Content of Soil Layer 2	Fraction	0	0.56	0.56	0.56	0.54	0.4	0.56	0.54	0.40
Initial Soil Moisture Content of Soil Layer 2	Fraction	0	0.46	0.46	0.46	0.4	0.1	0.46	0.40	0.10
Field Capacity of Soil Layer 2	Fraction	0	0.46	0.46	0.46	0.4	0.1	0.46	0.40	0.10
Wilting Point of Soil Layer 2	Fraction	0	0.27	0.27	0.27	0.19	0.04	0.27	0.19	0.04
Subsurface (1) or Groundwater (0) Reservoir	--	1	1	1	1	1	1	1	1	0
Interception Storage	mm	0	0	2	1	1	1	5	5	5

1.1.3.5 Model Calibration Plots

The calibration results are illustrated in Figure 1-2 through Figure 1-11. These figures show the calibration metrics and statistics for the Chippewa Creek at North Bay and the La Vase River at North Bay stream gauge stations.

The Chippewa Creek at North Bay stream gauge is located approximately 2 km upstream of where Chippewa Creek discharges into Lake Nipissing. The stream gauge has a drainage area of approximately 37 km^2, comprised mainly of sand and gravel. Simulated annual streamflow shows a very close match to observed streamflow as seen in Figure 1-2, with a mean difference over the calibration period of only 5 mm/year.

Mean monthly streamflow shown in Figure 1-3 demonstrates a good match between simulated and observed flow. A Nash-Sutcliffe coefficient of 0.70, shown in Figure 1-4, confirms a reasonable fit in monthly streamflow.

The daily flows are also well replicated, as shown in the sample daily hydrograph for 2001 in Figure 1-5. The simulated and observed ranked duration curves are shown in Figure 1-6. The ranked duration curves illustrate the percent of time in days that a value of daily streamflow is exceeded. Ranked duration curves are a useful tool to evaluate how well a model is replicating the full range of a flow regime. High flows are typically those that are exceeded <10% of the time; recession flows are typically within the 10-30% range; baseflows are within 30-90%; and extreme low flows are typically exceeded >90% of the time.

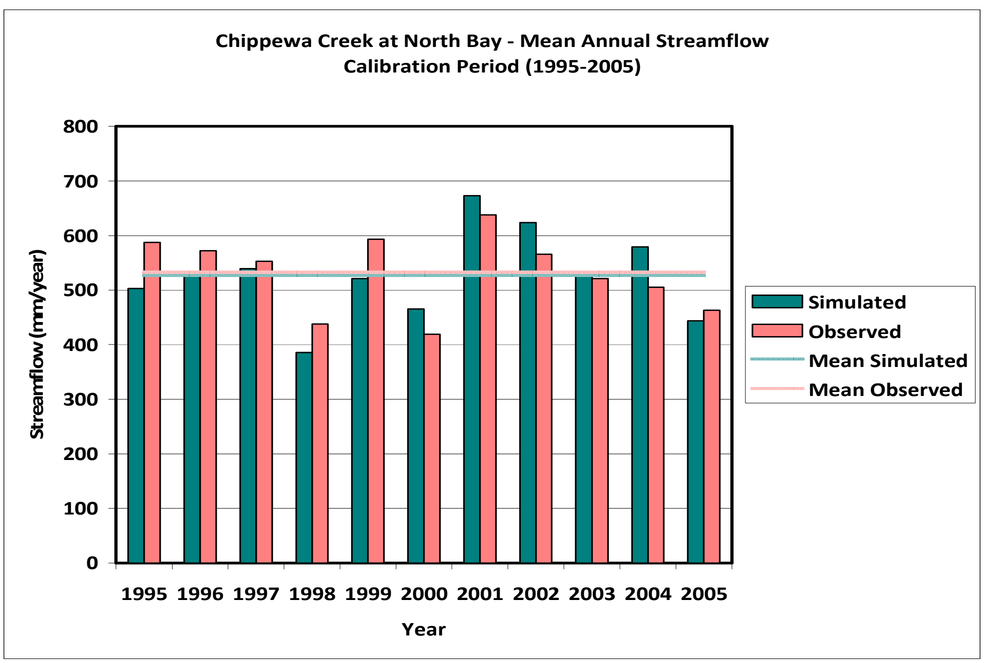

Figure 1-2: Chippewa Creek Gauge Mean Annual Streamflow – Calibration Period

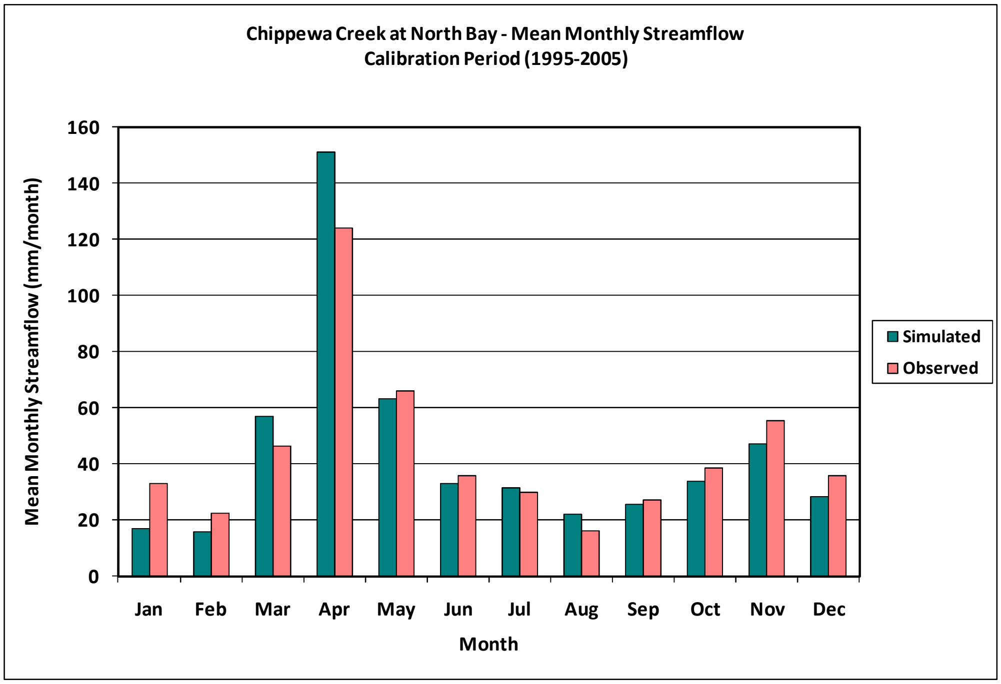

Figure 1-3: Chippewa Creek Gauge Mean Monthly Streamflow – Calibration Period

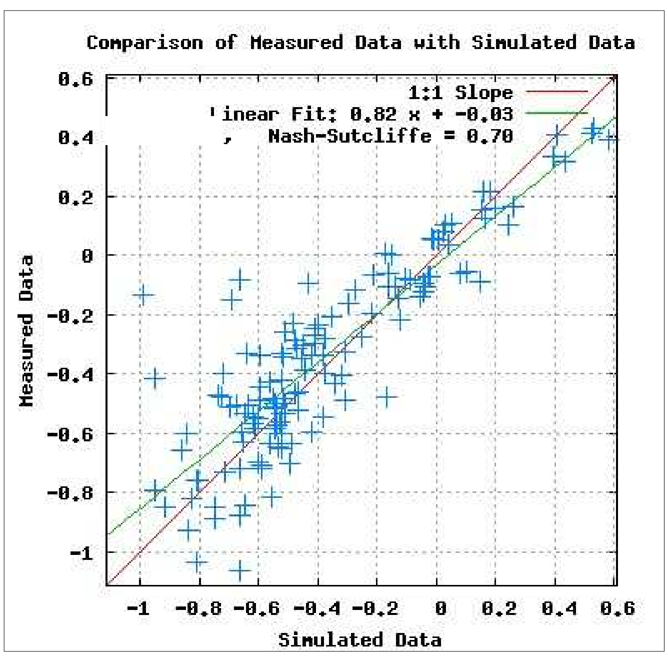

Figure 1-4: Chippewa Creek Gauge Nash-Sutcliffe Coefficient Plot - Calibration Period

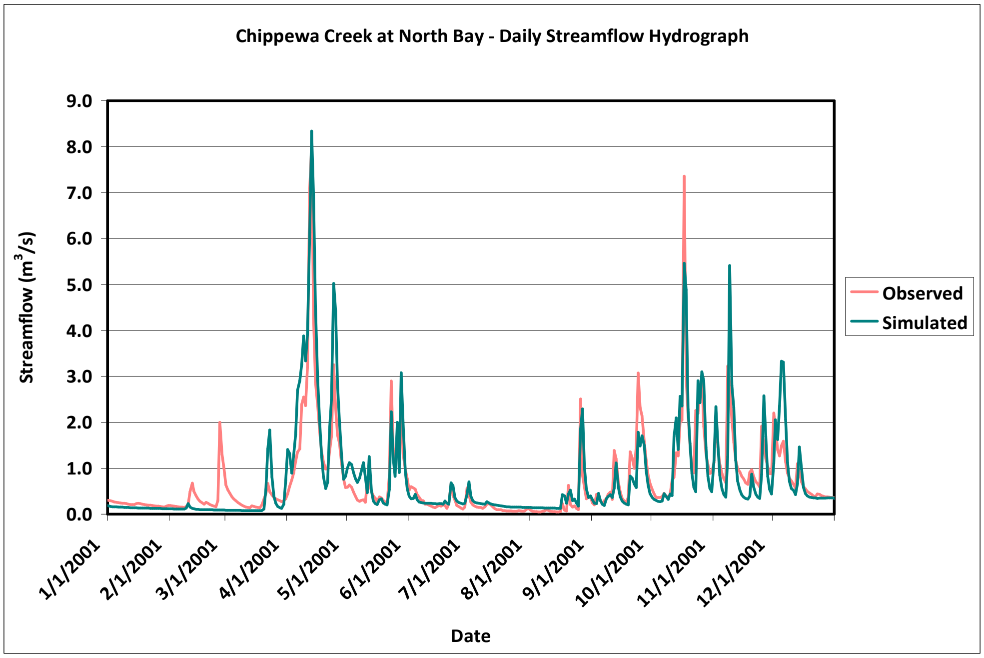

Figure 1-5: Chippewa Creek Gauge Sample Hydrograph – Calibration Period

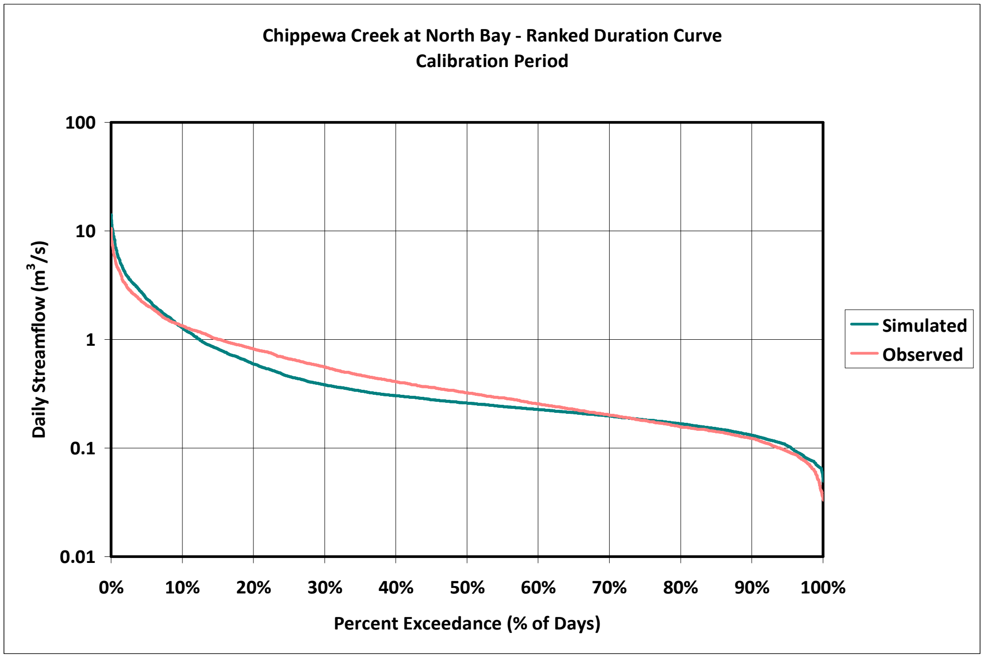

Figure 1-6: Chippewa Creek Gauge Ranked Daily Streamflow – Calibration Period

The La Vase River at North Bay streamflow gauge is located approximately 4 km upstream of Lake Nipissing and drains an area of approximately 70 km^2. The subwatershed is predominantly comprised of bedrock (85%), with a number of wetlands and small lakes.

Annual streamflow shows a very good match between simulated and observed values, as seen in Figure 1-7, with a mean difference of only 6 mm/year over the calibration period. The model is simulating monthly streamflow reasonably well, as evident from Figure 1-8 and a Nash-Sutcliffe coefficient of 0.70, shown in Figure 1-9. Discrepancy in the winter months can be attributed to uncertainties associated with collecting observed streamflow data under ice conditions, or difficulties representing snowpack processes.

The daily streamflows are being replicated reasonably well, as shown in the sample daily hydrograph for 2001 in Figure 1-10, and ranked duration curves in Figure 1-11.

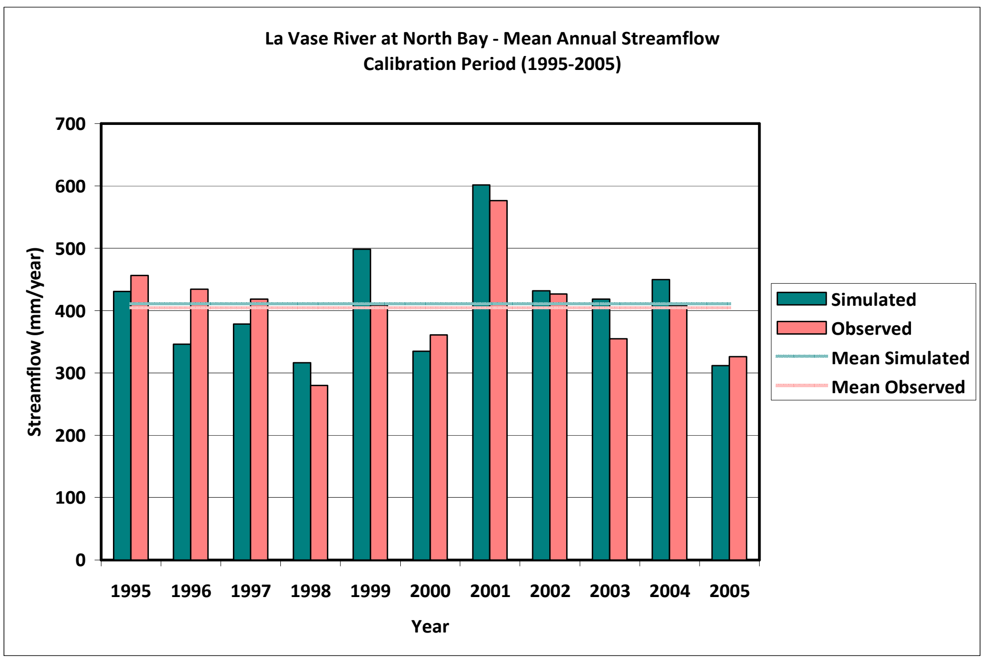

Figure 1-7: La Vase River Gauge Mean Annual Streamflow – Calibration Period

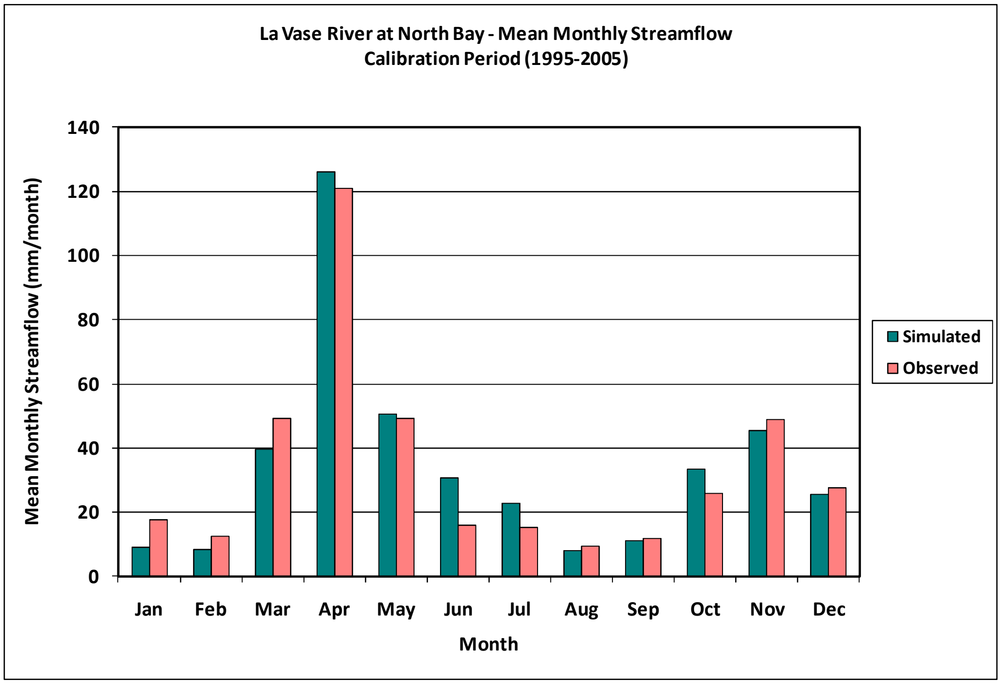

Figure 1-8: La Vase River Gauge Mean Monthly Streamflow – Calibration Period

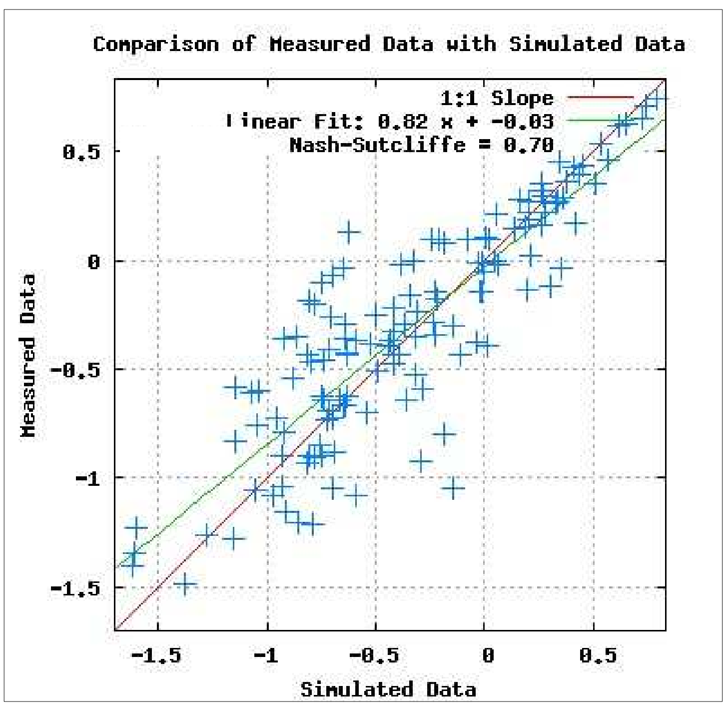

Figure 1-9: La Vase River Gauge Nash-Sutcliffe Coefficient Plot - Calibration Period

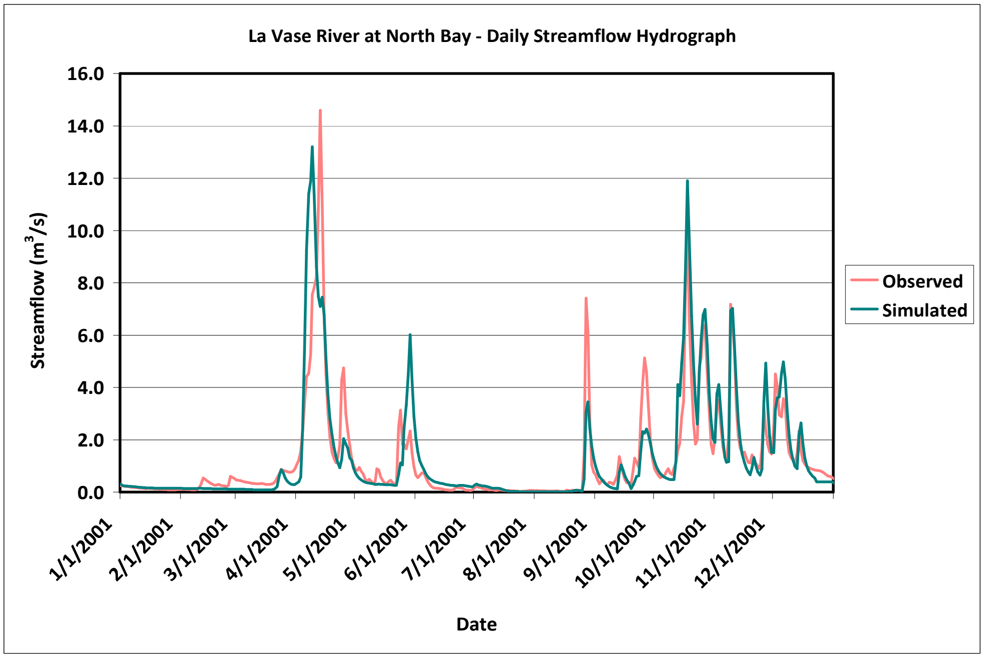

Figure 1-10: La Vase River Gauge Sample Hydrograph – Calibration Period

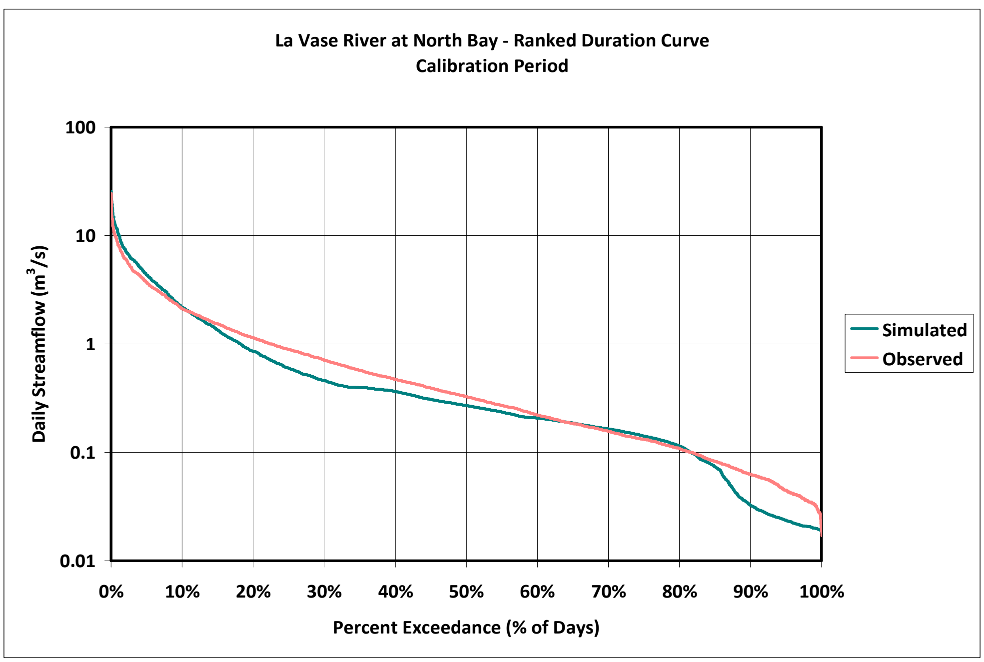

Figure 1-11: La Vase River Gauge Ranked Daily Streamflow – Calibration Period

The comparisons of observed to simulated streamflow shown in Figure 1-2 through Figure 1-11 indicate that the surface water model is well calibrated and is reasonably estimating streamflow.

While some discrepancies do exist, they are unlikely to impact the results of the Stress Assessment.

1.1.3.6 Model Verification Plots

Once calibrated for the 1995-2005 period, the model is subject to verification testing; a comparison of simulated to measured flow rates within the 1985-1994 period. Verification plots for Chippewa Creek and La Vase River stream gauges are included in Figure 1-12 through Figure 1-21.

At the Chippewa Creek stream gauge, simulated annual streamflow is on average 82 mm lower than observed annual streamflow, as shown in Figure 1-12. This difference is predominately driven by residuals for the years of 1985, 1992, 1993 and 1994. Other years during this period, such as 1987, 1988, 1989 and 1991 show excellent results; simulated annual streamflow is within 50 mm/year (5% of annual precipitation) of the observed annual streamflow. These four poor years represent a small sample of the entire calibration/verification period (1985-2005) which does not closely match the observed data. As the model predicts acceptable results for a majority of years, with a minority of years producing poor results, this suggests that the poor-fitting years are related to unrepresentative climate data for that year, rather than the model misrepresenting a specific process. Given that the climate for the entire watershed is represented by a single meteorological station, it is likely that the meteorological station did not capture the driving precipitation events during those poor-fitting years. Additionally, the magnitude of deviations (150-200 mm) between simulated and observed streamflow for the poor-fitting years is such that no other hydrologic processes, other than precipitation, could be the primary cause of the deviations.

Simulated and observed mean monthly streamflow are in good agreement, as shown in Figure 1-13. The log Nash-Sutcliffe coefficient shown in Figure 1-14 is higher than the coefficient for the calibration period at 0.74, meaning a reasonable fit between monthly streamflow.

The sample hydrograph in Figure 1-15 and the ranked duration plot in Figure 1-16 also confirm a reasonable simulation of streamflow within the Chippewa Creek subwatershed.

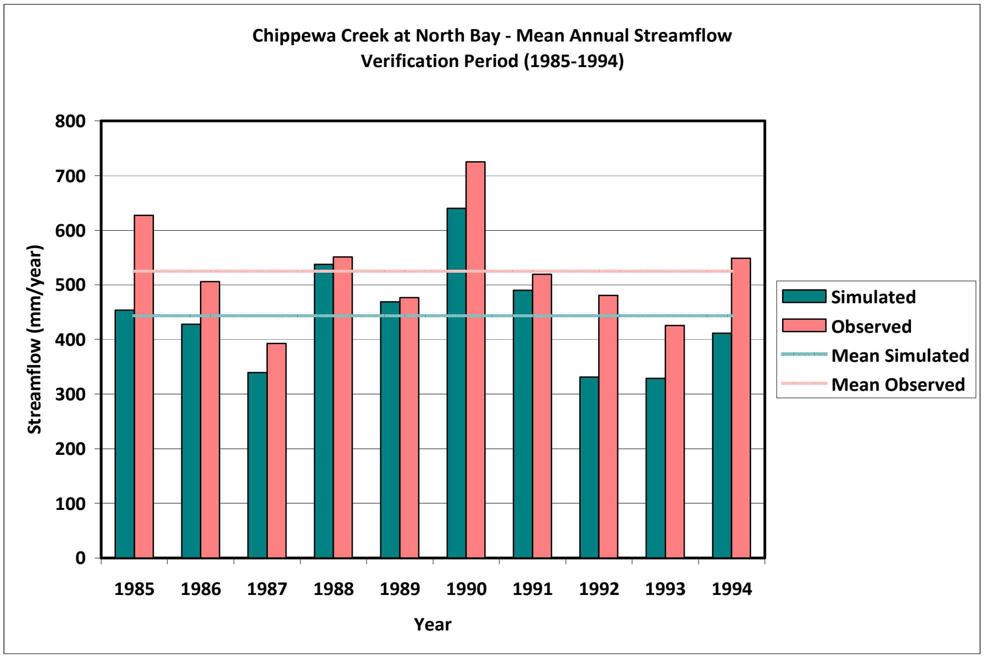

Figure 1-12: Chippewa Creek Gauge Mean Annual Streamflow – Verification Period

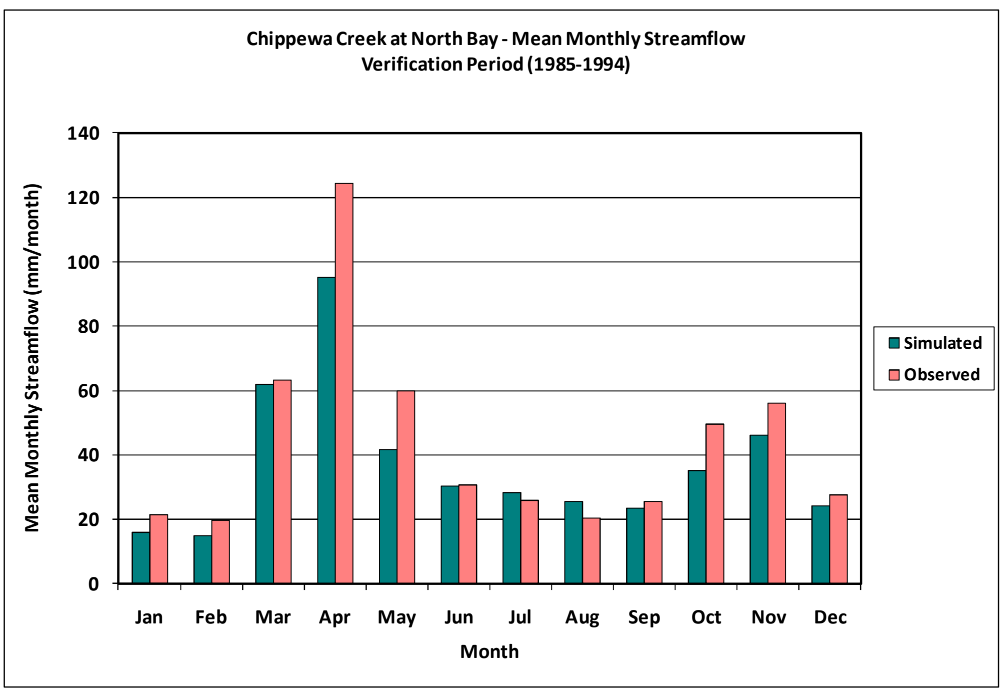

Figure 1-13: Chippewa Creek Gauge Mean Monthly Streamflow – Verification Period

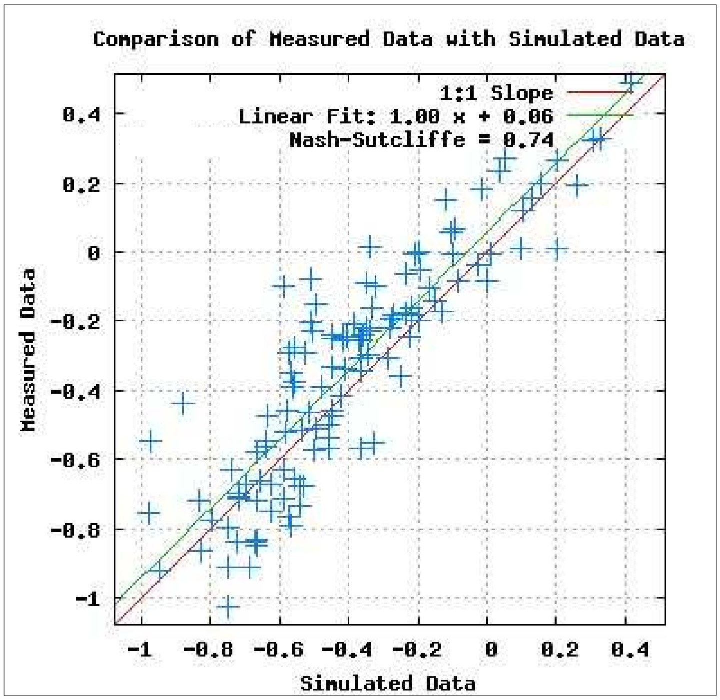

Figure 1-14: Chippewa Creek Gauge Nash-Sutcliffe Coefficient Plot - Verification Period

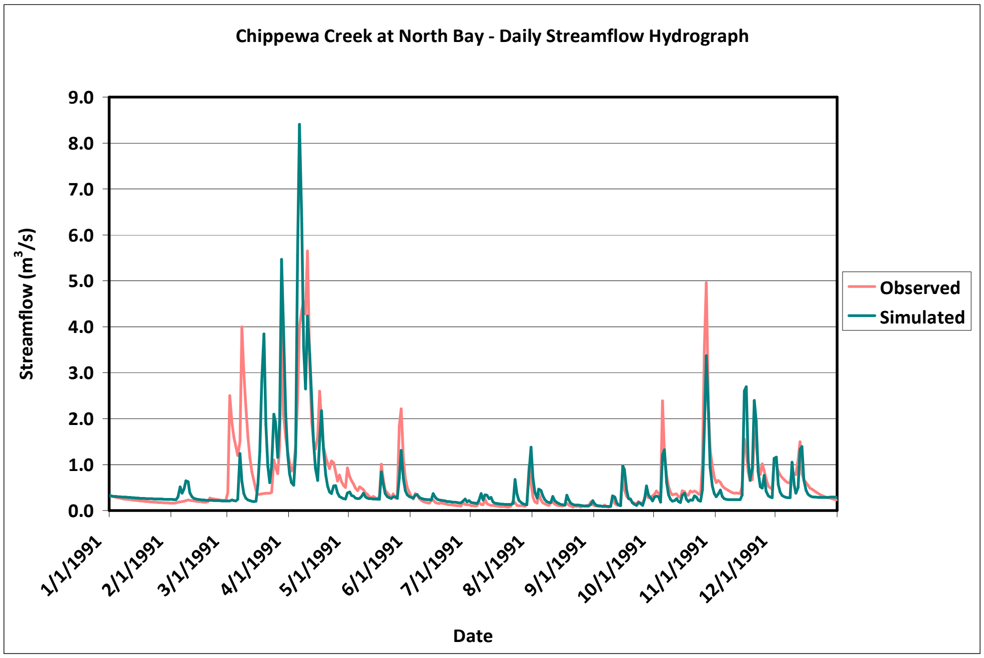

Figure 1-15: Chippewa Creek Gauge Sample Hydrograph – Verification Period

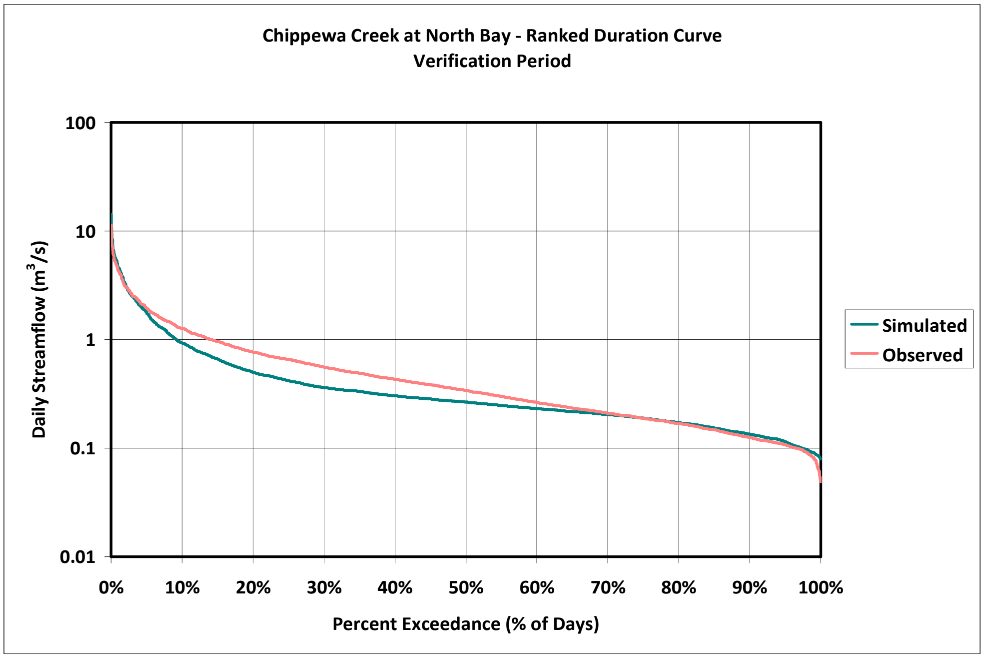

Figure 1-16: Chippewa Creek Gauge Ranked Daily Streamflow – Verification Period

At the La Vase River stream gauge, simulated annual streamflow is also lower than observed, with a mean difference of 52 mm/year, as shown in Figure 1-17. The largest differences are in 1985, 1992, and 1993, and are consistent with the differences seen for the Chippewa Creek stream gauge. As discussed above, this is likely an indicator of climate data collected at the North Bay Airport being unrepresentative of the average climate over the La Vase River subwatershed for these years.

The mean monthly streamflow is in reasonable agreement, as shown in Figure 1-18; however a large discrepancy exists for the month of April. The log Nash-Sutcliffe coefficient shown in Figure 1-19 is reasonable at 0.71 and slightly higher than the coefficient for the calibration period.

The sample hydrograph in Figure 1-20 and the ranked duration plot in Figure 1-21 also confirm a reasonable simulation of streamflow within the La Vase River subwatershed.

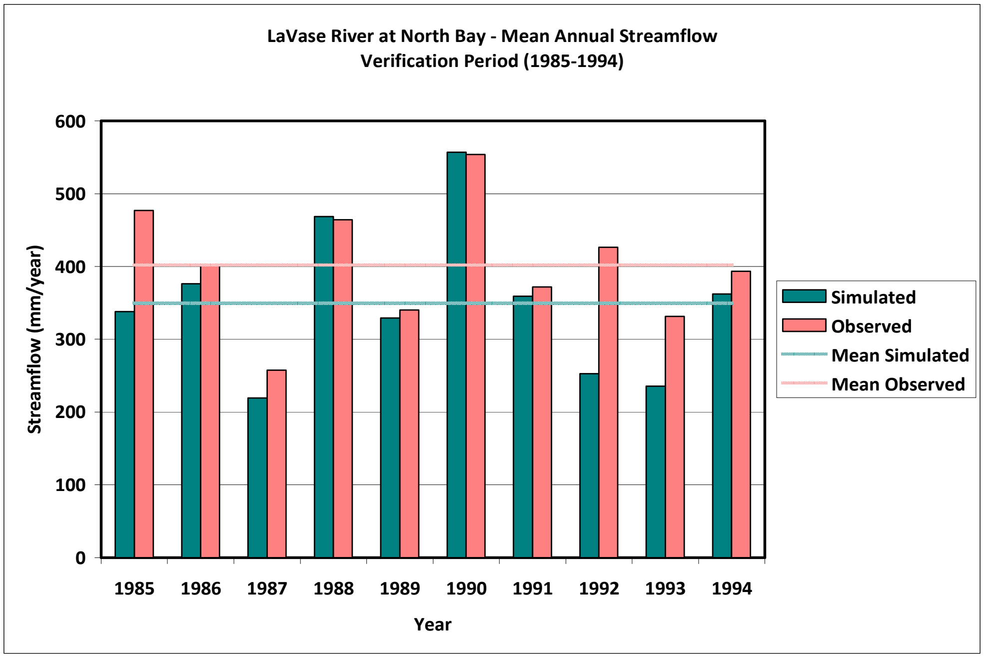

Figure 1-17: La Vase River Gauge Mean Annual Streamflow – Verification Period

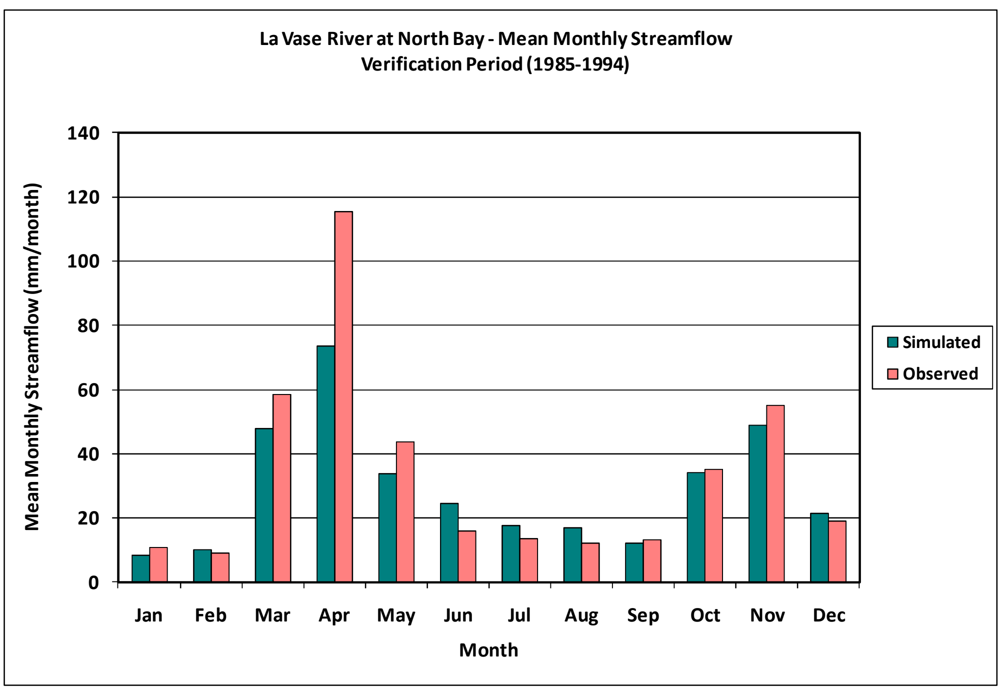

Figure 1-18: La Vase River Gauge Mean Monthly Streamflow – Verification Period

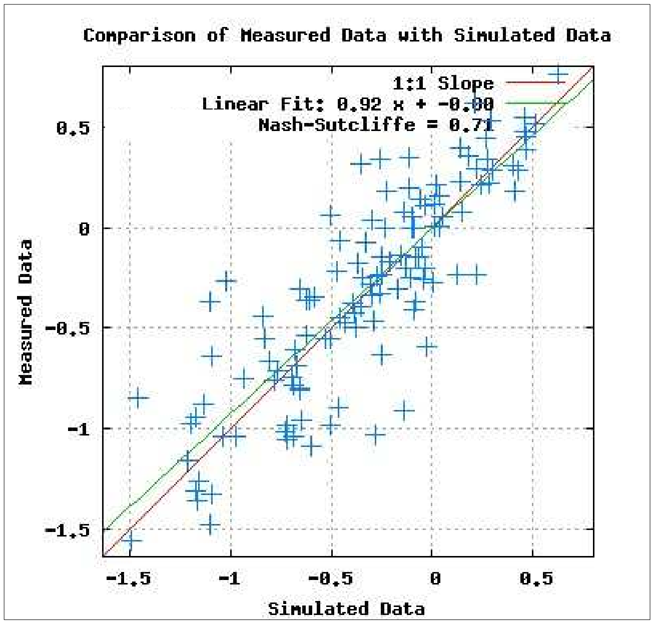

Figure 1-19: La Vase River Gauge Nash-Sutcliffe Coefficient Plot - Verification Period

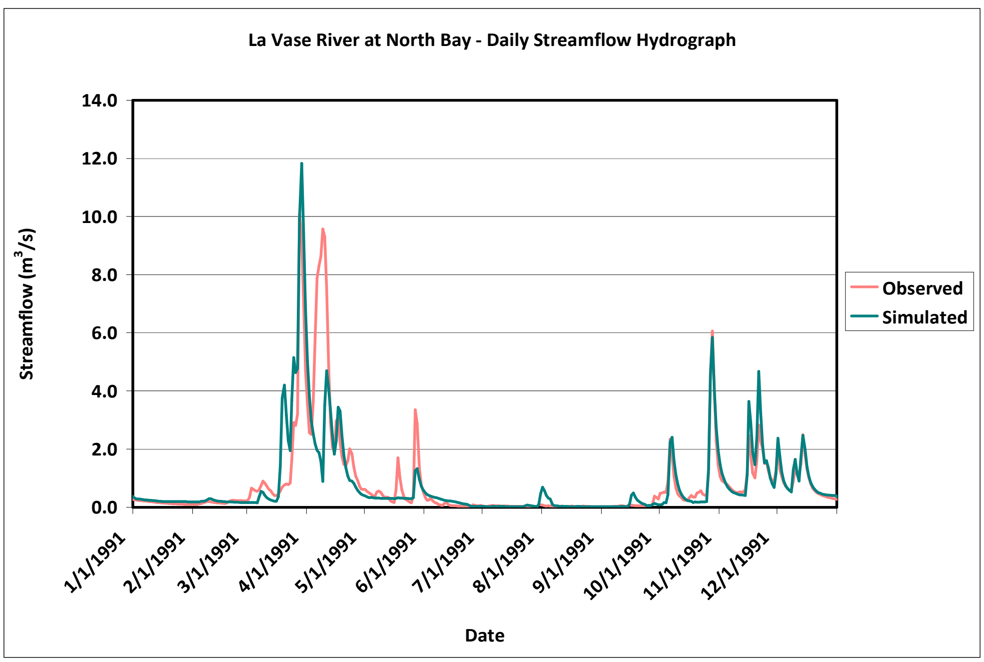

Figure 1-20: La Vase River Gauge Sample Hydrograph – Verification Period

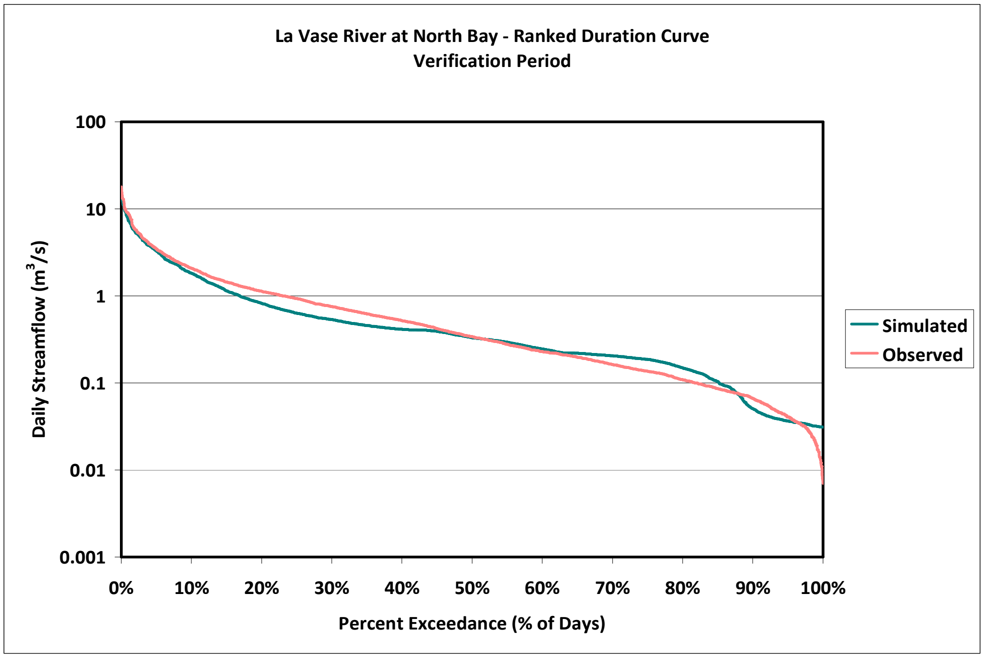

Figure 1-21: La Vase River Gauge Ranked Daily Streamflow – Verification Period

The verification phase of model development is a critical step in testing how accurate the model is performing outside the calibration period. While it is expected that the comparison of the simulated to the observed flows will be better during the calibration phase than during the verification phase, the model should still reasonably replicate observed flow. The results of this verification phase demonstrated that the model reasonably replicates the major hydrologic processes in the Chippewa Creek and La Vase River subwatersheds. As such the model parameterization can be transferred to the Trout/Turtle Lake subwatershed with confidence that natural conditions are being reasonably replicated.

1.1.4 Model Transfer to Trout/Turtle Lake Subwatershed

As there are no stream gauging stations in the Trout/Turtle Lake subwatershed, a full calibration and verification exercise as discussed in Section 1.1.3 is not possible. In place of the full calibration, the calibrated model parameters from the Chippewa Creek and La Vase River subwatersheds are applied to the Trout/Turtle Lake subwatershed, as discussed below:

- Climate data in the Trout/Turtle Lake subwatershed model is from the North Bay Airport meteorological station.
- Channel routing reaches utilized the simplified channel cross-section, related to drainage area, as in Chippewa Creek and La Vase River subwatersheds.
- The same Hydrologic Response Units used within the Chippewa Creek and La Vase River subwatersheds were used within the Trout/Turtle Lake subwatershed. Characterization of the Hydrologic Response Units is identical over the entire modelled area.

- The evapotranspiration factor and deep groundwater component from the Chippewa Creek subwatershed were transferred to the portion of Trout/Turtle Lake subwatershed *above* the Escarpment; and the evapotranspiration and deep groundwater component from the La Vase River subwatershed were transferred to the portion of Trout/Turtle Lake subwatershed *below* the Escarpment.
- Seasonal parameter adjustments are the same over the entire modelled area.

This methodology conserves the original land cover and geology, while utilizing calibrated Hydrologic Response Units.

This characterization was validated by comparing simulated streamflow at five locations in Trout/Turtle Lake subwatershed against observed spot flow measurements. Spot flow measurements were taken by NBMCA in May, June, July and August 2008. The spot flow locations are shown on Map 8 and the measured flow rates are listed in Table 1-9. As the model simulation period is from 1975-2005, a direct comparison of simulated and observed spot flows is not possible. Instead, mean monthly simulated streamflow for May to August for 1975-2005 was compared against the range of monthly spot flow measurements for 2008; therefore, the simulated mean monthly streamflow was expected to fall within the range of observed measurements. Since 2008 was a wet year, the minimum monthly spot flow measurements are likely more representative of average conditions than the maximum. Plots of the spot flow comparisons are shown in Figure 1-22 through Figure 1-26.

Correspondence between the simulated flows and minimum spot flow measurements is very good.

The results of the spot flow comparison increases certainty in the model results and confirms that the Trout/Turtle Lake subwatershed model is reasonably replicating streamflow.

Table 1-9: Spot Flow Measurements in Trout/Turtle Lake Subwatershed (m^3/s)

Date	Lees Creek at Trout Lake Rd (301)	Doran Creek at Trout Lake Rd (303)	Hogan Creek at Trout Lake Rd (305)	Four Mile Creek at Northshore Rd (311)	High Lake Creek at Northshore Rd (315)
5/20/2008	0.217	0.317	--	0.937	--
5/26/2008	0.178	0.129	--	0.571	--
6/2/2008	0.192	0.144	--	0.387	--
6/3/2008	--	--	0.024	--	0.045
6/9/2008	0.127	0.089	--	0.320	--
6/17/2008	0.266	0.154	--	0.547	--
6/23/2008	0.158	0.174	--	0.889	--
7/7/2008	0.196	0.086	0.013	0.296	0.020
7/14/2008	0.254	0.246	--	0.766	--
7/22/2008	0.194	0.116	--	0.606	--
7/31/2008	0.172	0.090	0.024	0.927	0.129
8/6/2008	0.309	0.454	0.093	2.577	0.089
8/13/2008	0.200	0.133	0.018	0.541	0.114
8/18/2008	0.134	0.073	0.020	0.330	0.034

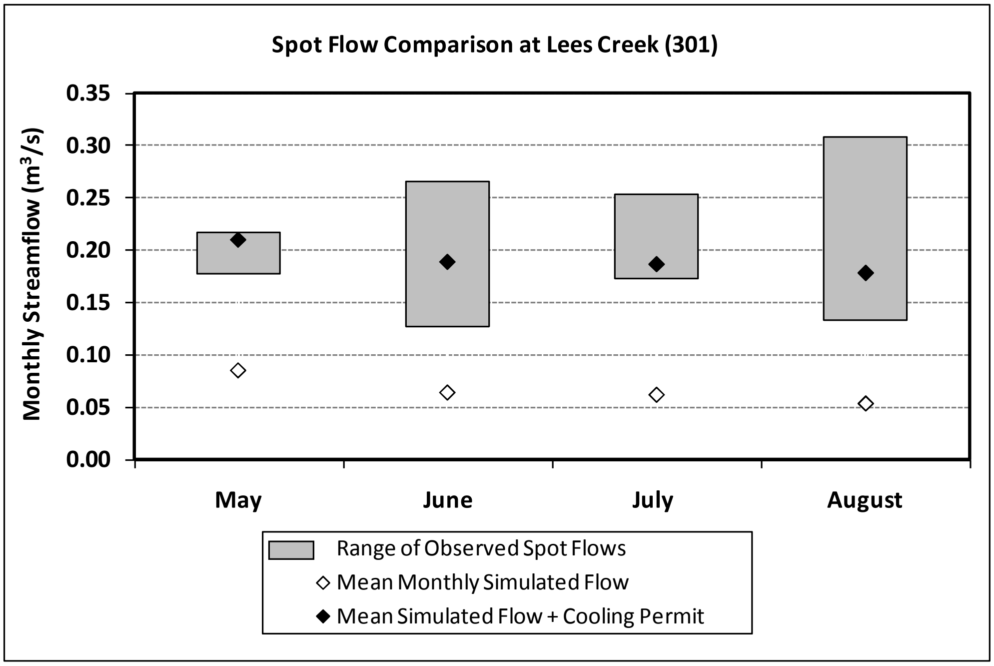

Figure 1-22: Comparison of Mean Monthly Simulated Flows (1975-2005) to Observed Spot Flows (2008) at Lees Creek

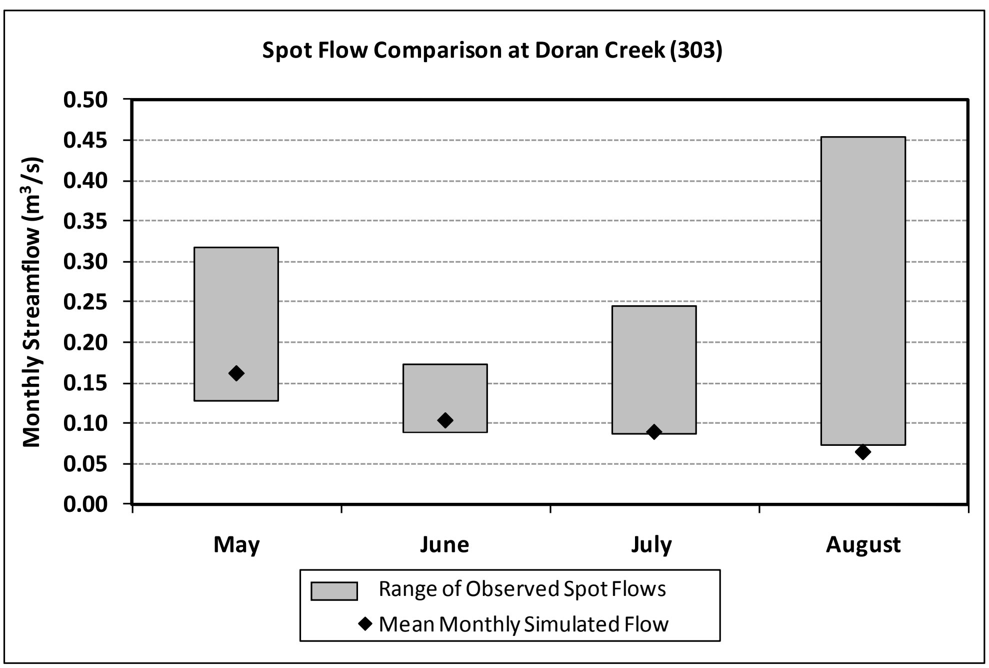

Figure 1-23: Comparison of Mean Monthly Simulated Flows (1975-2005) to Observed Spot Flows (2008) at Doran Creek

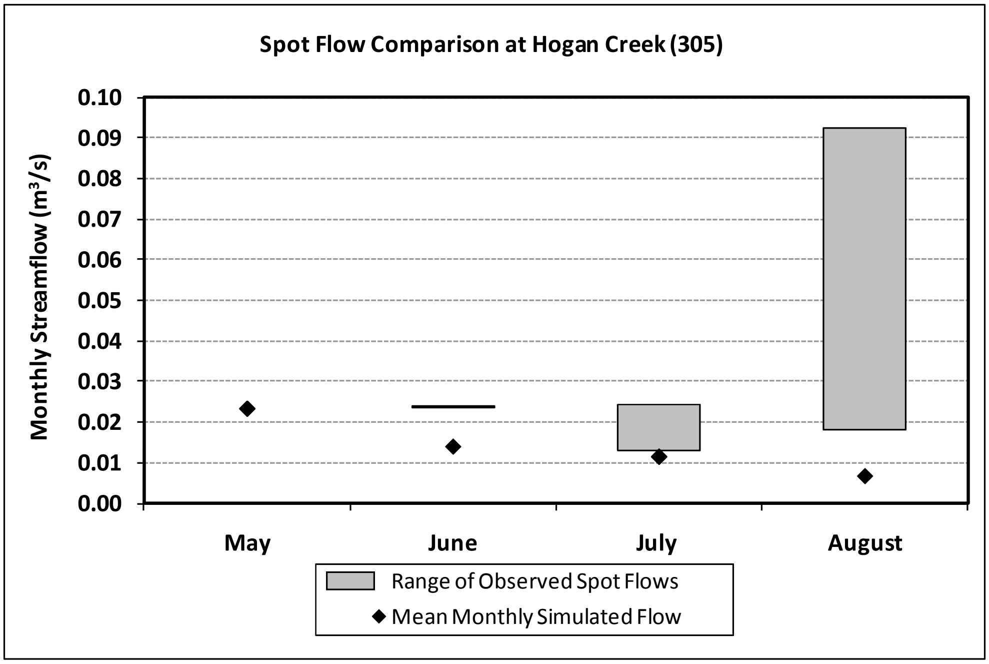

Figure 1-24: Comparison of Mean Monthly Simulated Flows (1975-2005) to Observed Spot Flows (2008) at Hogan Creek

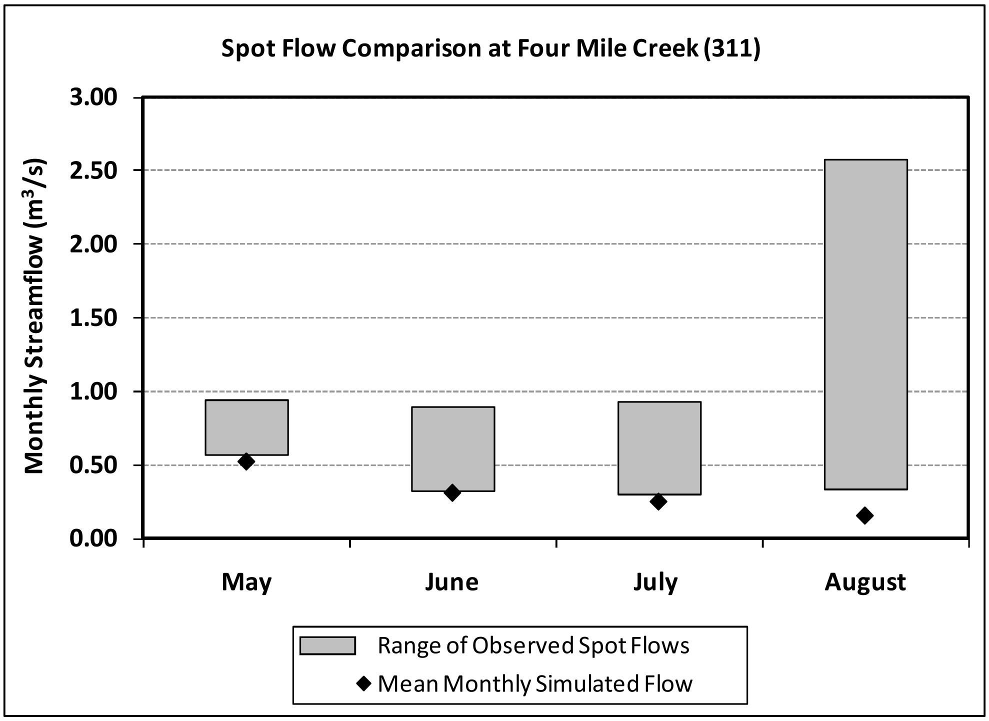

Figure 1-25: Comparison of Mean Monthly Simulated Flows (1975-2005) to Observed Spot Flows (2008) at Four Mile Creek

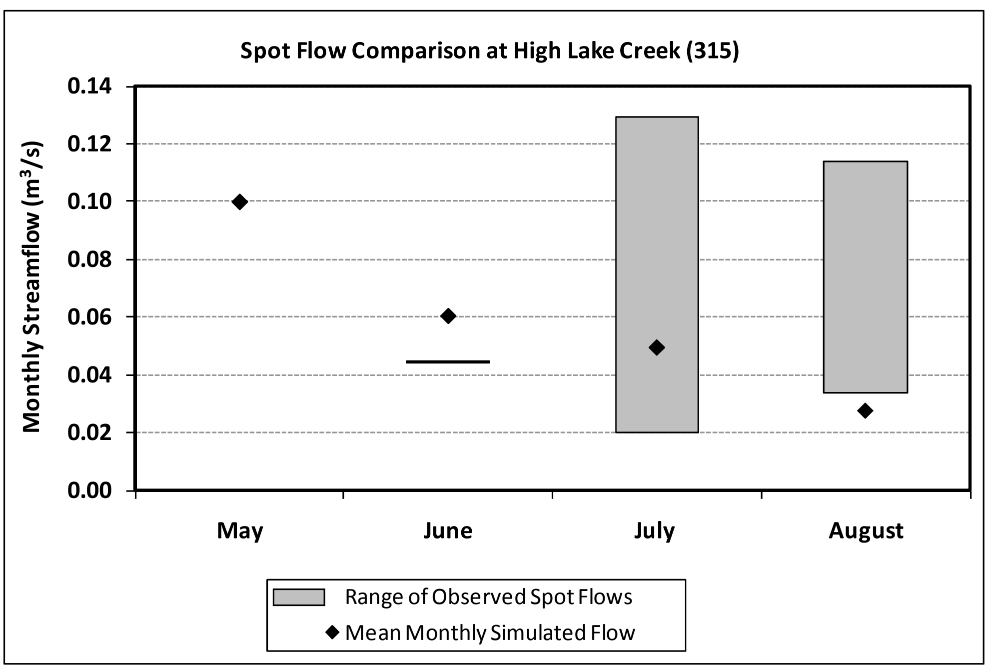

Figure 1-26: Comparison of Mean Monthly Simulated Flows (1975-2005) to Observed Spot Flows (2008) at High Lake Creek

1.2 RESERVOIR ROUTING

Inflows to the Trout/Turtle Lake reservoir are estimated through the application of the hydrologic model, which has been calibrated to both continuous stream gauges in adjacent watersheds, and spot flow measurements taken on Trout Lake tributaries. Inflows to the reservoir are one of the primary determinants of reservoir lake levels; and as such observed reservoir levels can be used to validate and increase the certainty of simulated inflows.

As described in Section 3 of the main report, reservoir levels are recorded at the MNR dock in Delaney Bay, as part of the Turtle Dam operations. This dataset includes water levels captured at a weekly frequency (or more) throughout the months of March to December. To generate simulated lake levels that will allow comparison to observed lake levels, a reservoir routing model is required.

Reservoir routing models consider all inflows (tributary inflow, direct precipitation), all outflows (dam discharges, lake evaporation and water takings), and utilizing reservoir level-storage-discharge relationships, predict lake levels. Should the reservoir model, using simulated inflows generated by the hydrologic model, reasonably replicate observed levels, a higher degree of confidence can be given to the hydrologic model.

1.2.1 Model Development

To estimate reservoir levels for Trout/Turtle Lake, an Excel spreadsheet was utilized to track inflows and outflows, and calculate changes in storage on a daily time step. Storage volume is related to reservoir water level through existing level-storage relationships. The time period included in this analysis is the 1995-2005 time period. This coincides with the calibration period utilized for the hydrologic model, and is the period in which available water withdrawal rates are generally representative. The following sections describe how each of the major inflow and outflow components were calculated.

1.2.1.1 Inflow

To consider the supply of water entering the reservoir, daily average inflow from all tributaries within the Trout and Turtle Lake subwatershed were output from the hydrologic model for the 1995-2005 period. In addition to tributary inflows, direct precipitation falling on the surface of the reservoir was also considered as inflow.

1.2.1.2 Evapotranspiration

The open water surface associated with the reservoir was assumed to evaporate at a rate equal to the potential evapotranspiration rate calculated by the hydrologic model. Daily rates of potential evaporation were used within the reservoir routing model to account for evaporative losses.

1.2.1.3 Water Takings

Daily rates of water withdrawals were obtained from the City of North Bay website for the time period of 2002-2005, and were represented as a direct withdrawal from the reservoir. Water withdrawals prior to 2002 were not made available to this study. A daily time series of water withdrawals for the entire 1995-2005 time period was developed by pro-rating 2005 withdrawals based on population growth rates determined by the Tier 1 Stress Assessment (Gartner Lee, 2008b). Consumptive water demand associated with the cooling permit (2 L/s) was also accounted for, and was assumed to be a steady withdrawal, 365 days per year.

The pro-rating of 2005 municipal withdrawals to the 1995-2001 time period is a significant source of uncertainty, as variations in daily water withdrawal rates due to climatic conditions are not represented.

1.2.1.4 Reservoir Discharge

Daily estimates of reservoir discharge are calculated based on the reservoir water level for the previous time step, the level-discharge relationships presented in Section 2.5.3 of the main report and the stop log settings of Turtle Lake Dam. Stop log settings for Turtle Dam were obtained from the MNR dam operation records. Stop log leakage is assumed to be zero.

It was found that the level-discharge curves presented in Section 2.5.3 of main report caused simulated reservoir levels to drop well below observed for the winter months. To maintain levels within the range of observed data, a reduction factor was applied to winter discharges. It is surmised that this factor is needed to consider the added head losses caused by reservoir ice cover. As ice cover develops on the reservoir, and constricts water flow through the three sluice gates, discharge would be reduced. Through calibration, this reduction factor was found to be 0.66.

1.2.1.5 Change in Reservoir Storage

Based on each day’s inflow, evaporation losses, water takings and calculated discharges, the net change in storage is calculated as per the following equation:

Change in Storage = Inflow – (Reservoir Discharge + Withdrawals + Evaporative Losses)

The change in storage is applied to the previous day’s reservoir storage volume, resulting in the reservoir storage volume for the current time step. Through use of the reservoir level-storage relationship outlined in Section 2.5.3 of the main report, the reservoir storage volume is translated to the reservoir level.

1.2.2 Results

The comparison of simulated and observed reservoir levels is an extremely rigorous test of a hydrologic model’s ability to predict inflows. Reservoir levels on a specific day are largely determined by inflows experienced over the previous month or even season. As such, simulated lake levels are considered to be an accumulator of error associated with inflow estimates. In particular, errors in simulated inflows during the critical snowmelt period can affect reservoir levels for the entirety of the year.

Figure 1-27 includes simulated inflows and water levels for Trout/Turtle Lake, as predicted by the reservoir routing model, as well as the water levels documented within the Turtle Dam operational records. A gap in the Turtle Dam operational records is present for 2001 and 2002, where no stop-log settings or lake levels were available.

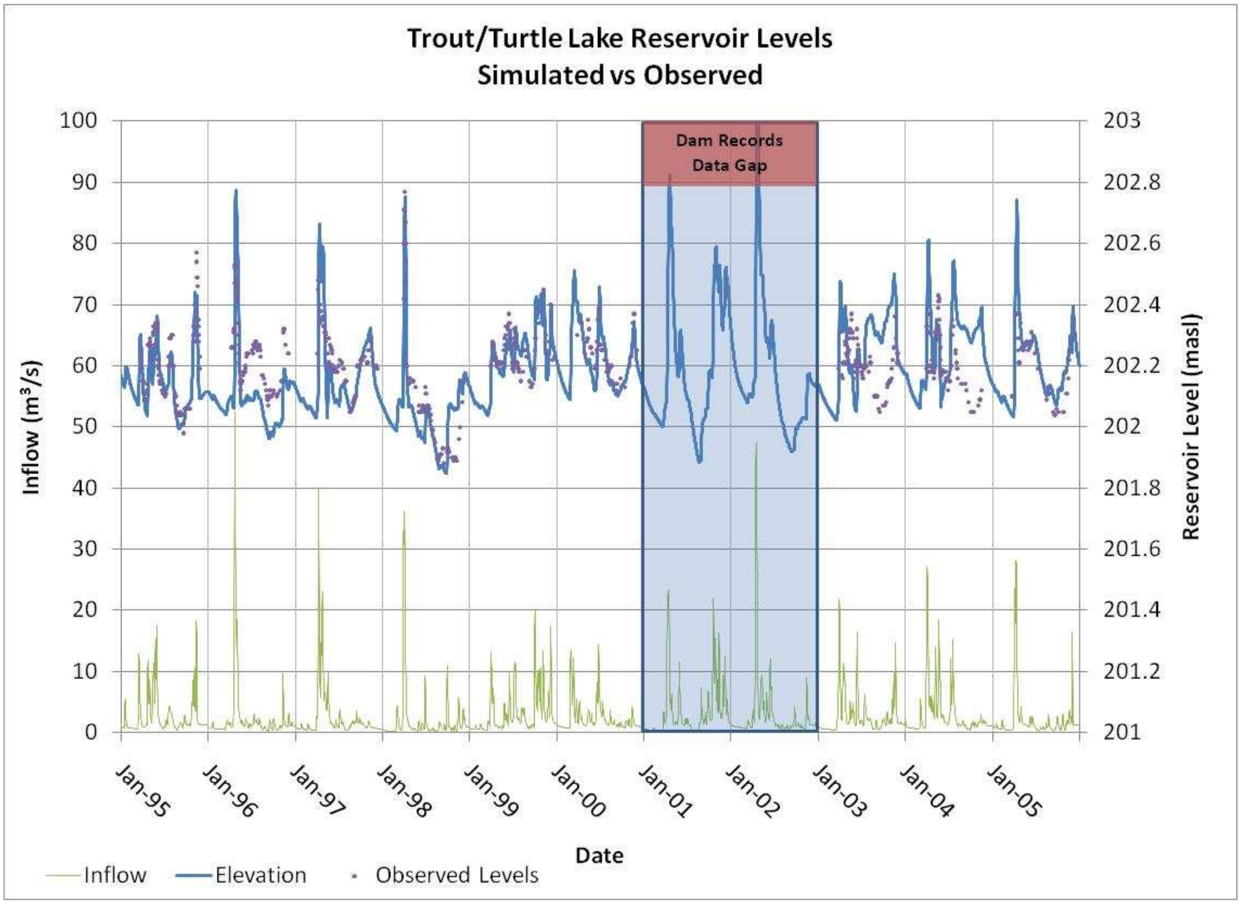

Figure 1-27: Trout/Turtle Lake Simulated vs. Observed Lake Levels

For most years, the reservoir routing model is replicating observed lake levels very well. Peak levels, coinciding with snowmelt periods, are typically well represented, as are extreme low periods (summer 1998). Years with significant differences are 1996 and 2004.

In 1996, the routing model is under predicting levels. It is surmised that this was caused by the simulated snowmelt and resultant inflow occurring too rapidly and being discharged before the summer stop-log setting was set. As the simulated volume associated with the freshet occurred prior to the installation of all stop-logs, there was insufficient simulated inflow to raise lake levels to their summer level, and caused simulated levels for the remainder of the year to be lower than observed levels.

In 2004, the lake levels are simulated significantly higher than observed levels throughout the summer and fall. This deviation can be traced back to a precipitation event in early July, where the simulated inflows caused lake levels to increase more than observed. This difference in lake levels caused by the July precipitation event is approximately 15 cm, which is the approximate difference in levels for the remainder of the year.

The comparison between simulated and observed lake levels is presented in Figure 1-28 as a scatter plot. The solid red line represents what would be a perfect fit between observed and simulated levels; blue diamonds represent observations. Where the observations are above the solid red line, the model has under-represented lake levels. Where the observations are below the solid red line, the model has over-estimated lake levels. Dashed red lines bound the line of perfect fit by 20 cm.

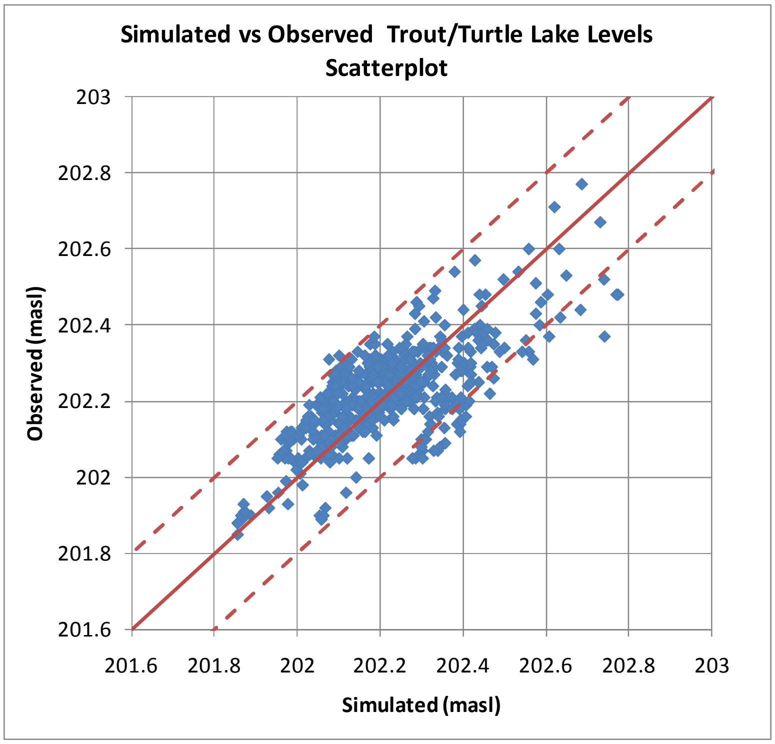

Figure 1-28: Scatter Plot of Simulated and Observed Trout/Turtle Lake Water Levels

1.2.3 Reservoir Routing Model Summary

A reservoir routing model was created to validate estimated inflows to Trout/Turtle Lake. This routing model considers inflows, withdrawals, evaporative losses, and level-storage-discharge relationships to generate a time series of Trout/Turtle Lake water levels. Comparison of simulated water levels to observed levels indicates that the reservoir routing model replicates observed water levels very well for most years.

Sources of uncertainty associated with the reservoir routing model include level-storage-discharge relationships, the quantity of stop-log leakage, the effect of ice conditions on the level-discharge relationship, and the pro-rating of 2005 North Bay withdrawal rates for years 1995-2001. Despite these uncertainties, the reservoir routing model produced simulated reservoir levels that were generally consistent with observations, and can be considered a secondary validation of the simulated Trout/Turtle Lake inflows.

1.3 SENSITIVITY ANALYSIS

The representation of individual hydrologic processes within a model is uncertain. This uncertainty is tied to an inability to completely characterize all hydrologic processes that can influence the overall hydrologic response of a catchment. Uncertainty is managed by calibrating and verifying model output to observed conditions, and where possible, validating model output against secondary datasets.

A sensitivity analysis can be used to determine how sensitive model output is to uncertainty associated with model parameters. A sensitivity analysis involves varying model parameters by specified ranges and determining the impact of those variations on model output. If model output is shown to be insensitive to variations in model parameters (as compared against observation error), certainty with respect to model output can be increased.

To determine the sensitivity of model output for the Trout/Turtle Lake hydrologic and reservoir routing model, four sensitivity scenarios were evaluated. The scenarios focused on varying hydrologic processes that were considered to be critical to water budget evaluation (infiltration) and lake level (evapotranspiration). Other hydrologic processes, such as routing, can also significantly impact simulated streamflow; however this effect is typically experienced at the hourly scale and not relevant for water budgeting investigations. The four scenarios investigated are listed as follows:

- Case 1: an increase of 25% in hydraulic conductivity, seepage rate, and percolation rate for Hydrologic Response Units;
- Case 2: a decrease of 25% in hydraulic conductivity, seepage rate, and percolation rate for the Hydrologic Response Units;
- Case 3: an increase of 10% in the calculated potential evapotranspiration rate; and
- Case 4: a decrease of 10% in the calculated potential evapotranspiration rate.

In GAWSER, the hydraulic conductivity is defined as the rate at which water infiltrates from ground surface to the first soil layer; the seepage rate is the rate at which water is transmitted from the first soil layer to the second soil layer; and the percolation rate is the rate at which water leaves the second soil layer (groundwater recharge). By reducing each rate by 25%, the amount of groundwater recharge that is produced is greatly reduced.

The sensitivity of model output was determined by evaluating changes in mean monthly streamflow for the Chippewa Creek gauge and La Vase River gauge, as well as Trout/Turtle Lake inflows. Changes in Trout/Turtle Lake water level elevations were also evaluated.

The infiltration parameter adjustments for Case 1 and 2 are listed in Table 1-10 and the evapotranspiration parameter adjustments for Case 3 and 4 are listed in Table 1-11.

Table 1-10: Infiltration Parameter Adjustments Applied in the Sensitivity Analysis

Hydrologic Response Unit	Base Case			Case 1: +25% Infiltration			Case 2: -25% Infiltration		
	Hydraulic Conductivity mm/h	Seepage Rate mm/h	Percolation Rate mm/h	Hydraulic Conductivity mm/h	Seepage Rate mm/h	Percolation Rate mm/h	Hydraulic Conductivity mm/h	Seepage Rate mm/h	Percolation Rate mm/h
Impervious	0	0	0	0	0	0	0	0	0
Open Water	0	0.10	0.10	0	0.13	0.13	0	0.08	0.08
Wetlands	0.20	0.20	0.010	0.25	0.25	0.013	0.15	0.15	0.008
Low Vegetation - Thin Soil over Bedrock	0.50	0.30	0.10	0.63	0.38	0.13	0.38	0.23	0.08
Low Vegetation - Clay and Silt Tills	0.20	0.20	0.010	0.25	0.25	0.013	0.15	0.15	0.008
Low Vegetation - Sands and Gravels	7.5	6.0	0.50	9.4	7.5	0.63	5.6	4.5	0.38
High Vegetation - Thin Soil over Bedrock	1.5	0.9	0.30	1.9	1.1	0.38	1.1	0.7	0.23
High Vegetation - Clay and Silt Tills	12	9.0	0.60	15	11	0.75	9.0	6.8	0.45
High Vegetation - Sands and Gravels	20	12	1.2	25	15	1.5	15	9.0	0.90

Table 1-11: Evapotranspiration Factor Parameter Adjustments Applied in the Sensitivity Analysis

Description	Base Case	Case 3: +10% ETFAC	Case 4: -10% ETFAC
	Evapotranspiration Factor	Evapotranspiration Factor	Evapotranspiration Factor
Chippewa Creek subwatershed and Trout/Turtle Lake subwatershed above the Escarpment	0.56	0.62	0.50
La Vase River subwatershed and Trout/Turtle Lake subwatershed below the Escarpment	0.53	0.58	0.48

1.3.1 Streamflow Sensitivity

The following sections describe the variations in simulated streamflow for each of the above four scenarios. Streamflow is compared at the Chippewa Creek gauge, the La Vase River gauge, and for Trout/Turtle Lake inflows.

In areas with good drainage, such as the Chippewa Creek subwatershed, additional water infiltrating into the ground and passing through the soil column, results in a more delayed response in the mean monthly streamflow. This translates to lower peak flows, and higher baseflow, as seen in Figure 1-29. In this figure, a 25% increase in infiltration results in a maximum increase in mean monthly streamflow of 2 mm/month in the summer, fall and winter, and a maximum decrease of 5 mm/month in the spring. Conversely, less water infiltrating results in a faster response in the mean monthly streamflows. In this case, a 25% decrease in infiltration results in a maximum decrease in mean monthly streamflow of 2 mm/month in the summer, fall and winter, and a maximum increase of 7 mm/month in the spring.

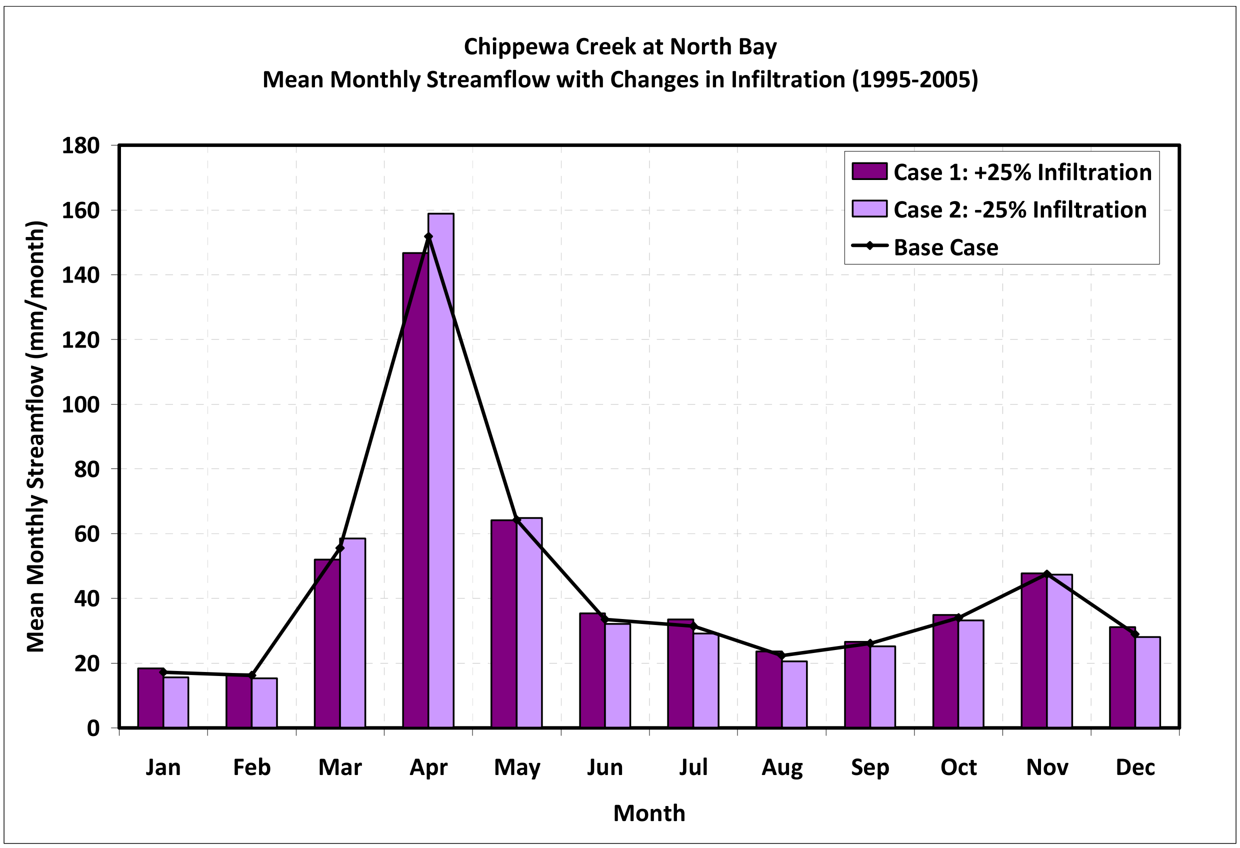

Figure 1-29: Sensitivity of Chippewa Creek at North Bay Mean Monthly Streamflow to ±25% Infiltration

The La Vase River subwatershed is mainly composed of bedrock, in which little infiltration occurs; thus streamflow is mainly due to overland runoff. As such, the mean monthly streamflow is less sensitive to changes in infiltration as within the Chippewa Creek subwatershed. Within the La Vase River subwatershed, baseflow remains practically unchanged with a 25% increase or decrease in infiltration, as seen in Figure 1-30. However, changes in mean monthly streamflow are evident in the winter and spring months. Similar to the Chippewa Creek subwatershed, a 25% increase in infiltration results in a 3 mm/month decrease in mean monthly streamflow in April and a 3 mm/month increase in December. Conversely, a 25% decrease in infiltration results in a 4 mm/month increase in mean monthly streamflow in April and a 3 mm/month decrease in December.

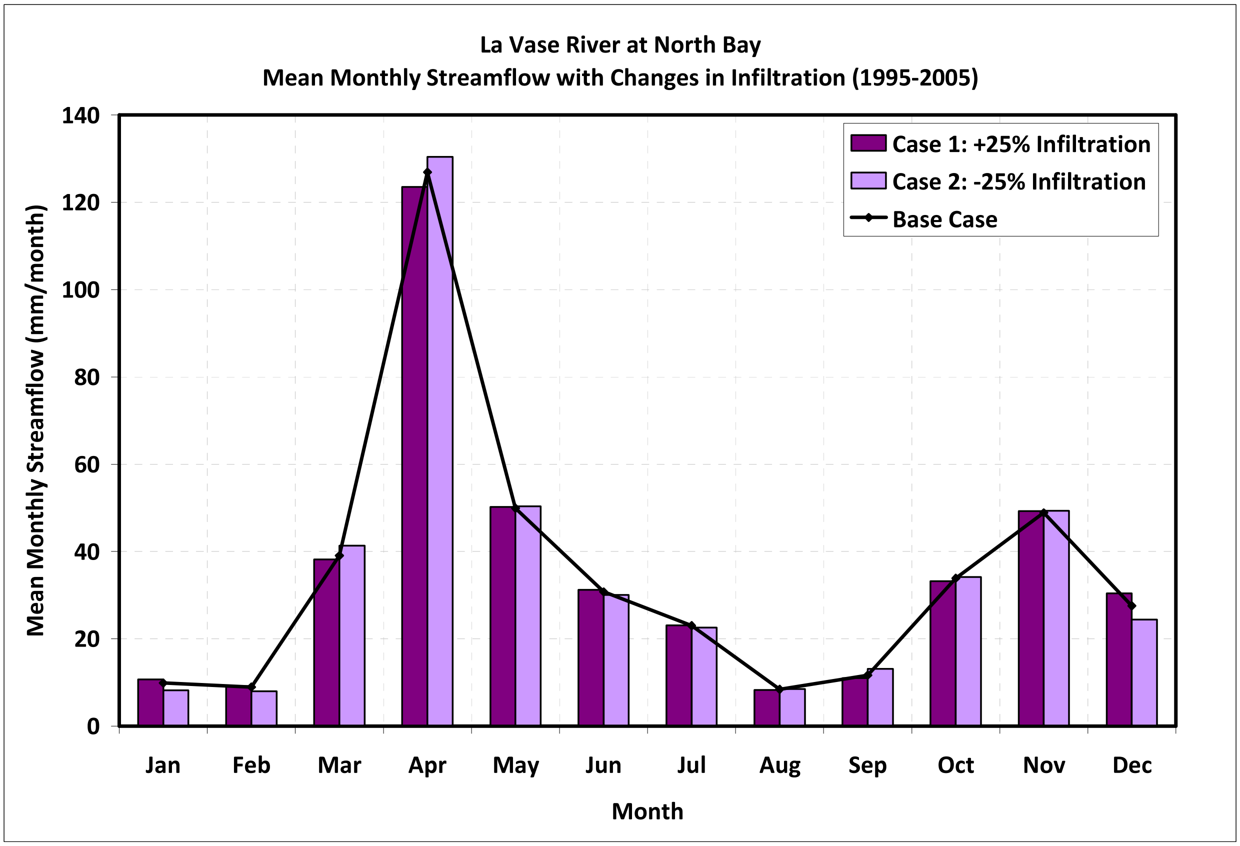

Figure 1-30: Sensitivity of La Vase River at North Bay Mean Monthly Streamflow to ±25% Infiltration

Within the Trout/Turtle Lake subwatershed, baseflow depths changed very little with a 25% increase or decrease in infiltration, as seen in Figure 1-31. However, changes in mean monthly streamflow are evident in the winter and spring months. Similar to the Chippewa Creek and the La Vase River subwatersheds, a 25% increase in infiltration results in a 4 mm/month decrease in mean monthly streamflow in April and a 3 mm/month increase in December. Conversely, a 25% decrease in infiltration results in a 4 mm/month increase in mean monthly streamflow in April and a 2 mm/month decrease in December.

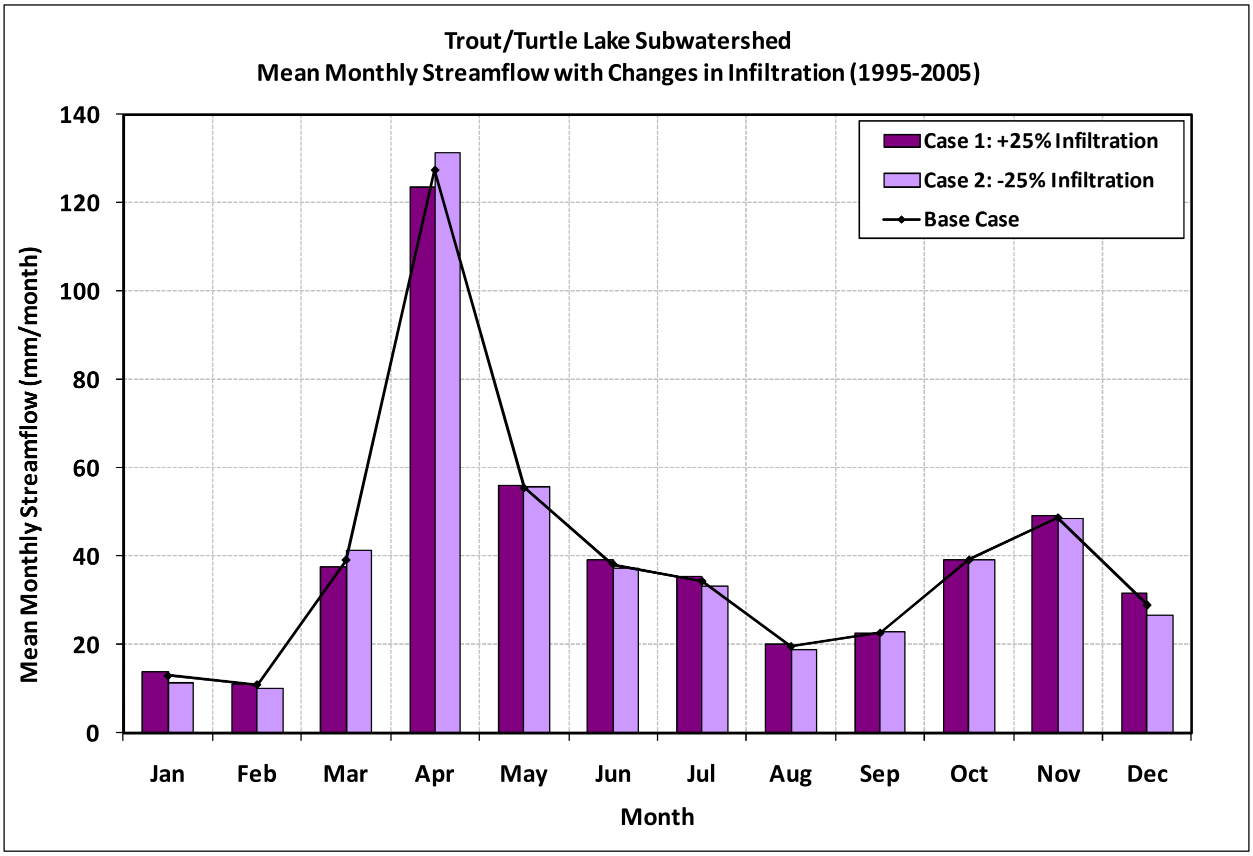

Figure 1-31: Sensitivity of Trout/Turtle Lake Subwatershed Mean Monthly Streamflow to ±25% Infiltration

The evapotranspiration factor, ETFAC, adjusts the potential evapotranspiration rate which is computed in GAWSER using the Linacre (1977) method. A higher ETFAC implies a higher potential evapotranspiration rate. When additional water is available for evapotranspiration, the net precipitation is reduced and less water is available for runoff and recharge.

As seen in Figure 1-32, in the Chippewa Creek subwatershed, a 10% increase in ETFAC results in a decrease in mean monthly streamflow year round, with a maximum decrease of 3 mm/month in May and October. Conversely, a 10% decrease in ETFAC results in an increase in mean monthly streamflow year round, with a maximum increase of 4 mm/month in October and November.

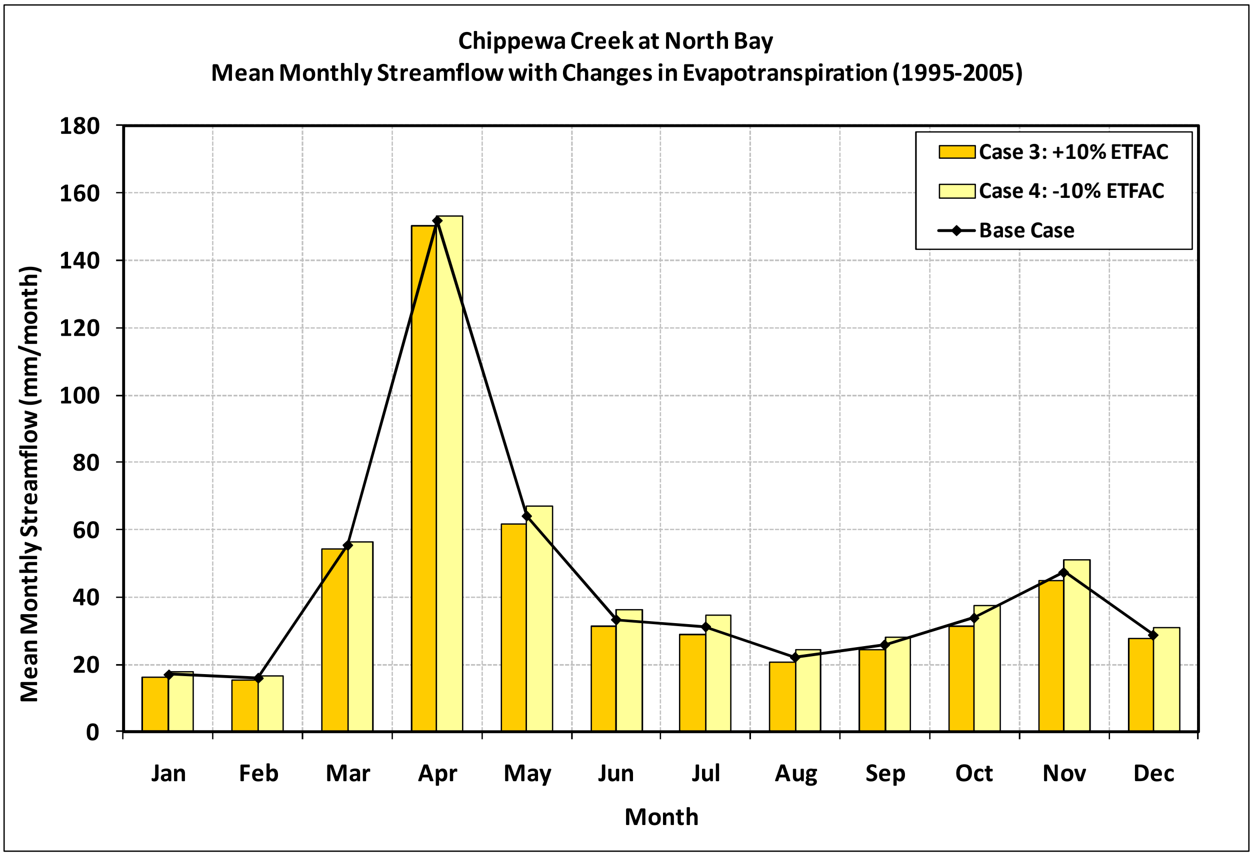

Figure 1-32: Sensitivity of Chippewa Creek at North Bay Mean Monthly Streamflow to ±10% Evapotranspiration Factor

Streamflow at the La Vase River stream gauge is slightly more sensitive to changes in ETFAC than at the Chippewa Creek stream gauge. As seen in Figure 1-33, a 10% increase in ETFAC shows a decrease in mean monthly streamflow year round, with a maximum decrease of 4 mm/month in May and October; while a 10% decrease in ETFAC results in an increase in mean monthly streamflow year round, with a maximum increase of 5 mm/month in May.

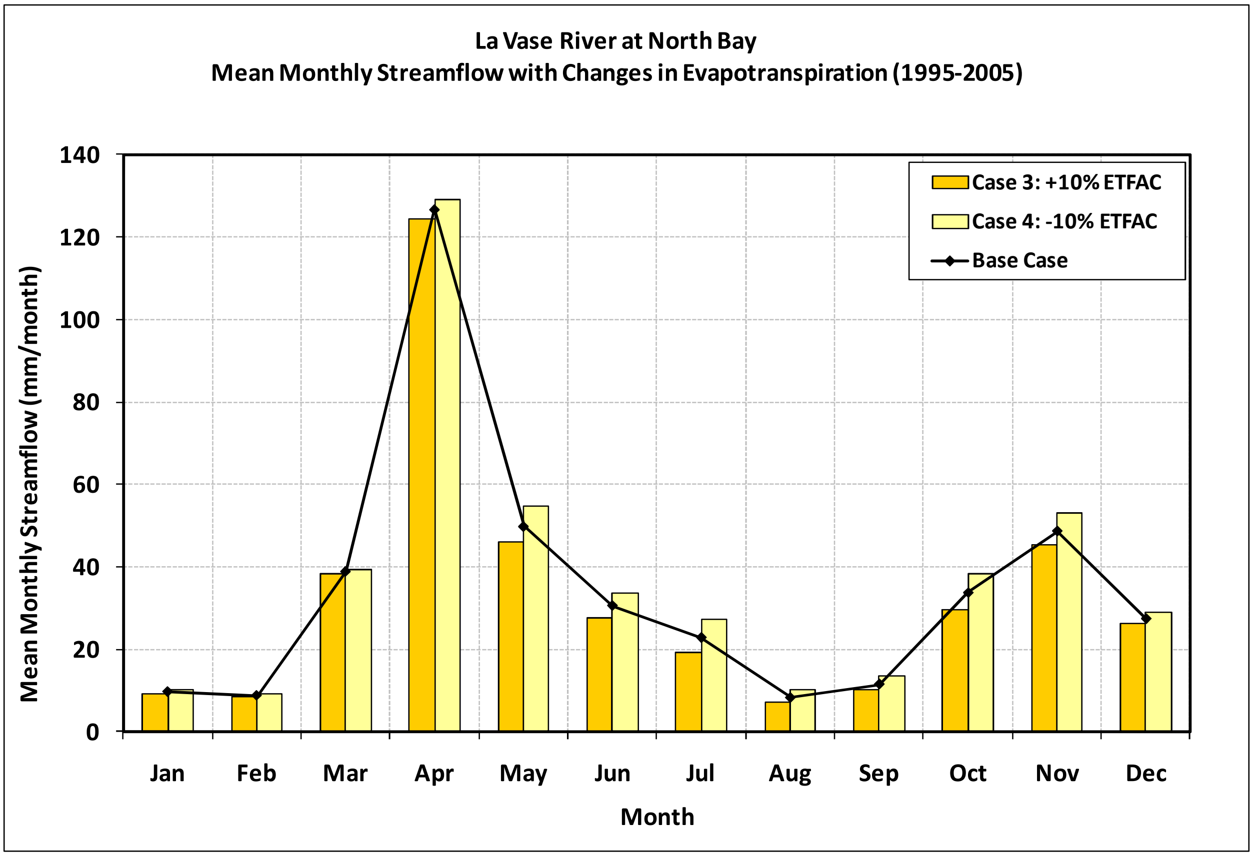

Figure 1-33: Sensitivity of La Vase River at North Bay Mean Monthly Streamflow to ±10% Evapotranspiration Factor

The Trout/Turtle Lake subwatershed streamflow shows very similar sensitivity to ETFAC as in the Chippewa Creek subwatershed. As seen in Figure 1-34, a 10% increase in ETFAC results in a decrease in mean monthly streamflow year round, with a maximum decrease of 3 mm/month. A 10% decrease in ETFAC results in an increase in mean monthly streamflow year round, with a maximum increase of 4 mm/month.

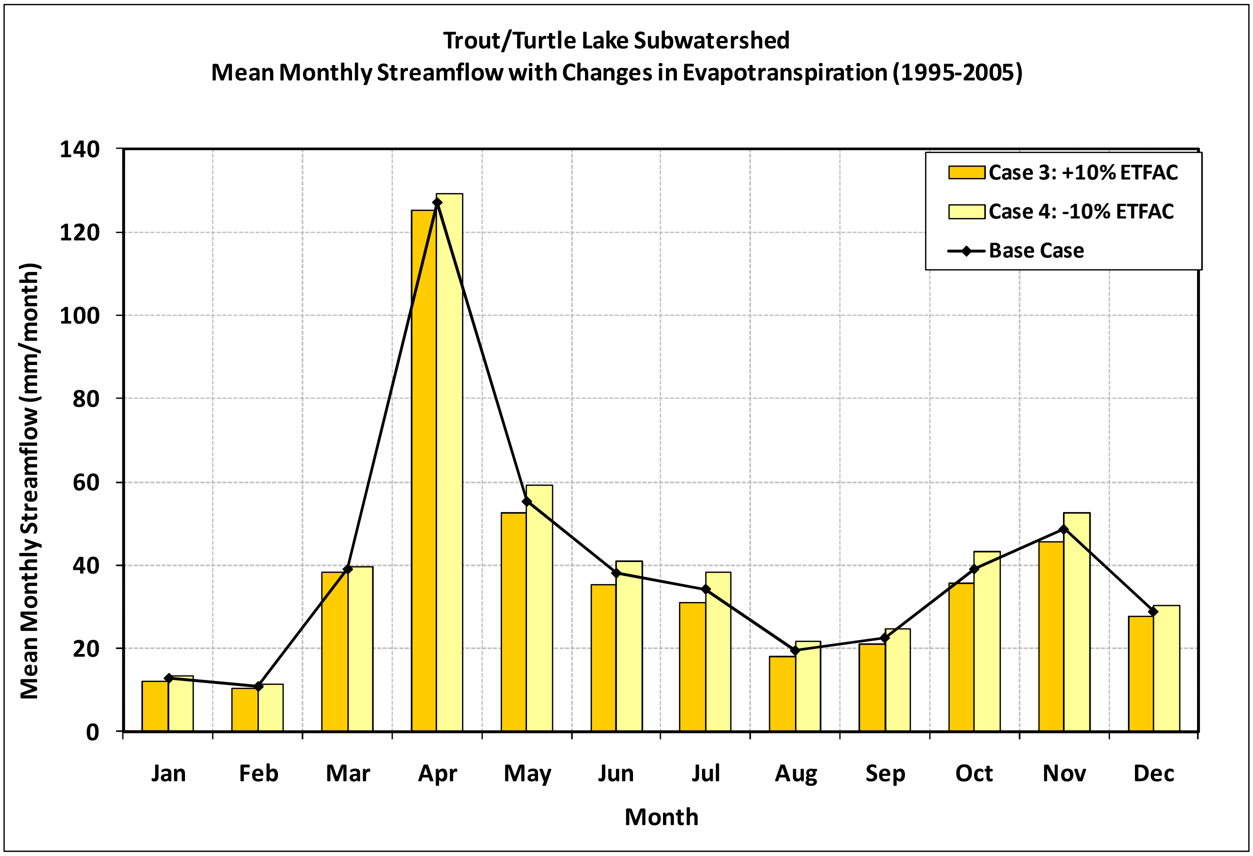

Figure 1-34: Sensitivity of Trout/Turtle Lake Subwatershed Mean Monthly Streamflow to ±10% Evapotranspiration Factor

1.3.2 Reservoir Level Sensitivity

To determine the sensitivity of the predicted water levels to uncertainty associated with infiltration parameters and calculated evapotranspiration rates, inflows and evapotranspiration rates from the above four scenarios were input into the reservoir routing model.

Simulated reservoir levels for each scenario are compared against the base case in the following ranked duration plot in Figure 1-35.

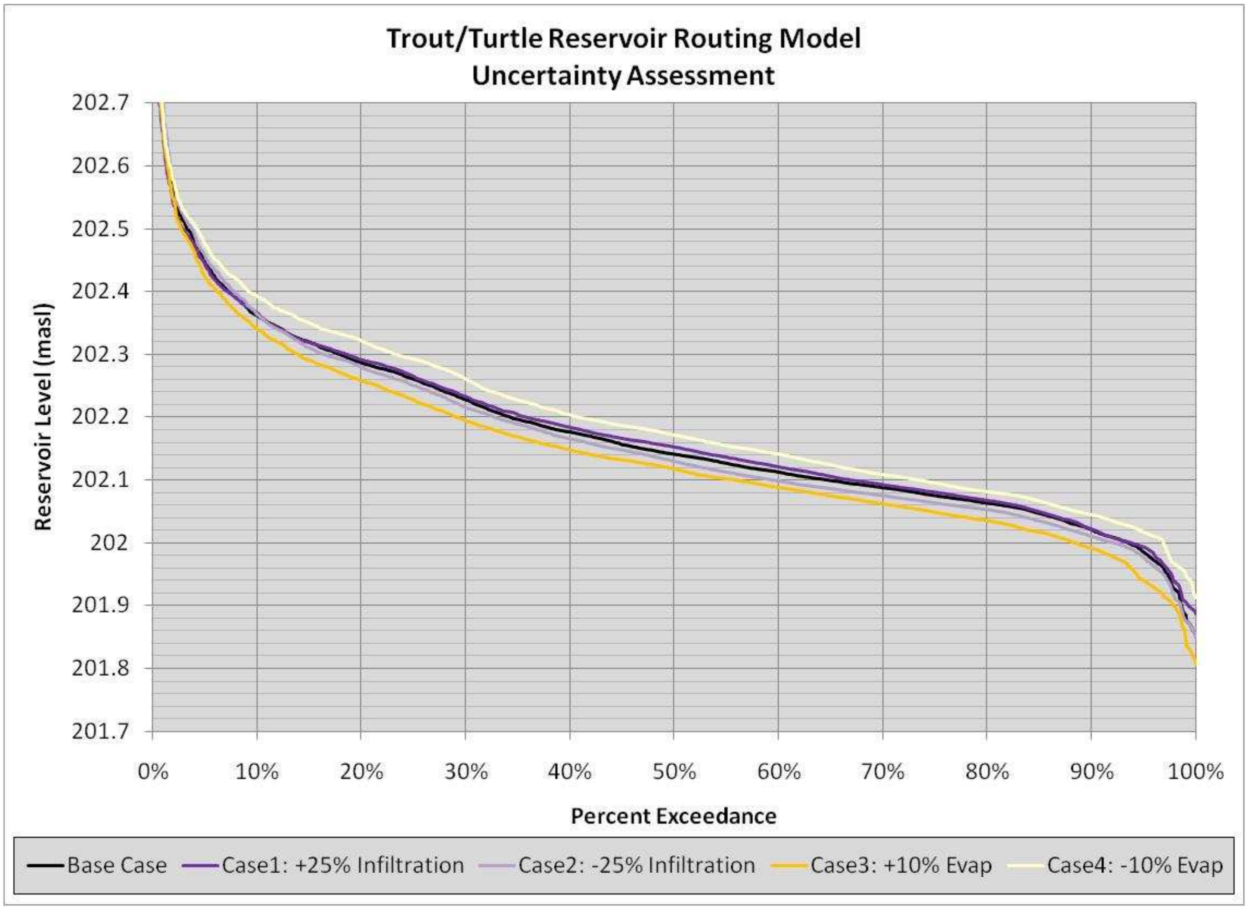

Figure 1-35: Sensitivity of Trout/Turtle Reservoir Levels to Infiltration Parameter and Evapotranspiration Uncertainty

Generally, when infiltration parameters are lowered, reservoir levels are also lowered, other than high reservoir levels. As infiltration parameters are reduced, runoff is promoted rather than recharge. With less recharge, summer baseflows are lowered, thereby reducing reservoir storage more rapidly, and consequently producing lower reservoir levels. The opposite occurs when infiltration parameters are increased; recharge is promoted over runoff, summer baseflows are raised and additional volume is added to reservoir storage during dry periods. The impact of infiltration parameter variations is generally insignificant, as the maximum difference in reservoir levels is approximately 2 cm.

Variations in evapotranspiration rates produce a more noticeable effect on reservoir levels than variations in infiltration parameters. This is expected as both inflows and evaporative losses are affected by the evapotranspiration scenarios. Reductions in evapotranspiration result in higher inflows, and smaller evaporative losses from the reservoir, leading to reservoir levels being approximately 4 cm higher than the base case. Increases in evapotranspiration result in lower inflows and higher evaporative losses from the reservoir, leading to reservoir levels being approximately 4 cm lower than the base case. Deviations from the base case become larger at low lake elevations; however are not significant when compared to the full range of reservoir level fluctuations.

1.3.3 Sensitivity Analysis Summary

As all models require the use of assumptions to simplify the hydrologic system, modelled results contain uncertainties. These uncertainties are due to the inability of a hydrologic model to replicate all individual physical processes that may influence the larger hydrologic response (hydrograph) from a catchment. These uncertainties can be managed or reduced by undertaking detailed calibration/verification exercises, and validating model output to additional observed datasets; however, they cannot be removed.

To determine the significance of this uncertainty on model output, four scenarios were investigated. These scenarios varied infiltration parameters (±25%) as well as the potential evapotranspiration rates (±10%). The scenarios did not result in significantly different model outcomes; Trout/Turtle Lake inflows varied by a maximum of 4 mm/month, and Trout/Turtle Lake water levels by a maximum of 4 cm.

The results of the sensitivity analysis indicate that the uncertainty associated with infiltration and evapotranspiration parameters does not significantly impact simulated Trout/Turtle Lake inflows or lake levels. This increases the level of certainty associated with the hydrologic model for estimating lake inflows or levels.

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Appendix C – Model Schematics

NBMCA
Model Schematic Diagrams

Legend

105	Catchment
1105	Routing Reach
2105	Junction
★	HYDAT Gauge
→	Flow Direction

Element IDs

Catchments: 100s – Chippewa Creek

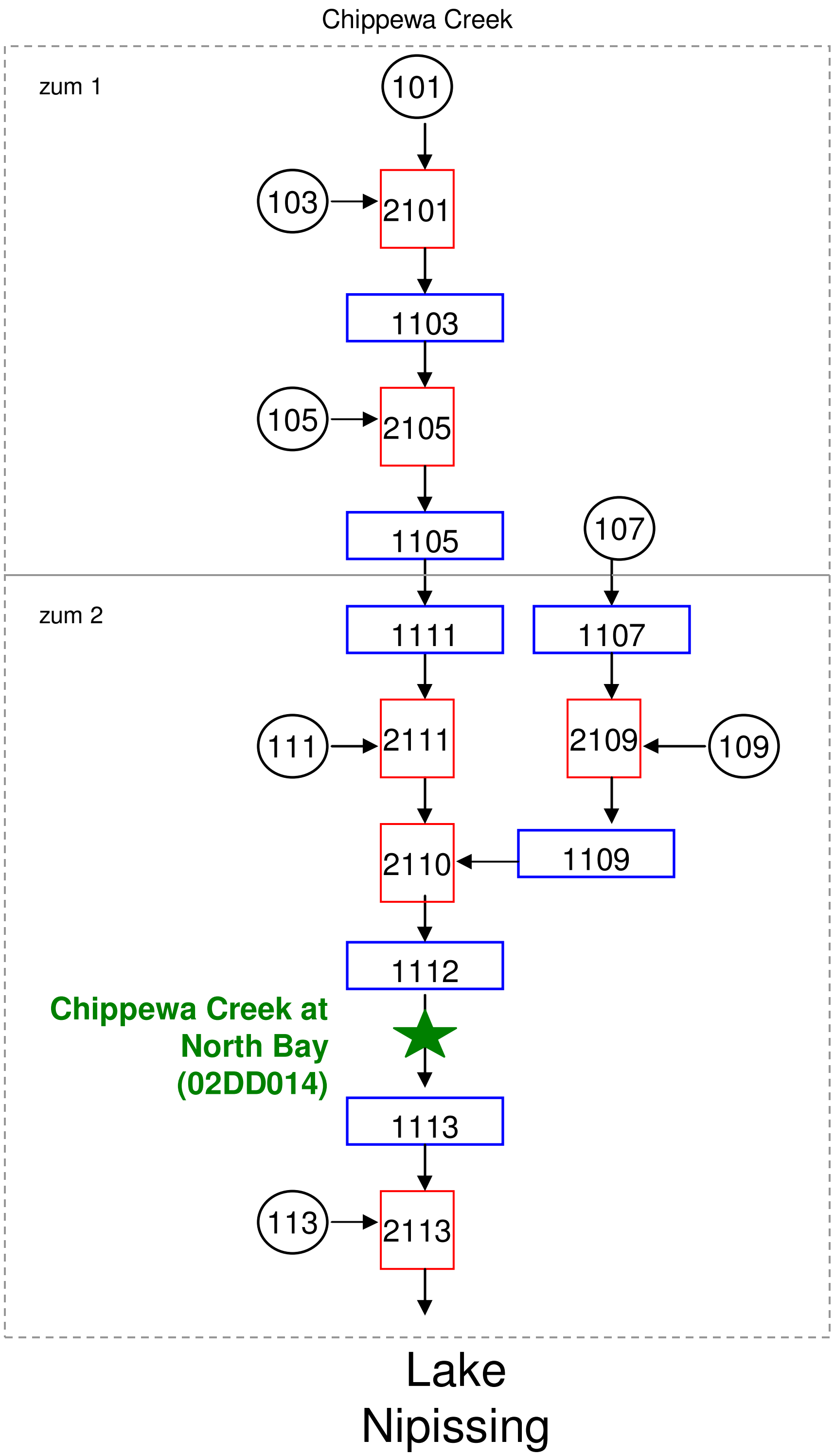
200s – La Vase River

300s – Trout/Turtle Lake

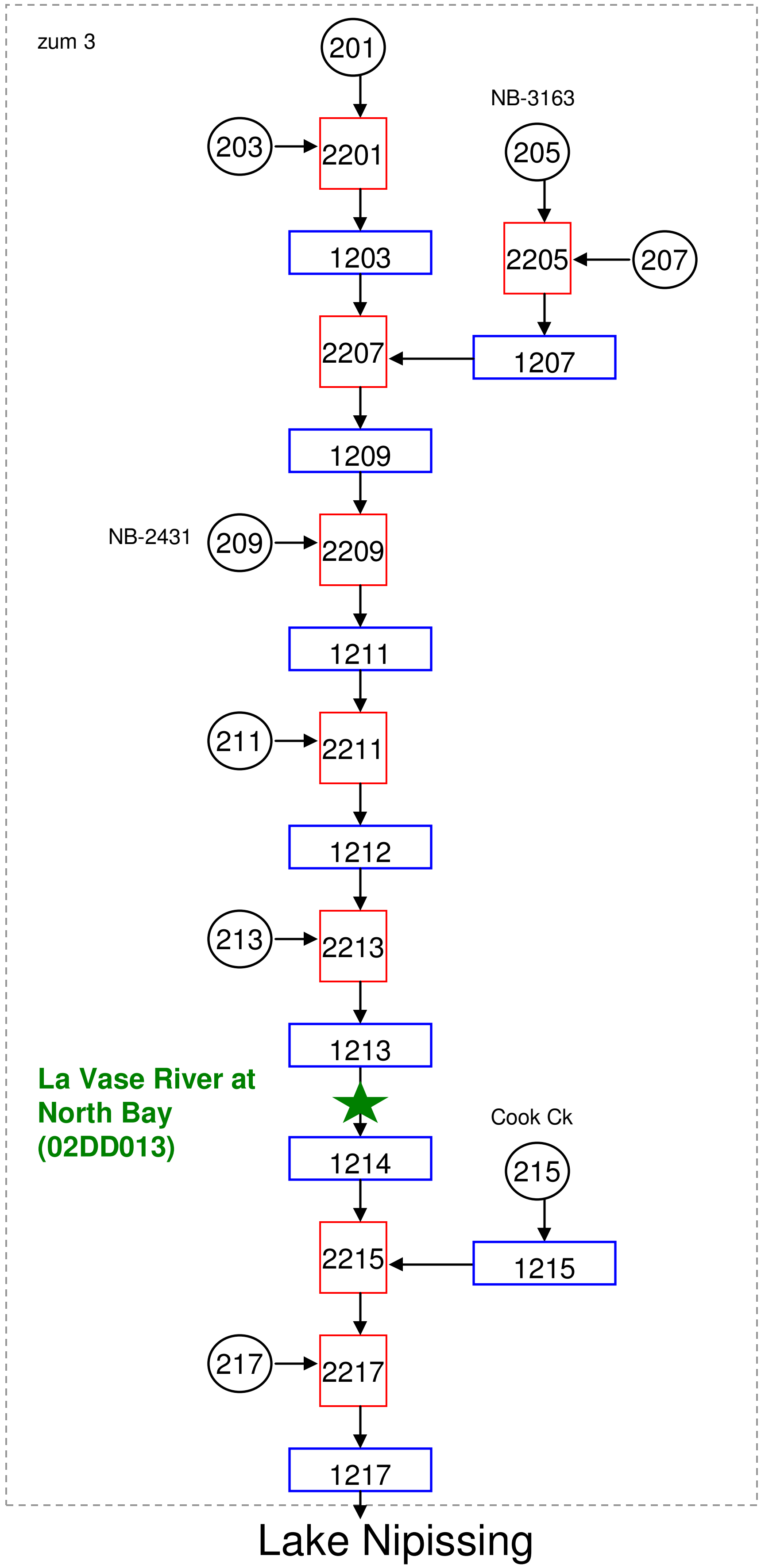
Routing Reach: 1000s

Junctions: 2000s

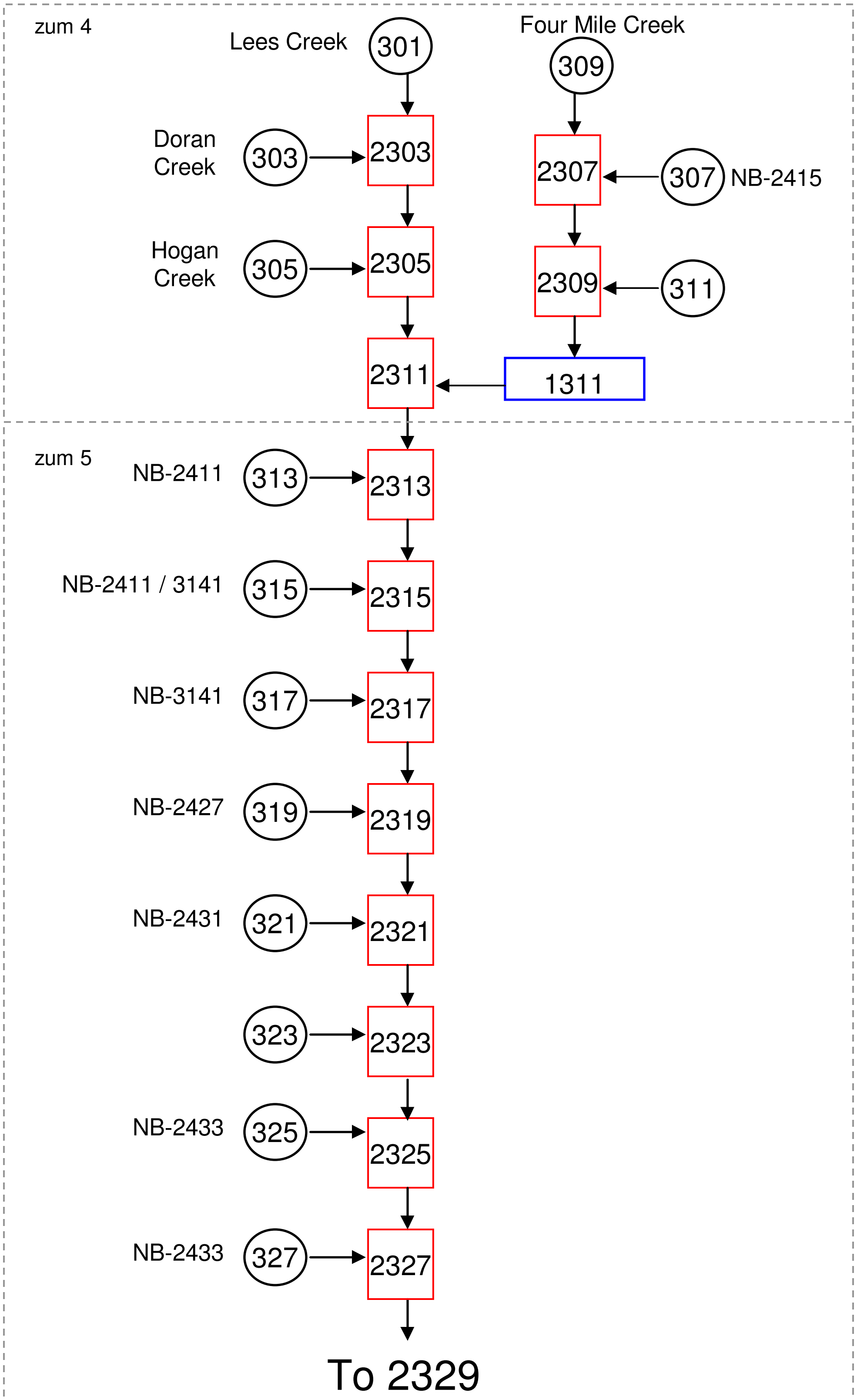
Chippewa Creek Subwatershed



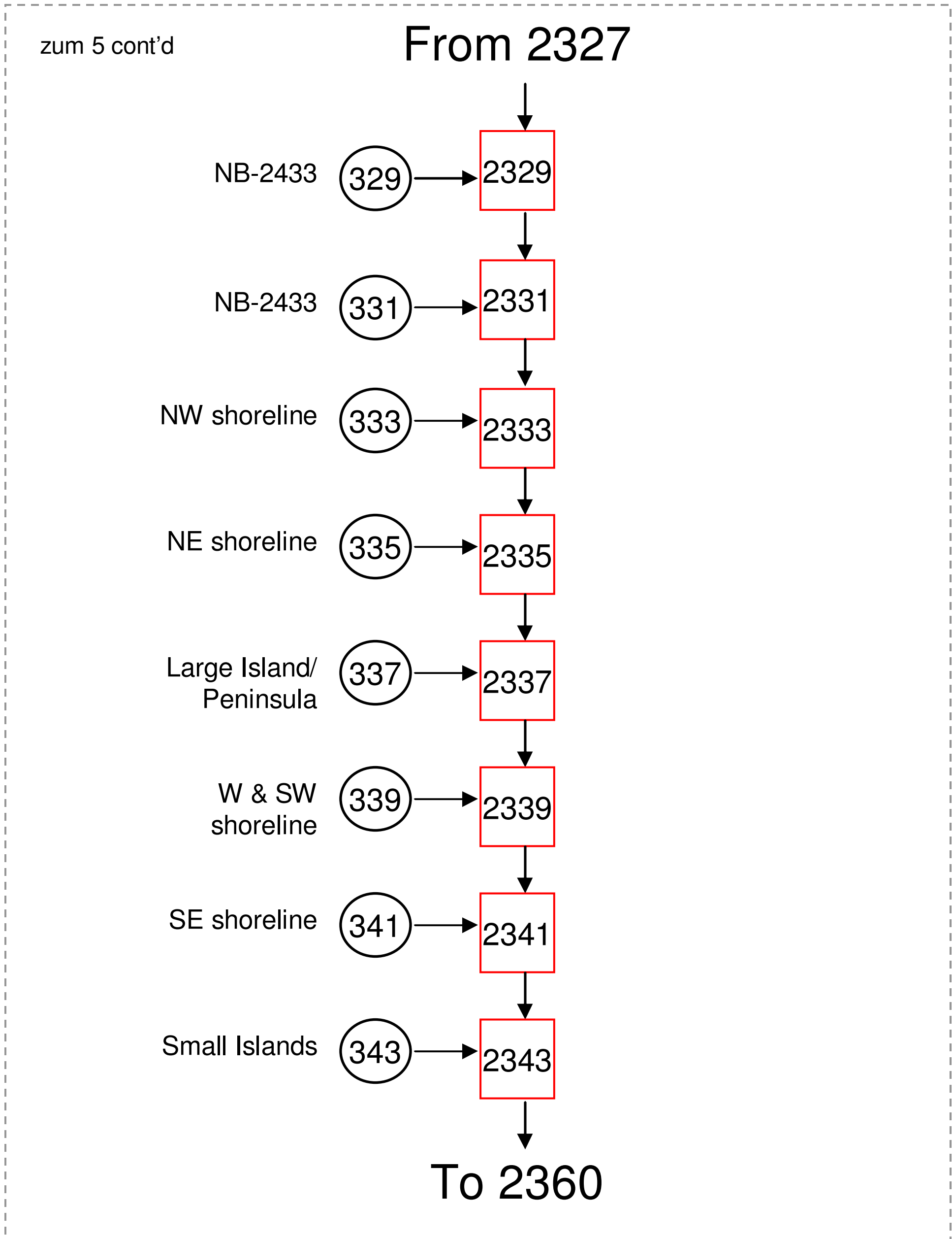
La Vase River Subwatershed



Trout/Turtle Lake Subwatershed



Trout/Turtle Lake Subwatershed



Trout/Turtle Lake Subwatershed