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Trent Severn Waterway

Water Management Study

Data Collection and Management Guide

Parks Canada Parcs Canada

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Parks Canada

Trent Severn Waterway: Water Management Study
Data Collection and Management Guide

Prepared by:

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Project Number:

60150039

Date:

April, 2011

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April 29, 2011

Roger Stanley
Director of Operations (Acting) – Trent Severn Waterway
Parks Canada
P.O. Box 567
Peterborough, Ontario, K9J 6Z6

Dear Mr. Stanley:

Project No: 60150039

Regarding: Trent Severn Waterway: Water Management Study
Data Collection and Management Guide

We are pleased to submit ten (10) paper copies of the Data Collection and Management Guide, the first report of the Trent Severn Waterway: Water Management Study.

If you have any questions or request additional information regarding this submittal, please contact the undersigned at (519) 650-8696.

Sincerely,
AECOM Canada Ltd.

Jeff Prince, P.Eng.
Senior Project Manager, Water
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JP:jp

Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	JP, GAW, MW, DCA	23-Dec-2010	Draft Report
2	JP,GAW, DCA	29-Apr-2011	Final Report

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1. Introduction and Background

1.1 Study Objectives and Rationale

A common theme that resonates throughout most, if not all water management programs is the desire to contribute to and enhance the environmental, social and economic well being of the watershed through sustainable management of the water resource. Through achieving this, the benefits of the resource can be fully enjoyed by present and future generations.

It is to that end, that the objectives of the Trent Severn Waterway - Water Management Improvement Program were developed. The specific objectives include the following:

1. To understand the variables that are critical to effective water management decision making;
2. To ensure that the Agency and its water management partners have access in an accurate and timely way to the appropriate data that allows these variables to be used in making decisions;
3. To describe the current approach to water management in the form of a “Water Management Manual” that describes in considerable detail how water is managed now;
4. To validate and/or suggest improvements in how water is currently managed such that broad water management goals described above are best achieved;
5. To construct a numerical predictive tool that allows the basic operational model(s) to be readily adjusted in response to changes in critical variables; and,
6. To construct a numerical management tool, linked to real time gauging and data collection systems that allows the water manager to:
    a) Understand the current state of water levels and flows throughout the system;
    b) Predict the quantifiable impact of specific water management decisions;
    c) Document when and why specific water management decisions are taken; and,
    d) Provide agencies and individuals with internet-accessible, real time information that contributes to their operations and enjoyment of the Trent Severn Waterway and its associated reservoir lakes.

The Trent Severn Waterway: Water Management Study addresses the first four of these program objectives.

The competition for the water of the Trent Severn Waterway has always been a condition of the system’s operation. However, in recent decades, the stakeholders and variables at play as part of that competition have increased and subsequently so to have the demands and complexities of the operating environment. The following examples highlight some of the operational considerations within the Waterway:

- The Haliburton Lakes have become one of the most significant cottage regions in the province; and more recently there has been a shift toward year round residency on these lakes;
- Shoreline properties have increased in value, and with that the demands to maintain the levels of the reservoir lakes have increased;
- Cities and Towns have developed along the shorelines and have infrastructure demands to draw water from the system;
- The shores are home to thousands of businesses that rely on those that live in and visit the area;
- The societal awareness of and desire to protect the natural environment is increasing;
- There are legitimate concerns about global warming and the potential impacts of climate change; and
- Growing environmental concern has led to an interest in the potential for hydro electric power generation as a source of renewable energy.

These issues have been recently documented by the Panel on the Future of the Trent Severn Waterway in, *It's All About the Water,* and a study of the past, present and future of the waterway completed in 2007 by Ecoplans Limited.

This study is intended to build upon this work toward ensuring that water management personnel have the tools necessary to assist them in making water management decisions. These tools must ensure that management decisions are; timely, information and science based, reflect a thorough understanding of the variables, and achieve an optimal and appropriate balance of the overall water management goals.

This study represents the first phase of what could be a multi-phase endeavour towards achieving the vision and objectives of the overall Water Management Improvement Program.

This study has been organized into four components that directly correspond to the specific objectives of the Water Management Improvement Program:

- **Data Collection and Management Guide**
- **Review of Water Management Systems and Models**
- **Water Management Manual – Description of the Current Approach to Water Management**
- **Evaluation of the Current Approach to Water Management**

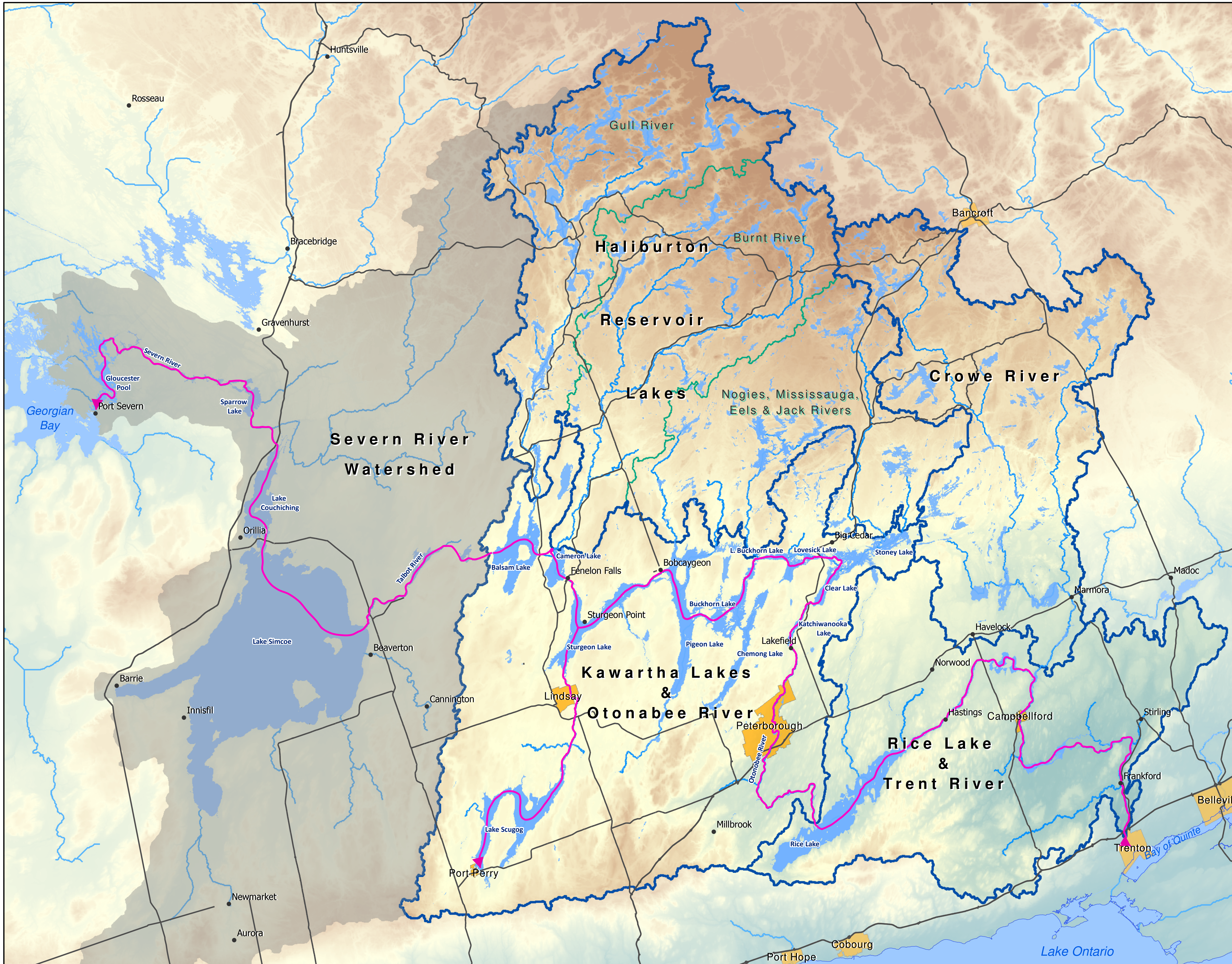
This component of the study, titled the "Data Collection and Management Guide" has been developed to describe the variables that are important to the operation of the Waterway as well as the data associated with or available to describe these variables.

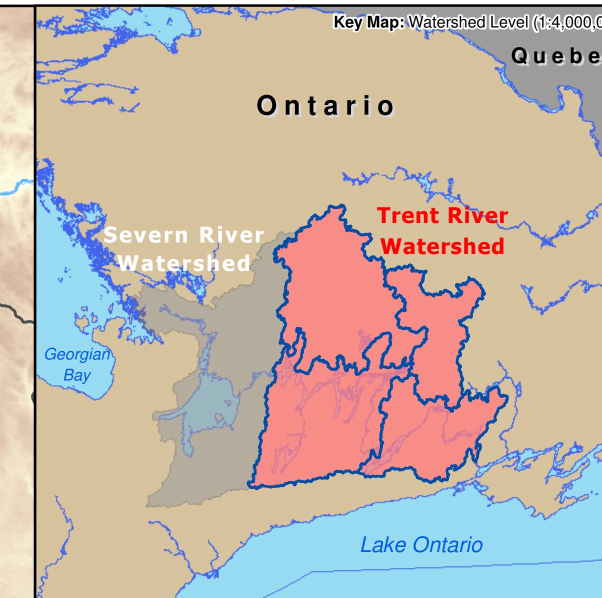
1.2 The Trent Severn Waterway

The Trent Severn Waterway (TSW or Waterway) is a 386km inland navigation route crossing south central Ontario, from Trenton on the Bay of Quinte to Port Severn on Georgian Bay with a total drainage area of 18,690km^2 (**Figure 1-1**). It comprises several navigable lakes and their interconnecting channels as well as many reservoir lakes. There are two watersheds within the Waterway: the Trent River Watershed and the Severn River Watershed. Although this Study concentrates only on the Trent River Watershed, both are characterized below.

The Trent River Watershed is the eastern watershed, with an area of 12,530km^2 draining to Lake Ontario. It lies in the rolling farmlands of southern Ontario. This watershed contains three (3) sub-watersheds:

- **The Haliburton Reservoir Lakes** (3,320km^2) to the north consists of forty-four (44) lakes in the northern shield area that have been dammed to collect Spring runoff. Water from these lakes is released over the summer to supply the Trent component of the Waterway. These lakes are on the tributaries of the Gull, Burnt and Mississauga rivers, as well as Nogies, Eels and Jack creeks.
- The **Kawartha Lakes and the Otonabee River** (4,862km^2) that drain to Rice Lake including: Katchewanooka, Clear, Stony, Lovesick, Lower Buckhorn, Buckhorn, Chemong, Pigeon, Sturgeon, Scugog, Cameron and Balsam Lakes. These lakes are south of the Canadian Shield in rolling countryside, where rainfall runoff is usually slow and evaporation losses in the summer are high.
- **Rice Lake and the Trent River** (4,348km^2) that drain to the Bay of Quinte (Lake Ontario), including the **Crowe River** (1,894km^2) sub-watershed that drains to the Trent River at a confluence downstream of Rice Lake.





Trent-Severn Waterway: Water Management Study

Figure 1-1
General Location Plan - TSW

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The Severn River Watershed lies immediately to the west of the Trent Basin and drains to Georgian Bay. This 6,160km^2 drainage area has three (3) sub-watersheds:

- The **Lake Simcoe and Lake Couchiching** sub-watershed, including the Talbot River. Most of the drainage area for this sub-watershed is in rolling farmland with deeper soils. As a result, water runoff is slow and evaporation losses from both land and lake surfaces are high. Only about 25% of the precipitation falling on this watershed eventually appears as runoff flows.
- The **Black River** sub-watershed feeds into the Severn River downstream of Lake Couchiching. This sub-watershed is characterized by the thin soils and rock of the Precambrian Shield. It is virtually unregulated and produces rapid runoff from precipitation while evaporation losses are lower. Consequently, even though the Black River sub-watershed is less than half of the area of the Simcoe-Couchiching basin, its long-term average flow is comparable. The Black River also has high peak flows during the spring period.
- The **Severn River** below Washago, including Sparrow Lake, Six Mile Lake Tea Lake, and Gloucester Pool. The natural watercourses of the Black and the Severn Rivers are constrained by numerous narrow reaches and constrictions, which are prone to increased water levels in the river and upstream flooding during high flows.

The area influenced by management of the TSW includes more than 120,000 properties as identified in a recent study (Ecoplans 2007):

- Approximately 35,000 shoreline properties in the reservoir lakes;
- More than 400 commercial operations;
- Six Conservation Authorities; and
- Several tiers of government, including: 6 First Nations; 2 regional municipalities; 3 municipalities; 1 district municipality; 5 counties; 5 cities; 4 towns; and, 26 townships.

1.3 Goals and Objectives of the Trent Severn Waterway

Construction of the Trent Severn Waterway began in the late 18th century with the building of small dams and water powered mills at numerous locations throughout south-central Ontario. In the early 19th century, dams and timber slides were added to support a growing logging industry by facilitating transportation of logs from the interior of Upper Canada to the United States and Great Britain.

Key early goals for management of the Waterway were to provide navigation and to protect public safety and property. By the mid-19th century, architects of the Waterway realized that a reservoir system was required to feed water to the system in order to maintain navigation through the summer months. A series of dams in the northern part of the TSW were transferred from the Province to the Federal government in 1905 and 1906. This transfer formally recognized the need for a reservoir system and provided the means to manage and control flow from a number of water bodies that collectively could be used as a reservoir lake system. The Orders-in-Council that transferred these works explicitly acknowledged that the transfers were to benefit operation of the TSW. The Orders-in-Council also designated the water in the listed lakes and rivers as reservoirs for the Waterway.

When the reservoir lakes were conceived, there was very little permanent settlement in the Haliburton region. Since the 1930s, the Haliburton lakes have grown to become one of the most important cottage areas in Ontario. Furthermore, a recent shift from seasonal to permanent, year-round residency in the Haliburton lakes region is occurring. Associated changes in the operating environment of the Waterway include increasing trends in uses other than through navigation, economic development and commercial operations along the Waterway, as well as increasing value placed on natural ecosystems and habitats. Finally, meteorological changes have also been observed (as discussed in the "**Evaluation of the Current Approach to Water Management**"), including: increased number of heavy rainfall events of shorter duration, increasing annual precipitation in some regions and decreasing

annual precipitation in others, regional warming in some areas resulting in increased water temperatures, life cycle impacts to aquatic and wetland species and habitat changes.

These changes in the operating environment of the Trent Severn Waterway are reflected in a recent study (Ecoplans, 2007) which indicates that the present-day array of expectations and obligations are unprecedented in the history of the Waterway operations. Six Water Management Goals and associated Objectives were developed in this study to capture these expectations and enhance operations. These goals and objectives are listed in **Table 1-1**.

Table 1-1 - Water Management Goals and Objectives of the Trent Severn Waterway

Water Management Goals	Objectives
Reducing threats to public safety and negative impacts to public and private infrastructure from over-bank flooding, ice damage, extreme water level fluctuations, and high volume flows	• Mitigate Flooding • Protect Infrastructure • Provide for Public Safety
Contributing to the health of Canadians through the availability of drinking water for residents, cities and towns throughout the watershed	• Manage for Water Supply (agricultural and municipal) • Manage for Water Quality (human health and aquatic life)
Providing safe boating and navigation along the marked navigation channels of the Trent Severn Waterway	• Provide Navigation
Protecting significant aquatic habitats and species	• Protect Natural Environment (wetlands, fish, wildlife, invasive species, species at risk)
Optimizing the enjoyment of the water throughout the watershed by shoreline residents and visitors	• Enhance Aesthetics • Optimize Recreation • Optimize Cultural Resources • Provide Public Access (physical access, access to information)
Allowing hydroelectric generation plants to operate at plant capacity and meet demand for renewable energy insofar as possible	• Optimize Water Power Generation

1.4 Introduction to the Water Management Process

The management of the Trent Severn Waterway to achieve these goals and objectives requires consideration of a variety of different factors, including the Waterway's mandated requirements, scientific objectives, regulatory impacts, environmental impacts, political and public concerns, as well as the day-to-day and long-term operation of the Waterway. A Water Management Process was developed through this study as a way to address this complexity and to consider the interests of the many different stakeholders. The Water Management Process is displayed in **Figure 1-2**, and describes the steps required to implement decisions with respect to the operation of the Waterway.

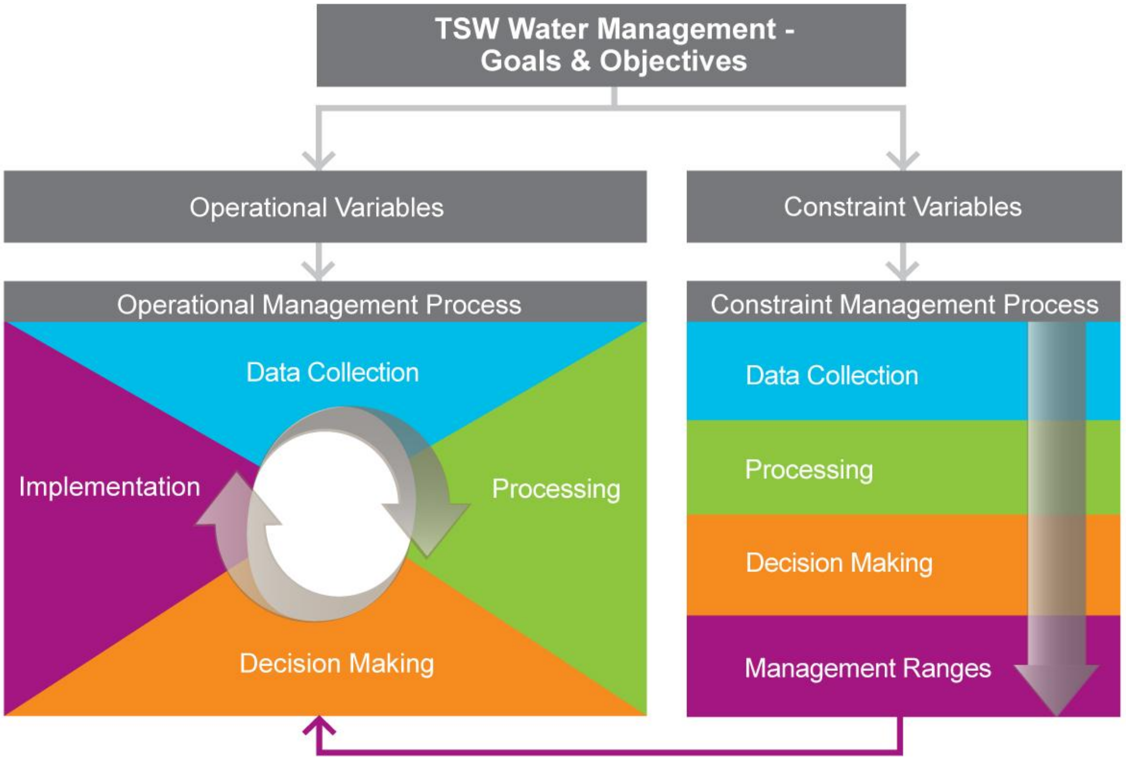

Figure 1-2 - Water Management Process for the Trent Severn Waterway

The Operational Management Process shown on the left side of **Figure 1-2** describes the core activities of Parks Canada staff in the operations of the TSW. These activities are implemented on a continual basis and consist of the day-to-day operations of the locks, dams and other water control structures to manage the flows and water levels in the Waterway through regular monitoring, the balancing of water between the different components of the Waterway (i.e., the Haliburton Reservoir Lakes and the Kawartha Lakes/Trent River), and the communications with staff to implement management decisions.

The Constraint Management Process shown on the right side of **Figure 1-2** describes the activities undertaken to establish the constraints, or "Management Ranges", that define the range of water levels and flows on all lakes with the aim of satisfying the goals and objectives of the Waterway in a comprehensive and balanced manner. This process includes the evaluation of a diverse array of variables that impact the goals and management of the Waterway. The frequency that the Constraint Management Process is undertaken depends on the data being evaluated; for example, the review of historic flood events and levels need only be completed once to establish the historical record, and then updated only when new events occur.

In both the Operational and Constraint Management Processes, there are three primary activities:

- **Data Collection**. The gathering of information that is applicable to either the operations (i.e., **operational variables**) or management ranges (i.e., **constraint variables**) of the Waterway.
- **Processing**. The use of processing and optimization tools to interpret the collected data and produce results appropriate for effecting operational or management/constraint changes.
- **Decision Making**. The evaluation of processing results to make operational decisions or to establish new management ranges throughout the Waterway.

These activities result in an **Implementation** decision with respect to the operation of the Waterway (i.e., increase or decrease water levels or flows at certain locations), or the establishment of a **Management Range** to consider in the processing of operational data (i.e., minimum water levels or flows for navigation in summer or fish spawning in fall).

Through the continual application of this management process, the Waterway can be effectively managed to achieve the goals and objectives of the TSW, giving due consideration to the wide range of stakeholders and users that make the Waterway the dynamic entity it is today.

1.5 Document Map

The Water Management Process introduced in **Section 1.4** provides a context upon which each of the four reports in the Water Management Study is presented. **Figure 1-3** overlays a Document Map on the management process (**Figure 1-2**), highlighting the different components of the Waterway Management Process that are described in this component of the study.

The **Data Collection and Management Report** identifies and ranks relevant water management variables, according to three criteria: essential to effective water management decision-making in light of the water management goals; desirable and will contribute to overall effectiveness of the Parks Canada program; and useful in responding to issues, questions and concerns that might arise from time to time.

The data associated with each variable are also described in the context of the management goals and objectives of the TSW, as well as in the context of the water management process described in **Section 1.4** (i.e., operational variables and constraint variables). The report then suggests a protocol for storing, managing and updating the data for effective operations and management, and provides metadata information about each data set to facilitate use and access.

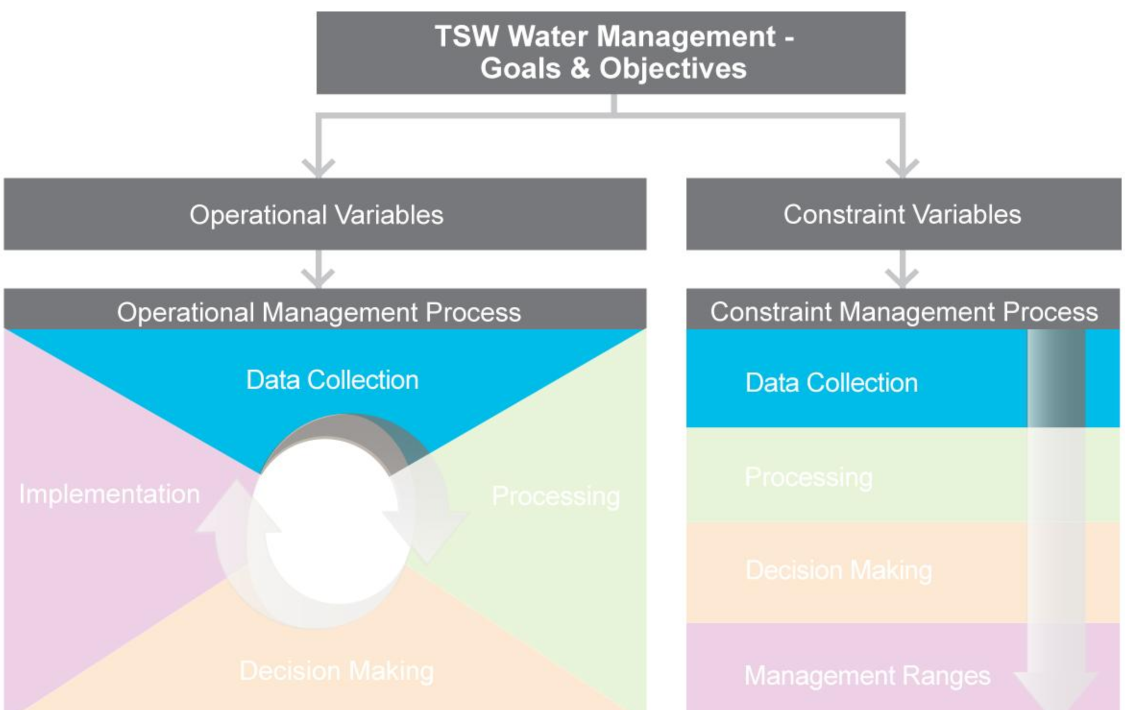

Figure 1-3 - Trent Severn Waterway: Water Management Study - Document Map

2. Selection of the Important Water Management Variables

2.1 Overview

The management of the Trent Severn Waterway is an extensive undertaking requiring consideration of the Waterway's mandated requirements while maintaining sensitivity to regulatory, political and public concerns. In the context of the Water Management Process outlined in **Section 1.4**, important water management variables have been identified through a multi-phase process, including:

- Review of Existing Information (**Section 2.2.1**);
- Stakeholder Survey (**Section 2.2.2**); and
- Study Team Workshop (**Section 2.2.3**).

The important variables are further described in the context of the management goals that they support (see **Section 4**), as well as the nature of their use, either for the day-to-day operations of the Waterway (i.e., operational variables) or to establish the management ranges for the operations (i.e., constraint variables).

One of the most important considerations when developing the variables for operations are the Water Management Goals of the Waterway, as mentioned previously in **Section 1.3**.

2.1.1 Reducing Threats to Public Safety and Infrastructure

The primary management goal of the Trent Severn Waterway is to provide for public safety (confirmed by substantial support in the stakeholder survey). This objective underscores all management decisions, and constrains each of the other management goals. For example, the provision of navigation throughout the Waterway, or the optimizing of the Waterway enjoyment by users, will never be provided at the expense of public safety. In addition, the protection of public and private infrastructure from damage associated with Waterway operations is a key component of this goal.

Threats to public safety and infrastructure along the Waterway can arise from events such as over-bank flooding, ice damage, extreme water level fluctuations and high volume flows. The operation of the Waterway aims to mitigate these threats through management of the dams and other water control structures in the system.

2.1.2 Contributing to Health of Canadians

Parks Canada aims to maintain water conditions that promote safe and healthy human use and consumption, recognizing that its water management decisions may influence human health within the TSW watershed under certain circumstances. The variables developed under this goal to support Parks Canada help to maintain drinking water quality and supply.

2.1.3 Safe Boating and Navigation

Providing for safe boating and navigation is the original objective of the Trent Severn Waterway from its construction as a vital link between Lake Ontario and Georgian Bay. Although the importance of the TSW for commercial and industrial transport has declined since the construction of the much larger Welland Canal, and since transport vessels have grown considerably in size, the TSW has nevertheless enjoyed significant use by private recreational vessels. Much of the economic production of the communities along the TSW depends on the recreational use of the Waterway, which in turn relies upon the maintenance of the Waterway to remain in a navigable state.

The provision of safe boating and navigation for users of the Waterway is also established in legislation as a common law right, and is overseen by the *Navigable Waters Protection Act* (NWPA). Navigation charts used by recreational users (published by the Canadian Hydrographic Service of Environment Canada) contains information on water levels and navigational depths for the channel. These depths must be maintained during the navigation season to ensure safe navigation.

2.1.4 Protect Significant Habitat and Species

The Trent Severn Waterway is home to 35 species at risk, sport fish, and wildlife including birds, mammals, amphibians and reptiles and their habitat. The TSW also supports numerous prime aquatic habitats including a reported 230 wetlands. Managing the Waterway to protect the natural environment and provide habitat to support species and key ecosystem functions represents a value reflected in recent consultation results (Ecoplans, 2007) and results of a stakeholder survey conducted as part of this study. Although not key to providing primary goals of public safety and navigation, future management of water flow and levels in the TSW may consider an explicit goal to protect significant habitat and species.

2.1.5 Optimize Enjoyment of the Waterway

As custodian of what is now largely a multi-use recreation and tourism resource, Parks Canada maintains a water management goal of optimizing enjoyment of the Waterway. Water conditions on the Waterway may affect aesthetics, recreational opportunities, or recreational access. It follows that Parks Canada’s water management decisions may influence recreation and tourism under certain circumstances. To optimize enjoyment of the Waterway, a number of variables need to be taken into account in managing the Waterway from a water resource and navigational perspective, including:

- The locations and extent of key recreational and tourism features adjacent to the Waterway;
- The timing and requirements of water-dependent tourism and recreational activities;
- The status and intensity of recreational boating during the open-water season; and
- The changing navigational conditions for boaters.

2.1.6 Optimize Hydroelectric Power Generation

The Trent Severn Waterway supports many generation facilities for the production of electricity. Electricity production at each facility ranges from 2 to 18 Megawatts. Hydroelectric power generation at any instant is primarily a product of the flow volume and ‘driving head’ (i.e., elevation difference between upstream and downstream of the facility) at a particular location. Flow volume is typically measured in litres per second or cubic metres per second. Water power generation can be optimized by timing peak flows through the turbines during periods of peak demand for electricity.

2.2 Approach to Selection and Ranking of Variables

2.2.1 Review of Existing Information

The 2007 Ecoplans study describes various aspects of the TSW. Individual components of the study are listed below and emphasize the following:

- **Water Management Program**: the purpose of this component provides an account of how Parks Canada manages water flows and levels on the TSW, and describes some of the challenges it faces when trying to maintain safe conditions across the Waterway while trying to meet the expressed needs of various stakeholders along the TSW.
- **Obligations and Expectations**: this component provides a review of expectations and obligations associated with managing the Waterway. These obligations are driven by legislation; formal, legally binding agreements; or corporate policy. This chapter assessed legislative instruments, policy obligations, lease agreements, bi-lateral or multi-lateral agreements, and unofficial agreements all of which related to water management in the TSW.
- **Legislative Review**: this component describes the evolution of ownership and jurisdiction of the TSW. In addition the legislative review summarizes Federal policy that guides the management of the Waterway, relevant Provincial legislation and policy that influence private and municipal use of the Waterway, legislative and regulatory authorities central to the management of the Waterway. This information could be considered in any future management model.
- **Other Water Management Organizations**: this component documents how other jurisdictions within North America manage their systems where water management conditions are similar. The chapter specifically examines the governance structures of other water management agencies. Six water agencies were studied: 4 from Ontario and 2 from the United States.
- **Stakeholder Consultation**: this component presents the range of stakeholder interests. In total 10 stakeholder groups were identified including: Federal and Provincial Governments, First Nations, Municipalities, Conservation Authorities, Commercial Operations, Water Power Operators, Recreational and Property Owners, and Environmental Non-Governmental Organizations.

The findings from the Ecoplans study help to confirm the goals and objectives for the TSW and to guide our workshop discussions on variable identification, selection and ranking (**Section 2.2.3**). This review provides a base upon which to develop the operational and constraint variables that are important to the management of the Waterway.

2.2.2 Stakeholder Survey

AECOM conducted an on-line survey of stakeholder attitudes and perceptions as a second component of variable selection. Stakeholders consisted of members of the TSW Water Management Advisory Committee (WMAC). The survey was designed and delivered using the SurveyMonkey.com website and software. Survey participants were asked to provide comment on the water management objectives developed during preliminary team discussions. The objectives represent broad categories of variables, which are aligned with Parks Canada's goals for management of the TSW. The objective level was considered by the team and Parks Canada to be the most appropriate level to seek stakeholder input, since it required a less detailed technical understanding while allowing input on how Parks Canada's high-level water management goals should be operationalized.

Survey participants were asked to answer a five-point Likert scale question (strongly agree to strongly disagree) to rate the importance of 12 objectives of water management, in each of three areas of the TSW - the Reservoir Lakes, Trent River basin, and Severn River basin. The survey was completed by all twelve (12) representatives of the WMAC who were members at the time the survey was conducted (May 3-14, 2010). There have been some additions to the membership of the committee since that time.

The survey also included a number of questions about Parks Canada's current water management approach in the TSW, and suggestions for water management going forward. Responses to these questions were presented at the study team workshop on May 26, 2010, and have been included in AECOM's analysis in the **Water Management Manual** and the **Evaluation of the Current Approach to Water Management**.

2.2.2.1 Summary of Survey Results

Likert scale results from the survey reflecting the degree of stakeholder support for the 12 water management objectives in different parts of the TSW watershed were compiled into binary categories of “agree/strongly agree” and “neutral/disagree/strongly disagree”. The degree of stakeholder support for the application of each objective in each watershed area was then determined using the criteria shown in **Table 2-1** below.

Table 2-1 - Criteria for the determination of stakeholder support for water management objectives, as part of variable screening and ranking.

Category	Criterion	Rationale
Strong Support	<2 respondents disagree/strongly disagree or <4 respondents neutral.	If between 9 and 12 WMAC members agree or strongly agree with the importance of the objective for a given area, with no more than one member who disagrees/strongly disagrees, there is strong support for the application of the objective in that part of the TSW watershed.
Substantial Support	<4 respondents are neutral or disagree/ strongly disagree, with more than one respondent indicating disagreement/strong disagreement.	If most (9 or 10) WMAC members agree or strongly agree with the importance of the objective for a given area, but two or more disagree/strongly disagree, there is substantial support for its application in that area of the TSW watershed.
Mixed	<9 respondents agree/strongly agree.	If fewer than 9 respondents agree or strongly agree with the importance of the objective for a given area of the TSW watershed, there is mixed support for its application in that area.

Note that a “poor support” category was not developed as survey results did not warrant it.

Table 2-2 shows a summary of Likert scale results from the survey. Results indicate that there is strong stakeholder support for the application of most objectives across the TSW. Exceptions to this strong support are discussed in **Table 2-3**.

Table 2-2 - Degree of stakeholder (WMAC) support for water management objectives in three areas of the TSW

Legend: ● Strong Support ■ Substantial Support ▲ Mixed Support

Water Management Objective	Reservoir Lakes	Trent River/Kawartha Lakes	Severn River Basin
Flood Mitigation	Strong Support	Strong Support	Strong Support
Infrastructure Protection	Strong Support	Strong Support	Strong Support
Public Safety	Strong Support	Strong Support	Strong Support
Water Supply	Strong Support	Strong Support	Strong Support
Water Quality	Strong Support	Strong Support	Strong Support
Navigation	Substantial Support	Strong Support	Strong Support
Natural Environment	Strong Support	Strong Support	Strong Support
Aesthetics	Mixed Support	Mixed Support	Mixed Support
Recreation	Mixed Support	Substantial Support	Substantial Support
Cultural Resources	Mixed Support	Strong Support	Strong Support
Public Access	Strong Support	Strong Support	Strong Support
Water Power Optimization	Substantial Support	Strong Support	Strong Support

Table 2-3 - Discussion of select survey results and related stakeholder comments

Survey Result	Synthesis of Related Stakeholder Comments
Mixed support for managing the watershed on the basis of aesthetics.	Other objectives are more important when balancing water management decisions. Aesthetic objectives might be achieved by managing for natural environment and water quality objectives.
Mixed support for managing the Reservoir Lakes area for recreational or cultural resource values.	While safe boating conditions (including marking of hazards) are considered important in all areas of the TSW watershed, recreational values are of lower importance than other objectives such as human health and safety or aquatic health, when making balanced water management decisions.
Substantial (but not strong) support for the management of the Reservoir Lakes for navigation or water power optimization.	While safe boating conditions (including marking of hazards) are considered important in all areas of the TSW watershed, navigation for local recreational boating purposes is considered a lower priority than other objectives when making balanced water management decisions for the TSW. The Reservoir Lakes have a critical function for water control in the rest of the TSW, and waterpower development should only be supported where it will have minimal impact on this function.
Substantial (but not strong) support for the management of the Trent River and Severn River basins for recreational values.	Recreational values are of lower importance than other objectives such as human health and safety or aquatic health, when making balanced water management decisions.

2.2.2.2 Application of Survey Results in Variable Selection

AECOM used the WMAC survey responses on water management objectives as part of developing a final ranked list of variables. This was done in combination with considerations of study team expert opinion, Parks Canada's mandated responsibilities and legislative and regulatory requirements. While these considerations were balanced on a case-by-case basis in developing the variable list, the survey results contributed positively to the process in the following ways:

- A small number of variables were developed or refined based on WMAC survey input.
- A small number of variables were screened out or altered on the basis of WMAC survey input.
- The degree and nature of WMAC support for water management objectives influenced variable rankings (Essential, Desirable, Useful).

2.2.3 Study Team Workshop

A workshop was held to identify variables and data supporting the stated goals and objectives, and relevant to managing the Trent Severn Waterway. Groups representing experience in public consultation and socioeconomic matters, water resources engineering and management, and ecological resources and habitat function attended the meeting. During the workshop the team reviewed the results of the *Consultation Report* (Ecoplans, 2007) which identified the following issues and concerns:

- Ecology – including fish spawning, wetland and wildlife habitat, species at risk, nesting areas, general ecosystem condition;
- Access – including shoreline access, navigation, water supply;

- Public Safety – including condition of locks, dams, wharfs, lock closures, navigation hazards, safe boating in general;
- Green Energy (Water Power) – including flooding and flood control
- Water and Sediment Quality – including agricultural practices, potable water supply, beach closures, sewage disposal;
- Economic Impact – including tourism, infrastructure and equipment costs; and
- Operational Issues – including communications (public notice), permit systems, monitoring and data access.

Water management goals and water management variables interact in complex ways. A review revealed that further organization and classification of variables is helpful to understand their role in the management of the TSW. For example, although each of the variables developed for this study may vary in time and space, they carry different meaning and relevance for Waterway management depending on the goals and objectives being considered. The workshop included the assessment of the relevant goals and objectives for each variable, as established in **Section 1.3**.

During the workshop it was confirmed that the six goals and 12 objectives associated with TSW management (shown in **Table 1-1**) reflected the issues listed in the *Consultation Report* (Ecoplans, 2007). A list of 41 variables was produced that could provide information to manage the Waterway in accordance with the broader set of goals and objectives developed in this project (**Table 2-4**).

An additional product of the workshop and subsequent study team discussion was the ranking of the final list of variables according to categories – Essential (E), Desirable (D) or Useful (U). Variables were assigned to one of the three categories based on experience of workshop participants and by results of the stakeholder survey described in **Section 2.2.2.1** above. The variables were classified as 'Operational Management Variables' or Constraint Management Variables' as defined in **Section 1.4**. These categories assist in understanding how variables listed here are used in the existing management of the Waterway as described in the **Water Management Manual – Description of the Current Approach to Water Management** and potential management as described in the **Evaluation of the Current Approach to Water Management**.

In summary, **Table 2-4** shows the final list of 41 variables that relate to each of the overall study goals and objectives. The table also shows how each variable is ranked in terms of 'Essential', 'Desirable, and 'Useful' categories, and how each variables serves in the 'operational' or 'constraint' management and decision-making process in the overall management of the Trent Severn Waterway.

TABLE 2.4 - MANAGEMENT VARIABLES FOR THE TRENT-SEVERN WATERWAY

NO.	WATER MANAGEMENT VARIABLES	RANKING	WATER MANAGEMENT GOALS AND OBJECTIVES: Reducing threats to public safety and negative impacts to public and private infrastructure from over-bank flooding, ice damage, extreme water level fluctuations			Contributing to the health of Canadians through the availability of drinking water for residents, cities and towns throughout the watershed		Providing for safe boating and navigation along the marked navigation channels of the TSW	Protecting significant aquatic habitats and species	Optimizing the enjoyment of the water throughout the watershed by shoreline residents and visitors				Allowing hydroelectric generation plants to operate at plant capacity and meet demand for renewable energy insofar as is possible
			Flood Mitigation	Infrastructure Protection	Public Safety	Water Supply i) Agricultural ii) Municipal	Water Quality i) Human Health ii) Aquatic life	Navigation	Natural Environment i) Wetlands ii) Fish iii) Wildlife iv) Invasive Species v) Species at Risk	Aesthetics	Recreation	Cultural Resources	Public Access i) physical access ii) Access to information	Water Power Optimization
OPERATIONAL VARIABLES														
O1	Flow (including velocity)	Essential	■		■	■	■	■	■	■				■
O2	Water surface elevations (lake levels)	Essential	■	■	■	■	■	■	■	■	■		■	■
O3	Hydrotechnical model outputs	Essential	■					■	■					■
O4	Operational condition of locks and dams	Essential		■				■						
O5	Staff resources	Essential						■			■			
O6	Current meteorological data (including snowpack)	Essential	■											
O7	Ice conditions (winter)	Essential			■									
O8	Frazil ice - locations and conditions for formation	Essential	■											
O9	Navigation markers (locations and operational limits)	Essential						■			■			
CONSTRAINT VARIABLES														
C1	Storage and discharge capacity for reservoir lakes	Essential	■			■			■	■	■		■	
C2	Historical climate data (precipitation, temperature, snowpack, flows)	Useful	■											■
C3	Navigable channel depth - desirable lake and watercourse elevations for navigation	Essential			■			■						
C4	Maximum flows and velocities for navigation	Essential			■			■						
C5	Navigation/boat use trends	Desirable						■			■			
C6	Regulated floodplain area	Essential	■	■	■									
C7	Historic flood events/levels	Desirable	■		■									
C8	Land use mapping (residential/commercial/industrial/institutional etc.)	Desirable		■	■					■			■	
C9	Existing built infrastructure, including dams, locks, bridges, roadways and buildings	Desirable		■										
C10	Water intake elevations (municipal water supply)	Essential				■								
C11	Minimum flow for water quality (assimilative capacity) - at Water Pollution Control Plants outfalls	Essential					■							
C12	MOE water well data, location of tile drains, septic beds, etc.	Useful				■								
C13	Water quality parameters (dissolved oxygen, turbidity, etc.)	Useful					■							
C14	Permit To Take Water (PTTW) - municipal, irrigation	Desirable				■								
C15	Hydro power generation locations - optimal flow (minimum and maximum flow)	Essential												■
C16	Wetland delineation (including flora and fauna identification/significance)	Desirable							■					
C17	Ministry of Natural Resources (MNR) management zones	Desirable							■					
C18	Known fish spawning areas (Ontario Base Map)	Desirable							■					
C19	Species at Risk Act (SARA) distribution/locations	Desirable							■					
C20	Fish community data	Useful							■					
C21	Distribution of invasive species	Useful							■					
C22	Wildlife and terrestrial corridor locations	Useful							■					
C23	Migratory bird data (nesting, migration routes)	Useful							■					
C24	Ecological Land Classification (ELC)	Useful							■					
C25	Designated Areas: National and Provincial Parks, ANSI, ESA, PSW	Useful							■					
C26	Tourism event timing and location	Useful										■		
C27	Commercial operations - marinas, restaurants etc.	Desirable											■	
C28	Heritage and archaeological sites	Desirable										■		
C29	Parks, campsites, rest-stop, day use, boat launch locations	Useful											■	
C30	Public safety notifications	Useful			■			■						
C31	Beach closures (E.coli)	Useful					■				■			
C32	Recreational water use optimization levels - desirable levels for recreation	Essential									■			

3. Analysis of Available Data

3.1 Overview

In order to accurately monitor and assess conditions within the Waterway, as they relate to the operational and constraint variables, a myriad of supporting datasets must be maintained and evaluated. Variables such as flow can encompass different datasets from different providers. For example, multiple organisations operate, some in conjunction with each other, flow gauges and gauging stations which measure flow within the system. The HYDAT system, operated under a joint cooperative cost sharing agreement between Environment Canada and Ontario Ministry of Natural Resources, provides flow measurements for stations within its network. Park's Canada also operates a network of flow gauges and gauging stations within the Trent Severn Waterway which measures flow within the watersheds that make up the system. The Crowe Valley Conservation Authority may also contribute information to the Flow variable such as water levels and flow at flood control structures. Each dataset contributes information which when amalgamated provide the necessary information to support management decisions and operational business processes.

The goal of this section is to catalogue these information data sources as they relate to each of the identified management variables. This catalogue will provide the framework upon which the management variables can be implemented and evaluated. The data will provide the base information that will support management decisions and operational processes. The catalogue will assist internal TSW support staff in compiling and maintaining an information repository that is concise, current and accurate.

3.2 Data Evaluation Approach

A standardized approach to data evaluation was adopted in order to gather information using an effective and structured methodology. Standards based approaches utilize internationally recognized standards to collect and document specific information about datasets, referred to as metadata. Metadata standards are comprised of multiple elements which are used to describe data. The metadata standard used in this section is a subset of the Content Standard for Digital Geospatial Metadata as defined by the Federal Geographic Data Committee (FGDC). Although this standard has been developed for the National Spatial Data Infrastructure initiative by the United States, it has been adopted by similar data infrastructure initiatives in Canada by both federal and provincial agencies. Data initiatives such as Canadian GeoSpatial Data Infrastructure (CDGI) and Land Information Ontario have all adopted the FGDC standard to document data repositories. Using this standard, each identified dataset was documented to the subset of data elements used. These documents are included in **Appendix A**.

3.2.1 Data Discovery/Data Mining

In order to identify the potential datasets required to support the variables, content and ownership, a graphic hierarchical tree was developed using the FreePlane mind mapping software. Mind mapping software organizes information in a hierarchical format with parent-child nodes and relationships. The Highest levels of organization are the Water Management Goals, as described in **Section 1.3**. The water management objectives under each goal further narrow the scope of organization.

Variables are identified to support the objectives, thus datasets that support the identified variables. Datasets are organized by governmental level and then by provider. **Figure 3-1** shows the data hierarchy for the Flow variable within the flood mitigation objective.

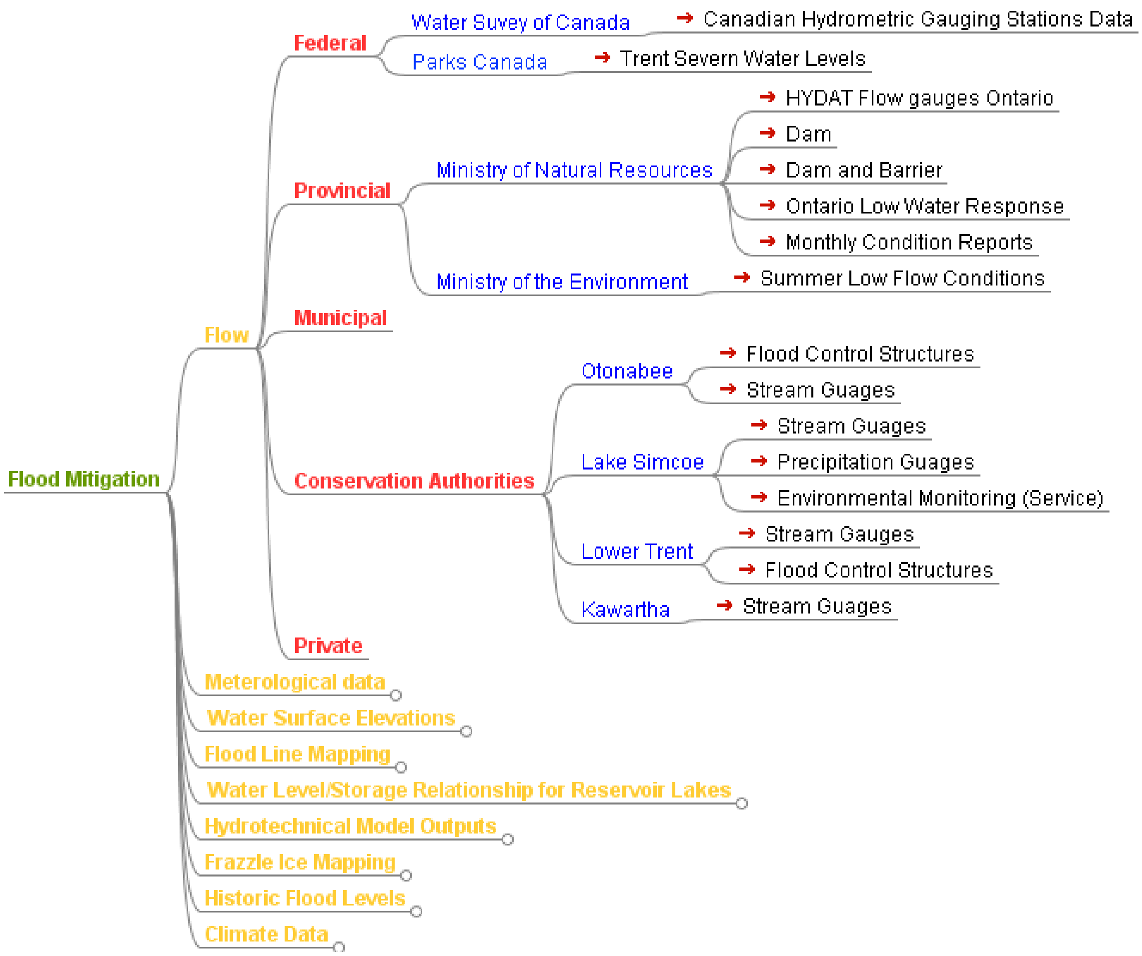

Figure 3-1 - Datasets Associated with Flow Variable

For each of the variables, relevant datasets were identified through searches of data warehouses, data provider websites, and commercially available information. For each dataset identified, metadata documents following the FGDC standard were generated.

3.2.2 Metadata Generation

A modified subset of seven elements of the FDGC standard was used to document the datasets. The elements were chosen to provide TSW staff with the information about the datasets in a concise format, and include all the necessary information to access the relevancy to the management plan.

<u>Description (Abstract)</u>

The description element, also called abstract, is intended to provide a general description of the dataset. For geospatial data, the abstract typically describes the feature class. For more complex datasets such as real time flow data, the abstract includes a more detailed description including background, ownership and history.

Currency

The currency element of the metadata is intended to provide information about how up to date the dataset is. For the most part, the currency is given as the time period over which the data was compiled or collected. Some datasets identify a currency range, however as data collection is ongoing, the potential exists for data within the dataset to have a currency beyond that of the range. It is important to understand that if the dataset is current over a date range, features within the dataset can be current to any date within the range, unless explicitly specified within the feature attribution. Occasionally the currency of a dataset is given as a date on which the dataset was created, in these cases the data is a snapshot of the information at the date of creation. Currency can also be noted in hours, days or months depending on the update frequency of the information, for example HYDAT flow gauges with satellite telemetry, can have a currency of 24 hours as the data is updated and made available on a 24 hour basis.

The currency can also refer to the data collection status: “ongoing” or “in progress”, for example, indicates that this data is still being collected, while “complete” indicates that data collection is finished and no further data will be added to the dataset. Where data is still being collected, the maintenance cycle refers to how often new information is added. Typically, the maintenance cycle will refer to a time period such as monthly, quarterly or yearly, although some datasets list their maintenance cycle as “as needed”. As needed updates are performed if requested or after new and more current information becomes available.

Format

The format element refers to the format of the dataset. Typical formats include databases, documents or geospatial datasets. Additionally, this element can provide information as to the specific formats of the datasets such as in the case of geospatial data, ESRI Shapefile, ESRI ArcInfo Coverage. Other specific formats include Microsoft Access, Excel or Web service.

Connection Mechanisms

This element is intended to provide information regarding how the data can be obtained or connected to the system. For the most part, data is obtained through acquisition of the actual physical data in either hard copy (Removal media such as CD-ROM/DVD/USB Drive) or digitally (FTP/Email). Connection mechanisms can also refer to online connections such as web services, RSS feeds or web page linkages. On line connections such as Land Information Ontario will require registration by the organization or the data manager prior to gaining access.

Data Quality

The Data Quality element is intended to provide information to the user about the quality of the dataset. Data Quality issues can include positional accuracy, attribute accuracy, scale, and currency. The data quality element is used to document specific quality issues about the dataset that should be taken into account when using the dataset.

Usage Restrictions/Disclaimers

The Usage Restrictions and Disclaimers elements have been combined into one element in the metadata documents. Usage restrictions are restrictions placed on the data which limit what the data can be used for, or who can receive or access the data. Most datasets have no usage restrictions; however, several datasets contain sensitive information that could breach privacy laws, in these cases restrictions are placed on the datasets. In addition to restrictions, caveats may be placed on the datasets to highlight specific limitations or issues with the dataset. A common caveat states that the “datasets are not to be used for legal purposes”.

Disclaimers are issued by the dataset providers typically releasing them from responsibility for the dataset in terms of completeness, accuracy or currency. Disclaimers should be thoroughly understood before using any dataset.

Contact Information

The contact information element documents the owner of the dataset and the contact information of an individual responsible for the dataset. In some cases the individual responsible for the metadata is different from the data custodian or the administrative contact. Some datasets have more than one set of contact information.

3.2.3 Data Management and Maintenance Protocols

There are a number of potential data suppliers for the datasets that will support the management plan. The two major contributors are the Federal and Provincial governments which both provide data through data infrastructure initiatives. Conservation areas and municipalities may also contribute datasets however most of these are available through data exchanges with the Province. The size and complexity of managing these datasets requires a coherent strategy to ensure the datasets are current and accurate. Organisations which typically manage large datasets, utilize a centralized approach with data maintained in one location and one data manager. Databases provide a mechanism to centralize and store datasets in an organized fashion called data models. Data models are a way of organising data within a database such that datasets are grouped and easily accessible. Geospatial data models are particularly efficient at simplifying data management and making data available to users.

The first step to developing a data management strategy is to design a data model to store the datasets. The data model would be specific to TSW needs and requirements and would be developed prior to the creation of the database. The data model would standardize the data entered and how those data relate to other features and tables in the database. Once the data model is designed it can be implemented through a geospatially enabled Enterprise Geodatabase such as ESRI ArcSDE or Oracle Spatial. Spatially enabled databases are designed to store not only the information contained within the dataset but also the spatial information pertaining to the feature location. Once the spatial database is implemented, data can be uploaded and stored. This initial upload of data would occur only once with the data updated based on a data maintenance plan.

To guarantee data integrity, databases can offer several checks prior to the upload of newly created or edited data. The first check occurs as the user enters data. The data being entered must adhere to the standards set within the data model; if the data do not adhere to these standards then the user will be notified of an error and must correct the error before the data entry reaches the next step. When the data meet all of the defined criteria the process advances to the second check. The data manager is notified that there have been changes to data in the database, the manager can check and approve the changes or notify the user that the data have not been approved and further refinement is required. If accepted by the manager the data are uploaded to the working database. There will be two replicated databases in the structure. One will be the production database and the other the working database. All edits are loaded and stored in the working database until the production database is updated. Users, both internally and externally will only have access to the production database which contains the up to date and verified data.

To further guarantee quality, geodatabases can be versioned, meaning that whenever data are created or edited those changes are logged within a separate table in the database. With these tables it is possible to restore the database to previous versions prior to any editing session of choice. Versioning could be considered a third check and is an important step in the maintenance of the database.

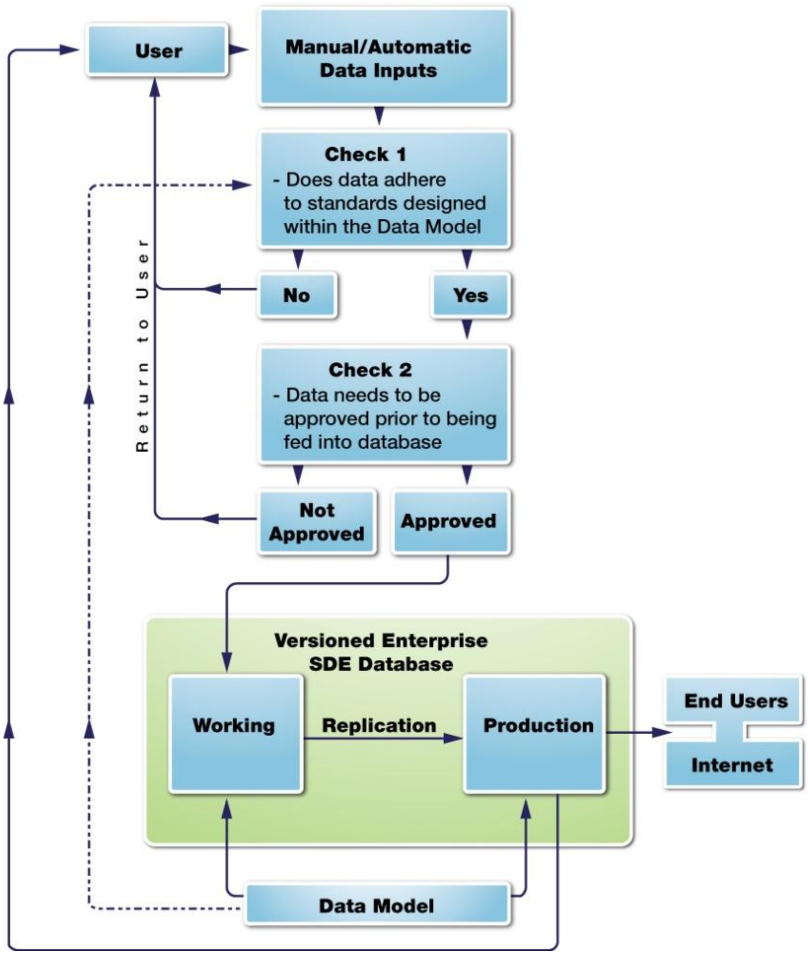

Figure 3-2 - Data Management Protocol

3.2.3.1 Data Maintenance Plan

With the database populated, a maintenance plan is developed to ensure the currency and accuracy of the data. The maintenance plan is dictated by the currency, maintenance cycle and status of the dataset. Datasets that have a status metadata element of “complete” will not be updated and therefore do not have to be updated after initial load. Ongoing collection or in progress status indicates new data is being added or updated, meaning the data would need to be updated to reflect the new information.

A majority of geospatial datasets listed in **Appendix A** include metadata outlining a suggested maintenance schedule; individual schedules should be noted as “information is acquired”. Data available through most government organizations, such as Land Information Ontario (LIO), allow for automatic updates at regular intervals. A request to receive updates can be made annually, semi-annually, monthly, weekly or as features change. If possible, vital data sets such as monitoring information, including HYDAT, Water Gauging Stations and Climate data could be updated weekly to better predict changing situations throughout the Waterway. For non-vital data sets without automatic update capabilities a quarterly maintenance and updated schedule should be created. Maintenance schedules can be altered as needs change throughout the seasons and as improved information becomes available.

4. Water Management Variable Descriptions

This section includes detailed descriptions for the Water Management Variables developed in **Section 2**, as well as references to applicable datasets discovered in **Section 3**. The complete metadata for all datasets referenced in the "Relevant Datasets" section for each variable is contained in **Appendix A**. The metadata includes a description of the dataset, currency, format, connection mechanisms, data quality, usage restrictions/disclaimers and contact information.

4.1 Operational Variables

The operational variables identified in **Section 2** are concerned with the operation of the locks, dams and other water control structures to manage the flows and water levels in the Waterway. The regular monitoring of these variables is an established operational task for the balancing of water between the different components of the system (i.e., the Reservoir Lakes and the Kawartha Lakes) and incorporates most of the current data collection, processing and decision making efforts.

4.1.1 Flow

Flow is one of the key operational variables for the management of the Trent Severn Waterway and guides many of the decisions during the day-to-day operations. Flow and water level are interrelated; one cannot typically be modified without affecting the other. Most of the operational decisions focus on the water levels at the various dams along the Waterway, since they are easily measured. However, knowledge of how the water levels affect flows downstream of the dams is important when considering each of the six water management goals for the TSW.

Application to Water Management Goals

The protection of public safety infrastructure is one of the primary goals of the TSW. High flows and velocities can increase risk to human safety around the Waterway, and can incur damage to public and private infrastructure.

The flow in the Waterway is important for managing both water supply and water quality. There are many users along the Waterway that rely on the use of the water for agricultural (e.g., irrigation) or municipal (e.g., drinking water) applications, and operation of the Waterway can impact the quantity available for the various applications. A minimum flow is also required for water quality, in order to assimilate wastewater effluent flows and provide habitat for aquatic life.

Characterization of flows is also important for navigation, because the management of flows determines the operational water levels in the navigation channels; flows must be maintained at a level to provide sufficient depth to allow navigation by the target vessels of the Waterway. As well, excessive flow resulting in increased velocity can make it difficult to traverse the Waterway against the current (i.e., upstream), and can make travel with the current (i.e., downstream) dangerous due to the reduced response time for a vessel to adjust course (analogous to speeding on a highway); maximum flows are established for key areas in the Waterway to mitigate these hazards.

Many species are adapted to the general predictability of seasonal variation in water flows. Relatively high flows (i.e., one- to two-year return period) shape channel morphology and help maintain habitat diversity. High seasonal flows also trigger the initiation of reproductive activities for many species of fish. For some species, the onset of reproduction begins with longitudinal migration, e.g., from downstream locales to upstream spawning grounds, or lateral migrations from the main channel to the floodplain where eggs are dispersed and incubated. Most migratory fish species in Ontario waters spawn in the spring; however, some of the stocked Pacific salmonids are migratory and spawn in the fall. Both spring and fall migratory spawners depend on water flow for successful reproduction.

Hydroelectric power generation depends on flowing water entering the turbines. Power production can be optimized by managing the discharge timing and quantity of water for power production. Parks Canada may be limited in the extent that the Waterway can be managed to optimize power production, however consideration of this goal is important nonetheless.

Relevant Datasets

There are several relevant datasets with respect to the flows along the Waterway, including the following:

- **Water Survey of Canada - Canadian Gauging Stations**
- **Parks Canada - Gauging Stations**
- **Provincial Gauging Stations - HYDAT**
- **Flow - Provincial - Dam**

4.1.2 Water Levels

Water surface levels are perhaps the most commonly encountered variable in the operation of the Trent Severn Waterway. Water levels are recorded at multiple locations throughout the Waterway and are controlled through the manipulation of stop logs and other water control structures. Water levels are also used to manage flows since the two are interrelated. The Waterway operators use daily level information as the key indicator for the performance of the Waterway. A description of how the Waterway is currently managed can be found in the **Water Management Manual - Description of the Current Approach to Water Management** report.

Application to Water Management Goals

Water level management in the lakes and rivers of the Waterway serve several purposes, a key one of which is the protection of public safety and infrastructure. High water levels can increase risk to public safety from flooding and damage to infrastructure. Water level information and comparison to historic records as well as operator knowledge of the system facilitate decision regarding the management of the Waterway during periods of high flow.

Operation of the dams can be used to augment water levels during dry periods or to maintain a certain flow for water quality purposes and to provide for municipal and agricultural users.

Water surface levels indicate the navigable depth of the Waterway. Sufficient depth is required to allow passage of vessels through the Waterway; these depths are published on charts that boaters use for navigation. Water levels are controlled through the operations of the dams and other water control structures along the Waterway, but significant precipitation or snow melt events can create periods of high water levels that may be unsafe for navigation. Conversely, extended periods of low precipitation or high temperatures can create periods of low water level which may be unsafe for navigation if not compensated for through increased release from upstream reservoirs.

Species are sensitive to water surface levels at various times through the year. Eggs for spring spawning fish such as Walleye can dehydrate if spring water levels drop after spawning has occurred and incubating eggs are exposed to the air. Lake Trout spawn in the fall and their eggs incubate through the winter. Lake Trout eggs will freeze and die if water levels drop after the fall spawning event and eggs are exposed to the air. Loons nest and lay eggs in

May or June. Beaver lodges and muskrat houses are vulnerable to freezing or flooding if water levels increase or decrease beyond appropriate ranges after houses and lodges are completed.

Water levels that fluctuate quickly can impact recreational opportunities and access to certain properties along the Waterway. Since their creation, the Reservoir Lakes have seen significant development, primarily cottagers, some of which have evolved into year-round residency. Consideration for these residents could be made when lowering the water level in the Reservoir Lakes, particularly during the winter months for those areas which have year-round residency, and for those residents who have lake-only access.

The flow through hydro power generation facilities are controlled through manipulation of water levels at water control structures on the Waterway.

Relevant Datasets

Parks Canada collects water level information at each of the water control structures along the Waterway, and uses those records in making operational decisions. In addition, the datasets listed under the "Flow" variable can often also be used to obtain water levels, since flows are typically calculated from observed water levels through application of a rating curve (i.e., a relationship between flow and water level). The relevant water level datasets are:

- **Water Survey of Canada - Canadian Gauging Stations**
- **Parks Canada - Gauging Stations**
- **Provincial Gauging Stations - HYDAT**
- **Flow - Provincial - Dam**

4.1.3 Hydrotechnical Model Outputs

Hydrotechnical model outputs provide information on the flows and water levels in the Waterway under different management and meteorological conditions.

Application to Water Management Goals

A hydrotechnical model can be used as a tool to assist in the processing of water level and flow information to manage each of the Water Management Goals and Objectives, including mitigating risk to human safety, mitigating flooding, protecting infrastructure, maintaining navigation, maintaining ecosystem functions, and maintaining hydro power generation. Model outputs can link management actions taken in one part of the system with responses in other parts of the system.

Relevant Datasets

Parks Canada currently uses a reservoir storage model to assist with the management of the Reservoir Lakes; however, the model does not extend to the management of water levels and flows in the majority of the navigable portions of the Waterway. Currently, no effective model is in use for managing and optimizing water levels and flows throughout the entire Waterway, including response to meteorological events and evaluation of alternate management scenarios.

The **Review of Water Management Systems and Models** report contains a discussion of water management models and the capabilities, benefits and drawbacks of using the models to manage a system like the Trent Severn Waterway.

4.1.4 Operational Condition of Locks and Dams

The water levels and flows throughout the Waterway are controlled by dams and other water control structures, and navigation through the Waterway is made possible through the use of locks, allowing navigation up-gradient. Accordingly, the management of the Waterway depends on these structures being in operational condition.

Application to Water Management Goals

A significant amount of the infrastructure in the Waterway was constructed to provide navigable water levels during the dry summer months (i.e., dams on the Reservoir Lakes), and to allow vessels to traverse along the Waterway (i.e., locks). However, these structures have also become critical for flood mitigation and the protection of public safety, and if they are in poor operating condition they can increase risk to human safety. The maintenance and operation of this infrastructure is a key component in the management of the TSW for public safety and navigation.

Relevant Datasets

The condition of locks and dams are typically monitored by Parks Canada staff during regular operations. If a problem occurs that affects the operation of the structure, it can be identified quickly and noted. The structural condition of the lock or dam, however, may be more difficult for Parks Canada staff to assess, and often requires a Dam Safety Review (DSR). A database of these reports as they are developed (such as the recent DSR for Dam 1) could be compiled for reference.

4.1.5 Staff Resources

The number of staff resources available in certain areas and/or at certain times of the year is critical to respond appropriately to management and climatic conditions that may arise. Typically, Parks Canada maintains a high staffing level during the summer months corresponding to the main navigation season for recreational users. When staffing levels drop in the late fall and winter periods, the Waterway is typically closed for navigation. During the main summer months the geographical distribution of staff can affect the decision making process when an emergency situation arises.

Application to Water Management Goals

Staff resources dictate the ability of Parks Canada to respond to public safety events. Low staffing levels in the winter may make it difficult to implement operational decisions to mitigate risk to public safety, as well as affect the frequency with which staff can adjust dams (particularly in the Reservoir Lakes); these low staffing levels are currently considered when planning winter operations.

Relevant Datasets

The level of staff available for operations is readily available when considering operational decisions. A specific dataset for this variable is not required beyond what is already maintained.

4.1.6 Current Meteorological Data

Current meteorological data can affect the operation of the Waterway, including precipitation forecasts, snowpack measurements, and temperature. Seasonal forecasts may indicate a recommended management regime to compensate for a dry season or a wet season.

Application to Water Management Goals

Of particular importance for flood mitigation and the protection of public safety is the monitoring of snowpack levels throughout the winter, since this will help to predict the size of the spring freshet when used with the ground condition and the weather during the freshet. Sufficient capacity must be planned in order for the Reservoir Lakes to accommodate the runoff volume from the snowpack and mitigate flooding.

Relevant Datasets

Environment Canada is the primary source for climate and meteorological information, and also issue seasonal forecasts/predictions to assist with the management of the Waterway.

Parks Canada currently collects information on the snowpack to manage for the spring freshet. However, these measurements only inconsistently include information on the ground conditions (i.e., frozen, thawed, saturated, dry, etc.), which are important in establishing the proportion of freshet melt-water that will run off into the lakes. The impact of rain during the freshet melt is also not considered.

Parks Canada does not currently use meteorological information, aside from the snowpack freshet forecast, as part of their operational process.

4.1.7 Ice Conditions

The lakes and rivers of the TSW will typically freeze over during the winter. The condition, thickness and extent of the ice cover in key areas are important to characterize ice conditions.

Application to Water Management Goals

Locations and development of seasonal ice cover, as well as the location of potential or existing ice jams, is important for mitigating public safety risk from flooding, as well as risk to infrastructure (including hydro power generation facilities) from ice-related damage.

Several lakes support winter recreation activities (e.g., ice fishing). The impact of operations on the ice cover of these lakes is important for mitigating risk to public safety.

Relevant Datasets

Ice conditions will typically be observed by Parks Canada staff during the regular operations of the Waterway. Key areas could be identified for winter monitoring due to optimize use of reduced staff levels in winter months.

4.1.8 Frazil Ice - Locations and Conditions for Formation

Frazil ice is a collection of small ice crystals that forms in moving water when the water is cooled below its freezing point. Frazil ice forms only in open water conditions when stable ice cover conditions are absent. It can stick to and accumulate on structures in the Waterway, and operating authorities will often try to control ice forming conditions to avoid frazil ice formation upstream of hydro electric generation facilities. This can be accomplished through the establishment of a solid, stable ice cover, through manipulation of flows and water levels to avoid frazil ice forming conditions, as soon as possible when temperatures allow.

Application to Water Management Goals

Locations of frazil ice formation can indicate potential locations of ice jams and impacts to water intakes and other infrastructure.

Frazil ice can reduce the operating efficiency or damage infrastructure designed to manage water flow and generate hydroelectricity. Management of flows and water levels can help protect infrastructure from frazil formation.

Relevant Datasets

Ontario Power Generation (OPG) will typically manage the flows entering their turbines to avoid conditions where frazil ice may form. OPG operations staff could be consulted to establish a notification agreement wherein frazil ice formations or conditions that are susceptible to frazil ice formation are reported to Parks Canada. Key areas that may be vulnerable to frazil ice (hydro power facilities, water intakes, narrow river sections, etc.) could be located and monitored for frazil ice formation during winter prior to the stable ice cover being established.

4.1.9 Navigation Markers

The navigation channel throughout the Waterway is indicated with markers. These markers can have operational limits with respect to flow, and the markers may potentially become dislodged if the flow limit is exceeded.

Application to Water Management Goals

Navigational markers are required in order to effectively and safely provide for navigation along the Waterway. If the markers become dislodged, there will be an increased risk to public safety.

Relevant Datasets

Parks Canada, TSW is the owner of most of the markers on the Waterway. They are maintained by TSW staff and are charted. The few private markers that exist along the Waterway are also charted but privately maintained.

4.2 Constraint Variables

The constraint management process describes the activities taken on a varying recurring schedule to establish the constraints, or “Management Ranges”, for the operations of the TSW. This includes the evaluation of a diverse array of datasets that impact the goals of the Waterway and have the potential to affect the management decisions made by Parks Canada staff when adjusting flows and water levels in the system. The frequency with which this process is undertaken depends on the data being evaluated; for example, the review of historic flood events and levels need only be completed once to establish the historical record, and then updated only when new events occur.

4.2.1 Storage and Discharge Capacity for Reservoir Lakes

As described in **Section 1**, the Reservoir Lakes are filled in the spring with the freshet and slowly drawn down over the summer to augment water levels for navigation, water supply, and other purposes in alignment with the TSW Water Management Goals. The lake levels are kept low over the winter in order to provide capacity to retain the following year’s spring freshet. This variable describes the relationships between storage and discharge for the Reservoir Lakes, which are a key component in the balancing of water supplies throughout the Trent River Watershed.

Application to Water Management Goals

The storage and discharge capacity for the reservoir lakes is a critical relationship in making operational decisions to protect human safety. Although the reservoir lakes are operated on a seasonal basis and have a limited capability to respond to isolated meteorological events, foresight in their operation can provide the ability to mitigate the effects of extreme events and thus mitigate the potential public safety risk. These lakes have also had increasing shoreline development and recreational water use since the construction of the Waterway. As a result, under certain circumstances and in certain locations, high water levels may increase safety risks to water users and shoreline residents on these lakes.

The Reservoir Lakes of the Trent Watershed serve as storage in the overall water management regime for the Waterway. Management of these lakes can affect the flows available downstream and can play a role for water supply as well as for water quality.

Information on water levels and storage in the Reservoir Lakes determines the availability of water to provide for navigation during summer months, which is the original purpose of the Reservoir Lakes. Water captured during the spring freshet is stored and released as needed over the summer months to facilitate navigation along the Waterway.

From a natural environment perspective, water levels and storage in the Reservoir Lakes at any given time can provide information to plan and make decisions on how to achieve water surface levels and flows in downstream areas (i.e., North, Central and South Sectors) that support the sensitive life cycle stages described previously.

Information on water levels and storage information in the reservoir lakes can provide information to make decisions for managing water surface levels and flow to provide for hydro power generation.

This variable could be incorporated into water management decision-making when water levels at flood prone locations exceed pre-established limits. Management responses might include water level management, risk communications (including hazard marking), and/or engaging partner organizations in providing flood-proofing assistance to affected residents. In addition, Parks Canada could be consulted regarding development proposals to avoid flood prone areas. Complementary tasks for operationalizing this variable include locating and georeferencing flood prone areas through resident or staff surveys, geospatial modelling, or other assessment methods. Based on this information criteria and rules for management response to various potential conditions (location, water levels, time of year) can be developed. Key partners in this effort could include municipal planning departments, Parks Canada, and district MNR offices that may have floodplain or related mapping as part of land-use planning efforts.

Relevant Datasets

The storage and discharge capacity relationships for the Reservoir Lakes have been established by Parks Canada, and are readily available in-house. The relationships were based on area-depth calculations conducted in the 1970s, and provide a reasonable estimate of the available water; however, more precise relationships could be established if improved lake bathymetry were available.

4.2.2 Historical Climate Data

Long-term trends in climate data can be used to provide insight into the likely climatic conditions that may be present in future years in order to optimize and prepare for operational scenarios and to help define the management ranges developed under the constraint management process.

Application to Water Management Goals

Assessment of long-term climate data offers the potential to implement long range plans for infrastructure development, staff resources and water use planning to optimize opportunities for water power production and navigation, as well as to anticipate precipitation event frequencies that can cause potential flooding issues and risks to public safety.

Relevant Datasets

Ontario In-filled Climate Data is a primary resource for historical climate data. Climate records frequently have missing data within the complete climate record. These gaps may be short term in nature (over a number of days due to equipment malfunction), or long term (over a period of years, due to station closures). Daily climate records typically have fewer gaps than hourly records, and are usually associated with station closures. Hourly datasets typically contain more significant gaps, and are usually associated with equipment malfunction or seasonal closings. Missing data can be estimated, or "filled in", using nearby climate stations to create a continuous dataset before completing hydrologic modelling tasks.

4.2.3 Navigable Channel Depth

This variable is related to the minimum depth of water that a vessel requires to safely navigate along the Waterway. The navigable depth for the Waterway was established in the Canal regulations in the early 1900s.

Application to Water Management Goals

This variable applies to the goal of mitigating risk to public safety because if the water levels drop below the advertised navigational depth, vessels using the Waterway may run aground, incurring a significant risk to the safety of the boaters.

This variable also applies to the goal of providing navigation , as an appropriate depth must be maintained during the Waterway's navigation season (i.e., May to October) to provide the potential for safe passage of vessels. The navigable requirements as established in the Canal regulations form the navigational management range within navigable portions of the Waterway.

Relevant Data Sets

The navigational requirements for the Waterway are established and form part of the current operational strategy. Further consultation with Transport Canada Navigable Waters Protection staff could be conducted if the targets are required to be revised or updated.

In addition, the data set "**Bathymetry Point**" and "**Bathymetry Line**", indicating the water depth at various places in a body of water, can be used to evaluate the depth of a lake or river at specific locations.

4.2.4 Maximum Flows and Velocities for Navigation

Navigation becomes hazardous when certain flow and velocity thresholds are exceeded. These thresholds depend on the maneuverability of the vessel, the dimensions of the Waterway and the skill of the operator; although it should always be assumed that the vessel operator is unskilled and inexperienced. Maximum thresholds for safe navigation at various points along the Waterway have already been established. If these pre-determined thresholds are exceeded then navigation is closed in the relevant section of the Waterway.

Application to Water Management Goals

Maximum flows and velocities for navigation are related to the goal of providing navigation in the Waterway. If these flows are exceeded the boaters are at an increased risk to unsafe conditions, navigation becomes difficult or impossible and the Waterway is closed. Public is notified via Notice to Mariners and information bulletins.

Relevant Datasets

Further consultation with Transport Canada Navigable Waters Protection staff could be considered to establish these maximum flows and velocities for safe operations. Maximum flows and velocities for the Waterway are provided in the Canal Regulations.

4.2.5 Navigation/Boat Use Trends

Information on the navigation and boat use trends is desirable for establishing the high-volume areas of the Waterway, thus indicating which areas are most sensitive to fluctuations in water level.

Application to Water Management Goals

This variable relates to the goal of providing navigation, as well as to optimizing recreational opportunities on the Waterway. Changing water levels and flows can influence navigational conditions for boaters along the Waterway, and boating conditions and boater density can be influenced by Parks Canada’s boating permit issuances.

Relevant Datasets

Periodic surveys at regular frequencies of boater navigational choices, boater accessibility, and boater densities at select index sites could be conducted to characterize this variable. Consideration of this variable throughout the boating season can indicate areas that are sensitive to fluctuations in water levels.

To operationalize this variable, establishing index sites based on previous surveys (Parks Canada, academic studies or reports etc.), expert opinion, or in consultation with the TSW Water Management Advisory Committee could be conducted. When index sites have been established, surveys could be conducted at a set frequency through Parks Canada staff observations, remote sensing, or other means (e.g., third party observations such as via a volunteer “Waterway watcher” monitoring program).

4.2.6 Regulated Floodplain Area

The regulated floodplain area is the estimated extent of flooding that would occur from a pre-determined (i.e., “regulated”) storm event. In most of Southern Ontario this event is typically Hurricane Hazel, while in Eastern Ontario this event is typically the 100-year return period storm. An engineering assessment of a Waterway can be performed using a hydrologic and hydraulic model, and the extents of expected flooding are displayed on maps.

Application to Water Management Goals

The extents of the regulated floodplain area can indicate areas that are susceptible to flooding, and can be used to anticipate potential impacts due to extreme flood events. Although the ability to respond to isolated meteorological events in the Waterway is limited, knowledge of critical areas could be used to mitigate potential risk to public safety (e.g., by defining more stringent management ranges for high water levels).

Relevant Datasets

The Conservation Authorities (CAs) throughout the TSW area are the agencies responsible for establishing the regulated floodplain; however, floodplain areas may not be established for some of the minor Waterways. The CAs could be consulted in order to establish a data sharing agreement with this and other datasets.

4.2.7 Historic Flood Events/Levels

Records of historic flood events and levels may consist of official recordings of water levels at certain dams and extents of flooded area, as well as anecdotal reports from local residents. Such records can be useful in establishing management ranges.

Application to Water Management Goals

Historic flood events and levels can provide insight into the potential risk to infrastructure and public safety from future events, especially since these events may exceed the regulated floodplain area. Key flood-prone areas can be identified from these records, and additional precautions can be taken to mitigate risk to public safety. Knowledge of these historical events could also be considered when defining management ranges, in order to attempt to predict areas that could experience flooding during extreme events.

Relevant Datasets

The CAs may have developed historic records of high flow events since flood protection is one of their primary mandates. If detailed records do not exist within Parks Canada, then consultation with the Conservation Authorities could be conducted to establish data sharing agreements for this variable.

4.2.8 Land Use Mapping

Land use mapping displays the nature of development, such as residential areas, commercial/industrial areas, agricultural areas, etc.

Application to Water Management Goals

Permitted land-use along the shorelines of the Waterway can indicate the level of risk to public safety and infrastructure. For example, a greater concentration of infrastructure is likely to be encountered in developed areas with residential, commercial or industrial land uses, thus incurring a higher risk of damage from high flows.

Permitted land-use along the shorelines of the Waterway can influence the viewscape and aesthetics for water recreation activities, thereby affecting the enjoyment of Waterway users.

This data could be used to provide insight for the development of management ranges.

Relevant Datasets

Land-use policy at the municipal level in Ontario is primarily set through the official plan and zoning bylaw, and zoning maps can typically be acquired through municipal planning departments in digital and hardcopy form. This applies to both rural and urban municipalities. Conservation Authorities provide advice and help to set municipal policy for land-use along Waterways through floodplain management mapping and policies. MNR district planning staff also help to set land and resource-use policy in Crown land areas and Provincial parks.

The following datasets may be useful in integrating land use information into the constraint management process:

- **Parcel Mapping**. The packaged product may contain the following data depending upon the geographic location: assessment parcels, Crown parcels and/or Ownership parcels, as well as background information such as registered plans, roads, water bodies, township fabric, etc.
- **Cottage Residential Area**. A Cottage Residential Area is a feature that identifies an area of dwellings having an official designation and is often represented by a cottager and/or residential association. The occupancy may be seasonal or year-round.
- **Traditional Land Use Area**. A Traditional Land Use Area is a feature that identifies an area commonly used for both current and past human activities that are deemed worthy of special consideration. These areas are not officially recognized, but may be located on the basis of local common knowledge.

4.2.9 Existing Built Infrastructure

This variable describes an array of mapping and geographical information that displays locations of infrastructure along the Waterway, including dams, locks, bridges, roadways and buildings.

Application to Water Management Goals

Locations of existing infrastructure can indicate the level of risk to infrastructure that may result from Waterway operations. These locations could be considered in parallel with the floodplain and land use mapping to create a broad-based risk screening tool (i.e., higher risk where sensitive infrastructure is located within the regulated floodplain area) and for the development of management ranges.

Relevant Datasets

Many agencies will possess information regarding existing built infrastructure along the Waterway, including Parks Canada, Ontario Power Generation (OPG), the Ministry of Transportation (MTO), and the various municipalities and Conservation Authorities. A description of this dataset is included, called "**Dam and Barrier**".

4.2.10 Water Intake Elevations

There are several municipal water intakes along the Waterway which require maintenance of minimum water levels in order to sustain operations.

Application to Water Management Goals

Knowledge of the locations of all intakes in the Waterway and their operating rules and conditions allows Parks Canada water managers to predict how these facilities may respond to changes in water levels and flows, as well as the upstream and downstream implications for water users. The minimum water level required for the intakes to function properly could be included in the development of management ranges through the constraint management process. In addition, high flows can increase the suspended solids which cause problems for water treatment plants. More consistent flows reduce this undesirable effect.

Relevant Datasets

Key dimensions of this variable include the geographic coordinates of the intakes, intake characteristics (i.e., elevation) and water level and flow thresholds triggering predictable negative upstream/downstream health, safety, or other impacts. Water intake elevations could be incorporated into the management ranges.

4.2.11 Minimum Flow for Water Quality (Assimilative Capacity) - at Water Pollution Control Plant Outfalls

The permitting requirements for water pollution control plants (WPCP) typically includes effluent discharge limits, and the determination of these limits can depend on an assimilative capacity in the receiving waterbody, requiring a minimum flow to ensure sufficient dilution. There are several WPCPs that discharge into the TSW, and consideration for the minimum flows could be made during operations.

Application to Water Management Goals

WPCP outfalls and permitted effluent discharge limits are designed with consideration of the assimilative capacity of the receiving water body. Under low flow conditions operational changes in the TSW may impact water quality in areas where the Waterway is exposed to WPCP effluent. This may impact on macronutrient loading (especially phosphates) and pathogen levels in downstream waters.

Relevant Datasets

Minimum flow for water quality information could be incorporated into the development of the management ranges as part of the constraint management process. Complementary tasks for use of this variable include locating and georeferencing WPCP outfalls sensitive to changes in water levels and flows, as well as developing management ranges for those reaches based on assimilative capacity modelling. Key partners in this effort could include municipal and industrial plant operators along the Waterway and relevant MOE district offices who administer Certificates of Approval for WPCPs, as well as the operating municipalities.

4.2.12 MOE Water Well Data

The locations of wells, tile drains and septic beds that discharge to a water course are inventoried by MOE, since approval from the Ministry is required for installation. Locations of these features close to the TSW can be useful for determining potential impacts.

Application to Water Management Goals

Locations of wells, tile drains and septic beds can indicate areas that are susceptible to contamination, resulting in potential water quality concerns to users of the Waterway.

Relevant Datasets

Further consultation with MOE could be conducted to obtain information related to this variable.

4.2.13 Water Quality Parameters

Water quality records can include constituents such as dissolved oxygen, turbidity (suspended solids), heavy metals, bacteria (i.e., *E. coli*), nitrogen, phosphorus and many others.

Application to Water Management Goals

Low dissolved oxygen (DO) and high turbidity, combined with visual observations, are indicators of algal blooms. Algal blooms may pose a health risk to water users through skin irritation or rashes, or in the case of certain species of blue-green algae, may be toxic if ingested untreated. High turbidity (low water transparency) due to planktonic algae may also pose a safety hazard for safe boating or swimming due to reduced visibility. Under certain circumstances during the ice-free season, particularly during periods of lower water flows and warmer weather, changes in water levels and flows may enhance conditions for algae blooms.

This variable could be considered during the development of the management ranges as part of the constraint management process.

Relevant Datasets

Water quality monitoring records are often established as a component of permitting for WPCPs or water intakes, or as a component of environmental studies. Municipalities and Conservation Authorities could be consulted to obtain this information where it exists. This information will not be geographically comprehensive, since it is produced only on an as-needed basis.

Information to determine such locations and seasonal timing can be acquired through a survey of public health departments in the TSW watershed. Public health notifications about algal blooms in the TSW watershed could also be tracked through e-mail based news alerts or agreements with public health departments. DO and turbidity data can be acquired remotely and continuously through water quality sensors, or occasionally through grab samples. Parks Canada could pursue partnerships with Conservation Authorities, or municipal public works departments or public health departments to gather or share this data. In the Reservoir Lakes area, MOE's Lake Partner volunteer monitoring program may be able to provide some ongoing water transparency monitoring capacity through secchi disk readings.

4.2.14 Permit To Take Water (PTTW)

Water users who withdraw more than 50,000 litres/day from Ontario's surface or groundwater resources are required to obtain a Permit To Take Water (PTTW) from MOE. This includes water takings for municipal, commercial/ industrial, or irrigation purposes.

Application to Water Management Goals

Under low water conditions, water intakes may be exposed, water quality and treatment requirements could be altered and water levels may need to be maintained to account for water withdrawals by permitted users. TSW staff may use this information to balance decisions, and/or understand the implications of decisions, to adjust or reallocate water levels and flows throughout the system during low water conditions. This information could also be used to develop water conservation strategies and communications for voluntary reductions in water takings by permitted users during low water conditions, perhaps in partnership with other agencies such as MOE.

Information on water takings could be considered during development of management ranges and a low water level threshold could be established. Additionally, sites that may be sensitive to the normal range of seasonal water level fluctuations could be identified.

Relevant Datasets

Key dimensions of this variable include the depth and location of permitted water intakes, purpose of the permitted use (drinking water or irrigation) and the permitted water taking (maximum) for each intake. TSW operational staff may already be aware of the locations and characteristics of most of these sites as a result of previous inquiries from permit holders.

Permit To Take Water data can be acquired from MOE's Eastern and Central Region offices.

4.2.15 Hydro Power Generation Locations

There are several water power generation facilities on the Waterway that use the flows to run turbines and produce electricity. Knowledge of the locations of all water power facilities in the TSW watershed and their operating rules and conditions could allow Parks Canada water managers to predict how these facilities may respond to changes in water levels and flows.

Application to Water Management Goals

The locations of water power generation facilities can be indications of areas that experience large and rapid fluctuations in water level, potentially impacting navigation and public safety. The range of hydro power operations are currently considered when managing the Waterway.

This variable could be incorporated into the development of water management ranges.

Relevant Datasets

Key dimensions of this variable include the geographic coordinates of the facility, facility characteristics (capacity, type, age, etc.), operating rules and ranges, ongoing water level information at the facilities relative to operating rules/ranges, and water level and flow thresholds triggering predictable negative upstream/downstream health, safety, or other impacts. Complementary tasks to make use of this variable include developing a spatial and attribute database of water level facilities, gathering the data suggested above, developing communication and data sharing protocols with water power facility operators, and installing or encouraging the installation of water level and flow instrumentation as required at facilities which do not have such instrumentation in place. The development or estimation of water level/flow thresholds triggering health and safety issues can be accomplished through some combination of operator or other key informant interviews, remote or on-site observations, or numerical modelling. Key partners in accomplishing these tasks include water power facility operators and MNR district or area office water resources staff.

The **Water Power Generation Station** dataset includes the location of waterpower generation stations and provides general information about the site including the equipment associated with the waterpower generation station.

4.2.16 Wetland Delineation

Wetlands can be areas of high ecological significance, and can contain a large diversity of species. In addition, they can serve an important function in the transport, cycling and retention of nutrients and other water quality elements.

Application to Water Management Goals

Subtle changes in water levels in wetlands can cause substantial changes in the composition and diversity of wetland flora and fauna. Information on wetland boundaries and water surface levels may facilitate appropriate definition of management ranges to support diverse wetland species and functions.

Relevant Datasets

Conservation Authorities and the Ministry of Natural Resources maintain databases of wetlands. Further consultation with these agencies could be conducted to obtain this information.

4.2.17 Ministry of Natural Resources (MNR) Management Zones

The MNR has established management zones for various purposes (e.g., fisheries and wildlife management) that may affect the operation of the Waterway.

Application to Water Management Goals

Management zones within or adjacent to riparian areas may be sensitive to changes in water levels and flows. These locations could be considered for the development of management ranges as they could be sensitive to fluctuations in water level or flows.

Relevant Datasets

Consultation with the MNR could be conducted to obtain information on these management zones.

4.2.18 Known Fish Spawning Areas (Ontario Base Map)

Fish typically spawn in the spring or fall, and may require a specific range of water levels and/or flows in the Waterway for spawning conditions.

Application to Water Management Goals

Seasonal flows and water levels support spawning, incubation of eggs, and dispersal of fry. Identification of spawning areas for specific species allows development of management ranges to better support fish reproduction and recruitment, supporting the goal of protecting the natural environment.

Relevant Datasets

The **Spawning Area** dataset is a feature that identifies an area where a species of fish habitually spawns, and is maintained by the Ministry of Natural Resources (see metadata in Appendix A).

4.2.19 Species at Risk Act (SARA) Distribution/Locations

Species at Risk, as defined under the SARA, are those species that are protected from interference.

Application to Water Management Goals

Knowledge of the locations for aquatic species at risk within the Waterway, and riparian species in adjacent areas, allows for development of management ranges to protect and enhance habitat functions for these species.

Relevant Datasets

The Ministry of Natural Resources maintains information and databases on the locations and types of Species at Risk throughout Ontario and Parks Canada resource conservation staff maintain similar records for the TSW. Further consultation and Species at Risk data coordination could be conducted with MNR and Parks Canada.

4.2.20 Fish Community Data

The presence, type and number of fish in a waterbody are an important consideration for the management of the waterbody, due to the Fisheries Act and associated legislation.

Application to Water Management Goals

Management ranges to support broader ecosystem objectives may be possible if fish community data were available for analysis and processing. By assessing the collective requirements of the fish community, management ranges can be set to provide a broad range of habitat functions.

Relevant Datasets

The Ministry of Natural Resources and the Department of Fisheries and Oceans could be consulted for detailed information on the fish communities in the Waterway. In addition, the following datasets could be consulted to characterize fish communities along the Waterway:

- **Feeding Area Fish**
- **Staging Area Fish**
- **Nursery Area Fish**
- **Aquatic Feeding Area**
- **Aquatic Resource Area Summary**

4.2.21 Distribution of Invasive Species

Invasive species includes those species that are not native to the area, and may possess characteristics that adversely affect the ability of native species to survive.

Application to Water Management Goals

As management ranges may enhance habitat functions for sensitive and valued species in the TSW, ranges to reduce success and dispersal of invasive species may prove effective if distributions of key areas for invasive species are identified and monitored.

Relevant Datasets

The Ministry of Natural Resources and the Department of Fisheries and Oceans could be consulted for information on invasive species.

4.2.22 Wildlife and Terrestrial Corridor Locations

This variable describes important terrestrial connections and wildlife corridors (i.e., migratory routes, habitats, etc.) that could potentially intersect with the Waterway and impact operations.

Application to Water Management Goals

Wildlife corridors may connect parts of the Waterway to upland habitat. Parts of these corridors in riparian areas may be sensitive to water level changes at certain times of year. Connecting functions of these corridors may be enhanced through development of management ranges.

Relevant Datasets

The following datasets can be consulted for information on this variable:

- **Breeding Area**
- **Breeding Zone**
- **Feeding Area Wildlife**
- **Staging Area Wildlife**
- **Wintering Area**

4.2.23 Migratory Bird Data

The presence of migratory routes or staging areas within the Waterway may affect operations.

Application to Water Management Goals

Information on migratory birds may indicate areas sensitive to water level fluctuations. For example, Loons typically nest near the water's edge and their nests and eggs are particularly vulnerable to fluctuations in water levels during the four-week incubation period. Effective management ranges to maintain suitable habitat for other species sensitive to water level fluctuation may be possible if suitable migratory bird information would be available.

Relevant Datasets

The following datasets can be consulted for information on migratory bird routes:

- **Nesting Sites**
- **Staging Area Wildlife**

Additional information can be obtained from the MNR.

4.2.24 Ecological Land Classification (ELC)

Ecological land classification may show locations for wetlands and other potentially sensitive ecological features not included in other mapped data layers.

Application to Water Management Goals

Integration of ELC information may provide additional information for management ranges to provide protection for wetlands and other riparian vegetation communities not well represented by other data sources.

Relevant Datasets

The Conservation Authorities produce ELC information, and can be consulted to obtain this information.

4.2.25 Designated Areas: National and Provincial Parks, ANSI, ESA, PSW

This variable includes a range of areas that may be ecologically or culturally significant.

Application to Water Management Goals

Spatial data showing specific management zones for designated areas may facilitate refined management ranges to enhance protection of these areas.

Relevant Datasets

The following datasets can be consulted for information on this variable:

- **Environmentally Sensitive Area (no longer available or used by MNR)**
- **Federal Protected Area**
- **Conservation Lands non-MNR**
- **Conservation Lands Regulated**
- **Crown Game Preserves**
- **ANSI (Areas of Natural and Scientific Interest)**

4.2.26 Tourism Event Timing and Location

Under certain circumstances, operations have the potential to affect tourism events along the Waterway. Tourism is important to municipalities and commercial operators in particular, and impacts on tourism events can affect enjoyment of the area by local residents, businesses and visitors. This variable pertains to water-related tourism events in the TSW watershed which may be affected by changes to Waterway access, aesthetics, or recreational opportunities.

Application to Water Management Goals

This information can be used to increase awareness of the requirements and locations of tourism events as a potential constraint or consideration for decisions to adjust water levels and flows in various parts of the TSW.

Relevant Datasets

Periodic review of tourism events could be conducted through checks with local municipalities and tourist associations, and internet searches throughout the year within the TSW watershed. Georeferencing of the locations of such events and collection of key attributes (dates, frequency, recurrence, activities, potential impact of water management decisions on event etc.) could also be conducted. Another option may be to solicit this information through tourism and other associations on a voluntary, proactive basis (i.e., the event organizers notify Parks Canada about the event).

Other sources for this information include local municipal Economic Development Offices, Ministry of Tourism and Culture, local economic development corporations (e.g., Community Futures), print, radio, TV and internet media searches.

4.2.27 Commercial Operations

Commercial operations which are dependent on or affected by operations in the TSW watershed include marinas, boat rental operators, resorts and private campgrounds, and shoreline amenities (e.g., waterfront restaurants and taverns, waterfront retailers). They may be affected by water levels and flows, water quality, and aesthetic issues such as nuisance algal blooms.

Application to Water Management Goals

Knowledge of the locations, issues, and characteristics of commercial operations may assist water managers during extreme high and low water events to help protect commercial business assets, or improve water conditions when and where it is possible to meet other water management goals simultaneously. This information can be used in the development of management ranges as part of the constraint management process.

Relevant Datasets

To operationalize this variable, an initial mapping and attribute database development exercise could be conducted, followed by a gap analysis to determine whether additional information is needed. Relevant “desktop” data sources on the locations, issues, and characteristics of commercial operations include municipal Chambers of Commerce, local business indexes, Community Futures Development Corporations, economic development surveys and reports, socioeconomic impact study reports, and internet searches. Targeted surveys of commercial operators may be required to address any identified data gaps.

4.2.28 Heritage and Archaeological Sites

This variable primarily relates to sites or areas with cultural heritage or archaeological value as identified through surveys or inventories by licensed professionals and/or through Aboriginal traditional knowledge.

Application to Water Management Goals

Cultural and archaeological heritage is a key feature for visitors to the Waterway system. Operations may affect heritage sites or features, or the enjoyment of users visiting them, and knowledge of their locations and characteristics can be incorporated into decisions to manage water levels and flows.

Relevant Datasets

The locations, extent, features, and access to these sites are key factors. To operationalize this variable, mapping and attribute database development could be conducted, with data mined from Parks Canada and Ontario Parks reports, the Ontario Heritage Properties Database, environmental assessment reports, academic research papers and reports, municipal long-range planning background documents, municipal planning and development files and report holdings, Aboriginal community archives, and other sources. The **Traditional Land Use Area** dataset is a feature that identifies an area commonly used for both current and past human activities that are deemed worthy of special consideration. These areas are not officially recognized, but may be located on the basis of local common knowledge.

4.2.29 Parks, Campsites, Rest-stop, Day Use, Boat Launch Locations

Application to Water Management Goals

The locations of recreational facilities can impact operational decisions when considering the goal of optimizing enjoyment along the Waterway. Consideration may be given, for example, to minimizing water level fluctuations close to marinas during the navigation season, or mitigating the drawdown of certain Reservoir Lakes that accommodate parks and campsites during the primary camping season.

Relevant Datasets

The dataset **Camp, Recreation** is a feature that identifies an area used for commercial tourist operations with a focus on outdoor activities other than hunting and fishing.

Other sources for this information include Ontario Parks, Tourism Offices, websites, surveys of local cottage and shoreline property owners' associations, as well as municipal offices.

4.2.30 Public Safety Notifications

Public safety notifications can occasionally by issued by other agencies, and can assist Parks Staff in addressing public inquiries about the Waterway.

Application to Water Management Goals

This variable relates primarily to the Goal of optimizing enjoyment of the waterway and reducing threats to public safety.

Relevant Datasets

Sources for this information include Conservation Authorities (floods), Ontario Ministry of Natural Resources district offices (floods- in areas without CAs), media monitoring (print, internet, radio, TV), Environment Canada Ontario flood forecasting centre.

4.2.31 Beach Closures

Advisories against swimming at public beaches are primarily issued when water quality samples exceed the Provincial Water Quality Objective for *E.coli* (a geometric mean of 100 CFU/100 ml). Under conditions of poor water circulation and warm water temperatures in the vicinity of public beaches, the likelihood of beach closures may increase. This may be exacerbated by reductions in water levels or flows.

Application to Water Management Goals

This variable could be incorporated into the development of management ranges, using a pre-established low water level threshold during the swimming season. A secondary task would be to determine which public beaches may be sensitive to water level and flow changes during such conditions due to their geographic situation and physical characteristics.

Relevant Datasets

Key dimensions of this variable include the locations of public beaches, issued public health advisories and related water sampling results and the frequency of beach closure due to *E. coli*. Beach closure advisories and related water quality data can be acquired through a data sharing and communication arrangement with municipal public health departments within the TSW watershed.

4.2.32 Recreational Water Use Optimization Levels

There are multiple recreational uses of water in the Waterway including swimming, canoeing and kayaking, fishing, water skiing, sailing and windsurfing, and power boating with craft of various sizes. Boating traffic can generally be characterized as "local" traffic (not travelling through locks) and "through" traffic (travelling through locks). These different types of traffic can have conflicting requirements, and while it is impossible to provide ideal conditions for all users all the time, efforts can be made to identify optimal water conditions for recreational water users as a group, and track conditions relative to the optimal for management purposes.

Application to Water Management Goals

This information can help to inform decisions to adjust water levels and flows at key locations in the Waterway, as well as the rate of issuance of boating permits for the Waterway.

Relevant Datasets

To operationalize this variable, a set of criteria describing optimum recreational water use conditions could be developed, and index sites could be identified for monitoring and assessing recreational water use relative to these criteria. A range of resources may be available to develop criteria including previous academic and government studies of recreational water use levels, conflicts and requirements in the Waterway, similar studies from other areas, expert opinion, and the websites of various recreational water user associations active in the TSW watershed. When index sites have been established, surveys could be conducted at a set frequency during the boating season through Parks Canada staff observations, remote sensing, or other means (i.e., third party observations such as via a volunteer "Waterway watcher" monitoring program).

Appendix A

Dataset Descriptions

Table of Contents

Constraint/Consideration

Flow – Federal – Water Survey of Canada – Canadian Gauging Stations

Description

The Water Survey of Canada (WSC) is the national authority responsible for the collection, interpretation and dissemination of standardized water resource data and information in Canada. In partnership with the provinces, territories and other agencies, WSC operates over 2500 active hydrometric gauges across the country. There are 41 active HYDAT stations located in the Trent and Severn Watersheds consisting of Sum of flow, Manual and Recorder gauge types. Depending on the type of gauge, air and water temperature, discharge and flow are measured. HYDAT Data are either collected manually or recorded for data download. Some stations in the network are remotely accessible through satellite telemetry and available within 24 hours. HYDAT data are archived and made available in database format.

Currency

HYDAT data are available as real-time, near real-time and archived information. Real time data are available within four hours of observation with near real-time information available within twenty four hours.

Archived HYDAT data depends on the age and status of gauges, of the 68 active and historic gauges within the Trent and Severn watersheds, 27 are no longer active. The oldest active gauge started operation in 1937. The newest gauges began operation in 2002.

Format

HYDAT data are available in a variety of formats. The most common form of data are tabular data referencing gauging station locations. Archived HYDAT data can be downloaded from Environment Canada (Water Survey of Canada) in comma or tab separated variables for historic daily, monthly or peak reports. For historic information regarding multiple gauging stations, data can be requested in Access or excel format.

Real and near real time data are available four hours after observation through web connection mechanisms. Environment Canada offers a map (Google) and text based search mechanism to view near real time HYDAT data. Data for individual stations are available as a graph for the preceding seven days.

Connection Mechanisms

Online file tabular file download, www.wateroffice.ec.gc.ca

Data Quality

The data are preliminary and have been transmitted automatically with limited verification and review for quality assurance. Subsequent quality assurance and verification procedures may result in differences between what is currently displayed and what will become the official record.

It is the responsibility of all persons who use this site to independently confirm the accuracy of the data, information, or results obtained through its use.

Usage Restrictions/Disclaimers

The Government of Canada does not warrant the quality, accuracy, or completeness of any information, data or product from these web pages. It is provided 'AS IS' without warranty or condition of any nature. The Government of Canada disclaims all other warranties, either expressed or implied, including but not limited to implied warranties of merchantability and fitness for a particular purpose, with respect to the information, data, product or accompanying materials retrieved from this web site. In no event will the Government of Canada or its employees, servants or agents have any obligation to the user for any reason including claims arising from contract or tort, or for loss of revenue or profit, or for indirect, special, incidental or consequential damages arising from the use of this information.

Contact Information

Environment Canada - Inquiry Centre
Telephone: 1-800-668-6767 (in Canada only)
Email: enviroinfo@ec.gc.ca

Constraint/Consideration

Flow – Federal – Parks Canada – Gauging Stations

Description

Parks Canada maintains hydrometric stations at key locations throughout the TSW (i.e., at dams and some rivers) for the purpose of conducting operations.

Currency

The information displayed on this site is obtained automatically through land-line transmissions from hydrometric stations operated by Parks Canada within the Trent-Severn Waterway. Data recovered from automated stations will typically be posted every 24 hours. In addition, manual water level readings are also displayed however the data are updated less often as a result of the time required to compile manual readings.

Format

HYDAT data are available in a variety of formats. The most common form of data are tabular data referencing gauging station locations. Archived HYDAT data can be downloaded from Environment Canada (Water Survey of Canada) in comma or tab separated variables for historic daily, monthly or peak reports. For historic information regarding multiple gauging stations, data can be requested in Access or excel format.

Real and near real time data are available four hours after observation through web connection mechanisms. Environment Canada offers a map (Google) and text based search mechanism to view near real time HYDAT data. Data for individual stations are available as a graph for the preceding seven days.

Connection Mechanisms

Online tabular file download, www.wateroffice.ec.gc.ca

Data Quality

The onus is on the individual to verify the accuracy of the data, information, or results obtained through its use and accept that this information cannot be guaranteed.

This information is not intended to be used for the purpose of flood warning and/or flood forecasting. If you require information regarding flooding you should contact the Trent-Severn Waterway directly.

Usage Restrictions/Disclaimers

The Parks Canada Agency is providing the information on this site under the express stipulation that the accuracy and reliability of the information is not guaranteed or warranted in any way and that Parks Canada Agency, its agents and servants, disclaim liability of any kind whatsoever and cannot be held liable for any damages, including, without limitation, claims, injury, expenses or other costs, or losses of revenue or profit, or indirect, special, incidental or consequential damages attributable to or arising from the use of this information.

Contact Information

Environment Canada - Inquiry Centre
Telephone: 1-800-668-6767 (in Canada only)
Email: enviroinfo@ec.gc.ca

Constraint/Consideration

Flow –Provincial –Gauging Stations - HYDAT

Description

These data are stored as series of shapefiles. One shapefile consists of known HYDAT FLOW gauge locations that are part of the Environment Canada/Ontario Ministry of Natural Resources Cost Share agreement. For each of these gauges, there is a shapefile containing a watershed. The name of the watershed shapefile contains the StationID of the gauge. Watershed boundaries were defined using NRVIS data and the Provincial Digital Elevation Model produced by the Water Resources Information Program (WRIP). A separate MS Access database stores a series of watershed characteristics that can be linked to the shapefiles. These characteristics include; watershed area, watershed perimeter, lake area, wetland area, other water area (double line streams, reservoirs), terrestrial area, reach slope, length of longest stream, longest stream slope, stream order, gauge elevation, geology summary, landcover

Currency

These data were collected over a time period range from 2003 to 2007. The data set is updated as needed.

Format

The data are available as a GIS Shapefile and linked MS Access database.

Connection Mechanisms

Online tabular file download

Data Quality

The station locations were compiled with a horizontal positional accuracy of +/- 100m and a vertical accuracy of +/- 5m

Usage Restrictions/Disclaimers

The Ministry of Natural Resources provides the information on this site under the express stipulation that the accuracy and reliability of the information is not guaranteed or warranted in any way and that Parks Canada Agency, its agents and servants, disclaim liability of any kind whatsoever and cannot be held liable for any damages, including, without limitation, claims, injury, expenses or other costs, or losses of revenue or profit, or indirect, special, incidental or consequential damages attributable to or arising from the use of this information.

Contact Information

Ministry of Natural Resources,
Mr. Bryce Matthews
Information Management Specialist
(705) 755-2243
Email:bryce.matthewsmnr.gov.on.ca

Constraint/Consideration

Flow –Provincial –Dam

Description

Dam is a Data Type of the Data Class - Water Structure, collected by the Natural Resources Values Information System (NRVIS) This GUT corresponds to the Ontario Base Map feature of the same name. Dams form part of the delineation of the body of water, superseding the shoreline feature.

Currency

This data was collected over a time period range from 1998 to 2006. The data set is updated as needed.

Format

The data are available as a GIS Shapefile

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Dam locations horizontal accuracy +/- 10m

Usage Restrictions/Disclaimers

Depending on any sensitivity or security issues associated with this information holding, all, some or none of the information may be available for viewing or distribution. All data requests are channeled through the Ministry of Natural Resources' Information Access Services. Information Access Services, (IAS) is responsible for providing access to a number of MNR products and services to support Ministry Goals and Objectives. IAS develops and administers policy relating to access, valuing and pricing of MNR information and protection of intellectual property. Signed Licenses and Agreements may be required.

Refer to the Distribution Contact details for information on how to contact Information Access Services with your request.

Some information holdings may be available for internet/online viewing - Free of charge, through the Ontario Land Information Warehouse.

Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Breeding Area

Description

Breeding Area is a polygon feature that identifies a site where a species habitually breeds.
Different Breeding Area types collected by the Natural Resources Values Information System (NRVIS) include:

- Caribou Rutting Area
- Deer Rutting Area
- Moose Rutting Area

Currency

These data were collected over a time period range from 1998 to 2004. Data are collected on an on-going basis therefore the data potentially can be current later than 2004.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

This Information holding is not to be used for Legal Purposes.

Caveat:

Data for this information holding varies by OMNR District in terms of:

- Completeness:
  - Concentrated surveys in one or more areas of the District.
  - Instances where no surveys were initiated, even though there is evidence of the value.
  - Instances where the value is not known to exist within the District.
  - Instances where attributes collected for the value will be minimal to verbose.
  - The data may exist only in a tabular form (files, hardcopy maps) within the District.
- Accuracy:
  - Dependant on the value's source capture methodology.
  - G.P.S. coordinates vs. sketched location, various map base sources.
  - Generalized location (buffered point) vs. mapped area (polygon)
- Vintage:
  - New vs. old value survey information for values in part(s) or all of the District.
- Sensitivity:
  - Some OMNR Districts may consider a specific value or group of values sensitive, others may not.
  - Some of the values may be flagged as sensitive due to intellectual copyright. (i.e.: Professional Research).
  - The value may be flagged as sensitive due to its link or relation to First Nation Peoples.
  - Please refer to this same section within the OMNR District's version of this record for specific use constraints details.

Distribution

Depending on any sensitivity or security issues associated with this information holding, all, some or none of the information may be available for viewing or distribution. All data requests are channeled through the Ministry of Natural Resources' Information Access Services. Information Access Services, (IAS) is responsible for providing access to a number of MNR products and services to support Ministry Goals and Objectives. IAS develops and administers policy relating to access,

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Some information holdings may be available for internet/online viewing - Free of charge, through the Ontario Land Information Warehouse.

Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Breeding Zone

Description

A Breeding Zone is a polygon feature that identifies a geographic area from which flora selections are made and interbred. Different Breeding Zone types collected by the Natural Resources Values Information System (NRVIS) include:

- Tree Seed Breeding Zone

Currency

These data were collected over a time period range from 1998 to 1999. Data are collected on an on-going basis therefore the data potentially can be current later than 1999.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

This Information holding is not to be used for Legal Purposes.

Distribution

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Some information holdings may be available for internet/online viewing - Free of charge, through the Ontario Land Information Warehouse.

Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Conservation Area – Great lakes Heritage Coast

Description

This Information Holding is used within the context of the following Great Lakes Heritage Coast subject area: Management Areas

Part of Ontario's Living Legacy, The Great Lakes Heritage Coast Project is an open forum for citizens to help determine the best ways to:

- Protect the Coast's scenic beauty and natural ecosystems;
- Promote the potential for recreation, tourism, and other economic benefits through a network of parks and protected areas and bring the world to this magnificent part of Ontario;
- Encourage development compatible with the overall intent for the area; and
- Foster co-operation, education, public information and partnerships with other levels of government, Aboriginal communities, and interest groups in the planning and management of the Heritage Coast.

Currency

This data are current to 2001. No ongoing data update or collection specified

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Units: Meters. Scale: 600000 (Also refer to Use Constraints)

Usage Restrictions/Disclaimers

Use Constraints

Quality is Limited due to Scale.

Distribution

No Information available

Contact Information

No Contact Specified – Use General MNR contact
Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Environmentally Sensitive Area

Description

An Environmentally Sensitive Area is a polygon feature that identifies an area with values which are identified to be of local interest and is designated and managed by a municipality. It may represent the habitat of vulnerable, threatened or endangered species.
Note: This data class is no longer available or used by MNR.

Currency

These data were collected over a time period range from 1997 to 2006. Data are collected on an on-going basis therefore the data potentially can be current later than 2006.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

This Information holding is not to be used for Legal Purposes. Some of the Environmentally Sensitive Area information may be considered sensitive, and as such may have restrictions placed on access.

Distribution

Depending on any sensitivity or security issues associated with this information holding, all, some or none of the information may be available for viewing or distribution. All data requests are channeled through the Ministry of Natural Resources' Information Access Services. Information Access Services, (IAS) is responsible for providing access to a number of MNR products and services to support Ministry Goals and Objectives. IAS develops and administers policy relating to access, valuing and pricing of MNR information and protection of intellectual property. Signed Licenses and Agreements may be required.
Refer to the Distribution Contact details for information on how to contact Information Access Services with your request.
Some information holdings may be available for internet/online viewing - Free of charge, through the Ontario Land Information Warehouse.

Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Federal Protected Area

Description

Areas protected by the Federal government for natural or cultural reasons. Include National Parks, National Marine Conservation Areas, Heritage canals, National Wildlife Areas or other Federal Protected areas

Currency

These data were created in 2008. Collection and maintenance is ongoing.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Data are provided by the Federal government and may not be inclusive of all Federal Protected lands

Distribution

Must identify Land tenure to fulfill requirements under the FIM.

Contact Information

Ministry of Natural Resources,
Crown Parcel Specialist
(705)-755-2219
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Feeding Area Fish

Description

A Fish Feeding Area is a polygon feature that identifies an area where a fish species habitually feeds.

Currency

These data were collected over a time period range from 1997 to 2005. Data are collected on an on-going basis therefore the data potentially can be current later than 2005.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Feeding Area information is considered sensitive, and as such has restrictions placed on access, especially for public distribution. This Information holding is not to be used for Legal Purposes.

Caveat:

Data for this information holding varies by OMNR District in terms of:

- Completeness:
  - Concentrated surveys in one or more areas of the District.
  - Instances where no surveys were initiated, even though there is evidence of the value.
  - Instances where the value is not known to exist within the District.
  - Instances where attributes collected for the value will be minimal to verbose.
  - The data may exist only in a tabular form (files, hardcopy maps) within the District.
- Accuracy:
  - Dependant on the value's source capture methodology.
  - G.P.S. coordinates vs. sketched location, various map base sources.
  - Generalized location (buffered point) vs. mapped area (polygon)
- Vintage:
  - New vs. old value survey information for values in part(s) or all of the District.
- Sensitivity:
  - Some OMNR Districts may consider a specific value or group of values sensitive, others may not.
  - Some of the values may be flagged as sensitive due to intellectual copyright. (i.e.: Professional Research).
  - The value may be flagged as sensitive due to its link or relation to First Nation Peoples.
- Please refer to this same section within the OMNR District's version of this record for specific use constraints details.

Distribution

Depending on any sensitivity or security issues associated with this information holding, all, some or none of the information may be available for viewing or distribution. All data requests are channeled through the Ministry of Natural Resources' Information Access Services. Information Access Services, (IAS) is responsible for providing access to a number of MNR products and services to support Ministry Goals and Objectives. IAS develops and administers policy relating to access, valuing and pricing of MNR information and protection of intellectual property.

Signed Licenses and Agreements may be required.

Refer to the Distribution Contact details for information on how to contact Information Access Services with your request.
Some Information Holdings may be available for internet/online viewing - Free of charge through the Ontario Land Information Warehouse. Follow the link provided under Online Distribution Browsing to find out if this information holding is available for online viewing.

Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Feeding Area Wildlife

Description

A Wildlife Feeding Area is a polygon feature that identifies an area where a wildlife species habitually feeds.
Different Wildlife Feeding Area types collected by the Natural Resources Values Information System (NRVIS) include:

- Bald Eagle Feeding Area
- Beaver Feeding Area
- Golden Eagle Feeding Area
- Osprey Feeding Area

Currency

These data were collected over a time period range from 1997 to 2005. Data are collected on an on-going basis therefore the data potentially can be current later than 2005.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Feeding Area information is considered sensitive, and as such has restrictions placed on access, especially for public distribution. This Information holding is not to be used for Legal Purposes.

Caveat:

Data for this information holding varies by OMNR District in terms of:

- Completeness:
  - Concentrated surveys in one or more areas of the District.
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  - The data may exist only in a tabular form (files, hardcopy maps) within the District.
- Accuracy:
  - Dependant on the value's source capture methodology.
  - G.P.S. coordinates vs. sketched location, various map base sources.
  - Generalized location (buffered point) vs. mapped area (polygon)
- Vintage:
  - New vs. old value survey information for values in part(s) or all of the District.
- Sensitivity:
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- Please refer to this same section within the OMNR District's version of this record for specific use constraints details.

Distribution

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may be available for viewing or distribution. All data requests are channeled through the Ministry of Natural Resources' Information Access Services. Information Access Services, (IAS) is responsible for providing access to a number of MNR products and services to support Ministry Goals and Objectives. IAS develops and administers policy relating to access, valuing and pricing of MNR information and protection of intellectual property.
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Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Traditional Land Use Area

Description

A Traditional Land Use Area is a polygon feature that identifies an area commonly used for both current and past human activities that are deemed worthy of special consideration. These areas are not officially recognized, but may be located on the basis of local common knowledge.

Different Traditional Land Use Area types collected by the Natural Resources Values Information System (NRVIS) include:

- Bear Baiting Stations
- Berry Picking Area
- Birdwatching Site
- Lookout
- Lookout, Potential
- Semi-Permanent Structure
- Traditional Fishing Area
- Traditional Hunting Grounds
- Viewpoint, Potential
- Viewscape

Currency

These data were collected over a time period range from 1997 to 2005. Data are collected on an on-going basis therefore the data potentially can be current later than 2005.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Some of the Traditional Land Use Area information may be considered sensitive, and as such may have restrictions placed on access. This Information holding is not to be used for Legal Purposes.

Caveat:

Data for this information holding varies by OMNR District in terms of:

- Completeness:
  - Concentrated surveys in one or more areas of the District.
  - Instances where no surveys were initiated, even though there is evidence of the value.
  - Instances where the value is not known to exist within the District.
  - Instances where attributes collected for the value will be minimal to verbose.
  - The data may exist only in a tabular form (files, hardcopy maps) within the District.
- Accuracy:
  - Dependant on the value's source capture methodology.
  - G.P.S. coordinates vs. sketched location, various map base sources.
  - Generalized location (buffered point) vs. mapped area (polygon)
- Vintage:
  - New vs. old value survey information for values in part(s) or all of the District.

- Sensitivity:
  - Some OMNR Districts may consider a specific value or group of values sensitive, others may not.
  - Some of the values may be flagged as sensitive due to intellectual copyright. (i.e.: Professional Research).
  - The value may be flagged as sensitive due to its link or relation to First Nation Peoples.
- Please refer to this same section within the OMNR District's version of this record for specific use constraints details.

Distribution

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Signed Licenses and Agreements may be required.

Refer to the Distribution Contact details for information on how to contact Information Access Services with your request.

Some Information Holdings may be available for internet/online viewing - Free of charge through the Ontario Land Information Warehouse. Follow the link provided under Online Distribution Browsing to find out if this information holding is available for online viewing.

Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Water Power Generation Station

Description

The Waterpower Generation Station data set is a point coverage. To identify the location of waterpower generation stations and provide general information about the site including the equipment associated with the waterpower generation station.

Currency

These data were created in 2001, with updates as needed.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

None

Distribution

FIPPA must be considered when data are distributed.

Under the Lakes and Rivers Improvement Act, the Minister may request authority for holding.

Contact Information

Ministry of Natural Resources,
Land Information Ontario
Information Management Specialist
(705)-755-1518
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Wintering Area

Description

A Wintering Area is a polygon feature that identifies an area in which a species habitually winters.
Different Wintering Area types collected by the Natural Resources Values Information System (NRVIS) include:

- Bat Hibernaculum
- Caribou Wintering Area
- Deer Wintering Area (Stratum 2)
- Deer Wintering Area (Stratum 1)
- Elk Wintering Area
- Moose Early Wintering Area
- Moose Late Wintering Area
- Snake Hibernaculum
- Waterfowl Winter Concentration Area

Currency

These data were collected over a time period range from 1997 to 2006. Data are collected on an on-going basis therefore the data potentially can be current later than 2006.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Some of the Wintering Area information may be considered sensitive, and as such may have restrictions placed on access. This Information holding is not to be used for Legal Purposes.

Caveat:

Data for this information holding varies by OMNR District in terms of:

- Completeness:
  - Concentrated surveys in one or more areas of the District.
  - Instances where no surveys were initiated, even though there is evidence of the value.
  - Instances where the value is not known to exist within the District.
  - Instances where attributes collected for the value will be minimal to verbose.
  - The data may exist only in a tabular form (files, hardcopy maps) within the District.
- Accuracy:
  - Dependant on the value's source capture methodology.
  - G.P.S. coordinates vs. sketched location, various map base sources.
  - Generalized location (buffered point) vs. mapped area (polygon)
- Vintage:
  - New vs. old value survey information for values in part(s) or all of the District.
- Sensitivity:
  - Some OMNR Districts may consider a specific value or group of values sensitive, others may not.

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- The value may be flagged as sensitive due to its link or relation to First Nation Peoples.
- Please refer to this same section within the OMNR District's version of this record for specific use constraints details.

Distribution

Depending on any sensitivity or security issues associated with this information holding, all, some or none of the information may be available for viewing or distribution. All data requests are channeled through the Ministry of Natural Resources' Information Access Services. Information Access Services, (IAS) is responsible for providing access to a number of MNR products and services to support Ministry Goals and Objectives. IAS develops and administers policy relating to access, valuing and pricing of MNR information and protection of intellectual property.

Signed Licenses and Agreements may be required.

Refer to the Distribution Contact details for information on how to contact Information Access Services with your request.

Some Information Holdings may be available for internet/online viewing - Free of charge through the Ontario Land Information Warehouse. Follow the link provided under Online Distribution Browsing to find out if this information holding is available for online viewing.

Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Spawning Area

Description

A Spawning Area is a polygon feature that identifies an area where a species of fish habitually spawns.

Currency

These data were collected over a time period range from 1997 to 2006. Data are collected on an on-going basis therefore the data potentially can be current later than 2006.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

These datasets are highly sensitive information and should not be available for public distribution. This Information holding is not to be used for Legal Purposes.

Caveat:

Data for this information holding varies by OMNR District in terms of:

- Completeness:
  - Concentrated surveys in one or more areas of the District.
  - Instances where no surveys were initiated, even though there is evidence of the value.
  - Instances where the value is not known to exist within the District.
  - Instances where attributes collected for the value will be minimal to verbose.
  - The data may exist only in a tabular form (files, hardcopy maps) within the District.
- Accuracy:
  - Dependant on the value's source capture methodology.
  - G.P.S. coordinates vs. sketched location, various map base sources.
  - Generalized location (buffered point) vs. mapped area (polygon)
- Vintage:
  - New vs. old value survey information for values in part(s) or all of the District.
- Sensitivity:
  - Some OMNR Districts may consider a specific value or group of values sensitive, others may not.
  - Some of the values may be flagged as sensitive due to intellectual copyright. (i.e.: Professional Research).
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Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Staging Area Fish

Description

A Fish Staging Area is a polygon feature that identifies an area where a fish species rests during migration.

Currency

These data were collected over a time period range from 1997 to 2006. Data are collected on an on-going basis therefore the data potentially can be current later than 2006.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Staging Area information is considered highly sensitive, and as such has restrictions placed on access and is not available for public distribution This Information holding is not to be used for Legal Purposes.

Caveat:

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- Accuracy:
  - Dependant on the value's source capture methodology.
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- Vintage:
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Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Staging Area Wildlife

Description

A Wildlife Staging Area is a polygon feature that identifies an area where a wildlife species rests during migration.
Different Staging Area types collected by the Natural Resources Values Information System (NRVIS) include:

- Deer Staging Area
- Hawk/Owl Staging Area
- Monarch Butterfly Staging Area
- Polar Bear Staging/Concentraion Area
- Waterfowl Staging Area

Currency

These data were collected over a time period range from 1998 to 2005. Data are collected on an on-going basis therefore the data potentially can be current later than 2005.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Staging Area information is considered highly sensitive, and as such has restrictions placed on access and is not available for public distribution This Information holding is not to be used for Legal Purposes.
Caveat:
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- Accuracy:
  - Dependant on the value's source capture methodology.
  - G.P.S. coordinates vs. sketched location, various map base sources.
  - Generalized location (buffered point) vs. mapped area (polygon)
- Vintage:
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Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Nesting Sites

Description

A Nesting Site is a point feature that identifies the location of one or more nests that belong to a particular species.

ARCTIC TERN	LOGGERHEAD SHRIKE
BALD EAGLE	MERLIN
BIRD POPULATIONS	NESTING
BIRDS	NESTS
BLACK TERN	OSPREY
COLONIES	OWLS
COMMON BARN OWL	PEREGRINE FALCON
COMMON LOON	PILEATED WOODPECKER
COOPERS HAWK	PIPING PLOVER
DUCKS	RAPTORS
EAGLES	RED ALDER
EASTERN BLUEBIRD	RED NECKED GREBE
GEESE	RED SHOULDERED HAWK
GOLDEN EAGLE	RED TAILED HAWK
GREAT BLUE HERON	RED-HEADED WOODPECKER
GREAT GRAY OWL	RING BILLED GULL
GREAT GREY OWL	SANDHILL CRANE
GULLS	SNOW GOOSE
HAWKS	TERNS
HERONS	TRUMPETER SWAN
TURTLES	TUNDRA SWAN

Currency

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Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Some of the Nesting Site information may be considered sensitive, and as such may have restrictions placed on access. This Information holding is not to be used for Legal Purposes.

Caveat:

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- Completeness:
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- The data may exist only in a tabular form (files, hardcopy maps) within the District.

- Accuracy:
  - Dependant on the value's source capture methodology.
  - G.P.S. coordinates vs. sketched location, various map base sources.
  - Generalized location (buffered point) vs. mapped area (polygon)
- Vintage:
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- Sensitivity:
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Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Nursery Area Fish

Description

A Fish Nursery Area is a polygon feature that identifies an area where a fish species raises its newborn, if that area is different from the Spawning Area.

AMERICAN EEL	LAKE WHITEFISH
ATLANTIC SALMON	LARGEMOUTH BASS
AURORA TROUT	LONGNOSE SUCKER
BLACK BULLHEAD	MUSKELLUNGE
BROOK TROUT	NORTHERN BOBWHITE
BROWN BULLHEAD	NORTHERN HOG SUCKER
BROWN TROUT	NURSERIES
BURBOT	NURSERY
CATOSTOMIDAE (FISH FAMILY)	NURSERY MANAGEMENT
CATOSTOMUS COMMERSONI	PINK SALMON
CENTRARCHIDAE	RAINBOW SMELT
CHANNEL CATFISH	RAINBOW TROUT
CHINOOK SALMON	ROUND WHITEFISH
COHO SALMON	SAUGER
COMMON CARP	SEA LAMPREY
GRASS PICKEREL	SHORTHEAD RED HORSE
ICTALURIDAE	SMALLMOUTH BASS
LAKE HERRING	SPLAKE
LAKE STURGEON	STURGEON
LAKE TROUT	WALLEYE
YELLOW PERCH	WHITE SUCKER
YELLOW BULLHEAD	

Currency

These data were collected over a time period range from 1997 to 2006. Data are collected on an on-going basis therefore the data potentially can be current later than 2005.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Nursery Area information is considered highly sensitive, and as such has restrictions placed on access and is not available for public distribution. This Information holding is not to be used for Legal Purposes.

Caveat:

Data for this information holding varies by OMNR District in terms of:

- Completeness:

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- The data may exist only in a tabular form (files, hardcopy maps) within the District.

- Accuracy:
  - Dependant on the value's source capture methodology.
  - G.P.S. coordinates vs. sketched location, various map base sources.
  - Generalized location (buffered point) vs. mapped area (polygon)
- Vintage:
  - New vs. old value survey information for values in part(s) or all of the District.
- Sensitivity:
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  - The value may be flagged as sensitive due to its link or relation to First Nation Peoples.
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Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Conservation Lands non-MNR

Description

Shape files of Conservation Lands non-MNR in ecoregions 6E and 7E of Ontario. Note that this is a dataset of unknown quality. Conservation Lands are land held by public and private agencies for the purpose of ongoing conservation of natural heritage values.

Currency

These data were created in 2008 and has an irregular maintenance cycle.

Format

The data are available as a GIS Shapefile

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Internal use only. This dataset's quality is unknown as is complete for ecoregions 6E & 7E of Ontario only.

Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Ministry of Natural Resources,
Mr Dave Ferguson – Information Management Coordinator
F&W Program
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Conservation Lands Regulated

Description

Land set aside under the Provincial Parks and Conservation Reserves Act, 2006:

1. To permanently protect representative ecosystems, biodiversity and provincially significant elements of Ontario's natural and cultural heritage and to manage these areas to ensure that ecological integrity is maintained.
2. To provide opportunities for ecologically sustainable land uses, including traditional outdoor heritage activities and associated economic benefits.
3. To facilitate scientific research and to provide points of reference to support monitoring of ecological change on the broader landscape.

Currency

These data were collected over a time period range from 1994 to 2008. First conservation reserve regulated in 1994 and most recent package of regulations was gazetted on June 9, 2008. The collection is complete and updated as needed.

Format

GIS Database - NRVIS

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Conservation reserve boundaries are open to the public.

Distribution

These data are made available through Ontario Land Information Warehouse though Ontario Geographic Data Exchange (OGDE)

Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Ministry of Natural Resources,
Mr. Louis Chora
Information Management Specialist
(705)-755-5965

Constraint/Consideration

Cottage Residential Area

Description

A Cottage Residential Area is a polygon feature that identifies an area of dwellings having an official designation and is often represented by a cottager and/or residential association. The occupancy may be seasonal or year-round.

Different Cottage Residential Area types collected by the Natural Resources Values Information System (NRVIS) include:

- Cottage Area, Not Remote
- Cottage Area, Proposed, Not Remote
- Cottage Area, Proposed, Remote
- Cottage Area, Remote
- Residential Area, Not Remote
- Residential Area, Remote.

Currency

These data were collected over a time period range from 1997 to 2006. Data are collected on an on-going basis therefore the data potentially can be current later than 2005.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Nursery Area information is considered highly sensitive, and as such has restrictions placed on access and is not available for public distribution. This Information holding is not to be used for Legal Purposes.

Caveat:

Data for this information holding varies by OMNR District in terms of:

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  - Instances where the value is not known to exist within the District.
  - Instances where attributes collected for the value will be minimal to verbose.
  - The data may exist only in a tabular form (files, hardcopy maps) within the District.
- Accuracy:
  - Dependant on the value's source capture methodology.
  - G.P.S. coordinates vs. sketched location, various map base sources.
  - Generalized location (buffered point) vs. mapped area (polygon)
- Vintage:
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- Sensitivity:
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Distribution

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Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Crown Game Preserves

Description

Crown Game Preserves are polygon features that were established to prohibit or regulate the hunting and trapping of wildlife in specific areas in order to restore local populations

Currency

These data were created in 1998 and updated as needed, although the collection is considered complete.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 10m

Usage Restrictions/Disclaimers

Use Constraints

Not for legal purposes. These data are collected with varying aerial photography dates and scales. It is a snap shot in time and maintenance of these features are uncertain.

Distribution

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Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Areas of Natural and Scientific Interest (ANSI)

Description

ANSI's (Areas of Natural and Scientific Interest) are polygon features that represent lands and waters containing important natural landscapes or features that are important for natural heritage, protection, appreciation, scientific study or education.

Different ANSI types collected by the Natural Resources Values Information System (NRVIS) include:

- ANSI, Earth Science
- ANSI, Life Science

Currency

These data were collected over a time period range from 1997 to 2009. Data are collected on an on-going basis therefore the data potentially can be current later than 2005.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Some of the ANSI Data Types may be considered sensitive and as such may have restrictions placed on access. This Information holding is not to be used for Legal Purposes.

Caveat:

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Distribution

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Information Access Services. Information Access Services, (IAS) is responsible for providing access to a number of MNR products and services to support Ministry Goals and Objectives. IAS develops and administers policy relating to access, valuing and pricing of MNR information and protection of intellectual property.
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Contact Information

Ministry of Natural Resources,
Land Information Ontario – Support
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Ministry of Natural Resources,
Land Information Ontario
Mrs. Monique Yolanda Kuyvenhoven
GIS Analyst
Email:monique.kuyvenhoven@mnr.gov.on.ca
(705)-755-1831

Constraint/Consideration

Aquatic Feeding Area

Description

A Natural Resources Values Information System (NRVIS) Data Class and Geographic Unit Types:
Moose Aquatic Feeding Area
Aquatic Feeding Area

Currency

These data were collected over a time period range from 1997 to 1999. Data are collected on an on-going and maintained on an as needed basis.

Format

The data are available as a GIS database NRVIS

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints
Quality of the dataset is suitable
Distribution
Sharing of this dataset is at the discretion of the Ontario Geospatial Data Exchange Administrator.

Contact Information

Ministry of Natural Resources,
Ontario Geospatial Data Exchange Administrator.
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Aquatic Resource Area Summary

Description

Description of the physical characteristics and fish species of lakes rivers or streams and links to more detailed external fish survey information for that waterbody. This attribute information for ARA Summary is contained in a consolidation class that does not have its own geographic representation. Instead ARA Summary is represented spatially by existing classes, the Water Segment (Poly and Line) data classes, via a unique ID. Since spatial information does not exist for this ARA class, edits can only be made to attribute information. The information in ARA Summary is based on a combination of many sources, including ARA Survey Point information. A body of water should have one record containing ARA summary information and may have zero to many ARA Survey Point data locations, the data of which may have been rolled up into the ARA Summary Information. The ARA summary and survey layers are linked through use of the 'ARA Identifier' attribute.

Currency

Data layer was implemented spring 2009. It is anticipated that data will be added to this class on an ongoing basis.

Format

Unknown

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Not for legal purposes

Distribution

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Contact Information

Ministry of Natural Resources,
Ontario Geospatial Data Exchange Administrator.
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Ministry of Natural Resources,
Ms Helen Ball – Aquatic Ecologist
(705)-755-2113

Constraint/Consideration

Aquatic Resource Area Summary

Description

Description of the physical characteristics and fish species that pertain to one survey location on a waterbody (lake, river or stream). Each survey is characterized by a single point with associated attributes, and may be representative of a portion of a water body or an entire waterbody (lake, river or stream). The information in ARA Survey Point is used to update the ARA Summary layer. Every ARA Survey Point must be associated with an ARA summary. The ARA summary and survey layers are linked through use of the 'ARA Identifier' attribute.

Currency

Data layer was implemented spring 2009. It is anticipated that data will be added to this class on an ongoing basis.

Format

Unknown

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal accuracy +/- 500m

Usage Restrictions/Disclaimers

Use Constraints

Full read access will only be granted to users that have undergone Data Sensitivity Training

Not for legal purposes

Distribution

Depending on any sensitivity or security issues associated with this information holding, all, some or none of the information may be available for viewing or distribution. All data requests are channeled through the Ministry of Natural Resources' Information Access Section. Information Access Section, (IAS) is responsible for providing access to a number of MNR products and services to support Ministry Goals and Objectives. IAS develops and administers policy relating to access, valuing and pricing of MNR information and protection of intellectual property. Signed Licenses and Agreements may be required. Refer to the Distribution Contact details for information on how to contact Information Access Services with your request.Some Information Holdings may be available for internet/online viewing - Free of charge through the Ontario Land Information Warehouse.

Contact Information

Ministry of Natural Resources,
Ontario Geospatial Data Exchange Administrator.
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Ministry of Natural Resources,
Ms Helen Ball – Aquatic Ecologist
(705)-755-2113

Constraint/Consideration

Parcel Mapping

Description

The packaged product may contain the following data depending upon the geographic location: assessment parcels, Crown parcels and/or Ownership parcels, as well as background information such as registered plans, roads, water bodies, township fabric, etc.

The data are packaged by Land Registry Office boundaries. In the geographic areas were the ownership data are available, the Crown parcel was not built, and is only available on a day forward basis. Updates are provided in blocks.

The supporting data provided depends upon the parcel data that is available. In those areas where the Assessment and the Crown parcel data were mapped and are available, the supporting data consists of the following: township fabric limits and text, road names, village names, digitized data, water body limits, and water body names. In those areas where the Ownership data exists the supporting data consists of any of the following: township limits and text, subdivision and municipal plan limits and text, reference plan limits and text, other plan limits and text, road names, easements and rights of way limits and text, natural resource parcel limits, village names, natural resource parcel centroids, condominium plans limits and descriptions, leasehold parcel limits, waterbody limits and names, political boundary limits and descriptions, leasehold parcel centroids, Indian reserve limits and names, ground control line work and points, connected fabric line work, railway lands names, municipal plan text, and strata centroids.

For more information on each layer refer to the metadata for assessment parcels, Crown parcels and ownership parcel.

Currency

These data were collected over a time period range from 1960 to 2004 (range is an estimate). Data are collected on an on-going basis at a maintenance quarterly maintenance frequency, therefore the data potentially can be current later than 2004

Format

Database

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Not applicable

Usage Restrictions/Disclaimers

Use Constraints

None

Distribution

None

Contact Information

Ministry of the Environment
Mr. Patrick Spezowka - Supervisor
(519)-873-5043
Email: idorienne.cushman@ontario.ca

Constraint/Consideration

Permit to Take Water

Description

The Permit to Take Water Database contains information collect from the Ministry of Environment's Permit to Take Water Program. Under this program the Ministry issues permits for water takings that exceed 50,000 Litres a day in accordance with the Ontario Water Resource Act. Full details can be found on the Ministry of Environment's Permit to Take Water Website.

Currency

Data layer was created 2009 and updated bi-annually

Format

AutoCAD packaged product v12

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Not applicable

Usage Restrictions/Disclaimers

Use Constraints

The data should not be used for legal purposes. The availability of the ownership and Crown parcel data are dependent upon the geographic location. Some List Users may be restricted access to data outside their own jurisdiction.

Distribution

MNR and MNR List Users can access the parcel data through the LIO warehouse. Eligible organizations must enter into a MNR List User Licence agreement and become members of the Ontario Geospatial Data Exchange (OGDE). MNR is licensed through the Ontario Parcel Master Agreement. Some List Users may be restricted to their own jurisdiction.

Contact Information

Ministry of Natural Resources,
Ontario Geospatial Data Exchange Administrator.
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Ministry of Natural Resources
Ms Carla Jordan-Cooke
Project Manager
(705)-755-1878

Constraint/Consideration

Ontario In-filled Climate Data

Description

Climate records frequently have missing data within the complete climate record. These gaps may be short term in nature (over a number of days due to equipment malfunction), or long term (over a period of years, due to station closures). Daily climate records typically have fewer gaps than hourly records, and are usually associated with stations closures. Hourly datasets typically contain more significant gaps, and are usually associated with equipment malfunction or seasonal closings. Schroeter, et. al. (2000) found that many hourly datasets are missing over 4013656700f the dataset. Missing data can be estimated, or “filled in”, using nearby climate stations to create a continuous dataset before completing hydrologic modelling tasks.

The MNR contracted Schroeter to infill daily and hourly datasets for climate stations within the Province of Ontario within the time period of 1950 to 2005. Sources of data used for this project included primarily
Environment Canada's Atmospheric Environment Service (AES) climate stations in addition to some stations maintained by Conservation Authorities.. As many as 1400 stations were considered.

The Ontario In-filled Climate Data packaged product contains 8 databases containing filled temporal data gaps. These filled data gaps include both daily and hourly precipitation and temperature records. The database 'Ontario Daily In-filled Climate Data.mdb' contains the daily climate parameters for the 339 major AES stations having filled in parameters during the period of 1950 to 2005. The remaining 7 databases contain a table containing hourly rainfall records for stations during the same period, which are divided into regions for manageability. Database format is MS Access 2000.

Currency

These data were collected over a time period range from 1950 to 2005. Data are complete for this time period.

Format

Tabular Database: MS Access 2000

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Not applicable

Usage Restrictions/Disclaimers

Use Constraints

It should be noted that with all climate data, there will exist erroneous or biased values within the dataset. These values may be affected by equipment malfunction/vandalism, or improper station siting/operation. The users of this climate data should exercise caution when utilizing this data, and be aware that discrepancies still exist..

Distribution

None

Contact Information

Ministry of Natural Resources,
Laura Landriault,
Water Budget Program Analyst
(705)-755-3189
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration
Bathymetry Line
Description
A continuous line formed of vertices indicating the same measurement of water depth at various places in a body of water.
Currency
This data was created in 2006 and continually updated.
Format
Unknown/ Shapefile
Connection Mechanisms
FTP file download or CD-Rom delivery
Data Quality
Horizontal +/- 10 m Precise Vertical +/- 5 m Reliable
Usage Restrictions/Disclaimers
Use Constraints Bathymetry line data are only available to Ontario Geographic Data Exchange (OGDE) members. Not to be used for navigational purposes **Distribution** None
Contact Information
Ministry of Natural Resources Ms Carla Jordan-Cooke Project Manager -GIM (705)-755-1451 Email:carla.jordan-cooke@mnr.gov.on.ca

Constraint/Consideration
Bathymetry Point
Description
Points indicating the measurement of water depth at various places in a body of water.
Currency
These data were created in 2006 and continually updated.
Format
Unknown/ Shapefile
Connection Mechanisms
FTP file download or CD-Rom delivery
Data Quality
Horizontal +/- 100 m Reliable Vertical +/- 5 m Reliable
Usage Restrictions/Disclaimers
Use Constraints Bathymetry point data are only available to Ontario Geographic Data Exchange (OGDE) members. Not to be used for navigational purposes **Distribution** None
Contact Information
Ministry of Natural Resources Ms Carla Jordan-Cooke Project Manager -GIM (705)-755-1451 Email:carla.jordan-cooke@mnr.gov.on.ca

Constraint/Consideration
Beaver Dam
Description
Linear features constructed by beavers. A beaver dam is a layered construction, consisting of sticks, mud and stones.
Currency
These data were collected over a time period range from 1976 to 1996 and has an irregular update cycle.
Format
GIS Database NRVIS
Connection Mechanisms
FTP file download or CD-Rom delivery
Data Quality
Horizontal +/- 5 m Reliable Vertical +/- 5 m Reliable
Usage Restrictions/Disclaimers
Use Constraints Not to be used for legal purposes. These data are collected with varying aerial photgraphy dates and scales. It is a snap shot in time and maintenance of these features are uncertain. Since water levels may vary significantly within a year, and/or year to year, the presence or absence of fallls, rapids or, rocks depicted on an OBM map should in no way be relied on exclusively. They are captured for reference purposes only. **Distribution** None
Contact Information
Ministry of Natural Resources, Ontario Geospatial Data Exchange Administrator. (705)-755-1878 Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration

Camp, Recreation

Description

A Recreation Camp is a polygon feature that identifies an area used for commercial tourist operations with a focus on outdoor activities other than hunting and fishing.

Different Recreation Camp types collected by the Natural Resources Values Information System (NRVIS) include:

- Recreation Camp
- Youth Camp

Currency

These data were collected over a time period range from 1997 to 2006 and is maintained as needed.

Format

The data are available as a GIS Shapefile, ArcInfo e00, and ArcInfo coverage

Connection Mechanisms

FTP file download or CD-Rom delivery

Data Quality

Horizontal +/- 500 m

Usage Restrictions/Disclaimers

Use Constraints

Not for Legal Purposes.

Data for this information holding varies by OMNR District in terms of:

- Relevance: no evidence of the value found within geographic extent of District.
- Completeness: concentrated surveys in one or more areas of the District, or perhaps not at all - even though there may be evidence of the value.
- Accuracy: Depending on the data's source. (ie: Methodologies such as GPS locations vs. Hand drawn-maps)
- Vintage: New vs. old survey information.

Please refer to this same section within the OMNR District's version of this record for specific use constraints details.

Distribution

Some of the Recreation Camp information may be considered sensitive, and as such may have restrictions placed on access.

Contact Information

Ministry of Natural Resources,
Ontario Geospatial Data Exchange Administrator.
(705)-755-1878
Email: info-Access@webmail.mnr.gov.on.ca

Constraint/Consideration
Dam and Barrier
Description
A feature representing an obstacle that disturbs or impedes the flow of surface water, excluding beaver dams, water crossings and culverts.
Currency
These data were collected over a time period range from 1990 to 2010 and is continually maintained.
Format
The data are available as a GIS Shapefile, Access database
Connection Mechanisms
FTP file download or CD-Rom delivery
Data Quality
Horizontal location accuracy varies. Location accuracy is based on established LIO location accuracy levels that are assigned to a dam/barrier object during object creation or during the time of spatial review.
Usage Restrictions/Disclaimers
Use Constraints Not for Legal Purposes. Individuals/Organizations must belong to a LIO data exchange **Distribution** Some of the Recreation Camp information may be considered sensitive, and as such may have restrictions placed on access.
Contact Information
Ministry of Natural Resources, Ontario Geospatial Data Exchange Administrator. (705)-755-1878 Email: info-Access@webmail.mnr.gov.on.ca Ministry of Natural Resources, Leslie Demal (705)-755-1806 Email: info-Access@webmail.mnr.gov.on.ca

AECOM

Trent Severn Waterway

Water Management Study

Review of Water Management Systems and Models

Parks Canada Parcs Canada

Canada

Water AECOM

Parks Canada

Trent Severn Waterway: Water Management Study
Review of Water Management Systems and Models

Prepared by:

AECOM
50 Sportsworld Crossing Road, Suite 290 519.650.5313 tel
Kitchener, ON, Canada N2P 0A4 519.650.3424 fax
www.aecom.com

Project Number:

60150039

Date:

April, 2011

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- was prepared for the specific purposes described in the Report and the Agreement
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AECOM
50 Sportsworld Crossing Road, Suite 290 519.650.5313 tel
Kitchener, ON, Canada N2P 0A4 519.650.3424 fax
www.aecom.com

April 29, 2011

Roger Stanley
Director of Operations (Acting) – Trent Severn Waterway
Parks Canada
P.O. Box 567
Peterborough, Ontario, K9J 6Z6

Dear Mr. Stanley:

Project No: **60150039**

Regarding: **Trent Severn Waterway: Water Management Study**
Review of Water Management Systems and Models

We are pleased to submit ten (10) paper copies of the Review of Water Management Systems and Models, the second report of the Trent Severn Waterway: Water Management Study

If you have any questions or would like to request additional information regarding this submittal, please contact the undersigned at (519) 650-8696.

Sincerely,
AECOM Canada Ltd.

Jeff Prince, P.Eng.
Senior Project Manager, Water
Jeff.Prince@aecom.com

JP:jp

Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	AJM, JNB, DCA, JP	18-Feb-2011	Draft Report
2	DCA, JP	29-Apr-2011	Final Report

AECOM Signatures

Report Prepared By:

Angela J. MacLean, M.A.Sc., EIT
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Report Prepared By:

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Report Reviewed By:

Jeff Prince, P.Eng.
Senior Project Manager, Water

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Letter of Transmittal

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Appendices

1. Introduction

1.1 Study Objectives and Rationale

A common theme that resonates throughout most, if not all water management programs is the desire to contribute to and enhance the environmental, social and economic well being of the watershed through sustainable management of the water resource. Through achieving this, the benefits of the resource can be fully enjoyed by present and future generations.

It is to that end, that the objectives of the Trent Severn Waterway - Water Management Improvement Program were developed. The specific objectives include the following:

1. To understand the variables that are critical to effective water management decision making;
2. To ensure that the Agency and its water management partners have access in an accurate and timely way to the appropriate data that allows these variables to be used in making decisions;
3. To describe the current approach to water management in the form of a “Water Management Manual” that describes in considerable detail how water is managed now;
4. To validate and/or suggest improvements in how water is currently managed such that broad water management goals described above are best achieved;
5. To construct a numerical predictive tool that allows the basic operational model(s) to be readily adjusted in response to changes in critical variables; and,
6. To construct a numerical management tool, linked to real time gauging and data collection systems that allows the water manager to:
    a) Understand the current state of water levels and flows throughout the system;
    b) Predict the quantifiable impact of specific water management decisions;
    c) Document when and why specific water management decisions are taken; and,
    d) Provide agencies and individuals with internet-accessible, real time information that contributes to their operations and enjoyment of the Trent Severn Waterway and its associated reservoir lakes.

The Trent Severn Waterway: Water Management Study addresses the first four of these program objectives.

The competition for the water of the Trent Severn Waterway has always been a condition of the system’s operation. However, in recent decades, the stakeholders and variables at play as part of that competition have increased and subsequently so to have the demands and complexities of the operating environment. The following examples highlight some of the operational considerations within the Waterway:

- The Haliburton Lakes have become one of the most significant cottage regions in the province; and more recently there has been a shift toward year round residency on these lakes;
- Shoreline properties have increased in value, and with that the demands to maintain the levels of the reservoir lakes have increased;
- Cities and Towns have developed along the shorelines and have infrastructure demands to draw water from the system;
- The shores are home to thousands of businesses that rely on those that live in and visit the area;
- The societal awareness of and desire to protect the natural environment is increasing;
- There are legitimate concerns about global warming and the potential impacts of climate change; and
- Growing environmental concern has led to an interest in the potential for hydro electric power generation as a source of renewable energy.

These issues have been recently documented by the Panel on the Future of the Trent Severn Waterway in, *It's All About the Water,* and a study of the past, present and future of the waterway completed in 2007 by Ecoplans Limited.

This study is intended to build upon this work toward ensuring that water management personnel have the tools necessary to assist them in making water management decisions. These tools must ensure that management decisions are; timely, information and science based, reflect a thorough understanding of the variables, and achieve an optimal and appropriate balance of the overall water management goals.

This study represents the first phase of what could be a multi-phase endeavour towards achieving the vision and objectives of the overall Water Management Improvement Program.

This study has been organized into four components that directly correspond to the specific objectives of the Water Management Improvement Program:

- **Data Collection and Management Guide**
- **Review of Water Management Systems and Models**
- **Water Management Manual – Description of the Current Approach to Water Management**
- **Evaluation of the Current Approach to Water Management**

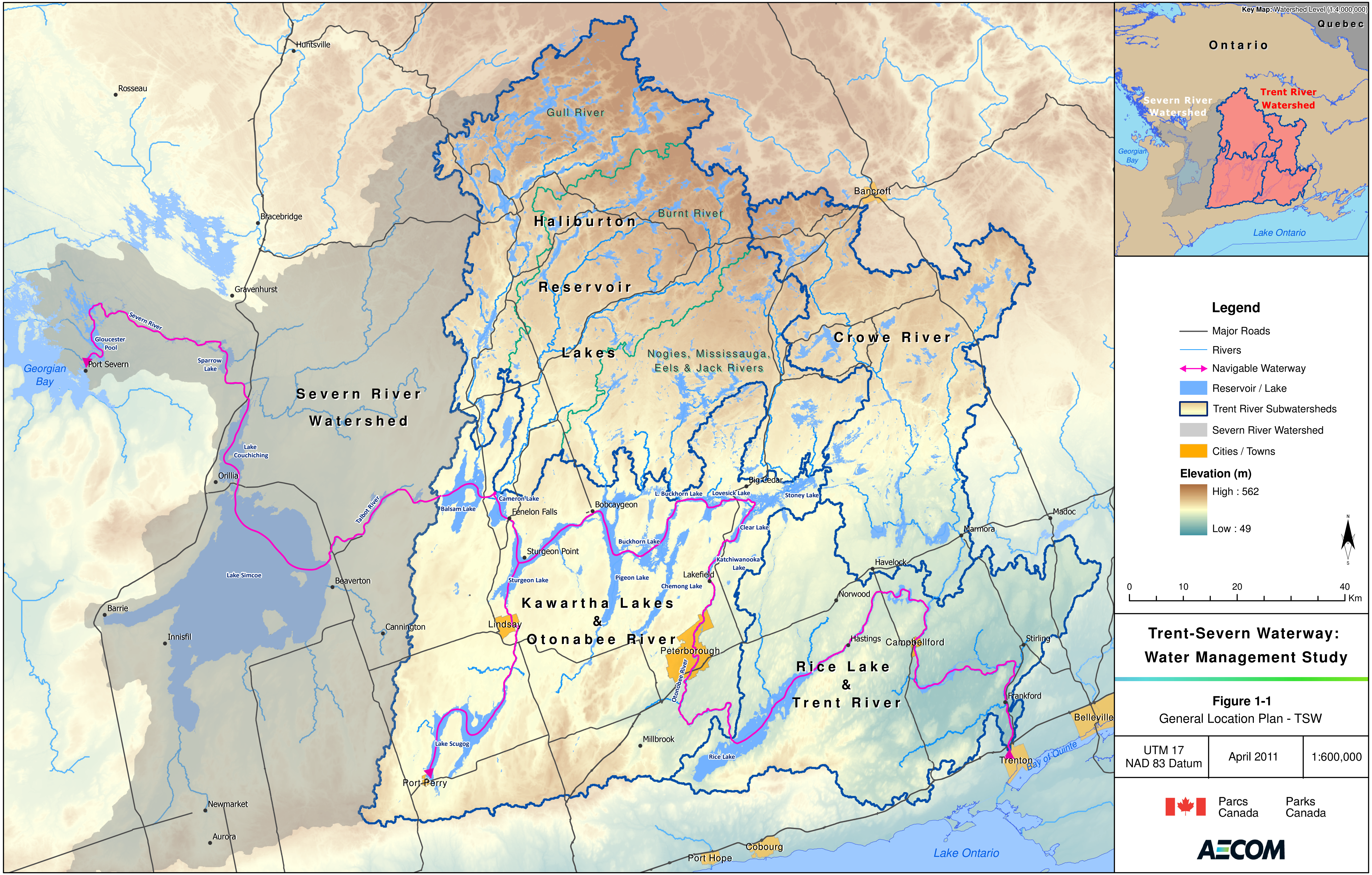
This component of the study, titled the "Review of Water Management Systems and Models" has been developed to describe the approach to water management by other systems, as well as available modeling approaches.

1.2 The Trent Severn Waterway

The Trent Severn Waterway (TSW or Waterway) is a 386km inland navigation route crossing south central Ontario, from Trenton on the Bay of Quinte to Port Severn on Georgian Bay with a total drainage area of 18,690km^2 (**Figure 1-1**). It comprises several navigable lakes and their interconnecting channels as well as many reservoir lakes. There are two watersheds within the Waterway: the Trent River Watershed and the Severn River Watershed. Although this Study concentrates only on the Trent River Watershed, both are characterized below.

The Trent River Watershed is the eastern watershed, with an area of 12,530km^2 draining to Lake Ontario. It lies in the rolling farmlands of southern Ontario. This watershed contains three (3) sub-watersheds:

- **The Reservoir Lakes** (3,320km^2) to the north consists of forty-four (44) lakes in the northern shield area that have been dammed to collect Spring runoff. Water from these lakes is released over the summer to supply the Trent component of the Waterway. These lakes are on the tributaries of the Gull, Burnt and Mississauga rivers, as well as Nogies, Eels and Jack creeks.
- The **Kawartha Lakes and the Otonabee River** (4,862km^2) that drain to Rice Lake including: Katchewanooka, Clear, Stony, Lovesick, Lower Buckhorn, Buckhorn, Chemong, Pigeon, Sturgeon, Scugog, Cameron and Balsam Lakes. These lakes are south of the Canadian Shield in rolling countryside, where rainfall runoff is usually slow and evaporation losses in the summer are high.
- **Rice Lake and the Trent River** (4,348km^2) that drain to the Bay of Quinte (Lake Ontario), including the **Crowe River** (1,894km^2) sub-watershed that drains to the Trent River at a confluence downstream of Rice Lake.


Key Map: Watershed Level (1:4,000,000)
Quebec
Ontario
Severn River Watershed
Trent River Watershed
Georgian Bay
Lake Ontario
Legend
Major Roads
Rivers
Navigable Waterway
Reservoir / Lake
Trent River Subwatersheds
Severn River Watershed
Cities / Towns
Elevation (m)
High : 562
Low : 49
0 10 20 40 Km
Trent-Severn Waterway: Water Management Study
Figure 1-1
General Location Plan - TSW
UTM 17
NAD 83 Datum
April 2011
1:600,000
Parcs Canada
Parks Canada
AECOM
Huntsville
Rosseau
Bracebridge
Gravenhurst
Severn River
Gloucester Pool
Port Severn
Georgian Bay
Sparrow Lake
Severn River Watershed
Lake Couchiching
Orillia
Talbot River
Lake Simcoe
Beaverton
Barrie
Innisfil
Cannington
Newmarket
Aurora
Gull River
Burnt River
Haliburton
Reservoir
Lakes
Nogies, Mississauga, Eels & Jack Rivers
Bancroft
Crowe River
Balsam Lake
Cameron Lake
Fenelon Falls
Bobcaygeon
L. Buckhorn Lake
Lovesick Lake
Big Cedar
Stoney Lake
Clear Lake
Buckhorn Lake
Sturgeon Point
Sturgeon Lake
Pigeon Lake
Chemong Lake
Katchiwanooka Lake
Lakefield
Kawartha Lakes & Otonabee River
Lindsay
Peterborough
Otonabee River
Lake Scugog
Port Perry
Millbrook
Rice Lake
Rice Lake & Trent River
Havelock
Norwood
Hastings
Campbellford
Marmora
Madoc
Stirling
Frankford
Trenton
Belleville
Bay of Quinte
Port Hope
Cobourg
Lake Ontario

The Severn River Watershed lies immediately to the west of the Trent Basin and drains to Georgian Bay. This 6,160km^2 drainage area has three (3) sub-watersheds:

- The **Lake Simcoe and Lake Couchiching** sub-watershed, including the Talbot River. Most of the drainage area for this sub-watershed is in rolling farmland with deeper soils. As a result, water runoff is slow and evaporation losses from both land and lake surfaces are high. Only about 25% of the precipitation falling on this watershed eventually appears as runoff flows.
- The **Black River** sub-watershed feeds into the Severn River downstream of Lake Couchiching. This sub-watershed is characterized by the thin soils and rock of the Precambrian Shield. It is virtually unregulated and produces rapid runoff from precipitation while evaporation losses are lower. Consequently, even though the Black River sub-watershed is less than half of the area of the Simcoe-Couchiching basin, its long-term average flow is comparable. The Black River also has high peak flows during the spring period.
- The **Severn River** below Washago, including Sparrow Lake, Six Mile Lake Tea Lake, and Gloucester Pool. The natural watercourses of the Black and the Severn Rivers are constrained by numerous narrow reaches and constrictions, which are prone to increased water levels in the river and upstream flooding during high flows.

The area influenced by management of the TSW includes more than 120,000 properties as identified in a recent study (Ecoplans 2007):

- Approximately 35,000 shoreline properties in the reservoir lakes;
- More than 400 commercial operations;
- 18 power generation facilities as of this report, with several more in planning;
- Six Conservation Authorities; and
- Several tiers of government, including: 6 First Nations; 2 regional municipalities; 3 municipalities; 1 district municipality; 5 counties; 5 cities; 4 towns; and, 26 townships.

1.3 Goals and Objectives of the Trent Severn Waterway

Construction of the Trent Severn Waterway began in the late 18th century with the building of small dams and water powered mills at numerous locations throughout south-central Ontario. In the early 19th century, dams and timber slides were added to support a growing logging industry by facilitating transportation of logs from the interior of Upper Canada to the United States and Great Britain.

Key early goals for management of the Waterway were to provide navigation and to protect public safety and property. By the mid-19th century, architects of the Waterway realized that a reservoir system was required to feed water to the system in order to maintain navigation through the summer months. A series of dams in the northern part of the TSW were transferred from the Province to the Federal government in 1905 and 1906. This transfer formally recognized the need for a reservoir system and provided the means to manage and control flow from a number of water bodies that collectively could be used as a reservoir lake system. The Orders-in-Council that transferred these works explicitly acknowledged that the transfers were to benefit operation of the TSW. The Orders-in-Council also designated the water in the listed lakes and rivers as reservoirs for the Waterway.

When the reservoir lakes were conceived, there was very little permanent settlement in the Haliburton region. Since the 1930s, the Haliburton lakes have grown to become one of the most important cottage areas in Ontario. Furthermore, a recent shift from seasonal to permanent, year-round residency in the Haliburton lakes region is occurring. Associated changes in the operating environment of the Waterway include increasing trends in uses other than through navigation, economic development and commercial operations along the Waterway, as well as increasing value placed on natural ecosystems and habitats. Finally, meteorological changes have also been observed (as discussed in the "**Evaluation of the Current Approach to Water Management**"), including: increased number of heavy rainfall events of shorter duration, increasing annual precipitation in some regions and decreasing

annual precipitation in others, regional warming in some areas resulting in increased water temperatures, life cycle impacts to aquatic and wetland species and habitat changes.

These changes in the operating environment of the Trent Severn Waterway are reflected in a recent study (Ecoplans, 2007) which indicates that the present-day array of expectations and obligations are unprecedented in the history of the Waterway operations. Six Water Management Goals and associated objectives were developed in this study to capture these expectations and enhance operations. These goals and objectives are listed in **Table 1-1**.

Table 1-1 - Goals and Objectives for the Management of the Trent Severn Waterway

Water Management Goals	Objectives
Reducing threats to public safety and negative impacts to public and private infrastructure from over-bank flooding, ice damage, extreme water level fluctuations, and high volume flows	• Mitigate Flooding • Protect Infrastructure • Provide for Public Safety
Contributing to the health of Canadian through the availability of drinking water for residents, cities and towns throughout the watershed	• Manage for Water Supply (agricultural and municipal) • Manage for Water Quality (human health and aquatic life)
Providing safe boating and navigation along the marked navigation channels of the Trent Severn Waterway	• Provide Navigation
Protecting significant aquatic habitats and species	• Protect Natural Environment (wetlands, fish, wildlife, invasive species, species at risk)
Optimizing the enjoyment of the water throughout the watershed by shoreline residents and visitors	• Enhance Aesthetics • Optimize Recreation • Optimize Cultural Resources • Provide Public Access (physical access, access to information)
Allowing hydroelectric generation plants to operate at plant capacity and meet demand for renewable energy insofar as possible	• Optimize Water Power Generation

1.4 Introduction to the Water Management Process

The management of the Trent Severn Waterway to achieve these goals and objectives requires consideration of a variety of different factors, including the Waterway's mandated requirements, scientific objectives, regulatory impacts, environmental impacts, political and public concerns, as well as the day-to-day and long-term operation of the Waterway. A Water Management Process was developed through this study as a way to address this complexity and to consider the interests of the many different stakeholders. The Water Management Process is displayed in **Figure 1-2**, and describes the steps required to implement decisions with respect to the operation of the Waterway.

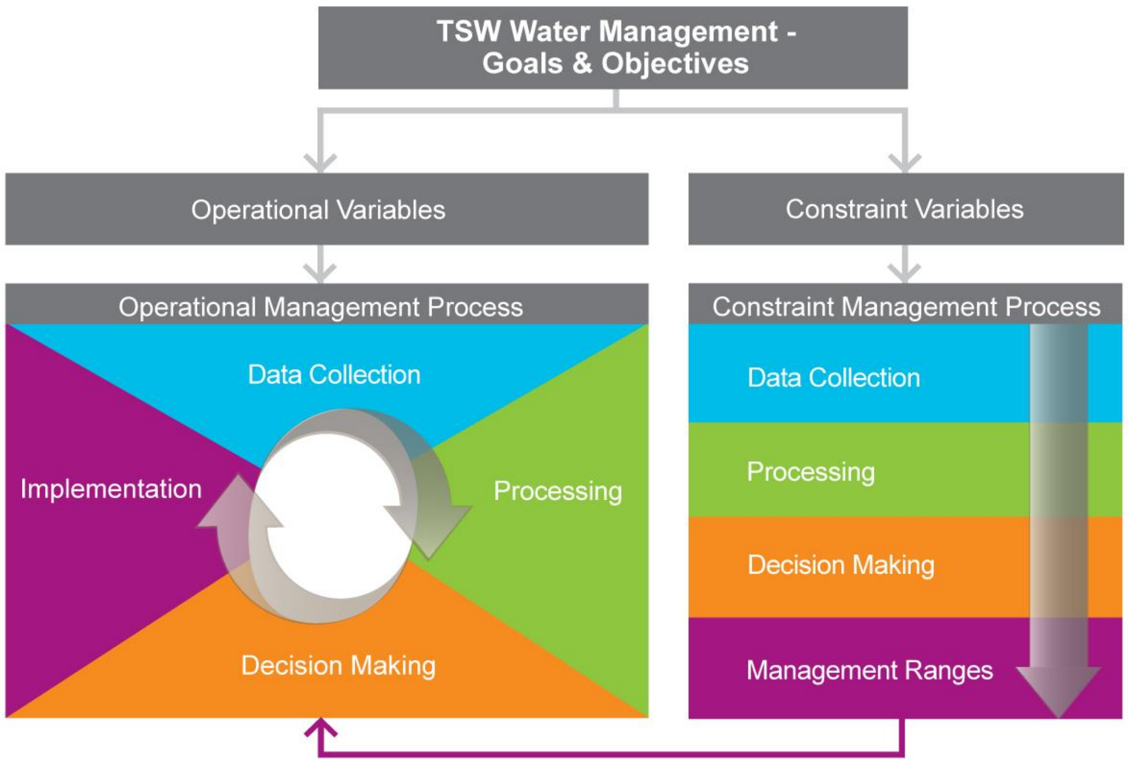


Figure 1-2 - Management Process for the Trent Severn Waterway

The Operational Management Process shown on the left side of **Figure 1-2** describes the core activities of Parks Canada staff in the operations of the TSW. These activities are implemented on a continual basis and consist of the day-to-day operations of the locks, dams and other water control structures to manage the flows and water levels in the Waterway through regular monitoring, the balancing of water between the different components of the Waterway (i.e., the Haliburton Reservoir Lakes and the Kawartha Lakes/Trent River), and the communications with staff to implement management decisions.

The Constraint Management Process shown on the right side of **Figure 1-2** describes the activities undertaken to establish the constraints, or "Management Ranges", that define the range of water levels and flows on all lakes with the aim of satisfying the goals and objectives of the Waterway in a comprehensive and balanced manner. This process includes the evaluation of a diverse array of variables that impact the goals and management of the Waterway. The frequency that the Constraint Management Process is undertaken depends on the data being evaluated; for example, the review of historic flood events and levels need only be completed once to establish the historical record, and then updated only when new events occur.

In both the Operation and Constraint Management Processes, there are three primary activities:

- **Data Collection**. The gathering of information that is applicable to either the operations (i.e., **operational variables**) or management ranges (i.e., **constraint variables**) of the Waterway.
- **Processing**. The use of processing and optimization tools to interpret the collected data and produce results appropriate for effecting operational or management/constraint changes.
- **Decision Making**. The evaluation of processing results to make operational decisions or to establish new management ranges throughout the Waterway.

These activities result in an **Implementation** decision with respect to the operation of the Waterway (i.e., increase or decrease water levels or flows at certain locations), or the establishment of a **Management Range** to consider in the processing of operational data (i.e., minimum water levels or flows for navigation in summer or fish spawning in fall).

Through the continual application of this management process, the Waterway can be effectively managed to achieve the goals and objectives of the TSW, giving due consideration to the wide range of stakeholders and users that make the Waterway the dynamic entity it is today.

1.5 Document Map

The Water Management Process introduced in **Section 1.4** provides a context upon which each of the four reports in the Water Management Study is presented. **Figure 1-3** overlays a Document Map on the Management Process (**Figure 1-2**), highlighting the different components of the Process that are described in this report as part of the study.

The **Review of Water Management Systems and Models** report evaluates other water management systems and relates them to the Operational Management Process of the TSW (as well as the Management Ranges that govern operations). In addition, computer software models are evaluated for their potential application to the TSW operations.

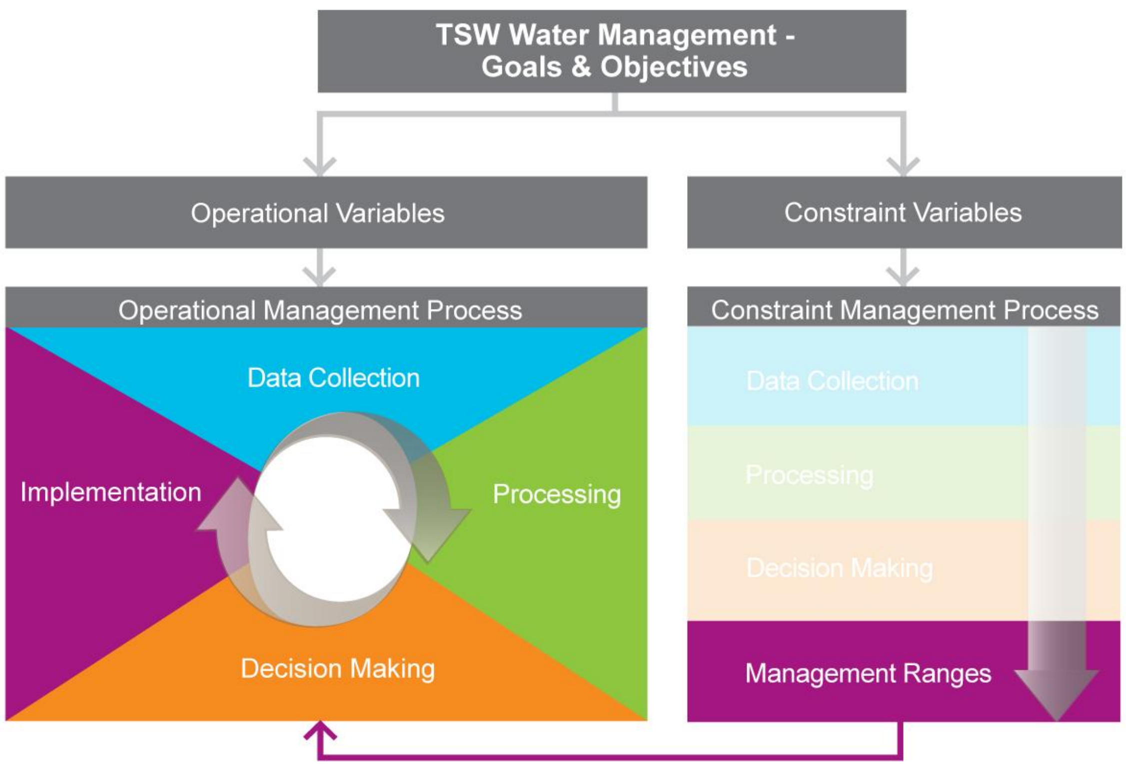


Figure 1-3 - Trent Severn Waterway: Water Management Study - Document Map

2. Water Management Systems Review

This section summarizes the approaches used by other agencies responsible for water management, similar to Parks Canada in the Trent Severn Waterway. This research was conducted to provide Parks Canada with information on alternative management systems. This information represents a cache of alternative effective practices for water management systems. Potential refinements to the current water management system for the Trent Severn Waterway may be developed from this cache.

The water management systems evaluated include:

- Hydro power generation facilities operated by Rio Tinto Alcan in the Saguenay/Lac Saint-Jean region of Quebec;
- The Lake of the Woods system in Ontario, Manitoba and Minnesota;
- The Kissimmee River Basin in central Florida; and
- The Missouri River Main Stem Reservoir system.

2.1 Rio Tinto Alcan – Saguenay/Lac Saint-Jean (Quebec)

2.1.1 Overview

Rio Tinto Alcan Inc. is a Canadian aluminum company based in Montreal. It is the largest aluminum company in the world, with significant presence in Canada, France and Australia, and is a leading producer of bauxite ore, alumina and aluminum. The company operates four aluminum smelters in the Saguenay/Lac Saint-Jean region of Quebec, powered by six hydro electric generation facilities constructed between 1926 and 1959 on the Saguenay and Peribonka Rivers. The six power houses are capable of producing a maximum of 2,920 megawatts per year, and average a production of approximately 2,050 megawatts per year. Three water reservoirs are used to store water for power production, Lac Saint-Jean (5.4 million cubic meter capacity), Lac Manouane (2.7 million cubic meter capacity), and Passes-Dangereuses (5.2 million cubic meter capacity); the combined total drainage area of the system is approximately 73,800km^2.

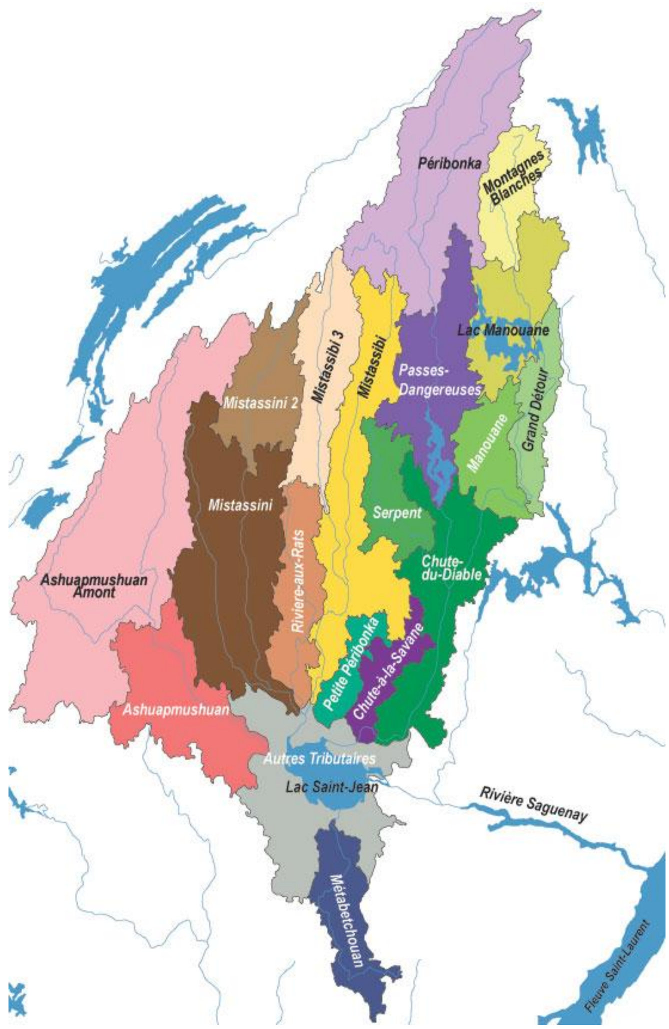


Figure 2-1 - Lac Saint-Jean Basin

Seventy-five percent of the drainage area contributing to Lac Saint-Jean is uncontrolled. The twenty-five percent of the flow that is regulated is controlled by the two upper reservoirs, Lac Manouane and Passes-Dangereuses. This large portion of unregulated flows in Lac Saint-Jean can result in large fluctuations in water level in the lake during high flow events, particularly the spring freshet. The average annual inflow into Lac Saint-Jean is approximately 1,500m^3/s, although there is a high amount of variation in these flows, such as when comparing flows during the spring freshet (which account for approximately

47% of the total annual inflows into the lake) to the lower summer flows. The Lac Saint-Jean drainage area is illustrated in **Figure 2-1** (source: Rio Tinto Alcan).

An interview was conducted by AECOM staff with a Rio Tinto Alcan water management consultant on February 10, 2011. The following sections summarize the information obtained during the interview regarding the management of water supplies throughout the Lac Saint-Jean basin, a system consisting of the following infrastructure:

- 28 dams and control works;
- Six powerhouses;
- 884km of transmission lines; and
- 38 hydrological and meteorological stations.

2.1.2 System Management

Rio Tinto Alcan water managers follow an established water management process, summarized in **Figure 2-2**. Data Collection is the first phase of the management process, and includes obtaining data on climate (i.e., precipitation and temperature, etc.) and stream flow, as well as forecasts of climate. This data become inputs for RTA's forecasting and optimization models, which are then analyzed to make decisions on the operations of their system. The quicker and more dependable the acquisition and processing of information are, the more the risks related to water management can be reduced.

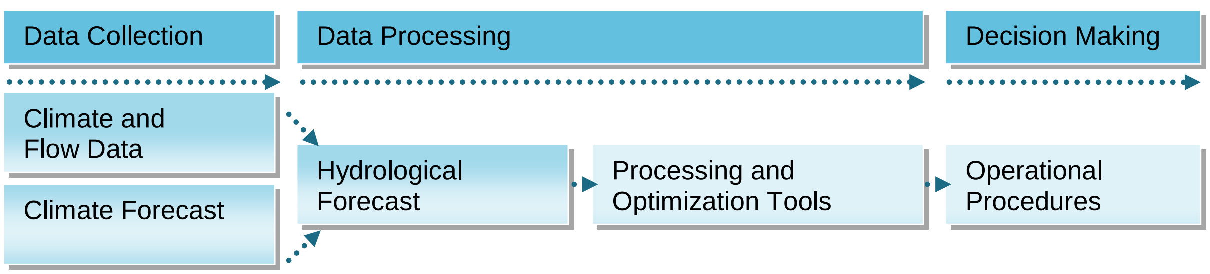


Figure 2-2 - Rio Tinto Alcan Water Management Process

2.1.2.1 Management Objectives and Considerations

The primary water management objective for Rio Tinto Alcan (RTA) staff is to produce electricity through their network of generation plants. However, there are also operational considerations for fish spawning, wastewater assimilation, resident recreation and enjoyment of the waterways and mitigation of erosion due to fluctuations in water levels.

The two reservoirs upstream of Lac Saint-Jean, Lac Manouane and Passes-Dangereuses, have no environmental restrictions with regards to their operation. In addition, there are no residents on these reservoirs; hydroelectric production and conveyance of flows to downstream areas are the primary objective. Lac Saint-Jean has more restrictions on the outflow of the reservoir: minimum discharge targets are in place for fish spawning in May, and for assimilative capacity requirements for the effluent from a paper mill downstream of the lake.

The Lac Saint-Jean area is also home to approximately 4,000 residents/cottagers. During the 1980's Lac Saint-Jean experienced extensive erosion issues that lead to public hearings in 1983. Since then, Rio Tinto Alcan has worked to restore the shoreline and add erosion protection features to mitigate the potential of future erosion and shoreline loss. As part of a public outreach campaign they also publish information regarding the three-day water level forecasts for the Lac Saint-Jean reservoir.

The management of water levels to mitigate flooding in the system is also a water management objective, particularly following the 1996 Saguenay floods which resulted from unprecedented levels of precipitation within the watershed. Since the RTA infrastructure is the sole means of water control for the reservoirs, the flows are carefully managed during high flow events to mitigate potential impacts. Other high flow events include the spring freshet, when Lac Saint-Jean receives a large amount of melt water from its watershed, approximately equal to $16km^3$ in a typical year.

Public safety is an important consideration for RTA’s water managers, and as such the company provides summaries of dam safety information to the local municipalities. All of their infrastructure must be designed for the Probable Maximum Flood (PMF), and despite having been constructed before such considerations were common place, each of RTA’s dams have been found to be capable of passing the PMF.

Given these objectives, the largest challenge faced by the water managers of the RTA system is dealing with uncertainties, and much of their management efforts are expended in finding the best strategies each day to accommodate the uncertainties while maximizing their performance objective, which for RTA is the generation of hydro electricity for aluminum production.

2.1.2.2 Data Collection, Management and Application

Rio Tinto Alcan water managers collect both meteorological and hydrological data to facilitate their operations.

RTA operates eighteen meteorological stations that record temperature and precipitation, and the data is transmitted back to the managers automatically via phone or satellite depending on the station location. Data is also collected at additional meteorological stations within the watershed operated by other agencies, for a total of forty stations of available data. Rio Tinto Alcan maintains data sharing agreements with other agencies at the Federal and Provincial levels to access these additional stations. Hydrometric data is collected from nineteen stations to monitor both lake and river levels. Seven of the stations monitor reservoir levels and the remaining twelve stations measure river stage that is used to calculate discharge.

Snow data is collected manually through the process of snow surveys collected at nineteen stations. The snow survey involves taking a series of point measurements at a set location (or snow course). At each point snow depth and weight for a measured volume of snow is recorded and used to calculate the snow water equivalent. As part of the research and development currently underway by RTA, water managers are evaluating various methods of measuring and recording snow data using automated methods. One potential method applies a sensor that measures natural gamma radiation readings before and after snowfall, reporting snow fall as a measurement of snow water equivalent. Measurements using gamma radiation are also beneficial as they take an average measure over an area of $50m^2$ in comparison to a snow course that averages a series of point measurements.

Additional data is also obtained or purchased through a number of agencies. Data from the Geostationary Operational Environmental Satellite (GOES) is used to monitor and track severe weather conditions. This data is obtained though a data sharing agreement between the USA and Quebec. Satellite imagery from the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) is obtained to provide a “big-picture” view of the watershed. This data can provide information regarding cloud and surface cover and the locations of ice and snow. Rio Tinto water managers typically use this data to monitor the progression of the spring snow melt to predict the peak freshet flows.

Meteorological forecasting data is also supplied by Environment Canada. Although Environment Canada data is typically available free of charge, an organization may decide to pay a fee each year to guarantee the availability of the data and delivery on a timely schedule, which is of particular importance to operations on the scale of Rio Tinto Alcan. Environment Canada provides RTA with quantity precipitation forecasts for the upcoming 10 days using their predictive model; these forecasts are updated daily. Estimated precipitation data is supplied on a 10x10km grid for the watershed, matching the scale of RTA's predictive model. Using forecasts such as these in their predictive models allow RTA water managers to anticipate large flow events and plan their operations accordingly to optimize their management objectives, which is typically the production of hydro electricity. The water managers may also use the Environment Canada staff to provide commentary on the forecasted data for the 1-2 day horizon, such as the confidence of the predicted precipitation volumes and other potential factors that may affect weather patterns in key areas.

With the exception of the snow pack records, most of the data collection and processing is automated. The information is automatically uploaded via satellite or phone modem connection to the Alcan alpha servers. Once the data is collected it is stored in a PI (Process Information) database. PI is a real-time data historian application with a highly efficient time-series database structure making it ideal for storing, analyzing and monitoring hydrological data. A data link allows for the information to be downloaded into Excel for ease of use. This system is also applied by BC Hydro.

2.1.2.3 Operational Procedures

The water managers at Rio Tinto Alcan process and analyze relevant meteorological and hydrological data on an ongoing basis to optimize production of hydro electricity. A number of factors are considered including a historical average of the flows for the upcoming months, existing snow pack and snow covered area.

When considering alternatives to handle large flows of water, or when flows are low, RTA water managers will perform an economic analysis of the value of the water, based on the production of hydro electricity. The managers will consult their forecasting models to determine the quantity of flows (or potential length of drought), and determine the optimal operating regime to yield the highest operational value for the water in the reservoirs.

Additional research and development is presently being conducted to evaluate how climate change could impact future operations for Rio Tinto Alcan. This study is investigating the changes that may occur in the water balance as a result of climate change and the associated fiscal impacts. The study also investigates what processes could be affected to determine possible solutions to mitigate the effects.

The majority of the time, the water managers attempt to maintain water levels within the long term averages, since these levels are typically what is required to optimize hydro production (see **Figure 2-3** for long-term average water levels in Lac Saint-Jean, source: Rio Tinto Alcan). The general seasonal considerations of RTA's hydro power operations are to fill up the reservoir in the spring using the freshet and to keep the water levels stable over the summer while maintaining hydro production. Starting in January, the water levels are slowly drawn down to provide some amount of storage for the spring freshet and to help mitigate potential flooding. During the winter months, most forecasting efforts are spent on determining the size of the spring freshet. The entire operating range of the lake, approximately 4.3m (14ft) has a volume of approximately 4km^3, requiring much of the spring freshet to be released downstream instead of being used for hydro power production, conducted in a manner as to mitigate potential downstream flooding impacts.

The water managers have established different "zones" for the reservoir levels, which indicate the desirability of a given water level depending on the season. For example, a low water level would be undesirable in summer since a sufficient reservoir must be maintained to ensure continued power generation, whereas in the late winter a water level that is too high may be undesirable due to the need to accommodate the spring freshet.

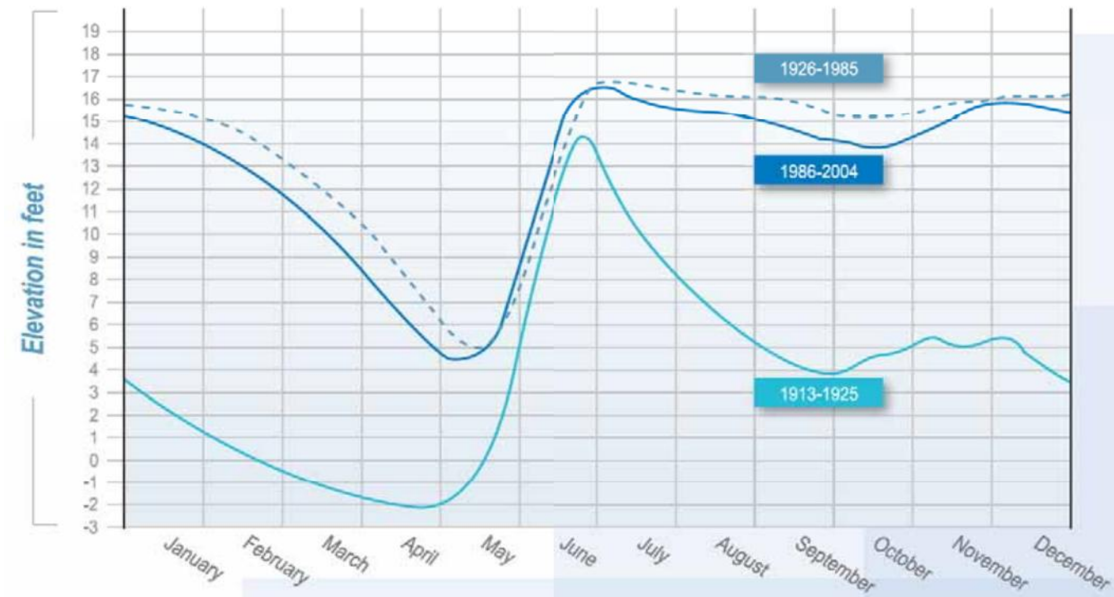


Figure 2-3 - Long-term Average Water Levels in Lac Saint-Jean

Water management operators use the CEQUEAL hydrological model, developed at INRS division of the University of Quebec, for forecasting and decision support. The model calculates flows, based on observed / forecasted meteorological and hydrologic data, and then routes the flow through the drainage network. The processes include the influence of lakes, marshes, and artificial waterworks such as dams, deviations, and canals. The CEQUEAL model has been extensively applied in the Province of Quebec for real-time flow analysis, making it an ideal tool for the Rio Tinto Alcan water managers.

The data applied to the CEQUEAL hydrological model includes observed meteorological data from Rio Tinto Alcan's eighteen meteorological stations, observed hydrometric data from nineteen sites and forecasted data from Environment Canada. To use the observed data from the previous 24hrs (or real-time data) in the hydrological model, the post processing of the data is automated. This makes it possible for the water management operators to run the model quickly and analyze the results for decision making purposes.

The end result of the operational decision making process is a daily phone call on week days to the operations team. However, there are staff on call 24 hours a day to respond to potential emergencies and operational requirements. Water management operations are monitored on a real-time basis, and rated in terms of hydro power production. This provides a real, quantitative assessment of the system performance, and allows any modifications to operations to be readily assessed.

The water managers also provide a significant amount of information on the system operations, often in real-time or regularly updated, to the public. Information is conveyed to the public regarding current and upcoming reservoir operations via a website (http://www.energie.alcan.com/), including:

- 3 Day forecasted water level for Lac Saint-Jean;
- 7 Day observed water level for Lac Saint-Jean;
- 7 Day flow observed from Lac Saint-Jean;

- 7 Day observed flows from different basins;
- 7 Day observed rainfall over the catchment;
- 7 day observed conditions with respect to operating levels; and
- Information regarding basin hydrology, operation, and shoreline protection.

2.1.3 Comparison to the Trent Severn Waterway

The operational characteristics of the Rio Tinto Alcan water management system have been described in the preceding sections. **Table 2-1** summarizes some of the key characteristics, and compares the RTA operations to the TSW.

Table 2-1 - Comparison of Operational Characteristics between RTA and TSW

Rio Tinto Alcan (RTA)	Trent Severn Waterway (TSW)
Primary operational objective is to produce hydro electricity. Secondary objectives include flood control, fish spawning, wastewater assimilation, resident recreation and enjoyment of the waterways and mitigation of erosion due to fluctuations in water levels	Primary objective is to conduct all operations in a manner that protects public safety. Legislated mandate to provide for navigation through the navigable portions of the Waterway. Additional goals to protect natural environment, resident recreation and enjoyment, hydro power generation, and wastewater discharge/water intake concerns
Drainage basin size: 73,800km^2, climate conditions and variations are similar between RTA and TSW	Drainage basin size: 18,690km^2, climate conditions and variations are similar between RTA and TSW
Operations include the use of reservoir zones, rule curves, and the application of operator experience and operational constraints	Operations include the use of reservoir zones, rule curves, and the application of operator experience and operational constraints
Daily operational decisions rely heavily on extensive water management modelling, forecasting tools, and the inclusion of real-time data and meteorological forecasts	No current use of system wide modelling or forecasting
RTA water management decisions are supported by economic impacts and climate change analysis	No current use of economic or climate change analysis to support water management decisions
Spring melt flows are estimated using extensive data collection and forecasting tools	Spring melt flows are estimated using snow pack surveys of five sites to calculate water equivalency
RTA purchases data from or has data-sharing agreements with many different sources for use in their decision-making process	No current data sharing agreements with other agencies to expand available information for management decisions
All water control structures have automated controls	Many water control structures (i.e., Haliburton Sector) rely on manual labour for stop log adjustments, although the TSW does have many automated dams as well.
RTA water managers post observed water levels on websites to inform users of the current conditions, as well as a 3-day forecast of water levels and operational strategies	TSW water managers post observed water levels on websites to inform users of current water levels

2.2 Lake of the Woods (Ontario/Manitoba)

2.2.1 Overview

The Winnipeg drainage basin covers areas in Ontario, Manitoba and Minnesota, with a total area of approximately 150,000 km^2 (LWCB, 2002). A map of the Winnipeg River drainage basin, showing the sub-drainage areas as well as the gauging stations and control structures, is shown as **Figure 2-4** (LWCB 2002).

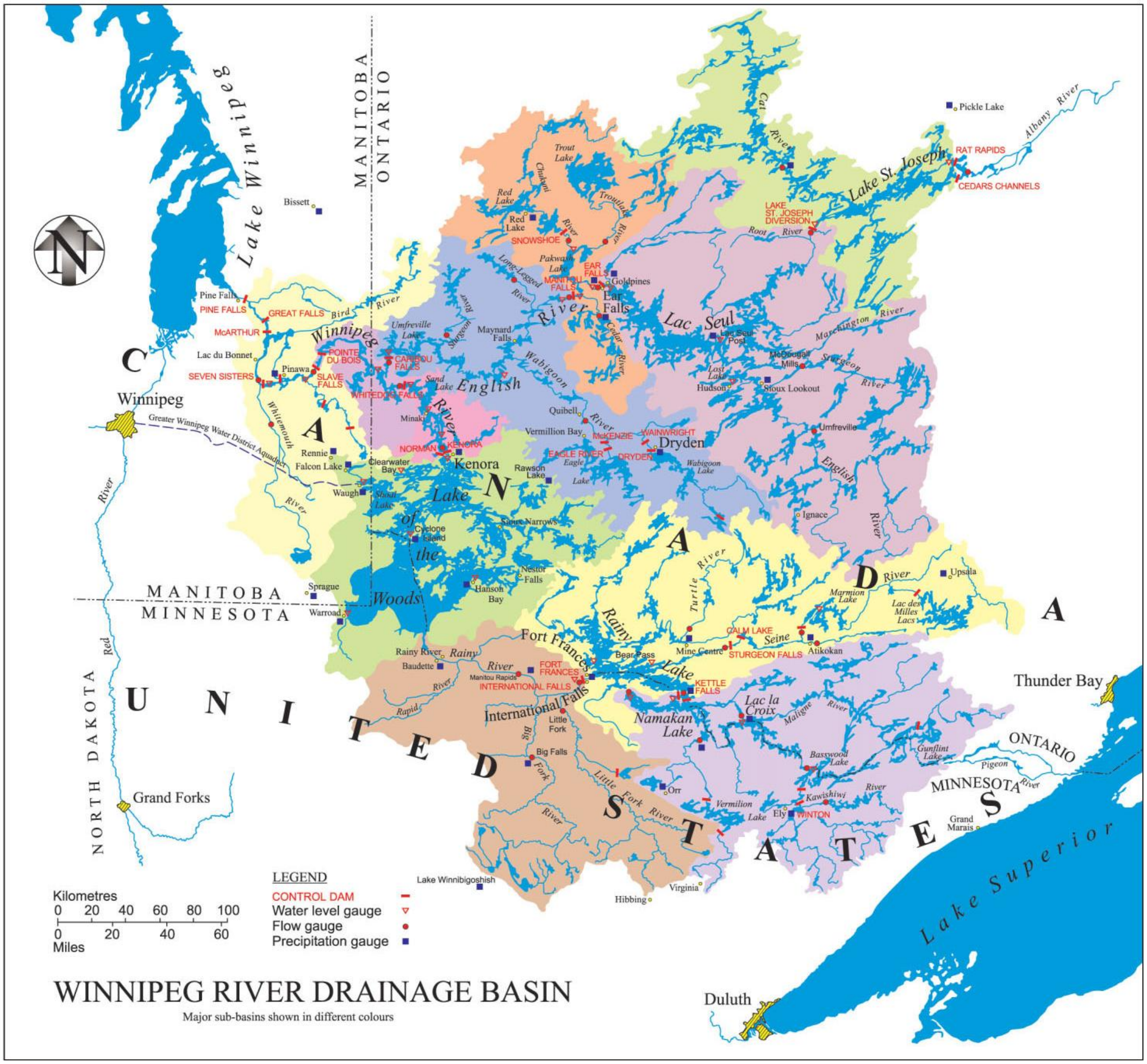


Figure 2-4 - Lake of the Woods and English River Drainage Areas

2.2.2 System Management

This watershed is covered by the International Joint Commission's Water Boundary Treaty and is managed by three agencies: the Lake of the Woods Control Board (LWCB), the International Rainy Lake Board of Control (IRLBC) and the International Lake of the Woods Control Board (ILWCB). These organizations work together to manage the competing objectives of the larger Winnipeg River drainage basin.

The LWCB is responsible for water management for all sub-drainage areas downstream of Rainy Lake. The LWCB water management operations are largely focused on the Lake of the Woods (LOW) and Lac Seul sub-drainage areas, as management of the overall system is significantly related to water level and flow control in these two sub-drainage areas. In addition, the majority of operations and control structures in these two sub-drainage areas are managed solely by the control boards. For other sub-drainage areas, such as English River, the system and its structures are managed in cooperation with private partners, including Ontario Power Generation, Manitoba Hydro, ACH LP, and Boise Cascade, The LWCB was formed by the International Joint Commission in 1919 (LWCB, 2002). This review focuses on the LWCB jurisdictional area of the overall system.

The ILWCB is responsible for overseeing and approving decisions once water level elevations fall outside specified elevations for normal operating procedures.

The IRLBC supervises water management of Rainy River, Namakan Lake, and Rainy Lakes sub-drainage areas. This combined drainage area the majority of the inflow into the Lake of the Woods water body.

2.2.2.1 Management Objectives and Considerations

The regulation strategies are based on the general guidelines and objectives from established regulations, the input from advisors and representatives (including stakeholders), and the current and projected basin conditions (LWCB, 2010).

Based on the recommendations of the International Joint Commission, the 1925 Lake of the Woods Convention and Protocol a 1925 treaty was established between Canada and the United States which specified a number of requirements regarding water management of the LWCB-managed portion of the basin, including:

- The (Canadian) Lake of the Woods Control Board shall regulate outflow from the lake;
- An international board shall be established and, whenever the lake level rises above or falls below specified limits, the outflow shall be subject to approval by this board;
- Lake of the Woods water levels shall normally be regulated between elevations 321.87m and 323.47m (1056.0ft to 1061.25ft) to produce the highest uniform outflow;
- During periods of excessive inflow, when the lake level reaches 323.39m (1061.0ft), regulation shall focus on keeping the level from exceeding 323.85m (1062.5ft); and
- A flowage easement shall be acquired on all United States shoreland to elevation 324.31m (1064.0ft).

In addition to maintaining these operational requirements under the international treaty, regulation strategies aim to satisfy Canadian federal and provincial legislation, and water management principles.

There is an extended list of stakeholders for the LWCB managed portions of the system. The Lake of the Woods and its associated tributaries provide benefits such as drinking water, hydroelectricity, and local fisheries that are shared and enjoyed by thousands of people. According to the *State of the Basin Report* (DeSellas *et al.*, 2009), First Nations' domestic and commercial fisheries in the lake are valued at $1 million with an additional $34 million associated with the sports fishery, the largest non-resident sport fishery in Ontario. Likewise, Minnesota supports a $44 million per year sport fishery in Lake of the Woods. The Lake also supports a $125 million tourism industry in

Ontario (Minnesota Department of Natural Resources and Ontario Ministry of Natural Resources, 2004). The system also supplies water to the City of Winnipeg, as such water quantity and quality in the system is a concern for the City of Winnipeg.

Like any water management system, the LWCB has to balance competing interests for water use within the basin. According to LWCB (2010) decisions are typically based on satisfying, as much as possible, the following overall system operational objectives and stakeholder expectations:

- Protection of cottage and permanent residences;
- Recreational (including boating and fishing);
- Nature (fish and wildlife protection);
- Tourist outfitting for game fishing;
- Wild rice production;
- Electric power production/consumption;
- Local industry (with respect to power and water quality);
- Domestic water supply; and
- Commercial fishing.

When two or more objectives or expectations conflict, a compromise strategy may be determined to minimize loss or damage overall. This compromise would typically be based on the judgement and experience of the operators.

To facilitate communication with the various interest groups, the LWCB holds meetings with interest groups and stake holders at least 3 times a year (March, June and October). The objective of the meetings is to provide a forum for the groups to have input to the regulation strategy for the upcoming months. Organizations present at these meetings include First Nation advisors, specific interest group representatives (include cottage owners, hydropower utilities, municipalities, a paper company and tourist outfitters) and natural resource agency advisors (LWCB, 2010). When necessary, a conference call may also be held to manage any special issues. Expert advice regarding the impacts of regulation on fish and water quality is also provided to the LWCB by resource advisors from the Ontario Ministry of Natural Resources and the Ontario Ministry of the Environment.

Current water level conditions and water management strategies for a one week period are conveyed to the public and interest groups though a website (http://www.lwcb.ca/). In addition to posting the forecasted changes to water levels, daily, weekly, and ten day flows are posted with a historical statistical analysis of the flows for each station. This data is updated on the website regularly to inform interested parties of the flows compared to the flow normals as well as historical maximum and minimum trends. All data is released in PDF format.

In the event that water level and flow conditions are changing rapidly or are hazardous, further actions are taken to alert the public. Advisories are broadcasted via a recorded message and the web site. News releases may also be issued during these times.

The LWCB holds a public open house once a year (or sometimes more frequently during years of extreme events). The purpose of these meetings is to (LWCB, 2010):

- maintain and strengthen public relations and communications;
- ensure that relevant information about regulation is available to the public; and
- improve the public's understanding of the competing demands on the resource and the regulation process.

2.2.2.2 Data Collection, Management and Application

Both hydrologic and meteorological data is collected from a number of different agencies that operate gauging stations. Data providers for the LWCB include ((LWCB, 2010):

- Meteorological Service of Canada (Environment Canada)
- Water Survey of Canada (Environment Canada),
- Ontario Ministry of Natural Resources,
- United States Geological Survey and US Army Corps of Engineers.
- ACH LP and Boise Cascade (hydroelectric and paper production dam operators),
- Manitoba Hydro and
- Ontario Power Generation.

Data collected includes: water levels, flows, precipitation (snow and rain) data and temperature data. This information is collected via satellite retrievers or modem lines where available. In some instances the data is posted on public or private web-sites and then retrieved by the LWCB. More than 6,000 pieces of data are processed and analyzed on a weekly basis.

The main objective of water management decisions is to consider and balance the various objectives and expectations of the system. To accomplish this, they determine hydrologic data such as stream flows and water levels within the system, as well as local inflows to the system resulting from rainfall or snowmelt runoff. This information, as well as knowledge and experience gained through past management of the watershed, is used to make educated decisions on the water/reservoir levels that will best balance the various objectives of the system.

Local inflows often drive basin management decisions, and as such managers often need to forecast local inflows over longer term periods (weeks or months). Five main factors are used to forecast future local inflows to the lakes:

- Future precipitation;
- Future evaporation and evapotranspiration;
- Water in natural storage either in soil moisture or in the many small lakes, marshes and rivers upstream of the lake;
- Water in storage on the ground as snow; and
- Water in storage in regulated reservoirs upstream of the system.

The relative importance of these factors in forecasting the system inflows varies throughout the year. For instance, precipitation and evaporation/evapotranspiration are key components in the summer, while soil moisture and reservoir release are key to forecasting inflows in the winter. Snow pack is an important factor with respect to spring flows.

It is difficult to accurately forecast each of these five factors longer than two or three days, given the relatively poor reliability of long-term climate forecasts. As a result, forecasted local flows to the system are currently based on:

- Antecedent conditions within the system;
- Historical local inflows and experience as to probable and potential extreme values for given antecedent conditions;
- Correlations of the winter snowpack to spring inflow. However it is difficult to predict spring inflows based on snow pack or even snow pack plus rainfall, as evidenced by the highly variable nature of past correlations; and

- Advanced flood forecasting using hydrological models is not typically applied for making management decisions with the basin, however forecasted modeling results are available to the LWCB through resources at Manitoba Hydro.

Data is managed and processed in-house using a database and data management techniques developed by the LWCB management. Data is used to produce daily and weekly reports summarizing the hydrologic conditions for the major lakes and tributaries. The reports summarize the current conditions as well as compare the observed conditions to minimum, maximum and normals over the course of the year. An example of a full report has been included in Appendix A and provides an example of the Daily Report, the 10-Day Inflow Report (for the previous 10 days), 10-Day Database Report, Weekly Report and graphs show annual trends for the lakes in the LOW basin. This data is released to the public through the LWCB's website. These reports are used to in conjunction with the LCWB "Notice Board" (http://www.lwcb.ca/noticeboard.html) to convey lake and water level conditions to the public.

2.2.2.3 Operational Procedures

The hydrologic data is used to make water management decisions regarding the regulation of the LWCB-operated area. Decisions are also based on operator knowledge of the basin and its hydrology, such as the required local inflows to raise lake levels by a certain depth. Furthermore, the decision making process includes information on past operational decisions under similar conditions, and how closely those operations resulted in the target outcomes. Furthermore, the LWCB continuously monitors the changing water levels and flows within the system and adjusts its operations accordingly to achieve its regulation objectives. In the spring, the water supply regulation may require weekly changes in schedule while, in the winter, longer term regulation plans can be implemented;

Overall different control strategies and considerations are utilized for each season. According to the LWCB (2002) the following considerations are made for each season:

- Spring - Spring runoff is used to fill the lakes. Estimates of spring inflows are made to provide a safety margin for high or low extremes that could occur.
- Summer - Typically by the end of the summer the lakes are full and flooding may occur in the event of heavy rain fall during the late summer or early fall months. During the summer months evaporation losses can be higher than lake inflow causing an unintentional drawdown in the lakes. Summer operation can be highly variable, in response to the climate (during the summer both successions of heavy rains and extended dry spells are possible).
- Autumn - operations concentrate on longer term planning for the coming winter. Considerations include likely inflow and winter drawdown as well as the targets for the following spring.
- Winter – operations concentrate on conducting a regular release schedule. LOW and Lac Seul are drawn down to provide hydroelectric power flows and to ensure adequate flood storage for the upcoming spring runoff. The extent of drawdown varies based on the estimated spring flow.

Currently, the water management decisions by the LWCB are not based on modeling or rule curves. Rule curves are set minimum or maximum targets which represent the normal operating range for lake levels or flows. However, operations controlled by the IRLBC, which controls flows into the LWCB area, are managed based on rule curve decisions. These rule curves are illustrated as part of Appendix A, for Rainy Lake and Namakan Lake. Note that during the 2010 water year, deviations were made from the rule curve due to low water levels. In the event of hydrological extremes, communication (typically a conference call) between the IRLCB, LWCB and ILWCB is used to pursue the best course of action for the overall watershed management.

In addition to the water management operations controlled by LWCB, system flows in the LOW and Lac Seul drainage areas are further controlled by a series of hydro electric dams. The water management decisions and operations by LWCB take into account expected hydro-electric dam operations. In the event that the flows from these facilities are impacting the management of the system, LWCB has jurisdiction over the release rates from these dams. Typically these systems are managed and controlled by Manitoba Hydro or Ontario Power Generation. The dams operate using sluices (or sometimes tunnels) with gates or stoplogs that are used to vary the amount of flow past the dam. The majority of the sites can be controlled remotely with the exception of a few dams that require manual adjustment of stop-logs.

A number of other hydroelectric power facilities are present within the domain of the LWCB; however, the storage capacity of these reservoirs is limited and will not generally impact the management of the watershed as a whole. As the focus of these areas is typically power production, the storage capacity does not fluctuate greatly.

2.2.3 Comparison to the Trent Severn Waterway

The overall water management objectives of the Lake of the Woods system are similar to those of the TSW, despite the varying basin scales. A summary of the objectives and expectations of both systems is given in **Table 2-2**. The primary objective for the LWCB water management system is balancing the overall objectives and expectations, where as the priority objective for the TSW system is to provide for public safety while maintaining navigation and satisfying the other objectives and expectations as much as possible.

Table 2-2 – Comparison of Lake of the Woods and Trent Severn Waterways Objectives and Expectations

Lake of the Woods (LOW)	Trent Severn Waterway (TSW)
Protecting cottagers and permanent residence from damage	Minimizing damage to public and private property
Recreational uses (including boating and fishing)	Optimizing recreational enjoyment of the waters
Environmental concerns(fish and wildlife protection)	Protecting aquatic habitats and species
Electric power production	Allowing hydroelectric generation
Domestic water supply	Domestic water supply and water quality management
Recreational uses (including boating and fishing)	Safe navigation and boating
Tourist outfitting for game fishing	Optimizing recreational enjoyment of the waters
Wild rice production	-
Local industry (with respect to power and water quality)	Allowing hydroelectric generation/ Domestic water supply and water quality management
Commercial fishing	-

The operational characteristics of the Lake of the Woods water management system have been described in the preceding sections. **Table 2-3** summarizes some of the key characteristics, and compares the LOW operations to the TSW.

Table 2-3 - Comparison of Operational Characteristics between LOW and TSW

Lake of the Woods (LOW)	Trent Severn Waterway (TSW)
Drainage basin size: 150,000km^2, climate conditions and variations are similar between LOW and TSW	Drainage basin size: 18,690km^2, climate conditions and variations are similar between LOW and TSW
Water management decisions are based heavily on historic data, seasonal variation and water management operator knowledge and experience	Water management decisions are based heavily on historic data, seasonal variation and water management operator knowledge and experience
Modeling and the use of rule curves are not applied in making water management decisions	Rule curves and limited modeling are included in decision-making
Freshet is managed considering local inflows due to spring melt based on correlations to snow depth	Freshet is managed considering local inflows due to spring melt based on correlations to snow depth
Water management decisions are predominantly carried out though hydroelectric facilities, although at a few locations this is not possible and an operations team must manually remove stop logs	Water management decisions are executed by TSW staff, and the hydroelectric utilities are given the option of running the water through their generators. TSW operators must still respond to water level fluctuations resulting from the operations of the hydro facilities
Data is used from many different sources including Environment Canada, Ontario Ministry of Natural Resources, private hydroelectric and paper production dam operators, Manitoba Hydro and Ontario Power Generation	No current data sharing agreements with other agencies to expand available information for management decisions
Information sharing with public is facilitated through: • website postings of current water level conditions and water management strategies for a one week period, as well as posting daily, weekly, and ten day flows with a historical statistical analysis for each station; • advisories via a recorded message and the web site of potentially hazardous conditions, with occasional news releases when justified; • at least 3 annual meetings with interest groups and stake holders; and • a public open house once a year.	No current facilitation of annual meetings with interest groups and stakeholders or public open houses, or postings advising public of water management strategies

2.3 Kissimmee River (South Florida)

2.3.1 Overview

The Kissimmee River once meandered for 166km through south central Florida. Its floodplain, reaching up to 3km wide, was inundated for long periods by heavy seasonal rains. Wetland plants, wading birds and fish were observed along with many species that thrived in the everglades. After numerous severe flooding events, Congress tasked the U.S. Army Corps of Engineers (USACE) with reducing flooding in the area. Between 1962 and 1971, the Corps cut and dredged the Kissimmee River into a 9.14m deep, 90km straightaway known as the C-38 canal. The project achieved flood reduction benefits, but it also harmed the river floodplain ecosystem.

Presently the Kissimmee River is undergoing significant restoration efforts. As such a large number of studies regarding the operation and management for the Kissimmee River have been undertaken to balance the needs of the ecosystem with the need for flood control. As part of restoration efforts the Kissimmee Basin Hydrologic Assessment, Modeling, and Operations Planning project was commissioned by the South Florida Water Management District (SFWMD). The purpose of this study was to assess how the existing operating criteria for the water control structures in the Kissimmee Basin (KB) could be modified to achieve a more acceptable balance of flood control, water supply, aquatic plant management, and natural resource water management objectives while accounting for other ecosystems impacts (Earth Tech, 2005).

KB covers an approximate drainage area of 5,902km^2 of south-central Florida and drains into Lake Okeechobee (Earth Tech, 2005). The KB, shown in **Figure 2-5**, is divided into a 4,131km^2 Kissimmee Upper Basin (KUB) and a 1,771km^2 (684mi^2) Lower Kissimmee Basin (LKB) (Loftin et. al., 1990). The KUB contains the Headwaters of the Kissimmee River and consists of Lake Kissimmee and its tributary watersheds. KUB is comprised of numerous lakes regulated by a system of canals and water control structures managed by the SFWMD in accordance with regulations prescribed by the Secretary of the Army. The KB includes portions of Lake, Orange, Osceola, Polk, Highlands, and Okeechobee counties. The KUB is the more heavily populated and developed part of the KB. Principal municipalities within the KUB are the southern half of the City of Orlando, the City of Kissimmee, and the City of St. Cloud. Walt Disney World is located in the upper portion of the KUB within the Reedy Creek Improvement District.

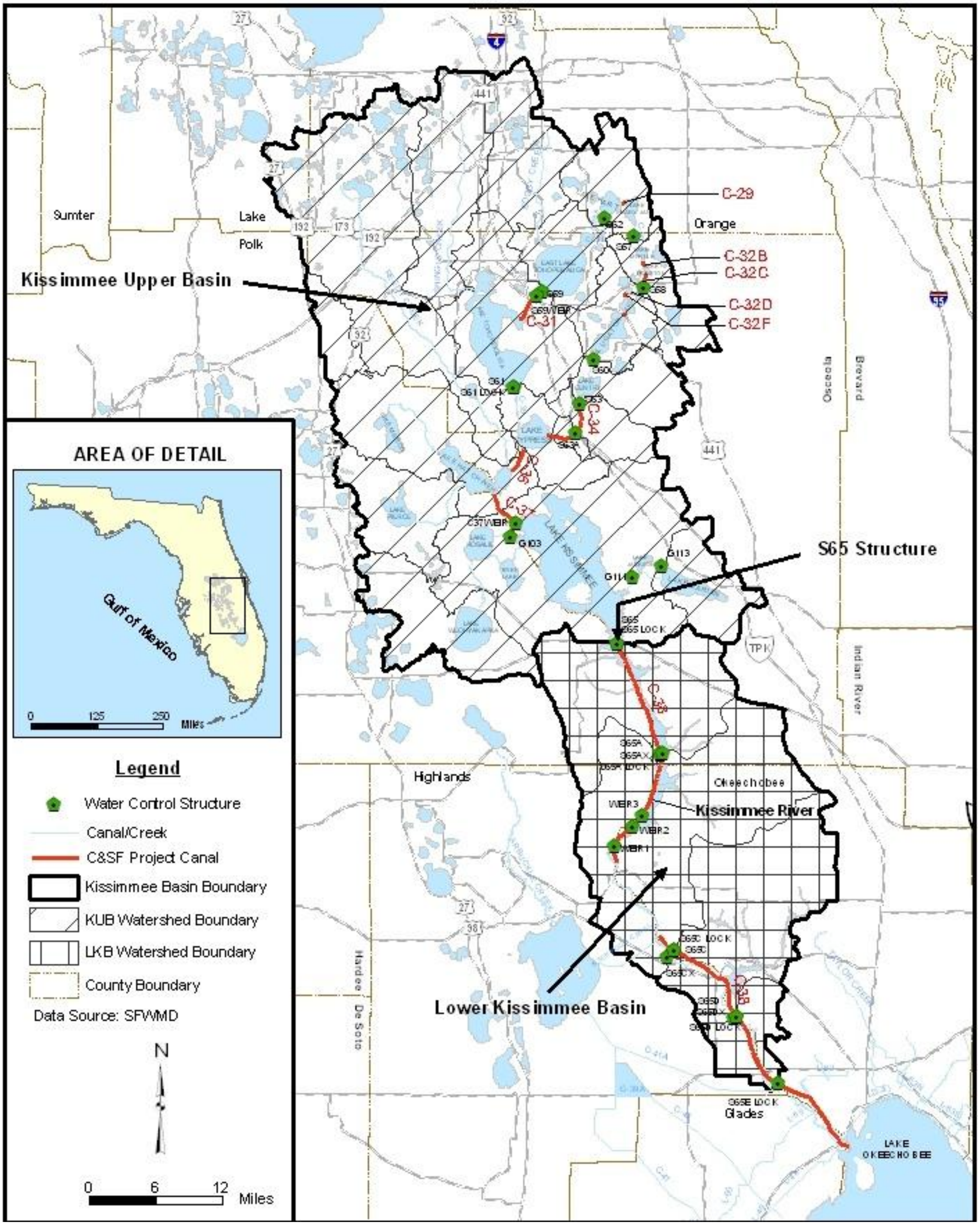


Figure 2-5 - Kissimmee Basin Overview, (Source: Earth Tech 2005)

2.3.2 System Management

The management of Kissimmee Basin is a joint effort that involves both the SFWMD and the USACE Jacksonville District. In addition to the operation management data collected by the SFWMD and USACE, real-time data is also collected from the U.S. Geological Survey and the National Weather Service (USACE Jacksonville District, 2010a). The role of the SFWMD in the KB is to manage and regulate the waters. This goes hand in hand with the SFWMD's mission statement "To manage and protect water resources of the region by balancing and improving water quality, flood control, natural systems and water supply" (SFWMD, 2010). The USACE under the Central and South Florida Project (C&SF) were mandated to manage the operations of the spillways, locks, pump stations, culverts, canals, reservoirs, and water conservation (USACE Jacksonville District, 2010a). The result of this joint effort is that the regulations and overall water management goals are provided by the SFWMD and the daily operations of the KB are controlled by the USACE.

2.3.2.1 Management Objectives and Considerations

The following section is summarized from the *Kissimmee Basin Hydrologic Assessment, Modeling and Operations Study (Task 1.3)* completed by Earth Tech (2005). The water management objectives and expectations in the KB include:

- Managing flood control;
- Maintain navigability for recreation and sport fishing
- Maintaining water supply for urban and agricultural applications;
- Controlling aquatic invasive plants; and
- Managing water levels to maintain natural resources.

The water management constraints and objectives from this study are summarized in the sub-sections below.

Under pre-2005 operating criteria, conflicts often arise among the objectives. Rather than seeking approaches that balance or use a fixed set of decision rules to deviate from those operations, the current process pits one operation's objective against another and often results in politically and/or environmentally unpopular consequences.

Flood Control

The KB flood control works of the C&SF Project were authorized to improve flood control, drainage and navigation. The KUB portion included the dredging of canals between lakes and construction of water control structures to regulate lake water levels and outflows. The LKB portion included channelization of the Kissimmee River (by digging canal C-38) and the addition of water control structures.

At the time that the C&SF Project was designed and built the future land use conditions were considered to estimate the necessary amount of flood control for the developed basin. However estimated land use conditions were never envisioned to reach present day levels of development intensity. As a result the current peak flows of the KB system are higher than the designed peak flows determined in the1950's. This underestimation of peak flows and the hydrological nature of the Kissimmee River have lead to concerns for the downstream water management and flooding potential within the KB.

Localized flooding caused by storm events occurs in many areas of the KB along tributaries and near lakes. Flooding occurs at roads, subdivisions, business, and agricultural fields. Areas most affected include the City of St. Cloud, City of Kissimmee and numerous subdivisions throughout Osceola County, Orange County, and Polk County. Less developed areas of Okeechobee County and Highlands County also experience flooding, but fewer persons are affected. Lakes in the KB also experience unusually high stages during large rain events and can cause flooding of shoreline properties. While many of the lake and tributary flooding issues are local in nature, some of the flooding issues may be addressed through operations changes to the rule curves used to operate the control structures.

Water Supply

The SFWMD is responsible for protecting and managing the water supply. Population growth has resulted in higher demands on the water system. Water supply problems encompass both human and ecosystem water supply needs within the KB. The water utilities serving the growing population within the KUB presently rely on ground water, however due to limits of available groundwater, consideration is give to surface water resources.

Aquatic Invasive Plants

Invasive plant species particularly Hydrilla is a significant problem in the lakes within Kissimmee, Hatchineha, Cypress, and Tohopekaliga counties. If the plants are not controlled they can create thick mats of floating plants reducing bio-diversity, clogging irrigation and flood canals and interfering with boating and other recreational activities. One of the more effective methods to control plant growth is through chemical treatment. In order to create the conditions necessary for chemical treatment, lake levels need to be lowered typically during the spring months, at the end of the dry season. Desired treatment conditions have been difficult to achieve due to uncertain weather conditions during the spring treatment period. This type of water level management is contrary to the needs of the natural system, which is inherently variable.

Maintaining Natural Resource

To maintain and support a healthy ecosystem within the KB, the lake levels need to be managed to support the needs of the ecosystem. Current operating criteria hold KUB lake levels at higher levels during the winter and spring to assure adequate water supplies. During the late spring and summer they are held at lower levels to provide storage for flood control. On an annual basis, lake levels are managed to mitigate water level fluctuations, which is contrary to the seasonal pattern of natural water level fluctuations. Under natural conditions the lake would be lowest in the spring at the end of the dry season and highest at the end of the wet season (November) and would experience extreme lows during droughts. These operating criteria and the resulting stabilized water levels have caused accumulations of organic material to build up in lake littoral zones, and the loss of lacustrine, littoral, and wetland habitats. As a result, fish and wildlife diversity and abundance have been affected.

Natural resource management objectives include hydrologic management, habitat preservation and enhancement, fish and wildlife, and water quality requirements. Collectively, these requirements are intended to provide quality habitat for the fish and wildlife resources. Natural resource operations criteria must provide flows, stages, and volumes compatible with the natural system while also considering impacts of those operations to upstream and downstream ecosystems. Successful implementation of such operating criteria will protect native wildlife and their food sources and increase the potential for recovery of threatened and endangered species.

2.3.2.2 Data Collection, Management and Application

Historical Data

Historical hydrological data was used to gain a better understanding of the changes in the basin hydrology by qualitatively analyzing trends. The trends might have occurred due to changes in climate, water use, land use and water management practices (Earth Tech, 2005). The purpose of this study was to investigate the changes of rainfall and flow data on the watershed scale.

The following summarizes the work completed by Earth Tech (2005). Data analysis was completed for five subwatersheds within the Kissimmee Basin. Locations were selected based on data availability, location within the basin (with respect to regulation schedule impacts), and hydrological characteristics. Historical data collected by the SFWMD, included rainfall and flows as well as land use coverage. A QA/QC check of the data was completed to insure that the data was free from outliers and complete. In cases where data was missing, the time-series was interpolated as appropriate.

Current Data

Using the USACE satellite system (or DOMSAT), data collected at various meteorologic and hydraulic stations are retrieved remotely. Collected data includes lake and reservoir water surface and groundwater elevations, river and channel water surface elevations, reservoir elevations, cumulative precipitation, wind speed and direction and barometric pressure. Real-time data is also received from the SFWMD as well as other local water management agencies and the National Weather Service. Real-time hydrometeorologic data is also obtained from some of the spillway/locks. These sites record headwater, tailwater, rainfall, wind speed and direction, barometric pressure, gate settings and discharge parameters on an hourly basis.

2.3.2.3 Operational Procedures

As part of the 2005 study, a hydrological model was developed to assess how the existing operating criteria for water control could be modified to achieve a better balance amongst the water management objectives (Earth Tech, 2005). Given the complexity of the operating criteria for KB, multiple models were selected. OASIS model from Hydrologics, Inc. was selected as a screening tool. OASIS is a water management model designed for conflict resolution of water management and developing operation policies to best satisfy the demands of the system. The other models applied to the KB included MIKE SHE/MIKE 11 developed by DHI. These models were used to complete the hydrological and hydraulic modeling components (Earth Tech, 2005). The MIKE SHE model will replicate the groundwater and overland flow processes where the MIKE 11 model will be used for channel hydraulics, routing and structure simulation. The purpose of these models was to develop a planning tool for the SFWMD. They are applied to assess and screen proposed regulation procedures. These models are not used in daily operation of the KB, which is aided by the use of .the Corps' Water Management System (CWMS), described further below.

Current operational procedures include:

- Maintaining KUB lake levels at higher levels during the winter and spring to assure adequate water supplies;
- Maintaining lower levels during the late spring and summer to provide storage for flood control; and,
- On an annual basis, fluctuations in lake levels are limited to no more than a metre.

Current daily operational procedures, the CWMS, and decision making procedures were detailed on the USACE Jacksonville District website (2010a) and are summarized here.

To control daily operations in the KB, the USACE applies the Corps' Water Management System. This system includes an integrated system of computer hardware and software packages that provides real-time water management. CWMS involves the retrieval and storage of time-series data into an Oracle database, data verification and transformation of the data, the development and use of an array of hydrologic models to determine streamflow, reservoir operations and downstream impacts from project releases (stage and damage), the visual display of edited and transformed data and model results, and dissemination of data to web applications. The array of models includes HEC RAS, HEC RAS Sim, HEC HMS and HEC DDS. Using the USACE satellite system (or DOMSAT), the data collected at various meteorological and hydraulic stations is received and automatically formatted into the HEC Data Storage System (DSS) databases and programs.

The system is readily usable by water managers and operators as an aid for making and implementing decisions. In addition, regulation rule curves are used within the decision-making process. Illustrated in **Figure 2-6** is the rule cure (see "Zone B Regulation") that is applied to the management of the control structures.

Once management decisions are made using the CWMS and the Regulation rule curves, the decisions are carried out by applying operational changes to the locks and control structures in the system.

The USACE communicates the water regulation decisions to the public predominantly though web postings, however in the event of an emergency situation, other tools for communication may be necessary. An example of the water levels posted on the USACE website for Lake Kissimmee is illustrated in **Figure 2-6**.

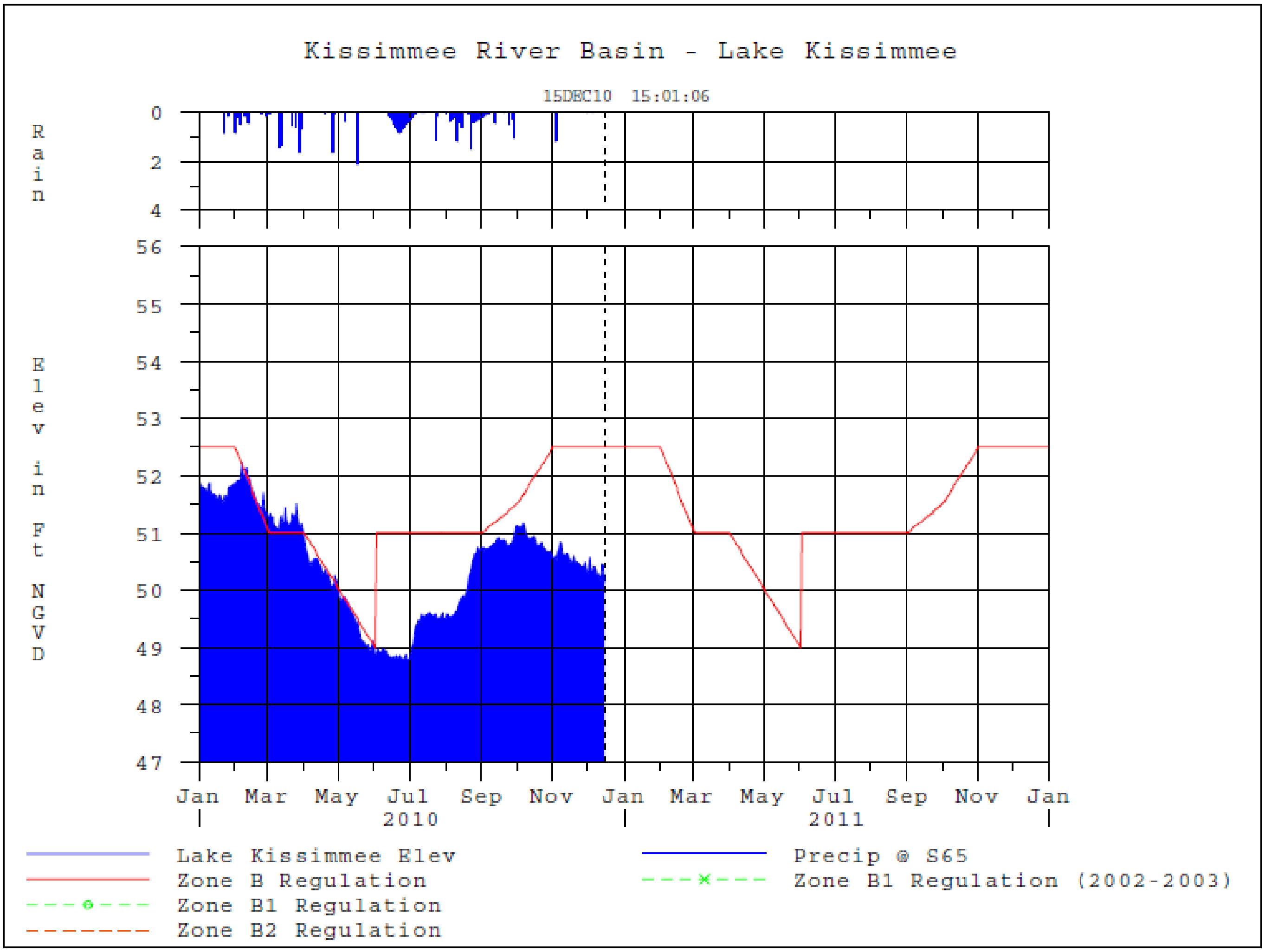


Figure 2-6 - An example of water levels at Lake Kissimmee

2.3.3 Comparison to the Trent Severn Waterway

The operational characteristics of the Kissimmee Basin water management system have been described in the preceding sections. **Table 2-4** summarizes some of the key characteristics, and compares the LOW operations to the TSW.

Table 2-4 - Comparison of Operational Characteristics between Kissimmee Basin and TSW

Kissimmee Basin (KB)	Trent Severn Waterway (TSW)
Primary operational objective is to balance flood control, water supply and the natural environment.	Primary objective is to conduct all operations in a manner that protects public safety. Legislated mandate to provide for navigation through the navigable portions of the Waterway. Additional goals to protect natural environment, resident recreation and enjoyment, hydro power generation, and wastewater discharge/water intake concerns
Drainage basin size: 5,902km^2, significantly warmer climate, with different runoff responses and increased flooding potential given the frequency of heavy seasonal rains	Drainage basin size: 18,690km^2
Operations include the use of operator experience, rule curves and operational constraints	Operations include the use of operator experience, rule curves and operational constraints
Daily operational decisions rely on extensive water management modeling and the inclusion of real-time data, meteorological forecasts and satellite data to determine control structure releases	No current use of system wide modelling or forecasting
Overall water management direction is determined by the SFWMD and the day to day operations a carried out by the USACE, Jacksonville District	All water management and operational activities determined and carried out by Parks Canada staff
Real-time data is collected at various meteorological and hydraulic stations remotely through the USACE satellite system (or DOMSAT)	No current use of real-time meteorologic data; some water level gauges must be manually read
Public communication includes current and recent flow and water levels, as well as operational strategies	Public communication includes website posting of current and historic water levels

2.4 Missouri River Mainstem Reservoir System

2.4.1 Overview

The Missouri River Mainstem Reservoir System (MRMRS) is a series of 6 reservoirs. The reservoirs (Fort Peck, Garrison, Oahe, Big Bend, Fort Randall and Gavins Point) were completed from 1937 to 1963 and the reservoir system was first filled in 1967. The total storage capacity of the system is approximately 9 billion cubic meters of water (USACE Northwestern Division, 1999).

The system spans the states of Montana, North and South Dakota, Wyoming, Nebraska, Missouri, Colorado, Kansas, Iowa and Minnesota and the provinces of Alberta and Saskatchewan. Its headwaters are located in the Rocky Mountains; from there it flows to its confluence with the Mississippi River near the City of St. Louis (**Figure 2-7**, source: USACE, 1999). Due to the geographical size of this basin, it covers many areas of varying land types from mountains to low lying plains. The total drainage area is approximately 1,370,103km^2 (or 529,000mi^2). Of this area approximately 25,122 km^2 (or 9,700 mi^2) are located in Canada (USACE Northwestern Division, 2007).

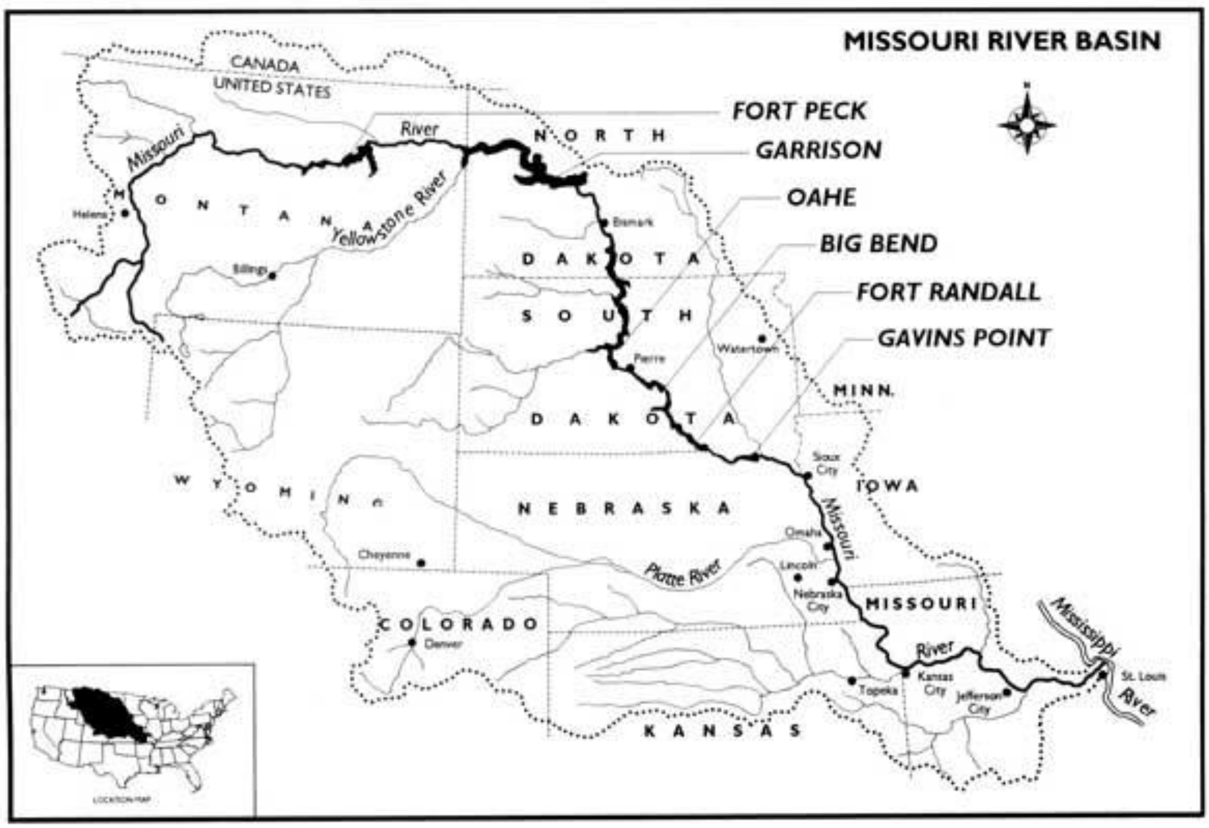


Figure 2-7 - Missouri River Basin

2.4.2 System Management

The reservoirs were constructed and are owned by the federal government. They are managed and operated by the USACE, Missouri River Basin Water Management Division. The management of the system is dictated by the MRMRS Master Water Control Manual, fist developed by USACE in 1960 and later revised in 1970's, 2004 and most recently in 2006. The information provided in the following sections is summarized from the Master Water Control Manual.

2.4.2.1 Management Objectives and Considerations

According to USACE Northwestern Division, (2007), this reservoir system was commissioned for the purpose of satisfying the following objectives and stakeholders expectations:

- Flood control;
- Navigation;
- Hydropower generation;
- Irrigation;
- Water supply;
- Water quality control;
- Recreation; and
- Fish and wildlife:

These objectives were developed, as part of the Master Water Control Manual, with no priority or bias towards any one objective. This was partly made possible by the size and capacity of the reservoirs.

The system was developed to provide water for each of the objectives. Each reservoir has been designed with set volumes (similar to the Reservoir zones in the TSW management system) for the various uses, as follows:

- 25% of the storage in the system is reserved to form a permanent pool;
- 53% of the storage is proportioned for multiple uses and annual changes in water level; and
- Remaining 22% is used predominately for flood control. However if necessary up to 16% of the 22% may be used for other uses, depending on the annual operating criteria.

The permanent pool zone ensures the maintenance of minimum power heads, minimum irrigation diversion levels, and minimum reservoir elevations for water supply, recreation, and fish and wildlife purposes. The flood control zone is provided for the regulation of the largest of floods, and will typically be empty.

These maximum and minimum required water levels, along with other requirements for navigation, irrigation, water supply, and ecological needs, form the base operating criteria for the basin.

In the recent years, changes have been made to the release schedule to protect endangered species as well.

2.4.2.2 Data Collection, Management and Application

In order to manage this system, accurate real-time data of existing and anticipated hydrologic and meteorological conditions is obtained. The geographical and seasonal variations with the basin required the USACE to develop a system to manage this real-time data. The result was the creation of the Missouri River Automatic Data System (MRADS), developed in 1978.

Real-time data is collected at sites through a variety of sources and is verified to insure that it is complete and statically validated to insure there are no data outliers. Data is collected though an automated satellite Data Collection Platform (DCP). This system uses a computer microprocessor at the gage site for the purpose of obtaining real-time information, perform simple analyses, and transmit that data via satellite.

Hydrological and meteorological data collected and monitored throughout the basin include:

- Precipitation is collected at Corps project weather stations, and also in conjunction with the USGS. Precipitation data is collected in both point format (such as rain gauge data) as well as distributed data that provides a grid of precipitation data that can be validated using the point gauge locations.
- Snow data estimation is a key component to forecasting the upcoming water cycle as nearly three-fourths of the total annual streamflow is comprised of melt water. Methods used to collect snow data vary throughout the basin but include snow blankets, airborne gamma radiation surveys, remote sensing, snow course sites, and SNOTEL stations (remote snow pillows) operated and maintained by the Natural Resources Conservation Service.
- River stage data and precipitation are both collected at Corps stations. Data when available is also collected from both public and private organizations that independently maintain stations.
- Reservoir data is obtained through the power plant control system.
- Evaporation has a large impact on this system and is monitored using an evaporation pan at each Mainstem reservoir. Daily manual measurements are taken April to October when temperatures are above freezing.
- Air temperature is important for determining snowmelt and river ice formation. Air temperature monitoring, along with wind speed, wind direction, and precipitation, are recorded hourly using automated weather equipment.
- Tailwater temperature is monitored as a water quality parameter; however it is also important to the regulation process for developing evaporation estimates. Tailwater temperature is also an important element in predicting downstream water temperatures and for estimating the formation and movement of the ice cover below the reservoirs.
- River observations are taken through field visits or where necessary using video cameras to monitor ice cover or bank erosion in areas of concern.

2.4.2.3 Operational Procedures

Management of the Missouri River system applies a combination of experience, operational constraints, runoff simulation and predictive models. The goal of the present model network is to use water efficiently, especially during years of low runoff. Both short and long term hydrological forecasts are used to assist in decision making.

Using the hydrological conditions from the previous year and the forecasted conditions of the upcoming year, the USACE creates an Annual Operating Plan is based on the *Missouri River Master Water Control Master Manual*. This provides the framework for the development of detailed monthly, weekly and daily reservoir regulation schedules.

The reservoir schedules are released to the public via the USACE website for the Missouri River Basin. Other information such as current conditions and warnings are also conveyed to the public using this website.

Missouri River applies a number of different forecasting periods for determining upcoming reservoir releases. As the basin applies long-term planning strategies, a calendar year forecast is developed at a monthly increment for various sites throughout the watershed in order to estimate the flows as a percent of the monthly norm. In addition to this, a three week forecast is prepared on a weekly basis and a five day forecast is prepared daily. For shorter term flood forecasting, data from the National Weather Service is used to estimate flows. This short term flood forecasting is independently done in parallel by the National Weather Service and the USACE to provide a range of flood conditions.

To conduct water simulations and modeling, the Corps Water Management System (CWMS) is used in addition to the MRADS database; however, the ultimate goal is to use CWMS as the primary database management system. This approach lays the foundation for the automation and integration of data management and real-time watershed modeling for all Corps water management activities in the Missouri River basin.

Models have currently been developed only for the areas that have the most impact on the regulation of the system. Hydrologic and hydraulic modeling of additional areas of the system may be developed in the future as required.

2.4.3 Comparison to the Trent Severn Waterway

The operational characteristics of the Missouri River Mainstem Reservoir System have been described in the preceding sections. **Table 2-5** summarizes some of the key characteristics, and compares the RTA operations to the TSW.

Table 2-5 - Comparison of Operational Characteristics between MRMRS and TSW

Missouri River Mainstem Reservoir System (MRMRS)	Trent Severn Waterway (TSW)
Objectives are based on capturing the peak seasonal flood flows (typically spring runoff), while maintaining flow regimes that are conducive to water supply (domestic and irrigation), environmental conditions, recreation, navigation and hydro-electric power generation	Primary objective is to conduct all operations in a manner that protects public safety. Legislated mandate to provide for navigation through the navigable portions of the Waterway. Additional goals to protect the natural environment, resident recreation and enjoyment, hydro power generation, and wastewater discharge/water intake concerns
Drainage basin size: 1,300,000km^2, encompasses several different climate conditions	Drainage basin size: 18,690km^2, climate conditions are relatively uniform across the system
Operations include the use of reservoir zones, and the application of operator experience and operational constraints	Operations include the use of reservoir zones, rule curves, and the application of operator experience and operational constraints
Daily operational decisions rely heavily on extensive water management modeling, forecasting tools, and the inclusion of real-time data and meteorological forecasts	No current use of system wide modelling or forecasting
Operations include development of annual, monthly, weekly and daily operational plans, to optimize hydro production and avoid impacts of extended droughts. The USACE develops the operational plans based on the previous year and the forecasted conditions of the upcoming year, as well as the *Missouri River Master Water Control Master Manual*	Operations include the use of seasonal operating strategies
Water control structures are automated hydro electric generation facilities.	Many water control structures (i.e., Haliburton Sector) rely on manual labour for stop log adjustments, although the TSW does have many automated dams as well.
Public communication includes current and recent flow and water levels, as well as operational strategies	TSW water managers post observed water levels on websites to inform users of the observed and historic water levels

2.5 Summary

The four water management systems evaluated in this section each have their own unique set of conditions, whether it be geography and climate, management objectives, governance structure or variety of stakeholders. However, these systems also have many similarities to the Trent Severn Waterway, and have developed their operational procedures or strategies to incorporate similar considerations that may provide valuable insight to the operation of the Waterway. As a result of this review, the following highlights several items for discussion for the potential enhancement of the TSW's operations, framed around the components of the Water Management Process, particularly the Operational Management Process, introduced in **Section 1.4**.

Data Collection

The data collection component of the Operational Management Process involves the collection and management of the information that is necessary to implement operational decisions, such as water levels, flows, meteorological data, etc. Two areas for potential enhancement of the current data collection procedures were identified in this report: improving collection and use of real-time operational data, and improving data-sharing agreements to expand the range of available information.

Real-Time Operational Data

Increasing the use of real-time data for operational decisions provides more timely information for water managers. Many of the water level gauges in the TSW, particularly in the North, Central and South Sectors, currently use automated data collection and transmission to water managers. However, there are also many gauges, particularly in the Haliburton Sector, that must be manually read and communicated to water managers. Real-time meteorological data could also be collected from numerous sources to validate and calibrate modelling tools.

Data-Sharing Agreements

There are a variety of reliable external data sources that could provide valuable information for consideration as part of the Water Management Process. Increased scope of data-sharing agreements may provide additional information resources for effective decision making in the TSW. Data sources can include constraint variables to develop management ranges (i.e., environmental and flooding data from Conservation Authorities), or operational variables to enhance day-to-day operations (i.e., meteorological data from Environment Canada).

Processing and Decision Making

The processing and decision making components involve the use of operational data in various tools that provide water managers with information on the state of the system and on potential operational alternatives to achieve desired results. The review of other water management systems have yielded two areas for potential enhancement of the current data processing activities of the TSW: forecasting and modelling, as well as the use of tools to optimize operations.

Forecasting and Modelling

Increased use of forecasting and modelling of meteorologic (including snowpack), hydrologic and hydraulic conditions in the Waterway to support operational decisions may reduce the frequency of short-term manual adjustments required for the system. Forecasting can be done on several time scales: daily, weekly, monthly and annually, with proportionate levels of detail. For example, daily forecasting would estimate precipitation quantities over the next one to three days, while annual forecasts would gauge the probability of precipitation being less than or greater than the average. The results can be used to time water releases from lakes, or to hedge against a dry season and attempt to conserve water throughout the system. Forecasting of meteorological conditions supports hydrologic and hydraulic modelling to simulate the effects of these conditions on the actual performance of the Waterway, i.e., the ability of operators to maintain water levels within management ranges.

Optimization of Operations

Tools are available for water managers to assist in the optimization of operations to maintain management ranges. The optimization algorithms could be created to ensure that the management ranges developed under the Constraint Management Process are maintained for as long as possible, in as many lakes as possible, or as high as possible, for example. Such an optimization tool could be integrated with the hydrologic and hydraulic models for the Waterway to contribute to the decision making process as part of the Waterway operations.

Implementation

The implementation component is the result of the data collection, processing and decision making of the Operational Management Process, and involves the actual execution of the operational decisions, i.e., the adjustment of dam settings to create a change in water levels or flows in the system. Two potential areas for enhancement were identified through the evaluation completed in this report: increasing the use of automated control structures at dams, and increasing the level of public and stakeholder engagement in operational decisions.

Automated Water Control Structures

Implementation of automated control structures within the Waterway would enhance fine tuning control of water levels and reduce manual labour involved in implementing dam setting adjustments. Many of the dams in the Haliburton Sector, in particular, are operated manually with stop logs, and could benefit from the installation of automated controls. All dams in the Waterway could benefit from implementation of remotely controlled automated gates.

Public and Stakeholder Engagement

Incorporation of annual meetings with interest groups and stakeholders, as well as an annual public open house, may facilitate communication of important information and promote a comprehensive understanding of TSW operations to a broader audience. In addition, improved communication of operations on a day to day basis through the TSW website, including anticipated operations/dam adjustments, may help to improve public understanding and acceptance of operational decision making.

3. Water Management Model Evaluation

Based on the review of other water management systems, potential refinements to the current water management system for TSW were recommended. One potential refinement is the expanded use of simulation software to perform detailed operation simulations primarily to incorporate given hydrological data to estimate future water levels and flows), and support the operational decision-making process.

The following sections detail computational modeling with respect to water resources, hydrological and meteorological data collection, as well as the review of available software packages.

3.1 Computational Modeling for Water Resources

3.1.1 Hydrological Modeling

A hydrological model is a mathematical model used to simulate the movement and redistribution of water within a defined area, typically a watershed. Most models are set up to mimic the hydrological cycle. They apply meteorological conditions (such as precipitation, temperature, snowpack depth, etc) to a representation of a watershed (based on parameters defining watershed area, land surface cover, land slope, soil permeability, etc), in order to determine the volumes or rates of flow of water to various components of the hydrologic cycle. In general, a model result of key interest is the time series of flows from a defined area or at a particular location (such as a total runoff hydrograph at the watershed outlet).

There are many different types of hydrological models and different applications. Some engineering applications include land use planning, flood forecasting, urban flooding studies, flood-frequency studies, reservoir design, hydraulic design, and water quality modeling.

3.1.1.1 Approach

Different modeling approaches are available to represent the hydrologic cycle.

For instance, a hydrological modeling may be *event* based or *continuous*. An *event* based model determines various components of the hydrologic cycle for a single storm event such as the 100 Year design event, Hurricane Hazel or a particular rainfall event during a given year. A *continuous* model simulates hydrologic cycle components for a series of events over a longer time period such as a month or a year (or more). The advantage of using a continuous model is that it is able to include antecedent conditions for the simulation of multiple storm events.

Modeling can incorporate different resolutions of variation in parameters and meteorological data within the watershed. A *distributed* model applies a higher resolution of data (e.g., meteorological inputs for various sites, spatially distributed land cover, slopes, etc.), while a lumped model may apply an averaged value for a large area.

There are various methods for incorporating the equations and relationships defining the hydrological cycle into the model. These are classified as *empirical* or *conceptual* models. A *conceptual* model is built upon the knowledge of physical processes while an *empirical* model applies relationships based on observations. Many models uses both a combination a *conceptual* and *empirical* processes (*semi-empirical*).

The type of model applied and the setup of the model will depend on the desired level of accuracy of the output.

3.1.1.2 Hydrological Cycle Components

Different hydrologic models include the various components of the hydrologic cycle at different levels of detail. A simplified model may estimate some components of the hydrologic cycle using assumptions and simplified equations. However, some models attempt to quantify both the hydrologic cycle and the energy balance (they are sometimes referred to as land surface models). The processes attempt to mimic what occurs in reality and incorporate energy equations to calculate evapotranspiration, evaporation, and snowmelt.

One issue that is typically encountered when more complexity is introduced to a hydrological model is the additional data requirements that accompany it, including data to support the further model parameterization and data for model validation.

The processes that are part of the hydrological cycle are:

- precipitation;
- interception;
- snow storage;
- depression storage / water body storage;
- infiltration;
- groundwater interactions;
- overland runoff;
- evaporation / evapotranspiration; and
- streamflow routing.

Precipitation is typically one of the required inputs for hydrological modeling. When precipitation occurs a number of different processes could result, including interception, depression storage, infiltration, overland flow and storage.

Interception is precipitation captured and temporarily stored on or in vegetation, such as in the depressions on leaves or water absorption into the vegetation. Most of the water in that is intercepted will evaporate.

In colder climates precipitation may also occur in the form of snow and accumulate as stored water in a snowpack over the course of winter. Precipitation inputs for hydrological models seldom distinguish between snow and rain; as such temperature is used to determine the form of precipitation. For example, the degree day method can be applied to determine the form of precipitation. To determine the melting processes of snow a temperature indicator can be applied or energy based equations used. Hydrological models that calculate the energy balance typical require additional input data including incoming solar radiation, slope and aspect.

Depression storage is another form of precipitation storage. Depression storage occurs when water becomes trapped in local ground depressions. A simple example of depression storage is a puddle. When this occurs the water will either evaporate or infiltrate into the soil depending on the conditions available. Infiltration is the process by which precipitation moves downward though the soil. In a natural environment, the majority of the precipitation reaching the ground will infiltrate into the ground if the soil is not saturated. In an urban environment, this does not occur as readily due to increase imperviousness of the ground. As a result, water is more likely to either evaporate or be captured by the stormwater management system. As a result land cover is important in determining the amount of water that is able to infiltrate into the soil. The rate of infiltration that occurs is highly dependent on factors such as vegetative cover, soil conditions, temperature, and rainfall intensity. There are several methods for calculating infiltration; some examples include Horton's Method, the Green-Ampt model, Philip Equation, Stanford Watershed Model.

Once the water has infiltrated into the soil there are three possible paths: interflow, aquifer recharge and deep groundwater. Interflow is subsurface horizontal flow that moves at shallow soil depths and reaches the surface again in a relatively short period of time. Alternatively, some of the water that infiltrates the soil will contribute to the recharging the ground water tables.

In a natural environment, overland flow or surface flow does not often occur and most runoff travels as interflow. The exception to this would be higher intensity rain storms, the presence of dense soils or impermeable surfaces that make it difficult for the water to penetrate the surface.

Evaporation is defined as the processes by which water returns to the atmosphere. Evaporation is a function of solar radiation, vapour pressure gradient between water and atmosphere, temperature, wind, and atmospheric pressure. Evaporation can also occur as evapotranspiration, where plants release moisture into the atmosphere. Evaporation and evapotranspiration rates can be estimate or calculated using the methods derived from the water balance or the energy balance. Some physical methods of estimation include measuring pan evaporation and using a lysimeter to determine evapotranspiration.

3.1.1.3 Model Inputs and Parameters

Given the complexity of the hydrological cycle and various approaches that can be applied, the required model data inputs and model parameters can vary considerably. Required model inputs are typically meteorological data, which can be as simple as temperature and precipitation. A more complex model may also include barometric pressure, wind speed, longwave and shortwave solar radiation and humidity.

Hydrological parameters can include but are not limited to:

- catchment area;
- land use data;
- land and river slopes and aspects (often derived from a digital elevation model);
- land and riverbed soil types and soil properties; and
- land and river bed/bank vegetative cover and properties.

These parameters are dependent on the processes calculated in the model.

3.1.2 Hydraulic Modeling

A hydraulic model is a mathematical model used to represent the physical in stream processes of a watercourse, creek or river, including the main channel and overbank / floodplain. The model outputs for a hydraulic model can include water surface elevation (stage), velocity, scour forces, left and right bank over flow and other valuable information. Typically models apply physically based equations that are derived from fundamental fluid dynamics and hydraulic equations.

Some engineering applications of hydraulic modeling include floodline mapping, culvert and bridge sizing, and scour and rock protection.

Modeling can be undertaken as steady state (for a single point in time such as a peak discharge flow) or dynamic (for a hydrological event such as a runoff hydrograph). As with hydrological modeling there is typically a trade-off between model accuracy and setup time/costs.

The required model inputs and model parameters will vary for each model. Required model inputs typically would include flow discharge (either from observed conditions or hydrological modeling), channel cross-sections or geometry, control structures, downstream water levels, and channel characteristics such as Manning's roughness coefficients.

3.1.3 Water Management Modeling

Many water management models are typically focused around managing and/or optimizing competing objectives such as flood control, power production, navigation and natural resources protection. Water management models are often used as a tool to assist operators in making informed decisions.

The complexity and data requirements of the water management models can vary greatly with the function of each program. To provide the most accurate results, it is necessary to accurately reflect current conditions along with the estimated future conditions.

Real-time data is often the most accurate way to reflect current conditions; however if this data is not available then the flows may be estimated using a hydrological model. The hydrological model can be incorporated by model coupling. To apply hydrological forecasting, typically a water management model would also be coupled with a hydrological model to estimate future flows for the system.

3.1.4 Coupling Models

Coupling of models allows the user to apply multiple models in series. Event flood flows can be estimated for a storm using a hydrological model. These flows could then be used in the hydraulic model to determine stage water levels and velocities. Finally this information could be applied in a water management model to assist the managers with decision making for reservoir levels and how to best mitigate flooding impacts.

Without the right model or set of models this process could quickly become very time consuming and convoluted. For this reason, selecting the correct software is a vital part of model functionality. While some software packages were designed for coupled use (such as the Mike models by DHI) other programs have been developed which act as an interface between various models making coupling a possible and efficient process (such as the Water Management Model described in Section 3.3.8) .

3.1.5 Calibration, Optimization and Validation

The purpose of model calibration is to confirm model performance accuracy by varying uncertain parameters within a realistic range of values until model results compare closely to observed data. Optimization is the process of performing multiple calibration runs, with the goal of improving the results, typically using a numerical measure to determine the quality of the results. Validation is the process of comparing the model results to observed data for a non-calibration event. It is very important that the validation data set is different than the calibration data set. Calibration and validation are most commonly applied to hydrological models that have a large number of unknown parameters and often can have long term data sets. Calibration and validation is beneficial to hydraulic modeling however the data required is often difficult to obtain.

Historically, model calibration was conducted by trial and error, with modellers changing parameter values and reviewing the changes in accuracy and statistical measures such as model fit. This trial and error (or manual) calibration approach can be applied to any model calibration. This approach generally leads to a strong understanding of model parameters and can be highly effective, when conducted by experienced modellers

(Madsen, 2000). The other common calibration method is automatic calibration, where parameters are adjusted according to a specified search algorithm and numerical measures assess the goodness-of-fit for the new parameter set (Madsen, 2000). Generally automatic calibration is much faster than manual calibration.

3.1.6 Geographic Information System (GIS)

A geographic information system (GIS) is a very powerful tool that can be applied for hydrology and hydraulics. GIS can be used for storing and processes large sets of data while retaining the spatial distribution by associating a coordinate system with the data. Some of the applications of GIS for water resources include processing land use data, post processing DEMs to delineate slope, aspect or watershed boundaries, and determining stream order. In addition to the pre-processing tools, GIS is also beneficial in post processing for creating floodline maps and other tools for interpreting data results.

Some programs have been developed to assist GIS users in hydrological modeling such as Arc Hydro and ArcGIS Spatial Analyst. Other hydrological models have been built to work with ArcGIS (such as some MIKE by DHI, and HEC-GeoRAS and HEC-GeoHMS) and incorporate the tools available from GIS and integrate the hydrological or hydraulic model. For instance a model may be setup to apply spatially available data such as land use data, soil data, DEM derived data such as terrain, slope and aspect.

3.2 Hydrological and Meteorological Data Collection

Data collection is a fundamental component to hydrological modeling and real-time watershed management. A well developed system of data collection can streamline the modeling processes. The following section discusses some of the methods for collecting precipitation and other hydrometric and meteorological data that may be applied to water resources management.

3.2.1 Precipitation

Precipitation data is often collected using automated meteorological stations. Both snow and rain can be measured using automated methods. The following section details some of the methods of collecting precipitation data and how it can be applied to hydrological modeling.

Quantifying precipitation in a liquid form can be achieved using many different types of gauges some of these include tipping buckets, weight based gauges. Tipping buckets are a simple instrument that allows the water to run down a funnel (with a known diameter) and measures a set increment (approximately 0.005ml, however it can vary with the gauge) and records the number of times that the measure drains by tipping back and forth. A weight based recording gauge is another method of recording precipitation. This method records the total cumulative weight of the water and need to be emptied and reset on a regular basis. Modification can be made to either instrument to measure snow water equivalent (SWE) by adding heating coils to the instruments however this is only practical when electricity is available and is not suitable for remote locations. Various configurations of gauge setup and gauge shield have been applied to improve the accuracy of the rain gauge measurements in events with high winds or blowing snow.

Radar is capable of producing a large scale distributed precipitation data. Weather radars transmit microwaves in a focused beam. The energy that reflects off of objects is measured by the radar. Typically this measured data is precipitation; however mountains and large city buildings can also produce interference. The intensity of the precipitation may also impact the measured results. For instance very heavy or very light precipitation events may be over or under estimated by the radar.

Rain gauges produce point source precipitation measurements, while radar data produces a distributed image of data. Precipitation however; does not often fall at one rate over a large area and is inherently variable. Mathematical methods of distributing point source rainfall data (such as Inverse distance weighting) are often applied to distribute rain gauge data. Rain gauge data can also be combined with radar data to produce a distributed data product. Both distributed radar and rain gauge data have been applied to hydrological models and compared to observed streamflow values. The results showed that radar alone does produce reliable results for the entire area covered by the radar.

In addition to rain gauges and radar data, there are other methods for measuring precipitation in the form of snow. Snow data can be measured as a depth, density, and snow water equivalent. Methods of measurement include snow pillows, snow survey courses, and remote sensing of snow covered area. Snow pillows operate by measuring the change in pressure on the pillow to determine the SWE. Measurements can be taken using automated data loggers allowing for placement in remote locations. Snow survey courses are not automated and are taken manually. They involve taking a series of point measurements at a set location. At each point snow depth and weight for a measured volume of snow is recorded and used to calculate the SWE. Remote sensing of snow cover can also be used to determine the snow pack over a large area however this method only provides data for one point in time and can be cost prohibitive.

3.2.2 Hydrometric Data

Hydrometric data includes the measurement of streamflow (or discharge) and water level (or water stage) data. Streamflow is typical measured in units of m^3/s and can be calculated using the velocity of the water (m/s) and the cross-sectional flow area (m^2). There are a number of methods for measuring flow in a stream or a creek. Stationary velocity gauging devices may be used at locations of flumes, weirs and control sections to determine discharge. As these methods are not always possible, rating curve can be developed to relate stage (or water depth) to discharge for a given location. A rating curve is determined by taking discrete measurements of discharge by measuring the channel velocity and geometry (typically using a velocimeter). This process must be completed regularly and where possible include extreme high and low flows. In areas with fixed channel area (such a culvert or concrete lined trapezoidal channel) flow measurement is possible by measuring the velocity and depth to calculate the area and discharge. Water level or stage data can be measured using pressure transducers or other logging equipment such as a float/weight on a pulley system.

Hydrometric data is measured by the Water Survey of Canada and sometime also available from local conservation authorities.

3.2.3 General Meteorological Data

Meteorological stations are used to measure and record meteorological conditions. Some of the meteorological data that may be applied to hydrological models includes:

- Temperature;
- Barometric Pressure;
- Solar radiation (longwave and shortwave); and
- Wind speed

Temperature is a very commonly applied hydrological input. Temperature can vary spatially and it can vary with elevation. Precautions should be taken to account for this, either thorough correction methods or multiple gauging stations.

Evaporation is measured using a standard Class A Evaporation Pan, with 5cm of water in the bottom of the pan. Measurements are taken daily and then the pan is refilled to exactly 5cm of water. This data is particularly useful in the management of reservoirs.

3.3 Available models

The following sections summarize some of the models available for hydrological, hydraulic and water management modeling. Each of these models could be applied to the Trent Severn Waterway.

3.3.1 MIKE

The MIKE software is developed and managed by DHI, a global and independent research and development organisation. The MIKE software packages are used around the world in research, consulting, and the private sector. The software is designed to work with other models or programs such as ArcGIS and have user friendly Graphical User Interfaces (GUI). The associated costs of the MIKE models vary depending on the model selected and the functions but could cost between $8,000 to $25,000 for the models discussed plus an annual support fee. The most appropriate MIKE models for the management of the Trent Severn Waterway are MIKE 11 and MIKE BASIN. Both of these programs are compatible with GIS for ease of use. Applications and details of each are summarized below.

MIKE 11 is a river modeling package that applies 1D hydrodynamic principles to river and open channel flow (DHI, 2011). MIKE 11 is capable of performing simplified hydrology. The ArcGIS extension can be applied for river delineation, cross-section and DEM data, and flood analysis. Model applications can include:

- Flood analysis and flood alleviation design studies;
- Real-time flood forecasting;
- Dam break analysis;
- Optimization of reservoir and canal gate/structure operations;
- Ecological and water quality assessments in rivers and wetlands;
- Sediment transport and river morphology studies;
- Salinity intrusion in rivers and estuaries; and
- Wetland restoration studies (DHI, 2011).

MIKE BASIN was designed as a multi-purpose decision support tool for addressing water allocation, conjunctive use, reservoir operation, or water quality issues (DHI, 2011). MIKE BASIN is used in conjunction with ArcGIS, for ease of use and data transferability. It allows for comprehensive hydrologic modeling and simplified flow routing to minimize the data requirements while still providing basin-scale solutions. This is important for water management optimization problems.

For hydrologic simulations, MIKE BASIN builds on a network model in which branches represent individual stream sections and the nodes represent confluences, diversions, reservoirs, or water users. Technically, MIKE BASIN is a quasi-steady-state mass balance model, however allowing for routed river flows. The water quality solution assumes purely advective transport; decay during transport can be modeled. The groundwater description uses the linear reservoir equation. Additional water management features of the MIKE BASIN program also include water allocation algorithms, reservoir operations options, hydropower simulation.

Typical areas of application are:

- Analysis of water use demands including domestic, industry, agriculture, hydropower, navigation, recreation, ecological, and optimization to find equitable trade-offs.
- Water availability analysis with conjunctive surface and groundwater use.
- Infrastructure planning including irrigation potential, reservoir performance, water supply capacity, waste water treatment requirements.
- Ecosystem studies for water quality, minimum discharge requirements, sustainable yield, and effects of global change.
- Regulation for water rights, priorities, water quality compliance.

In one case study DHI in concert with the SFWMD developed a real-time hydrological modeling system (DHI, 2009). The system uses information such as water levels, ground water levels and control structure data collected by the SFWMD with the MIKE SHE model (a hydraulic/hydrological model) to maintain the watershed. The study watershed, Cypress Basin, is particularly prone to both flooding and droughts making it a difficult basin to manage without accurate flow forecasting. By using real-time knowledge of the watershed with forecasted flows this provides water management operators with information on what the basin is currently experiencing and what may occur based on forecasts. This allows operators to make informed decisions regarding water release.

3.3.2 HEC Software

Software developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers are available for free to perform hydrologic and hydraulic simulations. The software relevant to the TSW includes:

- HEC-HMS (Hydrologic Modeling System);
- HEC-ResSim (Reservoir Simulation);and
- HEC-RAS (River Analysis System).

HEC-HMS can be used to perform precipitation-runoff analysis of watersheds to create flow hydrographs from spring snowmelt and/or rain events, HEC-ResSim is used to perform reservoir system simulation/optimization and HEC-RAS calculates water levels along a river reach by performing backwater calculations for given flows.

HEC-HMS was designed to model many different types of watershed and as such is not limited to mountainous terrain or urban hydrology. The program is generalized, allowing the user to input the basin, meteorological and time-series data separately into the model and then select the appropriate hydrological cycle processes necessary to obtain correct model outputs (USACE HEC, 2010b). This program requires a strong knowledge of hydrology and the basin being modeled.

HEC-ResSim was designed for real-time reservoir regulators as a decision support tool. It was designed to be used to model reservoir operations at one or more reservoirs whose operations are defined by a variety of operational goals and constraints such as flood control, power generation, navigation, water supply, recreation, and environmental quality (USACE HEC, 2007). Features include multiple reservoir outlets (for a single reservoir), outlet prioritization and conditional logic possible. The model attempts to reproduce the decision making process that an operator would use to set releases through a rule-based description of the operational goals and constraints.

HEC-RAS performs the hydraulic analysis as part of the HEC package using a one-dimensional approach to calculate surface water profiles (USACE HEC, 2010a). The HEC-RAS system can perform steady flow water surface profile computations, unsteady flow simulation, sediment transport computations, and water quality analysis. All elements reference a common geometric data and hydraulic computation routines.

HEC has also developed a geospatial version of HEC-HMS and HEC-RAS. They were developed hydrology/hydraulic toolkits for engineers and hydrologists with limited GIS experience. The programs use ArcView and the Spatial Analyst extension to develop model inputs and where applicable view model results.

Due to the magnitude and complexity of some of the systems that the USACE manages, HEC began development of the Corps Water Management System (CWMS) in the late 1990's. CWMS was developed as an Oracle database or a UNIX server for data management. The goal of CWMS was to encompass the steps of the water management process, starting with the integration of real-time data, then hydrological simulations and finally decision support so that operators are able to quickly and efficiently make decisions (USACE HEC, 2000). CWMS has not been released publically; however the software is being used by 35 Corps District and Division offices. To develop a publicly available version of CWMS the USACE started developing HEC-RTS (Real-Time Simulation), a windows platform version of CWMS. Presently version 1 of HEC-RTS loosely couples the modeling programs and is available by request only, however version 2 has a much more integrated platform and is expected to be released in 2011 (Charley, 2010).

3.3.3 RiverWare™

RiverWare™ is a water management model developed by the Center for Advanced Decision Support for Water and Environmental Systems at the University of Colorado under joint sponsorship by the U.S. Bureau of Reclamation, Tennessee Valley Authority and the U.S. Army Corps of Engineers. The program has been used extensively on the Colorado River basin. Software licensing fees range from $7,500 to $13,500USD plus annual maintenance fees.

RiverWare™ is reservoir and river based simulation and optimization model that allows the user to build the model and select the appropriate modeling methods (CADSWES, 2005). Some of the built in features of RiverWare™ include:

- Storage Reservoir,
- Hydro power production,
- Flow routing,
- River Gage stations allow for real-time or forecasted flow inputs,
- Allows for diversions and water users withdrawals,
- Groundwater Storage, and
- Canals allow for flow between reservoirs.

RiverWare™ is based on the mass balance of the water cycle. The system includes processes such as evaporation and groundwater inputs/losses but does not perform hydrological calculations based on precipitation inputs. The period of hydrological analysis may range from a single event or a continuous record length. The model allows for inputs from real-time data or forecasted data from a hydrological model. The software uses automatic calibration to optimize the model. Multi-objective optimization is also possible to balance multiple objectives using linear programming algorithms.

The RiverWare™ program can also be used as the reservoir optimization software for the soon to be released HEC-RTS package in lieu of the HEC-ResSim program.

3.3.4 MODSIM

MODSIM is a water management model initially developed at Colorado State University in the 1970's and has been sponsored by U.S. Bureau of Reclamation Pacific Northwest Region since 1992. MODSIM is a general-purpose reservoir/river system simulation designed to provide an integrated evaluation of hydrologic, economic, environmental, impacts related to development of alternative management scenarios as well as aid in real-time river basin operations and control (Labadie, 2010). The software and documentation are available to be downloaded free of charge.

Some features of MODSIM include:

- The model network is completely defined by the user;
- Capable to efficiently modeling large networks;
- Can be used for long-term planning and/or real-time operations;
- Georeferenced network topologies can be loaded via GIS;
- Reservoir balancing and hydropower capabilities;
- Modeling capabilities for surface water groundwater interactions and can be coupled with MODFLOW for more detailed groundwater modeling;
- Muskingum or user-specified time-lagged hydrologic streamflow routing; and
- Graphical/tabular display of the results (Labadie, 2010).

The inflows for unregulated stream are input into MODSIM from measured flow data, watershed runoff models, forecasts, drought scenarios, or flows can be generated using stochastic streamflow estimation.

3.3.5 Water Rights Analysis Package (WRAP)

Water Rights Analysis Package (WRAP) is a water management model initially developed at Texas A&M University in the 1980's and has been sponsored by a federal/state cooperative university research program administered by the U.S. Geological Survey and Texas Water Resources Institute. WRAP is a water resources, water allocation and river/reservoir system program that applies streamflow data, reservoir evaporation and precipitation rates to represent basin hydrology (Wurbs, 2010). The software and documentation are available to be downloaded free of charge.

Typically WRAP is applied at a policy level to assess the targets for satisfying reservoirs releases/storage for water supply, hydro power, streamflow and storage targets. WARP can be run at a daily simulation time step so that it can also be applied for operational purposes. To simplify the data management process, WARP can also work with the HEC-DSS program. WARP is capable of simulating a single basin may also be used to assess the basin (or multiple basin) impacts of a proposed water project.

3.3.6 OASIS

OASIS is a water management program developed by Hydrologics designed for conflict resolution of water management and developing operation policies to best satisfy the demands of the system. Software subscription fees were not provided by Hydrologics.

OASIS uses a combination of GUI and an Operation Control language that enables data to be entered as to describe the basin's operating conditions, constraints and demands (Hydrologics, 2011). OASIS does not compute the system hydrology and relies on imputed observed or estimated/forecasted conditions. Input files and data are typically stored in MS Access, ASCII, and HEC-DSS.

3.3.7 Aquatic Real-time Management System (ARMS)

ARMS (Aquatic Real-time Management System) was developed as an aquatic water management system that applies a combination of hardware and software (including data management systems) for monitoring and managing lakes and rivers. The system, developed by researchers at Center for Water Research (CWR) at the University of Western Australia, focuses on aquatic water quality of lakes, reservoirs and streams but can also be applied to aid water resources managers in decision making. Software fees range from $5,000 to $50,000AUS for annual membership fees depending on the required level of support. Hardware fees for the ARMS system were not provided by the CWR.

The ARMS software package manages historical and real-time water resource data, can post information to the internet, provides real-time and forecast numerical modelling capabilities, sends email messages via regarding the system status, and computes decision support indices to aid managers (Ewing et al, 2004). The system wirelesses transfers data from the equipment to researchers reducing the requirements for field staff and enabling managers to make more informed decisions. This technology has been implemented in various case studies around the world for applications of water quality, water supply, pollution control, flooding, and hydropower management.

3.3.8 Watershed Modeling System (WMS)

The Watershed Modeling System (WMS) is an integrated GUI for modeling watershed hydrology and hydraulics developed by Aquaveo. The system does not support reservoir optimization or water management software. The program does not use its own hydrologic and hydraulic models, but does include hydrologic modeling with HEC-1 (HEC-HMS), TR-20, TR-55, Rational Method, NFF, MODRAT, and HSPF. Hydraulic models supported include HEC-RAS and CE QUAL (Aquaveo, 2011). Software subscription fees range from $400 to $5,600USD.

In addition to the model integration, WMS also includes automated modeling processes such as basin delineation, parameter calculations, GIS overlay computations (CN, rainfall depth, roughness coefficients, etc.), cross-section extraction from terrain data and flood mapping.

3.3.9 WATFLOOD

WATFLOOD is a distributed hydrological model initially developed in the 1970's at the University of Waterloo. WATFLOOD applies a gridded modeling system for short- (event based) or long- (years) term hydrological simulations. One of innovative concepts of WATFLOOD was that it was the first hydrological program to introduce the Grouped Response Unit (GRU) concept in hydrological modeling (Kouwen, 2010). Over the years a focus has been added on incorporating remotely sensed data, such as radar rainfall data for precipitation inputs or LANDSAT data to determine the land classes. Data pre/post-processing, basin setup and basin delineation is accomplished with Green Kenue™ (formerly EnSim Hydrologic) developed by Environment Canada. Green Kenue™ uses a GUI similar to that of GIS systems and is capable of delineating watershed boundaries and water courses from a DEM, and developing input files using Water Survey of Canada and Environment Canada databases. Both the WATFLOOD and Green Kenue™ software and documentation are available to be downloaded free of charge.

Unlike the water management models, the WATFLOOD model is not orientated towards reservoir optimization. The WATFLOOD model will however determine the flows into the lakes and reservoirs based on the observed or forecasted precipitation events where no streamflow gauges exist. WATFLOOD routing routines can use inputted reservoir releases to determine the downstream flows.

Although Green Kenue™ provides a GUI for data setup and post processing, the WATFLOOD model is a FORTRAN based program, run from a command prompt. The documentation developed over the years for WATFLOOD is beneficial in developing and running the model however a strong working knowledge of hydrology and hydrological processes is required for model development.

3.3.10 HBV-EC Model

The HBV model is a rainfall-runoff model, which includes conceptual numerical descriptions of hydrological processes at the catchment scale. The model was developed Swedish Meteorological and Hydrological Institute. The model was later adapted by the University of British Columbia and Environment Canada and renamed HBV-EC distinguishing the Canadian version of HBV. HBV-EC is available for download as part of the Green Kenue^{TM}, free of charge.

As the HBV-EC Model is a hydrological routing model, it uses observed hydrological data such as precipitation, air temperature and evapotranspiration to determine the catchment hydrology. Some of the HBV-EC model variations include varied climate zones within the watershed, snow melt calculations vary with changes to slope and aspect, and watershed routing calculations (Canadian Hydraulics Center and Water Survey Canada, 2010).

This model has been incorporated into the Green Kenue^{TM} program, therefore the program has a GUI and a detailed user's manual for setting up and running the model. Presently the model is not setup to incorporate real-time streamflow or reservoir data into the hydrological model. The model could however be used for hydrological forecasting using estimated meteorological data.

3.3.11 Hydrological Simulation Program FORTRAN (HSPF)

The Hydrological Simulation Program FORTRAN (HSPF) model is a continuous hydrological model, which includes conceptual numerical descriptions of hydrological processes at the catchment scale. The model was developed initially as the Stanford Watershed Model and was later adapted by the U.S. Environmental Protection Agency and the U.S. Geological Survey. The HSPF model is available to download from the U.S. Geological Survey free of charge.

The HSPF model uses information such as the time history of rainfall, temperature and solar radiation; land surface characteristics such as land use and land management practices to simulate the processes occurring in the watershed. This model is able to provide simulation for both water quantity and water quality for urban or agricultural watersheds. Output results include flow rates, sediment loading, and nutrient and pesticide concentrations. The program is run through DOS command prompt, however it can also be run using a GUI though the WMS (previously discussed in Section 3.3.8).

4. References

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Appendix A

Lake of the Woods Reports and Graphs

LWCB
Lake of the Woods Control Board

Daily Report

Period Ending: Thu Jan 20, 2011

** Provisional Data **

	Precip Estimate		Elevation				Jan 21	Outflow		Inflow	
	30 Day 7 Day	30 Median %ile	3 Day Estimate	7 Day Change	Median	Storage Status	Level Outflow	14 Day 7 Day	7 Median %ile	14 Day 7 Day	7 Median %ile
	mm mm	mm %ile	m *ft*	m *ft*	m *ft*	%ile / % / m *ft*	m m³/s	m³/s m³/s	m³/s %ile	m³/s m³/s	m³/s %ile
ENGLISH SYSTEM											
Lake St. Joseph Albany Outflow							 0 E	1 0	1 40th		
LAKE ST. JOSEPH and Diversion	2 0	28 MIN	372.727 *1222.86*	-0.024 *-0.08*	372.613 *1222.48*	65th	372.727 105 E	107 105	84 75th	93 84	64 80th
Sturgeon River McDougall Mills							 26	27 27	23 70th		
English River Umfreville							 40	42 41	36 65th		
LAC SEUL	15 2	30 10th	355.808 *1167.35*	-0.058 *-0.19*	355.679 *1166.93*	60th	355.799 370 E	370 370	371 50th	247 241	178 70th
Chukuni River							 *20* ^	*20* ^ *20* ^	15 70th		
Troutlake and Cedar Rivers							 33	33 32	18 95th		
English River Pakwash / Manitou Falls			346.251 *1136.00*	-0.039 *-0.13*	346.237 *1135.95*	50th	346.219 432 E	433 436	429 55th		
Wabigoon River Quibell							 33	34 34	27 65th		
English River Caribou Falls	11 2	25 LT5th	318.075 *1043.55*	+0.102 *+0.33*	318.132 *1043.74*	-0.125 *-0.41*	 437 E	452 433	486 35th	473 467	481 45th
WINNIPEG SYSTEM											
Basswood Lake			396.085 *1299.49*	+0.000 *+0.00*	396.200 *1299.87*	15th	396.085 11	11 11	20 15th		
LAC LA CROIX	30 4	26 60th	360.532 *1182.85*	+0.007 *+0.02*	360.653 *1183.25*	25th	360.532 46	46 46	59 25th	47 48	58 30th
Vermilion River							 10	10 10	8 70th		
NAMAKAN AND KABETOGAMA LAKES			339.830 *1114.93*	-0.052 *-0.17*	339.488 *1113.81*	73%	339.824 111 E	111 113	87 70th	91 92	70 70th
Seine River Sturgeon Falls								46 42	38 80th		
RAINY LAKE	28 9	23 65th	337.197 *1106.29*	-0.021 *-0.07*	337.239 *1106.43*	39%	337.193 213 E	190 202	213 40th	171 172	163 60th
Little Fork and Big Fork Rivers							 *57* ^	*52* ^ *53* ^	11 95th		
Rainy River Manitou Rapids							 *480* ^	*455* ^ *448* ^	262 GT95th		
LAKE OF THE WOODS	16 4	21 30th	322.731 *1058.83*	-0.029 *-0.09*	322.746 *1058.88*	50th	322.727 547 E	553 551	423 75th	347 367	314 65th
Winnipeg River Below Norman			316.964 *1039.91*	+0.001 *+0.00*	316.724 *1039.12*	+0.271 *+0.89*	316.965				
Winnipeg River Minaki			316.030 *1036.84*	+0.010 *+0.03*	316.053 *1036.92*	-0.064 *-0.21*	316.028				
Winnipeg River Nutimik / Seven Sisters	— —	22 —	274.930 *902.00*	-0.115 *-0.38*	274.785 *901.53*	65th	274.916	1050 1030	934 70th		

^ These flow values are possibly over-estimated due to ice-effects

ISSUED: 2011.01.21

Most values are based on partial data

LWCB
Lake of the Woods Control Board

10-Day Inflow Report

Period Ending: Fri Jan 21, 2011

** Provisional Data **

	Elevation 1 Day	Elevation 3 Day Mean	Elevation 7 Day Change	Elevation Storage Status	Outflow	Inflow 1-Day	Inflow 7-Day	Inflow 14-Day	Inflow 7-Day %ile
	m	m	m	%ile/%/m	m³/s	m³/s	m³/s	m³/s	%ile
Lake St. Joseph									
Jan 12	372.728 P	372.745 P	-.016 P	65th	109	34 P	96 P	93 P	85th
13	372.767 P	372.751 P	-.010 P	65th	108	351 P	101 P	96 P	90th
14	372.757 P	372.754 P	-.002 P	65th	107	44 P	108 P	99 P	90th
15	372.738 P	372.744 P	-.007 P	65th	105	-13 P	102 P	97 P	90th
16	372.738 P	372.741 P	-.004 P	65th	105	105 P	104 P	97 P	90th
17	372.748 P	372.741 P	-.001 P	65th	106	168 P	106 P	98 P	90th
18	372.738 P	372.738 P	.001 P	65th	105	43 P	107 P	98 P	90th
19	372.727 P	372.731 P	-.014 P	65th	105	36 P	93 P	95 P	85th
20	372.727 P	372.727 P	-.024 P	65th	105	105 P	84 P	93 P	80th
21	372.727 P	372.727 P	-.027 P	65th	105 E	105 E	81 E	94 E	75th
Lac Seul									
Jan 12	355.869 P	355.873 P	-.058 P	60th	370	199 P	241 P	254 P	65th
13	355.870 P	355.866 P	-.053 P	60th	370	385 P	252 P	260 P	75th
14	355.859 P	355.859 P	-.051 P	60th	370	199 P	256 P	262 P	75th
15	355.847 P	355.852 P	-.050 P	60th	370	183 P	258 P	259 P	80th
16	355.849 P	355.844 P	-.052 P	60th	370	401 P	252 P	252 P	75th
17	355.837 P	355.838 P	-.051 P	60th	370	184 P	256 P	249 P	75th
18	355.829 P	355.830 P	-.049 P	60th	370	246 P	259 P	248 P	80th
19	355.825 P	355.818 P	-.055 P	60th	370	308 P	248 P	244 P	75th
20	355.801 P	355.808 P	-.058 P	60th	370	-3 P	241 P	247 P	70th
21	355.799 P	355.800 P	-.059 P	60th	370 E	339 E	239 E	248 E	70th
Namakan Lake									
Jan 12	339.890	339.891	-.046	80%	115	91	88	91 P	70th
13	339.883	339.882	-.050	78%	114	95	89	90 P	70th
14	339.874	339.875	-.053	78%	115	90	91	90	70th
15	339.867	339.867	-.056	77%	114	94	92	89	70th
16	339.860	339.860	-.057	76%	113	94	93	89	70th
17	339.854	339.853	-.056	75%	113	97	92	90	70th
18	339.845	339.846	-.054	75%	112	87	93	90	70th
19	339.838	339.837	-.053	74%	112	93	92	90	70th
20	339.829	339.830 P	-.052 P	73%	111	86	92 P	91 P	70th
21	339.824 P	339.827 P	-.048 P	73%	111 E	97 E	93 E	92 E	70th
Rainy Lake									
Jan 12	337.219	337.220 P	-.013 P	32%	171	142 P	174 P	180 P	55th
13	337.218	337.218	-.006 P	33%	172	162	170 P	181 P	50th
14	337.217	337.217	-.001 P	35%	198	189	174 P	176 P	55th
15	337.215	337.214	.001 P	36%	200	180	181 P	172 P	60th
16	337.210	337.212	.001 P	37%	199	150	185 P	171 P	65th
17	337.211	337.209	-.005 P	38%	201	210	181 P	172 P	60th
18	337.207	337.207 P	-.010 P	39%	199	160	177 P	173 P	60th
19	337.202 P	337.202 P	-.018 P	39%	203	154 P	171 P	173 P	55th
20	337.197	337.197 P	-.021 P	39%	213	164 P	172 P	171 P	60th
21	337.193 P	337.195 P	-.022 P	41%	213 E	174 E	173 E	174 E	60th
Lake of the Woods									
Jan 12	322.763	322.765	-.035	50th	554	198	334	386 P	55th
13	322.760	322.760	-.037	50th	554	420	326	384	55th
14	322.756	322.756	-.038	50th	553	375	313	376	50th
15	322.752	322.752	-.037	50th	553	375	319	367	50th
16	322.748	322.749	-.036	50th	553	374	325	358	55th
17	322.746	322.745	-.033	50th	552	464	343	356	60th
18	322.741	322.741	-.030	50th	552	329	362	354	65th
19	322.737	322.736	-.029	50th	550	372	368	351	65th
20	322.729	322.731 P	-.029 P	50th	547	191	367 P	347 P	65th
21	322.727 P	322.728 P	-.028 P	50th	547 E	457 E	372 E	343 E	70th

ISSUED: 2011.01.21

10-Day Database Report

Period Ending: Fri Jan 21, 2011

** Provisional Data **

Standard

	Cat River Flow	L St Joseph Root R Level	L St Joseph Root R Outflow	L St Joseph Computed Level	L St Joseph Rat Rapids Level	L St Joseph Albany R Outflow	L St Joseph Mean Level	L St Joseph 7-day Inflow	L St Joseph 14-Day Inflow	L St Joseph Total Outflow
Jan 12	42.4	372.060	106.8	372.757	372.699 P	2.0	372.728 P	96.3 P	93.1 P	108.8
13	42.1	372.057	107.6	372.767		0.0	372.767 P	101.1 P	96.2 P	107.6
14	41.8 P	372.057	106.8	372.757		0.0	372.757 P	107.5 P	98.8 P	106.8
15	41.5	372.039	105.3	372.738		0.0	372.738 P	102.3 P	96.6 P	105.3
16	41.1	372.030	105.3	372.738		0.0	372.738 P	104.2 P	97.0 P	105.3
17	41.1 P	372.041	106.1	372.748		0.0	372.748 P	106.3 P	98.4 P	106.1
18	40.8 P	372.032	105.3	372.738		0.0	372.738 P	107.4 P	97.6 P	105.3
19	40.4	372.024	104.5	372.727		0.0	372.727 P	93.4 P	94.8 P	104.5
20	40.2	372.014	104.5	372.727		0.0	372.727 P	84.0 P	92.6 P	104.5
21	40.0 P	372.008 P	104.5 E	372.727 E		0.0 E	372.727 P	81.0 E	94.2 E	104.5 E

	Sturgeon R McDougall Flow	English R Umfreville Flow	Lac Seul Hudson Level	Lac Seul LS Post Level	Lac Seul Goldpines Level	Lac Seul Ear Falls HPL	Lac Seul Mean Level	Lac Seul 7-day Inflow	Lac Seul 14-Day Inflow	Lac Seul Ear Falls Outflow
Jan 12	27.2	42.4	355.917		355.869	355.790	355.869 P	240.7 P	253.7 P	370.1
13	27.2	42.2	355.909		355.870	355.790	355.870 P	251.8 P	260.2 P	369.8
14	27.0	41.9	355.903		355.859	355.780	355.859 P	256.1 P	262.3 P	369.5
15	26.9	41.7	355.897		355.847	355.760	355.847 P	258.2 P	258.9 P	369.8
16	26.8	41.4	355.885		355.849	355.760	355.849 P	251.5 P	252.1 P	369.8
17	26.8	41.6	355.881		355.837	355.740	355.837 P	256.0 P	248.8 P	370.1
18	26.7	41.2	355.875		355.829	355.740	355.829 P	258.9 P	247.6 P	370.0
19	26.5	41.0	355.861		355.825	355.730	355.825 P	247.8 P	244.2 P	369.9
20	26.2	40.8	355.853		355.801	355.720	355.801 P	241.1 P	246.5 P	369.7
21	26.2 P	40.4 P	355.850 P		355.799 P		355.799 P	238.9 E	247.5 E	369.7 E

	English R Ear Falls TWL	Troutlk R Flow	Chukuni R Flow	Pakwash L Level	English R Camping L Level	Cedar R Flow	English R Manitou F HPL	English R Manitou F Outflow	English R Manitou F TWL	Longleg'd R Flow
Jan 12	346.330	*23.2 ^*	*20.2 ^*	346.262	346.158	8.7	345.657	442.5	330.190	2.5
13	346.320	*22.3 ^*	*20.0 ^*	346.257	346.158	8.6	345.657	439.2	330.190	2.5
14	346.320	*22.1 ^*	*20.0 ^*	346.250	346.158	8.6	345.657	439.9	330.190	2.5
15	346.320	*21.6 ^*	*20.0 ^*	346.251	346.158	8.6	345.657	434.3	330.190	2.5
16	346.310	*22.0 ^*	*19.9 ^*	346.252	346.158	8.6	345.657	427.1	330.190	2.5
17	346.330	*22.6 ^*	*20.0 ^*	346.252	346.158	8.6	345.657	446.5	330.190	2.5
18	346.310	*25.0 ^*	*20.2 ^*	346.242	346.153	8.6	345.641	440.7	330.209	2.5
19	346.310	*24.4 ^*	*20.4 ^*	346.229	346.139	8.5	345.718	431.9	330.129	2.5
20	346.310	*23.1 ^*	*20.5 ^*	346.220	346.139	8.4	345.722	432.1	330.127	2.5
21		*24.4 ^*	*20.4 ^*	346.219 P	346.125 P	8.4 P	345.626 P	432.1 E	330.206 P	2.4 P

	Wabigoon R Quibell Flow	English R Grassy N's Level	Sturgeon R Salveson Flow	English R Caribou F HPL	English R Caribou F Outflow	Kawishiwi R Flow	Basswood L Level	Basswood L Outflow	Lac La Croix Level	Lac La Croix Outflow
Jan 12	34.0	319.356	8.2	317.960	447.3	0.7	396.087	11.4	360.523	45.4
13	33.9	319.354	8.2	317.970	441.5	0.7	396.085	11.3	360.524	45.5
14	33.6	319.356	8.2	317.990	436.8	0.8	396.084	11.3	360.526	45.7
15	33.6	319.360	8.2	318.010	406.7	0.8	396.085	11.3	360.527	45.8
16	33.7	319.361	8.0	318.040	415.6	0.8	396.085	11.3	360.529	46.0
17	33.6	319.370	8.0	318.040	481.9	0.8	396.085	11.3	360.532	46.3
18	33.8	319.373	8.1	318.040	428.9	0.9	396.085	11.3	360.533	46.4
19	33.8	319.374	7.9	318.070	423.7	0.9	396.085	11.3	360.532	46.3
20	33.4	319.376	7.9	318.080	436.7	0.9	396.085	11.3	360.531	46.2
21	33.2 P	319.374 P	7.8 P		436.7 E	0.9 P	396.085 P	11.3 P	360.532 P	46.3 P

^ - These flow values are possibly overestimated due to ice effects

10-Day Database Report

Standard

Period Ending: Fri Jan 21, 2011

** Provisional Data **

	Vermilion R Flow	Crane Lake Level	Kabetogama Gold Portage Level	Kabetogama Gold Portage Outflow	Namakan L Squirrel Is Level	Namakan L Mean Level	Namakan L Kettle Falls Outflow	Namakan L Bear Portage Outflow	Namakan L 7-day Inflow	Namakan L 14-Day Inflow
Jan 12	10.0	339.914	339.869	3.7	339.910	339.890	111.8	0.0	88.4	90.7 P
13	10.1	339.902	339.864	3.7	339.901	339.883	110.8	0.0	89.2	90.4 P
14	10.1	339.896	339.854	3.6	339.894	339.874	111.1	0.0	90.9	90.2
15	10.1	339.894	339.844	3.5	339.890	339.867	110.0	0.0	91.6	89.2
16	10.0	339.880	339.841	3.5	339.879	339.860	110.0	0.0	92.5	89.1
17	9.9	339.875	339.833	3.4	339.875	339.854	109.9	0.0	92.3	89.5
18	10.0	339.870	339.823	3.3	339.867	339.845	109.0	0.0	92.9	90.2
19	10.1	339.858	339.817	3.3	339.859	339.838	108.6	0.0	92.0	90.2
20	10.1	339.853	339.805	3.2	339.852	339.829	107.4	0.0	92.2 P	90.7 P
21	10.3 P	339.849 P	339.804 P	3.2 P	339.844 P	339.824 P	107.4 E	0.0 P	93.2 E	92.0 E

	Nam/Kab L Total Outflow	Atikokan R Flow	Seine R Raft Lake Level	Seine R Raft Lake Outflow	Seine R Sturgeon F Outflow	Turtle R Flow	Rainy L Bear Pass Level	Rainy L Ft Frances Level	Rainy L Mean Level	Rainy L 7-day Inflow
Jan 12	115.5	*1.9 ^*	414.498	26.3	50.1	26.7	337.213	337.224	337.219	174.4 P
13	114.5	*1.9 ^*	414.486	25.9	47.6	26.2	337.210	337.225	337.218	169.7 P
14	114.6	*1.9 ^*	414.475	25.9	46.0	25.4	337.210	337.223	337.217	174.1 P
15	113.5	*1.8 ^*	414.466	25.7	42.2	25.4	337.210	337.219	337.215	180.9 P
16	113.5	*1.8 ^*	414.462	25.7	42.2	25.3	337.202	337.218	337.210	185.1 P
17	113.3	*1.9 ^*	414.462	25.7	42.6	25.2	337.204	337.218	337.211	180.6 P
18	112.4	*1.9 ^*	414.460	25.7	42.5	25.1	337.201	337.212	337.207	177.4 P
19	111.9	*1.9 ^*	414.459	25.7	42.2	25.0	337.194 P	337.210	337.202 P	170.7 P
20	110.6	*1.9 ^*	414.456	25.5	39.2	24.8 P	337.190	337.203	337.197	172.4 P
21	110.6 E	*1.9 ^*	414.457 P			24.7 P	337.185 P	337.200 P	337.193 P	173.1 E

	Rainy L 14-Day Inflow	Rainy L Ft Frances HPL	Rainy L Total Outflow	Rainy R Ft Frances TWL	Rainy R Int'l Falls TWL	Big Fork R Flow	Little Fork R Flow	Fork Rs Combined Flow	Rainy R Manitou Rap Level	Rainy R Manitou Rap Flow
Jan 12	179.9 P	337.110	171.1	328.270	328.270	*32.1 ^*	*17.8 ^*	*50.0 ^*	326.011	*426.4 ^*
13	180.9 P	337.105	171.8	328.240	328.220	*32.1 ^*	*17.5 ^*	*49.5 ^*	325.986	*419.7 ^*
14	175.9 P	337.070	198.2	328.314	328.310	*32.0 ^*	*17.4 ^*	*49.4 ^*	325.990	*420.8 ^*
15	171.7 P	337.063	199.6	328.399	328.400	*32.1 ^*	*17.5 ^*	*49.5 ^*	326.057	*438.8 ^*
16	171.3 P	337.064	199.3	328.458	328.470	*32.0 ^*	*17.7 ^*	*49.7 ^*	326.093	*448.5 ^*
17	172.4 P	337.063	200.5	328.444	328.450	*32.0 ^*	*20.1 ^*	*52.1 ^*	326.100	*450.4 ^*
18	173.4 P	337.061	199.4	328.447	328.460	*32.1 ^*	*24.7 ^*	*56.8 ^*	326.108	*452.6 ^*
19	172.6 P	337.049	203.3	328.493	328.510	*32.3 ^*	*25.8 ^*	*58.1 ^*	326.121	*456.1 ^*
20	171.0 P	337.019	212.9	328.582	328.590	*32.3 ^*	*25.6 ^*	*57.9 ^*	326.167	*468.4 ^*
21	173.6 E	337.107 P	212.9 E	328.458 P		*32.3 ^*	*25.2 ^*	*57.4 ^*	326.211 P	*480.3 ^*

	Rainy R Rainy R Level	Lake/Woods Warroad Level	Lake/Woods Springsteel Level	Lake/Woods Hanson Level	Lake/Woods Cyclone Level	Lake/Woods Clearwater Level	Lake/Woods Mean Level	Lake/Woods Keewatin Level	Lake/Woods Shoal Lake Level
Jan 12	322.889	322.824	322.824	322.774	322.759	322.695	322.763	322.665	322.834
13	322.884	322.828	322.829	322.764	322.757	322.690	322.760	322.658	322.835
14	322.881	322.820	322.820	322.766	322.752	322.685	322.756	322.653	322.833
15	322.883	322.812	322.814	322.764	322.748	322.680	322.752	322.650	322.832
16	322.875	322.814	322.816	322.751	322.745	322.680	322.748	322.649	322.832
17	322.884	322.807	322.811	322.757	322.741	322.673	322.746	322.641	322.831
18	322.877	322.801	322.804	322.751	322.737	322.672	322.741	322.640	322.829
19	322.864	322.796	322.800	322.740	322.733	322.673	322.737	322.640	322.829
20	322.867	322.787	322.789	322.741	322.725	322.662	322.729	322.631	322.825
21	322.588 P	322.794 P	322.793 P	322.731 P	322.724 P	322.659 P	322.727 P	322.627 P	322.820 P

^ - These flow values are possibly overestimated due to ice effects

10-Day Database Report

Period Ending: Fri Jan 21, 2011

Standard

** Provisional Data **

	Lake/Woods 7-day Inflow	Lake/Woods 14-Day Inflow	Lake/Woods Kenora PH HPL	Lake/Woods Norman Dam HPL	Lake/Woods Total Outflow	Winnipeg R Kenora PH TWL	Winnipeg R Norman Dam TWL	Winnipeg R Minaki Level	Winnipeg R Whitedog HPL	Winnipeg R Whitedog Outflow
Jan 12	334.1	386.2 P	322.377	322.438	553.9	316.934	316.972	316.040	315.481	575.2
13	326.3	384.1	322.369	322.431	553.5	316.925	316.962	316.020	315.481	575.2
14	312.9	375.6	322.363	322.427	553.2	316.920	316.957	316.000	315.481	574.8
15	318.8	367.0	322.358	322.424	553.1	316.918	316.949	315.997	315.481	536.0
16	324.7	358.2	322.359	322.424	553.2	316.913	316.948	316.008	315.481	502.7
17	343.3	355.9	322.349	322.418	552.2	316.920	316.953	316.027	315.481	506.2
18	362.2	353.5	322.348	322.415	551.9	316.923	316.956	316.032	315.486	510.0
19	367.9	351.0	322.342	322.403	549.9	316.966	316.962	316.030	315.502	534.4
20	366.9 P	346.6 P	322.319	322.377	546.6	317.001	316.966	316.032	315.487	529.8
21	372.3 E	342.6 E	322.319 P	322.374 P	546.6 E	316.999 P	316.965 P	316.028 P	315.485 P	529.8 E

	Winnipeg R Boundary F Level	Winnipeg R Pte du Bois HPL	Winnipeg R Slave Falls HPL	Winnipeg R Slave Falls Outflow	Winnipeg R Slave Falls TWL	Whiteshell R Flow	Winnipeg R Nutimik L Level	Winnipeg R Seven Sis HPL	Winnipeg R Seven Sis Outflow	Whitemouth Flow
Jan 12	301.145 P	299.075	284.563	1050.4	275.876	*4.8 ^*	275.049	274.105	1065.8	*14.0 ^*
13	301.139 P	299.080	284.552	1045.4	275.856	*4.8 ^*	275.042	274.108	1072.1	*13.9 ^*
14	301.128 P	299.070	284.540	1046.7	275.855	*4.7 ^*	275.043	274.105	1073.2	*13.9 ^*
15	301.083 P	299.057	284.576	1019.2	275.813	*4.7 ^*	275.014	274.083	1068.3	*13.9 ^*
16	301.035 P	299.073	284.572	1004.1	275.765	*4.7 ^*	274.968	274.086	1029.4	*13.8 ^*
17	301.032 P	299.078	284.578	977.9	275.678	*4.7 ^*	274.943	274.063	1018.9	*13.8 ^*
18	301.055 P	299.071	284.576	967.9	275.653	*4.6 ^*	274.944	274.091	989.3	*13.6 ^*
19	301.052 P	299.074	284.548	963.9	275.634	*4.6 ^*	274.944	274.097	1000.9	*13.3 ^*
20	301.056 P	299.080	284.582	935.8	275.580	*4.5 ^*	274.929			*13.1 ^*
21	301.060 P					*4.4 ^*	274.916 P			*13.0 ^*

	Pickle L Precip	Sioux Lookout Precip	Ear Falls Precip	Red Lake Precip	Dryden Precip		Upsala Precip		Winton Precip	Mine Centre Precip
Jan 12	0.30	0.00	0.00	0.00			0.00		0.25	0.00
13	0.00	1.20	0.30	1.80			0.00		1.78	3.00
14	0.00	1.50	0.00				1.50		3.81	3.60
15	0.00	0.30	0.00				0.30		0.00	0.00
16	0.80	0.60	2.50	2.20			0.60			7.60
17	1.30	3.80	1.10	2.00			5.00			1.00
18	0.00	0.00	0.00	0.00			0.00			0.00
19	0.00	0.00	0.00	0.20			0.00			
20			0.00							
21										

	Orr Precip	Kettle Falls Precip	Int'l Falls Precip	Ft Frances A Precip	Emo Precip		Winnibig L Precip	Warroad Precip	Sprague Precip	Rawson L Precip
Jan 12	0.00	0.00		0.00				1.27	0.00	0.00
13	2.54	0.00		4.00				1.02	1.80	0.00
14	0.00	0.25		10.00			7.37	4.06	2.30	0.00
15	0.00	0.00		0.00			0.00	0.00	0.80	0.00
16	11.68	1.27		5.00			1.27	4.06	2.50	0.00
17	0.00	0.00		0.00			0.00	0.00	2.00	0.00
18	0.00	0.00		0.00			0.00	0.00	1.90	0.00
19		0.00							0.00	0.00
20		0.00								0.00
21										

^ - These flow values are possibly overestimated due to ice effects

	Kenora Precip	Shoal Lake Precip	Pinawa Precip
Jan 12	0.00	2.00	2.00
13	2.80	1.00	2.00
14	2.60	0.50	2.00
15	0.00	5.50	0.00
16	3.00	0.00	8.00
17	1.60	0.00	0.00
18	0.00	0.00	0.00
19	0.40		
20			
21			

	L St Joseph Basin Mean Precip	Lac Seul Basin Mean Precip	Eng R Local Basin Mean Precip	Lac La Croix Basin Mean Precip	Rainy-Nam Basin Mean Precip	Lake/Woods Basin Mean Precip	Wpg R Local Basin Mean Precip
Jan 12	0.03	0.00	0.00	0.16	0.00	0.23	1.37
13	0.03	0.54	1.02	1.11	1.78	0.82	2.17
14	0.04	0.93	0.50	2.72	2.92	1.60	1.15
15	0.01	0.18	0.03	0.07	0.06	0.24	0.44
16	0.10	0.35	1.22	0.18	4.45	2.37	5.09
17	0.15	1.00	0.35	1.49	1.33	0.12	0.51
18	0.00	0.00	0.00	0.00	0.00	0.03	0.00
19	0.00	0.00	0.11	0.00	0.00	0.02	0.40
20	0.00	0.00	0.00	0.00	0.00	0.00	
21	0.00	0.00	0.00	0.00	0.00	0.00	

	Pickle L Max T	Pickle L Min T	Sioux Lkt Max T	Sioux Lkt Min T	Red Lake Max T	Red Lake Min T	Ear Falls Max T	Ear Falls Min T	Rawson L Max T	Rawson L Min T
Jan 12	-9.4 °	-14.1 °	-9.0 °	-20.7 °	-9.6 °	-17.5 °	-9.2 °	-23.2 °	-8.9 °	-15.4 °
13	-12.8 °	-17.7 °	-9.1 °	-21.7 °	-12.2 °	-24.5 °	-12.0 °	-24.2 °	-7.7 °	-14.6 °
14	-14.8 °	-22.3 °	-11.3 °	-18.1 °			-12.7 °	-19.1 °	-10.1 °	-17.3 °
15	-20.4 °	-28.6 °	-17.7 °	-26.8 °		-27.7 ° P	-19.1 °	-27.7 °	-17.1 °	-25.0 °
16	-18.3 °	-26.4 °	-16.6 °	-31.0 °	-17.5 °	-29.7 ° P	-16.9 °	-28.5 °	-16.5 °	-30.4 °
17	-14.8 °	-23.8 °	-14.8 °	-19.6 °	-16.6 °	-26.8 °	-14.9 °	-23.9 °	-14.3 °	-20.7 °
18	-23.4 °	-32.2 °	-19.5 °	-30.0 °	-22.9 ° P	-35.3 ° P	-21.3 °	-30.5 °	-19.1 °	-28.9 °
19	-17.4 °	-32.2 °	-15.0 °	-31.1 °	-16.9 °	-28.4 °	-15.3 °	-28.3 °	-16.0 °	-25.7 °
20							-22.3 °	-34.1 °	-19.3 °	-32.2 °
21										

	Dryden Max T	Dryden Min T	Upsala Max T	Upsala Min T	Kenora Max T	Kenora Min T	Int'l Falls Max T	Int'l Falls Min T	Sprague Max T	Sprague Min T
Jan 12			-8.4 °	-13.3 °	-10.0 °	-15.0 °			-9.7 °	-17.0 °
13			-10.0 °	-14.0 °	-8.8 °	-14.4 °			-8.1 °	-14.1 °
14			-9.6 °	-18.0 °	-10.9 °	-17.6 °			-9.3 °	-17.5 °
15			-14.0 °	-25.4 °	-19.6 °	-25.4 °			-17.2 °	-24.8 °
16			-15.0 °	-31.1 °	-16.1 °	-28.3 °			-14.0 °	-29.5 °
17			-11.4 °	-18.2 °	-14.9 °	-23.1 °			-13.2 °	-25.5 °
18			-16.6 °	-29.5 °	-21.4 °	-30.2 °			-19.7 °	-32.3 °
19			-13.3 °	-31.8 °	-17.2 °	-24.7 °			-15.2 °	-23.7 °
20										
21										

10-Day Database Report

Standard

Period Ending: Fri Jan 21, 2011

** Provisional Data **

	L St Joseph Basin Mean Avg T	Lac Seul Basin Mean Avg T	Eng R Local Basin Mean Avg T	Lac La Croix Basin Mean Avg T	Rainy-Nam Basin Mean Avg T	Lake/Woods Basin Mean Avg T	Wpg R Local Basin Mean Avg T
Jan 12	-13.4 °	-14.6 °	-14.8 °	-10.9 °	-11.5 °	-12.7 °	-12.5 °
13	-16.1 °	-15.5 °	-15.7 °	-12.0 °	-11.6 °	-11.2 °	-11.6 °
14	-17.4 °	-14.8 °	-15.1 °	-13.8 °	-13.8 °	-13.7 °	-14.3 °
15	-23.9 °	-22.2 °	-22.7 °	-19.7 °	-20.4 °	-21.3 °	-22.5 °
16	-22.7 °	-23.5 °	-22.9 °	-23.1 °	-23.3 °	-22.6 °	-22.2 °
17	-19.1 °	-17.3 °	-18.7 °	-14.8 °	-16.1 °	-18.5 °	-19.0 °
18	-26.9 °	-24.8 °	-25.4 °	-23.1 °	-23.5 °	-25.1 °	-25.8 °
19	-23.8 °	-22.8 °	-21.6 °	-22.6 °	-21.8 °	-20.3 °	-21.0 °
20	-28.2 °	-28.2 °	-27.3 °		-25.8 °	-25.8 °	
21							

	Sturgeon R McDougall WaterTemp	Lac Seul LS Post WaterTemp	Namakan L Squirrel Is WaterTemp	Int'l Falls PH WaterTemp	Rainy R Manitou Rap WaterTemp	Winnipeg R W Outlet WaterTemp
Jan 12	1.9 °	1.4 °	3.6 °	1.3 °	0.2 °	0.4 ° P
13	1.9 °	1.5 °	3.6 °	1.4 °	0.2 °	0.4 ° P
14	1.8 °	1.5 °	3.5 °	1.4 °	0.2 °	0.4 ° P
15	1.7 °	1.4 °	3.6 °	1.2 °	0.2 °	
16	1.8 °	1.4 °	3.6 °	1.3 °	0.2 °	0.3 ° P
17	1.7 °	1.4 °	3.6 °	1.3 °	0.2 °	0.3 °
18	1.7 °	1.5 °	3.6 °	1.2 °	0.2 °	0.3 °
19	1.7 °	1.4 °	3.5 °	1.3 °	0.2 °	0.3 °
20	1.8 °	1.6 °	3.5 °	1.2 °	0.2 °	0.3 °
21	1.7 ° P	1.4 ° P	3.6 ° P		0.2 ° P	0.2 ° P

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Lake of the Woods Control Board

Weekly Report

Period Ending: Tue Jan 18, 2011

** Provisional Data **

	Precipitation 30 Day 7 Day	Precipitation 30 Median %ile	Elevation 3 Day Mean	Elevation 7 Day Change	Elevation Median	Elevation Storage Status	Jan 20 Level Outflow	Outflow 14 Day 7 Day	Outflow 7 Median %ile	Inflow 14 Day 7 Day	Inflow 7 Median %ile
	mm mm	mm %ile	m *ft*	m *ft*	m *ft*	%ile / % / m *ft*	m m³/s	m³/s m³/s	m³/s %ile	m³/s m³/s	m³/s %ile
ENGLISH SYSTEM											
Lake St. Joseph Albany Outflow							 0 E	1 0	1 40th		
LAKE ST. JOSEPH and Diversion	2 0	28 MIN	372.738 P *1222.89*	+0.001 P *+0.00*	372.622 *1222.51*	65th	372.727 105 E	108 106	85 75th	98 107	65 90th
Sturgeon River McDougall Mills							 26 P	27 27	23 65th		
English River Umfreville							 41 P	43 42	37 65th		
LAC SEUL	15 3	30 10th	355.830 P *1167.42*	-0.049 P *-0.16*	355.698 *1166.99*	60th	355.802 370 E	370 370	371 50th	248 259	180 80th
Chukuni River							 *20* ^	*20* ^ *20* ^	15 70th		
Troutlake and Cedar Rivers							 31 P	33 31	18 90th		
English River Pakwash / Manitou Falls			346.279 *1136.09*	-0.027 *-0.09*	346.241 *1135.96*	55th	346.222 432 E	436 439	427 60th		
Wabigoon River Quibell							 34 P	34 34	28 65th		
English River Caribou Falls	11 3	25 LT5th	318.050 *1043.47*	+0.107 *+0.35*	318.129 *1043.73*	-0.150 *-0.49*	 424 E	466 437	482 35th	480 472	480 45th
WINNIPEG SYSTEM											
Basswood Lake			396.085 *1299.49*	-0.003 *-0.01*	396.204 *1299.88*	15th	396.085 11 P	11 11	20 15th		
LAC LA CROIX	33 6	26 65th	360.532 *1182.85*	+0.010 *+0.03*	360.657 *1183.26*	25th	360.531 46 P	46 P 46	59 25th	47 48	58 30th
Vermilion River							 10 P	10 10	8 70th		
NAMAKAN AND KABETOGAMA LAKES			339.846 *1114.98*	-0.054 *-0.18*	339.511 *1113.88*	75%	339.831 112 E	109 114	88 70th	90 93	70 70th
Seine River Sturgeon Falls								48 45	38 90th		
RAINY LAKE	33 11	23 75th	337.207 P *1106.32*	-0.010 P *-0.03*	337.250 *1106.46*	39%	337.199 203 E	198 191	216 30th	173 177	166 60th
Little Fork and Big Fork Rivers							 *58* ^	*51* ^ *51* ^	12 95th		
Rainy River Manitou Rapids							 *469* ^	*467* ^ *437* ^	259 GT95th		
LAKE OF THE WOODS	18 5	21 40th	322.741 *1058.86*	-0.030 *-0.10*	322.749 *1058.89*	50th	322.731 550 E	547 553	423 75th	354 362	314 65th
Winnipeg River Below Norman			316.957 *1039.89*	-0.020 *-0.06*	316.724 *1039.12*	+0.264 *+0.87*	316.965				
Winnipeg River Minaki			316.030 *1036.84*	-0.026 *-0.08*	316.052 *1036.91*	-0.064 *-0.21*	316.034				
Winnipeg River Nutimik / Seven Sisters	24 11	22 60th	274.944 *902.05*	-0.097 *-0.32*	274.774 *901.49*	65th	274.922	1040 1050	933 75th		

^ These flow values are possibly over-estimated due to ice-effects

ISSUED: 2011.01.20

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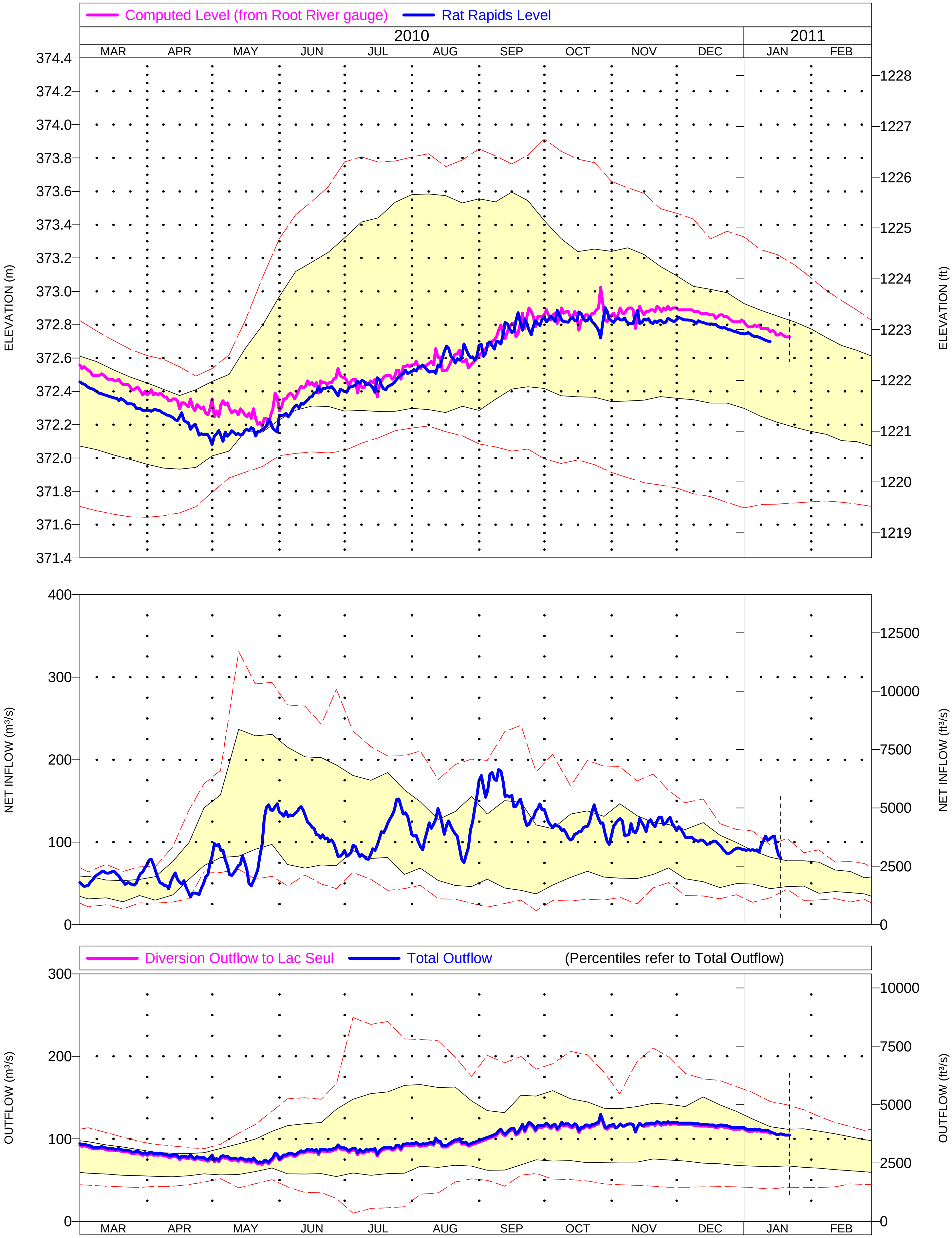
Lake of the Woods Control Board

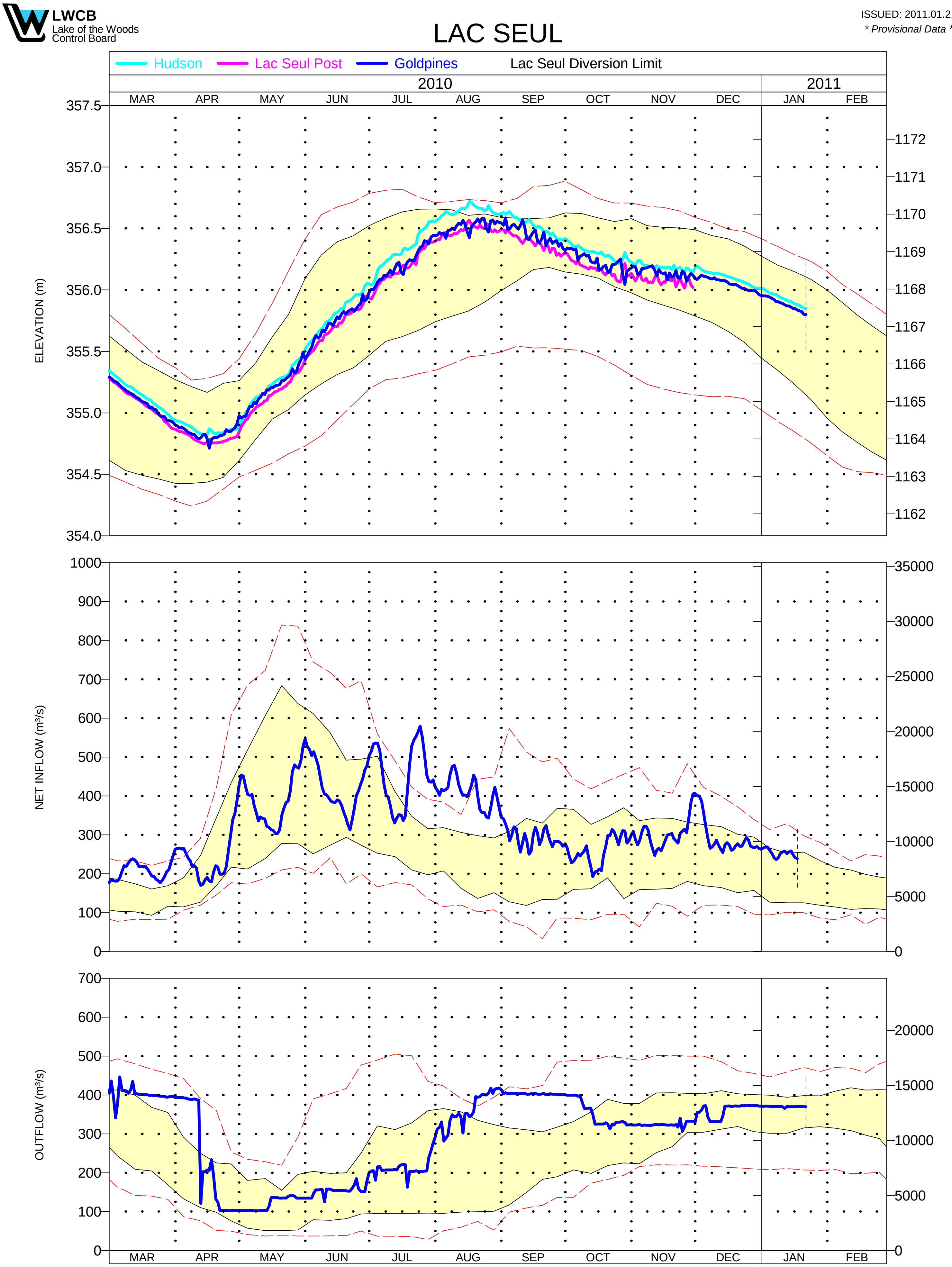
ISSUED: 2011.01.21
** Provisional Data **

LAKE ST. JOSEPH



ISSUED: 2011.01.21
** Provisional Data **

LAC SEUL



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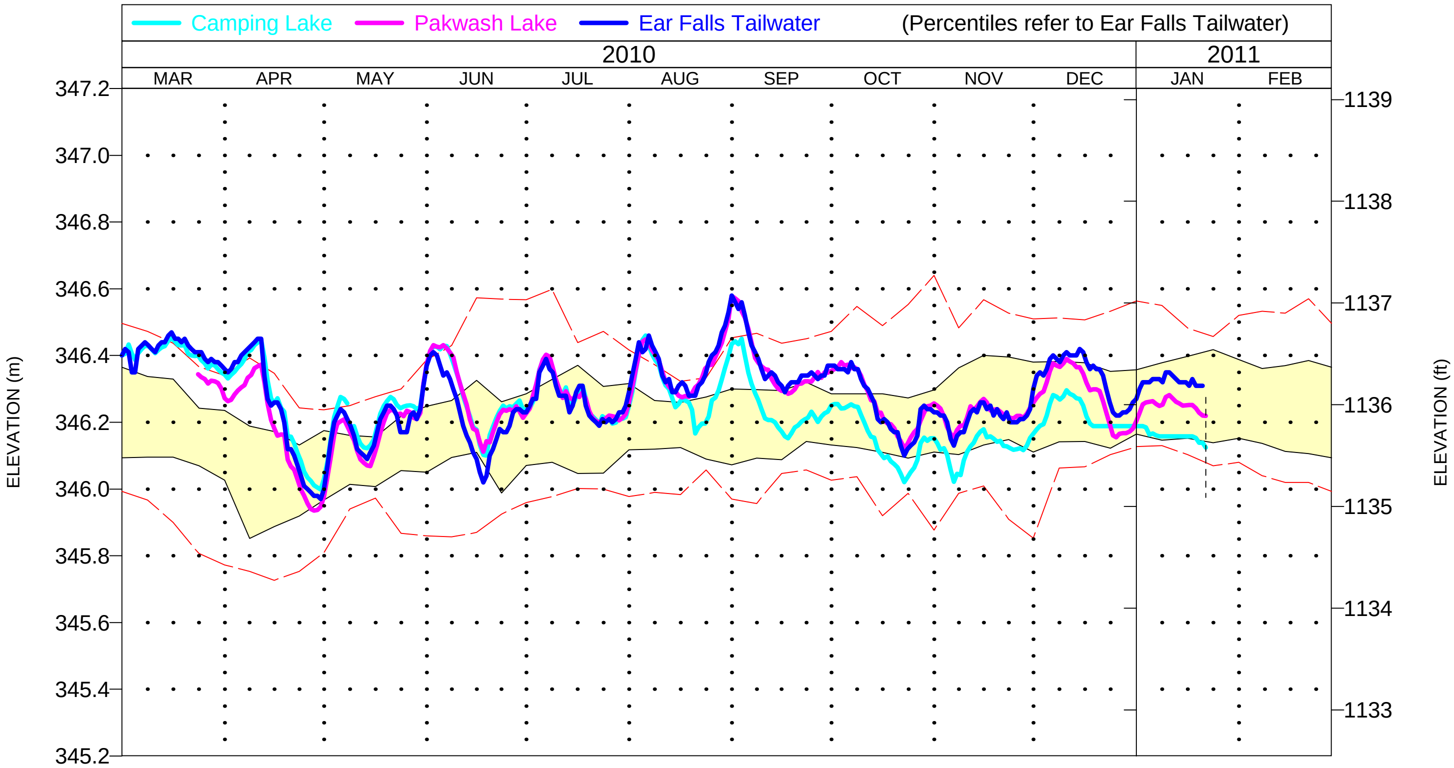
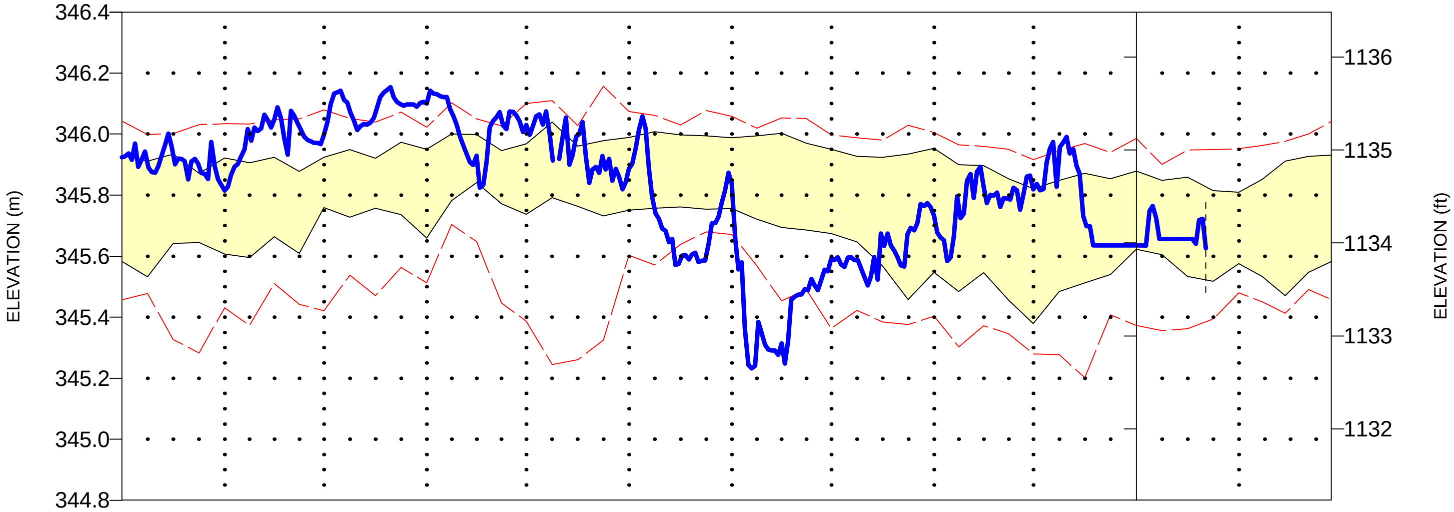
** Provisional Data **

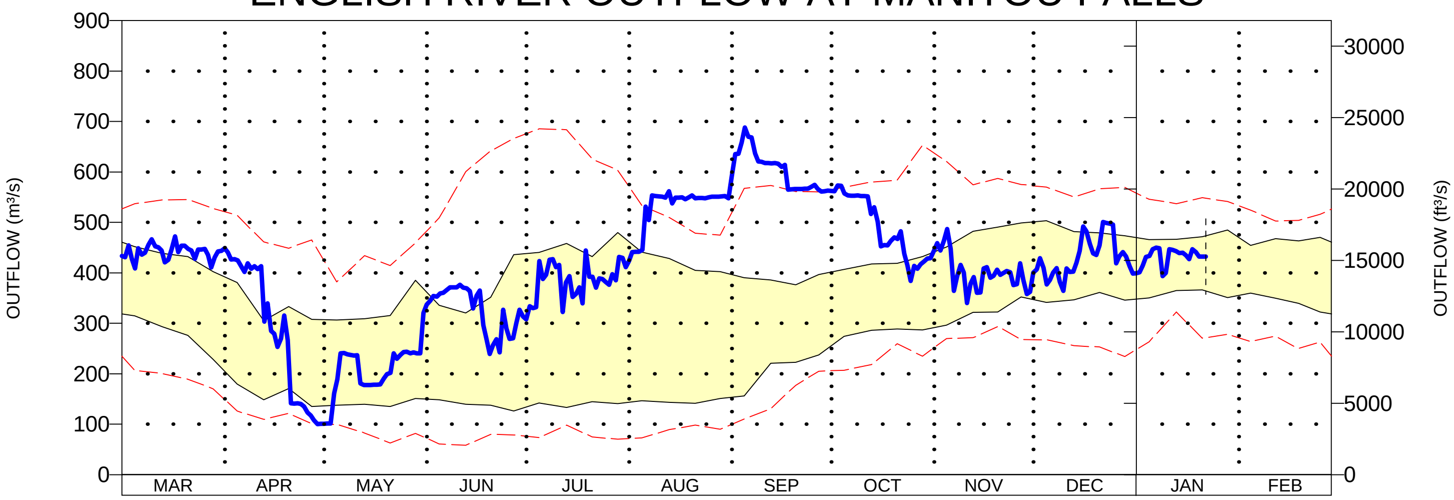
PAKWASH LAKE / EAR FALLS TAILWATER LEVEL



ENGLISH RIVER LEVEL AT MANITOU FALLS FOREBAY



ENGLISH RIVER OUTFLOW AT MANITOU FALLS



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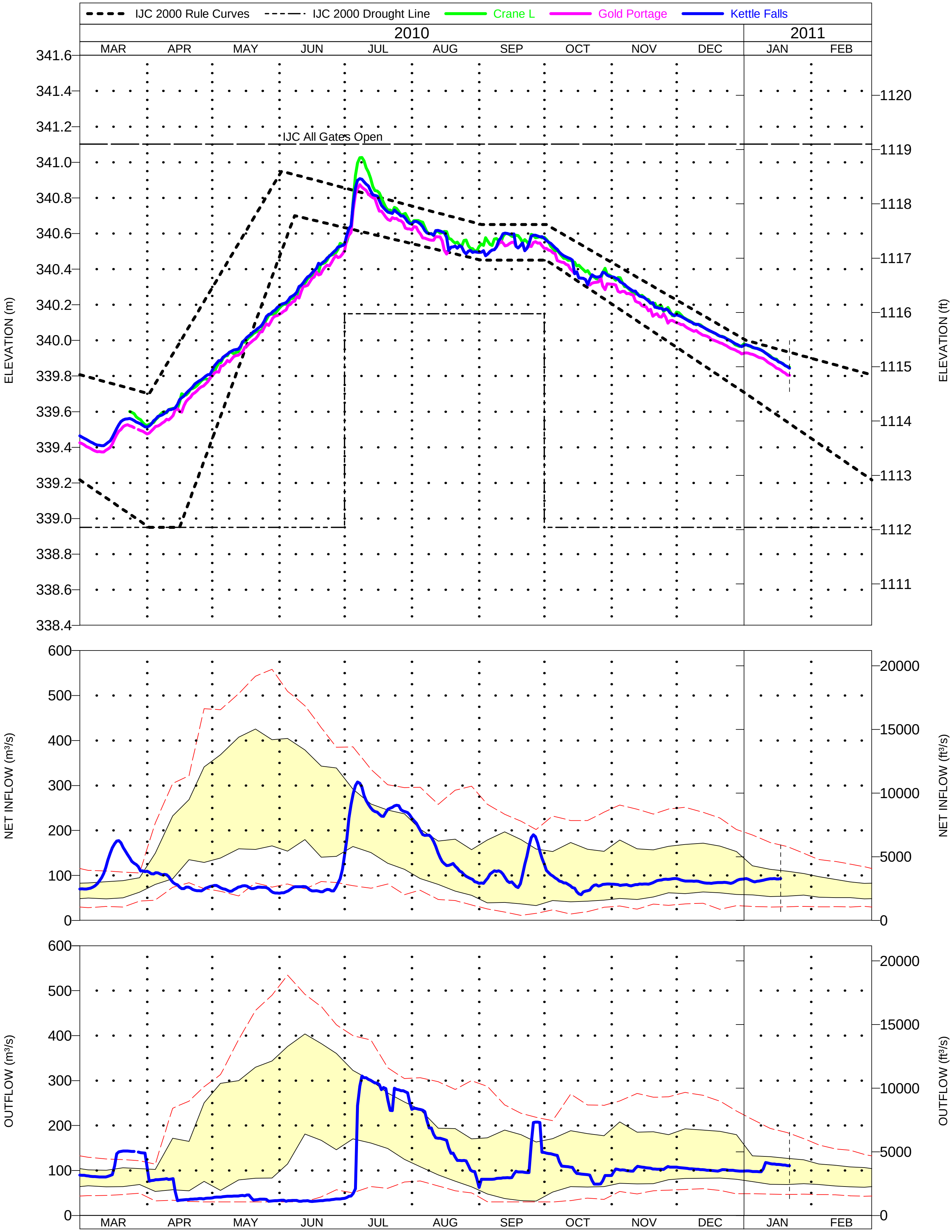
** Provisional Data **

NAMAKAN LAKE



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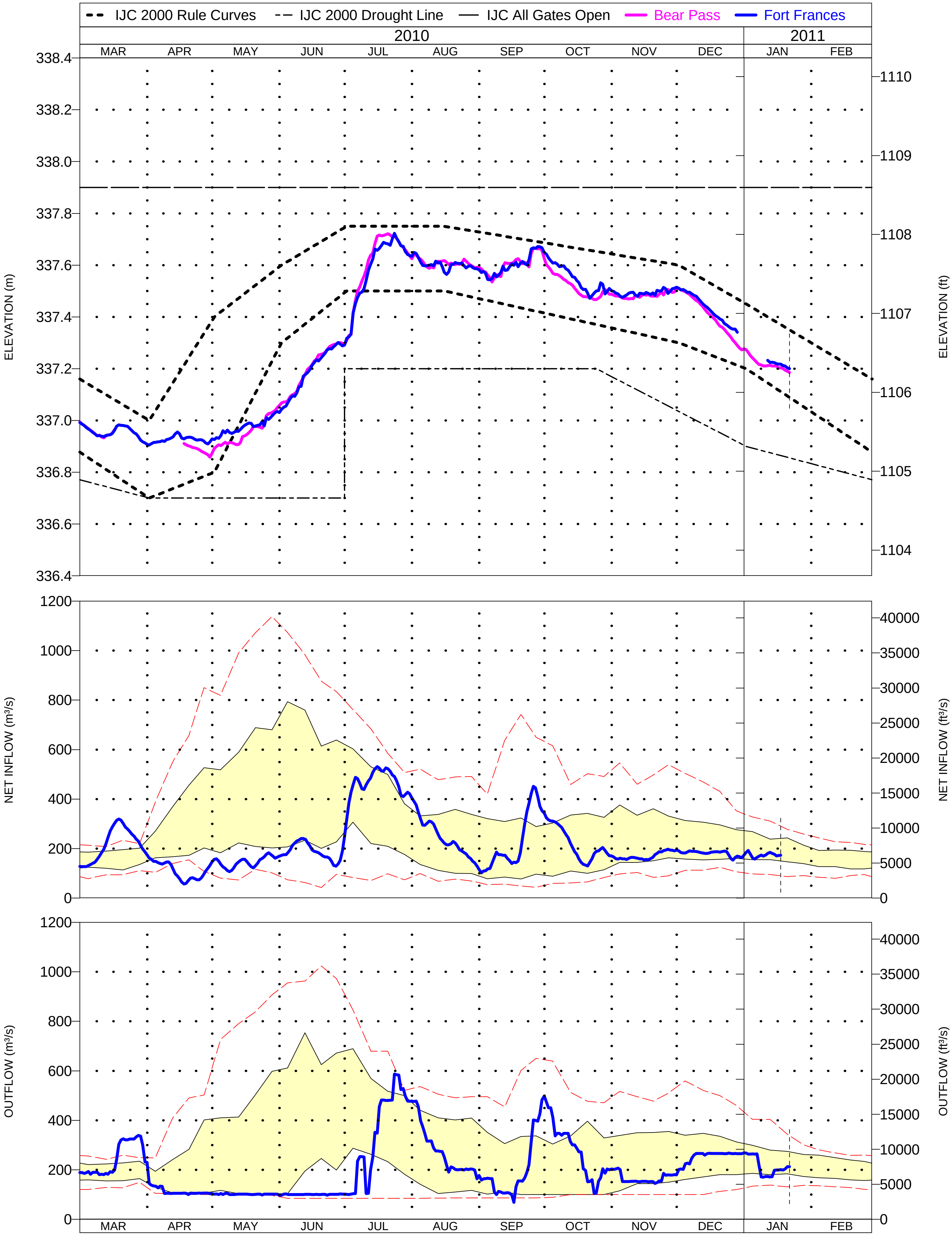
** Provisional Data **

RAINY LAKE



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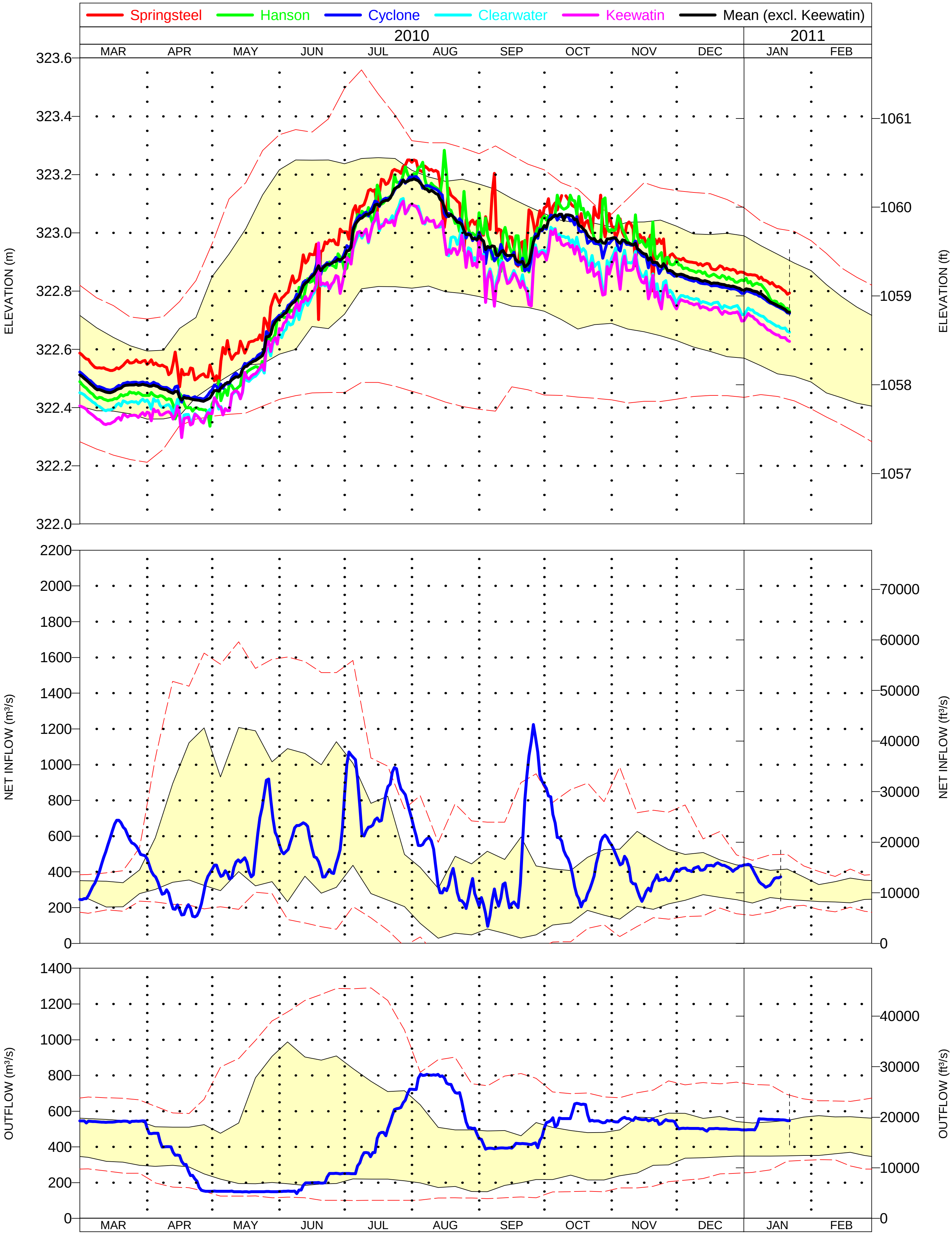
LAKE OF THE WOODS



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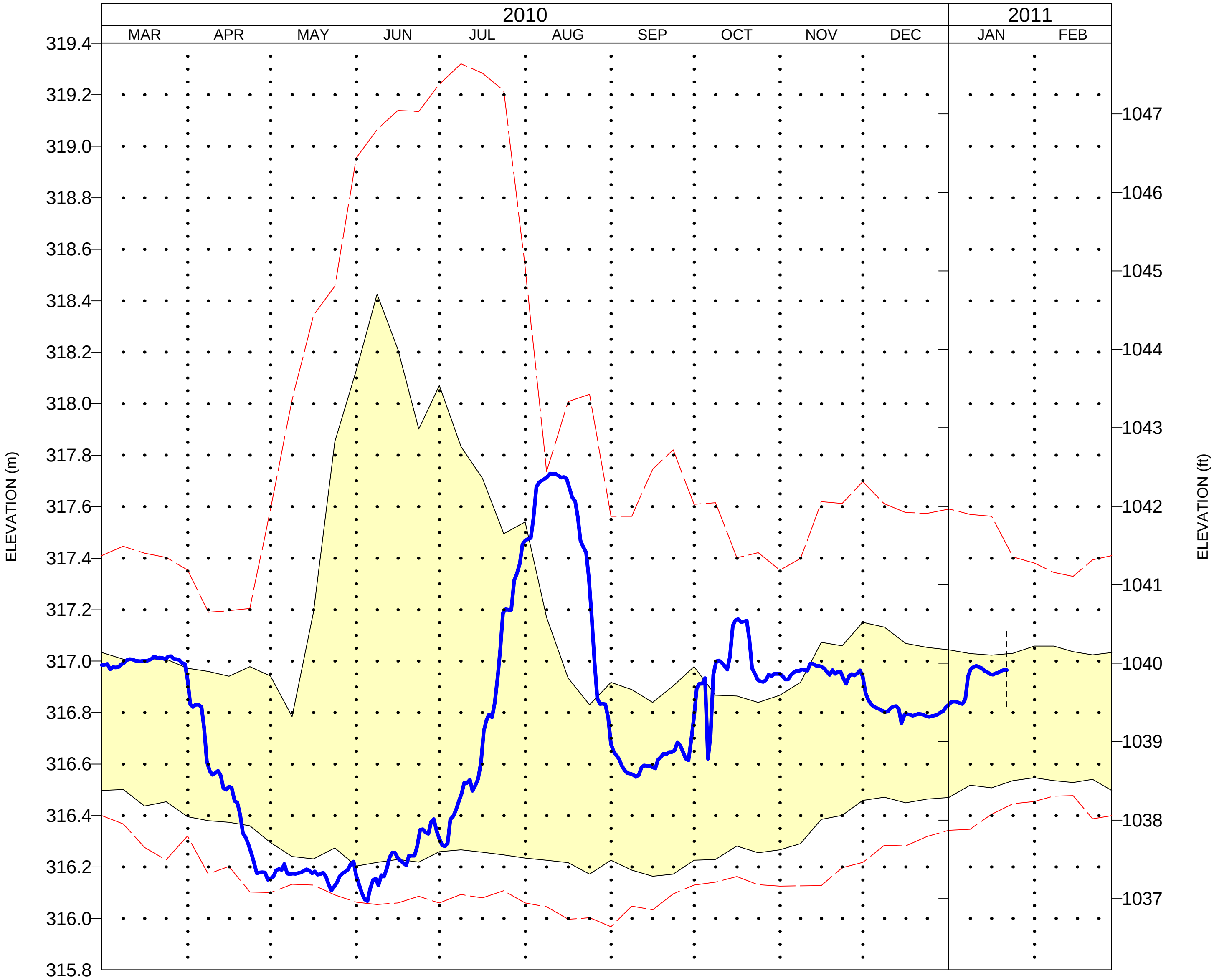

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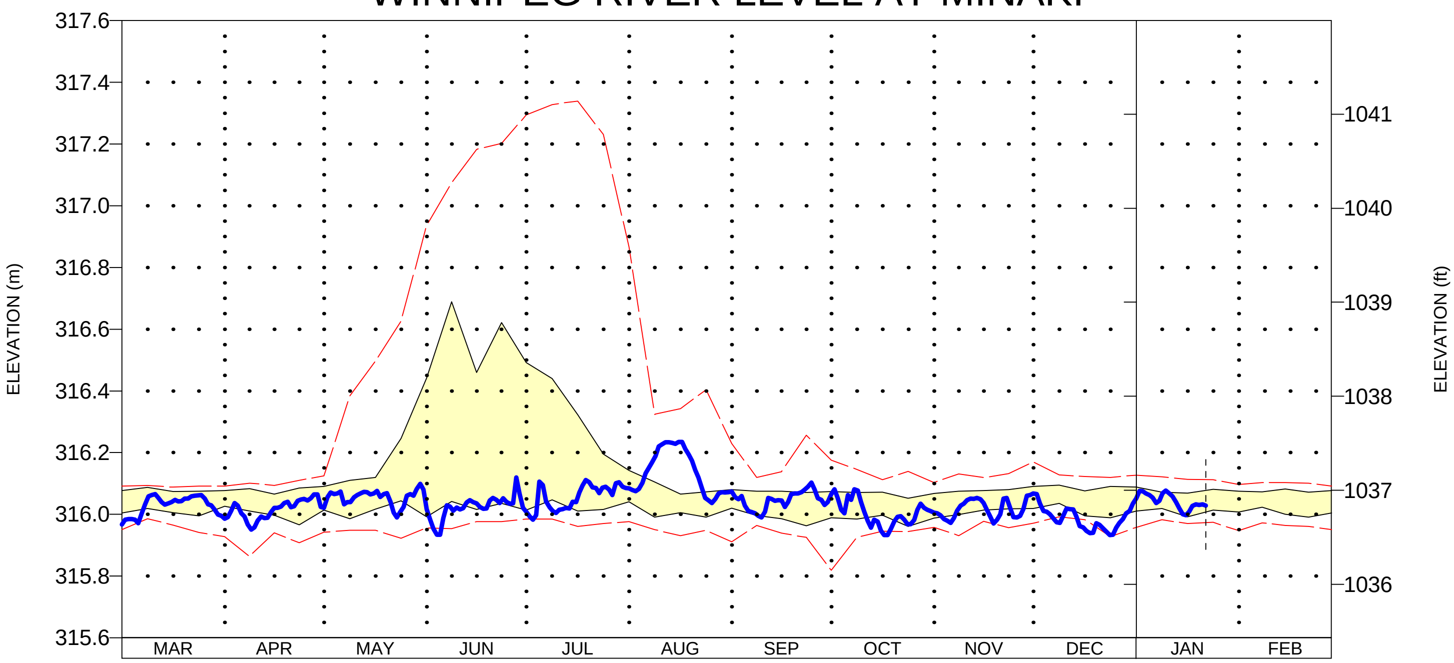

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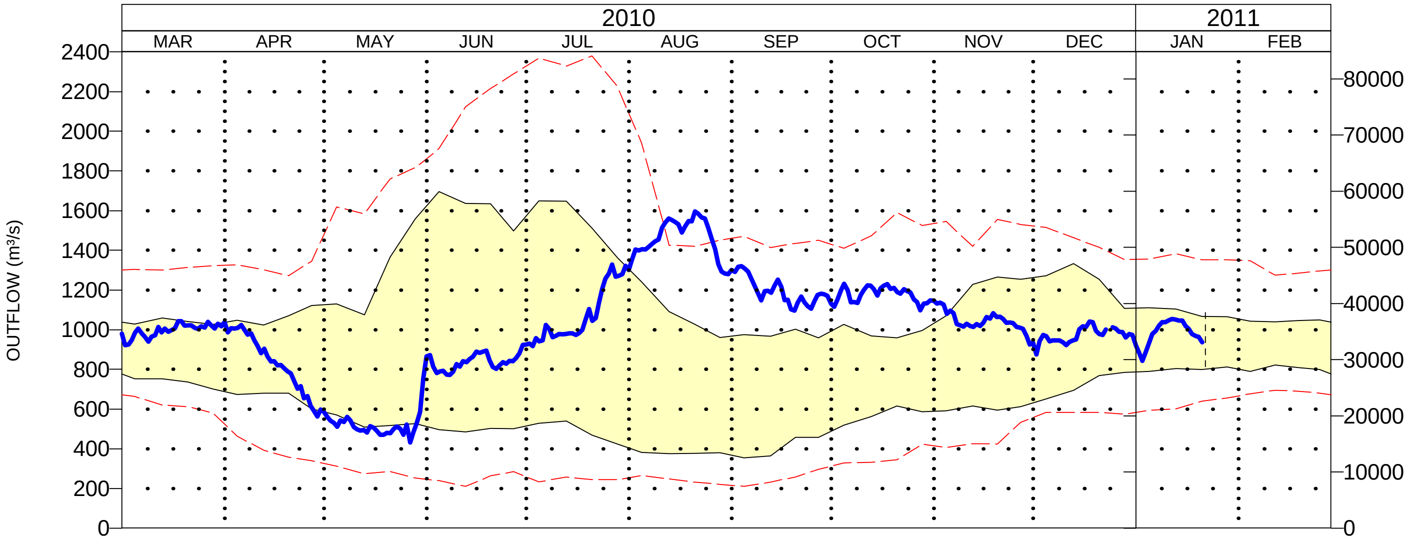
WINNIPEG RIVER OUTFLOW AT SLAVE FALLS



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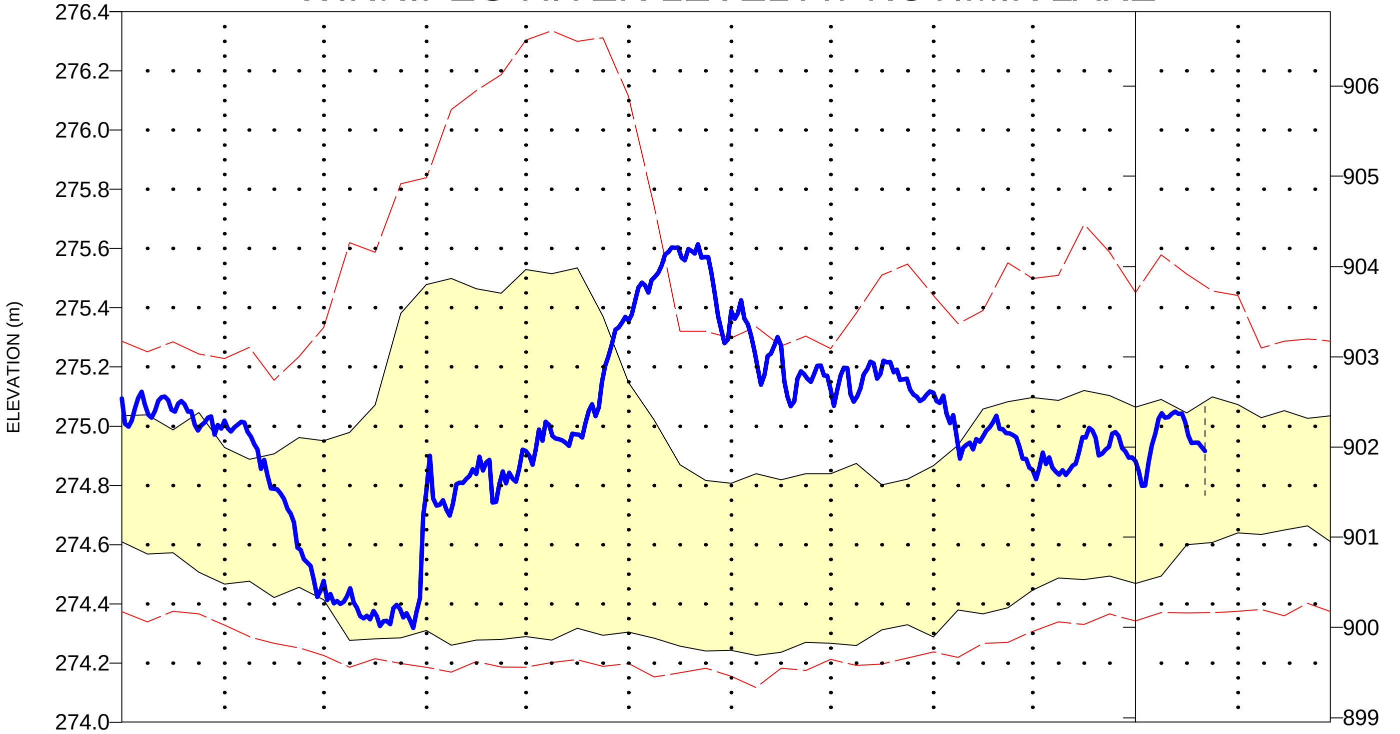

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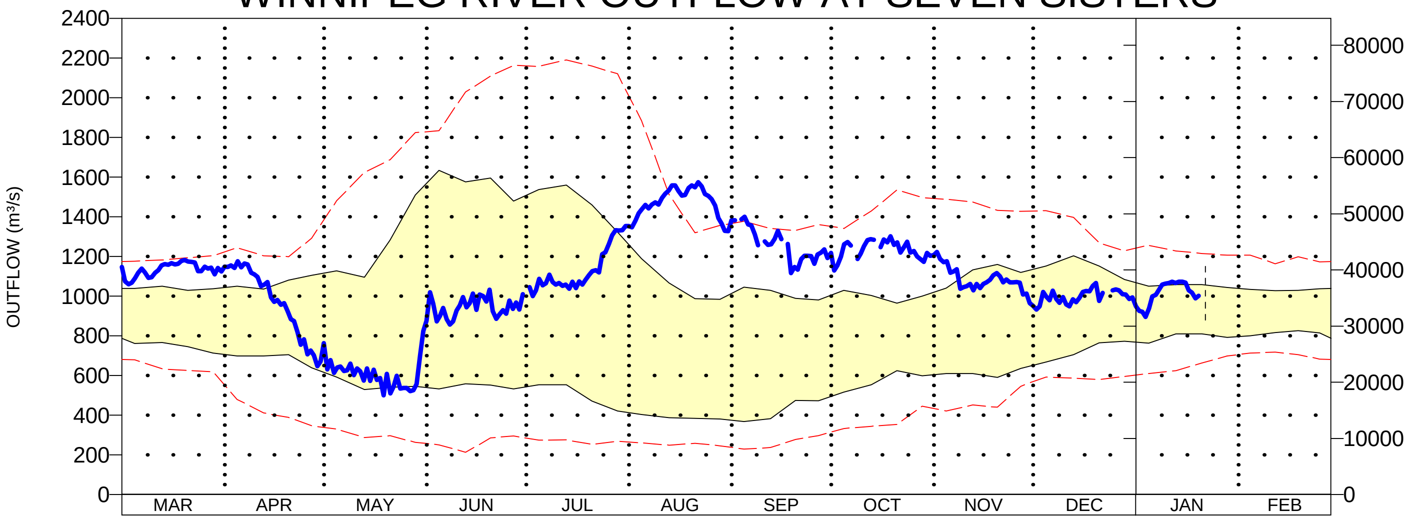

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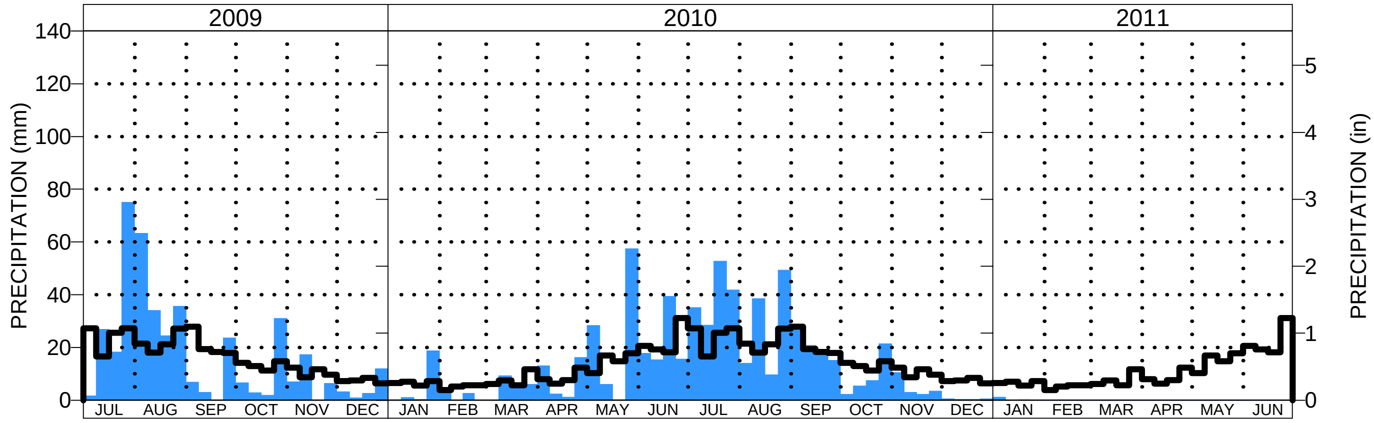
LAKE ST. JOSEPH PRECIPITATION



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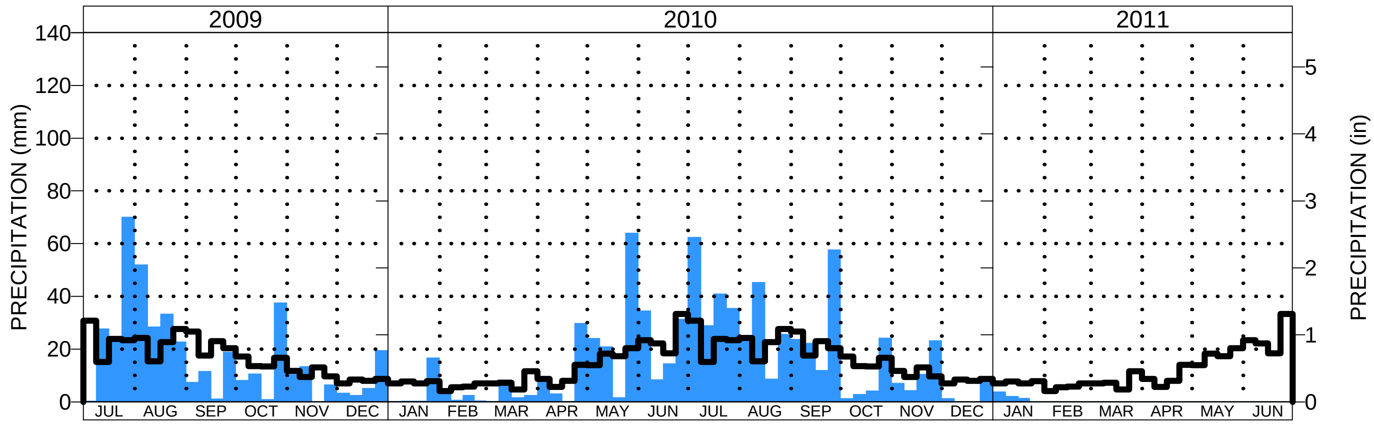

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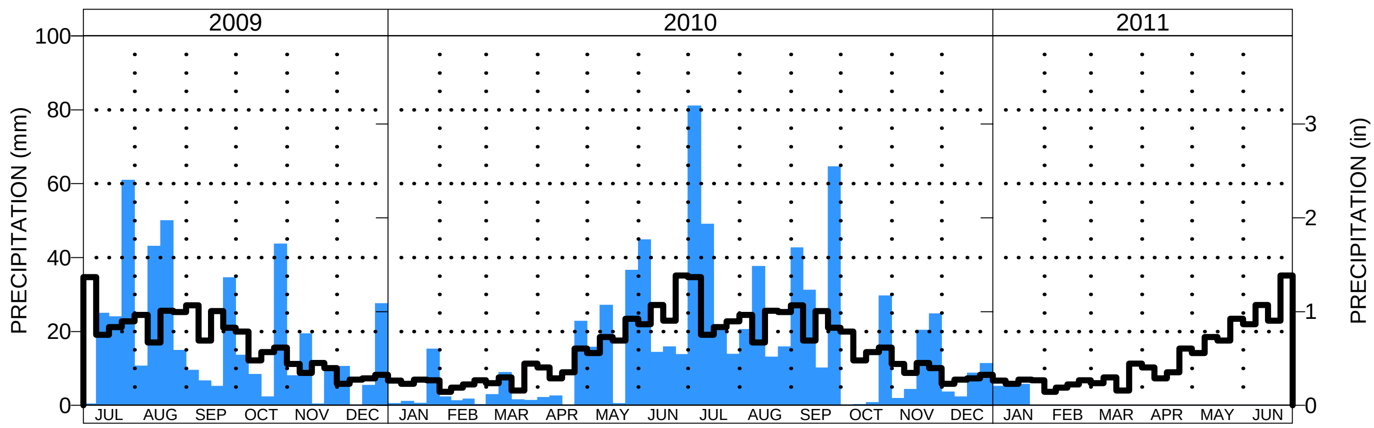

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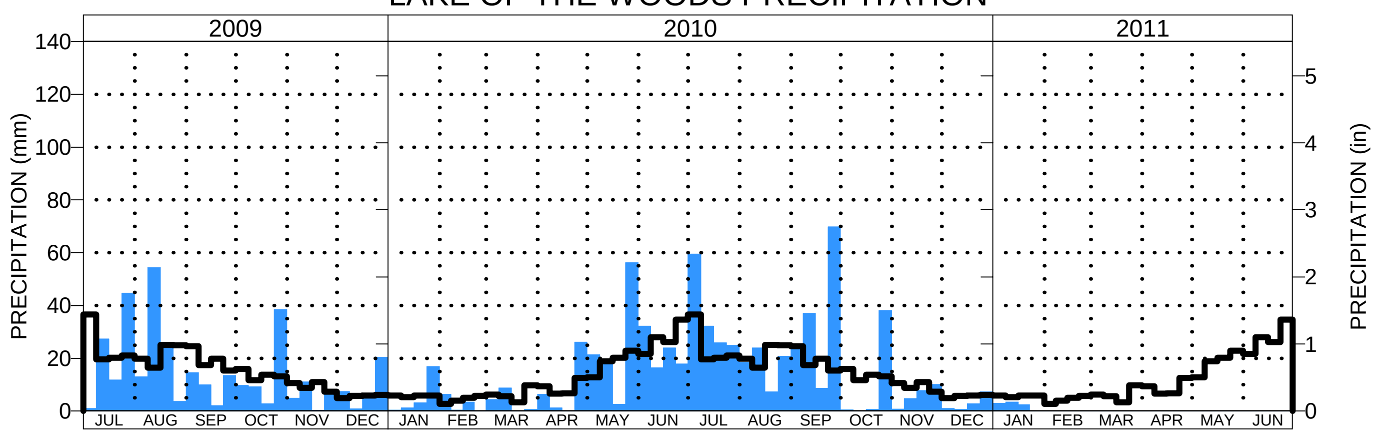

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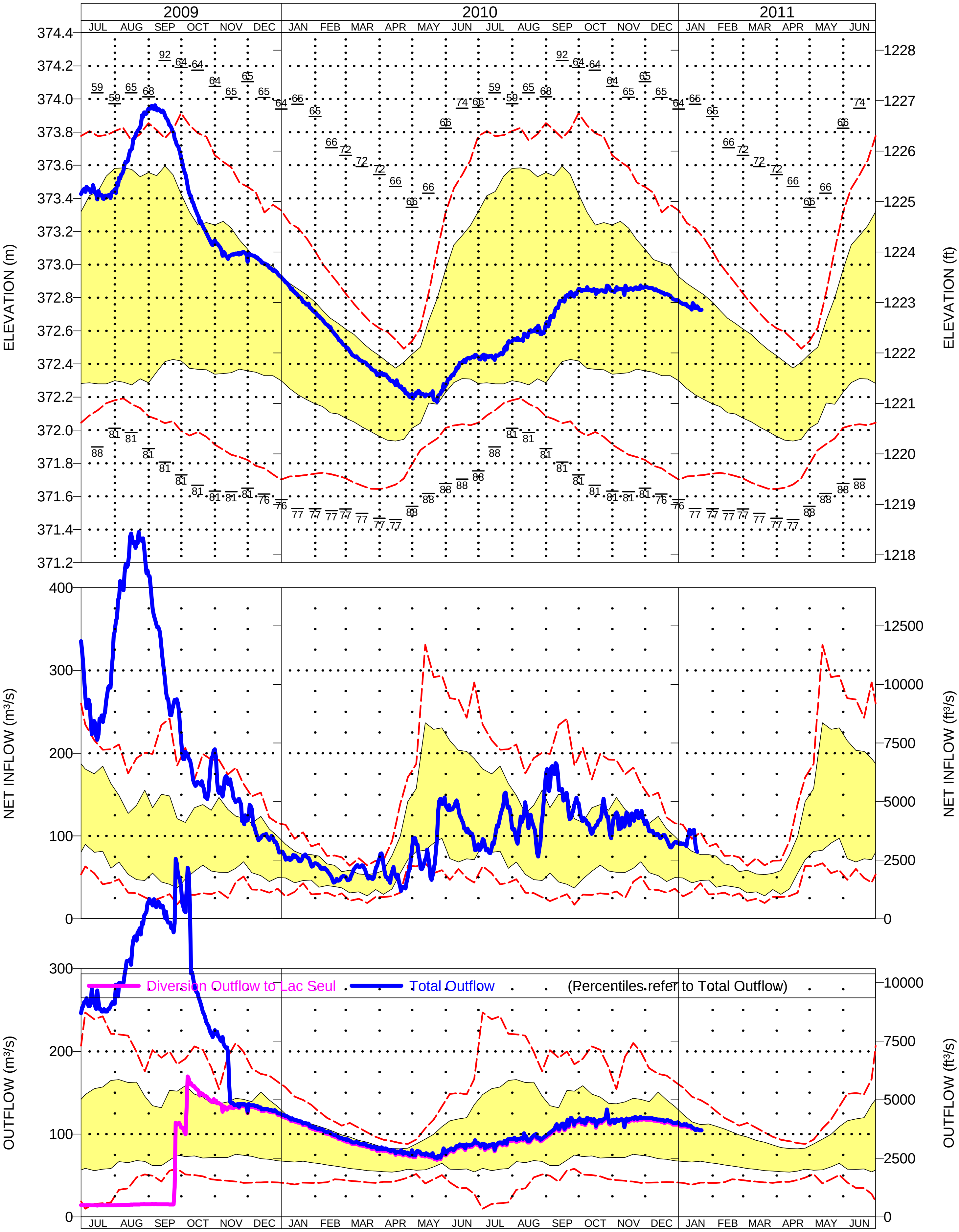

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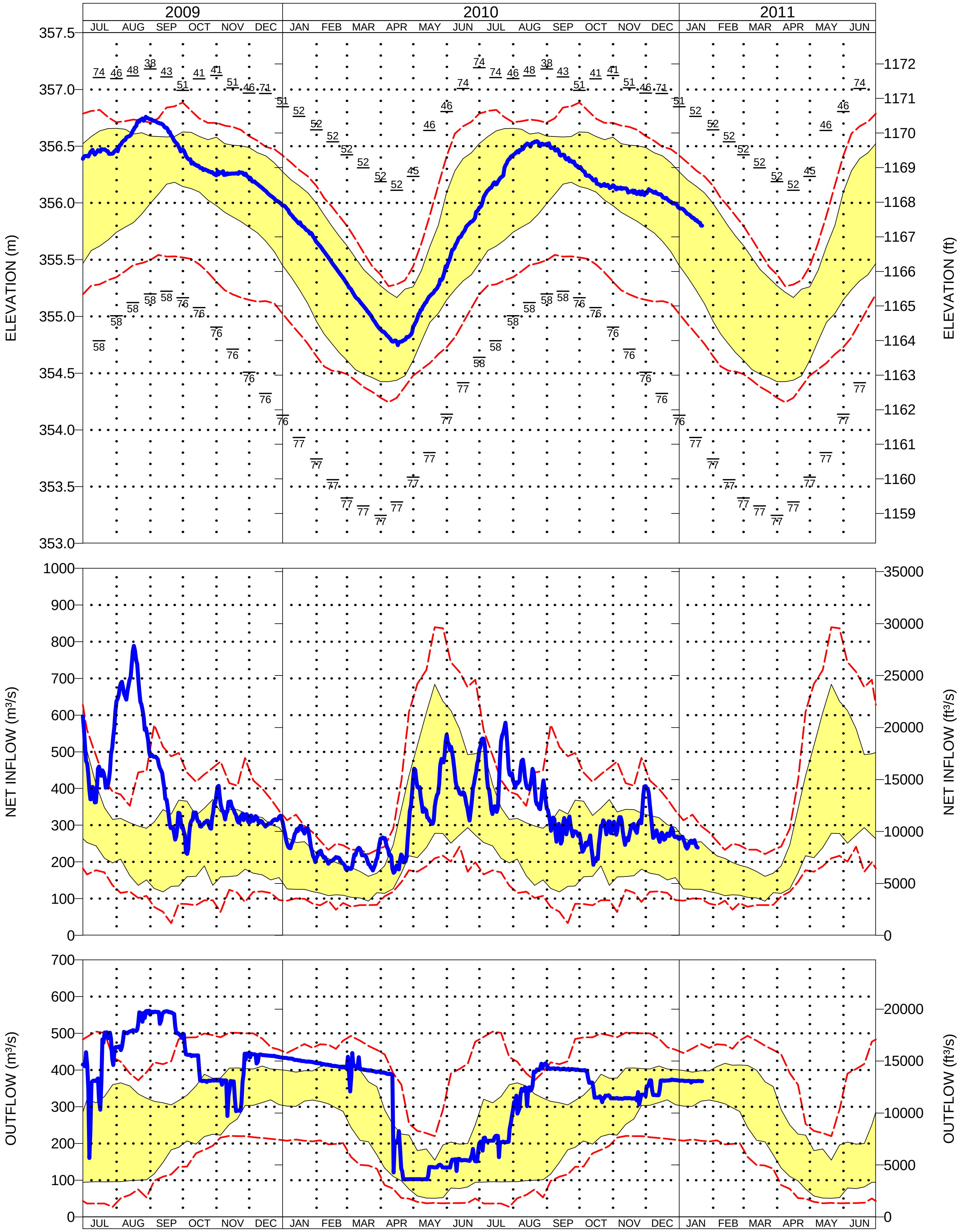

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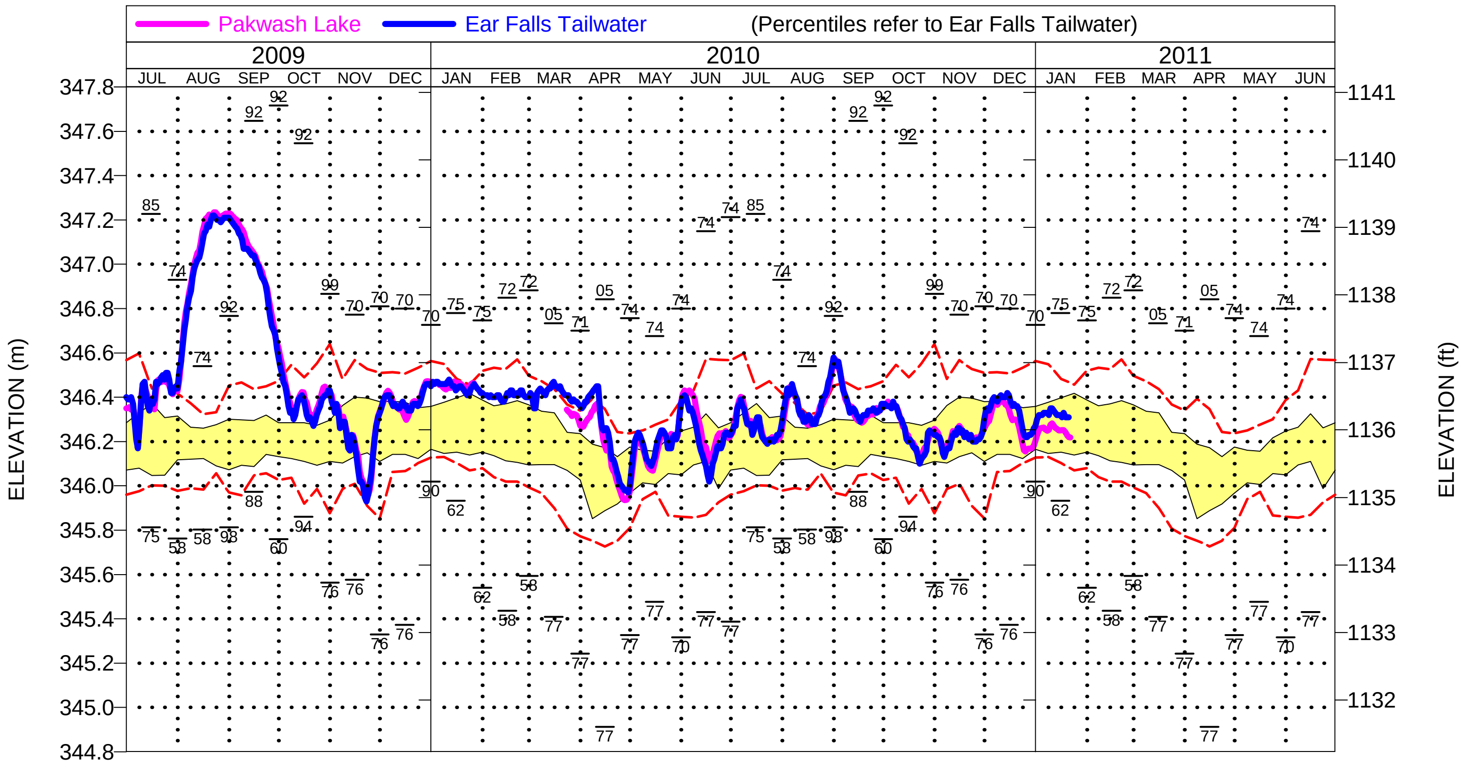
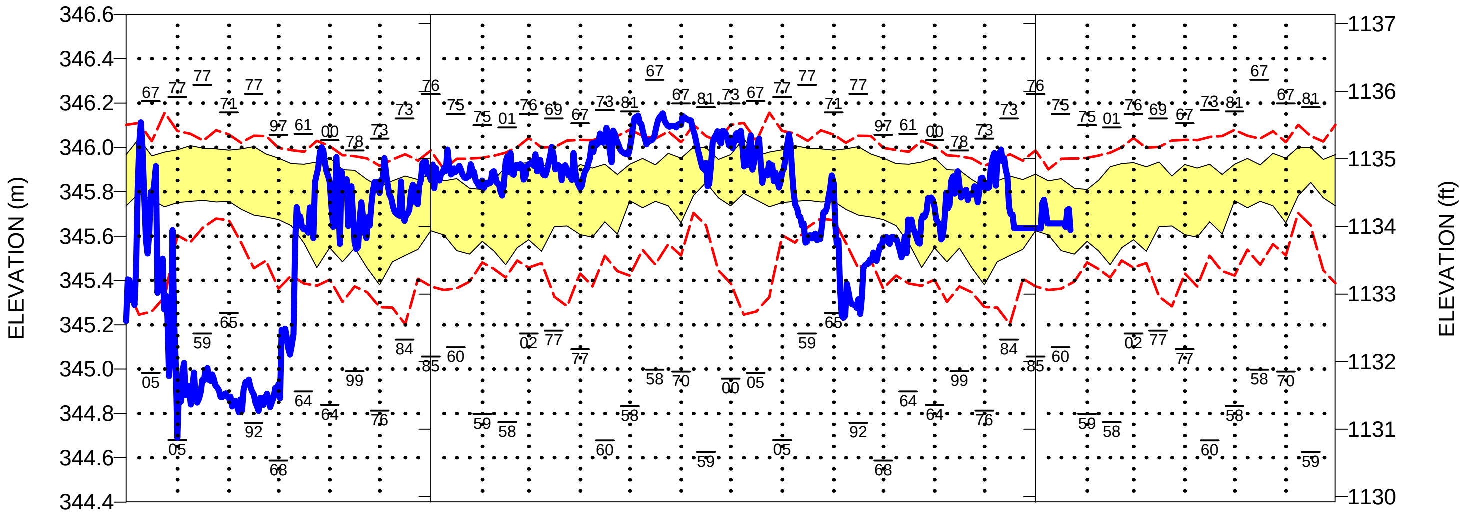
PAKWASH LAKE / EAR FALLS TAILWATER LEVEL



ENGLISH RIVER LEVEL AT MANITOU FALLS FOREBAY



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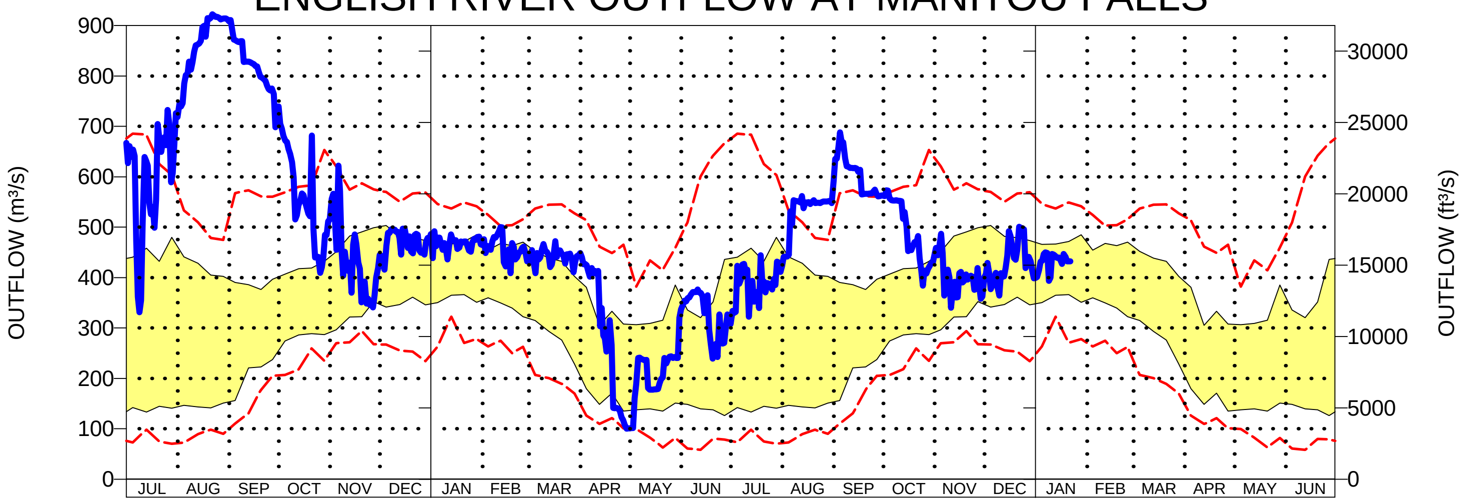

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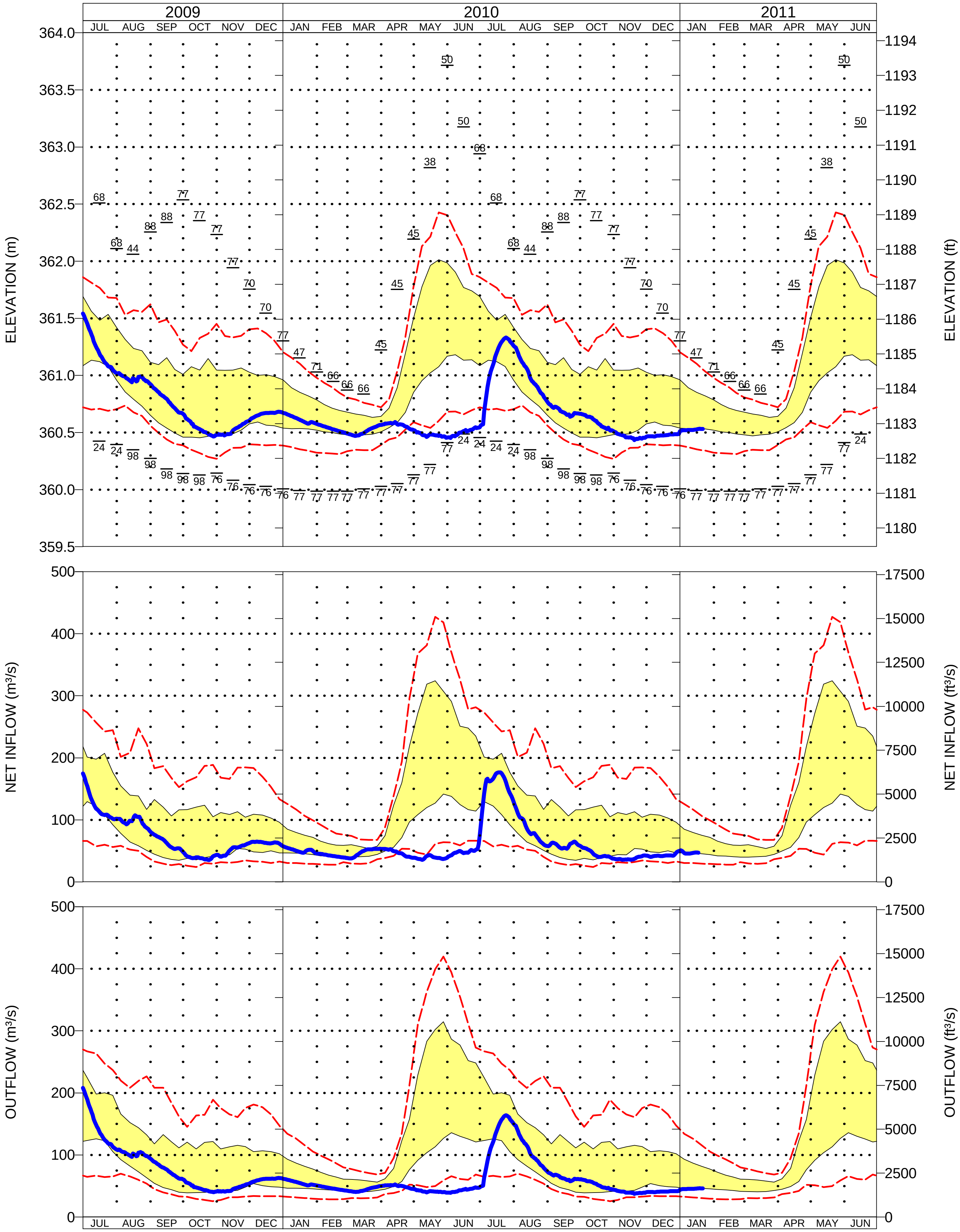

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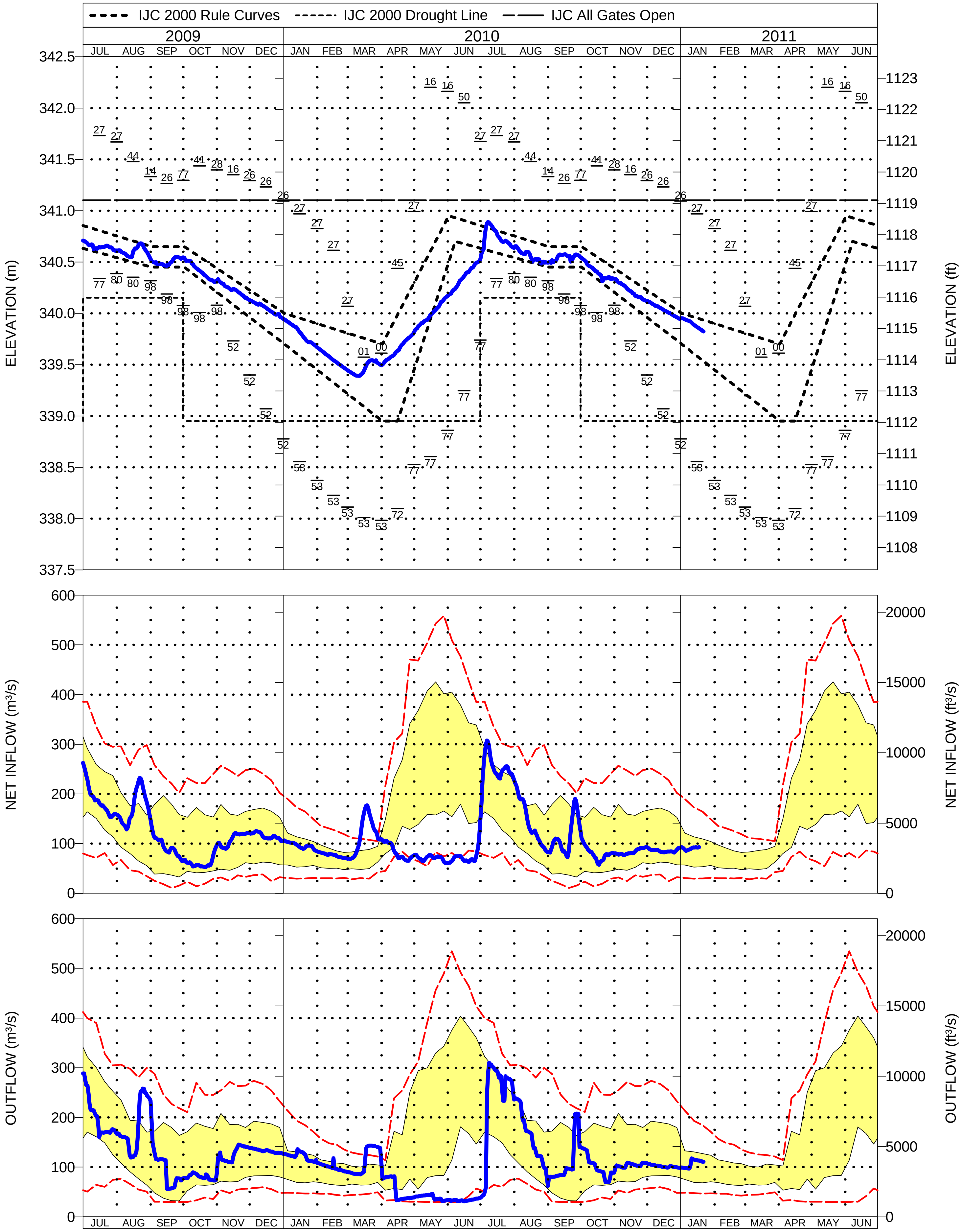

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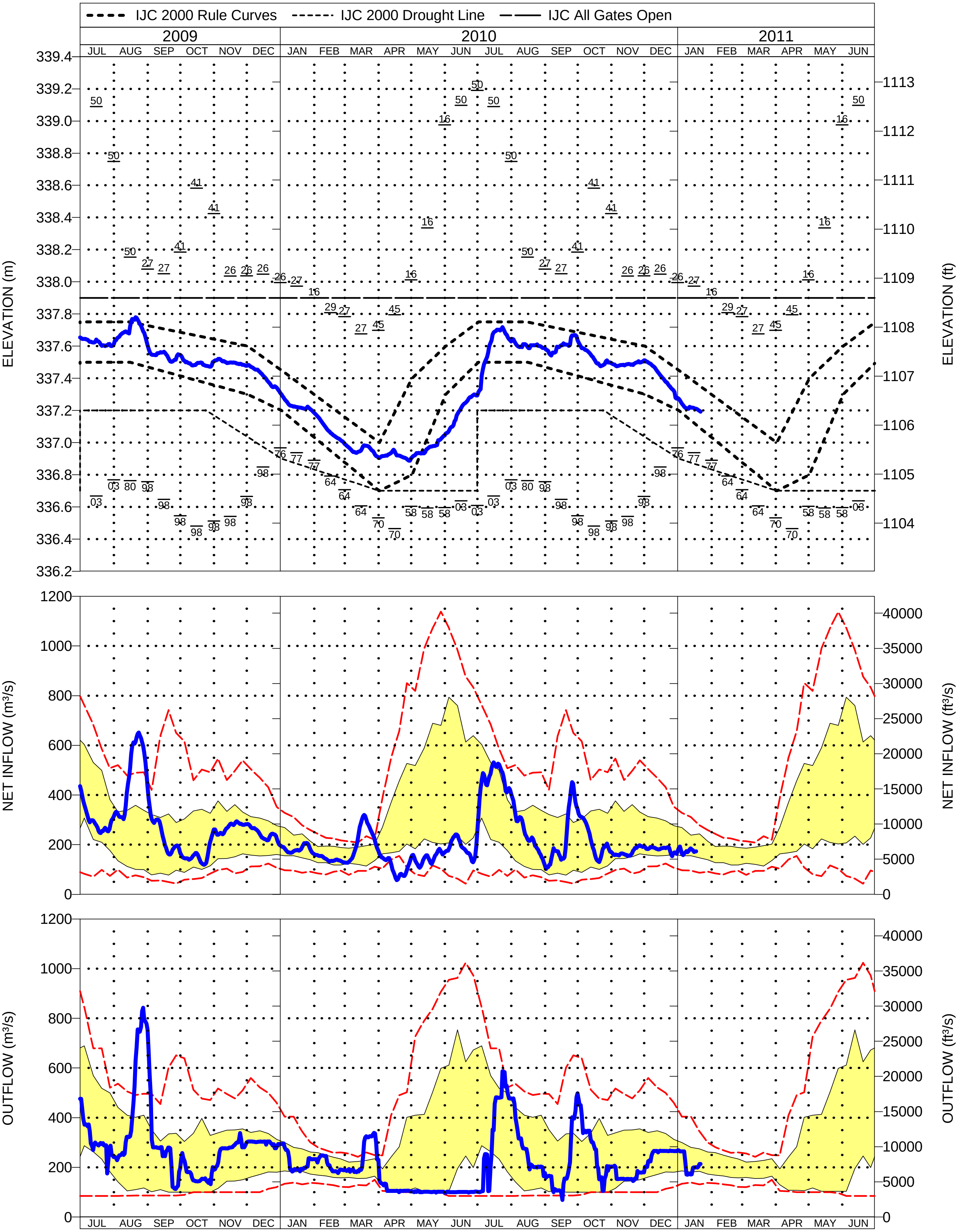
RAINY LAKE



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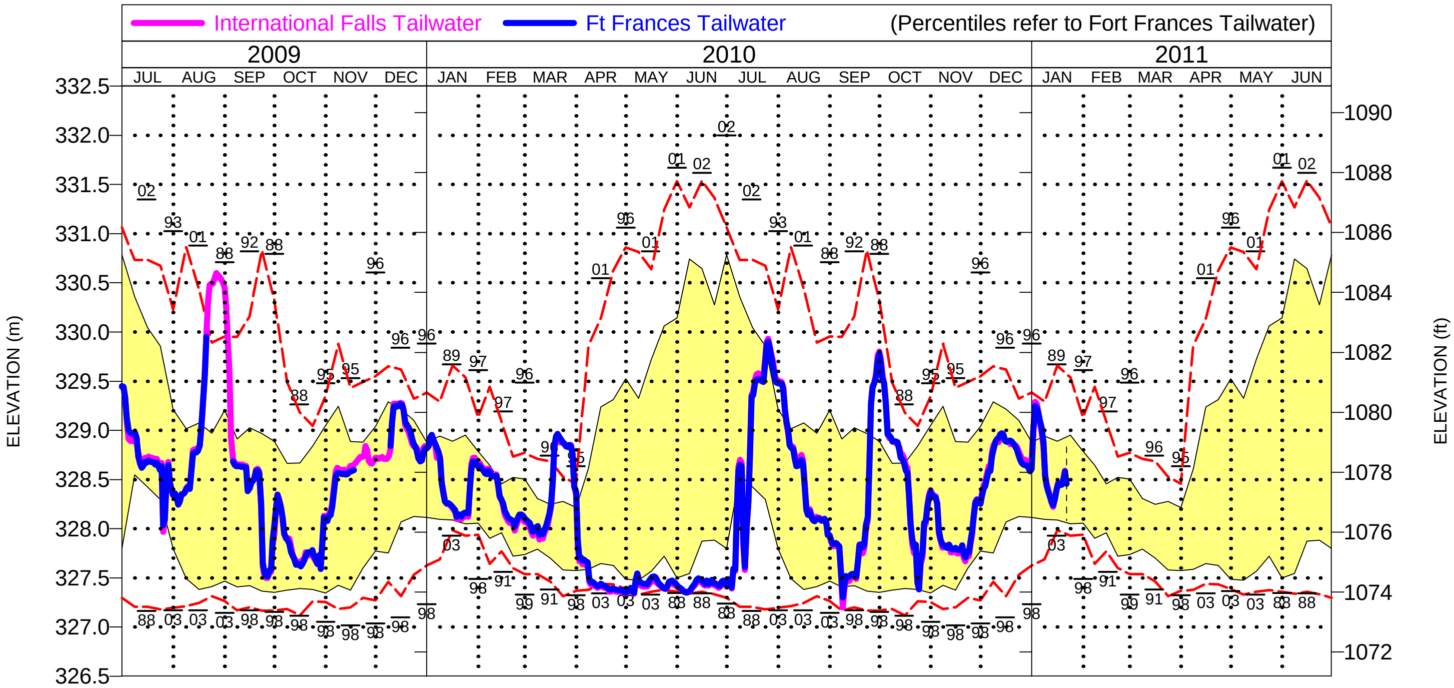
RAINY RIVER LEVEL BELOW RAINY LAKE DAMS



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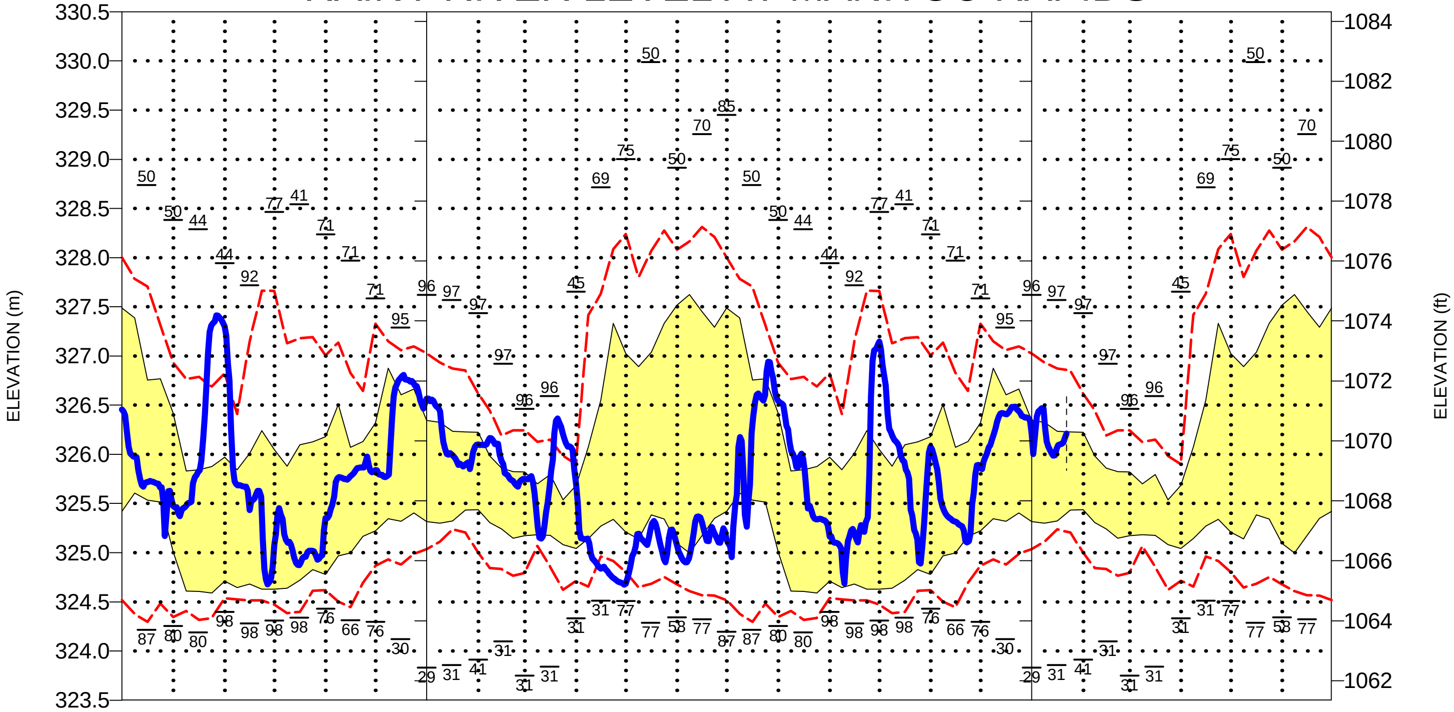
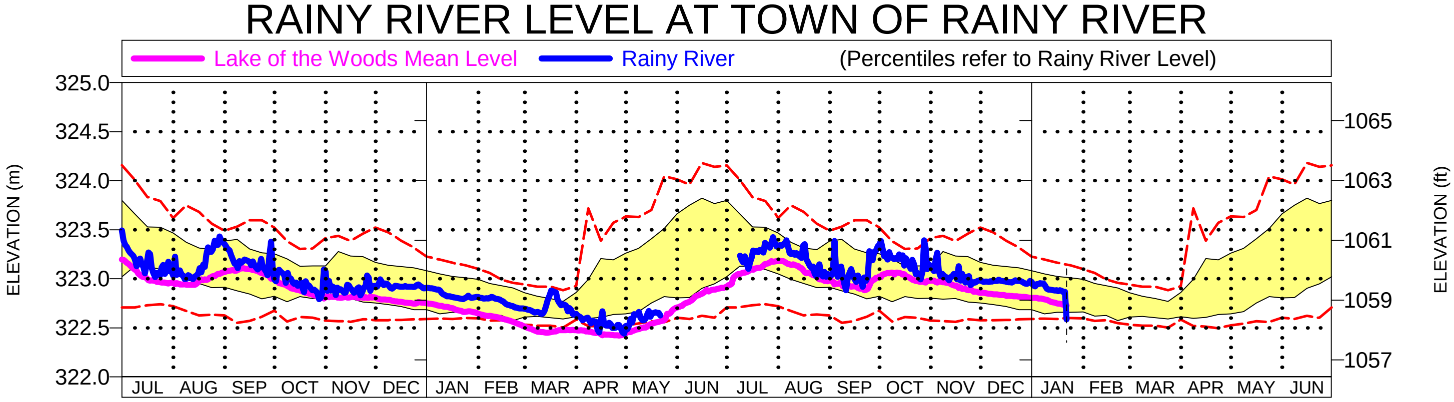


RAINY RIVER LEVEL AT TOWN OF RAINY RIVER



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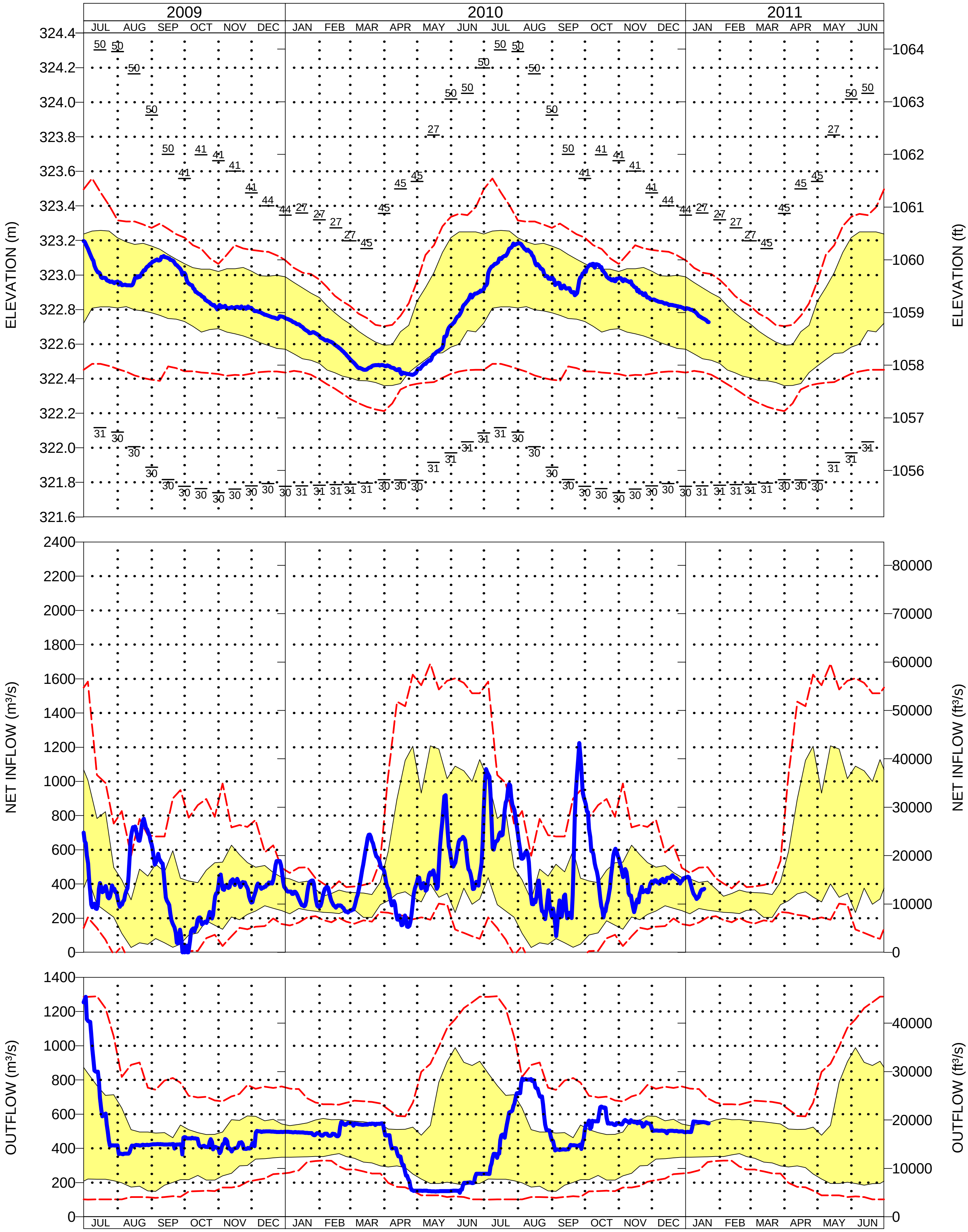

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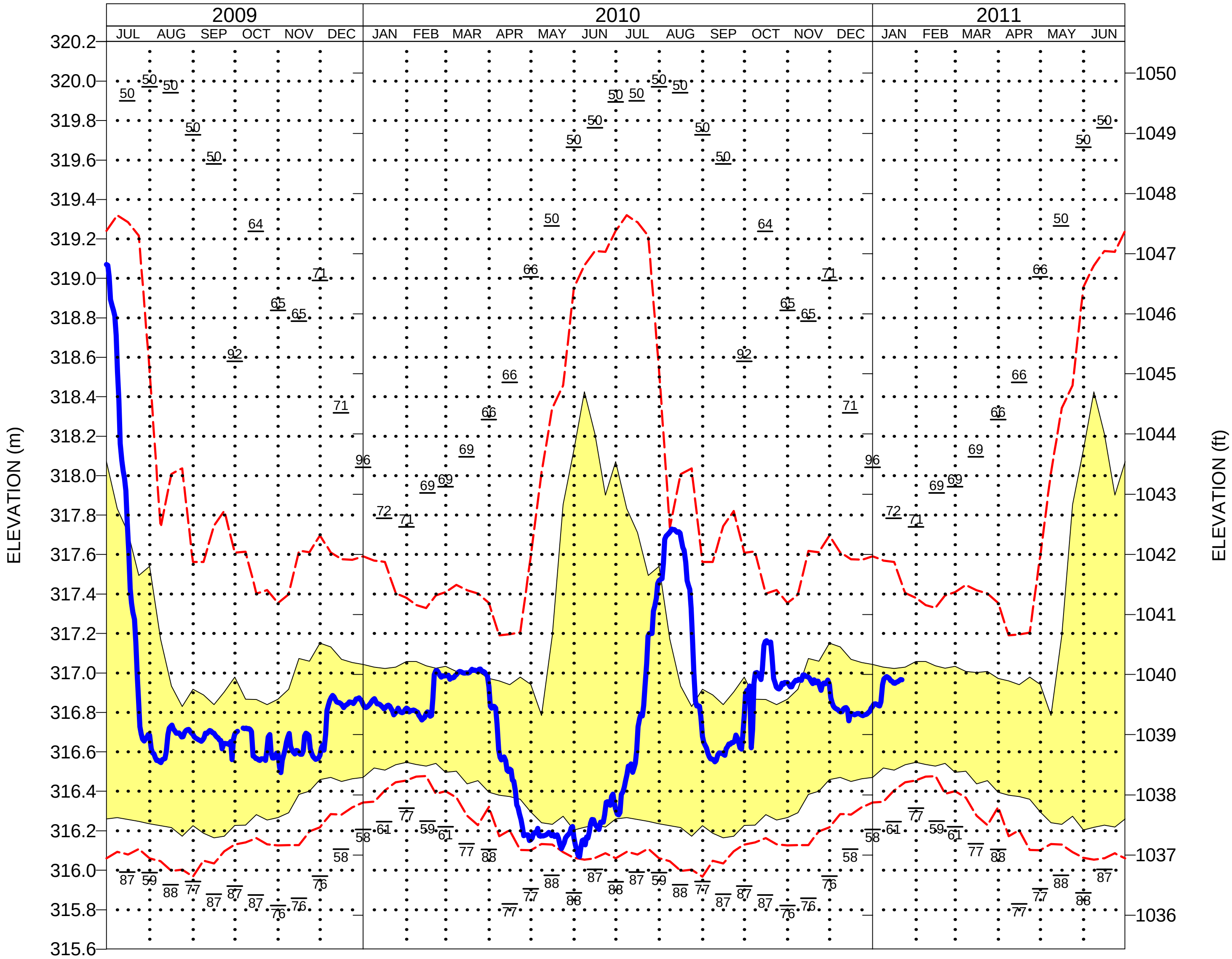

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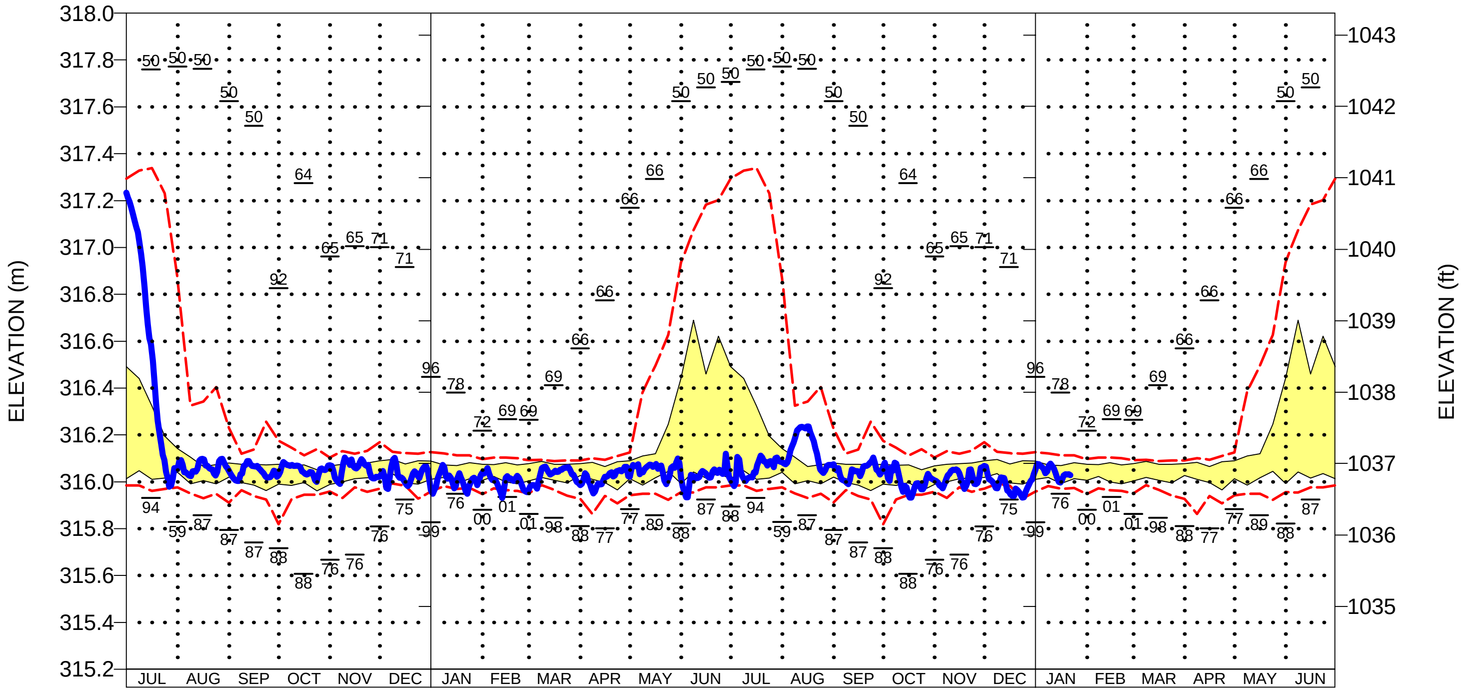

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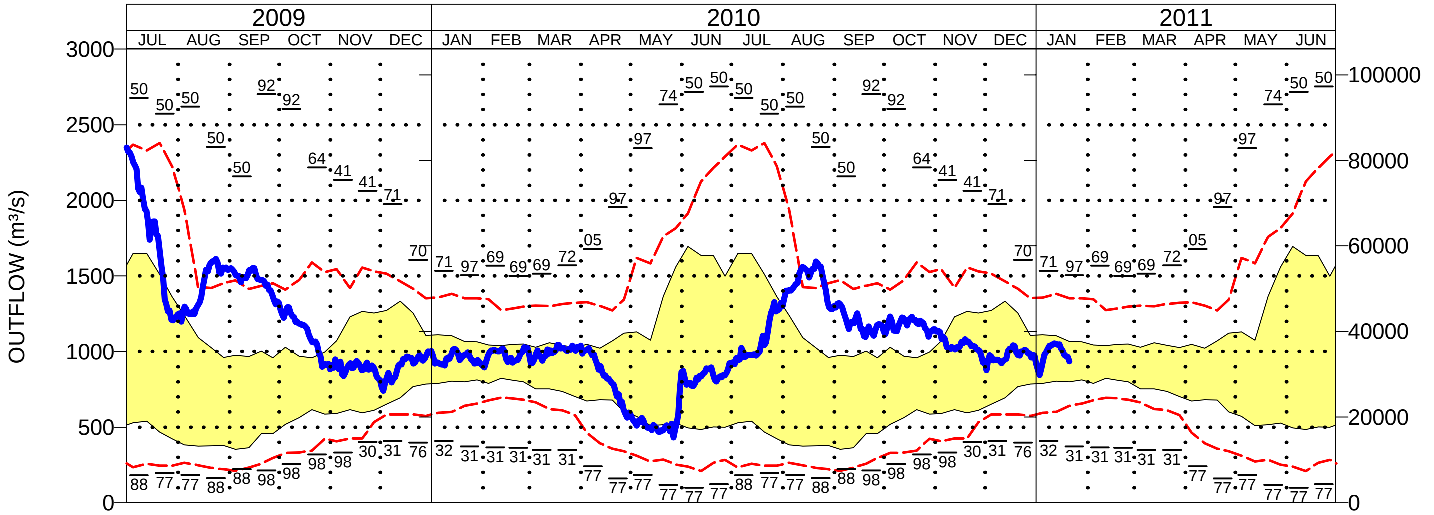

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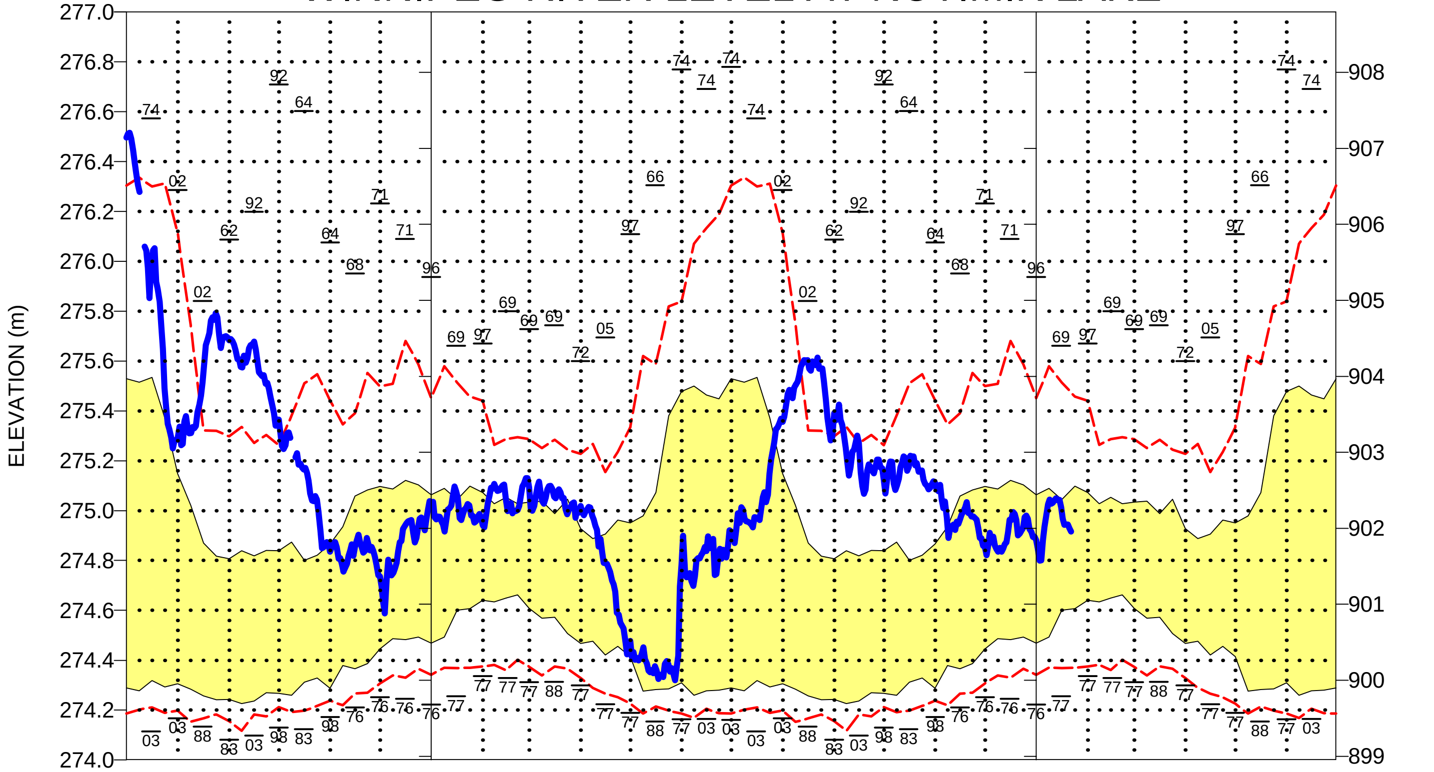
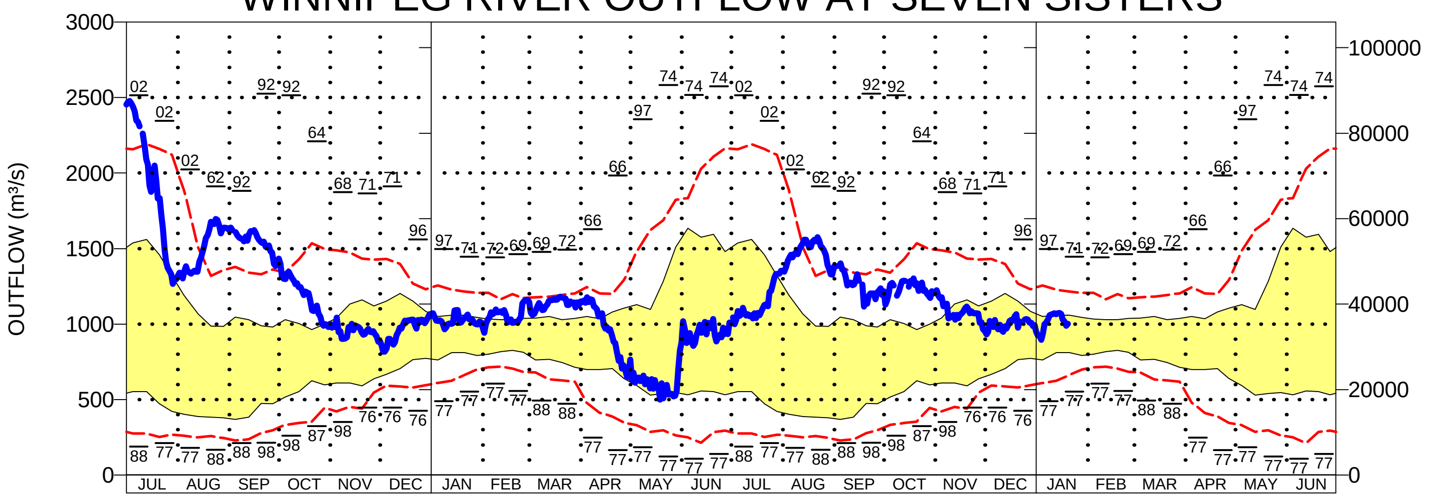


WINNIPEG RIVER OUTFLOW AT SEVEN SISTERS



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Trent Severn Waterway

Water Management Study

Water Management Manual

Parks Canada Parcs Canada

Canada

Parks Canada

Trent Severn Waterway: Water Management Study

Water Management Manual – Description of the Current Approach to Water Management

Prepared by:

AECOM
50 Sportsworld Crossing Road, Suite 290 519.650.5313 tel
Kitchener, ON, Canada N2P 0A4 519.650.3424 fax
www.aecom.com

Project Number:

60150039

Date:

May, 2011

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AECOM
50 Sportsworld Crossing Road, Suite 290 519.650.5313 tel
Kitchener, ON, Canada N2P 0A4 519.650.3424 fax
www.aecom.com

May 19, 2011

Roger Stanley
Director of Operations (Acting) – Trent-Severn Waterway
Parks Canada
P.O. Box 567
Peterborough, Ontario, K9J 6Z6

Dear Mr. Stanley:

Project No: **60150039**

Regarding: **Trent Severn Waterway: Water Management Study**
Water Management Manual – Description of the Current Approach to Water Management

We are pleased to submit ten (10) paper copies and an electronic copy of the Water Management Manual – Description of the Current Approach to Water Management.

If you have any questions or request additional information regarding this submittal, please contact the undersigned at (519) 650-8696.

Sincerely,
AECOM Canada Ltd.

Jeff Prince, P.Eng.
Senior Project Manager, Water
Jeff.Prince@aecom.com

JP:jp

Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	PF, DCA, JP	31-Jan-2011	Draft Report
2	JB, DCA, JP	21-Mar-2011	Draft Report – Additional Review
3	JB, DCA, JP	19-May-2011	Final Report

AECOM Signatures

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Water Resources

Report Reviewed By:

Jeff Prince, P.Eng.
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1. Introduction and Background

1.1 Study Objectives and Rationale

A common theme that resonates throughout most, if not all water management programs is the desire to contribute to and enhance the environmental, social and economic well being of the watershed through sustainable management of the water resource. Through achieving this, the benefits of the resource can be fully enjoyed by present and future generations.

It is to that end, that the objectives of the Trent Severn Waterway - Water Management Improvement Program were developed. The specific objectives include the following:

1. To understand the variables that are critical to effective water management decision making;
2. To ensure that the Agency and its water management partners have access in an accurate and timely way to the appropriate data that allows these variables to be used in making decisions;
3. To describe the current approach to water management in the form of a "Water Management Manual" that describes in considerable detail how water is managed now;
4. To validate and/or suggest improvements in how water is currently managed such that broad water management goals described above are best achieved;
5. To construct a numerical predictive tool that allows the basic operational model(s) to be readily adjusted in response to changes in critical variables; and,
6. To construct a numerical management tool, linked to real time gauging and data collection systems that allows the water manager to:
    a) Understand the current state of water levels and flows throughout the system;
    b) Predict the quantifiable impact of specific water management decisions;
    c) Document when and why specific water management decisions are taken; and,
    d) Provide agencies and individuals with internet-accessible, real time information that contributes to their operations and enjoyment of the Trent Severn Waterway and its associated reservoir lakes.

The Trent Severn Waterway: Water Management Study addresses the first four of these program objectives.

The competition for the water of the Trent Severn Waterway has always been a condition of the system's operation. However, in recent decades, the stakeholders and variables at play as part of that competition have increased and subsequently so to have the demands and complexities of the operating environment. The following examples highlight some of the operational considerations within the Waterway:

- The Haliburton Lakes have become one of the most significant cottage regions in the province; and more recently there has been a shift toward year round residency on these lakes;
- Shoreline properties have increased in value, and with that the demands to maintain the levels of the reservoir lakes have increased;
- Cities and Towns have developed along the shorelines and have infrastructure demands to draw water from the system;
- The shores are home to thousands of businesses that rely on those that live in and visit the area;
- The societal awareness of and desire to protect the natural environment is increasing;
- There are legitimate concerns about global warming and the potential impacts of climate change; and
- Growing environmental concern has led to an interest in the potential for hydro electric power generation as a source of renewable energy.

These issues have been recently documented by the Panel on the Future of the Trent Severn Waterway in, *It's All About the Water,* and a study of the past, present and future of the waterway completed in 2007 by Ecoplans Limited.

This study is intended to build upon this work toward ensuring that water management personnel have the tools necessary to assist them in making water management decisions. These tools must ensure that management decisions are; timely, information and science based, reflect a thorough understanding of the variables, and achieve an optimal and appropriate balance of the overall water management goals.

This study represents the first phase of what could be a multi-phase endeavour towards achieving the vision and objectives of the overall Water Management Improvement Program.

This study has been organized into four components that directly correspond to the specific objectives of the Water Management Improvement Program:

- **Data Collection and Management Guide**
- **Review of Water Management Systems and Models**
- **Water Management Manual – Description of the Current Approach to Water Management**
- **Evaluation of the Current Approach to Water Management**

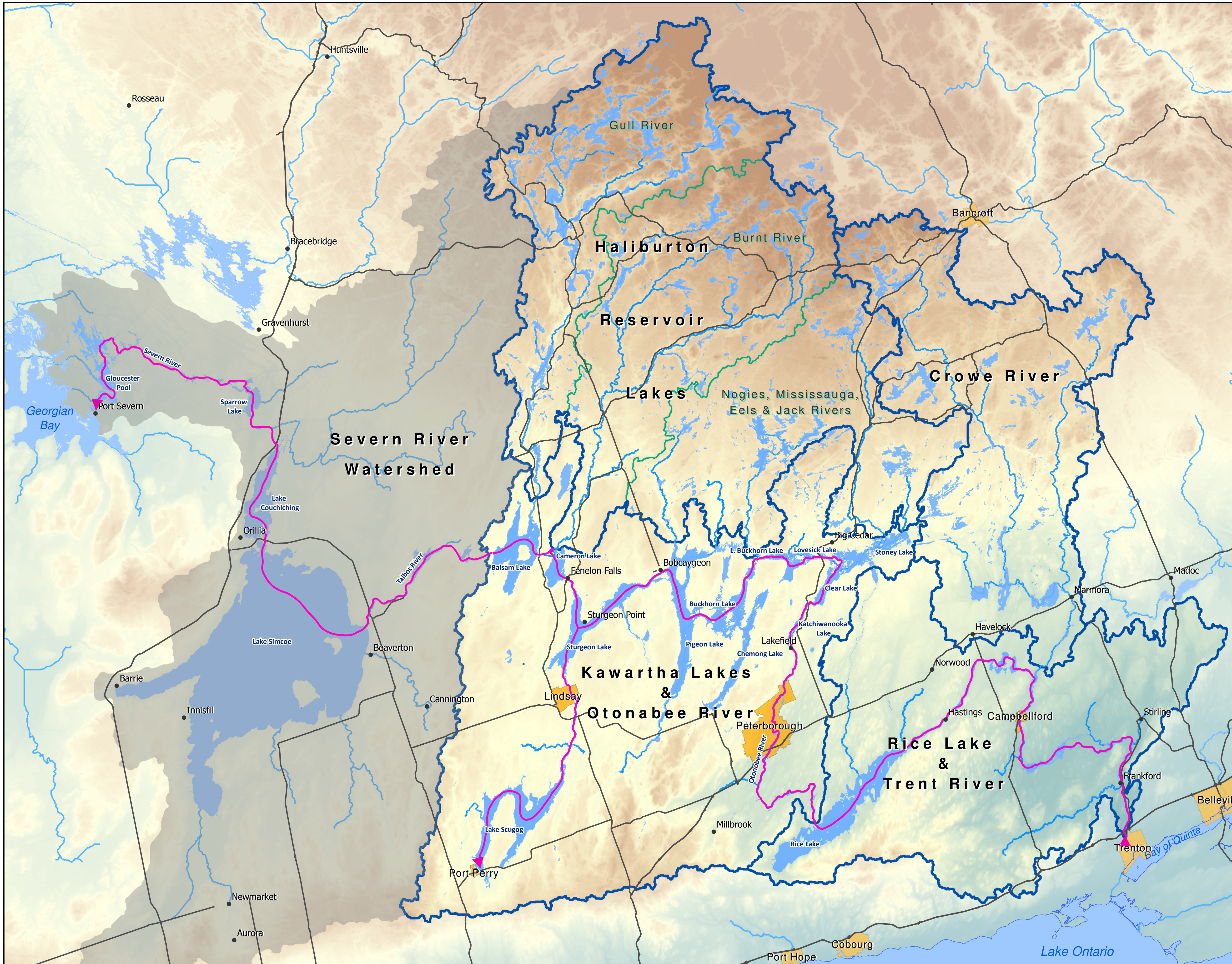
This component of the study, titled the "Water Management Manual – Description of the Current Approach to Water Management", has been developed to describe the current approach to water management by Parks Canada for the Trent River Watershed.

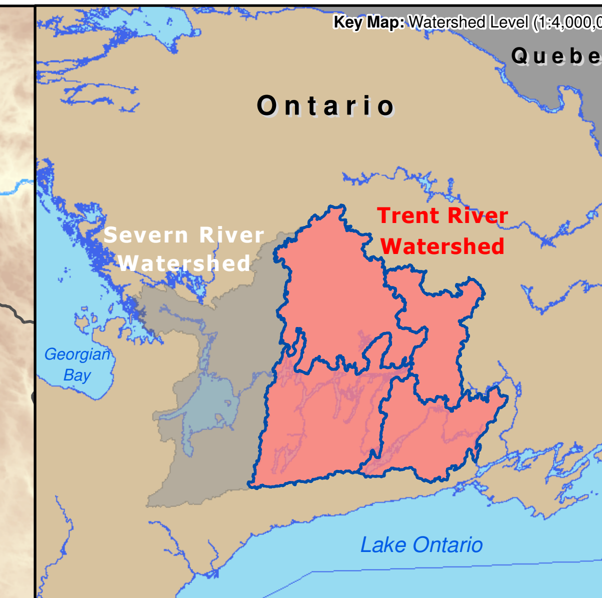
1.2 The Trent Severn Waterway

The Trent Severn Waterway (TSW or Waterway) is a 386km inland navigation route crossing south central Ontario, from Trenton on the Bay of Quinte to Port Severn on Georgian Bay with a total drainage area of 18,690km^2 (**Figure 1-1**). It comprises several navigable lakes and their interconnecting channels as well as many reservoir lakes. There are two watersheds within the Waterway: the Trent River Watershed and the Severn River Watershed. Although this Study concentrates only on the Trent River Watershed, both are characterized below.

The Trent River Watershed is the eastern watershed, with an area of 12,530km^2 draining to Lake Ontario. It lies in the rolling farmlands of southern Ontario. This watershed contains three (3) sub-watersheds:

- **The Haliburton Reservoir Lakes** (3,320km^2) to the north consists of forty-four (44) lakes in the northern shield area that have been dammed to collect Spring runoff. Water from these lakes is released over the summer to supply the Trent component of the Waterway. These lakes are on the tributaries of the Gull, Burnt and Mississauga rivers, as well as Nogies, Eels and Jack creeks.
- The **Kawartha Lakes and the Otonabee River** (4,862km^2) that drain to Rice Lake including: Katchewanooka, Clear, Stony, Lovesick, Lower Buckhorn, Buckhorn, Chemong, Pigeon, Sturgeon, Scugog, Cameron and Balsam Lakes. These lakes are south of the Canadian Shield in rolling countryside, where rainfall runoff is usually slow and evaporation losses in the summer are high.
- **Rice Lake and the Trent River** (4,348km^2) that drain to the Bay of Quinte (Lake Ontario), including the **Crowe River** (1,894km^2) sub-watershed that drains to the Trent River at a confluence downstream of Rice Lake.





Legend

- Major Roads
- Rivers
- Navigable Waterway
- Reservoir / Lake
- Trent River Subwatersheds
- Severn River Watershed
- Cities / Towns

Elevation (m)

High : 562

Low : 49

0 10 20 40 Km

Trent-Severn Waterway: Water Management Study

Figure 1-1
General Location Plan - TSW

UTM 17 NAD 83 Datum	April 2011	1:600,000

Parcs Canada Parks Canada

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The Severn River Watershed lies immediately to the west of the Trent Basin and drains to Georgian Bay. This 6,160km^2 drainage area has three (3) sub-watersheds:

- The **Lake Simcoe and Lake Couchiching** sub-watershed, including the Talbot River. Most of the drainage area for this sub-watershed is in rolling farmland with deeper soils. As a result, water runoff is slow and evaporation losses from both land and lake surfaces are high. Only about 25% of the precipitation falling on this watershed eventually appears as runoff flows.
- The **Black River** sub-watershed feeds into the Severn River downstream of Lake Couchiching. This sub-watershed is characterized by the thin soils and rock of the Precambrian Shield. It is virtually unregulated and produces rapid runoff from precipitation while evaporation losses are lower. Consequently, even though the Black River sub-watershed is less than half of the area of the Simcoe-Couchiching basin, its long-term average flow is comparable. The Black River also has high peak flows during the spring period.
- The **Severn River** below Washago, including Sparrow Lake, Six Mile Lake Tea Lake, and Gloucester Pool. The natural watercourses of the Black and the Severn Rivers are constrained by numerous narrow reaches and constrictions, which are prone to increased water levels in the river and upstream flooding during high flows.

The area influenced by management of the TSW includes more than 120,000 properties as identified in a recent study (Ecoplans 2007):

- Approximately 35,000 shoreline properties in the reservoir lakes;
- More than 400 commercial operations;
- Six Conservation Authorities; and
- Several tiers of government, including: 6 First Nations; 2 regional municipalities; 3 municipalities; 1 district municipality; 5 counties; 5 cities; 4 towns; and, 26 townships.

1.3 Goals and Objectives of the Trent Severn Waterway

Construction of the Trent Severn Waterway began in the late 18th century with the building of small dams and water powered mills at numerous locations throughout south-central Ontario. In the early 19th century, dams and timber slides were added to support a growing logging industry by facilitating transportation of logs from the interior of Upper Canada to the United States and Great Britain.

Key early goals for management of the Waterway were to provide navigation and to protect public safety and property. By the mid-19th century, architects of the Waterway realized that a reservoir system was required to feed water to the system in order to maintain navigation through the summer months. A series of dams in the northern part of the TSW were transferred from the Province to the Federal government in 1905 and 1906. This transfer formally recognized the need for a reservoir system and provided the means to manage and control flow from a number of water bodies that collectively could be used as a reservoir lake system. The Orders-in-Council that transferred these works explicitly acknowledged that the transfers were to benefit operation of the TSW. The Orders-in-Council also designated the water in the listed lakes and rivers as reservoirs for the Waterway.

When the reservoir lakes were conceived, there was very little permanent settlement in the Haliburton region. Since the 1930s, the Haliburton lakes have grown to become one of the most important cottage areas in Ontario. Furthermore, a recent shift from seasonal to permanent, year-round residency in the Haliburton lakes region is occurring. Associated changes in the operating environment of the Waterway include increasing trends in uses other than through navigation, economic development and commercial operations along the Waterway, as well as increasing value placed on natural ecosystems and habitats. Finally, meteorological changes have also been observed (as discussed in the "**Evaluation of the Current Approach to Water Management**"), including: increased number of heavy rainfall events of shorter duration, increasing annual precipitation in some regions and decreasing

annual precipitation in others, regional warming in some areas resulting in increased water temperatures, life cycle impacts to aquatic and wetland species and habitat changes.

These changes in the operating environment of the Trent Severn Waterway are reflected in a recent study (Ecoplans, 2007) which indicates that the present-day array of expectations and obligations are unprecedented in the history of the Waterway operations. Six Water Management Goals and associated Objectives were developed in this study to capture these expectations and enhance operations. These goals and objectives are listed in **Table 1-1**.

Table 1-1 - Water Management Goals and Objectives of the Trent Severn Waterway

Water Management Goals	Objectives
Reducing threats to public safety and negative impacts to public and private infrastructure from over-bank flooding, ice damage, extreme water level fluctuations, and high volume flows	• Mitigate Flooding • Protect Infrastructure • Provide for Public Safety
Contributing to the health of Canadians through the availability of drinking water for residents, cities and towns throughout the watershed	• Manage for Water Supply (agricultural and municipal) • Manage for Water Quality (human health and aquatic life)
Providing safe boating and navigation along the marked navigation channels of the Trent Severn Waterway	• Provide Navigation
Protecting significant aquatic habitats and species	• Protect Natural Environment (wetlands, fish, wildlife, invasive species, species at risk)
Optimizing the enjoyment of the water throughout the watershed by shoreline residents and visitors	• Enhance Aesthetics • Optimize Recreation • Optimize Cultural Resources • Provide Public Access (physical access, access to information)
Allowing hydroelectric generation plants to operate at plant capacity and meet demand for renewable energy insofar as possible	• Optimize Water Power Generation

1.4 Introduction to the Water Management Process

The management of the Trent Severn Waterway to achieve these goals and objectives requires consideration of a variety of different factors, including the Waterway's mandated requirements, scientific objectives, regulatory impacts, environmental impacts, political and public concerns, as well as the day-to-day and long-term operation of the Waterway. A Water Management Process was developed through this study as a way to address this complexity and to consider the interests of the many different stakeholders. The Water Management Process is displayed in **Figure 1-2**, and describes the steps required to implement decisions with respect to the operation of the Waterway.

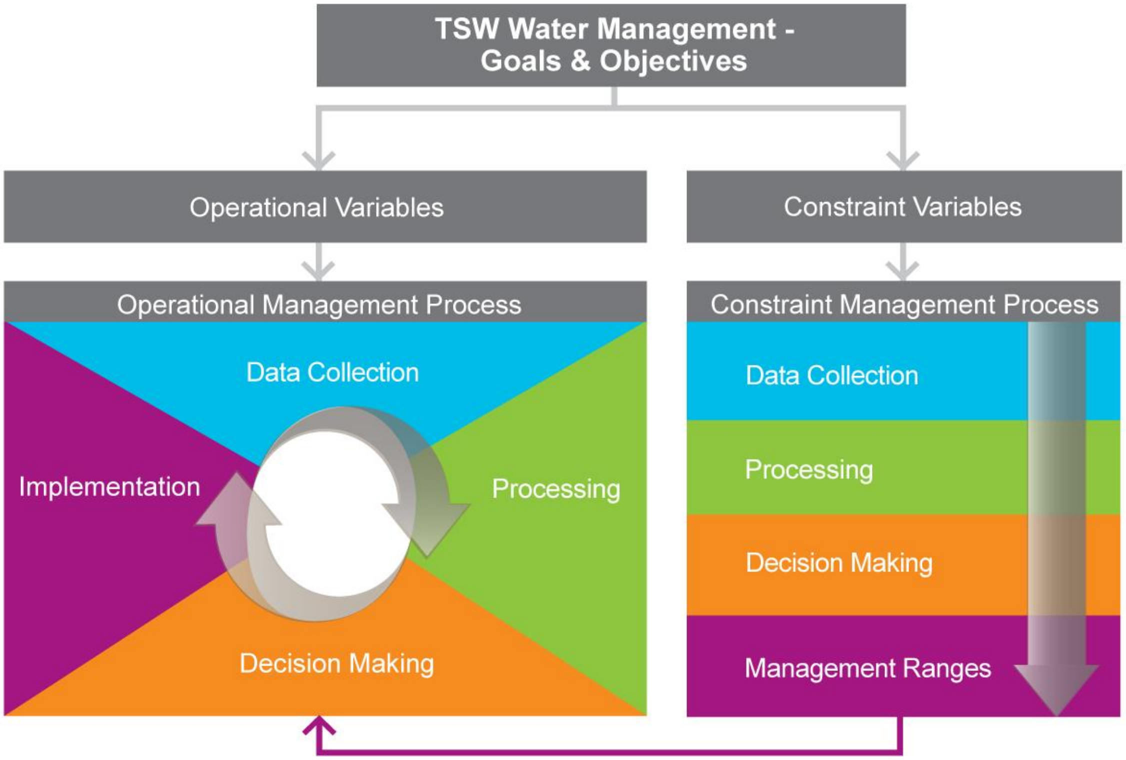

Figure 1-2 - Water Management Process for the Trent Severn Waterway

The Operational Management Process shown on the left side of **Figure 1-2** describes the core activities of Parks Canada staff in the operations of the TSW. These activities are implemented on a continual basis and consist of the day-to-day operations of the locks, dams and other water control structures to manage the flows and water levels in the Waterway through regular monitoring, the balancing of water between the different components of the Waterway (i.e., the Haliburton Reservoir Lakes and the Kawartha Lakes/Trent River), and the communications with staff to implement management decisions.

The Constraint Management Process shown on the right side of **Figure 1-2** describes the activities undertaken to establish the constraints, or “Management Ranges”, that define the range of water levels and flows on all lakes with the aim of satisfying the goals and objectives of the Waterway in a comprehensive and balanced manner. This process includes the evaluation of a diverse array of variables that impact the goals and management of the Waterway. The frequency that the Constraint Management Process is undertaken depends on the data being evaluated; for example, the review of historic flood events and levels need only be completed once to establish the historical record, and then updated only when new events occur.

In both the Operational and Constraint Management Processes, there are three primary activities:

- **Data Collection**. The gathering of information that is applicable to either the operations (i.e., **operational variables**) or management ranges (i.e., **constraint variables**) of the Waterway.
- **Processing**. The use of processing and optimization tools to interpret the collected data and produce results appropriate for effecting operational or management/constraint changes.
- **Decision Making**. The evaluation of processing results to make operational decisions or to establish new management ranges throughout the Waterway.

These activities result in an **Implementation** decision with respect to the operation of the Waterway (i.e., increase or decrease water levels or flows at certain locations), or the establishment of a **Management Range** to consider in the processing of operational data (i.e., minimum water levels or flows for navigation in summer or fish spawning in fall).

Through the continual application of this management process, the Waterway can be effectively managed to achieve the goals and objectives of the TSW, giving due consideration to the wide range of stakeholders and users that make the Waterway the dynamic entity it is today.

1.5 Document Map

The Water Management Process introduced in **Section 1.4** provides a context upon which each of the four reports in the Water Management Study is presented. **Figure 1-3** overlays a Document Map on the management process (**Figure 1-2**), highlighting the different components of the Waterway Management Process that are described in this component of the study.

The **Water Management Manual** describes, in detail, how the overall system is managed and operated and includes the processes and activities associated with making water management decisions, as well as an understanding of the relationships that are critical to the decision making process. It is anticipated that the Manual will provide a training and succession tool allowing new water managers and associated staff to understand the processes, procedures and responsibilities associated with water management.

An additional component of the manual describes two recent operational scenarios that required significant management and coordination efforts by Parks Canada staff. This includes initial operational conditions, ongoing meteorological inputs and operational decision making points including consultation and communications as part of the operational procedure.

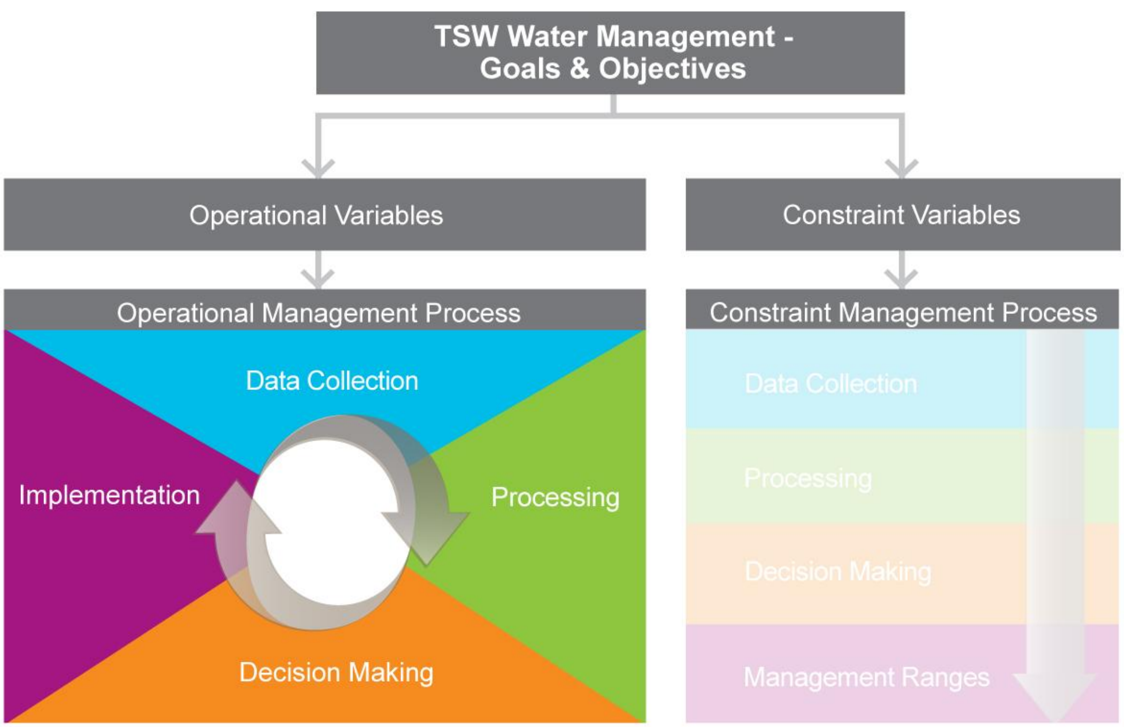

Figure 1-3 - Trent Severn Waterway: Water Management Study - Document Map

2. Legacy Operating Documents and Studies

The sections below provide a high-level summary of previous reports produced by Acres. A detailed summary of the reports is provided in **Appendix A**.

2.1 The Trent Basin – Volume 1 Plan of Operation & Volume 2 Analysis of the System (1973)

Acres Consulting Services Limited (Acres) previously undertook an examination of the operations and procedures for water control of the Trent Canal from Balsam Lake to the Bay of Quinte. The study was detailed in the reports *The Trent Basin – Volume 1 Plan of Operation* (Acres 1973a) and *The Trent Basin – Volume 2 Analysis of the System* (Acres 1973b).

2.1.1 Duty of Water / Water Demands

At the time of the study, the main water duty / demands within the system were:

- Acceptable water levels for navigation during the navigation season (primary objective);
- Range of water levels and flows suitable to accommodate various residential needs and recreational uses, and to avoid flooding damage;
- Minimum water levels required for drinking water supply and submergence of municipal water intakes;
- Minimum flows and water levels required to maintain acceptable water quality;
- Range of water levels and flows to provide reasonable conditions for water-supported wildlife; and
- Flows for operation of hydro-electric power stations.

2.1.2 Available System Data

Prior to 1972, available data for the system included: flows recorded at three flow gauging stations; water levels recorded every 1-5 days at each reservoir; snow depth measured in the spring in the Scugog area and around Lake Simcoe; and daily and long-term weather forecasting obtained from news media.

As of 1972, eleven meteorological stations were operating within the basin. Ten established snow survey courses existed, managed by three agencies (Ontario Hydro, Department of Lands and Forests, and Canals Division). There were nine available streamflow records and locations, as of 1972. Flows in the other locations were predominantly calculated from records of water levels in the reservoirs and stoplog positions.

2.1.3 System Operation Prior to 1972

Few firm guidelines were available to the water control manager regarding required discharges to satisfy the various water demands. Typically, the manager relied on his long experience and 'feel' for the system. The objectives and operational policies and procedures by season included:

- **Summer Operation**
    - The historical objective of summer operation was to provide sufficient water to maintain navigation in the canal, and to maintain a minimum flow of 800ft^3/s (22.6m^3/s) in the Otonabee River;
    - Kawartha Lake water levels were maintained close to the top of their operating ranges, whenever possible;

Flow demands may have required drawdown of water levels in the Northern Reservoirs, which were drawn down by an equal percentage of the operating range.

- **Fall / Winter Operation**
  - The historical objective of fall / winter operation was to lower the reservoir levels in preparation for the spring freshet;
  - Northern Reservoirs were drawn down in most cases to sill level at the start of the season;
  - Northern Reservoirs that have been proven to be difficult to fill during the spring freshet were drawn down to levels above the sill level;
  - Kawartha Lakes were drawn down gradually between January 1 and March 15 to the winter holding level, which in certain lakes was above the sill elevation;
  - In mid-February, the magnitude of the spring freshet was predicted from the snow depth data. The volume of the spring freshet was not calculated, however, the approach provided an indication of the volume to be expected;
  - Movement of stoplogs during the winter was difficult and hazardous for staff. Movement of stoplogs during the winter and early spring months was minimised.
- **Spring Operation**
  - The historical objective of spring operation was to avoid localised flooding within the system and fill all reservoirs using the spring freshet. Of particular emphasis was filling the Northern Reservoirs, for use in maintaining stable water levels and flows in the Kawartha Lakes and Trent canal during the relatively dry summer period;
  - Northern Reservoir stoplogs were generally inserted prior to snowmelt, due to the difficulty in predicting the timing of the peak flows and the need to fill these lakes.

2.1.4 Proposed Operational Policies and Procedures

Proposed operational policies and procedures included definition of the following:

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

A fundamental concept of the proposed operational policies and procedures was the definition of horizontal zoning of each reservoir. For each zone, the purpose or duty of the water was different. The study suggested five Reservoir Zones, as detailed in **Appendix A**.:Another fundamental concept was the definition of the prescribed relationships between reservoir storages when some (or all) of the individual reservoir target water levels cannot be satisfied. The proposed approach made use of both priority and equal function concepts.

The proposed objectives and operational policies and procedures by season included:

- **Summer Operation**
  - The recommended primary objective of summer operation was to provide suitable levels and flows to support navigation in the Kawartha Lakes canal system, while satisfying the other objectives where possible;
  - Maintain target water levels in the Kawartha Lakes at the top of the Conservation Zone;
  - Drawdown Northern Reservoirs water levels uniformly by depth through the Conservation and Buffer Zones, to supply water to maintain target water levels in the Kawartha Lakes;
  - Maintain water levels in each reservoir within the same zone;

  - Minimise fluctuations in water level in all reservoirs;
  - Conserve water by permitting only minimum required flows for water quality, at certain times; and
- **Fall / Winter Operation**
  - The recommended primary objective of fall / winter operation was to drawdown all reservoirs to provide available storage for the upcoming spring freshet, while satisfying the other objectives where possible,
  - Drawdown of water was on a priority system, starting at the top of the system;
  - The Northern Reservoirs target water level was sill level, except for reservoirs that are difficult to fill (in which case, a higher target level was adopted);
  - The Kawartha Lakes target water levels were to be set to 50% of the storage volume;
  - During drawdown, control discharges to avoid flooding;
  - Maintain minimum required flows for water quality in all channels; and
  - Adjust target water levels, as required, following the initial forecast of spring inflow on February 15.
- **Spring Operation**
  - The main suggested objective of spring operation was to attain, by the end of the season, water levels and flows within the Kawartha Lakes suitable for navigation (near the top of the summer Conservation Zone), while ensuring public safety and avoiding flooding of lakeshore and riverside properties;
  - Accumulate water storages within the Northern Reservoirs for use as a water supply to the Kawartha Lakes during the summer;
  - No policies for equality in the filling of the reservoirs;
  - proposed priority ranking for filling;
  - Pass surplus water out of the system as early as possible;
  - Reduce flooding to a minimum by judicial use of storage; and
  - Maintain minimum required flows for water quality in all channels.

In mid-February, it was recommended that a forecast be made of the expected volume of inflow into the system upstream of Peterborough due to the upcoming spring freshet (March 15 to May 15). If required, adjustments to the late-winter target water levels in each reservoir are to be made to better prepare the system for the predicted volume of inflow during the spring freshet. If additional storage volume is required, the Kawartha Lake reservoirs were to be drawn down uniformly by depth towards the new target water levels.

The recommended procedure to implement the above policy involved:

- Monitoring and recording of flows and water levels within the system;
- Using the recorded data and forecasted natural local inflows with the model, and system of operational charts for spring operation, developed for the study to forecast the average discharge and control structure setting necessary at each reservoir to attain the target water level (or provide an optimum water level if the target water level was unattainable) by the end of the current time period;
- Advise staff as to the control structure setting adjustments as indicated by the model; and
- On-site, augment the settings prescribed by the model, based on actual conditions in the field.

2.1.5 Modeling

A computer simulation model of the system was developed to assist in operational decision-making. The model attempted to obtain a solution such that the water levels in all reservoirs satisfied their respective operating procedures and all channel flows were within the prescribed ranges. However, under particularly wet or dry conditions, it is not possible to obtain a solution without violating some target water levels, prescribed flow ranges, or other operating policies. The model therefore also included generalised rules for balancing water level and flow deviations from target values, including:

- Preferable for all reservoirs to be in the same Reservoir Zone;
- Channel flows are allowed to deviate outside target zone, prior to allowing water levels to deviate outside the target zone; and
- Based on the interreservoir relationships (both priority and equal function definitions).

The model assigned penalty coefficients in proportion to the magnitude of the deviation from the target water levels or for channel flows outside the prescribed range. The model would then produce a series of solutions representing varying degrees of violation from the ideal operating procedures. The optimal solution was identified as the solution with the minimum sum of total penalties in the system.

2.2 Trent Simulation Package (1977)

The Trent Simulation Package (Acres 1977) was a manual summarizing the information from *The Trent Basin – Volumes 1 and 2* (Acres 1973) necessary to understand and operate the simulation models.

2.3 Post-Audit of the Trent-Severn Waterway Operating Procedures in the Haliburton Reservoir Lakes Area (1988)

Acres undertook a review of the existing water management procedures of Trent-Severn Waterway and recommended measures to improve future operations were recommended. The study is detailed in the report *Post-Audit of the Trent-Severn Waterway Operating Procedures in the Haliburton Reservoir Lakes Area* (Acres, 1988).

The review found that the primary objective of providing a navigable waterway between Trenton and Port Severn was satisfied. Also, this primary objective was met while minimising the drawdown of the Reservoir Lakes during the summer season in an equitable manner. In addition, operations in the Reservoir Lakes during spring freshet were found to be reasonably successful in filling the reservoirs and avoiding serious flooding.

In addition, the computer models were upgraded since the original study to include a Flow Forecast Module (QFORECAST) which predicts volumes of inflow to each reservoir during spring runoff based on snowpack and meteorological variables.

3. Current Approach to Operations

3.1 Management Structure

The water management program of the Waterway is led by the Director of Canal Operations and coordinated by the Water Control Engineer who works from TSW headquarters in Peterborough. The Water Control Engineer communicates daily with four Sector Managers. The office locations and boundaries for each sector are described in **Table 3-1**.

Table 3-1 - Sector Extents and Office Locations

Sector	Office Location	Sector Boundaries
Haliburton Reservoirs	Haliburton	Reservoir Lakes and lakes on the Gull River system
North Sector	Kirkfield	Severn River and Balsam, Cameron, Sturgeon and Scugog Lakes
Central Sector	Peterborough (TSW HQ)	Kawartha Lakes to Otonabee River excluding Balsam, Cameron, Sturgeon and Scugog Lakes
South Sector	Trenton	Rice Lake to Trenton

The Water Control Engineer is also in contact with other agencies such as the Ministry of Natural Resources, Conservation Authorities, Ontario Power Generation, and other public and private power generation stations in order to coordinate the sometimes competing interests for water in the system.

Decisions with respect to water levels and flows are made by the Water Control Engineer using a variety of data and in consultation with the Sector Managers. Directions are then communicated to the Sector Managers who implement the changes through operations and maintenance staff, led by an Operations Supervisor, who make the necessary adjustments at the dams. The Sector Managers have the experience and authority to suggest modifications to the water management decisions, which are then considered by the Water Control Engineer, though the decision is ultimately made by the Engineer. In short reaches, the Lockmaster at individual water control structures has the authority to make one log adjustments to maintain water in the upstream reach within a specified range.

3.2 Operational Mandate and Considerations

Managing the water levels in a system as complex as the Trent Severn Waterway is a challenging operation. The TSW exhibits changing hydrologic and hydraulic response characteristics throughout the system, as well as a variety of competing interests and stakeholders who are concerned with the management of the water levels.

Historically, providing water for navigation was the legislated mandate of the Waterway operating authorities (i.e., Parks Canada and its predecessors). Three canal policies that still guide Waterway operations to this day evidence this mandate (from Parks Canada Guiding Principles and Operational Policies, 1994):

- 1.1.2 - The following considerations will guide the provision of navigation: availability of adequate water levels, maintenance of public safety, preservation of heritage character, physical condition of the works, time of year, demand, and available human and financial resources.
- 1.1.3 - Where navigation is maintained, Parks Canada objectives will be to maintain adequate canal water depths, structures and navigation aids in order to provide for navigation.
- 1.1.4 - Water levels and flows required for navigation on the canals will be monitored and managed to minimize flooding and adverse resource impacts.

However, as development has progressed in areas that had been largely uninhabited while the Waterway was conceived and constructed, competing interests and advanced scientific understanding have increasingly been considered during operations. In an effort to recognize these interests, the current Trent Severn Waterway Management Plan (Parks Canada, 2000) contains two important policy statements:

- A.7 - Water levels and flows within the Trent and Severn watersheds are effectively managed in a manner that recognizes the diverse and sometimes conflicting needs of users while minimizing adverse environmental effects.
- A.8 - The potential effects of climatic change and other major emerging issues are monitored in consultation with others to ensure sound up-to-date water and ecosystem management.

Ongoing efforts to accommodate additional stakeholders in the Waterway led to the development of the Water Management Goals (EcoPlans, 2007), which form the operating philosophy for the current system management:

- Reducing threats to public safety and negative impacts to public and private infrastructure from over-bank flooding, ice damage, extreme water level fluctuations, and high volume flows;
- Contributing to the health of Canadians through the availability of drinking water for residents, cities and towns throughout the watershed;
- Providing safe boating and navigation along the marked navigation channels of the Trent-Severn Waterway;
- Protecting significant aquatic habitats and species;
- Optimizing the enjoyment of the water throughout the watershed by shoreline residents and visitors; and,
- Allowing hydroelectric generation plants to operate at plant capacity and meet demand for renewable energy insofar as possible.

Operational decisions typically involve how much water to release or hold from a reservoir or lake in order to optimise flows and water levels based on criteria relating to these six water management goals.

3.3 Operations – Geographic and Seasonal Considerations

The management of the Trent Severn Waterway is based on an annual cycle of operations augmented by historical records of over 100 years of recorded water levels, flows, weather data, and snowpack depths. This data is provided by a network of gauge stations in each sector and much of it can be accessed by computer and analyzed on a daily or hourly basis by the Water Control Engineer, Sector Managers, and Operations Supervisors.

The annual cycle of operations is divided into four distinct operating seasons, each with their own objectives and constraints:

- Spring – Mid-March to the Friday preceding Victoria Day weekend;
- Summer (Navigation) – from the Friday preceding Victoria Day to Thanksgiving;
- Fall (Post-navigation) – Thanksgiving to January 1st; and,
- Winter – January 1st to Mid-March, depending on climate conditions.

The exact start and end date of the navigation season is determined by the statutory spring and fall holiday long weekends, due to the large number of boaters that frequent the Waterway on these dates. The period between these two holidays forms the official navigation season for the Waterway. Navigation ranges are not guaranteed to be maintained outside of this period.

During each season of the year, the four sectors have discrete and distinct circumstances and water control functions. Water levels and flows are set for the lakes and channels in the system for different periods of the year, based on water level ranges, flow targets and rule curves. As identified in the six goals, cottagers, year-round residents, commercial operators, power generators, and others are all concerned with the management of water levels. However, the operating mandate of the Waterway is to provide for safe navigation while accommodating other water users insofar as possible.

Occasionally there is a need to consider how to address the impacts of sporadic weather patterns. Given the size and lag time inherent in operations, there is a limited capability for Parks Canada staff to act pre-emptively to predicted weather conditions. The general response, unless there is an extreme and imminent forecast, is not to operate pre-emptively but operate incrementally until the event has occurred and to mitigate as much as possible any adverse impacts through daily operations.

The following sections describe, in detail, the various operational objectives, constraints and procedures applied in each of the four sectors through the annual cycle of operating seasons. These efforts are co-ordinated by the Water Control Engineer who is ultimately responsible for operational optimization of the system; this co-ordination effort and the lines of communication used during operations are described in **Section 3.4**.

Various physical characteristics of the system are provided on the following pages and in **Appendix C**, including:

- A longitudinal profile of the Trent Severn Waterway in **Figure 3-1**;
- A schematic of relative storage based on reservoir area and active operating depth in **Figure 3-2**;
- Reservoir/lake characteristics including watershed area, storage potential and operating ranges are provided in **Table C1a** and **C1b**;
- Winter stoplog settings are provided in **Table C2** (Haliburton Lakes);
- Allowable range of water elevations to ensure navigation are provided in **Table C3**;
- Reservoir/lake discharge characteristics are provided in **Table C4a** and **Table C4c**;
- Average reservoir/lake levels (+max/min) over the annual operating cycle are provided in **Table C4b;**
- Dam Spillway Configurations and Discharge are provided in **Tables C5a**, **C5b** and **C5c**; and
- Flow constraints, minimum and maximum seasonal flows at Peterborough and Coboconk, are provided in **Table C10**.

Figure 3-1 - Profile of Minimum Controlled Water Level Elevations

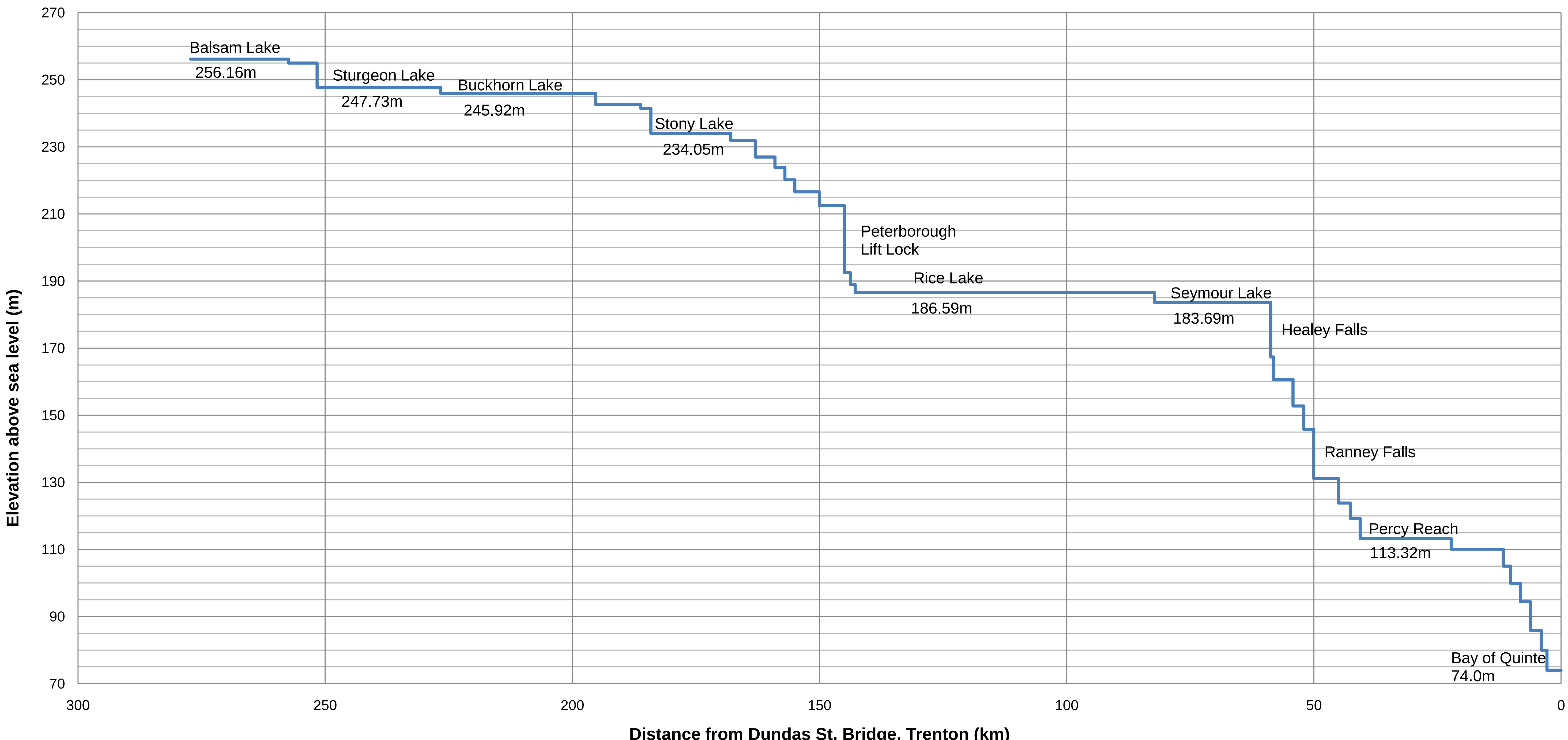

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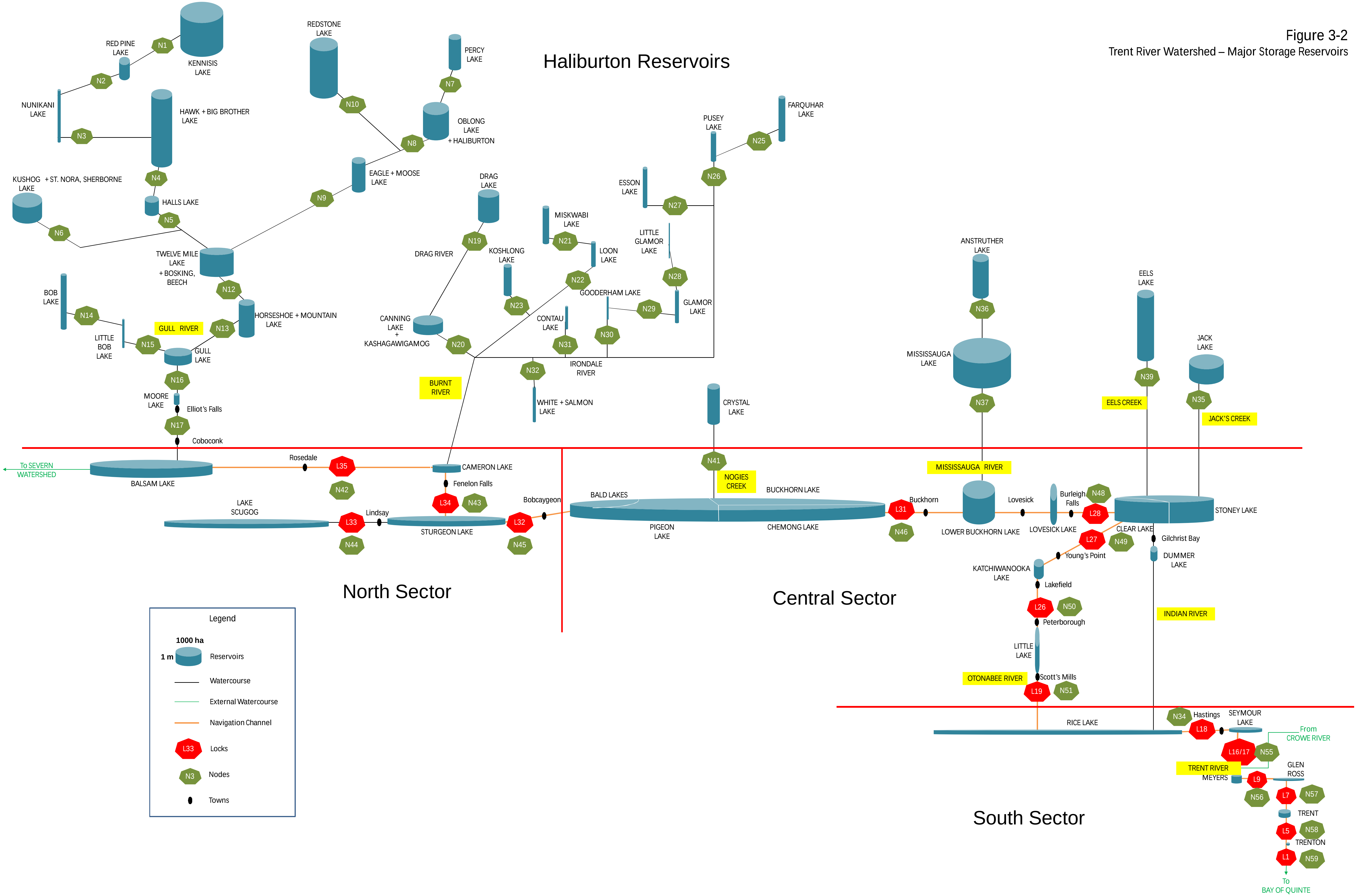
Figure 3-2
Trent River Watershed – Major Storage Reservoirs



3.3.1 Haliburton Reservoirs

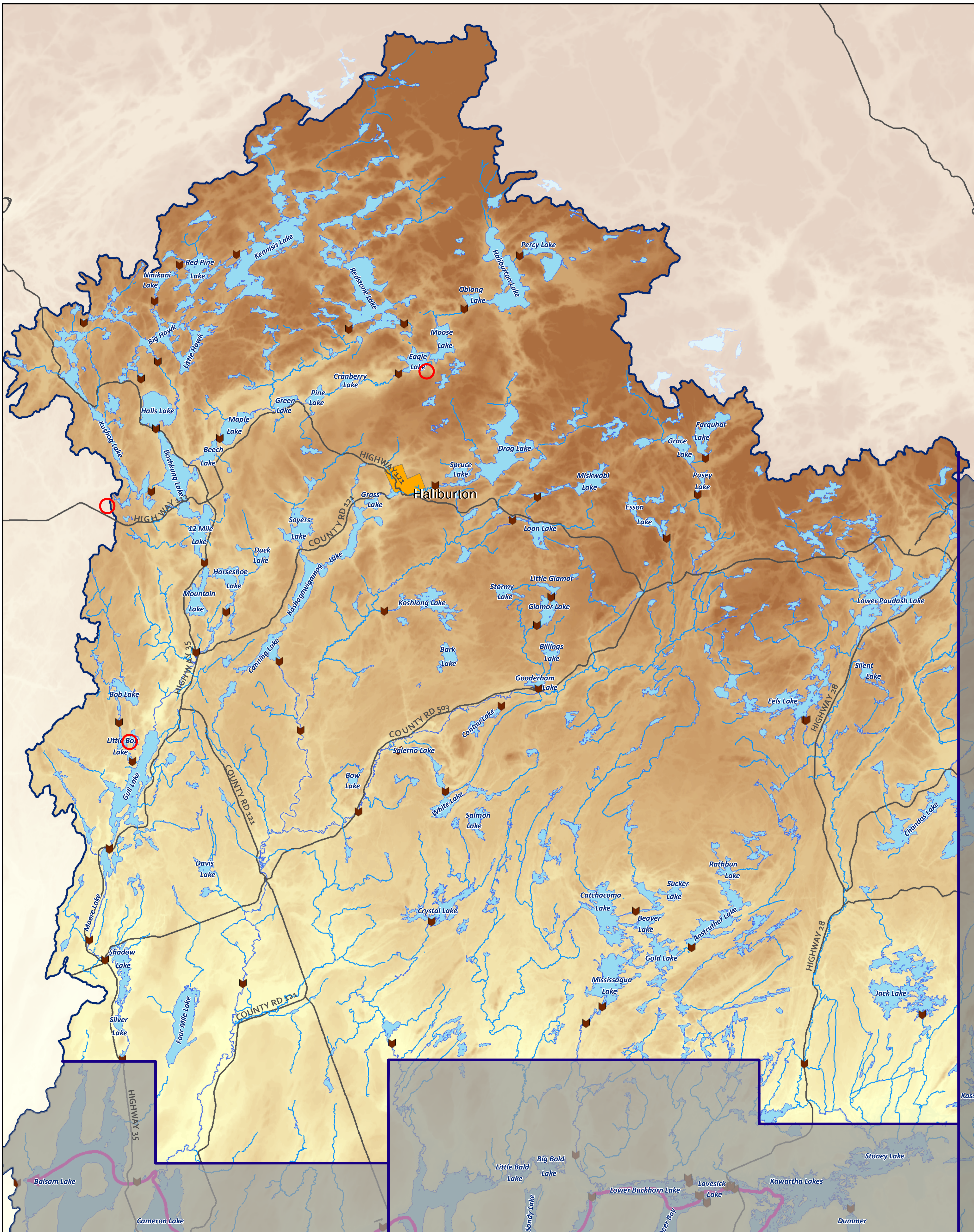
The Haliburton Reservoirs is made up of the Reservoir Lakes (3,320km^2), and comprise the northeastern portion of the Trent River watershed. The Reservoir Lakes are forty-four lakes in the northern shield area that have been dammed to collect spring runoff. Water from these lakes is released over the summer to supply the Trent component of the Waterway for navigation and other purposes, in alignment with the water management goals of the system. These lakes are located on the tributaries of the Gull, Burnt and Mississauga Rivers, as well as Nogies, Eels and Jack Creeks. A key map of the Haliburton Reservoirs is provided in **Figure 3-3**.

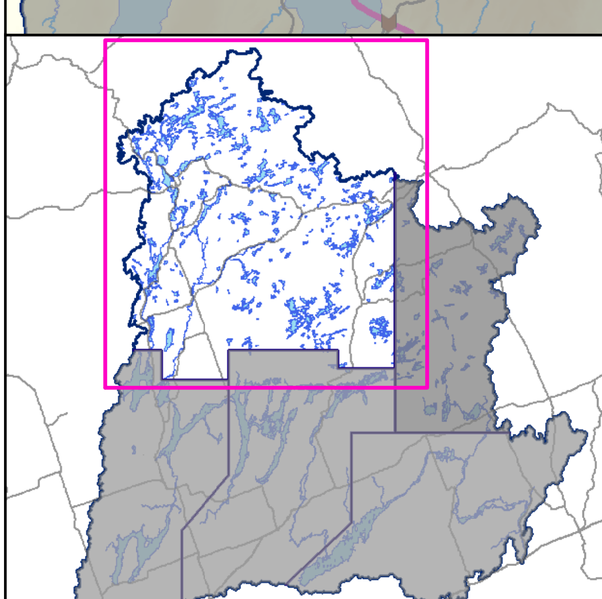
3.3.1.1 Operational Objectives and Constraints

The historical function of the Reservoirs is to store spring runoff and release water gradually over the summer to augment water levels in the navigable portion of the Trent Severn Waterway. The Reservoirs also serve to mitigate flooding in downstream areas by attenuating and storing excess flows. However, as development has increased there have been a greater number of interested users that can have conflicting demands for the water. Over time, these additional interests have been incorporated into the operational objectives of the system, as evidenced by the six Water Management Goals defined in Section 1.3. **Table 3-2** demonstrates how the current operational objectives for the Haliburton Reservoirs support the Water Management Goals.

Table 3-2 - Operational Objectives of the Haliburton Reservoirs

Water Management Goal	Operational Objective
Reducing threats to public safety and negative impacts to public and private infrastructure from over-bank flooding, ice damage, extreme water level fluctuations, and high volume flows	• Provide storage and attenuation of spring runoff to mitigate flooding in downstream areas while minimizing flooding impacts to shoreline residents
Contributing to the health of Canadians through the availability of drinking water for residents, cities and towns throughout the watershed	• Augment flows to downstream areas to maintain appropriate conditions for drinking water intakes and wastewater outfalls
Providing safe boating and navigation along the marked navigation channels of the Trent-Severn Waterway	• Provide storage of spring runoff to augment navigation water levels in downstream areas during the summer navigation season while minimizing the amount of water released
Protecting significant aquatic habitats and species	• Manage water levels appropriately during fish spawning seasons in lakes and channels identified as key aquatic habitat
Optimizing the enjoyment of the water throughout the watershed by shoreline residents and visitors	• Minimize water releases from lakes, and draw down lakes on an equal percentage basis, to maximize availability of water for shoreline residents and visitors for enjoyment and property access
Allowing hydroelectric generation plants to operate at plant capacity and meet demand for renewable energy insofar as possible	• Coordinate water management with hydro power utilities without impacting water available for other users





Legend

- Dam (with Hydroelectric Plant)
- Dams
- Snow Stations
- Major Roads
- Rivers
- Management Sectors
- Trent-Severn Waterway Navigable Channel
- Reservoir / Lake
- Cities / Towns

Elevation (m)

High : 562

Low : 49

0 2 4 8 12 Km

Trent Severn Waterway: Water Management Study

Figure 3-3
Haliburton Reservoirs

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Parcs Canada Parks Canada

AECOM

The management of water levels in the Haliburton Reservoirs is a balancing act. Water must be released from the lakes over the dry summer season to maintain navigation levels in the downstream portion of the Waterway; without this augmentation from the Reservoirs, navigation would not be possible in many summers. Release of this water must be done in a manner that respects the previously established range of permissible channel flows at Coboconk and Peterborough for each Reservoir Zone (refer to **Appendix C, Table C10**). In addition, there are several water intakes and wastewater discharges in the Waterway that require appropriate water levels to function.

Shoreline residents of the Haliburton Reservoirs, however, prefer a more stable water level regime and respond negatively when water levels decrease too quickly. To mitigate the impact of the required drawdowns on any one particular Reservoir, Parks Canada has long practiced an equal percentage drawdown across all lakes based on available depth. This ensures that all stakeholders in the Haliburton Reservoirs are affected by decreasing water levels equitably.

In addition to human users of the lakes, there are certain lakes and channels in the Reservoirs that have been identified as Lake Trout or Walleye spawning habitat. These areas require different management of water levels at spawning times, which in the case of these species are the fall and over-winter period (Lake Trout) and spring period (Walleye). Management decisions related to fish habitat are described in greater detail in the Operational Procedures section.

Coordination with hydro utilities is an important objective of water management as well. Typically, the Trent Severn Waterway staff will make water management decisions based on the need to provide for navigation and flood mitigation. The hydro utilities will then be informed of the available water, and will be given the option to use this water for energy production, funnelling it through the turbines and spillways owned by the hydro utility. Water that is not used by the hydro utility is conveyed through Parks Canada infrastructure. The overall amount of water conveyed downstream does not change as a result of the operation of the hydro utility, and thus does not impact the amount of water withdrawn from the Haliburton Reservoirs.

3.3.1.2 Operational Procedures

The following sections describe the operational procedures and objectives in the Haliburton Reservoirs on a season-by-season basis. They highlight the seasonal conditions in the sector, the different stakeholders and water users, and the operational interaction with the other sectors in the system. A summary of the sector operations is provided at the end of the section, in **Figure 3-4**.

The Haliburton sector receives water level and flow information from a network of approximately 40 gauges, of which 24 are automatic gauges (19 water level, 5 flow) and the remainder are manual level gauges. The flow gauges are located at Hawk Lake, Horseshoe Lake and Norland in the Gull River subwatershed; at Furnace Falls and on the Burnt River in the Burnt subwatershed; and on the Mississauga River and Eels Creek.

Snowpack information is collected in the winter from four snow survey sites (a fifth survey site is located in the North sector). Water level information in the Haliburton sector is typically reported to the Water Control Engineer on a weekly basis, due to the time required to collect readings from the manual level gauges.

<u>*Spring Season*</u>

The objective of spring operations in the Haliburton Reservoirs is to manage the spring freshet (i.e., snow melt) both to fill up the Reservoirs in preparation for the summer navigation season, and to mitigate the impact of flooding. In most years there is more inflow than needed to fill the lakes and some surplus is released to the rest of the system, although this release is carefully coordinated with the other sectors since there typically is a reduced capacity to mitigate excessive flows in downstream areas.

As the freshet begins, stoplogs are placed in the dams as the lakes are rising with runoff from melting snow. If the measured snowpack is observed to be smaller than expected, some stoplogs may be put in the dams as early as February (see winter season operations) to retain as much water as possible. As the lakes are nearing their full levels, snow survey data and all available sources of information are checked to determine remaining runoff volumes:

- If low volumes are expected then lakes levels are filled to maximums to prepare for summer; and
- If high volumes are expected then lakes levels are allowed to discharge more freely.

Heavy inflows can result in removing stoplogs again to spill the surplus. The equal filling of lakes during extreme events is practiced to mitigate water level fluctuations throughout the sector. Even in periods without heavy inflows, there is a requirement to maintain flows in the downstream portions of the system, and thus some water is released while the lakes are filling.

Some areas in the Haliburton Reservoirs are sensitive to high flows that commonly occur in spring, including the Gull River at Minden, and at Shadow Lake (between Norland and Coboconk). Relatively large increases in water level are caused by increases in flow, in comparison to other parts of the Waterway. Particular attention is required at these areas during times of high or fluctuating flow to mitigate potential impacts. **Table C4c** in **Appendix C** shows the variation in flow due to water level changes in Shadow Lake.

Certain rivers in the Trent Severn Waterway, including the river downstream of Drag Lake, have been identified as Walleye spawning habitat. Walleye spawn in the spring, their preferred habitat abundant with the high spring freshet flows. Due to the requirement to maintain spawning flows in these rivers, the Reservoirs upstream of the rivers may not be completely filled during the freshet. An inventory of fish spawning locations and the required flows to be maintained during spawning season is included in **Appendix C**.

Typically, reservoirs are filled to their upper limit of storage range by May 1st for a Victoria Day waterway opening. The reservoir water level ranges are provided in **Appendix C**.

Summer (Navigation) Season

The operational objective for summer operations in the Haliburton Reservoirs is to provide water to the navigable portion of the system (i.e., North, Central and South sectors) so that the average navigational water levels are maintained. This is accomplished while minimizing the release of water from the Reservoirs. There are no navigational locks in this sector, and thus the Reservoirs are not managed to allow inter-lake navigation.

Water is retained in the Reservoirs for as long as possible during the summer until downstream conditions require flow augmentation. Typically, the Kawartha Lakes will require augmentation of flows due to the high rate of evaporation. This can occur as early as May or as late as August, depending on temperature and precipitation.

A complicating factor in the release of water from the Reservoirs is the requirement to provide for minimum permissible channel flows at Coboconk (450ft^3/s or 12.7m^3/s) and Peterborough (800ft^3/s or 22.6m^3/s) during this period, as outlined earlier from a number of previous studies. Therefore, it is typically not possible to completely eliminate the release of water from the Reservoir; some water must be continually released to maintain flows.

When required, water is drawn from each of the lakes on an equal percentage basis according to the storage range established for that lake. For example, when a lake with a relatively large storage range of 3 metres is drawn down 50%, its level will drop 1.5 metres, while a lake with 2 metres of usable storage will be lowered by 1 metre. This ensures an equitable distribution of the impact from decreasing water levels to all stakeholders.

The management of the Reservoirs is assisted by a computer model run by the Water Control Engineer. Several times a week, water level measurements are taken at the dams throughout the Haliburton, North and Central sectors. These data are input to the model, which is run each Monday afternoon or Tuesday morning. The model, which was developed by Acres (1973), uses a flow at a downstream junction (i.e., Lakefield) decided by the Water Control Engineer in combination with the measured water levels in upstream lakes to determine the required water withdrawals from the Reservoirs that will provide the required flow. The target flow at Lakefield that is used in the model is based on the requirements of the system (i.e., to maintain navigational depths). The percentage drawdown in the Reservoirs are produced by the model, expressed in terms of a target water elevation and subsequently translated into a stoplog adjustment for communication to operations staff. The water level adjustments are simulated to occur over a two week period; however the model is re-run every week with the new observed water levels. This allows the Water Control Engineer to adapt to changing conditions while providing a smoother adjustment of water levels than if the model simulated the change over just one week.

The Haliburton Sector Manager is responsible for scheduling the water level adjustments within the sector to ensure that proportionate drawdown of the Reservoirs is achieved. Typically the adjustments are made from upstream to downstream to accommodate the lag in water level response. Most of the adjustments will have been made by the end of day Wednesday in a typical operating week. The goal is to achieve the adjustments early in the week to allow additional time to react to changing conditions. Since there are no automatic/hydraulic dams in the Haliburton sector, and since the lakes are distributed over a large area, the adjustment of dam stoplog settings requires the use of several field crews.

Starting in mid-August, the Haliburton Reservoirs begin to be drawn down towards the target of 50% of total volume by October 1st. A redline technique is used to hind cast a decrease of 0.5% of water level per day from October 1st back to August 15th. After August 15th the operations of the Reservoirs attempt to remain at or below this redline. This is done to make sure that there is not too much water left in the Reservoirs at the end of the summer season, as they have limited ability to draw down excessive amounts of water at that time. This means that water is released from the Reservoirs regardless if it is required for navigation. This rate of drawdown was selected to mimic natural conditions, since a 0.5% per day loss of water is approximately what would occur naturally during a dry year.

Between October 1st and the close of the waterway (approximately the 15th) operations attempt to match the 25-year long-term average water level. The goal at this time of the year is to have the reservoirs at their winter settings by October 31st. At winter settings levels, the Reservoirs have approximately 35% of their total storage volume.

Certain river reaches contain Bass and Muskie spawning sites. However, spawning for Bass occurs in early summer and, in a normal year, the spawning depths are typically maintained through regular drawdowns to achieve navigational depths. Muskellunge typically spawn in vegetated areas of flooded wetlands during from April to May. Because they spawn in flooded areas, care must be taken to maintain sufficient water depth to keep incubating eggs submerged until they hatch. Walleye typically spawn when Muskellunge spawn however Walleye deposit their eggs on cobble shoals in lakes or rivers. Successful reproduction for Walleye requires a water management regime similar as that for Muskellunge. An inventory of fish spawning locations and the required flows to be maintained during spawning season is included in **Appendix C**.

Fall (Post-Navigation) Season

The operating goal during the fall season is to implement winter stoplog settings as quickly as possible. The fall season begins after the Thanksgiving holiday weekend, when the navigation season on the Waterway officially closes. In the Haliburton Reservoirs, stoplogs are adjusted at most dams to their winter settings, allowing excess water to drain and creating storage capacity to receive the freshet the following spring. Winter stoplog settings are provided in **Appendix C**, **Table C2**. In addition to the need to create storage capacity, many of the dams become inaccessible in winter, and stoplog changes, often done by cutting the logs free of ice with chainsaws, is a costly and hazardous operation. As well, only a reduced crew is available for operation and maintenance. As a result, the winter stoplog settings are put in place as soon as possible in the fall season. Some additional changes may be required in the downstream portions of the sector to mitigate flooding, depending on weather conditions during the season.

An emerging concern with the management of water levels in the fall season is for certain properties along the lakes that are accessible by boat only. As water levels decrease, access to these properties may be jeopardized. This is compounded as more residents of the Haliburton Reservoirs adopt an extended or year-round residency, unlike the traditional summer vacationer. Additional consideration for fall and winter operations may be required at lakes that support such properties.

However, a further complicating factor occurs when too much water is retained in the reservoirs over the summer which then necessitates releasing large quantities of water in the fall. In doing so, the Lower Gull River, and lakes on the river, are subject to high water levels and localised flooding. Resultant water levels as much as four feet higher than the summer target water levels may be experienced. These high water levels are then conveyed to the Kawartha Lakes and ultimately the Trent River, requiring extensive operational adjustments. Therefore, it is desirable to draw down the lakes gradually, at a rate that can be readily accommodated in downstream areas.

The management of water levels for Lake Trout, a species that spawns in the fall months, is a significant operating objective in the Reservoirs. Lake Trout will deposit their eggs in certain cold-water lakes (identified in **Appendix C**) in the period between September and November, depending on location. The eggs remain in the lake over the winter, until the fish hatch in the early spring. If lake levels are reduced any time after this spawning has occurred, there is a risk that the eggs will become stranded out of the water, resulting in the loss of those fish. Therefore, in the lakes identified for Lake Trout management, it is critical that the winter water level be achieved as soon as possible after the end of the navigation season, from which no further decreases will take place. Past practice has involved the drawdown of water levels on critical lakes by September 30th, including Kushog, Kashagawigamog, and Big Bob Lakes.

Winter Season

During the winter season only minimal management of the Reservoirs is practiced, due to the reduced staffing levels, the difficulty of stoplog adjustments during winter, and the difficulty of access at some remote lakes. However, water management is practiced as necessary, particularly in the Lower Gull River area which often requires more active management in the winter. In addition, there is sometimes a requirement to adjust operations to accommodate hydro power users, such as the generating station at Elliot Falls.

At the target winter lake levels, some dams have all stoplogs out and the final level attained will vary from year to year depending on the natural inflow during the winter. Winters with high inflows mean that some lakes do not reach their historical low water level, thus reducing flood storage for the spring freshet. Dry, cold winters with low inflow can cause some lakes to drop lower than the average low level, creating problems on the dams because there is not enough water to run over the spillways to keep stoplogs from freezing in.

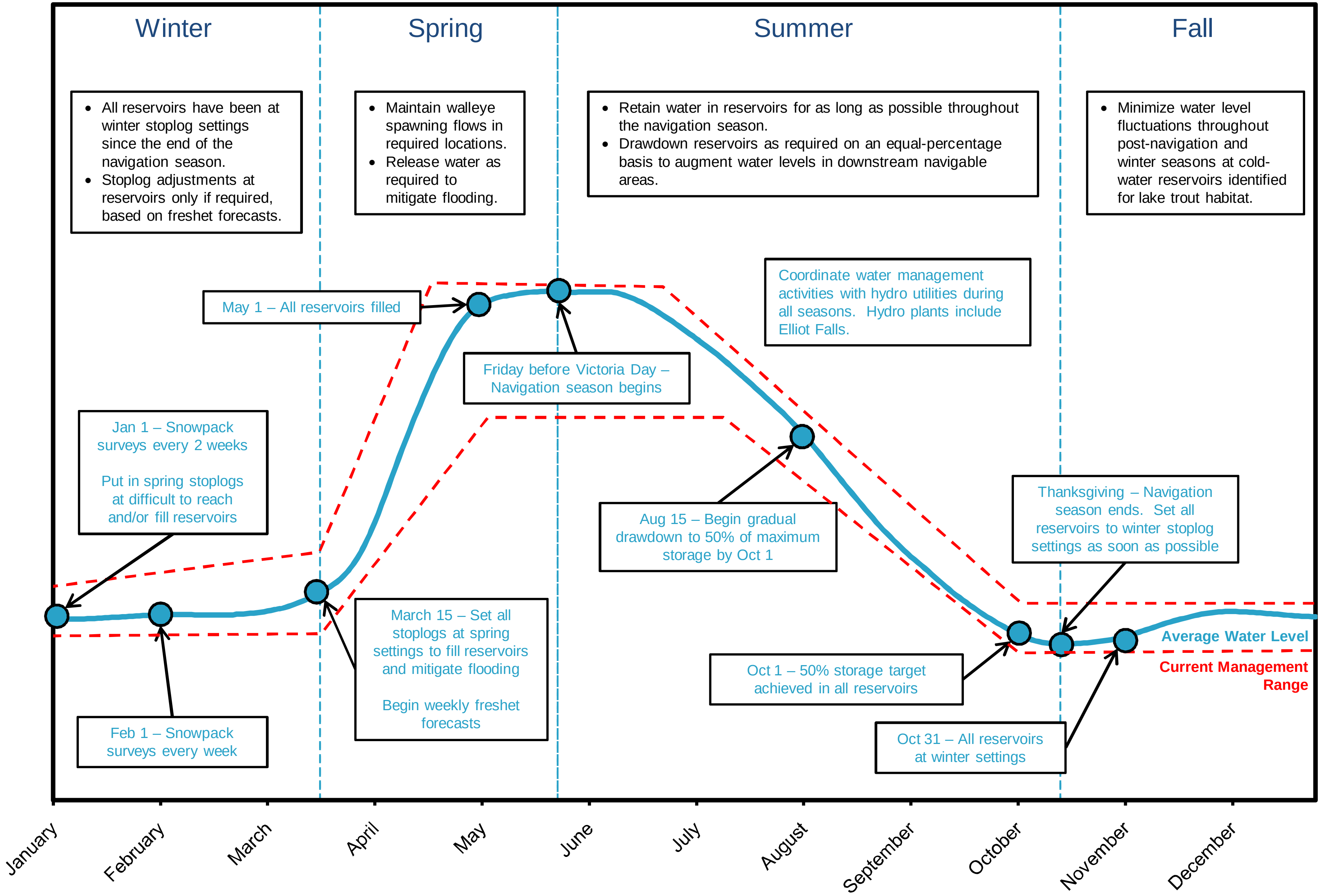
January 1st marks the beginning of snowpack surveys at the established survey sites, namely Eagle Lake, Brady Lake, Little Bob Lake and Emily Park (in the Central Sector). A snowpack survey is conducted at these four sites every two weeks in January, and then increasing to every week through February and March (see **Appendix C Table C6** for snowpack survey sheet). The freshet volume begins to be forecast around February 1st using a spreadsheet developed for that task (see **Appendix B**, **Table B1** for sample snowpack data), beginning with snowpack data from the Little Bob Lake survey site to gauge the first freshet. The freshet volume is updated around February 15th using information from the Little Bob Lake, Eagle Lake, Eels Lake and Emily Park snowpack sites, and stoplog setting are adjusted if required (i.e., if the freshet volume is lower than anticipated).

To complement the snowpack surveys, some of the lakes that are not controlled by water control structures, such as Brady Lake and 4 Mile Lake, are observed anecdotally for natural water conditions. Groundwater conditions, as evidenced by high or low lake levels, can help to indicate the proportion of spring runoff that will enter the lakes versus infiltrating. The ground condition (i.e., frozen, unfrozen) is also important when predicting the volume of water that will runoff from the snowpack, and forms part of the snowpack surveys.

At some of the more remote lakes in the sector or the lakes that are difficult to fill, such as Miskawbi and Esson Lakes, the spring stoplogs are placed at the start of the winter season to minimize the potential that runoff will be released before staff can make the necessary stoplog adjustments in the spring.

The low winter levels require some coordination with hydro electric and municipal entities, for example at Norland where there is a municipal intake and hydro power plant, to ensure that these functions can continue.

Figure 3-4 - Haliburton Reservoirs - Annual Operations Summary



3.3.2 North and Central Sector

The North sector comprises the Kawartha Lakes that are west of Pigeon Lake (i.e., Lake Scugog, Sturgeon Lake, Cameron Lake and Balsam Lake), as well as the entire portion of the Trent Severn Waterway that is located in the Severn Watershed. The Severn River Watershed lies immediately to the west of the Trent Basin and drains to Georgian Bay. However, this study is concerned with operations in the Trent River Watershed only. The Central sector includes the Kawartha Lakes from Pigeon Lake in the west to Katchewanooka Lake in the east, and then downstream to Little Lake in Peterborough. Lakes included in this sector are Clear Lake, Stoney Lake, Lovesick Lake, Lower Buckhorn Lake, Buckhorn Lake, Little and Big Bald Lake and Chemong Lake. The North and Central Sectors have similar operational considerations, and are therefore addressed together in this section.

The North sector receives inflows from the Haliburton sector via the Gull River and Burnt River, which flow into Balsam Lake and Cameron Lake, respectively. The Burnt River is largely uncontrolled and water level response can fluctuate quickly and by large amounts (i.e., a “flashy” response), especially during the spring freshet. This rapidly fluctuating response is compounded as it enters Cameron Lake, which is sensitive to changes in flow due to its small size. However, the Gull River flow is relatively steady due to a high degree of regulation and Balsam Lake is large enough to absorb most fluctuations without significant impact. Central sector receives water primarily from the North sector through Sturgeon Lake, as well as several smaller tributaries, including: Nogies Creek into Buckhorn Lake; Mississauga River into Lower Buckhorn Lake; and Eels Creek and Jack’s Creek into Stoney Lake.

3.3.2.1 Operational Objectives and Constraints

The North and Central sectors are part of the navigational portion of the Trent Severn Waterway, and contain the highest point in the Waterway (Balsam Lake) and the Kawartha Lakes which are a popular tourist destination and support a large number of permanent residents. Since these sectors are part of the main navigational waterway, maintaining sufficient depths for navigation is one of the primary objectives for operations; however, there are a number of additional stakeholders and water users, as represented in the six Water Management Goals of the system, which must also be considered. **Table 3-3** describes the operational objectives of the North and Central sectors as they apply to these six goals.

Table 3-3 - Operational Objectives of the North and Central Sectors

Water Management Goal	Operational Objective
Reducing threats to public safety and negative impacts to public and private infrastructure from over-bank flooding, ice damage, extreme water level fluctuations, and high volume flows	• Manage water levels as required to mitigate water level fluctuations and impacts from flooding or drought
Contributing to the health of Canadians through the availability of drinking water for residents, cities and towns throughout the watershed	• Provide sufficient water levels for the function of water intakes and wastewater outfalls
Providing safe boating and navigation along the marked navigation channels of the Trent-Severn Waterway	• Maintain average navigational depths through the marked navigational portions of the Waterway
Protecting significant aquatic habitats and species	• Operations shall assist and respond to fish habitat and spawning requirements in other sectors
Optimizing the enjoyment of the water throughout the watershed by shoreline residents and visitors	• Maintain water levels at an appropriate level to optimize enjoyment and property access by residents and visitors
Allowing hydroelectric generation plants to operate at plant capacity and meet demand for renewable energy insofar as possible	• Coordinate water management with hydro power utilities without impacting water available for other users

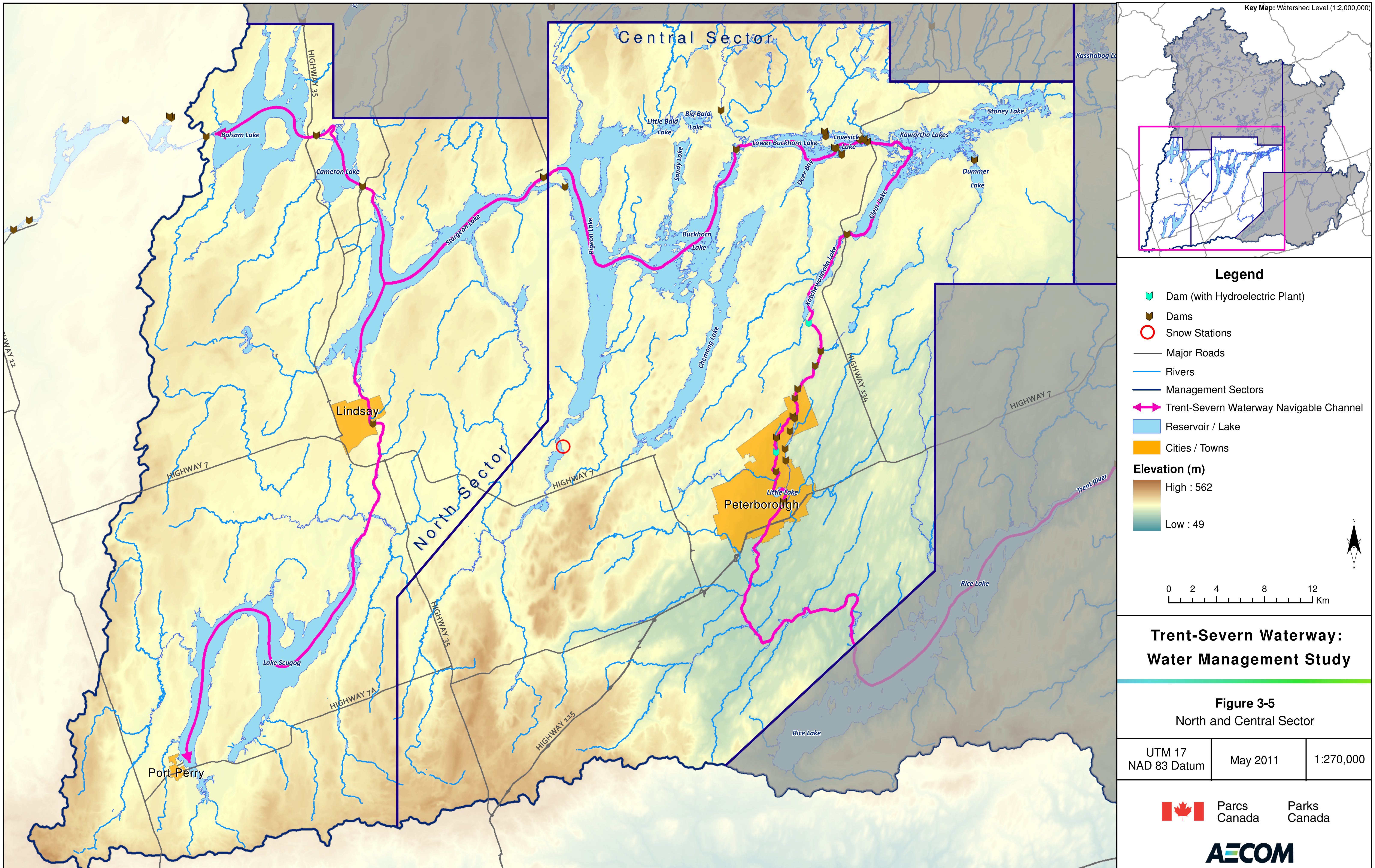


Figure 3-5
North and Central Sector

As stated earlier, the primary objective of these sectors is to provide for navigation, since they contain part of the navigable portion of the Waterway. Other interested stakeholders include water intakes, such as the Lindsay municipal intake on Lake Scugog, shoreline residents and hydro power. Some areas of the sector, such as Balsam Lake, have areas that can only be accessed by boat, and maintaining access to these areas in non-navigation seasons has become an emerging concern. In addition, the Central sector supports several water intakes and wastewater discharges. These have created two key locations at which a minimum flow must be maintained during operations in all seasons:

- Otonabee River at Peterborough - 17 m^3/s; and
- Buckhorn (i.e., downstream of Lock #31) - 3m^3/s.

The North and Central sectors support a relatively large amount of both permanent residents and seasonal visitors on its lakes, compared to the other sectors. This creates a higher level of demand for water from a wider variety of users, and the effects of these demands are felt throughout the system in the form of water releases from the Haliburton Reservoirs and the management of flows downstream in South sector.

The management of water levels in these sectors is also challenging due to the characteristics of its lakes. Central sector contains some of the Waterway's largest lakes, such as the Tri-Lakes (Pigeon, Buckhorn and Chemong Lakes), but also some of the smallest lakes, such as Lovesick and Katchewanooka Lakes. Small water level changes on the big lakes can create large fluctuations to be managed on the small lakes, increasing the amount of operational effort that must be expended. Katchewanooka Lake must also be maintained at the navigational range throughout the year, which can be challenging given its small size and variable flows from the upstream lakes.

The North and Central sectors also support several hydro power generation facilities, with plants at Fenelon Falls, Peterborough, Auburn, Lakefield, Nassau Dam and London Street. Coordination with hydro utilities is an important objective of water management. Typically, the Trent Severn Waterway staff will make water management decisions based on the need to provide for navigation and flood mitigation. The hydro utilities will then be informed of the available water, and will be given the option to use this water for energy production, funnelling it through the turbines and spillways owned by the hydro utility. Water that is not used by the hydro utility is conveyed through Parks Canada infrastructure. The overall amount of water conveyed downstream does not change as a result of the operation of the hydro utility.

The Kawartha Lakes do not tend to support fish species that spawn in the fall months, so there is less of a constraint on the timing of the winter drawdown. However, there are issues with decreased dissolved oxygen in some areas. This has resulted in "winter kill" of fish in the Kawartha Lakes, requiring additional operations.

3.3.2.2 Operational Procedures

The following sections describe the operational procedures and objectives in the North and Central sectors on a season-by-season basis. They highlight the seasonal conditions in the sector, the different stakeholders and water users, and how operations in the sector interact with other areas of the system. A summary of the sector operations is provided at the end of the section, in **Figure 3-6**.

These sectors receive water level and flow information from a network of approximately 23 gauges, of which 13 are located in the Severn Watershed (North sector); 6 gauges are located in Central sector. This does not include the flow gauges situated on the Gull and Burnt Rivers, which are under the jurisdiction of the Haliburton sector but are critical to, and monitored by, operations in the North sector. These gauges automatically send daily and hourly water level data to the Sector Manager on a daily basis to facilitate operations and coordination with the Water

Control Engineer. North sector also contains one snow survey site, located in the Severn watershed (Sibbald Point) which augments data from the four survey sites in the Haliburton sector.

Spring Season

During the spring operating season, the large freshet flows are managed to mitigate flooding and to raise the water level in the lakes to navigation levels. Once the freshet starts, many Kawartha Lakes fill or overfill even with all the stoplogs out of their dams. After the peak of the freshet has passed the stoplogs are replaced in the dams and the water levels decline until they are slightly underfilled so that the flow gates can be lowered. Then the lakes are filled to the top of the navigation range to prepare for the summer season. There are also several specific concerns with these sectors:

- Operators attempt to fill Lake Scugog by approximately 0.1m beyond summer navigation levels in the spring to compensate for the high evaporation rate, the relatively low inflows from the catchment drainage, and lack of supplemental flow from upstream reservoirs.
- Balsam Lake and Mitchell Lake need to be equalized so that the guard gate that separates the two lakes and controls flow to the Severn River Watershed can be lowered to permit navigation. If Balsam Lake isn't lowered to match the levels in Mitchel Lake, then Mitchel Lake must be raised to the level of Balsam Lake. To do this, water is supplied to Mitchel Lake through valves in the gate to supplement local inflow. However, if inflows are not sufficient to equalize the water levels on either side of the gate, then potentially the guard gate cannot be lowered delaying the opening of the navigation canal.
- The navigation range at the headpond at Katchewanooka Lake is required to be maintained during the entire operating year. Given the small size of the lake (and thus sensitivity to fluctuating inflows), and its position at the downstream end of the sector, it can be very challenging to manage the large freshet flows with this restriction.

During these high flow conditions a consideration for the downstream area (i.e., South sector) must also be made. South sector has a much lower capacity compared to Kawartha Lakes to store excess water and prevent flooding. Occasionally extra water must be retained in North and Central sector lakes to prevent serious flooding in South sector.

Managing for flooding impacts in the spring can be difficult as there is often little that can be done to reduce water levels if flows are very high. All operations must be coordinated throughout the system by the Water Control Engineer, and this often includes a principle of equal filling across the system to mitigate the overall potential flooding impact.

March 15th is the target date to achieve a minimum water level in the Kawartha Lakes from the winter drawdown. This provides the most capacity to receive the spring freshet. Once the minimum water level is attained, the runoff volume calculations for the Otonabee River are conducted to prepare for spring operations.

In some locations, flows are also managed to accommodate fish species that spawn in the spring (e.g., Walleye), although during a typical season there is usually sufficient flow to provide spawning habitat.

Summer (Navigation) Season

The objective of operations in the summer navigation season is to maintain the advertised navigational depths along the marked portions of the Waterway. However, since evaporation losses (up to 0.02m of loss per day) account for more water than can be replenished naturally through precipitation and groundwater inflows, additional water must be supplied to these lakes from the Haliburton sector. Indeed, this was the intention behind the creation of the Reservoir Lakes. The Kawartha Lakes typically have a very narrow navigational range (information included in

Appendix C, Table C3), which can make operations challenging, especially considering the wide range of lake characteristics as discussed previously.

Managing the water levels on Cameron Lake is made more challenging due to the fact that the largely uncontrolled Burnt River empties into it. This makes monitoring of the Burnt River gauge by the Operations Supervisor very important. During the spring freshet and large precipitation events, the flow in the Burnt River can fluctuate significantly, requiring extensive operations on Cameron Lake to maintain navigational ranges and mitigate flooding.

At any time of the season, significant or unusual weather events can cause flows that are heavy enough to make navigation difficult or even dangerous. As such, maximum flows have been established at strategic locations wherein if they are exceeded the navigation locks are closed to traffic to protect boaters; these locations are:

- Bobcaygeon (i.e., downstream of Lock #32) - 160m^3/s maximum.
- Fenelon Falls (i.e., downstream of Lock #34) - 100m^3/s maximum.
- Otonabee River at Peterborough (i.e., downstream of Lock #19) - 125m^3/s maximum.

When deciding whether to modify the water control settings on the Kawartha Lakes outflow dams, the Sector Manager will determine if the current trend of water levels (increasing or decreasing) will move the water level outside of the navigational range. If the water levels will remain within the navigational range, then typically no change will be made. If the water levels will likely move out of the range, then a change will be initiated through the Water Control Engineer in order to coordinate required changes throughout the Waterway. This will mitigate the amount of operational changes required at the dams which, in most cases, necessitates the operation of the locks to cease and navigation to halt temporarily, due to the fact that the staff operating the locks are also responsible for the operation of the adjacent dams.

The Sector Manager monitors the weather conditions on a continual basis to identify potential precipitation events that may require additional operations. However, unless there is an extreme forecast, operations are typically not executed on a pre-emptive basis, such as releasing water from a lake to accommodate additional inflows, due to the unpredictability of weather.

Maintaining the lakes at their average navigational depth typically satisfies the demands of other water users, including municipal water intakes and wastewater discharges, hydro generation plants and recreational users. Those fish species that spawn in the summer months are also typically accommodated during this season with little to no additional operations required.

Fall (Post-Navigation) Season

Although the navigation season is officially closed during this time, there remains on the lakes of the North and Central sector an ongoing demand for water levels within the navigational range due to barging, recreational and construction-related activities. An example of this is found on Balsam Lake, where increasing construction has occurred on the large island in the lake.

However, the operational objective for the fall season is to allow the lake levels to decline slightly to provide increased capacity for large fall flows which have historically occurred. This decline amounts to approximately 0.1m on most lakes, yielding a water level that is relatively close to the lower end of the navigational range. Thus, the use of the lakes for boat-related activities is not typically impacted significantly.

As the fall season progresses, the Lake levels are allowed to decline further towards a January 1st target, whereupon the official winter drawdown schedule is begun for the larger Kawartha Lakes. The smaller navigation lakes (i.e., Cameron Lake, Lower Buckhorn Lake and Lovesick Lake) are drawn down to their low level entirely during the fall season due to difficulty of access and staffing. The long-term, 25-year average fall drawdown schedule for the Kawartha Lakes is included in **Appendix C, Table C7**.

The lakes in Central sector do not support a sensitive fall fish spawning community, as do some of the Reservoir Lakes, and thus are not operated in this regard. However, consideration for the requirement of Haliburton sector to manage for fall spawning is made when coordinating operations in all sectors, since several lakes must be drawn down quickly once the navigation season is over.

Winter Season

Operations in the winter season involve the drawdown of lake water levels to approximately 1.0m below the summer navigation levels. This winter minimum level was established based on approximations of what the water level would be naturally, in a condition where there is no dam. This also provides storage capacity for the spring freshet. The drawdown is conducted incrementally, and is informed by real-time weather and flow conditions so that it may be adjusted to suit the changing situation. A sample of the Kawartha Lakes drawdown schedule, based on beginning and end targets, has been included in **Appendix C, Table C7**.

Similar to the Haliburton sector, snowpack surveys are conducted every two weeks in January and then every week through February and March. Although the North Sector snow survey site is located in the Severn watershed, it is used to augment the three survey sites in the Haliburton Sector and one in the Central Sector (Emily Park). The drawdown schedule for the North and Central Sector is revisited in mid-February based on the results of the snowpack surveys.

Additionally, in a dry winter, filling the western lakes (e.g., Mitchel and Canal Lakes) that flow to the Severn Watershed can be difficult if the drawdown in Balsam Lake stops too soon and does not reach a sufficiently low level to match that in Mitchel Lake and facilitate lowering of a guard gate.

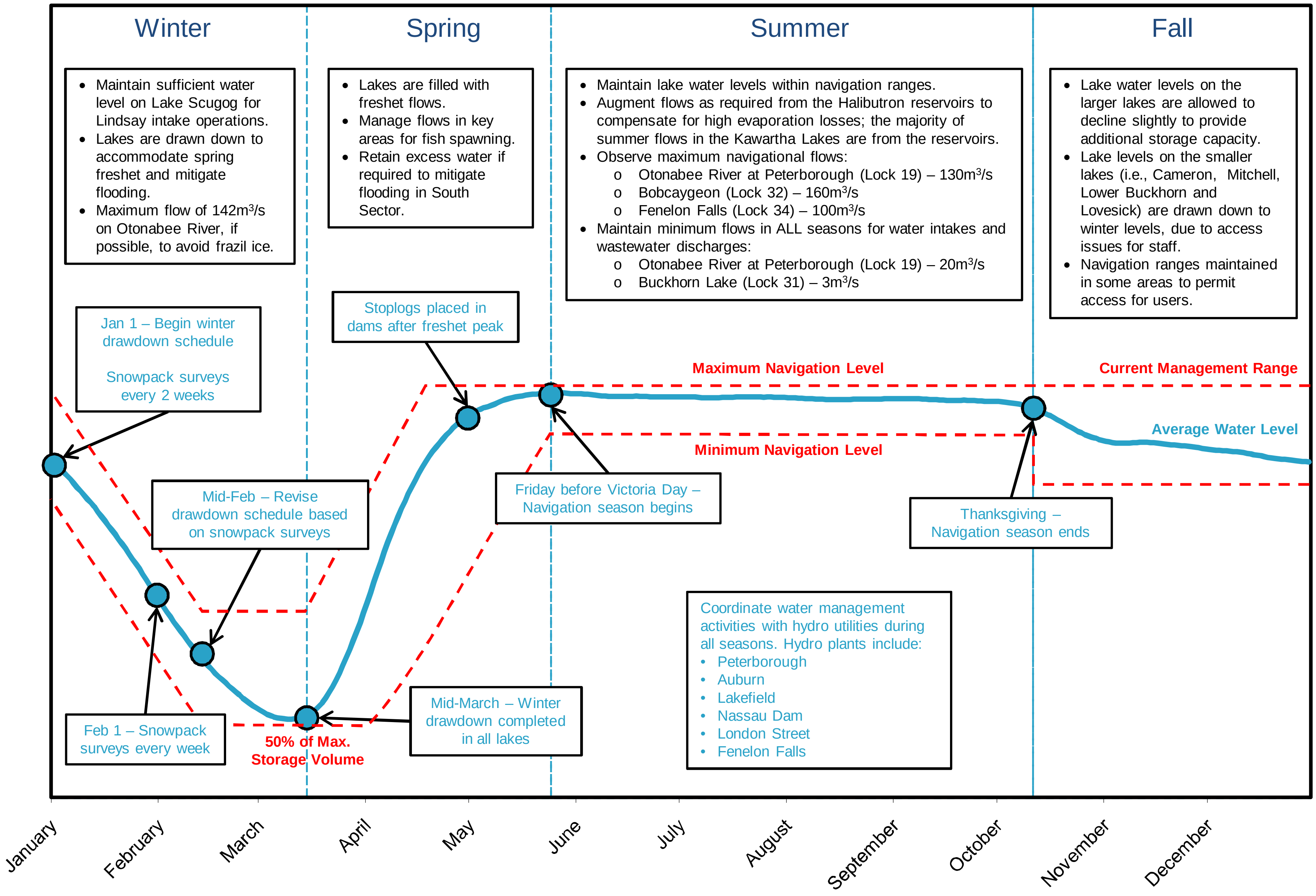
Additional care must be taken on Lake Scugog when drawing down to winter levels so as to not interfere with the operations of the Lindsay municipal water supply. The current intake may cavitate if the river flows are too high while the water level is too low, although this issue is to be addressed by the Municipality in future upgrades.

In recent years there has been an increase in the amount of winter recreation activities, particularly ice-fishing, on Rice Lake and other areas once a stable ice cover has formed. Large fluctuations in water level can compromise this ice cover, thus operations attempt to avoid large changes in water level.

The Kawartha Lakes do not tend to support fish species that spawn in the fall months, so there is less of a constraint on the timing of the winter drawdown. However, there are issues with decreased dissolved oxygen in some areas. This has resulted in “winter kill” of fish in the Kawartha Lakes. In some locations flows are maintained during the winter to oxygenate water for fish. Sometimes “winter kill” is unavoidable where water levels cannot be maintained due to dry seasons or anticipated high spring runoff and/or cold winters with thick ice cover.

Winter operations also include the mitigation of situations that are conducive to the formation of frazil ice, which can be detrimental to municipal water intakes and hydro power generation facilities, and cause localized flooding. Frazil ice typically forms when fast moving water becomes super-cooled; a general guideline for frazil ice conditions on the Waterway in this sector is a flow above $200m^3/s$ at Peterborough and temperatures of -15°C or lower. In the Otonabee River a maximum flow of $142m^3/s$ is desirable, if possible, to encourage a stable ice cover formation and limit frazil ice production.

Figure 3-6 - Central and North Sector - Kawartha Lakes Annual Operations Summary



3.3.3 South Sector

The South Sector contains the portion of the Waterway that is downstream of Peterborough, namely Rice Lake and the Trent River, including inflow from the Crowe River. This section of the Waterway drains into the Bay of Quinte (Lake Ontario). There are relatively few lakes or other storage features in the South sector; most of the sector consists of short reaches of river or canal between dams and locks. Many of these dams feature hydro power generation plants, more so than the other sectors. A key map of the South Sector is provided in **Figure 3-7**.

3.3.3.1 Operational Objectives and Constraints

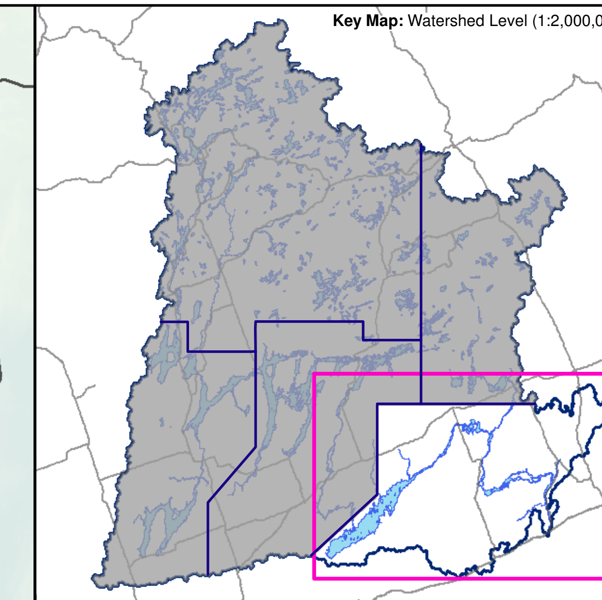
The South sector is part of the navigational portion of the Trent Severn Waterway, although there is less boating traffic in this sector than either the North or Central sector. Since this sector is part of the main navigational waterway, maintaining sufficient depths for navigation is one of the primary objectives for operations; however, there are a number of additional stakeholders and water users, as represented in the six Water Management Goals of the system, which must also be addressed. **Table 3-4** describes the operational objectives of the South sector as they apply to these six goals.

Table 3-4 - Operational Objectives of the South Sector

Water Management Goal	Operational Objective
Reducing threats to public safety and negative impacts to public and private infrastructure from over-bank flooding, ice damage, extreme water level fluctuations, and high volume flows	• Manage water levels as required to mitigate water level fluctuations and impacts from flooding or drought
Contributing to the health of Canadians through the availability of drinking water for residents, cities and towns throughout the watershed	• Provide sufficient water levels for the function of water intakes and wastewater outfalls
Providing safe boating and navigation along the marked navigation channels of the Trent-Severn Waterway	• Maintain average navigational depths through the marked navigational portions of the Waterway
Protecting significant aquatic habitats and species	• Although there are no specific aquatic habitat requirements in South sector, operations shall assist and respond to fish habitat and spawning requirements in other sectors
Optimizing the enjoyment of the water throughout the watershed by shoreline residents and visitors	• Maintain water levels at an appropriate level to optimize enjoyment and property access by residents and visitors
Allowing hydroelectric generation plants to operate at plant capacity and meet demand for renewable energy insofar as possible	• Coordinate water management with hydro power utilities without impacting water available for other users

Maintaining navigational depths and mitigating flood impacts downstream of Rice Lake is a challenging operational task and requires complex management decisions. This is due to a variety of conditions, including:

- The size and configuration of Rice Lake and its outlet result in little storage or flow augmentation capabilities;
- A considerable lag time between flood control and augmentation operations in other sectors and the effects reaching South sector;
- The general configuration of short river reaches between dams with little available storage capacity to respond to flow events;
- The topography of some channel reaches, with bank levees situated above the surrounding landscape;
- The Crowe River system being operated independently of the Trent Severn Waterway; and,
- The requirement to respond to power plant operations.



Legend

- Dam (with Hydroelectric Plant)
- Dams
- Snow Stations
- Major Roads
- Rivers
- Management Sectors
- Trent-Severn Waterway Navigable Channel
- Reservoir / Lake
- Cities / Towns

Elevation (m)

High : 562

Low : 49

0 2 4 8 12 Km

Trent Severn Waterway: Water Management Study

Figure 3-7
South Sector

UTM 17 NAD 83 Datum	May 2011	1:260,000

Parcs Canada Parks Canada

AECOM

Given the larger proportion of power generation facilities in South sector (12 facilities as of this report) a greater amount of operational effort is expended in managing the system to accommodate the hydro utilities. Flow is maximized as much as possible for power generation and to satisfy navigational requirements; although system usage by boaters is typically less than in the Kawartha Lakes sectors. Most of the dams in this sector have hydraulic gate operations, with few stoplog locations, increasing the ability of operators to react to the rapidly changing conditions. Although the South Sector operates to help optimize hydro power, no water is drawn from the Haliburton sector to augment power production.

The high level of interaction between TSW and the hydro power producers is increased further through the current practice of managing power production for peak usage periods. This means that the utility will augment their flows rapidly to increase production during peak periods, and then throttle them during non-peak periods to build up the reservoir again. In addition, the facilities may shut down in anticipation of thunderstorms (i.e., large precipitation events), to clean trash racks, clear ice formations, etc. When this occurs, TSW staff alter their dam configurations on very short notice (typically within 30 minutes) to avoid impacting the flood prone parts of system. Such hydro power operations can occur at any time of the day, so operators must be on call 24 hours a day, although every sector has on-call emergency staff to respond to emergency events.

Hydro operations are coordinated from North Bay, and all power plant gates are fully automated. The 12 power plants in this sector are located at: Glen Miller, Sills Island, Crowe Bay, Frankford, Frankford Lock 5, Hagues Reach, Campbellford, Sidney, Myersburg, Seymour, Ranney Falls and Healy Falls.

Dam control adjustments in South sector begin at the upstream end (i.e., near Rice Lake) and move downstream with each operator notifying the next in sequence of their changes, passing along the required adjustments to ensure that all required changes are made. Each operator will typically contact the individual hydro utility in their area of responsibility to coordinate operations.

Flows from the Crowe Watershed are managed by the Crowe Valley Conservation Authority. Although there are currently effective communications between the Authority and the TSW, the Authority manages flows and water levels to meet its own objectives. Therefore, there can be a significant uncontrolled contribution of water from the Crowe Watershed into the TSW downstream of Rice Lake. Water from the North and Central Sector then needs to be controlled to adapt to the Crowe flows to mitigate flooding.

3.3.3.2 Operational Procedures

The following sections describe the operational procedures and objectives in the South sector on a season-by-season basis. They highlight the seasonal conditions in the sector, the different stakeholders and water users, and how operations in the sector interact with other areas of the system. A summary of the sector operations is provided at the end of the section, in **Figure 3-8**.

Spring Season

Spring season operations in South sector typically involve reacting to water management decisions from the upstream sectors. Since there is little storage available within this sector to accommodate large flows, and the few lakes in this sector are easily filled towards the end of the freshet, South sector staff manage the large freshet flows from upstream through careful and frequent dam adjustments. During an average season the operations result in little to no flooding; however, there are several areas that are more vulnerable to flooding that require additional management, including: above and below Lock #7 at Glen Ross; Percy Reach; Meyers Island; upstream of Healey Falls near the Trent River bridge; and below Lock #18 at Hastings.

Large flows from the Crowe River exhibit an approximately 12 hour lag time prior to impacting the Waterway. These flows are monitored through the Water Survey of Canada gauge at Crowe Bay, and translating the water levels to a flow through an established rating curve.

There is constant interaction with the hydro power utilities during the spring season to maintain flows below flood levels. Ontario Power Generation retains detailed floodplain mapping, and Parks Canada staff meet with OPG annually to discuss operating strategies for the upcoming year.

Summer (Navigation) Season

In addition to coordinating operations with the hydro power utilities, the summer season objectives include maintaining water levels in the channels and lakes at the advertised average navigational depths, although the South sector usually sees less boat traffic than the Central or North sectors. Like the other sectors, many areas have a relatively narrow navigational range, such as the 0.1m range on Rice Lake. Other areas have established maximum flows which if exceeded create dangerous navigational conditions. If the maximum flow is exceeded the navigation locks are closed, such as at Lock #2, that has a maximum flow of 230m^3/s.

Operators typically monitor upstream flows at the Lakefield dam and rainfall trends to determine required actions in this sector. If the flow is less than 17m^3/s at Lakefield and there has been little or no precipitation, there are typically navigation problems at Dam#1, Lock#1 in Trenton. If the water level upstream of Dam #1 begins to exhibit a decreasing trend, flow is augmented with water from the Glen Ross reservoir, and may continue with water from Rice Lake and eventually the reservoirs in the Haliburton Sector, if necessary. The Dam #1 operator will monitor the water level trend and anticipate a shortage one or two days in advance of when the water is required, so that operations may be coordinated upstream. The Water Control Engineer also monitors the trends through the daily water level updates received from the automatic gauge at Lock #1.

The reservoirs at Glen Ross and Rice Lake are kept close to or slightly above maximum levels in the summer season to anticipate potential water shortages. When water is required at Dam #1, all dams between Glen Ross or Rice Lake and Dam #1 are operated together, creating very little lag in flow through this sector.

Summer operations include continual interaction with hydro utilities, as discussed previously. Within the constraint of the water available in the system, and with no additional water released from the Haliburton sector to do so, TSW operations attempt to optimize the production of hydro power.

Fall (Post-Navigation) Season

Like the Central and North sector, the three main reservoirs in South sector (Rice Lake, Glen Ross and Seymour Lake) are drawn down to close to minimum water levels, early in the fall season. This provides some additional capacity to respond to high flow events through the season. The other lakes and channel reaches in the sector are maintained close to navigational levels to facilitate hydro power generation.

Another reason for the early drawdown is the reduction of staffing levels once the navigation season ends, as in all sectors. The reduced staffing level combined with the same amount of coordination required for hydro power generation means that TSW operations must be streamlined.

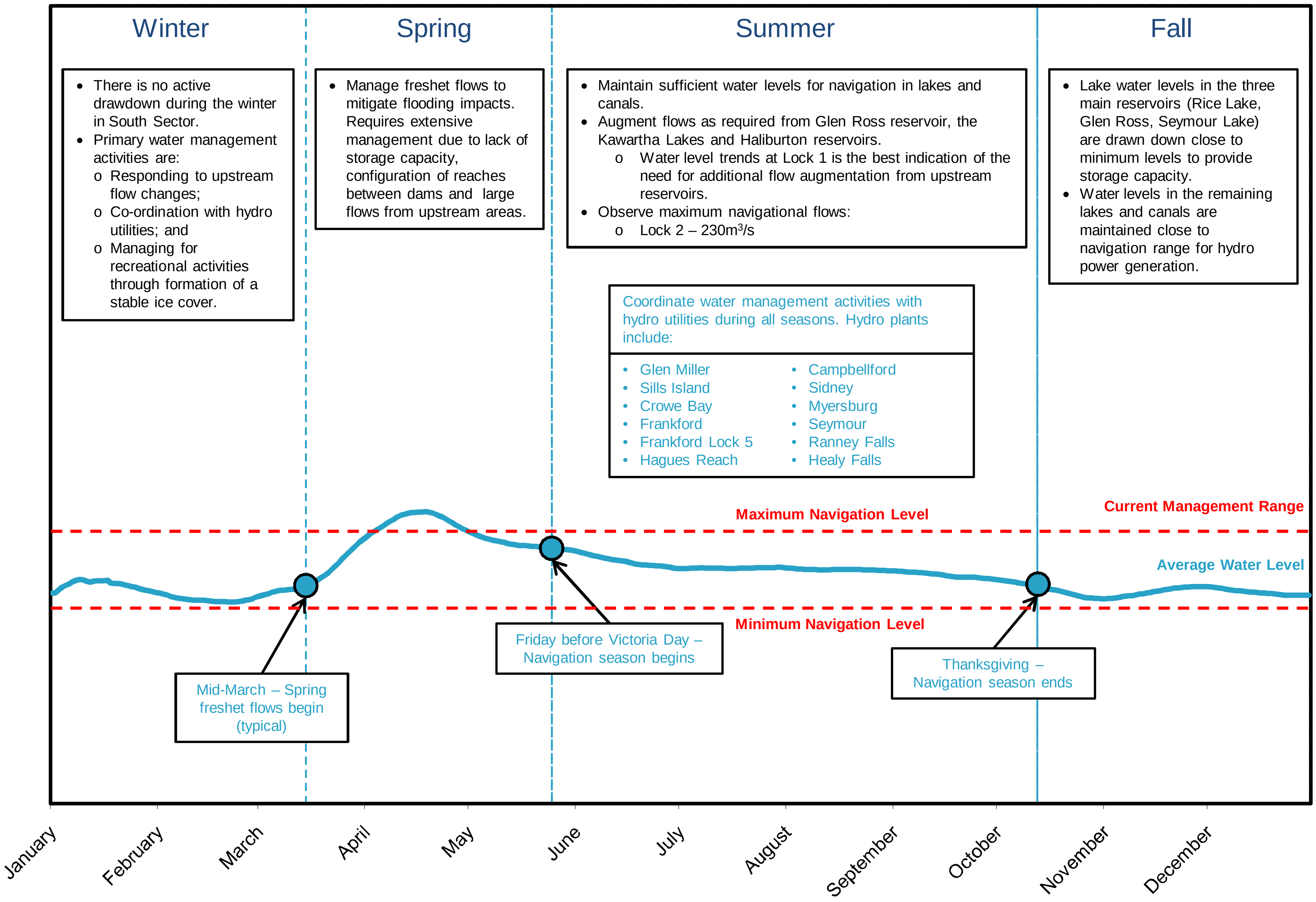
There are frazil ice formation issues in this sector when cold snaps are experienced late in the season. When temperatures are forecast to drop quickly and a stable ice cover has not yet formed, operations will typically reduce flows below the critical amount required for frazil ice formation, depending on the specific location within the Waterway.

Winter Season

Unlike the upstream sectors, there is no formal drawdown in South sector during the winter season. Instead, most operations involve responding to upstream conditions, as well as continuing to coordinate with hydro utilities. In recent years there has been an increase in the amount of winter recreation activities, particularly ice-fishing, on Rice Lake and other areas once a stable ice cover has formed. Large fluctuations in water level can compromise this ice cover, thus operations attempt to avoid large changes in water levels.

As described in the North and Central sector operations, South sector also operates for the mitigation of situations that are conducive to the formation of frazil ice, which can cause localized flooding and be detrimental to municipal water intakes and hydro power generation facilities. Frazil ice typically forms when fast moving water become super-cooled; a general guideline for frazil ice conditions on the Waterway is a flow above $200m^3/s$ at Peterborough and temperatures of -15^0C or lower. Areas where there have been frazil ice issues include: Healy Falls at Hastings; Glenn Ross; Frankford; and Dam #4. Typical operations will attempt to manage flows and water levels in order to form stable ice covers in the dam head ponds to avoid frazil ice impacts.

Figure 3-8 - South Sector - Rice Lake and Trent River Annual Operations Summary



3.4 Operational Co-ordination and Communications

The four Sector Managers and the Water Control Engineer comprise the team responsible for effective operation of the Trent Severn Waterway, including the reservoir lakes in the Haliburton sector. This is achieved by their daily communication through most of the operational seasons. The Water Control Engineer's activities also include: keeping records up to date; addressing phone calls and inquiries; seeing to the maintenance of gauges for reliability; and creating/confirming rating tables for dams. .

In general, the Haliburton Reservoirs and the Kawartha Lakes are controlled by stoplog/gate changes in an effort to maintain long term average lake levels that provide sufficient flow for navigational depths to be achieved in the Summer season: a lake level within 5% of the average is the target. If system "indicators" suggest a need to reduce or increase flows (cut or fill), the flow requirements are determined by the Water Control Engineer, in consultation with the Sector Managers, and a computer program/spreadsheet simulation is used to distribute the flow requirement between the Haliburton Sector reservoirs and the North Sector and Central Sector. If there is too much water in the Lakes, sometimes the modelled demand at Lakefield is changed to produce a higher draw from the Haliburtons: the modelled required flows are checked against the flow gauges which provides a useful validation process

3.4.1 System Indicators

Certain key locations exist in the Waterway system that have been used to infer operational conditions and requirements throughout the remainder of the system. These locations include:

- **Buckhorn, Pigeon, Chemong** (referred to as the Tri-lakes). These lakes form the largest single combined waterbody in the TSW and decisions can be made based on recent water level trends in Tri-lakes:
  - If these lakes are gaining, shortages can be managed elsewhere through redistribution of water from these lakes;
  - If these lakes are losing, indicating high evaporation rates, augmentation from the Haliburton reservoirs will be required to maintain flows in the system.
- **Gull River**. The Gull River watershed is the largest potential source of water to feed the TSW. The majority of the Gull River watershed is controlled through the Reservoir Lakes, and flows at the automatic gauge at Norland can be an indication of the general state of supplies to the navigable portion of the system.
  - **Kennisis Lake**. This is one of the largest Reservoir Lakes, and can be an indication of the general condition of reservoir supplies.
- **Rice Lake.** With a high surface area to volume ratio, Rice Lake experiences high evaporation during the summer. Decisions can be made in the lower portions of the Waterway based on recent water level trends in this lake in order to keep the lake levels stable.
- **Reach above Dam #1** is a critical reach; if this reach can be maintained at navigable levels, the rest of the upstream system will typically be able to be maintained, as well. This is due to the high leakage rates through Dam #1.

Although these points can provide greater indication of operational conditions throughout the system, monitoring of all reservoirs, lakes and channels is required for effective system management on a long-term basis.

3.4.2 Typical Operational Coordination

Managing the flows and water levels throughout the Trent Severn Waterway is the highest priority for TSW staff. Other management and maintenance activities must be secondary to the water management operations, as they often directly impact public safety.

The general coordination for sector operations is to determine water requirements on a lake-by-lake basis, starting upstream and working downstream. As changes are made to the upstream lakes and channels, the changes are carried downstream and the required alterations to respond to these new changes are made, as well as any existing changes required in the downstream lake. An exception to this general rule would occur only if there was a problem in a downstream area that required immediate attention.

Prior to communication with the Water Control Engineer, Sector Managers will typically develop potential alternatives to respond to water management needs. These plans are discussed with the Engineer and placed in the context of the requirements of other sectors. The Water Control Engineer then coordinates all required operational decisions to optimize water levels throughout the system, and these decisions are communicated to the appropriate Sector Managers and Operations Supervisors for implementation.

In the past, a paper log book of operations was kept: an example is provided in **Appendix C**, **Table C9a.** This has been updated to a spreadsheet as illustrated in **Table C9b** which summarises information from the weekly operations sheets illustrated in **Table C9c**, for the Haliburton sector. Similar record sheets are kept for the other sectors.

The decision schedule for the Haliburton reservoirs typically follows a weekly routine and is described in **Table 3-5**, although it is dependent on water requirements in downstream sectors. In the rest of the Waterway (North, Central and South Sectors) there is daily communication with the Water Control Engineer to adapt to changing conditions. A sample of the daily information provided to Sector Managers from the Water Control Engineer is included in **Appendix C**, **Table C8**; both target water levels and trends with respect to changes in the water levels are provided. There are several reasons for this increased frequency of operations: in these large lakes even a small change in water level represents a large volume of water being moved; the timing of operations is important to coordinate between the different sectors; and some lakes experience seiche effects that can distort water gauge readings on windy days (in this scenario if a major decision is required, operators will typically wait a day to confirm the gauge readings if there are high winds). The South sector requires more daily operations in order to respond to upstream activities and to coordinate with the hydro utilities.

Table 3-5 - Water Management Decision Schedule during a Typical Week

Day	Description of General Activities
Monday	• Review the events of the previous weekend • Collect water level and flow information from gauges • Communicate data to Water Control Engineer for interpretation and coordination • Water Control Engineer runs the simulation model to determine required dam alterations
Tuesday	• Required dam alterations are implemented • Water Control Engineer provides weekly sheet to Haliburton sector to adjust their lakes (**Appendix C**)
Wednesday	• The results of Tuesday's management decision are reviewed
Thursday	• Management decisions are revised and implemented as required
Friday	• Review and fine-tune Thursday's decisions to prepare for weekend users
Saturday and Sunday	• Respond to emergency events as required

In periods of significant weather, weather forecasts are used to develop thresholds in approaching operating decisions, based on how long the decision can be delayed. This is done because of the unpredictability of weather forecasts. In other words, if water is released from the lakes in anticipation of a large precipitation event and the event is smaller than forecast or does not cover as large an area, then the system will run a water deficit that may impact navigation or other users.

3.4.3 Public and Stakeholder Communication

Public communication and education is an important component of the TSW management, and forms one of the key tasks of the Water Control Engineer and Director of Canal Operations. Currently, the Water Control Engineer maintains an online record of the measured water levels in the lakes and reservoirs throughout the Waterway. The record consists of a visual graph, displaying the historic high and low water levels with the current measured water level, as well as the navigation range for those lakes that support navigation (an example of these graphs for Buckhorn and Kennisis Lakes are shown in **Figure 3-9**, accessed from the Parks Canada TSW website on May 17, 2011). The graphs provide an opportunity for the public to monitor the water level conditions at locations of interest (e.g., the lake where their cottage is located), and provides context for expectations about future water levels. The water levels on the graphs are currently updated manually by the Water Control Engineer, and are not linked to any of the automatic gauges on the Waterway. Also included on the Trent Severn Waterway website are updates on various activities in the Waterway, such as dam maintenance or closures.

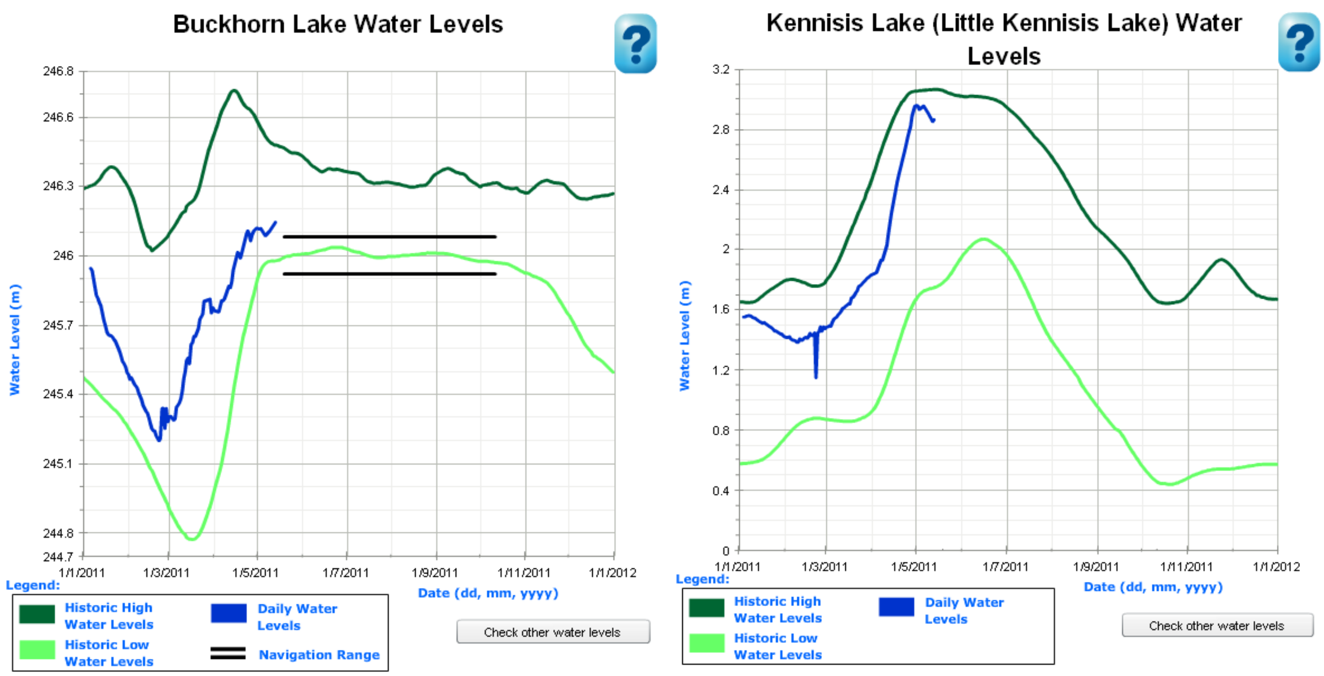


Figure 3-9 - Example of Water Level Graphs Produced for Public Information

The Water Control Engineer and Director of Canal Operations are also responsible for addressing any inquiries that the public or other stakeholders (i.e., elected officials, Conservation Authorities, other federal and provincial agencies, etc.) may have regarding operations on the Waterway. These inquiries are addressed on an ongoing basis as they arise.

The TSW staff have also recently published (2008) a document describing the current Water Management Program, intended for distribution to the public. The document describes the general context for operations within the Waterway, the operating management structure, specific seasonal operational considerations, discussion of key issues (i.e., fisheries, flooding, hydro electric generation, etc.) and provides summary sheets of the operations of the different sectors.

Interactions and communication with hydro power utilities are a critical component of the day-to-day operations of the Waterway. The bulk of this communication occurs between the Sector Managers or operations staff and the specific utilities that are located in their sectors. Water management decisions made by TSW staff are communicated to the utilities, and they are given the option to share in the water being released from the lakes and reservoirs of the Waterway. Similarly, operational decisions made by the utility, such as reducing or stopping flow to a turbine, are communicated to TSW staff so that the appropriate adjustments can be made to Parks Canada dams.

3.5 Development of the Water Management Operational Matrix

3.5.1 Overview

The current approach to operations in the Waterway encompasses a number of actions that take place on a recurring basis throughout the four operating seasons. The actions are supported by three operational assessments (see Section 5.2), and operational changes are executed through three operational instructions (see Section 5.3). In order to summarize the current Waterway operations, these actions, assessments and instructions were organized into a matrix, shown in **Table 3-6**. The matrix presents the breadth of Waterway operations in a concise and comprehensive format, allowing potential areas of enhancement to be identified.

Table 3-6 - Water Management - Current Approach Summary Matrix

Water Management (WM) - Current Approach Summary Matrix of Key Operational Procedures

1. This WM Matrix is a summary of the current operating approach.
2. The current operating approach uses a moving 25 year observed average lake/reservoir Water Level (WL) as a Rule Curve.
3. A Rule Curve is a graph that represents a target WL for every day of the year.
4. The current WM approach aims to follow the Rule Curves for lakes/reservoirs while managing flows to respect identified minimum/maximum flows throughout the system.
5. Related to the current Rule Curves are WL ranges:
    1. Minimum WL (outlet sill or deduction), Maximum WL (greater than emergency spillway sill)
    2. Minimum Observed WL, Maximum Observed WL
    3. Management Range, the acceptable deviation from the Rule Curve, varies depending on the lake/reservoir and the season
6. General guidance for flow release from the Haliburton Sector reservoirs: when flow is required in the downstream sectors, drawdown is by equal percentage of storage depth.

DATE		ACTION		SECTORS			
From	To	Description	Frequency	Haliburton	North	Central	South
				Reservoir Lakes	Balsam, Scugog, Sturgeon, Cameron	Pigeon, Buckhorn , Chemong (tri-lakes) + Lower Buckhorn, Lovesick, Clear, Stoney, Katchewanooka	Rice, Seymour, Glenn Ross
All Seasons							
January 1st	**December 31st**						
		Assess WL and Flow in the Waterway (B) (C)	Daily	Adjust dam settings (1)	Adjust dam settings (1)	Adjust dam settings (1)	Adjust dam settings (1)
		Adjust gates/stoplogs to reflect Stakeholder requirements	Co-ordinated with Stakeholders	One power site - Elliot Falls	One power site - Fenelon Falls	All power sites (5) PUC Intake - Peterborough	All power sites (12)
Winter							
January 1st	**March 15th**						
January 1st		Place stoplogs at reservoirs that are difficult to fill or reach	N/A	Add stoplogs (1)	N/A	N/A	N/A
January 1st	March 15th	Kawartha Lakes drawdown - final (based on drawdown schedule) (B) (C)	Weekly	N/A	Scugog, Balsam and Sturgeon (3)	All Lakes (3)	Adjust dam settings as required (1)
January 15th	February 15th	Freshet forecast (A) (B) (C)	Bi-weekly	Adjust dam settings as required (1)	Adjust dam settings as required (1)	Adjust dam settings as required (1)	Adjust dam settings as required (1)
February 15th	Spring Freshet	Freshet forecast (A) (B) (C)	Weekly	Adjust dam settings as required (1)	Adjust dam settings as required (1)	Adjust dam settings as required (1)	Adjust dam settings as required (1)
Spring (Freshet Period)							
March 15th	**May 15th**						
Beginning of freshet		Freshet forecast (A) (B) (C)	Weekly	Adjust dam settings to fill reservoir (1)	Adjust dam settings to fill lake (1)	Adjust dam settings to fill lake (1)	Adjust dam settings to fill lake (1)
March 15th	May 15th	Assess Flow (to prevent high and low flow release) - Haliburton (B) (C)	Weekly	Adjust dam settings to fill reservoir (1)	N/A	N/A	N/A
March 15th	May 15th	Assess Flow (to prevent high and low flow release) - Waterway (B) (C)	Daily	N/A	Adjust dam settings to fill lake (1)	Adjust dam settings to fill lake (1)	Adjust dam settings to fill lake (1)
May 1st		All lakes/reservoirs filled to upper limit for Summer	N/A				
Summer (Navigation Season - Mid-May to Mid-October)							
May 15th	**October 15th**						
May 15th	October 15th	Assess WL and Flow in the Waterway (B) (C)	Daily	Adjust dam settings (1)	Adjust dam settings (1)	Adjust dam settings (1)	Adjust dam settings (1)
August 15th	October 1st	Haliburton Reservoirs Drawdown to Meet Winter Settings (B) (C)	Weekly	Drawdown to 50% of storage volume (2)	N/A	N/A	N/A
October 1st	October 15th	Haliburton Reservoir Winter Settings	N/A	All stoplogs to winter settings	N/A	N/A	N/A
Fall (Post-Navigation Season)							
October 15th	**January 1st**						
October 15th	January 1st	Kawartha Lakes drawdown - initial (10cm+/-) (B) (C)	Weekly	N/A	Balsam and Sturgeon (3)	All Lakes (3)	N/A
November 15th	December 1st	Kawartha Lakes drawdown - Cameron Lake (B) (C)	Weekly	N/A	Cameron Lake (3)	N/A	N/A

Notes:

- (A) Freshet Forecast
- (B) Water Needs Assessment
- (C) Water Level and Flow Assessment
- (1) Adjust Dam Settings
- (2) Haliburton Reservoirs Drawdown to Meet Winter Settings
- (3) Kawartha Lakes Winter Drawdown

Legend:

- (orange) Assessment
- (green) Instruction

3.5.2 Operational Assessments

The operational assessments, shown in **Table 3-6** as the symbols A (freshet forecast), B (water needs assessment) and C (water level and flow assessment), represent the evaluations conducted to assess the state of water in the Waterway.

3.5.2.1 Freshet Forecast

The freshet forecast is represented by the symbol A in the current approach summary matrix, and is the primary assessment for the freshet forecast actions conducted in the winter and spring seasons. The freshet forecast action occurs on a bi-weekly basis at the beginning of January, and then on a weekly basis from mid-January up to the spring freshet.

The freshet forecast assessment involves the estimation of snow pack water equivalency (SPWE) at five snow course survey sites in the Waterway (4 in Trent Watershed, one in Severn Watershed). The five snow course survey sites are assigned to representative areas in the Waterway. The SPWE measured at each site is applied to the entire representative area, yielding a total volume of water that is anticipated to run off into the reservoirs and lakes. This volume is compared to the available storage in the Haliburton Reservoirs with the following rules:

- If the SPWE is greater than the available storage in the Reservoirs, then maintain dams at winter settings.
- If the SPWE is equal to or less than available storage in the Reservoirs, then replace stop logs in dams to begin capturing freshet water.
- If the SPWE is shown to be declining as winter progresses, replace stop logs in dams to begin capturing freshet water.

The freshet forecast does not currently account for additional precipitation during the spring season that also contributes to the freshet, but also does not explicitly account for water losses to infiltration. Conducting the freshet assessments on a regular basis through the winter and spring increases the ability of operators to ensure that Reservoirs are filled; if assessments are missed there is the potential that dam settings will not be adjusted in time to catch part of the freshet, and that the Reservoirs will not be completely filled.

3.5.2.2 Water Needs Assessment

The water needs assessment is represented by the symbol B in the current approach summary matrix, and is one of the core assessments performed on a daily basis in the Waterway.

The water needs assessment involves the balancing of water requirements throughout the entire Waterway. It is a holistic, macroscopic perspective that evaluates the inflows into the system (e.g., freshet, precipitation, flows from Reservoirs) and the flow requirements of the system (e.g., Trent River running low requires water from the Haliburton Reservoirs).

Due to the time delay in releasing water from the Haliburton Reservoirs and the water reaching the downstream portions of the Waterway (e.g., there is approximately a one-week travel time from the Haliburtons to Trenton), anticipated water needs in the Waterway must be forecast to a certain extent. The water manager must know a week ahead of time if the flow or water level will drop below the management range at a particular lake, for example. This is currently accomplished through evaluation of the flow and water level trend, i.e., if the trend has been decreasing steadily for a few days, the water manager will withdraw water from the Haliburtons several days before the trend drops below the management range.

The current hydraulic model, developed by Acres in 1973, assists the water control engineer with the water needs assessment by balancing the withdrawal of water from the Haliburton Reservoirs to meet the flow requirements in downstream areas. The water level and flow assessments at each lake and reservoir, established in assessment C, is an important consideration for the water needs assessment: the individual requirements must be balanced against the requirements of the system as a whole to optimize operations.

3.5.2.3 Water Level and Flow Assessment

The water level and flow assessment is represented by the symbol C in the current approach summary matrix, and is one of the core assessments performed on a daily basis in the Waterway.

The water level and flow assessment involves the evaluation of water levels and flows at specific lakes and reservoirs in the Waterway, according to the following rules. Note that this assessment is conducted in parallel with the water needs assessment (B), so that flows and water levels can be balanced appropriately:

- If water levels/flows are within the management range, then no action is required.
- If water levels/flows are above the management range then adjust dam settings to decrease water level/flows to within the management range.
- If water levels/flows are below the management range, then adjust dam settings to increase water level/flows to within the management range.

These rules describe situations in which the water levels or flows are outside of the management range and there is a clear operational action that can be taken. When taken into the context of the water needs assessment (B), there could be situations wherein a release of flow from one lake can cause the downstream lake to exceed its management range. In these situations, the water control engineer must balance the water throughout the system through the water needs assessment. Protocols for these critical situations should be developed, forming both a High Water Level Management Plan and a Low Water Level Management Plan to more effectively balance the water throughout the Waterway.

3.5.3 Operational Instructions

Operational instructions are represented in **Table 3-6** as the symbols 1 (adjust dam settings), 2 (Haliburton Reservoir drawdown to meet winter settings) and 3 (Kawartha Lakes winter drawdown). These instructions describe the implementation of water management decisions from the operational assessments, typically involving the alteration of dam settings (gates or stoplogs). Note that these instructions are for normal operating conditions only, and do not represent protocols for action in extreme flow or water level conditions.

3.5.3.1 Adjust Dam Settings

The adjust dam settings instruction, represented by the symbol 1 in the current approach summary matrix, comprises the required dam settings adjustment in response to the assessments (A, B or C) described in the previous section. This procedure begins at the upstream end of the Waterway (i.e., the Haliburton Reservoirs), and proceeds downstream from lake to lake to balance dam settings as required. The general procedure for dam setting adjustments is as follows:

- Compare the current water levels/flows with required water levels/flows, established in assessment A or C.

- Define the required downstream water levels and flows (from assessment B):
  - If an increase in water levels or flows is required downstream, adjust dam settings to release more water, if the release will not cause the reservoir to leave its management range.
  - If a decrease in water levels or flows is required downstream, adjust dam settings to release less water, if the release will not cause the reservoir to leave its management range.

When adjusting water levels in the Haliburton Reservoirs, the general guidance is to drawdown on an equal percentage basis, based on the total available storage depth.

3.5.3.2 Haliburton Reservoir Drawdown to Meet Winter Settings

Between August 15th and October 1st of each year, the Haliburton Reservoirs are drawn down close to their winter settings, so that large amounts of water do not need to be discharged in October. The drawdown schedule is established by hindcasting 0.5% reduction in storage per day from a target of 50% total volume on October 1st. If water levels in the Reservoirs are above this line between August 15th and October 1st, water is released regardless of downstream needs. If water levels stray too far from this line there is only a limited capacity to draw the levels down in October, potentially creating high flow/flood conditions in downstream areas.

The procedure for this instruction is to adjust the stoplogs in each Reservoir as required to ensure that water levels are maintained close to the 0.5% per day reduction in total storage. If water levels are below this line, no stoplogs should be removed.

This instruction/protocol is represented by the symbol 2 in the current approach summary matrix.

3.5.3.3 Kawartha Lakes Winter Drawdown

The Kawartha Lakes in the North and Central Sectors are drawn down between January 1st and March 1st each year to provide additional storage capacity for spring freshet flows. The water control engineer produces a drawdown schedule at each lake (see **Table C7** in **Appendix C** for an example) which contains weekly water level targets. The lakes are typically drawn down to approximately 1.0m below the minimum navigation range.

The procedure for this instruction is to adjust the dam settings at each lake to maintain water levels according to the drawdown schedule established by the water control engineer.

This instruction/protocol is represented by the symbol 3 in the current approach summary matrix.

4. Discussion of How Operations Have Evolved

This section provides a discussion of the changes that have occurred over time regarding the operation of the system. The discussion is based on the legacy operating documents reviewed in Section 2 and the description of current operations provided in Section 3. This discussion sets the stage for the Evaluation of the Current Approach to Water Management.

The primary catalyst for evolution of system operations has been the increased engagement of a wider variety of stakeholders (i.e., cottagers, residents, municipalities, hydro power, environmental agencies, etc.). In recent decades, this increase in the stakeholders and variables at play with regards to the competition for water within the system has subsequently resulted in increased demands and complexities of the operating environment. Increases in the demands and complexities of the operating environment have included the following:

- The Haliburton Lakes have become one of the most significant cottage regions in the province; and more recently there has been a shift toward year round residency on these lakes;
- Shoreline development has increased, and with that the demands to maintain the levels of the Haliburton Reservoirs have increased;
- Cities and Towns along the shorelines and have increasing infrastructure demands to draw water from the system;
- The shores are home to thousands of business that rely on those that live in and visit the area;
- The societal awareness of and desire to protect the natural environment is increasing;
- There are legitimate concerns about global warming and the potential impacts of climate change; and
- Growing environmental concern has led to an interest in the potential for hydro electric power generation as a source of renewable energy, with a corresponding increase in the number of hydro generation facilities.

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

- A more detailed account of water levels, flows and climate within the system;
- Increased role of Sector Managers within the decision making process;
- Development of policies and procedures regarding the operation of the TSW; and
- Use of modeling to assist in the development of daily operational activities.

4.1 Available Data

As the demands and complexity of the operation environment increased, a more detailed account of water levels, flows and climate within the system was warranted. The TSW water management system has evolved over time to include this information at a greater number of locations and to be accessed remotely in some cases.

Prior to the 1970's, operational decisions used available flow information from three gauge stations. Currently, flow data from fifteen gauge stations is used to determine daily operations within the system. In addition, manual recording stations have been replaced in some locations by automatic, remotely accessed stations. For example, prior to 1970's the majority of water levels were recorded manually. Presently, about 30 stations in the Haliburton, North and Central Sectors, as well as most water level gauges in the South Sector, are automatic stations.

In addition, the access to climate data has increased significantly, as a result of an increase in the number of available climate stations within the system. The Sector Managers monitor weather conditions on a continual basis to identify potential precipitation events that may require additional operations. However, unless there is an extreme forecast, operations are typically not executed on a pre-emptive basis, such as releasing water from a lake to accommodate additional inflows, due to the unpredictability of weather.

4.2 Management Structure

As the complexity of the system has increased, the role of Sector Managers within the decision making process has also increased. Prior to the 1970's, the Water Control Manager was responsible for determining daily operations, with some input from the Divisional Superintendents. However, under the current operational approach there is an increased level of consultation with Sector Managers in not only making initial daily operational decisions, but also in fine-tuning those decisions during the week. The Sector Managers, given their focus on one section of the system, are likely to have an enhanced understanding of their system and its reaction to upstream changes.

4.3 Policies and Procedures

Prior to the 1970's, few firm guidelines were in place regarding the operation of the system other than the mandated operational objective to maintain navigation. Operators relied heavily on experience and knowledge of the system.

Currently, policies and procedures are in place to aid and support operators in making daily operational decisions. The policies and procedures were initially developed as part of the Acres 1972 study and were based on:

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

The operational policies and procedures included the previously described fundamental concepts:

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

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

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

4.4 Modeling

The volume of inflow to the system during the spring snowmelt was not estimated prior to the 1970's. The magnitude of the spring freshet was predicted from the snowpack data, but no calculations of the expected inflow volume were made. Currently, a spreadsheet is used to determine the estimated volume of inflow based on the snowpack data. In addition, a detailed tracking of water levels and flows in the system during the spring is now undertaken. This not only assists the operators in decision-making regarding adjustments to the system as required to ensure both flood mitigation and the filling of the lakes to summer levels is achieved, but also provides a historical record of spring conditions, operations and corresponding system reactions.

5. Operational Case Studies

In order to highlight the operational characteristics of TSW water management and to assist in identifying possible areas for improvement, especially under extreme conditions, several examples of operations in a given year are presented and discussed below. The examples include a high flow year (1991) and a low flow year (1999). The discussion will identify, as clearly as possible: the chain of meteorologic events; TSW activities including assessment, decisions and physical actions; and the results in context of system constraints.

Charts for specific lakes and reservoirs for 1991 and 1999 have been developed, representing: daily observed lake/reservoir levels for the year; observed lake/reservoir level max/min and average over a 25 year period; monthly observed precipitation (P) in the form of either rainfall or snowfall and Snowpack Water Equivalents (SPWE); as well as the 25 year average for P and SPWE. Charts have been prepared for:

- Kennisis Lake – Gull River (Haliburton Sector)
- Redstone Lake – Gull River (Haliburton Sector)
- Drag Lake – Burnt River (Haliburton Sector)
- Balsam Lake – TSW (North Sector)
- Sturgeon Lake – TSW (North Sector)
- Buckhorn Lake – TSW (Central Sector)
- Stoney Lake – TSW (Central Sector)
- Rice Lake – TSW (South Sector)

5.1 Case Study #1 – 1991 High Flows

Significant flooding occurred in the lower reaches of the Burnt River system from April 9th to 12th 1991 as a result of intense rains from April 8th to April 10th. The peak flow at the Burnt River gauge was 211m^3/s, which is a 1:30 Year Return Period event. It should also be noted that the 1991 observed rainfall in August and September was significantly below normal, suggesting a potential dry period.

The general response of the TSW is reflected in **Figure 5-1** through **Figure 5-8** which illustrates the specific response of the selected reservoirs and lakes in the system through reported lake levels. It is evident that, by March 1st of 1991, the all reservoirs were in a state of readiness for the Spring freshet:

- The Haliburton Lakes (Kennisis, Redstone and Drag) were at their winter settings;
- The Kawartha drawdown schedule had been implemented for the Kawartha Lakes (Balsam, Sturgeon, Buckhorn and Stoney Lakes); and
- Rice Lake was hovering near its normal level for that time of year

From March 1st until approximately April 5th, reservoir levels were monitored in the Haliburton Sector and stoplog adjustments made to increase water levels and resultant storage, to their optimum levels.

The Sector response to the intense rains in mid-April is illustrated in **Table 5-1** in the form of stoplog placement and removal. It is clear from the lake level responses in all lakes of the system, that the intense rainfall and resulting flows were beyond the capacity of the system and that water levels were well above the 25 year average for that time of year. The *Burnt River 1991 Flood Investigation (MacLaren 1992)* concluded that “the water passing through the headwater reservoirs less in magnitude compared to what may have naturally occurred”.

By May 15th at the start of navigation, the Haliburton Lakes were still above normal levels while the Kawartha Lakes and Rice Lake were close to their normal levels.

By mid-June, all Lakes were at their expected levels.

From mid-June to the end of July, Haliburton Reservoir water levels were significantly below normal, although the monthly precipitation for July appears higher than normal and the Kawartha Lakes and Rice Lakes are maintaining normal water levels. This needs further investigation to explain.

August precipitation was well below normal and Haliburton Reservoir water levels remained below normal to the middle of September and only started to rise in early October. There would have been no need to implement the Haliburton drawdown sequence from August 15th to October 1st.

From October 15th to January 1st, the initial Kawartha drawdown was implemented so that all Kawartha Lakes were at or close to their January 1st setting.

Table 5-1 - Reservoir Stoplog Settings – Haliburton Sector – April 5th to 12th 1991

Station	April 5 Stop Log Settings	April 6	April 7	Stop Log Changes April 8	April 9	April 10	April 11	April 12
BURNT RIVER BASIN RESERVOIRS								
Drag	8 in, 7 out	NC	NC	NC	X	NC	•	NC
Canning	4 in, 9 out	NC	NC	X X X X	NC	NC	NC	NC
Miskwabi	6 in, 2 out	NC	NC	NC	NC	NC	NC	NC
Dudman (Loon)	4 in, 3 out	NC	NC	X	X	NC	X X	NC
Koshlong	7 in, 1 out	NC	NC	NC	NC	X	NC	NC
Farquhar	8.5 in, 1.5 out	NC	NC	(1/2)•	NC	NC	X	NC
Grace (Pusey)	4 in, 3 out	NC	NC	NC	•	NC	X	NC
Esson	8 in, 2 out	NC	NC	•	NC	NC	NC	X
L. Glamor	3 in, 3 out	NC	NC	NC	NC	NC	NC	(1/2)•
B. Glamor	5.5 in, 2.5 out	NC	NC	NC	NC	NC	NC	NC
Gooderham	4 in, 2 out	NC	NC	•	X	NC	NC	•
Contau	5 in, 1 out	NC	NC	NC	NC	NC	NC	NC
White	3 in, 3 out	NC	NC	NC	NC	NC	X	NC
Salerno	3 in, 3 out	NC	NC	NC	NC	NC	NC	NC
Cameron Lake	92 in, 25 out	NC	NC	6 X	14 X	18 X	NC	NC
GULL RIVER BASIN RESERVOIRS								
Kennsis	7 in, 3 out	NC	NC	NC	NC	X	X	NC
Paint	1 in, 3 out	NC	NC	NC	NC	NC	NC	NC
Hawk	10 in, 5 out	NC	NC	•	NC	NC	NC	NC
Halls	7 in, 2 out	NC	NC	NC	NC	(1/2)X	(1/2)X	NC
Kushog	8 in, 3 out	NC	NC	NC	X	X X	NC	•
Percy	4 in, 3 out	NC	NC	NC	NC	NC	NC	NC
Oblong	7 in, 3 out	NC	NC	•	NC	NC	NC	NC
Redstone E.	7 in, 3 out	NC	NC	•	NC	NC	NC	NC
Redstone W.	8 in, 4 out	NC	NC	•	NC	NC	X	NC
Eagle	5 in, 3 out	NC	NC	(1/2)•	NC	NC	(1/2)X	NC
Boshkung	5 in, 6 out	NC	NC	NC	X	NC	NC	NC
Horseshoe	8 in, 6 out	NC	NC	NC	X X	NC	NC	NC
B. Bob	7.5 in, 2.5 out	NC	NC	NC	NC	(1/2)X	NC	NC
L. Bob	3.5 in, 1.5 out	NC	NC	NC	(1/2)X	X	NC	NC
Gull	2 in, 5 out	NC	NC	NC	X X	NC	NC	NC
Moore	5 in, 4 out	NC	NC	X	X X X X	NC	NC	NC
EELS RIVER BASIN RESERVOIR								
Eels	8.5 in, 3.5 out	NC	NC	NC	NC	•	(1/2)X	NC
YORK RIVER BASIN RESERVOIR								
Baptiste Lake	25 in, 15 out	NC	NC	NC	X X	NC	NC	NC

NOTE: • denotes 1 log added, etc.
X denotes 1 log removed, etc.
NC denotes no change to stop log settings.

Figure 5-1 - Kennisis Lake Levels - 1991

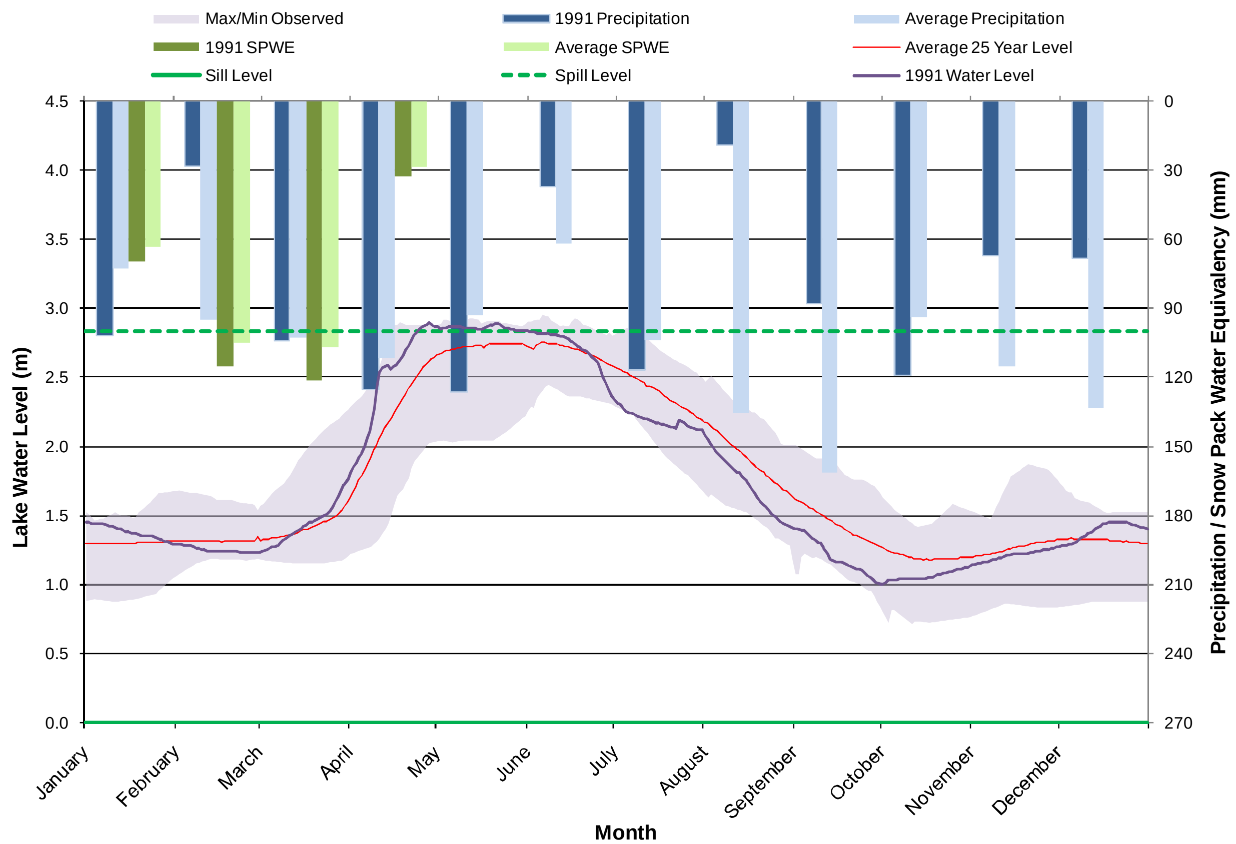


Figure 5-2 - Redstone Lake Levels - 1991

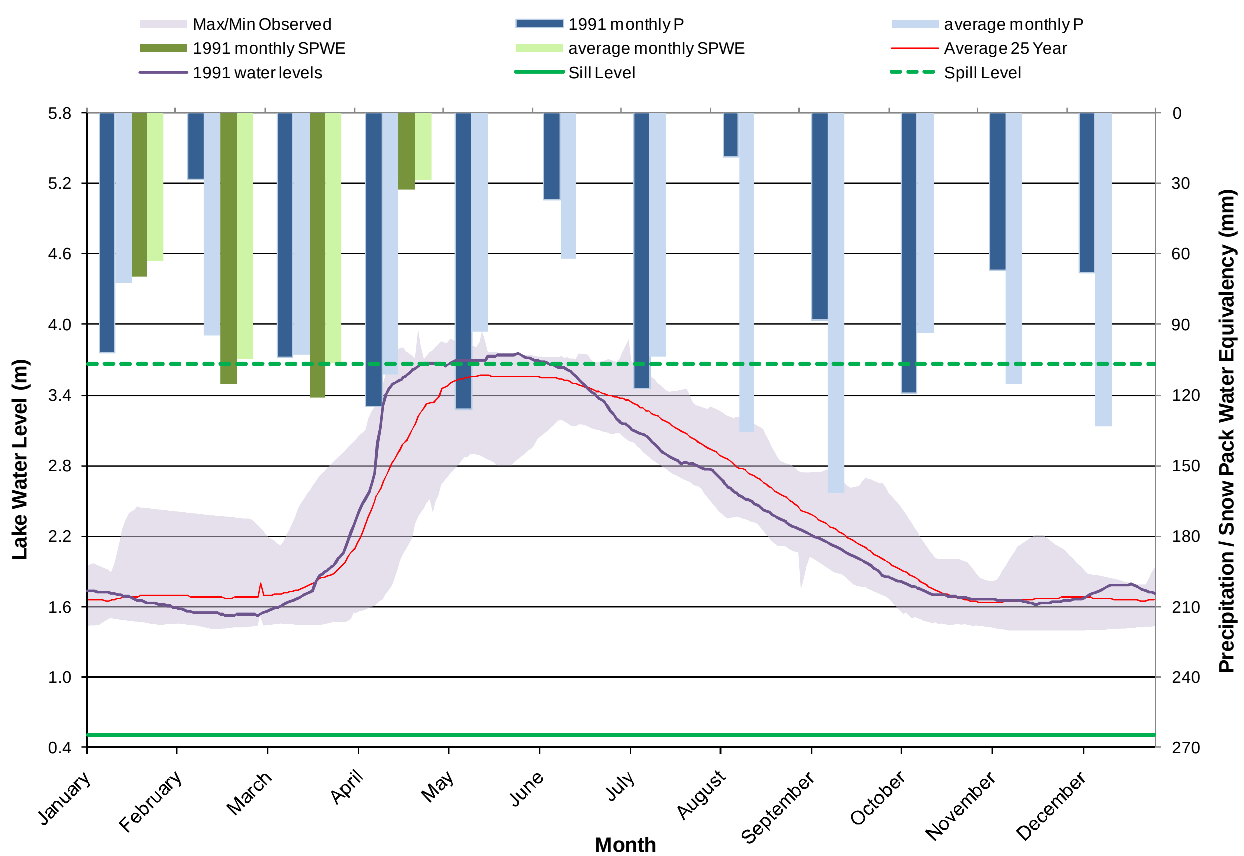


Figure 5-3 - Drag Lake Levels - 1991

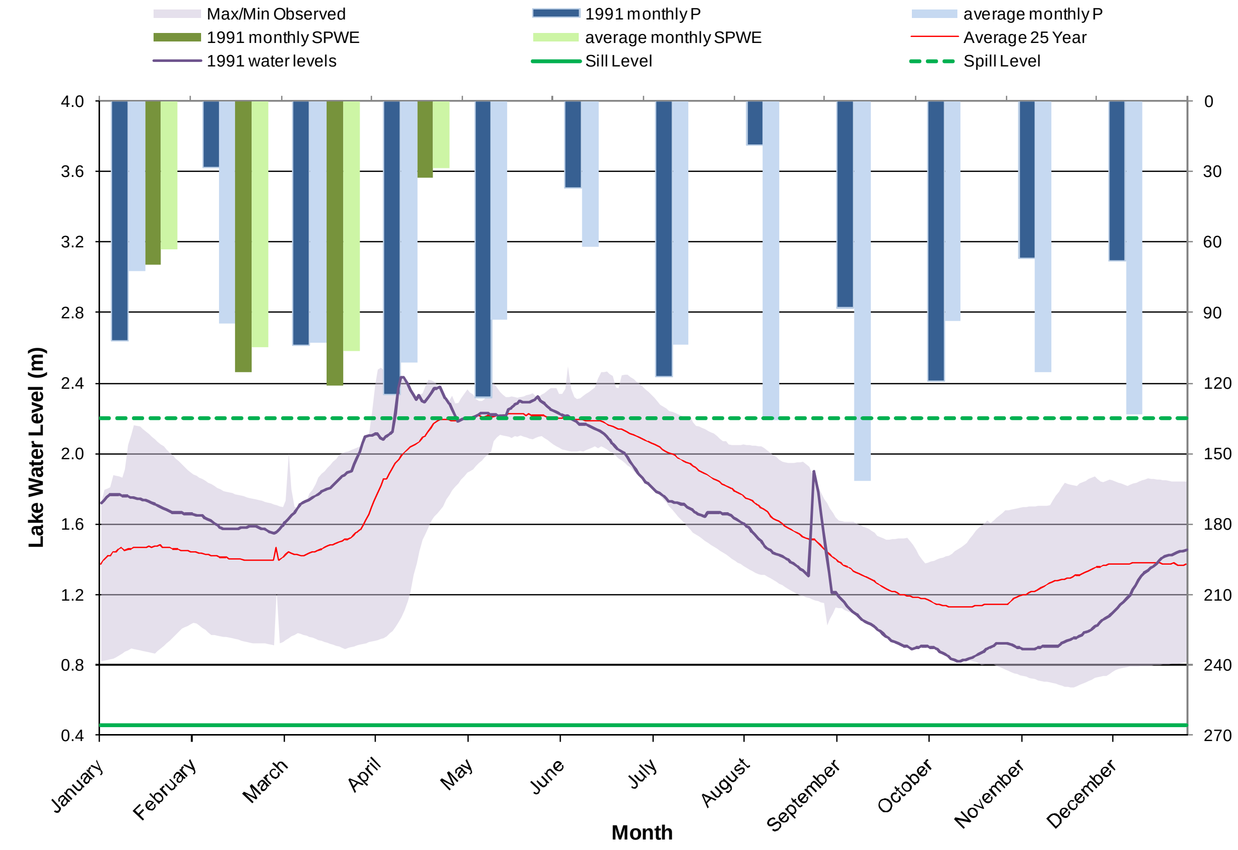


Figure 5-4 - Balsam Lake Levels - 1991

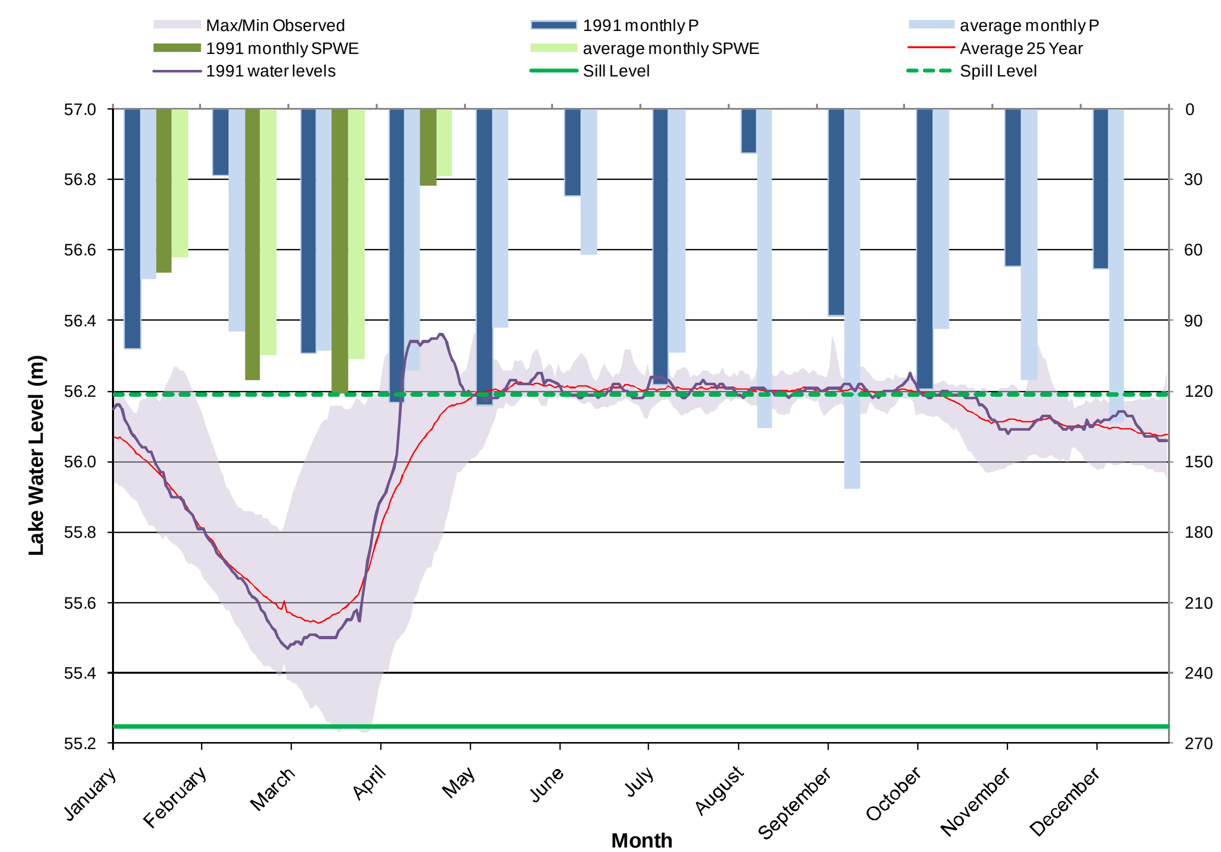


Figure 5-5 - Sturgeon Lake Levels - 1991

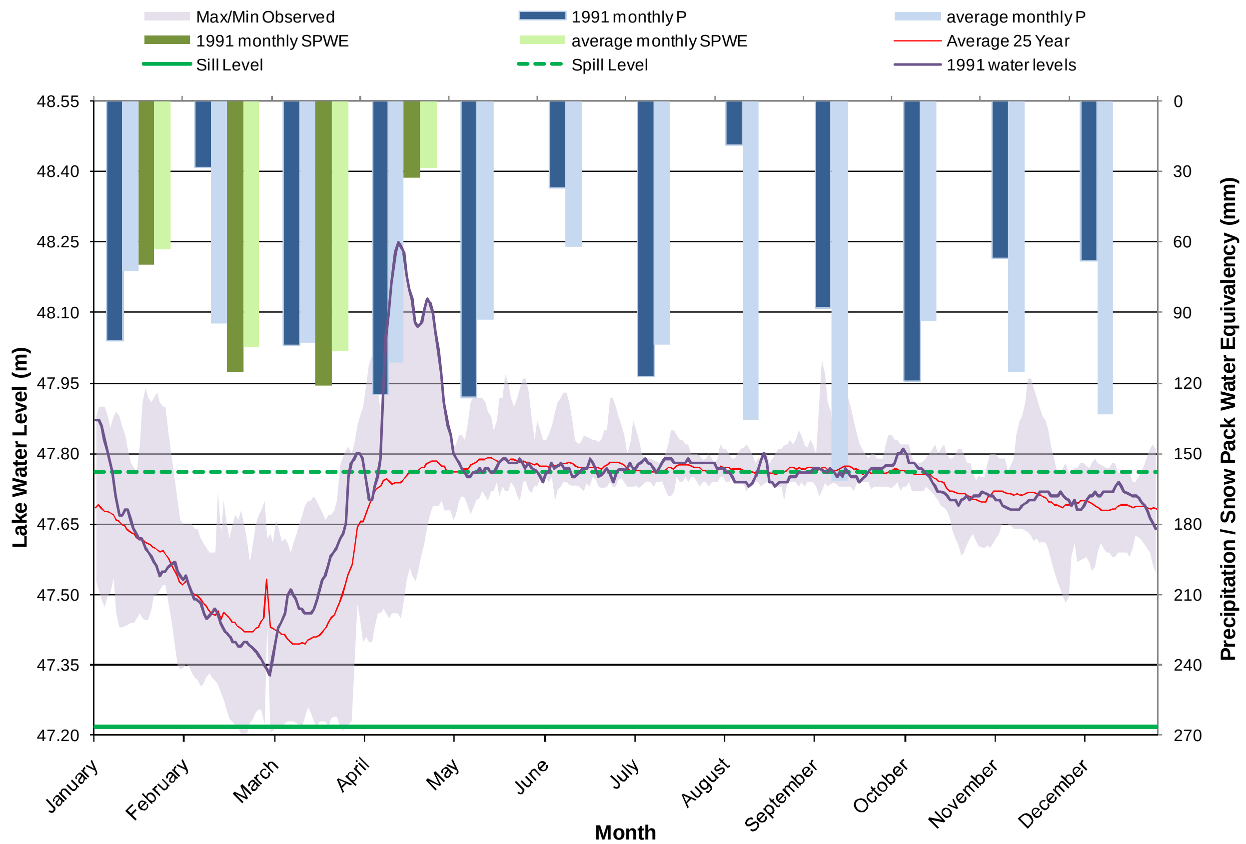


Figure 5-7 - Stoney Lake Levels - 1991

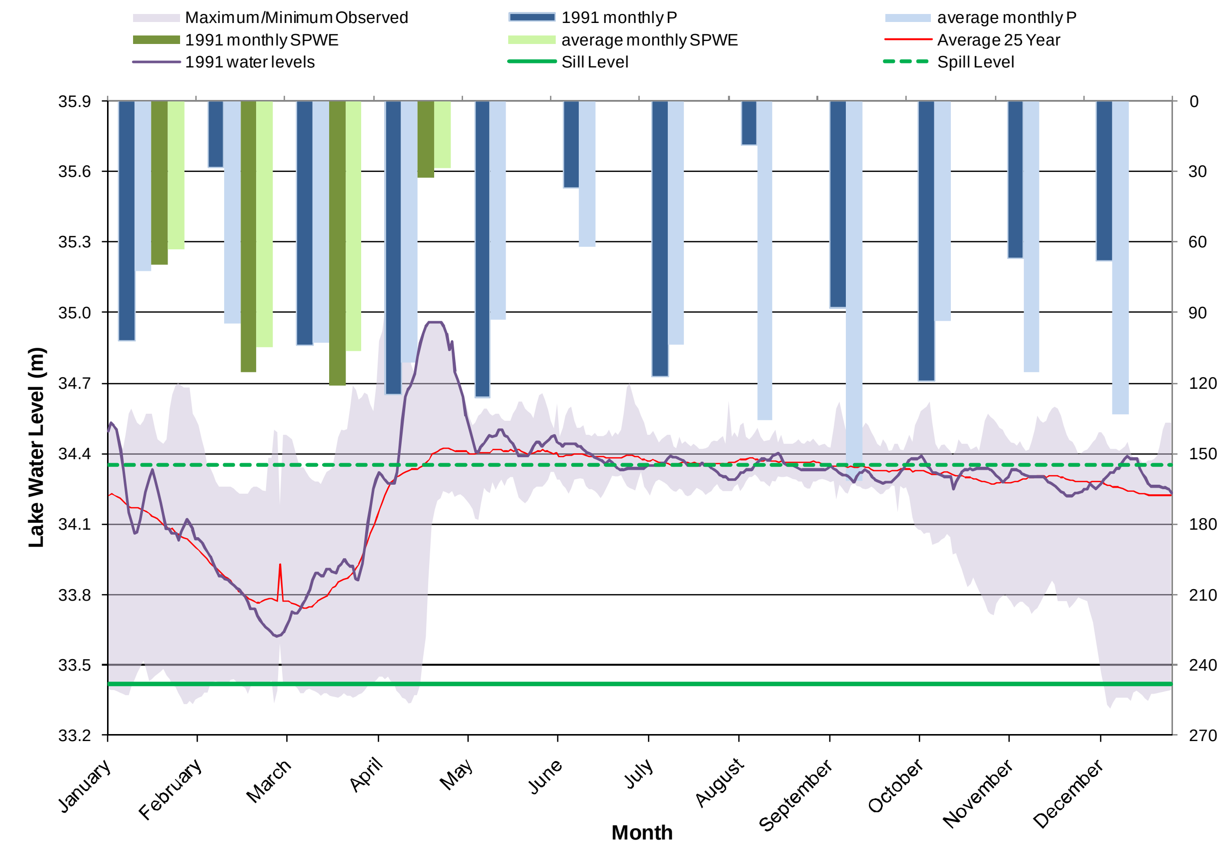


Figure 5-6 - Buckhorn Lake Levels - 1991

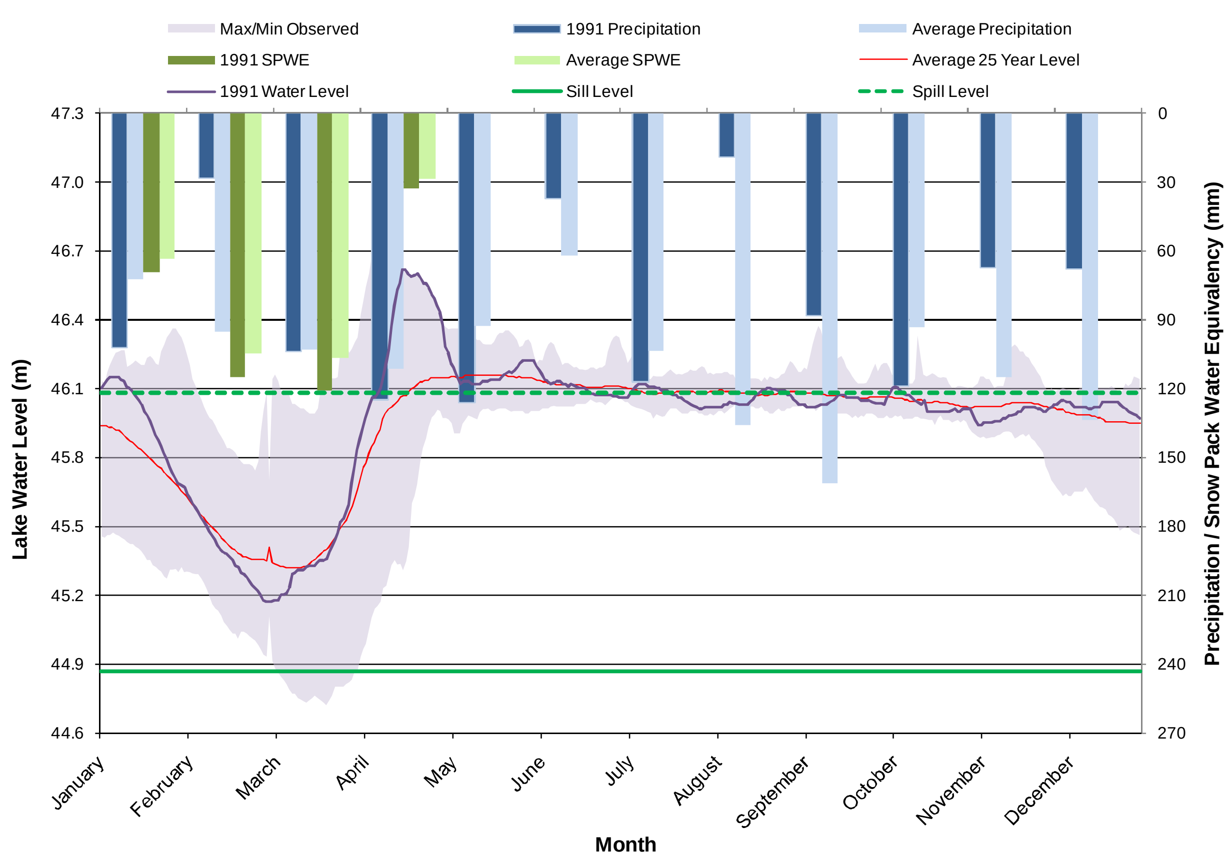
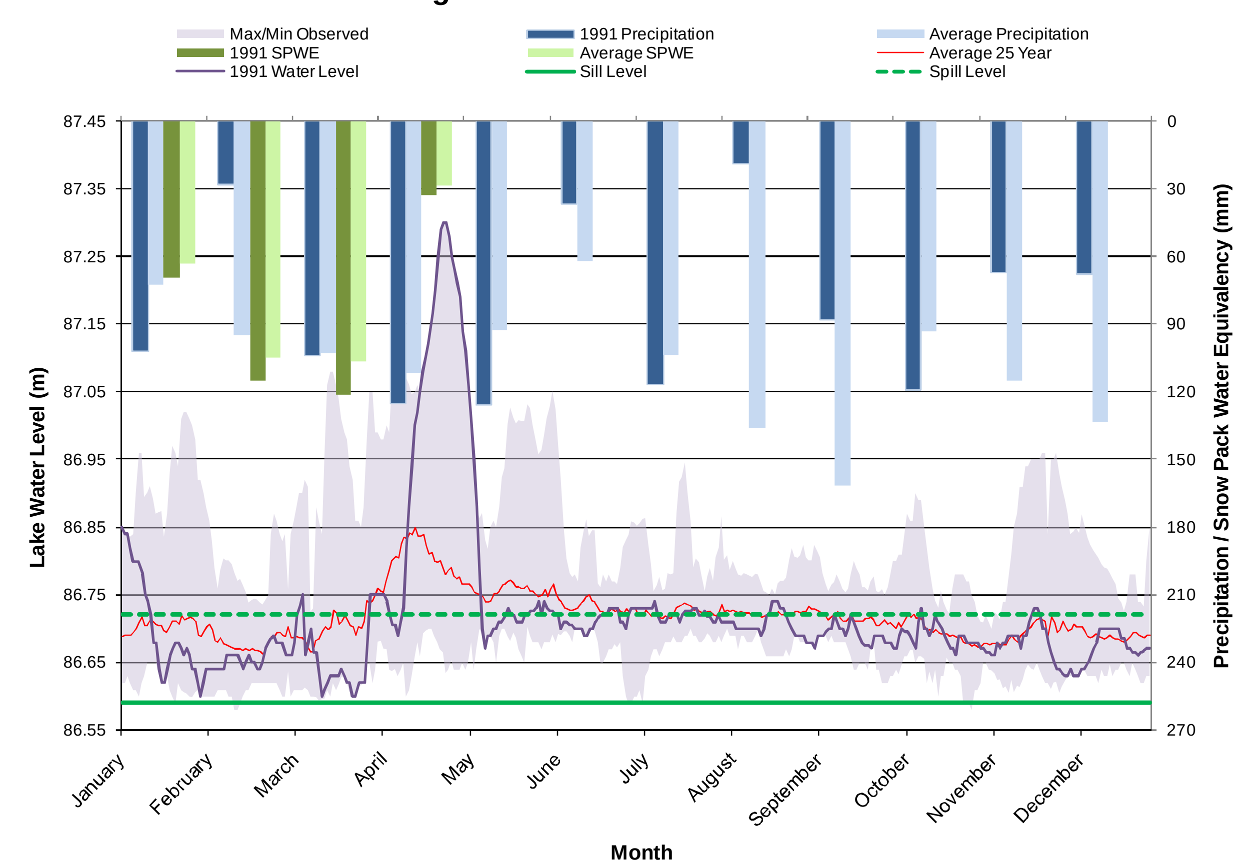


Figure 5-8 - Rice Lake Levels - 1991



5.2 Case Study #2 – 1999 Low Flows

The combination of a normal snowpack but lower than normal Spring rainfall in March and April likely contributed to the well below normal water levels in the Haliburton Lakes at the start of navigation season on May 15th.

The general response of the entire TSW system is reflected in **Figure 5-9** through **Figure 5-16** which illustrates the specific response of the selected reservoirs and lakes in the system through reported lake levels.

It is evident that, by March 1st of 1991, that only some of the reservoirs were in a state of readiness for the Spring freshet:

- The Haliburton Lakes (Kennisis, Redstone) were at their winter settings while Drag Lake was well below.
- the Kawartha drawdown schedule had been implemented for the Kawartha Lakes although Buckhorn and Stony Lakes were higher than normal.
- Rice Lake was hovering near its normal level for that time of year

By May 15th, the Haliburton Reservoirs were well below normal levels while the Kawartha Lakes and Rice Lake were maintained close to their normal levels.

By mid-July, all Lakes were at their expected levels; the Haliburton Reservoirs likely benefitting from much higher than normal rainfall in June.

Although August and September precipitation were below normal, both the Kawartha Lakes and the Haliburton Reservoirs were operated close to their normal levels and the Haliburton drawdown sequence was implemented from August 15th to October 1st.

From October 15th to January 1st, the initial Kawartha drawdown was implemented so that all Kawartha Lakes were at or close to their January 1st setting.

Figure 5-9 - Kennisis Lake Levels - 1999

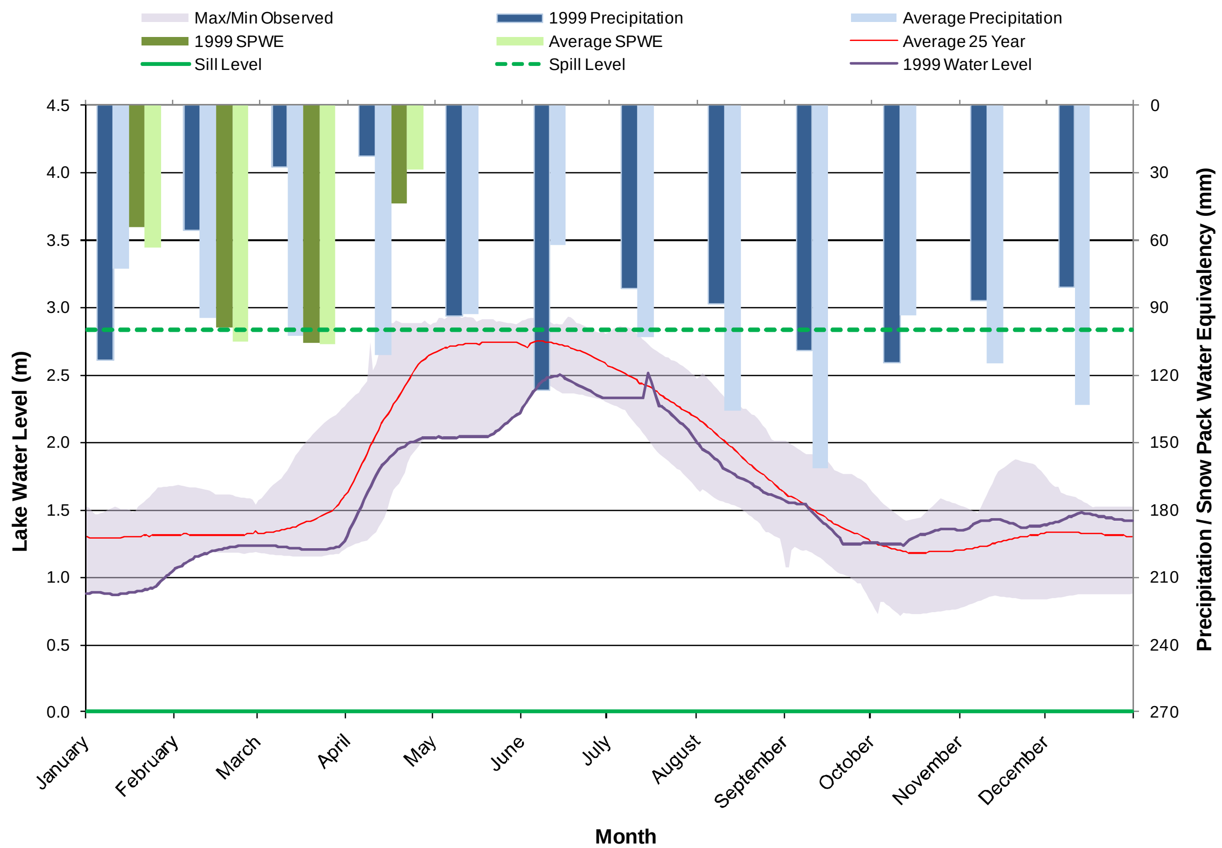


Figure 5-11 - Drag Lake Levels - 1999

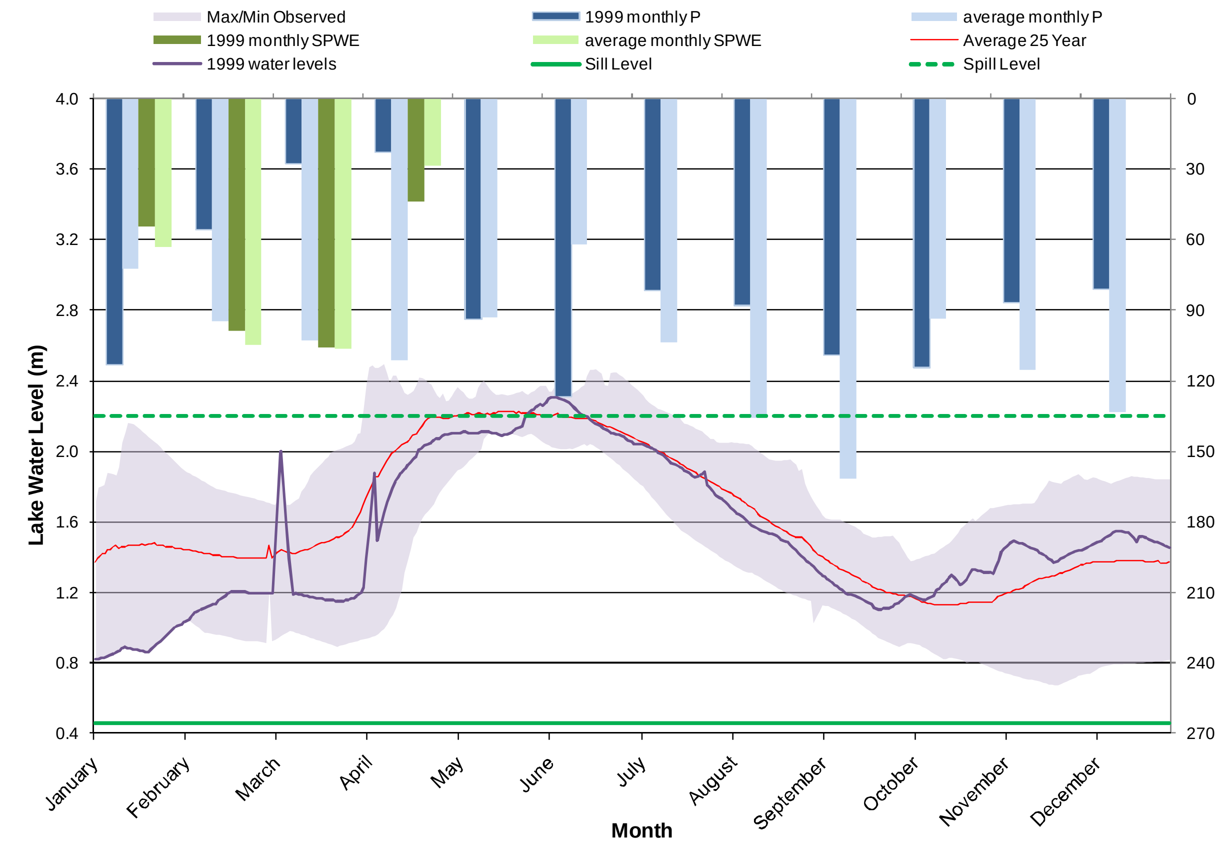


Figure 5-10 - Redstone Lake Levels - 1999

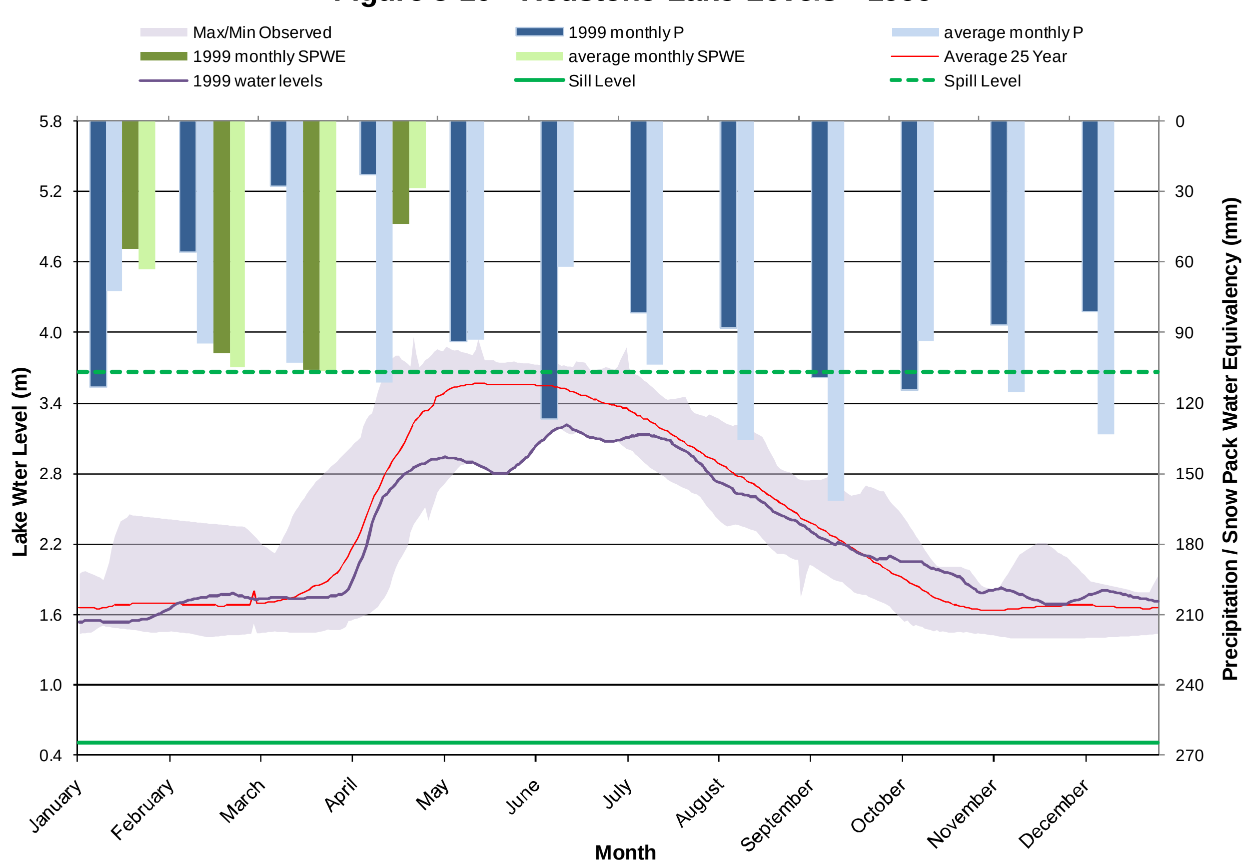


Figure 5-12 - Balsam Lake Levels - 1999

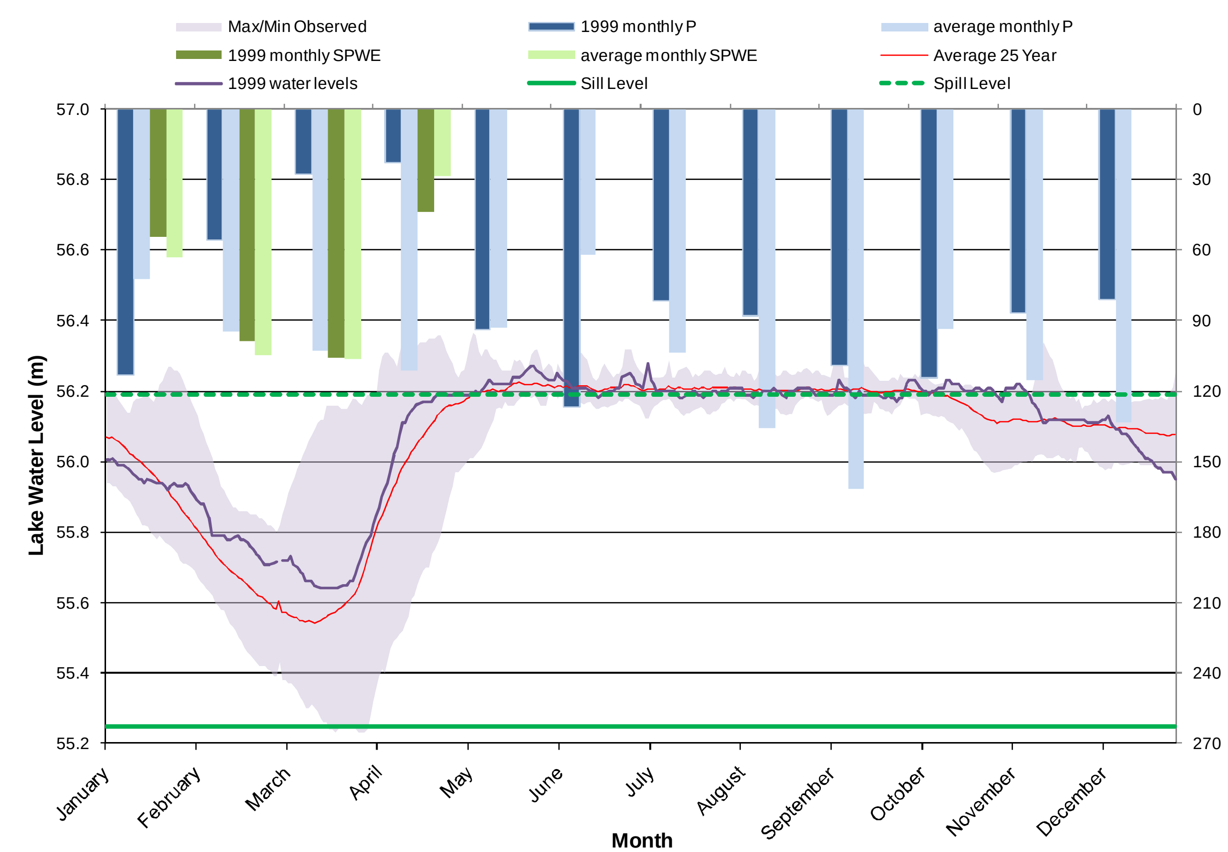


Figure 5-13 - Sturgeon Lake Levels - 1999

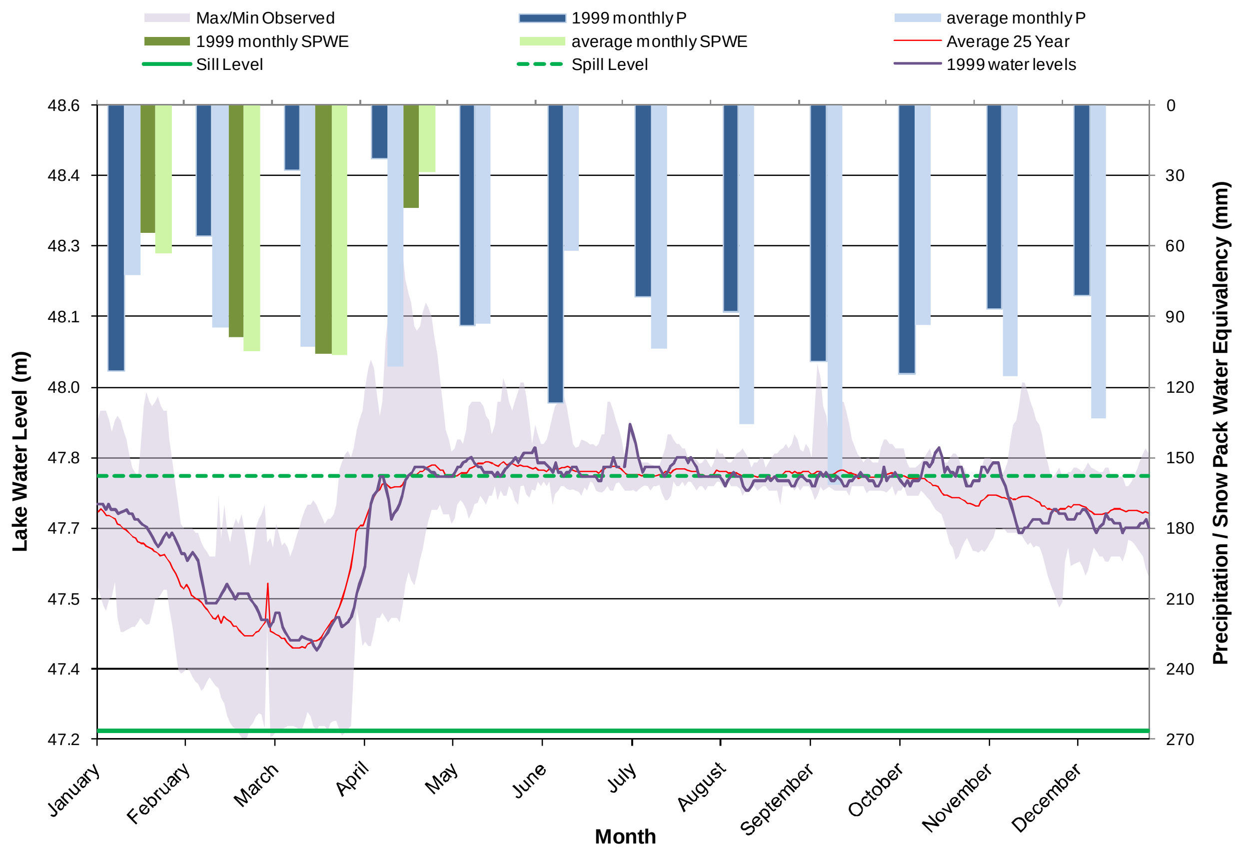


Figure 5-15 - Stoney Lake Levels - 1999

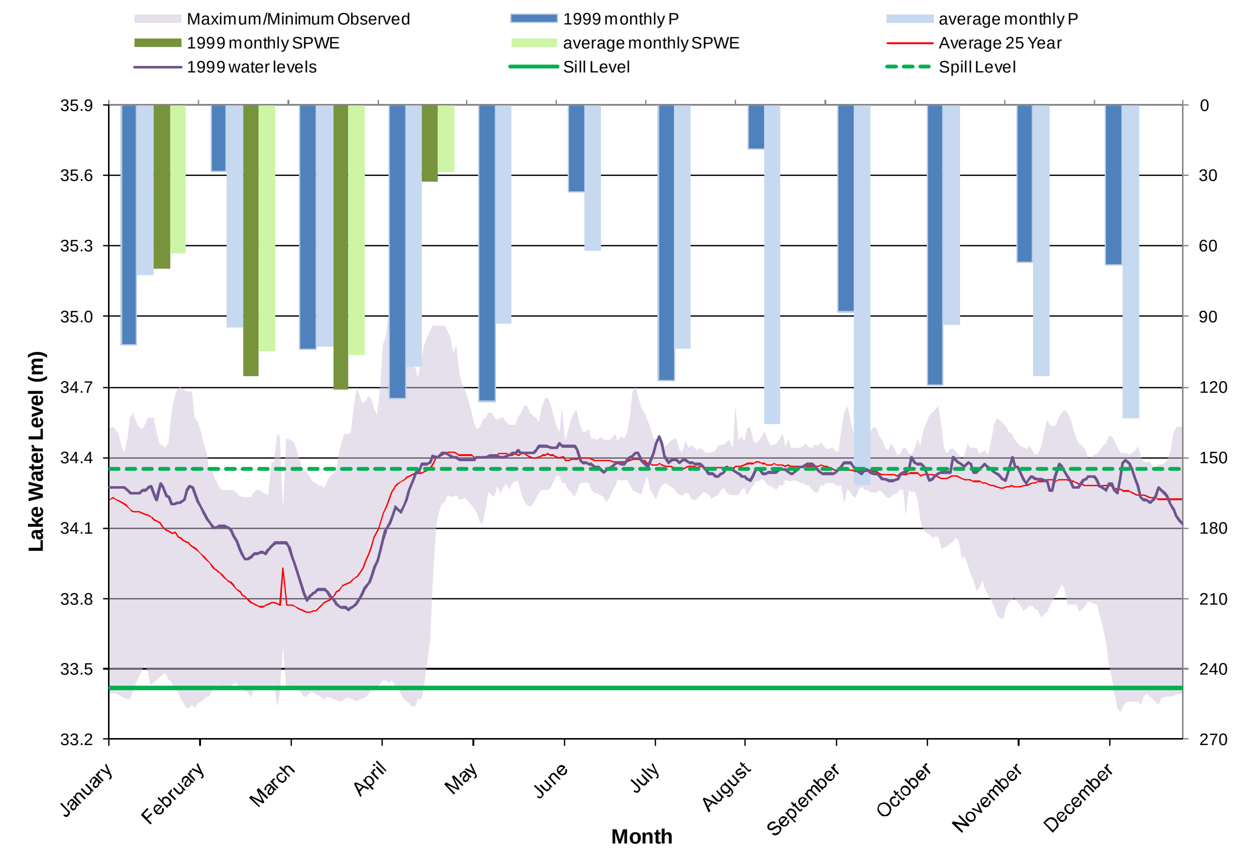


Figure 5-14 - Buckhorn Lake Levels - 1999

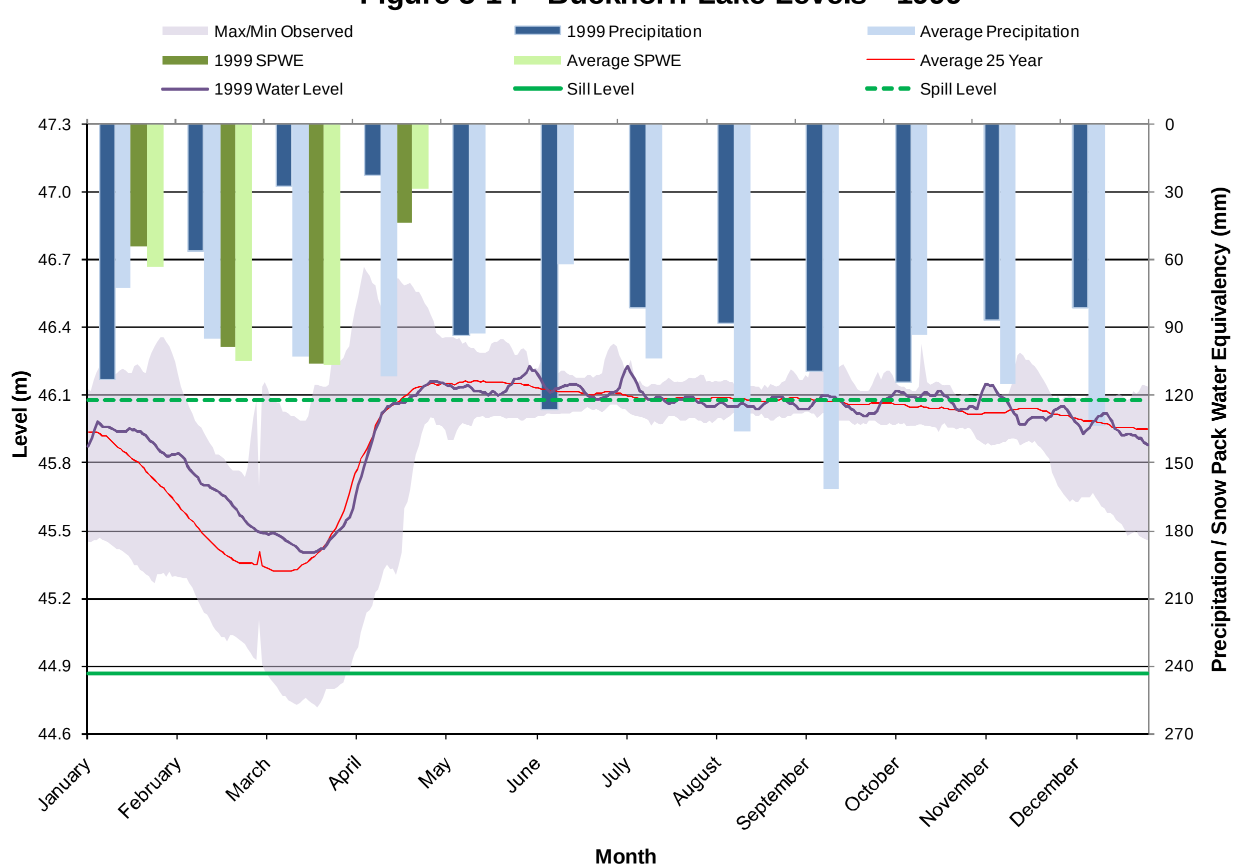
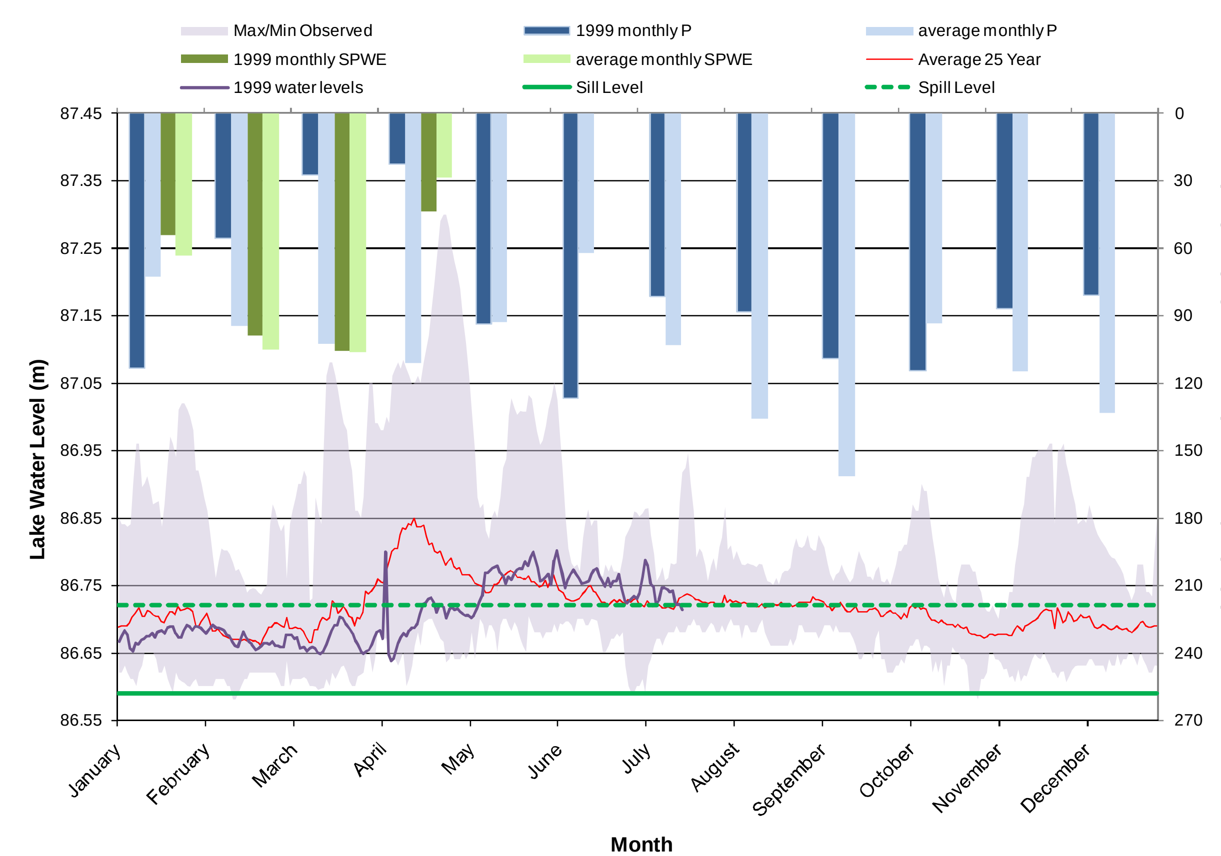


Figure 5-16 - Rice Lake Levels - 1999



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Appendix A

Legacy Operating Documents Review

Table of Contents

Statement of Qualifications and Limitations

page

1. The Trent Basin – Volume 1 Plan of Operation & Volume 2 Analysis of the System (1973)

Acres Consulting Services Limited (Acres) previously undertook an examination of the operations and procedures for water control of the Trent Canal from Balsam Lake to the Bay of Quinte. The study is detailed in the reports *The Trent Basin – Volume 1 Plan of Operation* (Acres 1973a) and *The Trent Basin – Volume 2 Analysis of the System* (Acres 1973b).

The sections below provide a summary of the information, analysis and recommendations of the two reports produced by Acres.

1.1 The Trent River System

The Trent River basin has an area of 4,400 square miles (11,395km^2) and includes the watershed draining into the Trent Canal from Balsam Lake to the Bay of Quinte. The system is composed of two main areas: the Kawartha Lakes area; and the Northern Reservoir area. The Kawartha Lakes area includes the lakes from Balsam Lake to Katchiwano Lake and form a continuous navigable waterway. This area is in low-lying land and rolling countryside south of the southern limit of the Canadian Shield, from which rainfall runoff is slow and losses are relatively high. The Northern Reservoirs area drains south into the Kawartha Lakes area, and lies within the limits of the Canadian Shield. This area is composed of rocky outcrops and shallow overburden, resulting in fast runoff response and relatively high runoff amounts. The drainage area of the Northern Reservoirs area is approximately 3,000 square miles (7,770km^2).

1.1.1 Available System Data

As of 1972, eleven meteorological stations were operating within the basin. Appendix A1 of Volume 2 showed the location and details of the stations.

Ten established snow survey courses existed, managed by three agencies (Ontario Hydro, Department of Lands and Forests, and Canals Division). Appendix A2 showed the location and details of each snow course.

Available streamflow records and locations, as of 1972, were detailed in Appendix A3 of Volume 2. There were nine recording gauges. Flows in the other locations were predominantly calculated from records of water levels in the reservoirs and stoplog positions.

Details of each control structure as of 1972 were given in Appendix A5 of Volume 2. For the Northern Reservoirs, control structures generally contained one to three sluices, with up to ten stoplogs in each sluice. For the Kawartha Lakes, control structures are generally larger, with up to twelve sluices.

Appendix A5 also detailed the lake surfaces and drainage areas for each reservoir.

1.1.2 Hydrology

Based on a review of historic meteorological records, precipitation was found to be relatively constant throughout the year. However, in the summer, evaporation was determined to account for a significant part of the outflow from the system. The study also found that fall and spring seasons had relatively large runoff volumes, particularly during the spring freshet, with considerably lower runoff volumes in the summer and winter.

1.1.3 Duty of Water / Water Demands

The duty or use of water within the system at the time of the study included maintaining acceptable navigation within the canal system, as well as satisfying demands of the various stakeholders. The duty of the available water in the system was complex and varied and often opposed. This was further complicated by the fact that demands were more severe during the summer, when water inflows were relatively low. The main water duty / demands within the system were:

- Acceptable water levels for navigation during the navigation season (primary objective);
- Range of water levels and flows suitable to accommodate various residential needs and recreational uses, and to avoid flooding damage;
- Minimum water levels required for drinking water supply and submergence of municipal water intakes;
- Minimum flows and water levels required to maintain acceptable water quality;
- Range of water levels and flows to provide reasonable conditions for water-supported wildlife; and
- Flows for operation of hydro-electric power stations.

1.1.4 Seasons

The reports describe three distinct operating seasons in the Trent Severn Waterway:

- Summer: The summer season is considered to be May 15 to October 15, and corresponds to the navigation and high recreation activity demand time of year. During this time it is typically necessary to draw water from the Northern Reservoirs to maintain target water levels in the Kawartha Lakes for navigation.
- Fall/Winter: The fall / winter season is October 15 to the following March 15. During this period, the lakes are drawn down in preparation for the spring runoff period.
- Spring: The spring season is considered to be March 15 to May 15. During the spring freshet, available storage within the Reservoir Lakes and Kawartha Lakes is used to provide flood mitigation and to fill the lakes to the summer target water levels. Low reservoir levels at the start of the spring season are suggested to permit maximum impoundment of this runoff.

1.1.5 Reservoir Groupings

For the study, reservoirs were grouped based on similar location, hydrology and water duty. The reservoirs were grouped into sixteen groupings, as shown in Plate 2 of Volume 1. The downstream reservoir of each group was to be the controlling reservoir at which flow out of the group was monitored and adjusted as per the operating procedures.

1.2 System Operation Prior to 1972

The system operation prior to the study was examined to identify operating behaviours. Few firm guidelines were available to the water control manager regarding required discharges to satisfy the various water demands. Typically, the manager relied on his long experience and 'feel' for the system.

Prior to 1972, available data for the system included:

- Flows recorded at three flow gauging stations;
- Water levels recorded every 1-5 days at each reservoir;
- Snow depth measured in the spring in the Scugog area and around Lake Simcoe; and
- Daily and long-term weather forecasting obtained from news media.

1.2.1 Summer Operation

The historical objective of summer operation was to provide sufficient water to maintain navigation in the canal, and to maintain a minimum flow of 800ft^3/s (22.6m^3/s) in the Otonabee River.

The previous operational policies and procedures included:

- Kawartha Lake water levels were maintained close to the top of their operating ranges, whenever possible;
- Water control manager determined daily the stoplog settings along the canal route, as well as the flows to be released from the major tributaries;
- Flow demands may have required drawdown of water levels in the Northern Reservoirs, which were drawn down by an equal percentage of the operating range; and
- Divisional superintendents arranged for stoplog movements in the Northern Reservoirs to provide the demanded flows.

The observed effects of the existing procedures were found to be:

- High flows maintained in the Otonabee River resulted in low reservoir levels at the end of the summer season. A minimum flow in the Otonabee River of 800ft^3/s was adopted to provide satisfactory conditions. This flow, if maintained over the entire navigation season was found to draw down the reservoir lakes an average of approximately 25% of the operating range;
- Lowering the water levels in the Northern Reservoirs, as well as the magnitude of water level fluctuations, were objected to by many property owners on the lakeshore, even though levels were lowered by equal percentage of depth; and
- The gradual lowering of reservoir levels apparently caused little damage to the ecology of the system.

1.2.2 Fall / Winter Operation

The historical objective of fall / winter operation was to lower the reservoir levels in preparation for the spring freshet.

The previous operational policies and procedures included:

- Northern Reservoirs were drawn down in most cases to sill level at the start of the season;
- Northern Reservoirs that have been proven to be difficult to fill during the spring freshet were drawn down to levels above the sill level;
- Kawartha Lakes were drawn down gradually between January 1 and March 15 to the winter holding level, which in certain lakes was above the sill elevation;
- In mid-February, the magnitude of the spring freshet was predicted from the snow depth data. The volume of the spring freshet was not calculated, however, the approach provided an indication of the volume to be expected;
- All stoplogs were removed at the Deer Bay Reach dams downstream and the Burleigh dams were also open; and

- Movement of stoplogs during the winter was difficult and hazardous for staff. Movement of stoplogs during the winter and early spring months was minimised.

1.2.3 Spring Operation

The historical objective of spring operation was to avoid localised flooding within the system and fill all reservoirs using the spring freshet. Of particular emphasis was filling the Northern Reservoirs, for use in maintaining stable water levels and flows in the Kawartha Lakes and Trent canal during the relatively dry summer period.

The previous operational policies and procedures included:

- Northern Reservoir stoplogs were generally inserted prior to snowmelt, due to the difficulty in predicting the timing of the peak flows and the need to fill these lakes;
- Commencement of spring freshet was indicated by the first signs of snowmelt in Scugog Lake;
- At that time, any stoplogs in the Lindsay Dam were removed, and the dam remained open as the lake fills and overflows. Stoplogs were replaced in the dam once the peak of local runoff had passed;
- At that time, water control management began to closely observe the runoff (uncontrolled) from Burnt River and opened the dams at Fenelon Falls and Bobcaygeon;
- Rosedale Dam was manipulated to reduce flow into Cameron Lake and to fill Balsalm Lake to the average water level for that date. This, along with the early closing of the Reservoir Lake dams, had a dampening effect on the main freshet;
- Prior to snowmelt, Pigeon, Chemong and Buckhorn Lakes were at their natural low level, with all stoplogs out. Freshet flows from Scugog and Fenelon Lakes, as well as the surrounding drainage area, raised the water level of these lakes to typically above summer navigation levels, even with the stoplogs at Buckhorn Dam still all out; and
- Stony Lake generally rose from its winter levels at about the same rate as the uncontrolled Buckhorn Lake levels. Additional discharge from Stony Lake was available by opening the gates further, to the capacity of the Otonabee River downstream.

The observed effects of the existing procedures were found to be:

- Most of the freshet passed through the system;
- Sufficient water was available during most years to fill the reservoirs during the spring freshet;
- Due to the size of the overall basin and the distribution of storage within it, difficulties arose because water and storage were not always available in an appropriate location;
- The Kawartha Lakes and Otonabee River did not experience flooding, except during exceptionally wet spring seasons; and
- Flooding in certain areas occurred if abnormal rains fell during the later part of the spring freshet or during final filling stages for the reservoirs.

1.3 Proposed Operational Policies and Procedures

The proposed operational policies and procedures were formulated based on:
- Reviews of previous operational procedures and experience;
- The water duty / water demands on the system; and
- Historical records and observations.

The initial operational procedures were then tested, assessed, and refined using trial simulations of the model established as part of the study. Using an iterative process, the operational procedures were further refined using additional testing and re-evaluation via the model. Proposed operational policies and procedures included definition of the following:
- Reservoir Zone water level limits for each reservoir;
- Target water levels for each reservoir for each season;
- Channel flow limits;
- Interreservoir relationships (both priority and equal function definitions); and
- Variations in the above items season to season in response to changing water duty and stakeholder demands.

1.3.1 Reservoir Zones

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

For each reservoir, water levels defining the upper and lower limits of each Reservoir Zone were adopted. The water levels were selected based on review of historic records of flows and water levels in the system, operational experience, the water demands of stakeholders, and ecological and water quality targets. Plate 3 and Appendix C of Volume 1 summarized the recommended water levels defining each Reservoir Zone for each reservoir, for the summer season. Volume 2 detailed the manner by which the limits of the zones were selected.

Reservoir zones in the summer were of the most importance and included all five zones. Reservoir zones for the fall/winter and spring seasons were operationally unimportant, and included only the Flood Control and Spill Zones, as operation in these seasons was directed towards preparation for and regulation of flood inflows during the spring freshet.

The study also developed limits on channel flows as a function of the zonal conditions of upstream reservoirs. Appendix D of Volume 1 detailed the range of permissible channel flows at Coboconk and at Peterborough for each Reservoir Zone for each season. Volume 2 detailed the manner by which the limits of the zones were selected.

1.3.2 Interreservoir Relationships

Another fundamental concept of the proposed operational policies and procedures was the definition of the prescribed relationships between reservoir storages when some (or all) of the individual reservoir target water levels cannot be satisfied. The proposed approach made use of both priority and equal function concepts.

For priority relationships, deviations from individual target water levels occurred in a predetermined sequence and without any requirement for uniform deviation between reservoirs. Thus, some reservoirs could violate their respective target water levels, while others still satisfied theirs.

For equal function relationships, the reservoirs equally deviated from the target water levels, based on either:
- equal elevation deviation; or
- equal deviation based on percentage of live storage.

1.3.3 Proposed Summer Operation

The recommended primary objective of summer operation was to provide suitable levels and flows to support navigation in the Kawartha Lakes canal system. In addition, a main objective was to use storages within the Northern Reservoirs as a water supply to maintain target water levels in the Kawartha Lakes. Additional objectives included providing water levels and flows to:
- Support recreational, residential and commercial activities throughout the entire basin, as best possible;
- Maintain appropriate water quality;
- Avoid exposure of municipal water supply intakes;
- Provide for operation of hydroelectric power stations; and
- Enhance natural habitat.

The operational policy for summer operation was developed using the above-mentioned approach and included, among other items, the following:
- Target water levels in the Kawartha Lakes at the top of the Conservation Zone;
- Drawdown Northern Reservoirs water levels uniformly by depth through the Conservation and Buffer Zones, to supply water to maintain target water levels in the Kawartha Lakes;
- Maintain water levels in each reservoir within the same zone;
- Minimise fluctuations in water level in all reservoirs;
- Conserve water by permitting only minimum required flows for water quality, at certain times; and
- Reduce the Flood Control Zone upper limit for each reservoir after June 15 when weather stabilizes.

Appendix C of Volume 1 summarized the target water levels within each Reservoir Zone for each reservoir for each season. Appendix D of Volume 1 detailed the channel flow ranges for each Reservoir Zone for the system at Coboconk and at Peterborough, for each season.

The recommended procedure to implement the above policy involved undertaking the following over each time period:
- Monitoring and recording of flows and water levels within the system;
- Using the recorded data and forecasted natural local inflows with the model developed for the study to forecast the average discharge and control structure setting necessary at each reservoir to attain the target water level

(or provide an optimum water level if the target water level was unattainable) by the end of the current time period; and

- Advise staff as to the control structure setting adjustments as indicated by the model.

The settings prescribed by the model may need to be augmented on site during the time period, based on actual conditions in the field. The objective of the alterations to the control structure settings was to minimise the actual deviations from the target water level and were to be based on operator experience and knowledge.

1.3.4 Proposed Fall / Winter Operation

The recommended primary objective of fall / winter operation was to drawdown all reservoirs to provide available storage for the upcoming spring freshet. Additional objectives included providing water levels and flows to:

- Maintain appropriate water quality;
- Avoid exposure of municipal water supply intakes;
- Provide for operation of hydroelectric power stations; and
- Provide appropriate water levels to preserve natural habitat and wildlife.

The operational policy for fall / winter operation was developed using the above-mentioned approach and included, among other items, the following:

- Lower water levels in all reservoirs to provide flood storage volume for the spring;
- Drawdown of water was on a priority system, starting at the top of the system;
- Drawdown the Northern Reservoirs first starting October 15, and then the Kawartha Lakes;
- The Northern Reservoirs target water level was sill level, except for reservoirs that are difficult to fill (in which case, a higher target level was adopted as per Appendix F of Volume 1);
- The Kawartha Lakes target water levels were to be set to 50% of the storage volume;
- During drawdown, control discharges to avoid flooding;
- Maintain minimum required flows for water quality in all channels; and
- Adjust target water levels, as required, following the initial forecast of spring inflow on February 15.

Appendix C and D of Volume 1 summarized the target water levels and discharges within each Reservoir Zone for each reservoir for the fall / winter season.

The recommended procedure to implement the above policy was as per the proposed summer operation.

In mid-February, it was recommended that a forecast be made of the expected volume of inflow into the system upstream of Peterborough due to the upcoming spring freshet (March 15 to May 15). If required, adjustments to the late-winter target water levels in each reservoir are made to better prepare the system for the predicted volume of inflow during the spring freshet. If additional storage volume is required, the Kawartha Lake reservoirs are drawn down uniformly by depth towards the new target water levels.

1.3.5 Proposed Spring Operation

The main suggested objective of spring operation was to attain, by the end of the season, water levels and flows within the Kawartha Lakes suitable for navigation. In addition, a main objective was to accumulate water storages within the Northern Reservoirs for use as a water supply to the Kawartha Lakes during the summer. Additional objectives included:

- Avoid flooding of lakeshore and riverside properties;
- Maintain appropriate water quality;
- Avoid exposure of municipal water supply intakes; and
- Provide for operation of hydroelectric power stations.

The operational policy for spring operation was developed using the above-mentioned approach and included, among other items, the following:

- Produce, at the end of the spring (May 15), the target water levels in all reservoirs of near the top of the summer Conservation Zone;
- No policies of equality in the filling of the reservoirs;
- Follow the proposed priority ranking for filling (see Appendix E of Volume 1);
- Pass surplus water out of the system as early as possible;
- Reduce flooding to a minimum by judicial use of storage; and
- Maintain minimum required flows for water quality in all channels.

Appendix C and D of Volume 1 summarized the target water levels and discharges within each Reservoir Zone for each reservoir for the spring season.

The recommended operational procedure for spring to implement the above policy involved:

- Close monitoring of flows (via the streamflow gauges) and available storages (via water level readings at each reservoir) within the system;
- Developing and maintaining operational charts of freshet and discharge volumes, as well as flow hydrographs, throughout the spring to provide a guide as to the rate of disposal of surplus water and the timing and amount of water to be retained; and
- Use of the model developed for the study to summate the changes in storage and total discharge from each Reservoir group to date since March 15, at a given time.

The draft operational charts were provided in Plate 7 – Appendix I of Volume 1. The charts were to provide an indication of the status of the spring freshet, from which the decisions were made regarding the disposal or surplus water and timing and rate of storage.

For Chart I, the suggested procedure was as follows. The February 15 forecast of total volume of inflow due to the spring freshet (March 15 to May 15) was to be plotted at March 15 on the Chart. The volume of storage to be filled was to be plotted at May 15 on the Chart. This volume was to be calculated as the difference between the target water levels for May 15 (which are levels near the top of the summer Conservation Zone) and the recorded water levels on March 15). Chart I included minimum and maximum outflows as guidelines, which were based on the minimum flows to maintain water quality and the maximum flows to avoid flooding. Appendix D of Volume 1 provided suggested values.

From March 15, water levels in all reservoirs were to be recorded every 2 days. For each of the 16 Reservoir groups, outlet flows were recorded continuously at the corresponding streamflow gauges and averaged over the 2 day period. The model was then to be used to summate the change in storage and total discharge from each Reservoir group to date since March 15. The total discharge from the basin was determined as the sum of the values for all Reservoir groups. A forecast of the residual total volume of inflow due to the spring freshet was calculated as the difference between the initial forecast of the volume of inflow from February 15 data and this current value of total discharge from the basin. This point was to then be plotted on Chart I. The difference between the residual total volume of inflow due to the spring freshet and the volume of storage to be filled indicated the total amount of water that needed to be discharged from the system between the current date and May 15.

It was proposed that the mass curves of accumulated discharge volume from the system and accumulated volume of inflow to the system due to the spring freshet be developed on a continuing basis during the spring season. The accumulated discharge volume was to be based on the flow records at the outlet to the basin (Otonabee River gauge). The volume of inflow to the system was to be determined as the sum of the volumes discharged, stored and/or remaining in transit in the system over a particular period of time. This was to be calculated by the model based on recorded data. It was also proposed that the hydrograph of discharge from the system be developed as Chart III. Also included in Chart III was to be the hydrograph of total volume of inflow to the system due to the spring freshet.

When possible, it was recommended that the original forecast of the total volume of inflow due to the spring freshet be updated, based on experience and historical records.

Once the predictions and operational charts indicated that volumes of freshet water remaining were just sufficient to fill the required storage while maintaining acceptable outflows, the stoplogs and gates were to be lowered to impound the required water. A priority order for installing stoplogs and gates was recommended, and detailed in Appendix E of Volume 1.

1.4 Proposed Modeling

1.4.1 Input Data

The following input data, among others, was required in the model:

- Stage – storage relationships for each reservoir;
- Stage – discharge relationships for each control structure;
- Seasonal target water levels for each reservoir;
- Seasonal Reservoir Zone definition for each reservoir (zonal upper and lower water level boundaries);
- Range of permissible channel flows at Coboconk and at Peterborough for each Reservoir Zone for each season;
- Definitions of the priority and equal function relationships between reservoirs
- Average recorded flows (from streamflow gauges) at the outlet of each of the sixteen Reservoir Groups in the system for the previous time period;
- Recorded water levels in each reservoir at the beginning and end of the previous time period; and
- Natural local inflow to each reservoir for current time period.

The required input data was obtained from physical surveys of the system, the developed operational policies and water level / flow data recorded from the system.

It was suggested that the unit of time used in computing and forecasting simulations be 1-2 weeks in the summer and fall/winter, while 1-2 days in the spring season.

1.4.2 Proposed Modeling Approach

A computer simulation model of the system was developed to assist in analysing current conditions and forecasting the required alterations to the system in order to satisfy, as closely as possible, the operational policies. The model extents were the Trent Basin watershed upstream of Peterborough, and included approximately 55 reservoirs.

The model represented the system's relationship of reservoir inflows to outflows and the change in storage on a time period by time period basis. The model expressed the relationships in the form of simultaneous equations which account for the successive sequencing of the reservoirs and also the physical constraints of the structures and channels. The governing equations were the equations defining continuity. Priority and equality functions were included in the determination of water levels and flows. Also, based on the current Reservoir Zone and water level, the model selected and accounted for the permissible channel flow limits at Coboconk and Peterborough, as well as any additional minimum specified flows in the system.

An "out-of-kilter" solution algorithm technique was used. This technique represented the system as a series of nodes and connecting arcs. Each node represented either a reservoir or channel reach. Each arc represented the channel flow or change in storage in a reservoir. Continuity was defined at each node; the sum of flow in the incoming arc must equal the sum of flows in the outgoing arcs.

The main objective of the model was to obtain a solution such that the water levels in all reservoirs satisfied their respective operating procedures and all channel flows were within the prescribed ranges. Under typical conditions, it is generally possible to achieve this objective. However, under particularly wet or dry conditions, it is not possible to obtain a solution without violating some target water levels, prescribed flow ranges, or other operating policies. The model included generalised rules for balancing water level and flow deviations for target values, including:

- Preferable for all reservoirs to be in the same Reservoir Zone;
- Channel flows are allowed to deviate outside target zone, prior to allowing water levels to deviate outside the target zone; and
- Based on the interreservoir relationships (both priority and equal function definitions).

For situations in which a deviation was necessary, the model assigned penalty coefficients, in proportion to the magnitude of the deviation, to any arcs representing:

- deviation from the target water levels; or
- channel flows outside the prescribed range.

The model would then produce a series of solutions for each time period representing varying degrees of violation from the ideal operating procedures. Furthermore, the optimal solution was identified as the solution with the minimum sum of total penalties in the system.

It was recommended that the predicted flows and water levels be compared to recorded values to determine these deviations and identify required improvements to the definitions of reservoir zones, target water levels, flow limits and interreservoir relationships within the model.

1.4.3 Forecasting Natural Local Inflows

The natural local inflow was defined as the net input to a reservoir from its local uncontrolled drainage area, and did not include the regulated inflow from upstream reservoirs.

1.4.3.1 Short-Term Forecasting

During the summer and fall/winter seasons, natural local inflows for the previous time period were determined using a separate computer program which simulates the continuity of flow. The natural local inflow was calculated as:

Natural Local Inflow = Outflow – Regulated Inflow + Change in Storage

Natural local inflows were calculated for each of the sixteen groupings of reservoirs. Regulated inflows and outflows to each grouping were determined from recorded flows at the streamflow gauges. Changes in storage within each grouping were determined from the recorded water levels in each reservoir. Based on the drainage areas, the natural local inflow was then prorated to provide a value for each reservoir.

The forecasted natural local inflow during the current time period was assumed to be equal to that determined for the preceding time period. This approach relied on persistence of conditions over short-term periods. However, as required, modifications should be made to the forecast by the system operator in accordance with their judgement and an analysis of historical trends. This value serves as an input to the model.

1.4.3.2 Long-Term Forecasting

For the proposed approach for spring operations, a forecast was required of the volume of inflow into the system due to the upcoming spring freshet (March 15 to May 15). The forecast was based on a regression equation between total inflow volume and average snow depth on February 15. The regression equation was developed from historical records, and is explained in further detail in Appendix E of Volume 2.   The average snow depth was calculated as the arithmetic average of snow depth measured at 4 snow survey courses (Minden, Haliburton, Gooderham and Apsley) by the Dept. of Lands and Forests – Research Division.

1.5 Study Recommendations

The study recommended additional assessments or work be undertaken, including:

- Identify areas within the system susceptible to flooding, and for these areas undertake an analysis of flood discharge versus damage;
- Improve the accuracy of water accounting by updating stage-storage details based on updated topographic surveys of each reservoir;
- Improve the physical description of the system, as well as to the operational policies and procedures by installing additional flow gauges and snow courses;
- Install underflow gates to improve flow control;
- Evaluate reservoir constraints, particularly the impacts of obstructions to flow upstream of the control structures;
- Undertake the Gull River improvements recommended by previous studies, including the removal of channel constraints in 3 locations and construction of a control weir at the outlet of Silver Lake;
- Improve long-term forecasts of total volumes of inflow due to spring freshet via improved basin records of depth of snow and refined empirical relationships of snow depth to inflow volumes;
- Improve approaches for forecasting short-term natural local inflows at the current time period, presently based on assuming similarity to the previous time period;
- Undertake flood studies at locations susceptible to local flooding;
- Undertake ecological studies to assess the impacts of the proposed operational policies and procedures; and
- Assess the need for additional staffing;

2. Trent Simulation Package (1977)

The Trent Simulation Package (Acres 1977) was a manual summarizing the information from *The Trent Basin – Volumes 1 and 2* (Acres 1973) necessary to understand and operate the main simulation model and Natural Local Inflow model. The manual also detailed:

- The Executive Control Package, a package for organizing data files and running the programs;
- Descriptions of the data input forms for the model;
- Techniques to modify the existing model descriptions of the Trent Basin;
- Data listings;
- Program listings;
- Example program results;
- Day-to-day run procedures and guidelines; and
- Theory background for the model.

3. Post-Audit of the Trent-Severn Waterway Operating Procedures in the Haliburton Reservoir Lakes Area (1988)

Acres undertook a review of the existing water management procedures of Trent-Severn Waterway. In addition, measures to improve future operations were recommended. The study is detailed in the report *Post-Audit of the Trent-Severn Waterway Operating Procedures in the Haliburton Reservoir Lakes Area* (Acres, 1988).

The review found that the primary objective of providing a navigable waterway between Trenton and Port Severn was satisfied. Also, this primary objective was met while minimising the drawdown of the Reservoir Lakes during the summer season in an equitable manner. In addition, operations in the Reservoir Lakes during spring freshet were found to be reasonably successful in filling the reservoirs and avoiding serious flooding.

The review also evaluated potential upgrades to control structures. It was found that although all the stoplog structures leaked to some degree, in nearly all cases the leakage was significantly less than the minimum releases required to satisfy other water demands.

The computer models were upgraded since the original study, including:

- A Flow Forecast Module (QFORECAST) was added which predicts volumes of inflow to each reservoir during spring runoff based on snowpack and meteorological variables; and
- The models were provided on a computer in the TSW offices in Peterborough, to increase utilization of the model;
- Data management has been added to the Natural Flow Module to archive calculated flows;

QFORECAST, developed by McLaren Plansearch Inc in 1985, generates a one-week forecast on inflows from observed snow, rainfall and temperature data, plus a longer term forecast or weekly flows until the end of the spring runoff period. The long-term forecasts are based on probalistic estimates of the snow, rainfall and temperature.

Also, with the addition of the QFORECAST tool, the model can now be used as an operational tool during the spring season. The procedure is detailed in Section 4.7 of the report.

Simulations with the upgraded model were undertaken to demonstrate that the refined model adequately represented the system. In addition, simulation studies were conducted to test recommended improvements to the operational policies and procedures, as well as flood mitigation.

Updated inventories of the available system data (i.e., streamflow gauges, reservoir and control structure details, etc.) were provided. In addition, the current Reservoir Zone defined water levels were provided.

Recommendations of the review study included:

- Improvements to data acquisition, including installation of remote interrogation equipment at all flow gauges and the installation of electronic water level gauges, with remote interrogation capabilities, on the Reservoir Lakes as resources permit;
- Processing flow and water level data daily and establishing electronic data archives for raw and processed data;
- Calculate weekly natural local inflows for all reservoirs to provide additional historical data for use in further studies of operating policy options;
- Continually assess the realism of model operations and adjust the model as required
- Develop a new module to translate flow releases and lakes levels into structure gate and stoplog settings;
- Continue to develop tools for forecasting the volume of inflow from the spring freshet; and
- Review the potential for reducing minimum flow constraints at Norland and Peterborough, as these strongly influence Reservoir Lake drawdown during the summer season.

AECOM

Appendix B

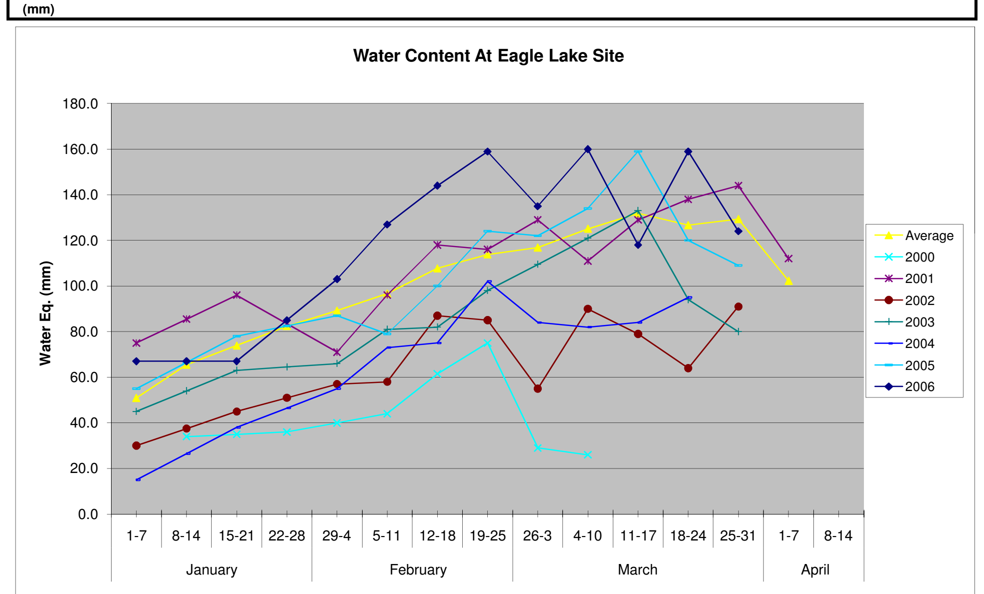
Data Sources and Formats

Eagle Lake Snow Course - Observations

Depth (mm)	January 1-7	8-14	15-21	22-28	February 29-4	5-11	12-18	19-25	March 26-3	4-10	11-17	18-24	25-31	April 1-7	8-14
2010	**356**		328		375	344	341	402							
2009															
2008		271	351	329	431	519	572		433	723	639	661	591	396	
2007			255		245	278	354	327	336	407	319	231			
2006	259	247	234	305	375	499	561	679	683	655	487	473	402		
2005	396	378	359	407	454	376	436	542	585	700	700	619	472		
2004	118	182	245	305	364	407	400	476	323	265	316	342			
2003	258	327	395	402	409	452	460	570	592	614	686	513	278		
2002	156	209	261	271	280	414	431	451	335	312	267	230	372		
2001	377	447	516	587	657	709	532	603	635	679	761	667	571	508	
2000		127	179	231	262	293	359	386	97	71					
1999		441	387	332	335	338	400	354	380	440	367	397	264		
1998	230	324	418	464	510	480	440	462	414	388	412	560			
1997	196	312	428	488	548	660	637	523	580	678	665	762	626	350	256
1996	488	497	506	525	544	441	462	486	424	564	508	402	414	292	243
1995	428	291	153	160	166	218	434	344	351	426	226	26			
1994	243	308	372	391	410	486	539	330	394	354	439	382	286	143	
1993	168			332	460	450	452	622	558	603	651	676	344	294	
1992	135	220	304	329	353	404	487	510	669	377	553	517	392	368	349
1991	175	288	400	464	528	456	385	443	455	395	360	304	276	200	
1990	281	333	384	360	336	381	340	343	485	432	340	134			
1989	248	324	400	397	393	422	520	646	685	614	589	696	293	260	133
1988	370	331	292	275	258	307	451	580	617	536	546	525	310		
1987	327	364	400	467	534	638	582	568	588	454	430	254			
1986			295	371	446	428	454	458	449	440	575	445	378		
1985			354	425	496	479	462	478	494	582	670	609	548	495	441
1984	613	610	606	648	689	590	491	399	306	364	421	398	374		
1983			161	205	248	240	232	231	230						
1982	419	462	504	606	707	713	718	740	762	732	702	683	664	519	374
1981	516	544	572	617	661	660	659								
1980	50	86	122	161	200	210	220	283	346	354	362	287	211		
1979	388	536	684	743	801	813	824	801	778	685	592	424	256		
1978	478	518	558	609	659	655	650	658	666	625	584	610	636		
1977	340	427	513	538	562	581	599	609	618						
Mean (cm)	30.8	34.8	37.3	41.1	44.5	46.5	48.1	49.4	49.3	49.9	50.6	45.8	40.7	34.8	

Water Content (mm)

Water Content (mm)	January 1-7	8-14	15-21	22-28	February 29-4	5-11	12-18	19-25	March 26-3	4-10	11-17	18-24	25-31	April 1-7	8-14
2010	**41**		66		79	83	92	86							
2009															
2008		82	81	93	105	120	143		119	163	171	194	156	121	
2007			26		53	46	50	59	63	74	57	58			
2006	67	67	67	85	103	127	144	159	135	160	118	159	124		
2005	55	67	78	83	87	79	100	124	122	134	159	120	109		
2004	15	27	38	47	55	73	75	102	84	82	84	95			
2003	45	54	63	65	66	81	82	98	110	121	133	94	80		
2002	30	38	45	51	57	58	87	85	55	90	79	64	91		
2001	75	86	96	84	71	96	118	116	129	111	129	138	144	112	
2000		34	35	36	40	44	62	75	29	26					
1999		66	72	78	89	100	96	97	111	112	112	115	84		87
1998	6	48	89	103	116	112	114	127	113	103	130	160			95
1997	36	52	68	84	100	119	125	133	149	171	176	172	163	102	
1996	68	88	108	108	107	104	130	131	139	158	167	153	160	118	95
1995	49	45	41	37	33	46	65	79	76	104	56	8			
1994	24	35	45	45	45	53	65	71	86	83	87	82	91	38	116
1993	34			64	95	95	107	122	127	152	154	176	118	98	
1992	32	48	63	66	69	75	97	115	140	98	148	150	146	132	116
1991	47	62	77	92	107	105	108	124	132	141	124	112	108	65	
1990	41	55	69	73	77	94	91	93	121	109	91	39			
1989	27	41	54	63	72	68	86	110	115	138	135	148	82	88	44
1988	45	54	63	63	62	75	112	144	147	149	158	142	107		
1987	62	74	85	94	102	122	121	125	139	128	124	71			145
1986			76	96	116	114	119	131	130	129	145	148	140		
1985			52	68	84	88	91	108	125	154	182	175	167		
1984	117	127	136	139	141	135	128	121	114	123	131	139	147	149	151
1983			31	38	44	44	43	57	70						
1982	77	91	104	133	161	167	172	180	187	191	194	212	229		
1981	99	118	136	131	125	150	174								
1980	4	18	31	38	45	50	54	56	57	68	78	74	70		
1979	102	124	145	166	187	197	206	193	180	195	210	166	121		
1978	92	114	136	137	138	153	168	166	163	162	161	185	209		
1977	34	62	89	101	112	121	130	144	157						
Mean (mm)	50.9	65.5	73.9	82.4	89.2	96.7	107.7	113.8	116.9	125.1	131.9	126.7	129.4	102.3	

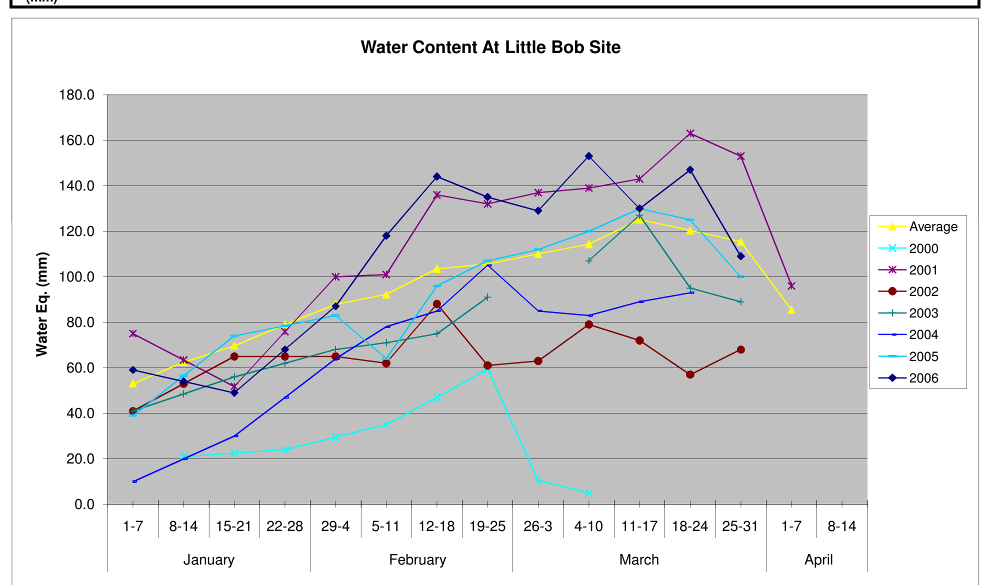


Little Bob Snow Course - Observations

Depth (mm)	January 1-7	8-14	15-21	22-28	February 29-4	5-11	12-18	19-25	March 26-3	4-10	11-17	18-24	25-31	April 1-7	8-14
2010	411		417		491	431	452	480							
2009															
2008		237	321	350	503	550	526		485	680	592	599	507	305	
2007			156		229	270	357	338	351	441	350	292			
2006	191	186	181	257	332	432	561	618	637	607	461	438	366		
2005	353	355	358	404	450	371	417	494	566	630	619	535	416		
2004	45	131	217	306	395	484	423	451	369	291	323	309			
2003	269	334	399	403	407	454	429	629	632	634	726	511	291		
2002	398	358	317	312	306	424	375	363	316	263	297	209	25		
2001	410	463	516	548	579	638	498	532	624	689	737	633	516	409	
2000		84	126	168	199	229	326	356	38	16					
1999		439	386	332	337	342	363	423	326	415	356	292	176		
1998	190	282	373	417	461	422	359	343	307	289	344	460			
1997	209	319	429	479	528	606	610	504	500	600	694	743	512	335	235
1996	425	436	446	423	400	348	418	397	339	507	423	335	314	216	138
1995	228	171	114	104	94	147	367	273	315	354					
1994	232	324	416	414	412	402	501	342	403	376	476	402	312	136	
1993	138			306	452	397	424	593	487	536	610	590	248	258	
1992	155	241	326	335	343	410	432	474	580	318	476	454	311	261	290
1991	173	302	430	482	534	432	374	420	449	387	369	305	324	196	
1990	298	338	378	352	326	403	299	426	454	431	340	100			
1989	214	226	238	259	279	301	400	411	494	495	504	656	284	199	10
1988	324	323	321	280	239	330	446	586	630	546	519	538	361		
1987	274	342	410	446	482	616	558	510	497	406	384	254			
1986			300	373	446	475	480	459	449	439	654	467	391		
1985			298	392	486	464	442	420	398	434	470	441	412	351	290
1984	532	546	559	627	695	625	554	469	383	404	424	367	309		
1983			132	171	209	203	197	194	190						
1982	334	395	456	582	708	701	694	694	694	677	659	675	690	566	442
1981	497	523	549	574	598	622	645								
1980	72	102	131	173	214	209	204	284	364	387	410	295	179		
1979	332	467	602	620	638	676	714	690	666	584	501	347	192		
1978	454	476	497	534	571	578	584	593	601	555	509	511	512		
1977	349	411	472	531	590	590	590	599	607						
Mean (cm)	28.9	32.6	35.2	38.5	42.2	44.2	45.5	46.3	45.6	46.2	49.0	43.5	34.8	29.4	

Water Content (mm)

Water Content (mm)	January 1-7	8-14	15-21	22-28	February 29-4	5-11	12-18	19-25	March 26-3	4-10	11-17	18-24	25-31	April 1-7	8-14
2010	**93**		110		118	108	118	115							
2009															
2008		80	61	87	93	114	136		125	144	156	186	151	108	
2007			19		30	40	55	58	52	89	69	68			
2006	59	54	49	68	87	118	144	135	129	153	130	147	109		
2005	39	57	74	79	83	64	96	107	112	120	130	125	100		
2004	10	20	30	47	64	78	85	105	85	83	89	93			
2003	41	49	56	62	68	71	75	91		107	127	95	89		
2002	41	53	65	65	65	62	88	61	63	79	72	57	68		
2001	75	63	52	76	100	101	136	132	137	139	143	163	153	96	
2000		21	23	24	30	35	47	60	11	5					
1999		65	73	80	88	96	98	104	97	104	115	100	57		66
1998	51	68	85	97	109	112	106	104	93	94	107	129			55
1997	36	54	71	86	101	124	136	132	150	161	180	187	168	86	
1996	73	81	88	89	90	97	110	114	112	144	132	131	112	74	55
1995	34	30	26	20	14	22	52	53	58	70					
1994	30	42	53	68	82	47	58	80	90	74	93	54	89	42	75
1993	26			58	87	90	96	110	107	122	134	142	81	83	
1992	33	49	65	67	68	78	87	114	130	73	128	131	116	90	75
1991	48	69	89	98	107	105	112	115	131	138	134	107	128	71	
1990	43	55	66	72	77	88	84	90	117	117	103	34			
1989	30	38	46	54	62	65	72	58	88	102	82	128	68	55	4
1988	61	65	69	68	67	81	113	130	141	141	153	151	117		
1987	71	73	75	88	101	109	114	107	125	114	123	76			99
1986			81	96	111	95	114	131	131	130	155	138	141		
1985			52	72	92	97	101	108	114	131	147	142	136		
1984	85	94	102	115	128	134	140	126	112	120	127	126	125	149	173
1983			30	40	50	49	48	54	60						
1982	64	86	107	133	159	158	156	166	175	179	183	201	219		
1981	108	117	126	127	128	148	168								
1980	15	29	42	43	44	42	40	56	71	81	90	73	56		
1979	78	101	124	145	166	172	178	185	192	168	144	107	70		
1978	76	106	136	127	117	121	124	132	139	136	132	159	186		
1977	60	73	86	101	116	123	130	144	157						
Mean (mm)	53.1	62.5	69.7	79.0	87.9	92.2	103.5	105.6	110.1	114.3	125.1	120.4	115.4	85.4	

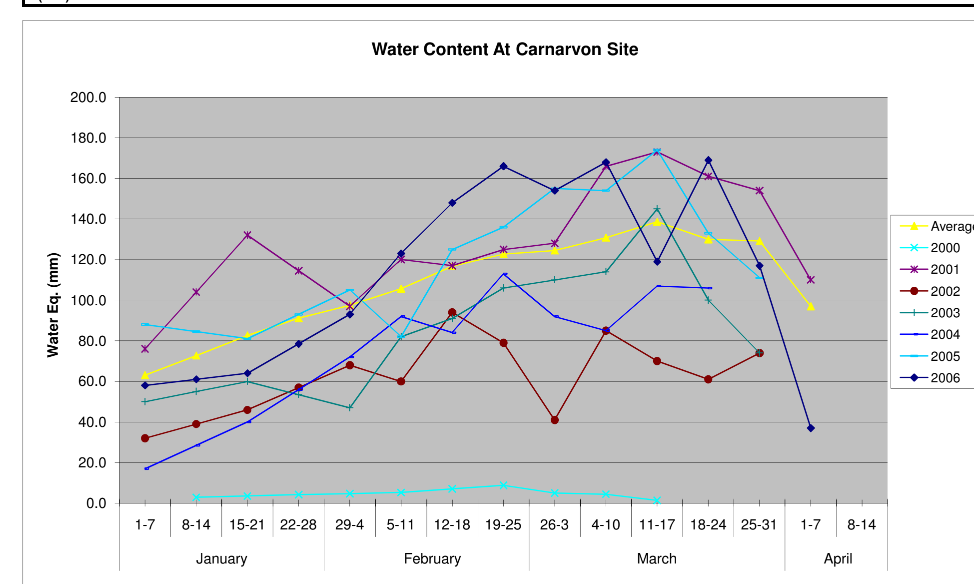


Carnarvon Snow Course - Observations

Depth (mm)	January 1-7	8-14	15-21	22-28	February 29-4	5-11	12-18	19-25	March 26-3	4-10	11-17	18-24	25-31	April 1-7	8-14
2010	449		438		528	418	442	490							
2009															
2008		293	374	429	490	596	556		488	781	621	579	625	436	
2007			213		281	322	451	387	409	493	416	3151			
2006	242	230	218	314	410	533	649	828	788	725	461	540	366	108	
2005	392	405	418	446	474	405	486	544	659	725	714	547	476		
2004	88	168	248	338	428	480	466	539	393	334	423	392			
2003	369	408	447	470	492	535	508	729	729	729	822	591	288		
2002	301	301	301	309	317	469	444	431	345	319	258	250	298		
2001	432	528	623	638	652	720	567	647	73	803	830	680	542	495	
2000		195	236	277	311	344	418	450	178	143	74				
1999		545	474	403	420	436	376	436	396	469	385	373	223		
1998	250	362	474	496	518	504	428	466	417	394	492	534			
1997	266	388	510	598	686	724	724	606	618	784	862	880	672	400	300
1996	480	490	499	573	647	493	560	540	476	596	553	448	419	316	238
1995	552	388	224	227	230	286	572	440	445	541					
1994	287	361	434	455	476	492	558	358	454	394	512	464	312	178	
1993	222			410	566	530	539	728	640	636	722	730	399	336	
1992	142	259	376	399	422	520	546	588	737	418	622	548	424	292	292
1991	216	351	485	563	640	505	427	564	571	466	439	366	388	215	
1990	343	391	438	443	448	468	418	470	613	565	450	212			
1989	310	368	426	453	480	476	622	738	691	696	649	836	335	269	204
1988	495	465	434	390	346	398	575	674	723	647	626	620	387		
1987	344	387	430	501	572	726	626	610	654	455	409	250			
1986			360	438	516	489	551	556	549	542	731	529	436		
1985			389	478	567	538	508	504	500	594	688	620	552	504	455
1984	613	609	604	658	711	645	579	431	282	356	429	376	322		
1983			192	255	317	314	311	306	300						
1982	509	552	595	721	847	837	826	842	858	814	770	773	775	635	494
1981	549	573	597	657	717	708	698								
1980	119	158	196	239	282	293	304	395	486	493	500	405	310		
1979	452	634	815	835	854	864	874	874	874	765	655	476	297		
1978	518	572	626	646	666	646	626	640	654	619	583	604	624		
1977	416	490	564	617	670	709	748	723	697						
Mean (cm)	36.0	40.2	42.7	47.3	51.5	52.8	54.5	56.6	53.9	56.2	56.1	62.1	43.0	34.9	

Water Content (mm)

Water Content (mm)	January 1-7	8-14	15-21	22-28	February 29-4	5-11	12-18	19-25	March 26-3	4-10	11-17	18-24	25-31	April 1-7	8-14
2010	**85**		128		114	115	108	113							
2009															
2008		84	77	112	103	127	145		106	163	148	143	166	137	
2007			23		43	52	68	66	79	100	94	78			
2006	58	61	64	79	93	123	148	166	154	168	119	169	117	37	
2005	88	85	81	93	105	82	125	136	155	154	174	133	111		
2004	17	29	40	56	72	92	84	113	92	85	107	106			
2003	50	55	60	54	47	82	91	106	110	114	145	100	74		
2002	32	39	46	57	68	60	94	79	41	85	70	61	74		
2001	76	104	132	115	97	120	117	125	128	166	173	161	154	110	
2000		3	4	4	5	5	7	9	5	4	1				
1999		9	9	10	10	11	11	11	12	12	13	11	7		
1998	61	79	97	106	115	120	120	132	102	108	155	15			89
1997	40	67	93	108	123	148	135	166	182	200	214	186	182	109	89
1996	70	87	104	111	117	116	149	143	139	172	170	167	139	121	89
1995	60	53	46	49	52	62	98	110	98	146					
1994	32	42	52	60	67	52	56	86	95	60	103	85	96	48	
1993	28			82	114	115	127	144	146	157	175	178	120	108	88
1992	34	56	78	82	86	96	116	138	167	90	163	158	144	98	88
1991	54	75	96	104	111	126	116	145	150	139	130	118	130	71	
1990	42	58	73	89	105	88	106	121	140	140	108	56			
1989	38	53	68	80	91	82	110	103	137	119	118	168	82	72	55
1988	81	91	100	86	71	108	147	155	164	172	183	186	121		
1987	75	84	92	99	105	136	138	141	150	128	120	73			
1986			87	108	129	127	129	153	154	155	168	160	160	156	152
1985			69	85	100	106	111	116	120	157	194	178	161		
1984	105	120	134	144	153	154	154	127	100	111	122	124	125		
1983			38	41	44	50	56	68	80						199
1982	105	120	135	163	191	195	198	208	217	218	219	227	234		
1981	122	130	137	148	158	166	174								
1980	22	37	52	60	68	69	70	88	106	110	113	112	110		
1979	113	142	170	185	200	217	234	207	179	200	220	176	132		
1978	72	108	144	136	128	141	154	156	158	160	162	182	202		
1977	80	99	118	126	134	146	157	175	192						
Mean (mm)	63.1	72.8	82.7	91.2	97.6	105.7	116.8	122.7	124.5	130.8	138.6	130.0	129.1	97.0	

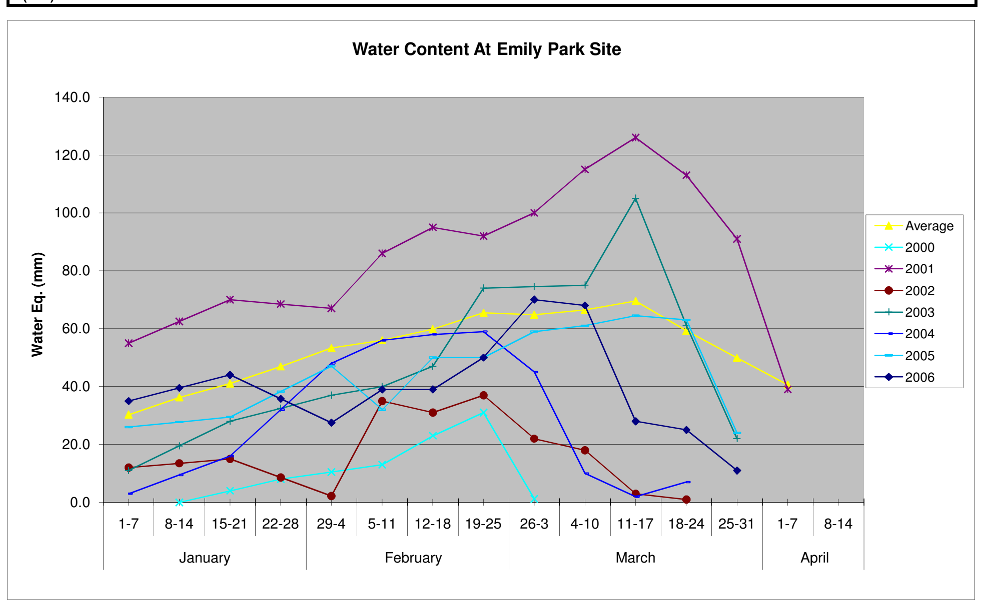


Emily Park Snow Course - Observations

Depth (mm)	January 1-7	8-14	15-21	22-28	February 29-4	5-11	12-18	19-25	March 26-3	4-10	11-17	18-24	25-31	April 1-7	8-14
2010	181		179		160	177	181	249							
2009															
2008		104	196	179	350	344	343		315	622	482	478	375	172	
2007			130		171	235	280	301	332	380	337	196			
2006	145	118	91	91	91	158	176	208	305	258	82	80	27		
2005	153	137	121	168	216	126	172	243	282	239	237	213	77		
2004	24	81	137	225	312	315	298	295	132	43	11	24			
2003	104	142	180	194	207	220	234	362	382	401	510	274	82		
2002	87	102	117	93	68	210	152	184	71	52	15	5			
2001	329	334	338	379	420	455	351	347	367	53	456	392	289	169	
2000		0	31	61	89	117	255	244	3						
1999		345	295	245	245	244	202	187	166	284	198	129	40		
1998	0	60	120	154	188	148	134	138	121	94	84	247			
1997	110	131	151	182	212	223	272	146	108	208	244	278	172		
1996	296	299	302	278	253	212	176	164	114	120	116	80	39		
1995	118	59	0	36	72	100	147	104	137	147					
1994	90	197	303	288	272	262	344	104	136	114	144	109	74		
1993	420			132	184	162	226	464	396	352	401	360	130	60	
1992	76	179	282	264	246	272	288	286	296	100	181	164	57		
1991	24	97	170	174	178	156	114	132	116	79	70	33			
1990	148	152	155	138	121	128	40	156	168	140					
1989	17	82	146	118	89	85	94	161	174	182	163	170			
1988	100	81	62	98	133	144	140	128	186	125	102	88			
1987	204	245	286	318	349	437	409	404	317	212	180	60			
1986	261	168	75	140	204	200	244	222	219	216	268	165	62		
1985			177	238	298	319	339	275	211	233	255	190	125		
1984	274	319	364	400	436	341	246	262	277	274	270	198	126		
1983			90	99	107	107	106	63	20						
1982	142	188	234	336	438	459	480	468	456	413	370	351	332		5
1981	224	262	299	265	230	234	238								
1980	0	0	0	48	96	103	109	142	174	194	214	117	20		
1979	130	183	235	295	354	384	414	389	364	292	220	110	0		
1978	358	378	398	449	500	498	496	513	530	508	485	445	404		
1977	203	269	334	341	348	401	453	395	337						
Mean (cm)	15.6	16.8	18.7	20.7	23.1	24.2	24.7	25.0	23.3	22.6	23.4	19.1	13.5	13.4	

Water Content (mm)

Water Content (mm)	January 1-7	8-14	15-21	22-28	February 29-4	5-11	12-18	19-25	March 26-3	4-10	11-17	18-24	25-31	April 1-7	8-14
2010	**56**		56		54	45	43	59							
2009															
2008		40	32	41	88	73	74		91	122	147	148	137	60	
2007			10		20	28	39	46	55	46	66	47			
2006	35	40	44	36	28	39	39	50	70	68	28	25	11		
2005	26	28	30	38	47	32	50	50	59	61	65	63	24		
2004	3	10	16	32	48	56	58	59	45	10	2	7			
2003	11	20	28	33	37	40	47	74	75	75	105	61	22		
2002	12	14	15	9	2	35	31	37	22	18	3	1			
2001	55	63	70	69	67	86	95	92	100	115	126	113	91	39	
2000		0	4	8	11	13	23	31	1						
1999		47	54	60	62	64	64	63	55	75	31	46	17		
1998	0	13	25	36	47	43	43	51	36	30	29	52			
1997	15	23	30	41	52	46	66	52	42	48	72	81	61		
1996	69	72	75	69	62	64	62	72	39	36	32	24	16		
1995	2	1	0	6	12	15	18	18	24	36					
1994	10	21	31	43	54	40	46	27	34	36	46	37	21		
1993	14			26	44	41	54	85	84	92	111	105	45	23	
1992	22	40	58	58	57	62	78	86	92	50	68	60	25		
1991	3	22	40	42	44	38	36	46	40	38	29	16			
1990	22	30	37	34	31	36	13	32	32	40					
1989	20	26	31	30	28	27	38	44	46	54	42	46			
1988	22	24	26	20	14	18	32	42	48	44	32	48			
1987	64	70	76	85	94	123	116	125	106	90	95	19			
1986	40	35	29	37	44	46	46	58	61	64	84	61	24		
1985			43	56	68	70	72	76	80	91	102	76	50		3
1984	66	71	76	87	98	88	77	64	51	57	62	54	45		
1983			6	14	22	26	30	18	5						
1982	36	43	50	72	94	109	124	128	132	123	113	101	89		
1981	38	49	60	53	46	51	56								
1980	0	0	0	5	10	12	13	26	38	43	48	25	2		
1979	42	52	61	95	128	129	129	139	148	128	108				
1978	102	112	121	139	156	154	151	166	180	172	163	166	168		
1977	33	57	80	86	92	101	110	114	118						
Mean (mm)	30.3	36.3	41.0	46.9	53.3	56.0	59.8	65.4	64.8	66.4	69.6	59.2	49.9	40.7	

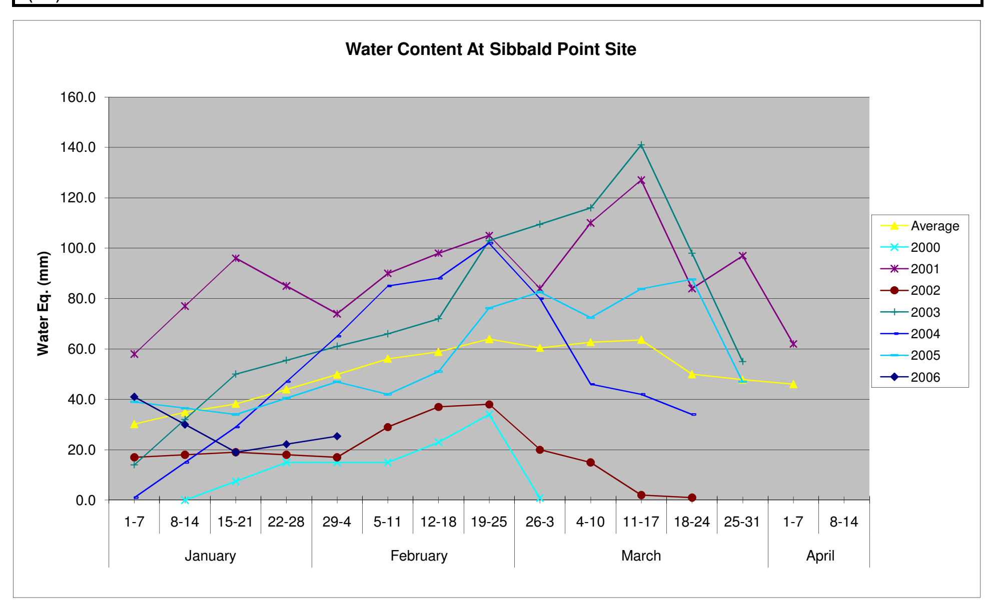


Sibbald Point Snow Coarse - Observations

Depth (mm)	January 1-7	8-14	15-21	22-28	February 29-4	5-11	12-18	19-25	March 26-3	4-10	11-17	18-24	25-31	April 1-7	8-14
2010															
2009															
2008															
2007															
2006	107	78	48	55	62										
2005	150	160	169	195	221	130	125	272	333	263	287	250	119		
2004			178	292	405	404	377	416	231	140	113	93			
2003	113	198	282	266	250	319	349	493	508	522	612	378	122		
2002	70	94	118	86	53	142	121	131	43	41	10	5			
2001	316	321	326	374	422	436	373	381	345	579	431	345	333	206	
2000		0	54	108	132	155	281	257	2						
1999		414	311	208	209	209	141	130	95	222	194	94	44		
1998	0	43	85	119	152	148	95	104	53	38	95	138			
1997	140	168	196	227	258	248	356	239	160	264	328	353	200		
1996	356	347	338	319	300	267	201	188	95	227	188	130	84		
1995	112	56	0	42	84	86	146	133	176	172	131	90			
1994	161	245	328	300	272	285	348	122	168	156	166	122	93		
1993	39			222	243	204	257	485	364	338	361	354	134	88	
1992	49	153	256	236	215	241	232	212	229	56	53	51			
1991	30	111	192	180	168	126	95	133	86	62	48	28			
1990	178	178	177	149	121	153	70	188	201	160	53				
1989	157	160	162	137	112	131	140	200	200	91	310	264			
1988	107	72	36	65	94	169	147	161	198	171	135	126			
1987	128	168	208	257	305	370	317	323	276	147	128	41			
1986			94	167	239	233	296	291	281	271	295	211	78		
1985			168	246	323	333	343	274	204	230	256	164	72		
1984	354	378	401	458	514	357	199	244	288	286	284	226	168		
1983			44	27	10	31	51								
1982	175	245	314	399	484	486	488	495	502	444	385	345	304		
1981	329	354	379	350	320	288	256								
1980	0	0	0	70	139	137	134	176	218	212	206	145	84		
1979	176	283	390	398	405	455	504	434	364	302	240	120	0		
1978	316	323	330	365	400	415	430	457	484	450	415	387	358		
1977	242	315	388	404	420	388	356	338	319						
Mean (cm)	15.9	19.4	20.6	22.4	24.4	25.3	24.9	26.9	23.8	23.4	22.9	18.6	14.6	14.7	

Water Content (mm)

Water Content (mm)	January 1-7	8-14	15-21	22-28	February 29-4	5-11	12-18	19-25	March 26-3	4-10	11-17	18-24	25-31	April 1-7	8-14
2010															
2009															
2008															
2007															
2006	41	30	19	22	25										
2005	39	37	34	41	47	42	51	76	83	72	84	88	47		
2004	1	15	29	47	65	85	88	102	80	46	42	34			
2003	14	32	50	56	61	66	72	103	110	116	141	98	55		
2002	17	18	19	18	17	29	37	38	20	15	2	1			
2001	58	77	96	85	74	90	98	105	84	110	127	84	97	62	
2000		0	8	15	15	15	23	34	1						
1999		38	50	61	64	67	51	42	39	56	56	37	23		
1998	0	5	10	22	33	33	37	36	23	14	22	38			
1997	18	23	27	40	53	53	67	67	55	71	75	88	6		
1996	89	90	90	85	80	79	72	77	41	58	61	45	33		
1995	23	12	0	7	14	15	23	22	38	56	46	36			
1994	11	27	42	47	51	42	50	32	34	41	44	32	24		
1993	10			30	44	53	66	75	79	92	93	100	44	30	
1992	18	32	46	46	46	44	61	51	71	36	16	13			
1991	4	18	32	31	29	36	23	39	18	29	21	13			
1990	39	39	39	30	20	53	19	28	37	38	18	0			
1989	18	22	25	29	32	27	30	33	37	48	69	51			
1988	10	12	13	11	8	23	29	31	42	52	33	33			
1987	46	41	36	47	58	80	78	77	70	47	46	17			
1986			28	38	47	58	69	80	80	80	121	79	22		
1985			25	43	61	65	69	74	78	89	99	64	29		
1984	61	64	66	81	96	78	59	51	42	50	58	58	58		
1983			4	3	1	5	8								
1982	53	53	53	74	94	105	116	125	134	117	100		96		
1981	56	65	74	75	75	82	89								
1980	0	0	0	6	11	13	15	23	30	32	34	32	30		
1979	42	55	68	86	104	120	136	127	117	94	71				
1978	42	49	55	71	86	89	91	98	105	109	112	109	105		
1977	44	58	71	78	84	82	80	82	84						
Mean (mm)	30.2	34.9	38.2	43.9	49.8	56.1	58.9	63.9	60.4	62.7	63.6	49.9	47.8	46.0	



Appendix C

System Characteristics

Table C1a - List of Dam and Reservoir nodes

ID	Node Description	Type of Node	Comment	Drainage Area (ha) Intermediate	Drainage Area (ha) Cumulative	Reservoir range (m) Min	Reservoir range (m) Max	Storage depth	Lake Area (ha)
Gull River Watershed									
1	Kennisis Lake Dam	Dam		147.1	147.1	0.000	2.838	2.838	1649.6
2	Red Pine Lake Dam	Dam		37.9	185	0.000	1.219	1.219	423.5
3	Nunikani Lake Dam	Dam		6.2	191.2	0.305	3.050	2.745	108.6
4	Hawk Lake and Little Brother Lake Dams	Dam		56.7	247.9	0.381	4.420	4.039	806.4
5	Halls Lake Dam	Dam		21.1	269	0.914	2.506	1.592	542.3
6	Kushog Lake Dam	Dam	including St. Nora Lake and Sherborne Lake and Dam	109.1	109.1	1.219	3.101	1.882	1149.9
7	Percy Lake Dam	Dam		72.1	72.1	0.000	1.980	1.980	487.2
8	Oblong Lake Dam	Dam	including Haliburton Lake	77.7	149.9	1.067	3.050	1.983	1007.2
9	Eagle Lake Dam	Dam	including Moose Lake	49.3	199.1	0.457	2.290	1.833	521.1
10	Redstone Lake East and West Dams	Dam		183.2	183.2	0.509	3.660	3.151	1435.8
11	Gull River at Maple Lake	H.ST (H4-1)		126.7	509			0.000	576.4
12	Twelve Mile Lake Dam	Dam	including Boshkung, Little Boshkung and Beech Lakes	72.1	959.3	0.457	1.980	1.523	1306.1
13	Horseshoe Lake Dam	Dam	including Mountain Lake	50.1	1009.4	0.457	2.440	1.983	620.6
14	Bob Lake Dam	Dam		38	38	0.000	2.900	2.900	230.3
15	Little Bob Lake Dam	Dam		6.5	44.5	0.000	1.524	1.524	86.1
16	Gull Lake Dams 1 & 2	Dam		178.8	1232.6	1.219	2.130	0.911	1067.8
17	Moore Lake Dam and Norland Dam (Elliott Falls)	Dam, H.ST (H4)		63.3	1295.9	0.914	1.520	0.606	207.9
18	Coboconk Dam	Dam	including Silver and Shadow Lakes	60.2	1356.2	?	?		450.2
Burnt River Watershed									
19	Drag Lake Dams North & South	Dam		129	129	0.457	2.198	1.741	1105.7
20	Canning Lake Dams 1 & 2	Dam	including Kashagawigamog Lake	170.3	299.3	0.457	1.467	1.010	1548.6
21	Long Lake Dam	Dam	including Miskwabi Lake	21.3	21.3	0.305	2.290	1.985	346.1
22	Loon Lake Dam	Dam		43.3	64.7	0.610	1.953	1.343	248.1
23	Koshlong Lake Dam	Dam		29.1	29.1	0.610	2.290	1.680	403.9
24	Burnt River at Gelert	H.ST (H5-1)		129.7	522.7				
25	Farquhar Lake Dam	Dam		20.7	20.7	0.610	2.977	2.367	340.3
26	Pusey Lake Dam	Dam	including Grace Lake	44.1	64.8	0.457	2.028	1.571	277.8
27	Esson Lake Dam	Dam		24	24	0.914	3.050	2.136	241.4
28	Little Glamor Lake Dam	Dam		26	26	0.000	1.830	1.830	69
29	Glamor Lake Dam	Dam		6.6	32.6	0.701	2.440	1.739	198.6
30	Gooderham Lake Dam	Dam		27.2	59.8	0.610	1.830	1.220	88.6
31	Contau Lake Dam	Dam		5.3	5.3	0.457	1.680	1.223	135.1
32	White Lake Dam	Dam	including Salmon Lake	50.6	50.6	0.000	1.830	1.830	166.5
33	Irondale River at Furnace Falls	H.ST (H5-2)		326.1	530.7				
34	Kinmount Dam (MNR)	Dam, H.ST (H5)		211.7	1265	?	?		
Jacks Creek									
35	Jack Lake Dam	Dam		81.9	81.9	0.381	1.930	1.549	1329.4
Mississagua River									
36	Anstruther Lake Dam	Dam		89.9	89.9	0.000	2.290	2.290	629.4
37	Mississagua Lake Dam	Dam		209.5	299.3	0.000	2.591	2.591	2233.5
38	Mississagua River below Mississagua Lake	H.ST (H8)		6.2	305.6				
Eels Creek									
39	Eels Lake Dams 1 & 2	Dam		106	106	0.00	3.66	3.66	932.7
40	Eels Creek below Apsley	H.ST (H7)		153.4	259.3				
Nogies Creek									
41	Crystal Lake Dam	Dam		45.6	45.6	0.61	2.74	2.13	476
Kawartha Lakes									
42	Dam at Lock 35 (Rosedale) - Balsam Lake	Dam		282.5	1638.6	255.25	256.19	0.94	4793.1
43	Dam at Lock 34 (Fenelon Falls) - Cameron Lake	Dam		344.1	3247.7	254.60	255.04	0.44	1437.7
44	Dam at Lock 33 (Lindsay) - Lake Scugog	Dam		1014	1014	249.44	249.92	0.48	6745.4
45	Dam at Lock 32 (Bobcaygeon) and Little Bob Channel Dam - Sturgeon Lake	Dam		566.4	4828.2	247.22	247.76	0.54	4787.5
46	Dam at Lock 31 (Buckhorn) - Buckhorn Lake	Dam	including Chemong, Pigeon, Little Bald and Big Bald Lakes	1127.5	6001.3	244.87	246.08	1.21	12316.2
47	Dams at Lock 30 (Lovesick) - Dams 1, 2, 3, 4, 5, 6 & 7 - Lower Buckhorn Lake	Dam	including Scott Mills Dam (no reservoir) on Missisagua River	286.2	6593.1	241.50	242.64	1.14	1273.9
48	Dams at Lock 28 (Burleigh Falls) - Lovesick Lake	Dam	including Perrys Creek Dams 1, 2 & 3	8.7	6601.8	240.40	241.47	1.07	256.1
49	Dam at Lock 27 (Young's Point) - Stony Lake, Clear Lake	Dam	including Gilchrist Bay Dam	342.86	7285.8	233.42	234.35	0.93	3834.5
50	Dam at Lock 26 (Lakefield) - Katchewanooka Lake	Dam, H.ST (H3)		93.4	7379.2	231.50	232.02	0.52	403.7
Otonabee River									
51	Dam at Lock 19 (Scotts Mills) - Little Lake	Dam	including Dam at Lock 20 (Ashburnham), Dam at Lock 21 (Peterborough Lift Locks), Dam at Lock 22 (Nassau Mills), Dam at Lock 23 (Otonabee), Dam at Lock 24 (Douro), Dam at Lock 25 (Sawyer Creek)	288.1	7667.3	187.97	189.17	1.20	176.5
52	Otonabee River at Rice Lake	-		507.7	8175.1				
Crowe River									
53	Crowe River at Marmora	Dam, H.ST (H6)		1893.8	1893.8				
Rice Lake									
54	Dam at Lock 18 (Hastings) and Hastings Side Dams	Dam		906.3	9081.4	186.59	186.72	0.13	9597.5
Trent River									
55	Dam at Locks 16/17 (Healey Falls) - Seymour Lake	Dam, H.ST (H2)	including Dam at Lock 15 (Healey Falls)	156.1	9237.5	183.69	183.99	0.30	1267.8
56	Dam 8 at Lock 9 (Meyers)	Dam	including Dam 9 at Lock 10 (Hagues Reach), Dam 10 at Locks 11/12 (Ranney Falls), Trout Creek Aqueduct, Dam 11 at Lock 13 (Campbellford) and Dam 12 at Lock 14 (Crowe Bay)	157.2	11288.5	123.83	124.29	0.46	400.8
57	Dam 7 at Lock 7 (Glen Ross)	Dam, H.ST (H1)		727	12015.5	113.32	113.47	0.15	1195.4
58	Dam 5 at Lock 5 (Trent)	Dam	including Dam 6 at Lock 6 (Frankford) and Sill Island Dam C	485	12500.5	105.04	105.49	0.45	460.4
59	Dam 1 at Lock 1 (Trenton)	Dam	including Dam 2 at Lock 2 (Sidney), Dam 3 at Lock 3 (Glen Miller), Dam 4 at Lock 4 (Batawa) and Sonoco Papermill Dam	22.8	12523.3	79.95	80.10	0.15	129.1

(grey shading) No dam or not managed by PCA, node not used for WM

H.ST Hydrometric Station, as listed in Flood Flows Estimation Study Report

Table C1b - Detailed Reservoir Characteristics

Trent-Severn Waterway
Haliburton Sector
Reservior Lake Control Parameters

	Drainage Area (sq km)	Lake Area (ha)	Full Control Level	Target Percent (%)	Crest Level (m)	Sill or Deduction (m)	Max. Storage Depth(m)	Max. Storage (ha-m)	Reason for reduced Traget Percentage			
Gull River Watershed												
Kennisis Lake	174	1641	2.896	98	2.838	0.000	2.838	4657	the dam sits on sand			
Red Pine	39.5	385	1.219	100	1.219	0.000	1.219	469				
Nunikani Lake	7.4	109	3.050	100	3.050	0.305	2.745	299				
Hawk Lake	62.5	842	4.420	100	4.420	0.381	4.039	**2748**				
Halls Lake	21.5	529	2.590	95	2.506	0.914	1.592	842	100% was felt to be too high for residents			
Trout Lake	21.5	245	1.520	100	1.520	0.000	1.520	372				
Kushog Lake	111	915	3.200	95	3.101	1.219	1.882	1722	100% was felt to be too high for residents			
Percy Lake	74	563	1.980	100	1.980	0.000	1.980	1115				
Oblong Lake	77	1094	3.050	100	3.050	1.067	1.983	2169				
Redstone East Lake	169	1422	3.660	100	3.660	0.509	3.151	4481				
Redstone West Lake												
Eagle Lake	44	515	2.290	100	2.290	0.457	1.833	944				
Gull River @ Maple Lake												
Twelve Mile	29	1161	1.980	100	1.980	0.457	1.523	**1666**				
Horseshoe Lake	46.6	556	2.440	100	2.440	0.457	1.983	**833**				
Big Bob	32.3	226	2.900	100	2.900	0.000	2.900	655				
Little Bob	13.5	73	1.524	100	1.524	0.000	1.524	111				
Gull Lake	167	998	2.130	100	2.130	1.219	0.911	909				
Moore Lake	42.2	194	1.520	100	1.520	0.914	0.606	118		Drainage	Lake Area	Storage
Gull River @ Norland										Area		
Total	**1132**	**11468**						**24111**		4.93	5.32	5.46
Burnt River Watershed												
Drag Lake	121	1102	2.290	95	2.198	0.457	1.741	1919	100% was felt to be too high for residents			
Canning Lake	168	1274	1.520	95	1.467	0.457	1.010	1287	100% was felt to be too high for residents			
Miskwabi Lake	20.2	335	2.290	100	2.290	0.305	1.985	665				
Loon Lake	45.7	254	1.980	98	1.953	0.610	1.343	341	100% was felt to be too high for residents			
Koshlong Lake	30.1	405	2.290	100	2.290	0.610	1.680	680				
Burnt River @ Gelert												
Farquhar Lake	29.5	345	3.050	97	2.977	0.610	2.367	817	100% was felt to be too high for residents			
Grace Lake	47.2	295	2.060	98	2.028	0.457	1.571	463	100% was felt to be too high for residents			
Esson Lake	20.2	236	3.050	100	3.050	0.914	2.136	504				
Little Glamor Lake	26.8	63	1.830	100	1.830	0.000	1.830	115				
Big Glamor Lake	4.7	187	2.440	100	2.440	0.701	1.739	325				
Gooderham Lake	41.2	85	1.830	100	1.830	0.610	1.220	104				
Contau Lake	5.4	119	1.680	100	1.680	0.457	1.223	146				
White Lake	54	160	1.830	100	1.830	0.000	1.830	293				
Irondale @ Furnace Falls												
Burnt River @ Burnt River												
Total	**614**	**4860**						**7659**		2.68	2.25	1.73
Nogies Creek Watershed												
Crystal Lake	50	449	2.740	100	2.740	0.610	2.130	956		0.22	0.21	0.22
Mississagua River Watershed												
Anstruther Lake	93	621	2.290	100	2.290	0.000	2.290	1422				
Mississagua Lake	218	2061	2.591	100	2.591	0.000	2.591	**5021**				
Total	**311**	**2682**						**6443**		1.36	1.24	1.46
Eels Creek Watershed												
Eels Lake	104	815	3.660	100	3.660	0.000	3.660	2983		0.45	0.38	0.68
Jack Creek Watershed												
Jack Lake	83	1296	1.930	100	1.930	0.381	1.549	2008		0.36	0.60	0.45
Reservior Total	**2294**	**21570**						**44160**		10.00	10.00	10.00

Drainage	**Area**	**(sq km)**	Drainage area surrounding a particular lake
Lake	**Area**	**(ha)**	The surface area of the lake.
Full	**Control**	**Level**	The depth of water the dams were originally constructed to retain.
Target	**Percent**	**(%)**	Some lakes have a reduced target, either because the dam sits on sand (Kennisis) or the residences felt the 100% was too high so the 'full' level was reduced.
Crest	**Level**	**(m)**	The 100% sotrage depth multiplied by the target % plus the sill or deduction.
Sill or	**Deduction**	**(m)**	The elevation of the sill of the dam or the elevation of the rock control upstream of the dam. Each reduces the amount of water that is available to run through the dam.
Max.	**Storage**	**Depth(m)**	The difference between the target percentage and the sill or deduction at the site.
Max.	**Storage**	**(ha-m)**	The actual volume of water available to maintain navigation along the canal route.

Table C2 – Reservoir Winter Stoplog Settings

Name	Winter Stoplog Setting
Gull River Watershed	
Kennisis Lake	3
Red Pine	1
Nunikani Lake	2
Hawk Lake	5
Halls Lake	4
Trout Lake	0
Kushog Lake	4
Percy Lake	1
Oblong Lake	4
Redstone East Lake	4
Redstone West Lake	3
Eagle Lake	2
Twelve Mile	3
Horseshoe Lake	4
Big Bob	3
Little Bob	0
Gull Lake	2
Moore Lake	8
Burnt River Watershed	
Drag Lake	4
Canning Lake	2
Miskwabi Lake	5
Loon Lake	2
Koshlong Lake	3
Farquhar Lake	6
Grace Lake	2
Esson Lake	4
Little Glamor Lake	0
Big Glamor Lake	2
Gooderham Lake	3
Contau Lake	2
White Lake	1
Nogies Creek Watershed	
Crystal Lake	2
Mississauga River Watershed	
Anstruther Lake	2.5
Mississagua Lake	2
Eels Creek Watershed	
Eels Lake	4
Jack Creek Watershed	
Jack Lake	2

Table C3 – Navigational Water Levels

Lock Name	Lock Number	Lake Name (where applicable)	Max Water Elevation (m)	Min Water Elevation(m)
			1978 GSC	
Trenton	Lock 1		80.1	79.95
Sydney	Lock 2		86.29	85.83
Glen Miller	Lock 3		94.54	94.38
Batawa	Lock 4		99.99	99.84
Trent	Lock 5		105.49	105.04
Frankford	Lock 6		110.39	110.09
Glen Ross	Lock 7	Percy Reach	113.47	113.32
Percy Reach	Lock 8		119.38	119.23
Meyers	Lock 9		124.29	123.83
Hagues Reach	Lock 10		131.61	131.15
Ranney Falls	Lock 11/12		146.21	145.76
Campbellford	Lock 13		153.24	152.78
Crowe Bay	Lock 14		160.85	160.7
Healey Falls	Lock 15		167.52	167.37
Healey Falls	Lock 16/17	Seymour	183.99	183.69
Hastings	Lock 18	Rice Lake	186.72	186.59
Scott's Mills	Lock 19	Little Lake	189.17	189.01
Ashburnham	Lock 20		192.72	192.52
Peterborough Liftlock	Lock 21		212.58	212.48
Nassau Mils	Lock 22		216.7	216.62
Otonabee	Lock 23		220.33	220.17
Bouro	Lock 24		223.99	223.84
Sawer Creek	Lock 25		227.14	226.98
Lakefileld	Lock 26	Katchewanooka	232.02	231.92
Young's Point	Lock 27	Stony/Clear	234.35	234.05
Burleigh Falls	Lock 28	Lovesick	241.47	241.42
Lovesick	Lock 30	Lower Buckhorn	242.64	242.56
Buckhorn	Lock 31	Buckhorn/Pigeon/Chemong	246.08	245.92
Bobcaygeon	Lock 32	Sturgeon	247.76	247.73
Lindsay	Lock 33	Scugog	249.92	249.78
Fenelon Falls	Lock 34	Cameron	255.04	254.96
Rosedale	Lock 35	Balsam	256.19	256.16
Kirkfield Lift lock	Lock 36	Mitchell	256.19	256.16
Bolsover	Lock 37	Canal	241.25	241.15
Talbot	Lock 38		234.68	234.58
Portage	Lock 39		230.44	230.34
Thorah	Lock 40			226.04
Gamebridge	Lock 41			221.82
Couchiching	Lock 42	Couchiching/Simcoe	219.06	218.69
Swift Rapids	Lock 43	Sparrow	212.48	212.36
Big Chute	Marine Railway		198.21	198.06
Six Mile Lake	Six Mile Dam	Six Mile	186.43	185.67
Port Severn	Lock 45	Gloucester Pool	180.5	180.42

Table C4a – Water Level Change vs. Discharge

North Sector												
Level Change (cm)	**Gloucester (2690 ha)**		**Six Mile (1785 ha)**		**Big Chute (437 ha)**		**Sparrow (1190 ha)**		**Wasdell (82 ha)**		**Simcoe (76285 ha)**	
	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)
1	3.11	74.7	2.07	49.6	0.51	12.1	1.38	33.1	0.09	2.3	88	
2	6.23	149.4	4.13	99.2	1.01	24.3	2.75	66.1	0.19	4.6	177	
3	9.34	224.2	6.2	148.8	1.52	36.4	4.13	99.2	0.28	6.8	265	
4	12.45	298.9	8.26	198.3	2.02	48.6	5.51	132.2	0.38	9.1	353	
5	15.57	373.6	10.33	247.9	2.53	60.7	6.89	165.3	0.47	11.4	441	
6	18.68		12.4		3.03		8.26		0.57		530	
7	21.79		14.46		3.54		9.64		0.66		618	
8	24.91		16.53		4.05		11.02		0.76		706	
9	28.02		18.59		4.55		12.4		0.85		795	
10	31.13		20.66		5.06		13.77		0.95		883	
11	24.25		22.73		5.56		15.15		1.04		971	
12	37.36		24.79		6.07		16.53		1.14		1060	
13	40.47		26.86		6.58		17.91		1.23		1148	
14	43.59		28.92		7.08		19.28		1.33		1236	
15	46.7		30.99		7.59		20.66		1.42		1324	
16	49.81		33.06		8.09		22.04		1.52		1413	
17	52.93		35.12		8.6		23.41		1.61		1501	
18	56.04		37.19		9.1		24.79		1.71		1589	
19	59.16		39.25		9.61		26.17		1.8		1679	
20	62.27		41.32		10.12		27.55		1.9		1766	

North Sector												
Level Change (cm)	**Lock 39 (20.4 ha)**		**Lock 38 (22 ha)**		**Canal (886 ha)**		**Mitchell (363 ha)**		**Balsam (4745 ha)**		**Cameron (1450 ha)**	
	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)
1	0.0	0.6	0.0	0.6	1.03	24.60	0.42	10.10	5.5	131.8	1.7	40.3
2	0.0	1.1	0.1	1.2	2.05	49.20	0.84	20.20	11.0	263.6	3.4	80.6
3	0.1	1.7	0.1	1.8	3.08	73.80	1.23	30.30	16.5	395.4	5.0	120.8
4	0.1	2.3	0.1	2.4	4.10	98.40	1.68	40.30	22.0	527.2	6.7	161.1
5	0.1	2.8	0.1	3.1	5.13	123.10	2.10	50.40	27.5	659.0	8.4	201.4
6	0.1	3.4	0.2	3.7	6.15		2.52		33.0		10.1	
7	0.2	4.0	0.2	4.3	7.18		2.94		38.4		11.7	
8	0.2	4.5	0.2	4.9	8.20		3.36		43.9		13.4	
9	0.2	5.1	0.2	5.5	9.23		3.78		49.4		15.1	
10	0.2	5.7	0.3	6.1	10.25		4.20		54.9		16.8	
11	0.3	6.2	0.3	6.7	11.28		4.62		60.4		18.5	
12	0.3	6.8	0.3	7.3	12.31		5.04		65.9		20.1	
13	0.3	7.4	0.3	7.9	13.33		5.46		71.4		21.8	
14	0.3	7.9	0.4	8.6	14.36		5.88		76.9		23.5	
15	0.4	8.5	0.4	9.2	15.38		6.30		82.4		25.2	
16	0.4	9.1	0.4	9.8	16.41		6.72		87.9		26.9	
17	0.4	9.6	0.4	10.4	17.43		7.14		93.4		28.5	
18	0.4	10.2	0.5	11.0	18.46		7.56		98.9		30.2	
19	0.4	10.8	0.5	11.6	19.48		7.98		104.3		31.9	
20	0.5	11.3	0.5	12.2	20.51		8.40		109.8		33.6	

Table C4a – Water Level Change vs. Discharge

Kawarthas												
Level Change (cm)	**Scugog (6354 ha)**		**Sturgeon (4562 ha)**		**Buckhorn (12186 ha)**		**Lower Buck. (1250 ha)**		**Lovesick (226 ha)**		**Stony (3733 ha)**	
	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)
1	7.4	176.5	5.3	126.7	14.1	338.5	1.4	34.7	0.3	7.4	4.3	103.7
2	14.7	353	10.6	253.4	28.2		2.9	69.4	0.6	14.8	8.6	207.4
3	22.1	529.5	15.8	380.2	42.3		4.3	104.2	0.9	22.2	13	311.1
4	29.4	706	21.1	506.9	56.4		5.8	138.9	1.2	29.6	17.3	414.8
5	36.8	882.5	26.4	633.6	70.5		7.2	173.6	1.5	36.9	21.6	518.5
6	44.1		31.7		84.6		8.7		1.8		25.9	
7	51.5		37		98.7		10.1		2.2		30.2	
8	58.8		42.2		112.8		11.6		2.5		34.6	
9	66.2		47.5		126.9		13		2.8		38.9	
10	73.5		52.8		141		14.5		3.1		43.2	
11	80.9		58.1		155.1		15.9		3.4		47.5	
12	88.3		63.4		169.3		17.4		3.7		51.8	
13	95.6		68.6		183.4		18.8		4		56.2	
14	103		73.9		197.5		20.3		4.3		60.5	
15	110.3		79.2		211.6		21.7		4.6		64.8	
16	117.7		84.5		225.7		23.1		4.9		69.1	
17	125		89.8		239.8		24.6		5.2		73.5	
18	132.4		95		253.9		26		5.5		77.8	
19	139.7		100.3		268		27.5		5.8		82.1	
20	147.1		105.6		282.1		28.9		6.2		86.4	

Kawarthas														
Level Change (cm)	**Katch. (379 ha)**		**Lock 25 (30.7 ha)**		**Lock 24 (11.9 ha)**		**Lock 23 (33.6 ha)**		**Lock 22 (8.3 ha)**		**Nassau (65.7 ha)**		**Little Lake (82.3 ha)**	
	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)
1	0.4	10.5	0.04	0.9	0.01	0.3	0.04	0.9	0.01	0.2	0.08	1.8	0.1	2.3
2	0.9	21.1	0.07	1.7	0.03	0.7	0.08	1.9	0.02	0.5	0.15	3.7	0.19	4.6
3	1.3	31.6	0.11	2.6	0.04	1.0	0.12	2.8	0.03	0.7	0.23	5.5	0.29	6.9
4	1.8	42.1	0.14	3.4	0.06	1.3	0.16	3.7	0.04	0.9	0.3	7.3	0.38	9.1
5	2.2	52.6	0.18	4.3	0.07	1.7	0.19	4.7	0.05	1.2	0.38	9.1	0.48	11.4
6	2.6		0.21	5.1	0.08	2.0	0.23	5.6	0.06	1.4	0.46	11	0.57	13.7
7	3.1		0.25	6	0.1	2.3	0.27	6.5	0.07	1.6	0.53	12.8	0.67	16
8	3.5		0.28	6.8	0.11	2.6	0.31	7.5	0.08	1.8	0.61	14.6	0.76	18.3
9	3.9		0.32	7.7	0.12	3.0	0.35	8.4	0.09	2.1	0.68	16.4	0.86	20.6
10	4.4		0.36	8.5	0.14	3.3	0.39	9.3	0.1	2.3	0.76	18.3	0.95	22.9
11	4.8		0.39	9.4	0.15	3.6	0.43	10.3	0.11	2.5	0.84	20.1	1.05	25.1
12	5.3		0.43	10.2	0.17	4.0	0.47	11.2	0.12	2.8	0.91	21.9	1.14	27.4
13	5.7		0.46	11.1	0.18	4.3	0.51	12.1	0.12	3	0.99	23.7	1.24	29.7
14	6.1		0.5	11.9	0.19	4.6	0.54	13.1	0.13	3.2	1.06	25.6	1.33	32
15	6.6		0.53	12.8	0.21	5.0	0.58	14	0.14	3.5	1.14	27.4	1.43	34.3
16	7		0.57		0.22	5.3	0.62	14.9	0.15	3.7	1.22	29.2	1.52	36.6
17	7.5		0.6		0.23	5.6	0.66	15.9	0.16	3.9	1.29	31	1.62	38.9
18	7.9		0.64		0.25	6.0	0.7	16.8	0.17	4.2	1.37	32.9	1.71	41.2
19	8.3		0.68		0.26	6.3	0.74	17.7	0.18	4.4	1.44	34.7	1.81	43.4
20	8.6		0.71		0.28	6.6	0.78	18.7	0.19	4.6	1.52	36.5	1.91	45.7

Table C4a – Water Level Change vs. Discharge

South Sector

Level Change (cm)	Rice (10123 ha)		Lock 17 (1335 ha)		Lock 14 (194 ha)		Lock 13 (37.6 ha)		Lock 12 (53.4 ha)		Lock 10 (29.1 ha)		Lock 9 (49.6 ha)	
	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)
1	11.7	281.2	1.55	37.1	0.22	5.4	0.04	1	0.06	1.5	0.03	0.8	0.06	1.4
2	23.4		3.09	74.2	0.45	10.8	0.09	2.1	0.12	3	0.07	1.3	0.11	2.7
3	35.1		4.64	111.3	0.67	16.2	0.13	3.1	0.19	4.5	0.1	2.4	0.17	4.1
4	46.9		6.18	148.3	0.9	21.6	0.17	4.2	0.25	5.9	0.13	3.2	0.23	5.4
5	58.6		7.73	185.4	1.12	26.9	0.22	5.2	0.31	7.4	0.17	4	0.28	6.8
6	70.3		9.29		1.35		0.26	6.3	0.37	8.9	0.2	4.9	0.34	8.1
7	82		10.82		1.57		0.3	7.3	0.43	10.4	0.24	5.7	0.39	9.5
8	93.7		12.36		1.8		0.35	8.4	0.49	11.9	0.28	6.5	0.45	10.8
9	105.4		13.91		2.02		0.39	9.4	0.56	13.4	0.3	7.3	0.51	12.2
10	117.2		15.45		2.25		0.44	10.4	0.62	14.8	0.34	8.1	0.56	13.5
11	128.9		17		2.47		0.48	11.5	0.68	16.3	0.37	8.9	0.62	14.9
12	140.6		18.54		2.69		0.52	12.5	0.74	17.8	0.4	9.7	0.68	16.2
13	152.3		20.09		2.92		0.57	13.6	0.8	19.3	0.44	10.5	0.73	17.6
14	164		21.63		3.14		0.61	14.6	0.87	20.8	0.47	11.3	0.79	18.9
15	175.7		23.18		3.37		0.65	15.7	0.93	22.3	0.51	12.1	0.84	20.3
16	187.5		24.72		3.59		0.7		0.99		0.54		0.9	
17	199.2		26.27		3.82		0.74		1.05		0.57		0.66	
18	210.9		27.81		4.04		0.78		1.11		0.61		1.01	
19	222.6		29.36		4.27		0.83		1.17		0.64		1.07	
20	234.3		30.9		4.49		0.87		1.24		0.67		1.13	

South Sector

Level Change (cm)	Lock 7 (1447 ha)		Lock 6 (348 ha)		Lock 5 (33.6)		Lock 4 (29.9 ha)		Lock 3 (25.9 ha)		Lock 2 (43.3 ha)		Lock 1 (16.2 ha)	
	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)
1	1.71	41	0.4	9.7	0.04	0.9	0.03	0.8	0.03	0.7	0.05	1.2	0.02	0.5
2	3.42	82.1	0.81	19.3	0.08	1.9	0.07	1.7	0.06	1.4	0.1	2.4	0.04	0.9
3	5.13	123.1	1.21	29	0.12	2.8	0.1	2.5	0.09	2.2	0.15	3.6	0.06	1.4
4	6.84	164.1	1.61	38.7	0.16	3.7	0.14	3.3	0.12	2.9	0.2	4.8	0.08	1.8
5	8.55	205.1	2.01	48.3	0.19	4.7	0.17	4.2	0.15	3.6	0.25	6	0.09	2.3
6	10.26		2.42		0.23	5.6	0.21	5	0.18	4.3	0.3	7.2	0.11	2.7
7	11.97		2.82		0.27	6.5	0.24	5.8	0.21	5	0.35	8.4	0.13	3.2
8	13.68		3.22		0.31	7.5	0.28	6.6	0.24	5.8	0.4	9.6	0.15	3.6
9	15.39		3.63		0.35	8.4	0.31	7.5	0.27	6.5	0.45	10.8	0.17	4.1
10	17.09		4.03		0.39	9.3	0.35	8.3	0.3	7.2	0.5	12	0.19	4.5
11	18.8		4.43		0.43	10.3	0.38	9.1	0.33	7.9	0.55	13.2	0.21	5
12	20.51		4.83		0.47	11.2	0.42	10	0.36	8.6	0.6	14.4	0.23	5.4
13	22.22		5.24		0.51	12.1	0.45	10.8	0.39	9.4	0.65	15.6	0.24	5.9
14	23.93		5.64		0.54	13.1	0.48	11.6	0.42	10.1	0.7	16.8	0.26	6.3
15	25.64		6.04		0.58	14	0.52	12.5	0.45	10.8	0.75	18	0.28	6.8
16	27.35		6.44		0.62		0.55		0.48		0.8		0.3	
17	29.06		6.85		0.66		0.59		0.51		0.85		0.32	
18	30.77		7.25		0.7		0.62		0.54		0.9		0.34	
19	32.48		7.65		0.74		0.66		0.57		0.95		0.36	
20	34.19		8.06		0.78		0.69		0.6		1		0.38	

Table C4a – Water Level Change vs. Discharge

Haliburton Sector																		
Level Change (cm)	Kennisis (1641 ha)		Red Pine (385 ha)		Nunikani Lake (109 ha)		Hawk Lake (842 ha)		Halls Lake (529 ha)		Trout Lake (245 ha)		Kushog Lake (915 ha)		Percy Lake (563 ha)		Oblong Lake (1094 ha)	
	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)
1	1.9	45.6	0.45	10.7	0.13	3	0.97	23.4	0.61	14.7	0.28	6.8	1.06	25.4	0.65	15.6	1.27	30.4
2	3.8	91.2	0.89	21.4	0.25	6.1	1.95	46.8	1.22	29.4	0.57	13.6	2.12	50.8	1.3	31.3	2.53	60.8
3	5.7	136.8	1.34	23.4	0.38	9.1	2.92	70.2	1.84	44.1	0.85	20.4	3.18	76.3	1.95	46.9	3.8	91.2
4	7.6	182.3	1.78	42.8	0.5	12.1	3.9	93.6	2.45	58.8	1.13	27.2	4.24	101.7	2.61	62.6	5.06	121.6
5	9.5	227.9	2.23	53.5	0.63	15.1	4.87	116.9	3.06	73.5	1.42	34	5.3	127.1	3.26	78.2	6.33	151.9
6	11.4		2.67		0.76		5.85		3.67		1.7		6.35		3.91		7.6	
7	13.3		3.12		0.88		6.82		4.29		1.98		7.41		4.56		8.86	
8	15.19		3.56		1.01		7.8		4.9		2.27		8.47		5.21		10.13	
9	17.09		4.01		1.14		8.77		5.51		2.55		9.53		5.86		11.4	
10	18.99		4.46		1.26		9.75		6.12		2.84		10.59		6.52		12.66	
11	20.89		4.9		1.39		10.72		6.73		3.12		11.65		7.17		13.93	
12	22.79		5.35		1.51		11.69		7.35		3.4		12.71		7.82		15.19	
13	24.69		5.79		1.64		12.67		7.96		3.69		13.77		8.47		16.46	
14	26.59		6.24		1.77		13.64		8.57		3.97		14.83		9.12		17.73	
15	28.49		6.68		1.89		14.62		9.18		4.25		15.89		9.77		18.99	
16	30.39		7.13		2.02		15.59		9.8		4.54		16.94		10.43		20.26	
17	32.29		7.58		2.14		16.57		10.41		4.85		18		11.08		21.53	
18	34.19		8.02		2.27		17.54		11.02		5.1		19.06		11.73		22.79	
19	36.09		8.47		2.4		18.52		11.63		5.39		20.12		12.38		24.06	
20	37.99		8.91		2.52		19.49		12.25		5.67		21.18		13.03		25.32	

Haliburton Sector																		
Level Change (cm)	**Redstone (1422 ha)**		**Eagle Lake (515 ha)**		**Twelve Mile (1161 ha)**		**Horseshoe (556 ha)**		**Big Bob (226 ha)**		**Little Bob (73 ha)**		**Gull Lake (998 ha)**		**Moore (194 ha)**		**Norland (5.5 ha)**	
	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)
1	1.65	39.5	0.6	14.3	1.34	32.3	0.64	15.4	0.26	6.3	0.08	2	1.16	27.7	0.22	5.4	0.01	0.2
2	3.29	79	1.19	28.6	2.69	64.5	1.29	30.9	0.52	12.6	0.17	4.1	2.31	55.4	0.45	10.8	0.01	0.3
3	4.94	118.5	1.79	42.9	1.03	96.8	1.93	46.3	0.78	18.8	0.25	6.1	3.47	83.2	0.67	16.2	0.02	0.5
4	6.58	158	2.38	57.2	5.38	129	2.57	61.8	1.05	25.1	0.34	8.1	4.62	110.9	0.9	21.6	0.03	0.6
5	8.23	197.5	2.98	71.5	6.72	161.3	3.22	77.2	1.31	31.4	0.42	10.1	5.78	138.6	1.12	26.9	0.03	0.8
6	9.88		3.58		8.06		3.86		1.57		0.51		6.93		1.35		0.04	
7	11.52		4.17		9.41		4.5		1.83		0.59		8.09		1.57		0.04	
8	13.17		4.77		10.75		5.15		2.09		0.68		9.24		1.8		0.05	
9	14.81		5.36		12.09		5.79		2.35		0.76		10.4		2.02		0.06	
10	16.46		5.96		13.44		6.44		2.62		0.84		11.55		2.25		0.06	
11	18.1		6.56		14.78		7.08		2.88		0.93		12.71		2.47		0.07	
12	19.75		7.15		16.13		7.72		3.14		1.01		13.86		2.69		0.08	
13	21.4		7.75		17.47		8.37		3.4		1.1		15.02		2.92		0.08	
14	23.04		8.34		18.81		9.01		3.66		1.18		16.17		3.14		0.09	
15	24.69		8.94		20.16		9.65		3.92		1.27		17.33		3.37		0.1	
16	26.33		9.54		21.5		10.3		4.19		1.35		18.48		3.59		0.1	
17	27.98		10.13		22.84		10.94		4.45		1.44		19.64		3.82		0.11	
18	29.63		10.73		24.19		11.58		4.71		1.52		20.79		4.04		0.11	
19	31.27		11.33		25.53		12.23		4.97		1.61		21.95		4.27		0.12	
20	32.92		11.92		26.88		12.87		5.23		1.69		23.1		4.49		0.13	

Table C4a – Water Level Change vs. Discharge

Haliburton Sector

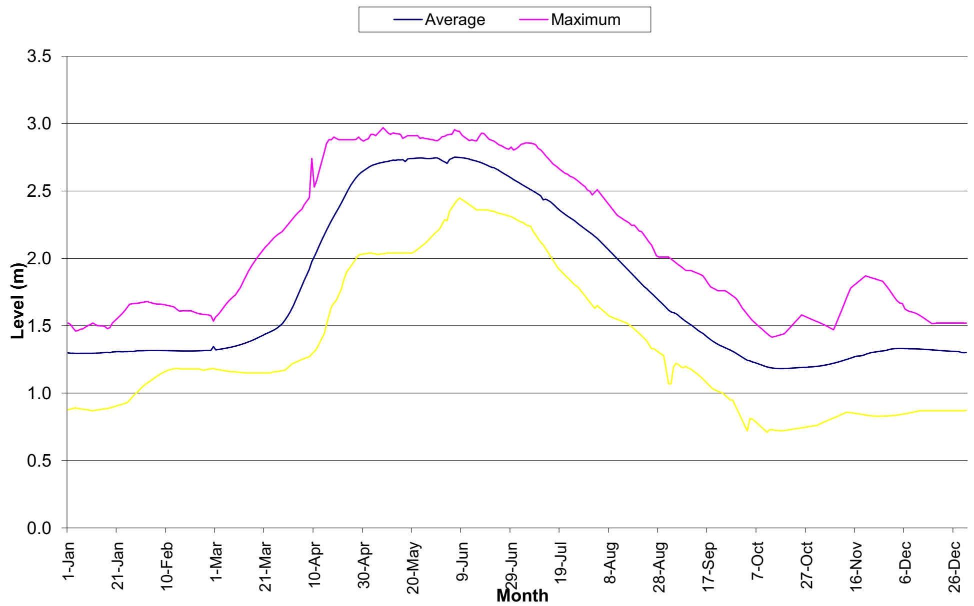
Level Change (cm)	Drag Lake (1102 ha)		Canning Lake (1274 ha)		Miskwabi (335 ha)		Loon Lake (254 ha)		Koshlong Lake (405 ha)		Farquhar Lake (345 ha)		Grace Lake (295 ha)		Esson Lake (236 ha)		Little Glamor Lake (63 ha)	
	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)
1	1.28	30.6	1.47	35.4	0.39	9.3	0.29	7.1	0.47	11.3	0.4	9.6	0.34	8.2	0.27	6.6	0.07	1.8
2	2.55	61.2	2.95	70.8	0.78	18.6	0.59	14.1	0.94	22.5	0.8	19.2	0.68	16.4	0.55	13.1	0.15	3.5
3	3.83	91.8	4.42	106.2	1.16	27.9	0.88	21.2	1.41	33.8	1.2	28.8	1.02	24.6	0.82	19.7	0.22	5.3
4	5.1	122.4	5.9	141.6	1.55	37.2	1.18	28.2	1.88	45	1.6	38.3	1.37	32.8	1.09	26.2	0.29	7
5	6.38	153.1	7.37	176.9	1.94	46.5	1.47	35.3	2.34	56.3	2	47.9	1.71	41	1.37	32.8	0.36	8.8
6	7.65		8.85		2.33		1.76		2.81		2.4		2.05		1.64		0.44	
7	8.93		10.32		2.71		2.06		3.28		2.8		2.39		1.91		0.51	
8	10.2		11.8		3.1		2.35		3.75		3.19		2.73		2.19		0.58	
9	11.48		13.27		3.49		2.65		4.22		3.59		3.07		2.46		0.66	
10	12.75		14.75		3.88		2.94		4.69		3.99		3.41		2.73		0.73	
11	14.03		16.22		4.27		3.23		5.16		4.39		3.76		3		0.8	
12	15.31		17.69		4.65		3.53		5.63		4.79		4.1		3.28		0.88	
13	16.58		19.17		5.04		3.82		6.09		5.19		4.44		3.55		0.95	
14	17.86		20.64		5.43		4.12		6.56		5.59		4.78		3.82		1.02	
15	19.13		22.12		5.82		4.41		7.03		5.99		5.12		4.1		1.09	
16	20.41		23.59		6.2		4.7		7.5		6.39		5.46		4.37		1.17	
17	21.68		25.07		6.59		5		7.97		6.79		5.8		4.64		1.24	
18	22.96		26.54		6.98		5.29		8.44		7.19		6.15		4.92		1.31	
19	24.23		28.02		7.37		5.59		8.91		7.59		6.49		5.19		1.39	
20	25.51		29.49		7.75		5.88		9.38		7.99		6.83		5.46		1.46	

Haliburton Sector

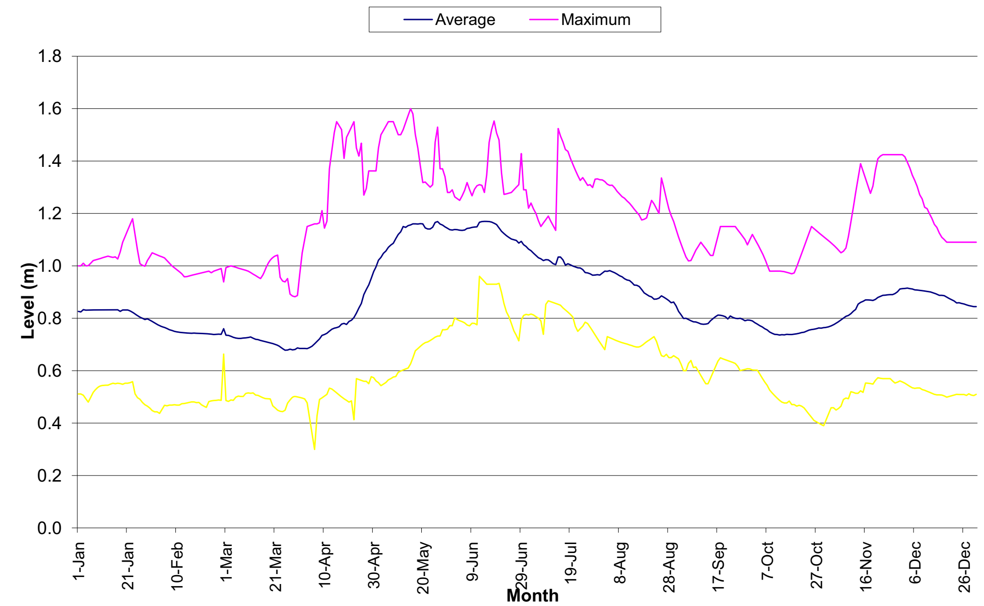
Level Change (cm)	Big Glamor (187 ha)		Gooderham Lake (85 ha)		Contau Lake (119 ha)		White Lake (160 ha)		Crystal Lake (449 ha)		Anstruther Lake (621 ha)		Mississauga L (2061 ha)		Eels Lake (815 ha)		Jack Lake (1296 ha)	
	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)	Day (m^3/s)	Hour (m^3/s)
1	0.22	5.2	0.1	2.4	0.14	3.3	0.19	4.4	0.52	12.5	0.72	17.3	2.39	57.3	0.94	22.6	1.50	36.00
2	0.43	10.4	0.2	4.7	0.28	6.6	0.37	8.9	1.04	24.9	1.44	34.5	4.77	114.5	1.89	45.3	3.00	72.00
3	0.65	15.6	0.3	7.1	0.41	9.9	0.56	13.3	1.56	37.4	2.16	51.8	7.16	171.8	2.83	67.9	4.50	108.00
4	0.87	20.8	0.39	9.4	0.55	13.2	0.74	17.8	2.08	49.9	2.88	69	9.54	229	3.77	90.6	6.00	144.00
5	1.08	26	0.49	11.8	0.69	16.5	0.93	22.2	2.6	62.4	3.59	86.3	11.93	286.3	4.72	113.2	7.50	180.00
6	1.3		0.59		0.83		1.11		3.12		4.31		14.31		5.66		9.00	
7	1.52		0.69		0.96		1.3		3.64		5.03		16.7		6.6		10.50	
8	1.73		0.79		1.1		1.48		4.16		5.75		19.08		7.55		12.00	
9	1.95		0.89		1.24		1.67		4.68		6.47		21.47		8.49		13.50	
10	2.16		0.98		1.38		1.85		5.2		7.19		23.85		9.43		15.00	
11	2.38		1.08		1.52		2.04		5.72		7.91		26.24		10.38		16.50	
12	2.6		1.18		1.65		2.22		6.24		8.63		28.63		11.32		18.00	
13	2.81		1.28		1.79		2.41		6.76		9.34		31.01		12.26		19.50	
14	3.03		1.38		1.93		2.59		7.28		10.06		33.4		13.21		21.00	
15	3.25		1.48		2.07		2.78		7.8		10.78		35.78		14.15		22.50	
16	3.46		1.57		2.2		2.96		8.31		11.5		38.17		15.09		24.00	
17	3.68		1.67		2.34		3.15		8.83		12.22		40.55		16.04		25.50	
18	3.9		1.77		2.48		3.33		9.35		12.94		42.94		16.98		27.00	
19	4.11		1.87		2.62		3.52		9.87		13.66		45.32		17.92		28.50	
20	4.33		1.97		2.75		3.7		10.39		14.38		47.71		18.87		30.00	

Table C4b - Average 20-year Lake Levels

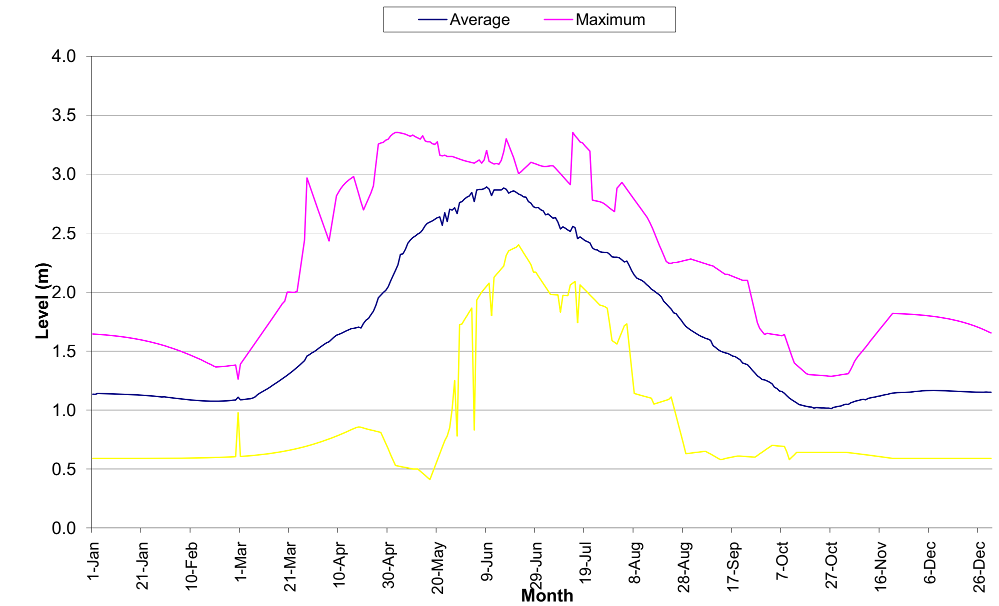
Kennisis Lake Levels



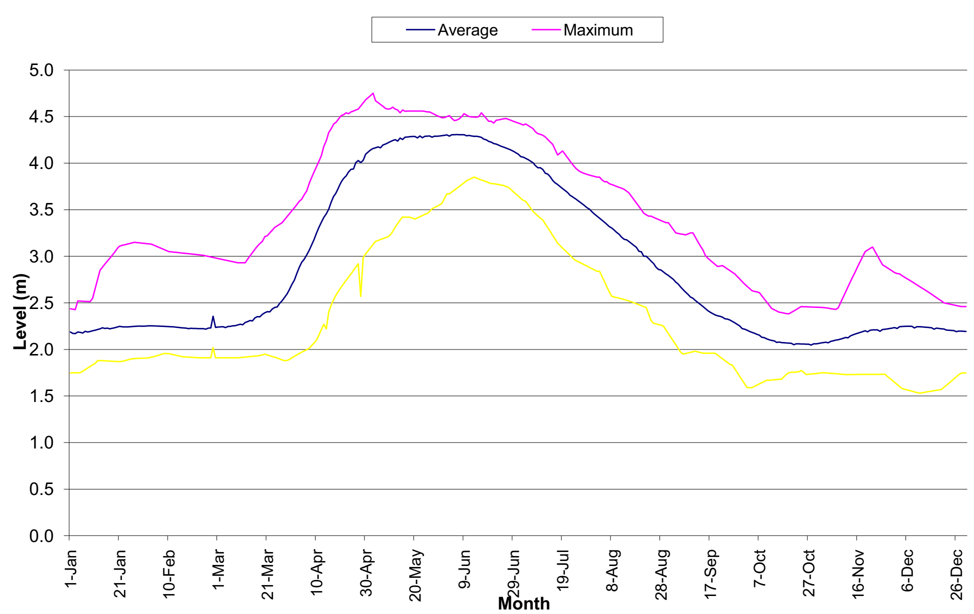
Redpine Lake Levels



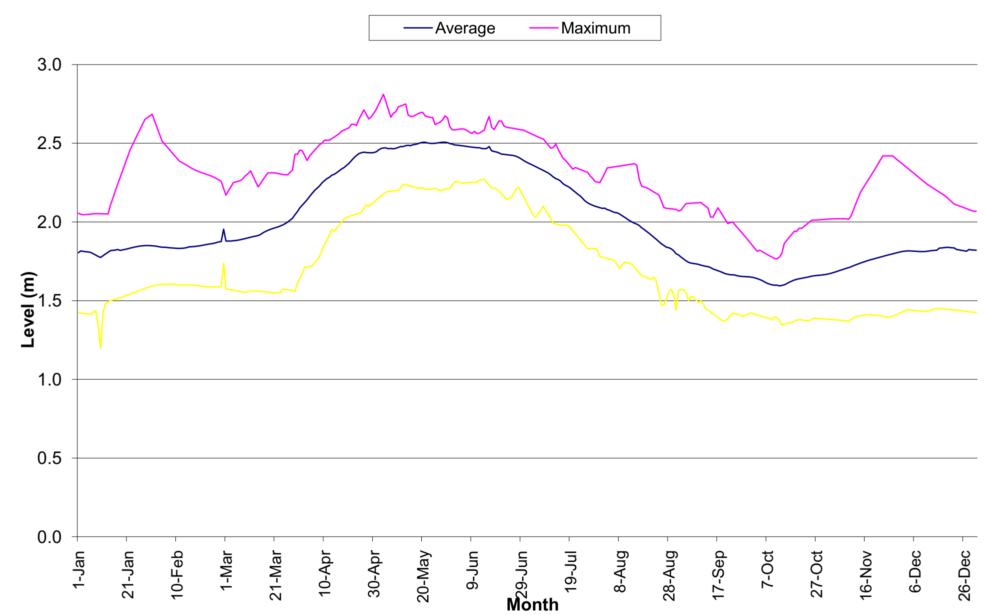
Nunikani Lake Levels



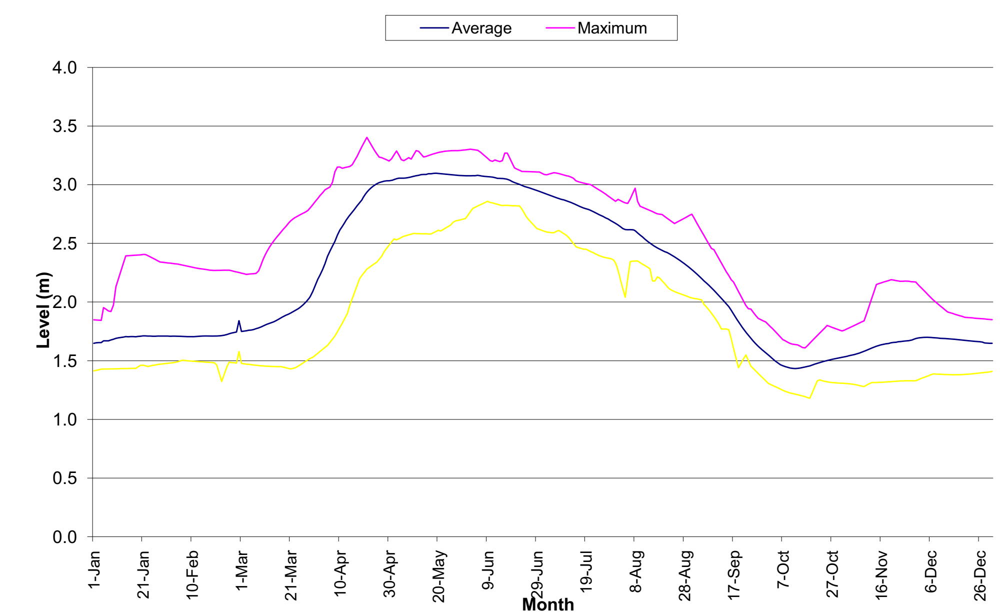
Hawk Lake Levels



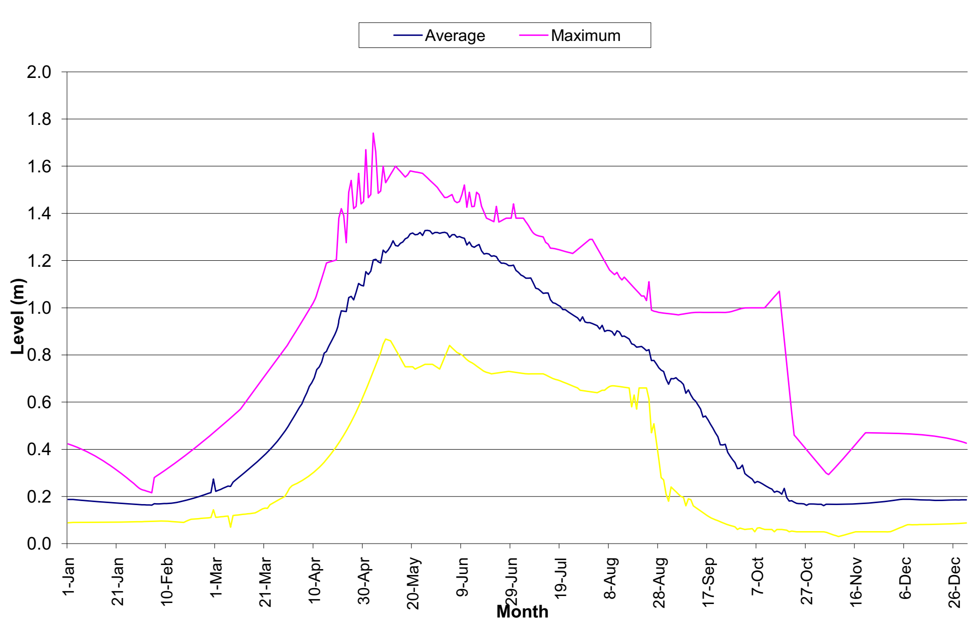
Halls Lake Levels



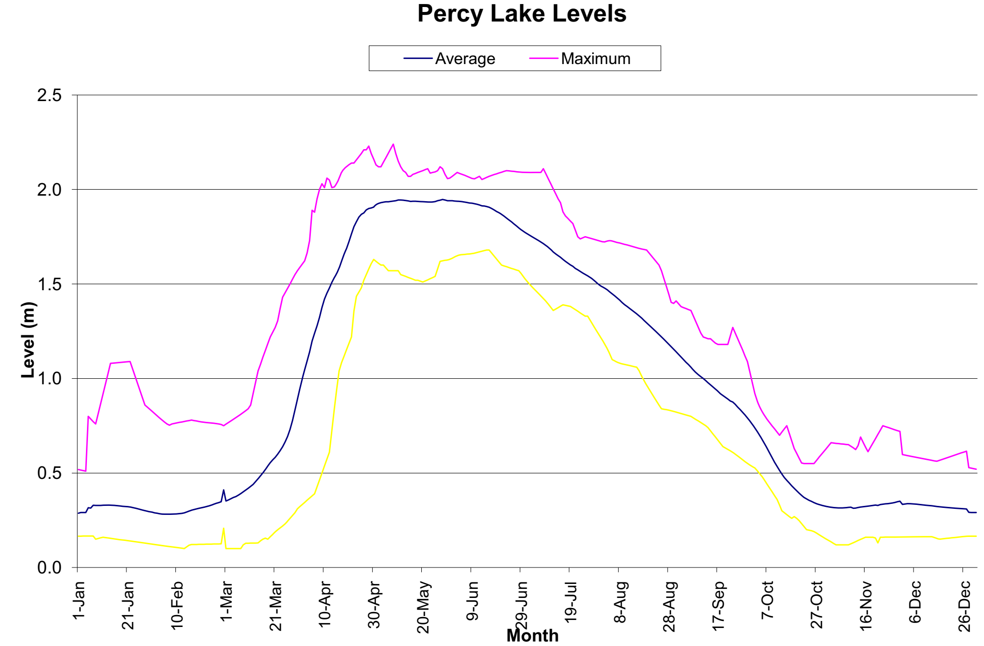
Kushog Lake Levels



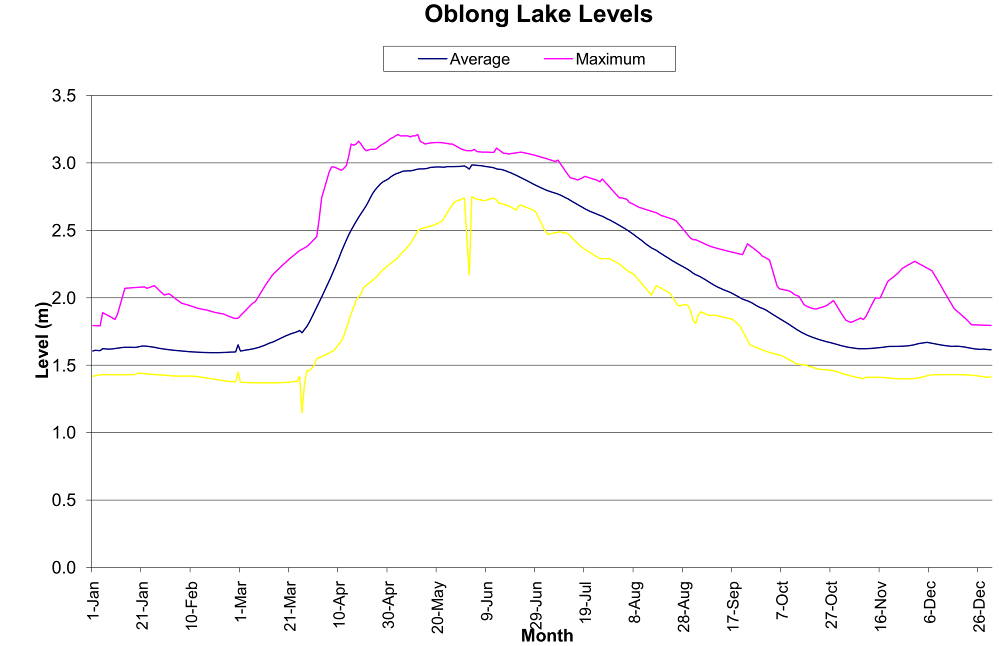
Trout Lake Levels

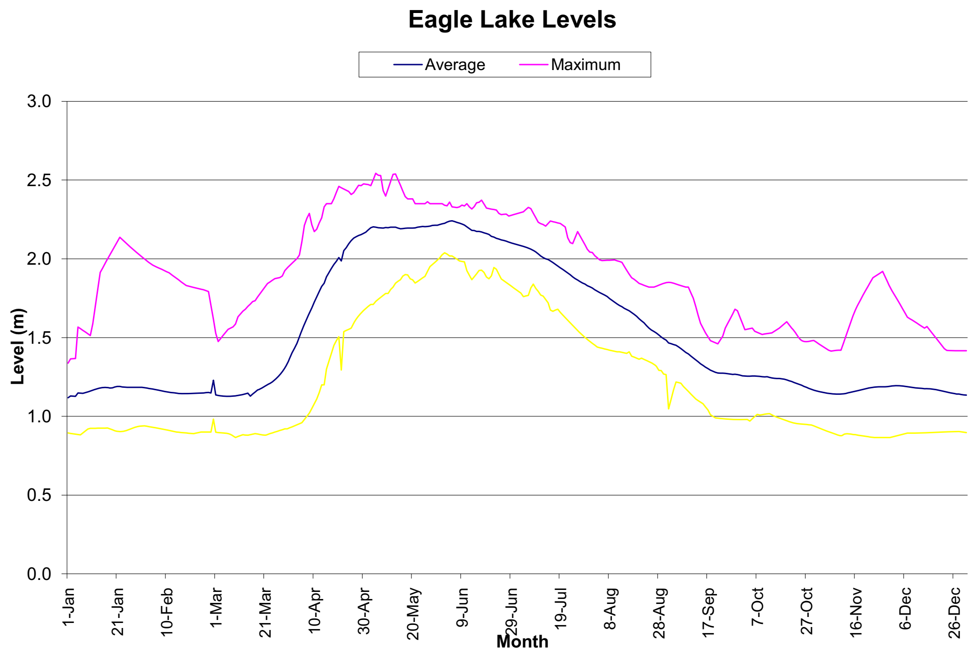


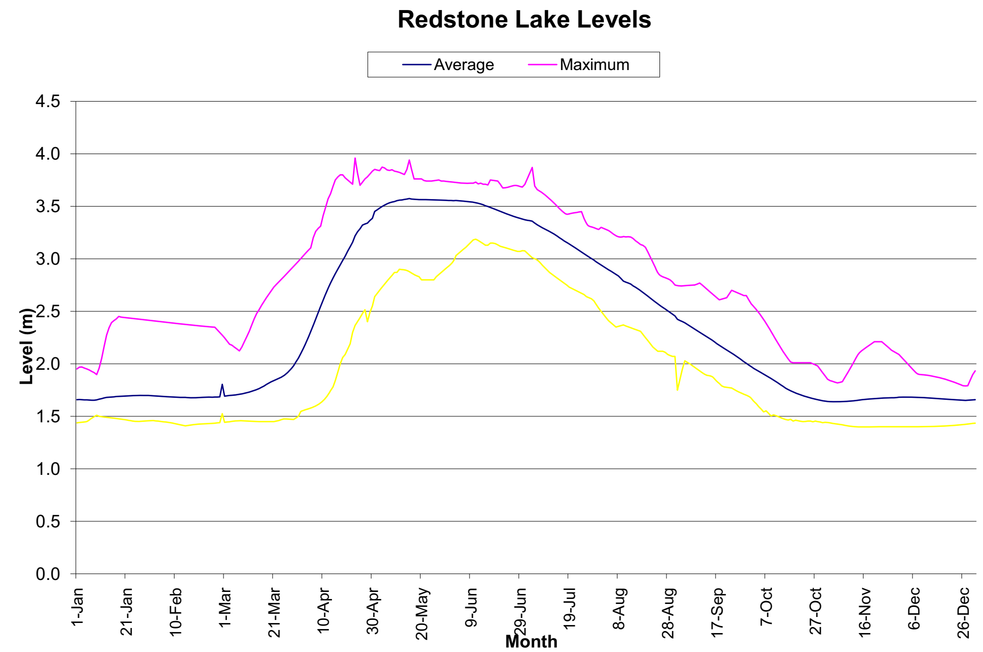
Percy Lake Levels

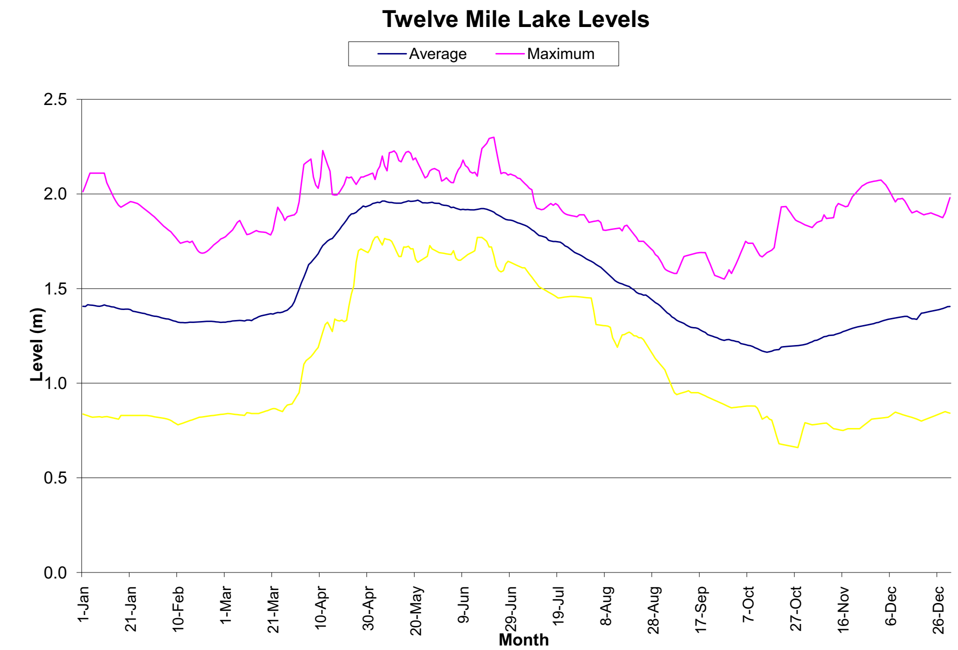


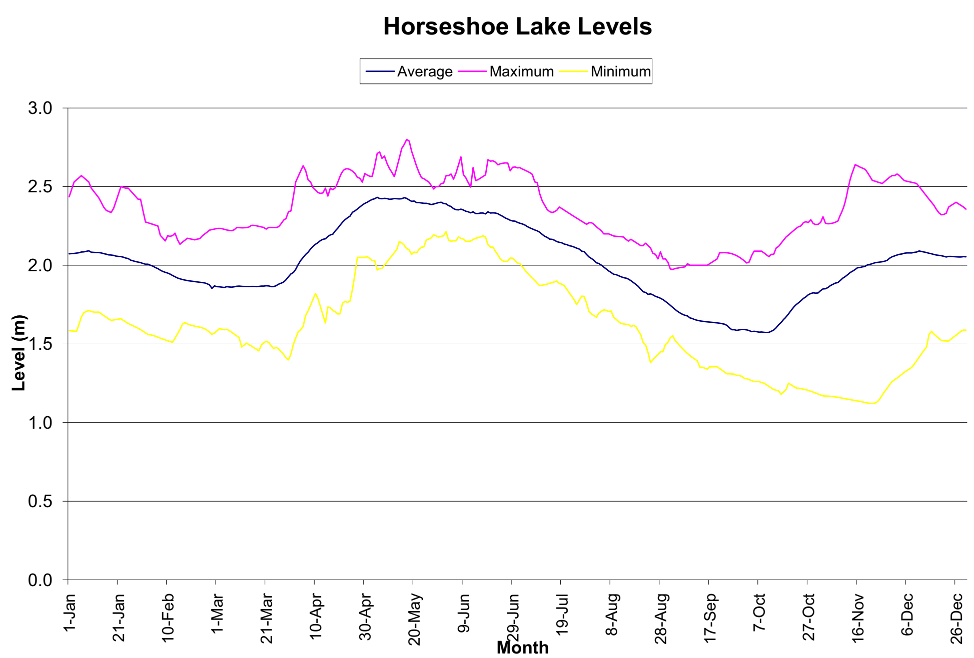
Oblong Lake Levels

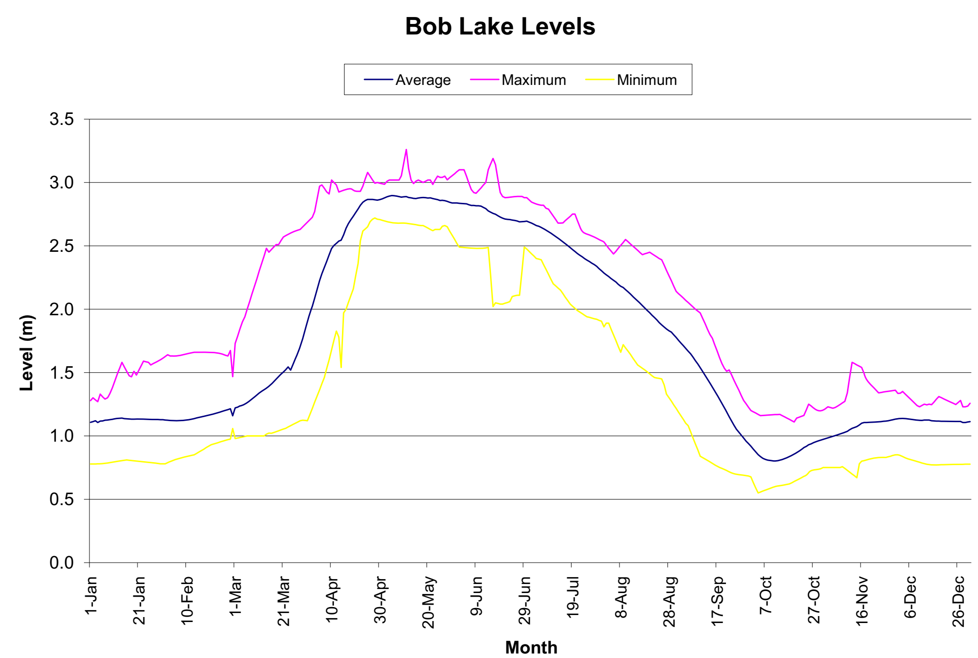


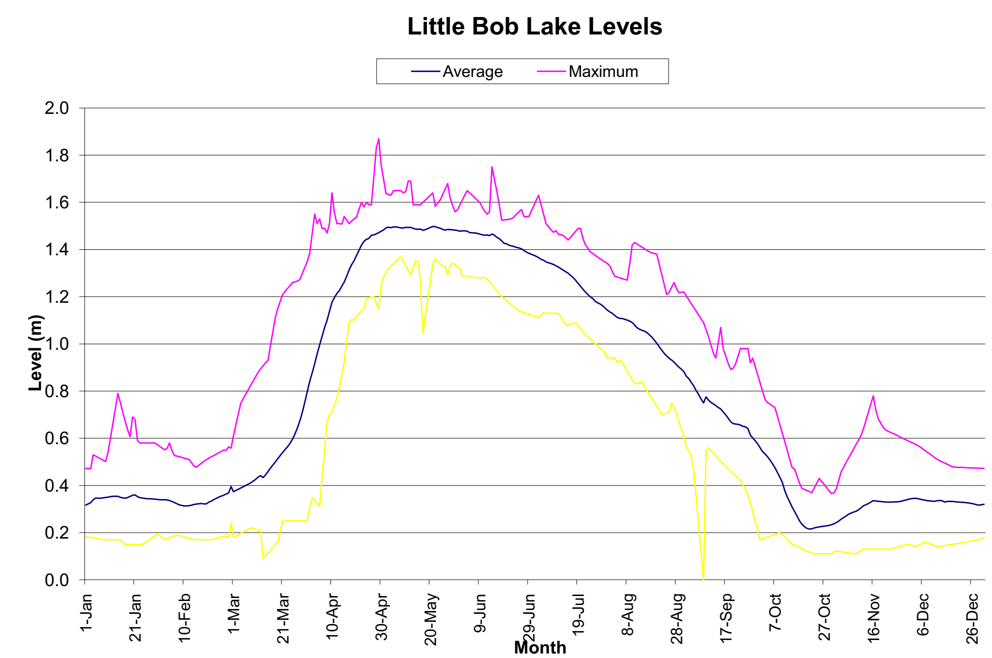

Eagle Lake Levels
Average
Maximum
Level (m)
Month

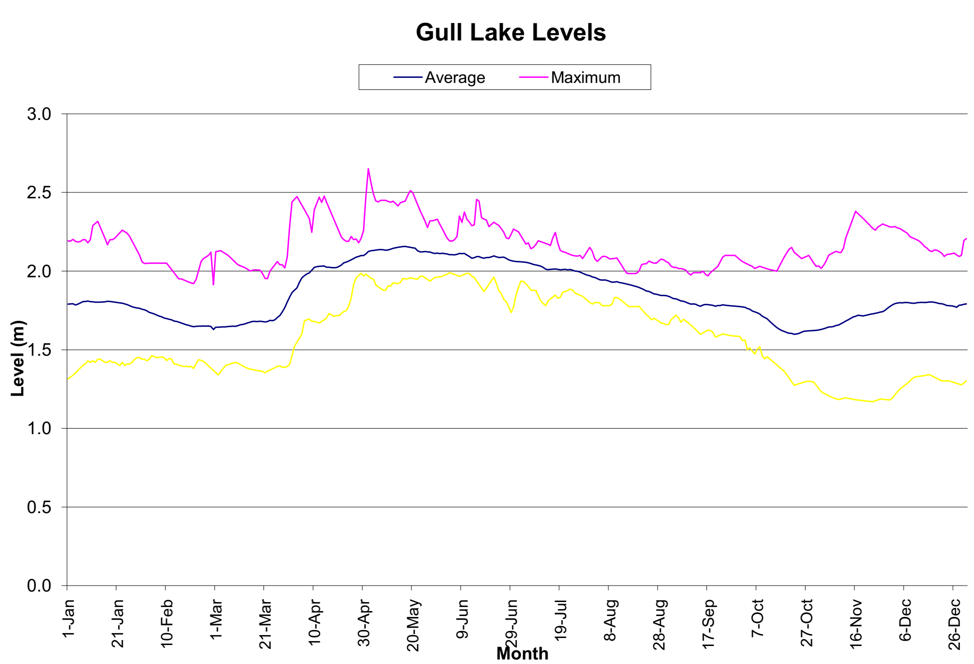

Redstone Lake Levels
Average
Maximum
Level (m)
Month

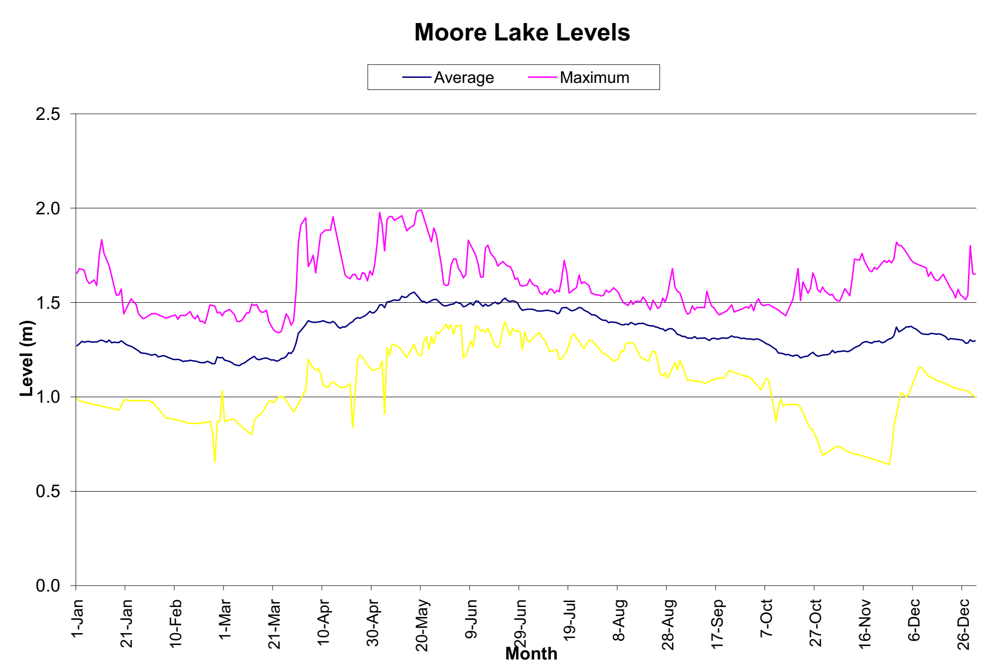

Twelve Mile Lake Levels
Average
Maximum
Level (m)
Month

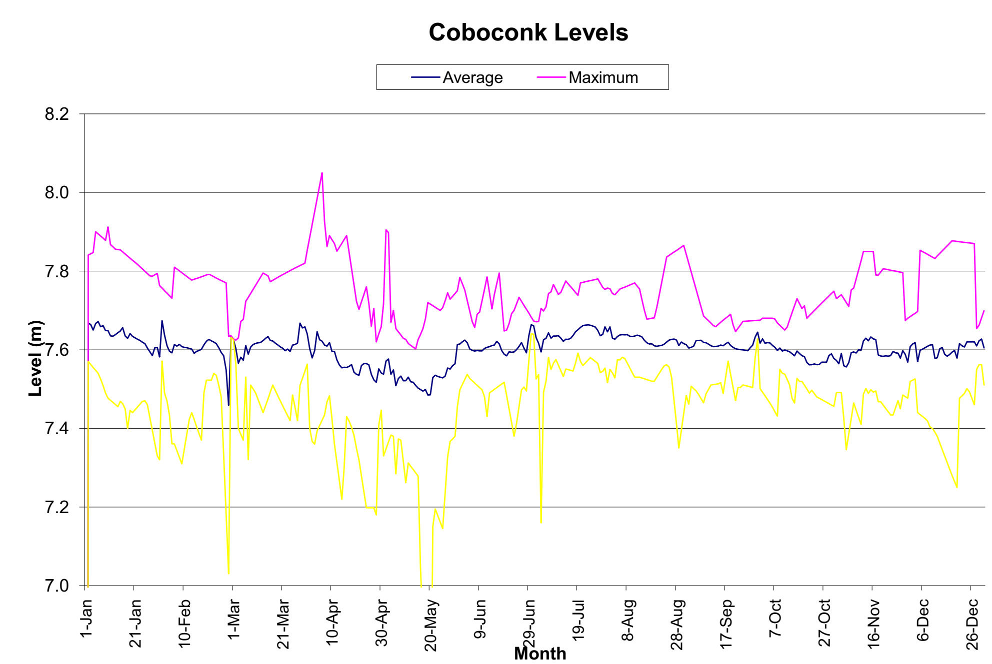

Horseshoe Lake Levels
Average
Maximum
Minimum
Level (m)
Month


Bob Lake Levels
Average
Maximum
Minimum
Level (m)
Month

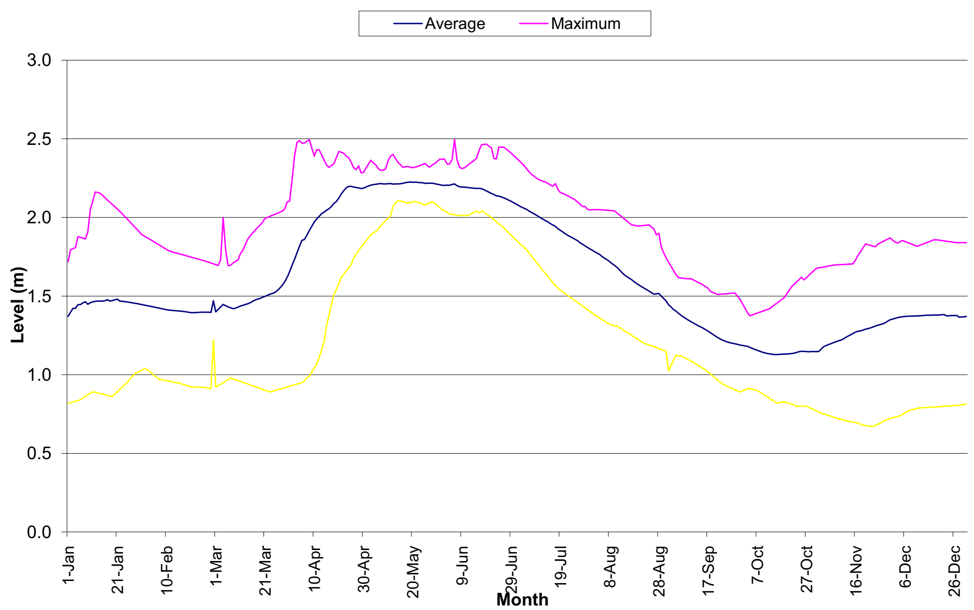

Little Bob Lake Levels
Average
Maximum
Level (m)
Month


Gull Lake Levels
Average
Maximum
Level (m)
Month

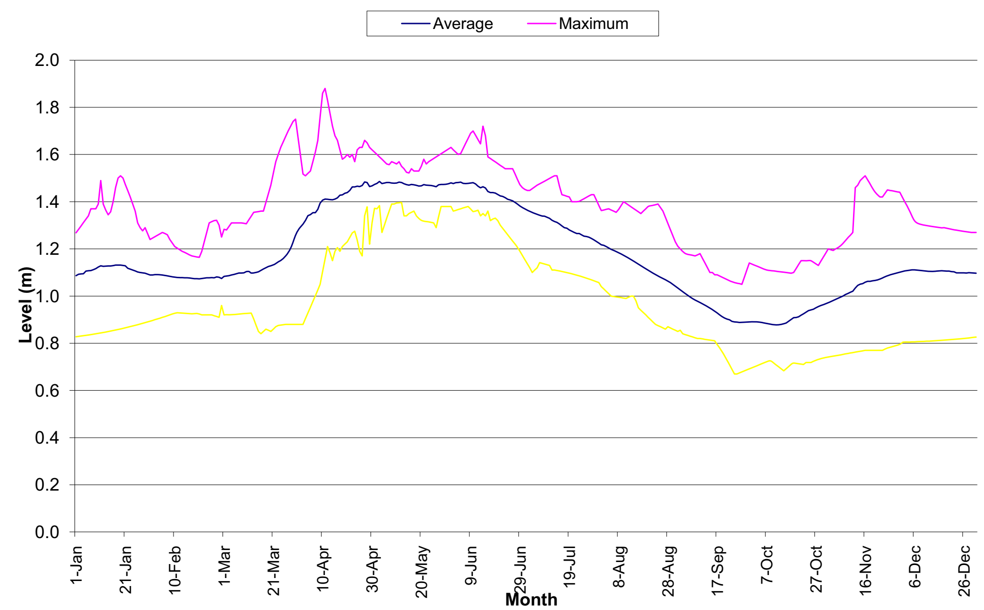

Moore Lake Levels
Average
Maximum
Level (m)
Month


Coboconk Levels
Average
Maximum
Level (m)
Month

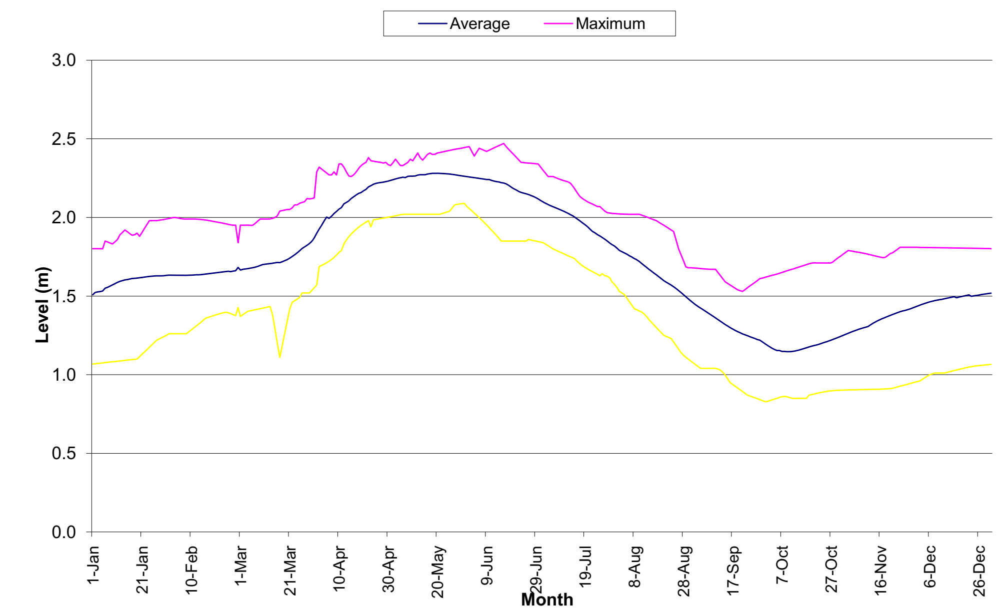
Drag Lake Levels



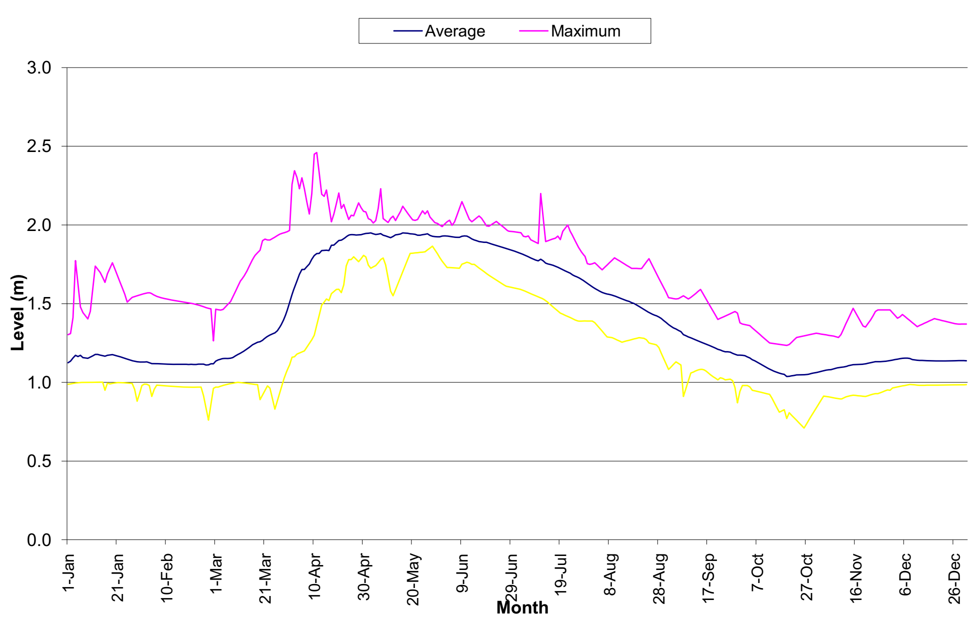
Canning Lake Levels



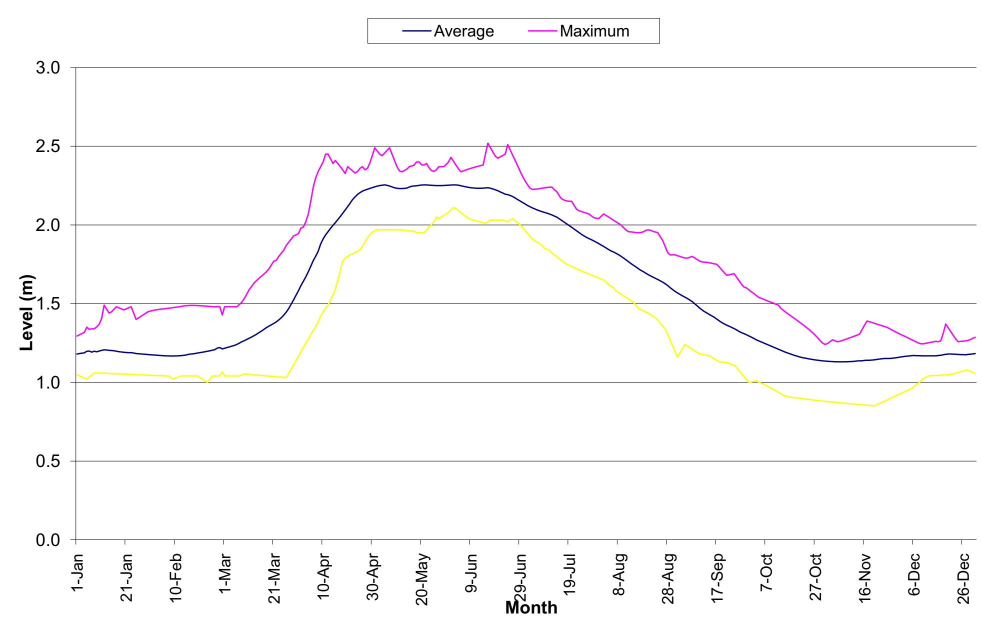
Miskwabi Lake Levels



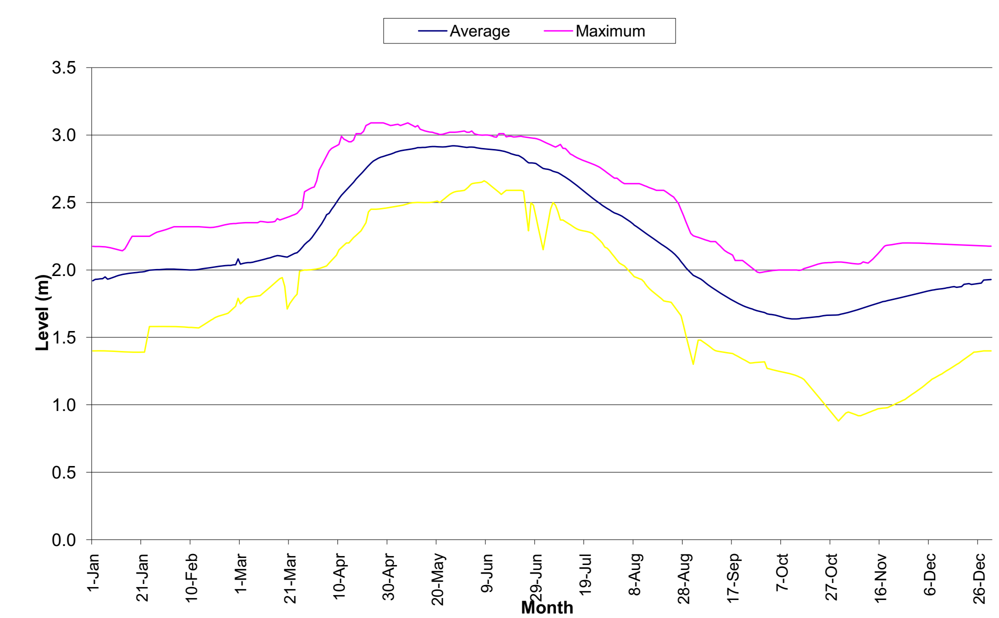
Loon Lake Levels



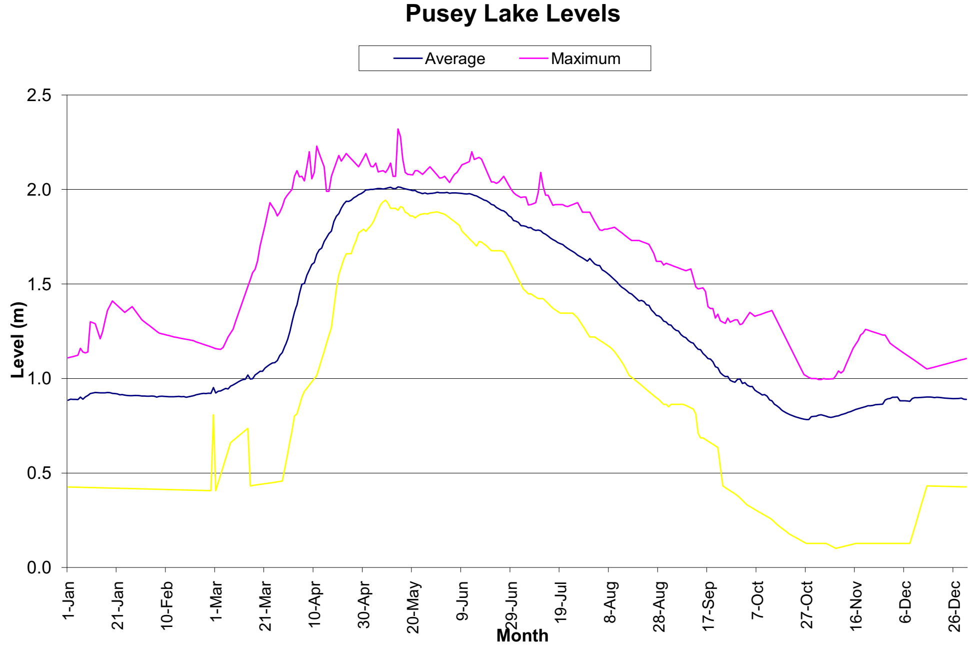
Koshlong Lake Levels



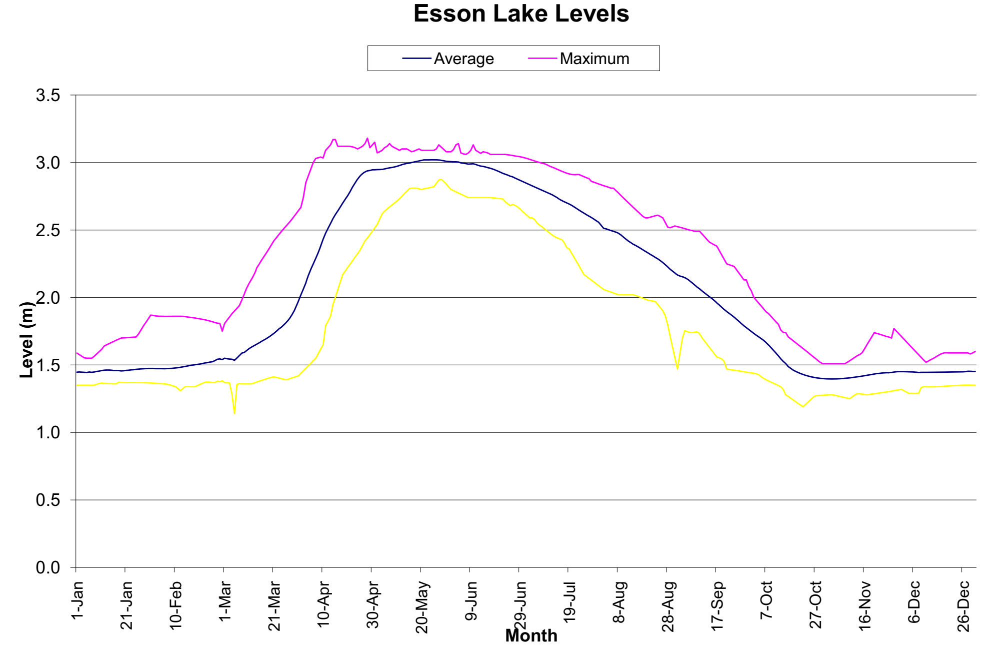
Farquhar Lake Levels



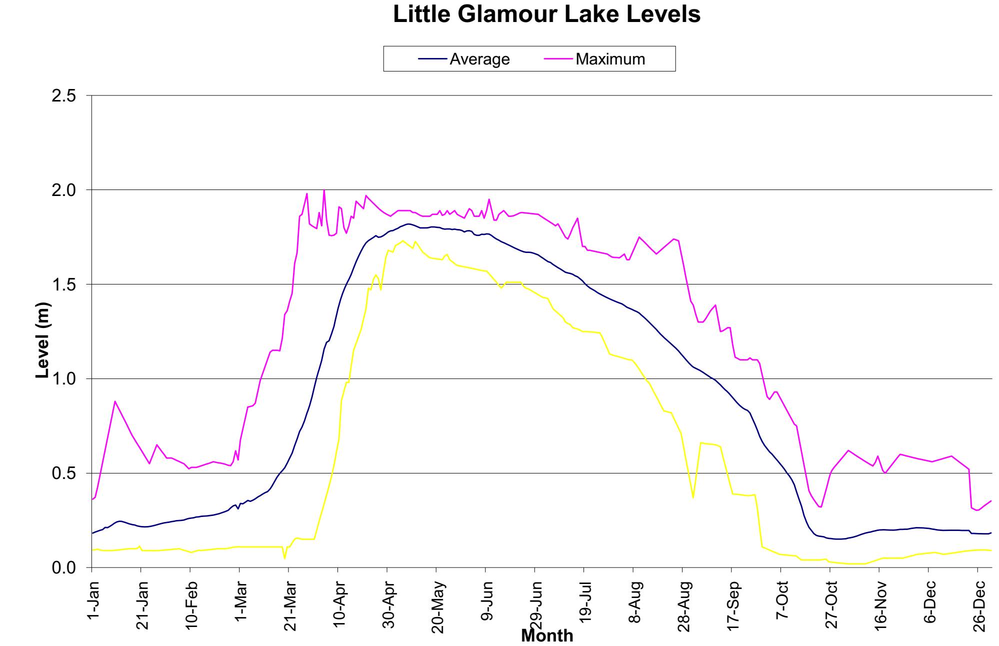
Pusey Lake Levels

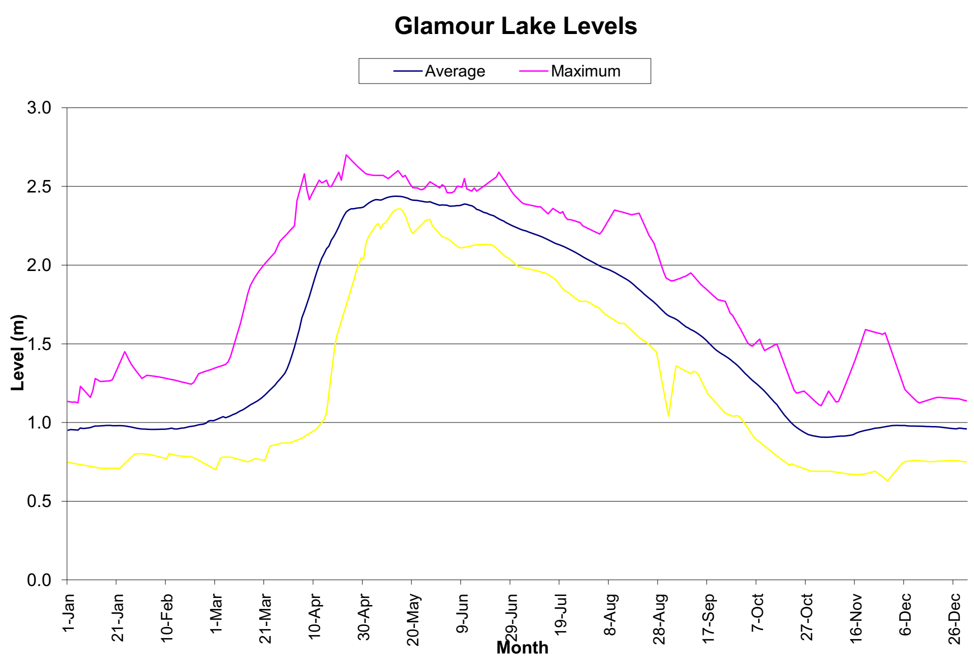


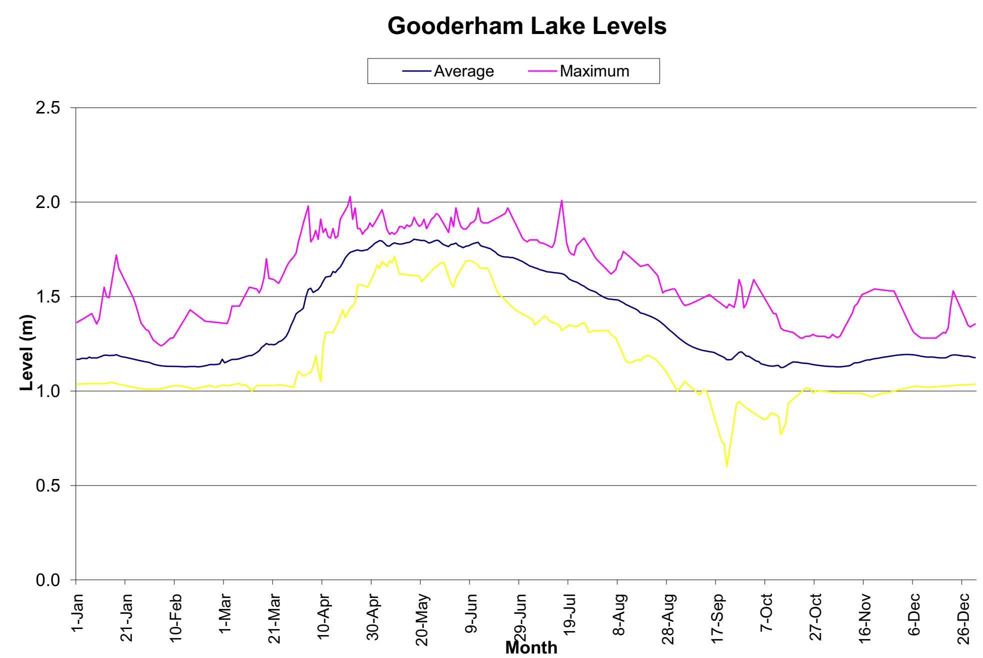
Esson Lake Levels

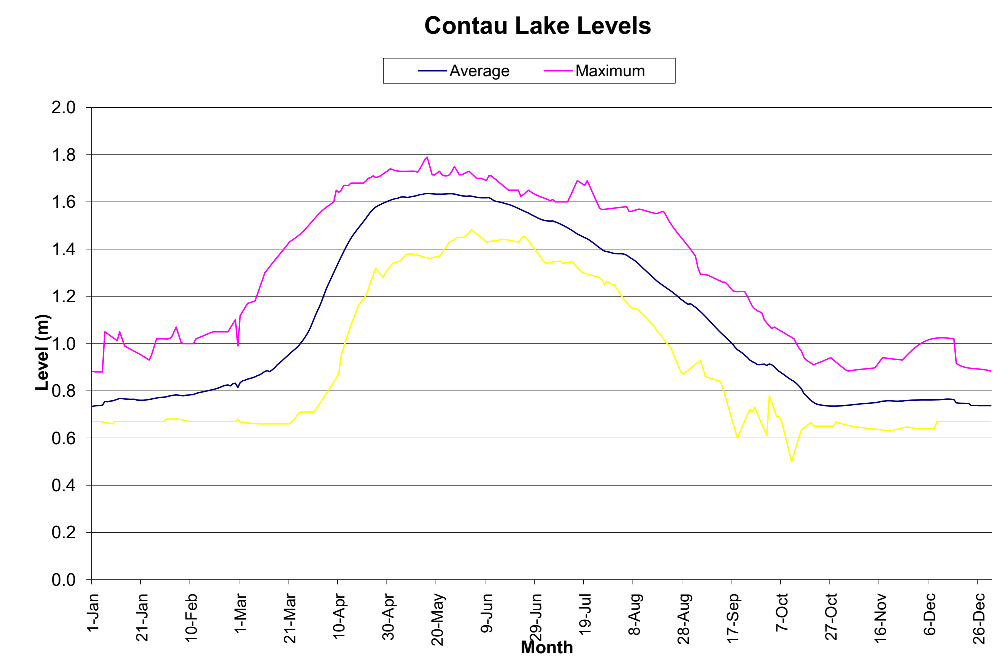


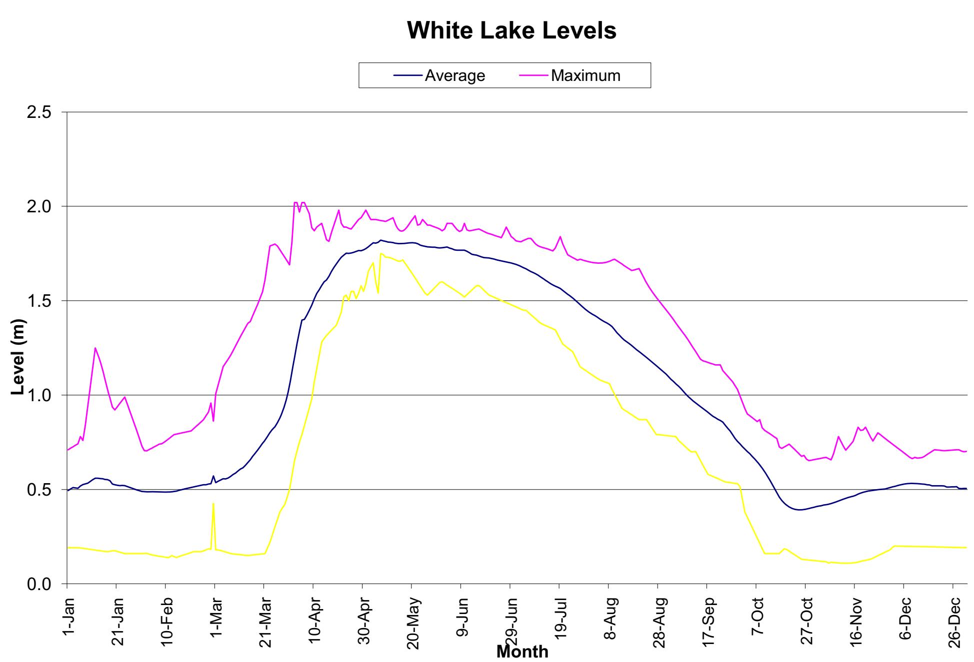
Little Glamour Lake Levels

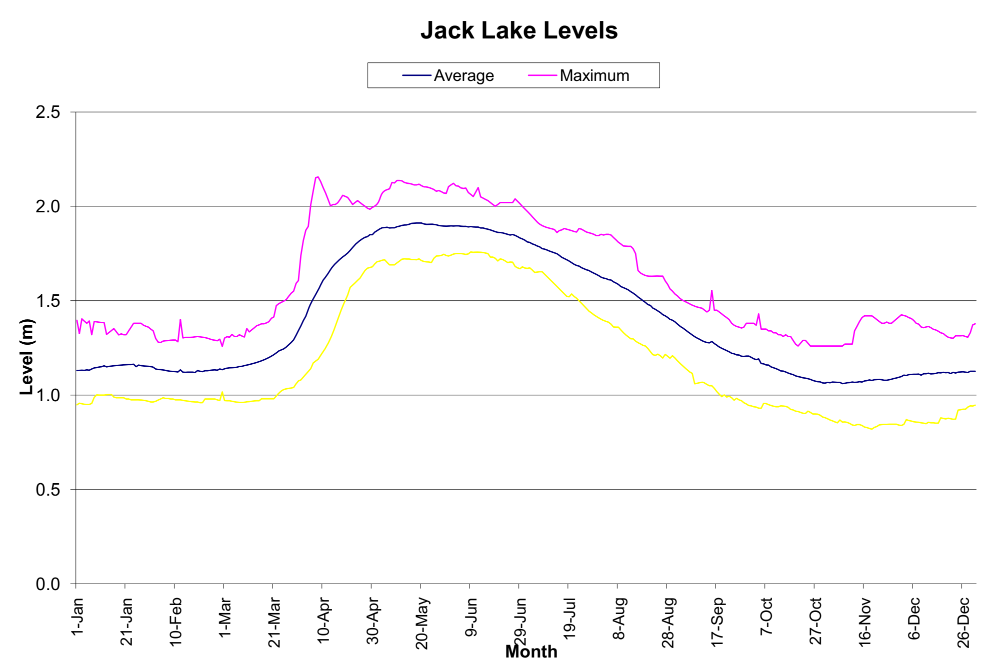


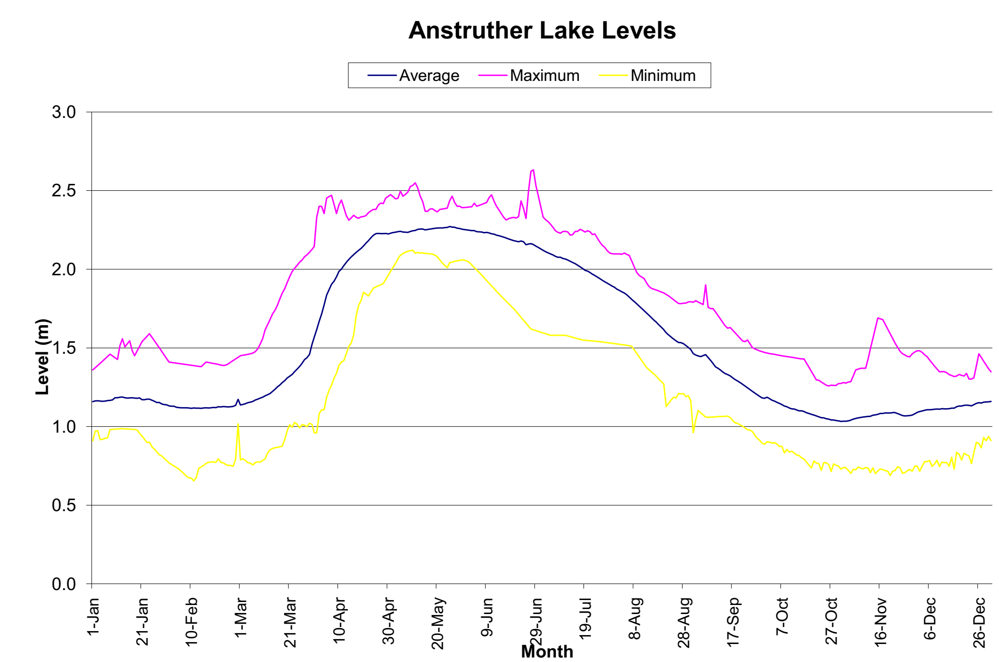

Glamour Lake Levels
Average
Maximum
Level (m)
Month

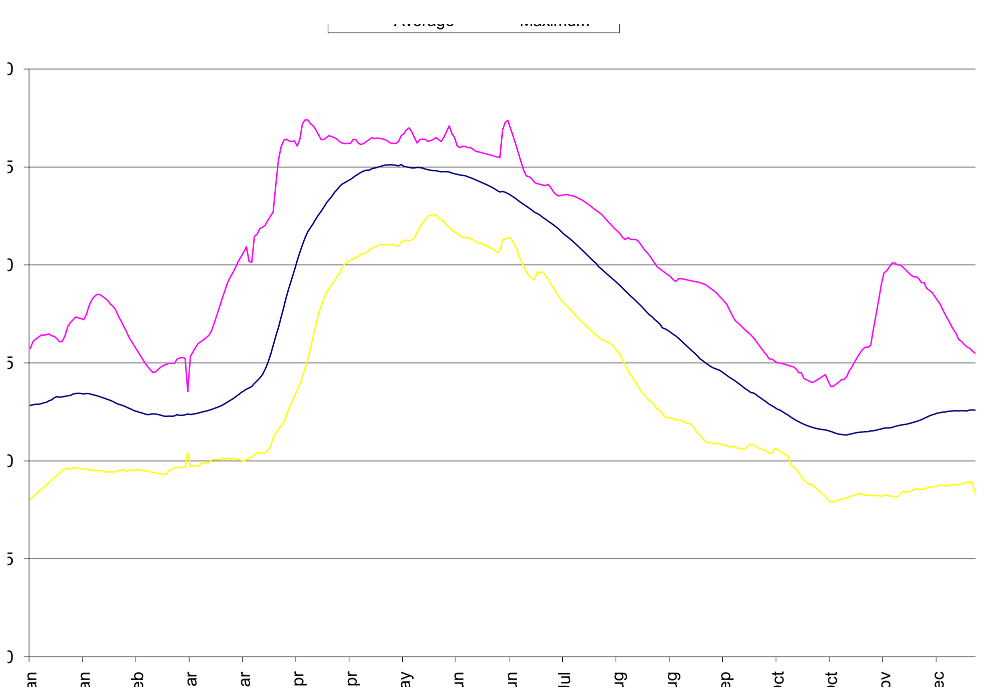

Gooderham Lake Levels
Average
Maximum
Level (m)
Month

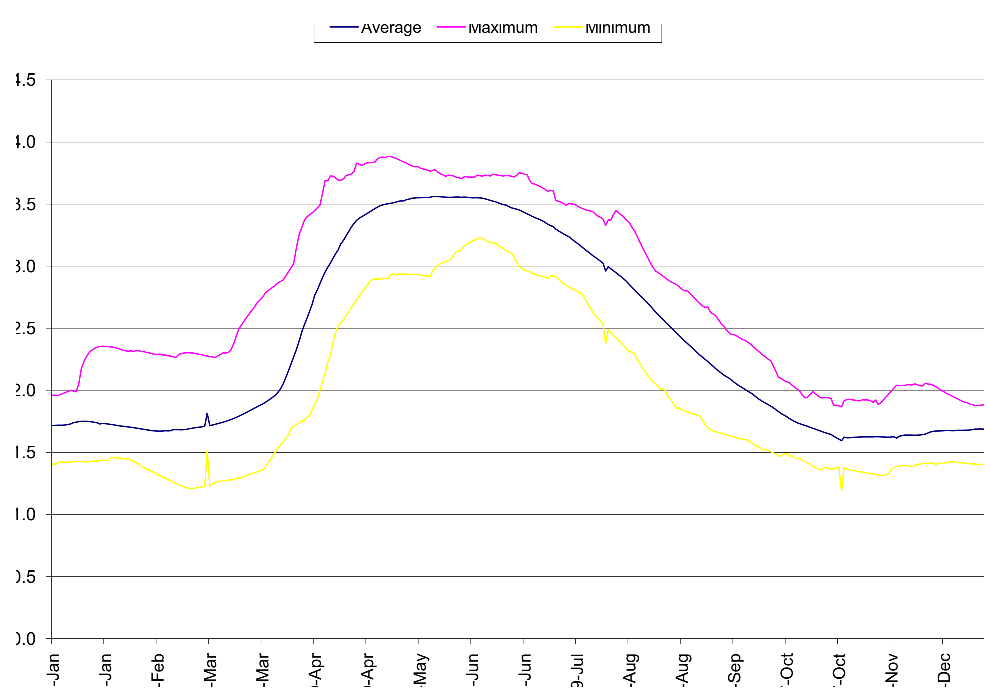

Contau Lake Levels
Average
Maximum
Level (m)
Month

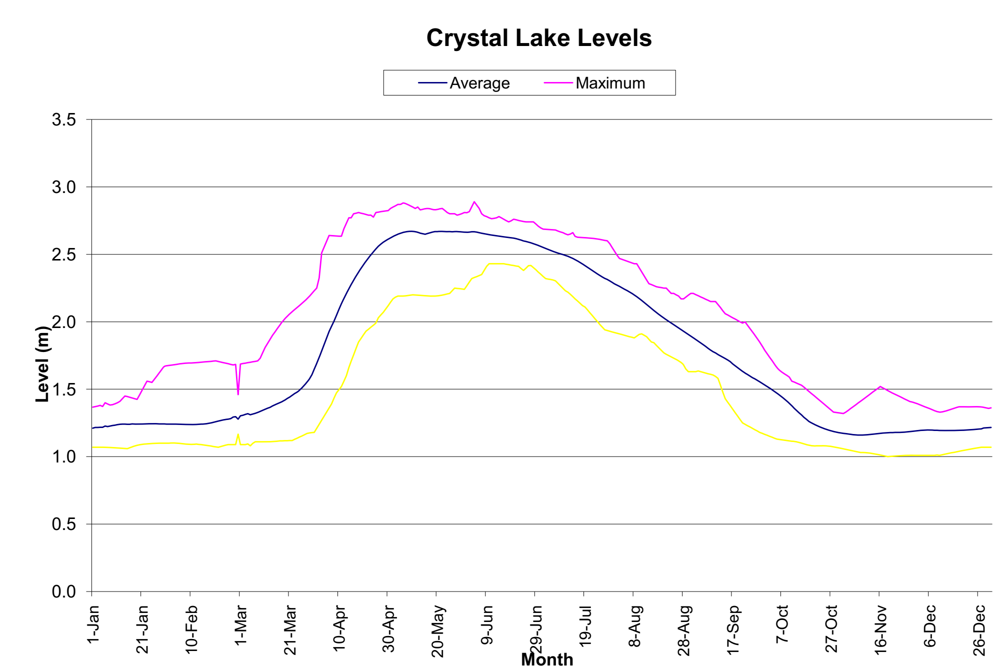

White Lake Levels
Average
Maximum
Level (m)
Month

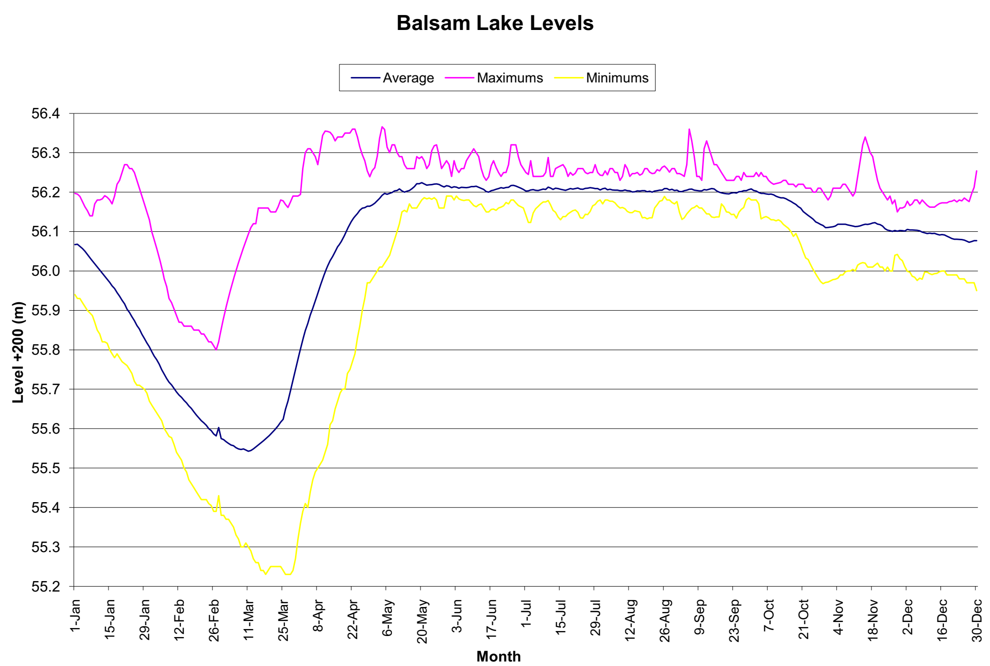

Jack Lake Levels
Average
Maximum
Level (m)
Month

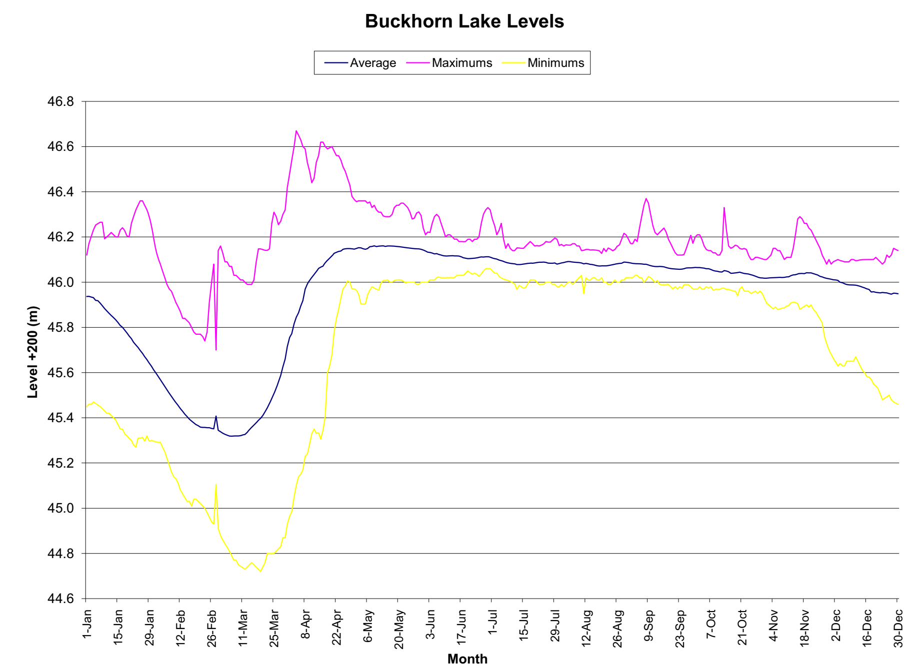

Anstruther Lake Levels
Average
Maximum
Minimum
Level (m)
Month

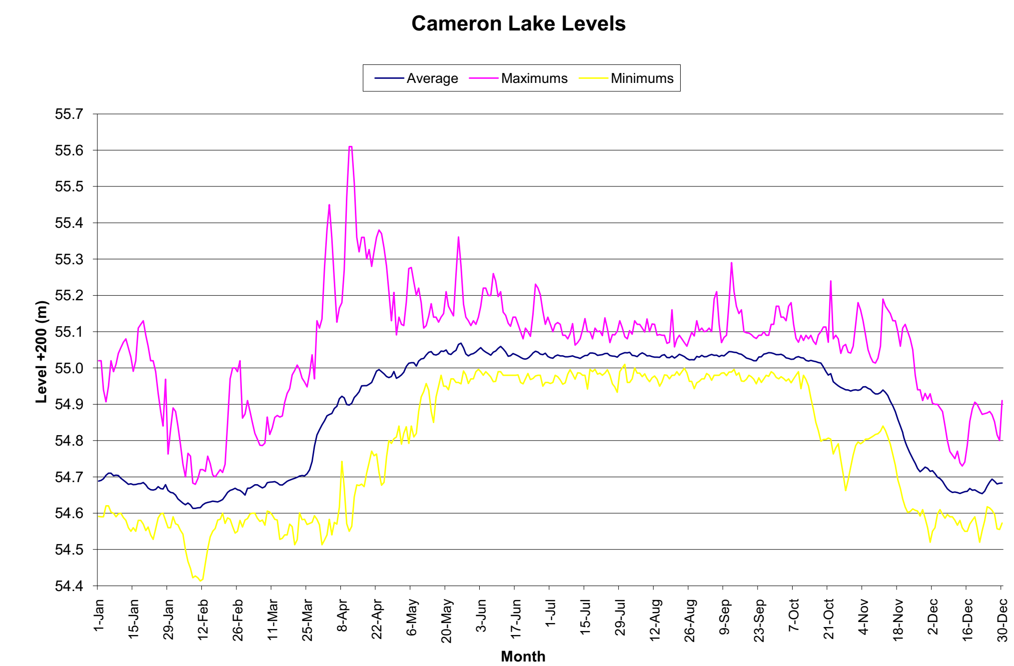


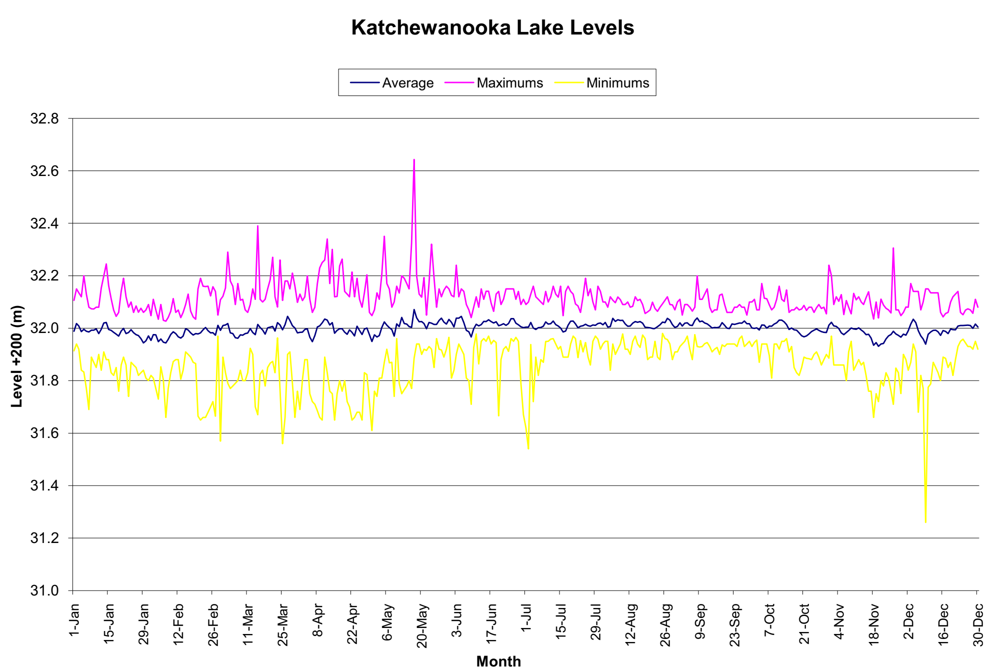

Average
Maximum
Minimum

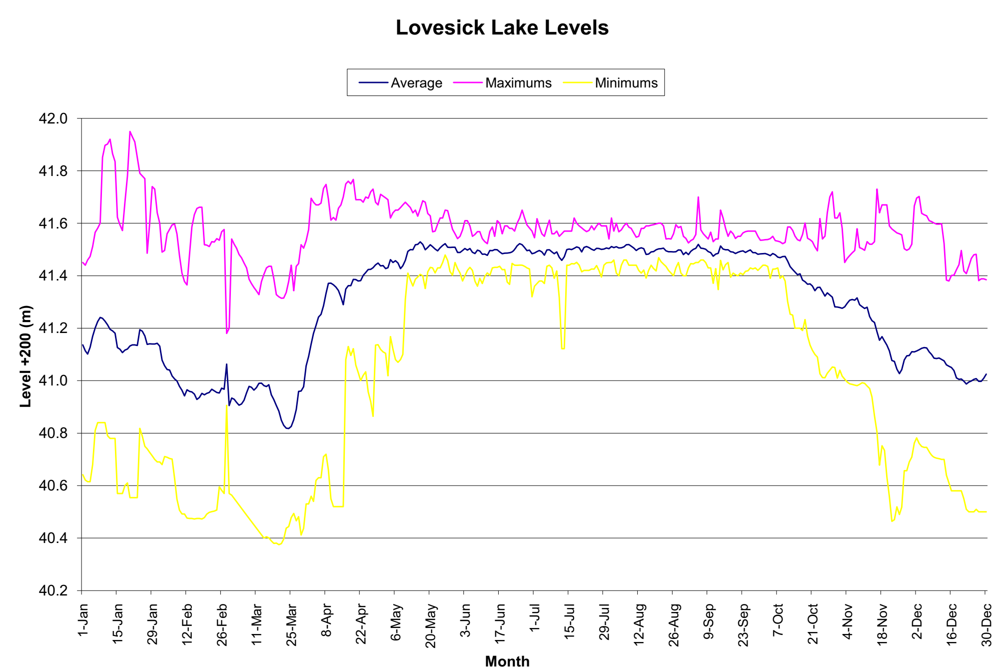

Crystal Lake Levels
Average
Maximum
Level (m)
Month

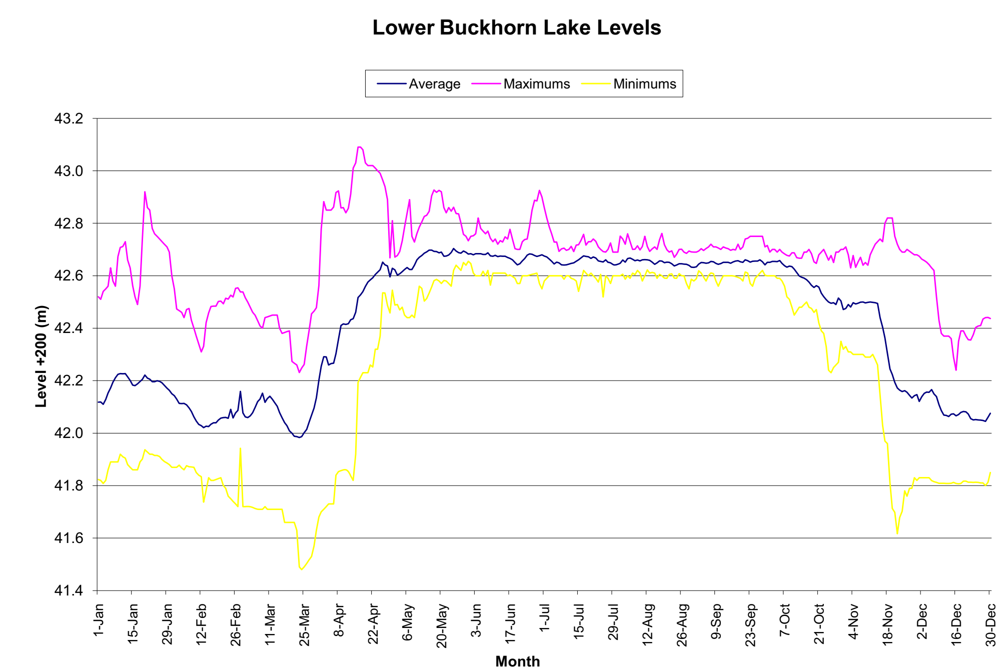

Balsam Lake Levels
Average
Maximums
Minimums
Level +200 (m)
Month

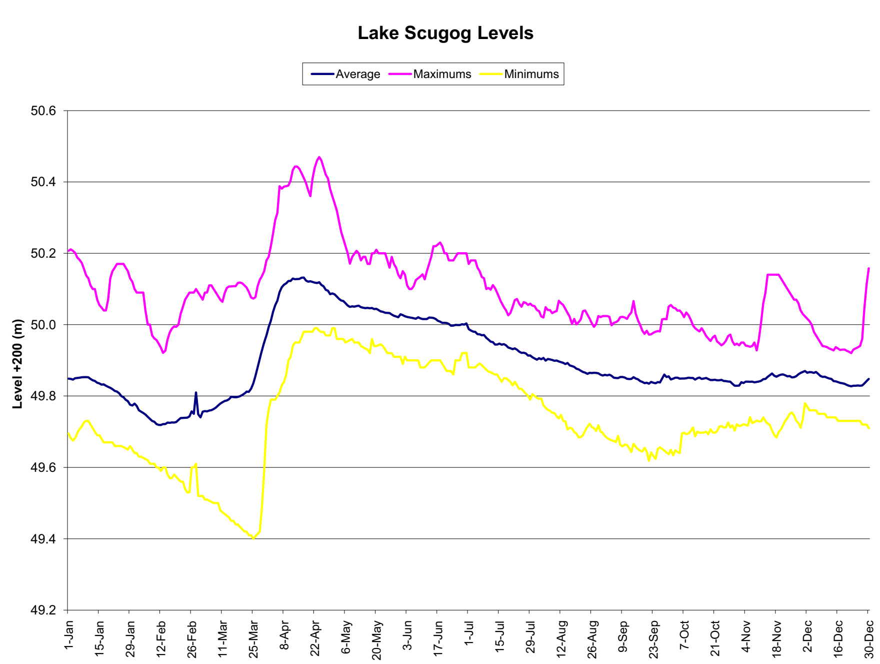

Buckhorn Lake Levels
Average
Maximums
Minimums
Level +200 (m)
Month

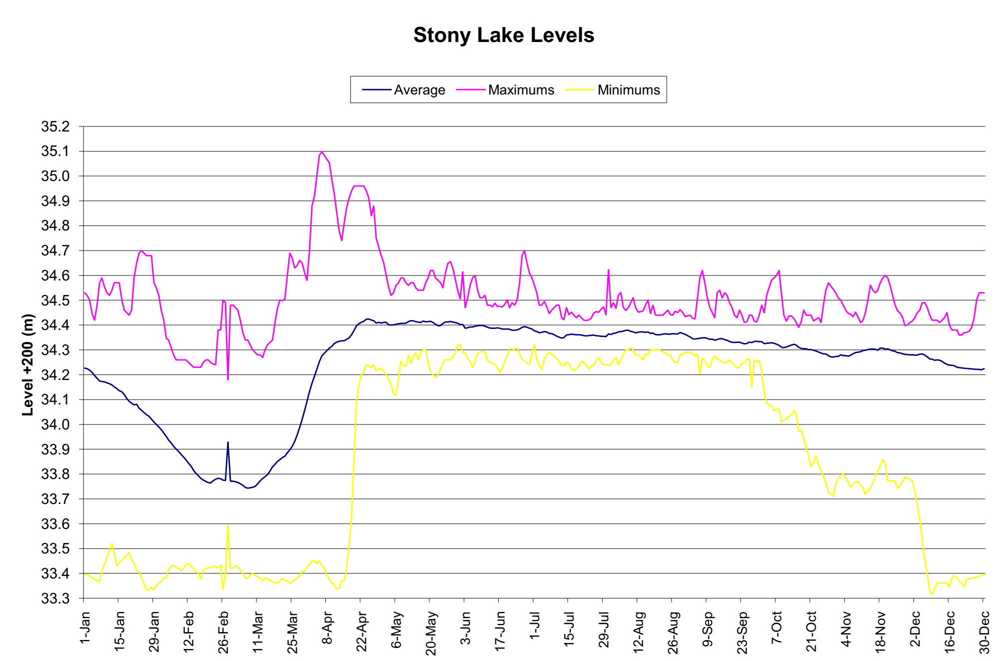

Cameron Lake Levels
Average
Maximums
Minimums
Level +200 (m)
Month

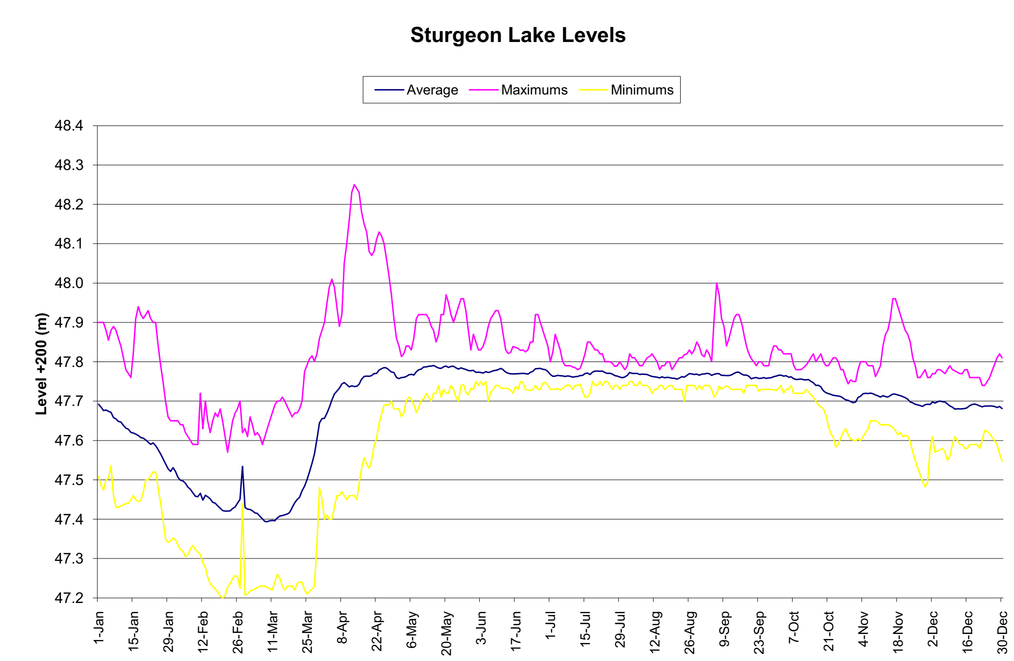

Katchewanooka Lake Levels
Average
Maximums
Minimums
Level +200 (m)
Month


Lovesick Lake Levels
Average
Maximums
Minimums
Level +200 (m)
Month

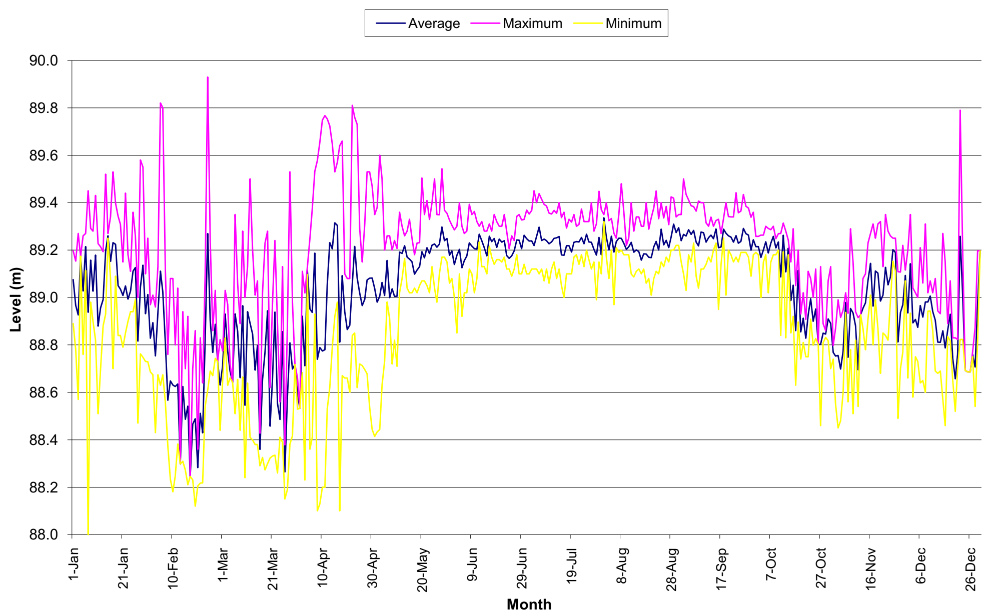

Lower Buckhorn Lake Levels
Average
Maximums
Minimums
Level +200 (m)
Month


Lake Scugog Levels
Average
Maximums
Minimums
Level +200 (m)
Month

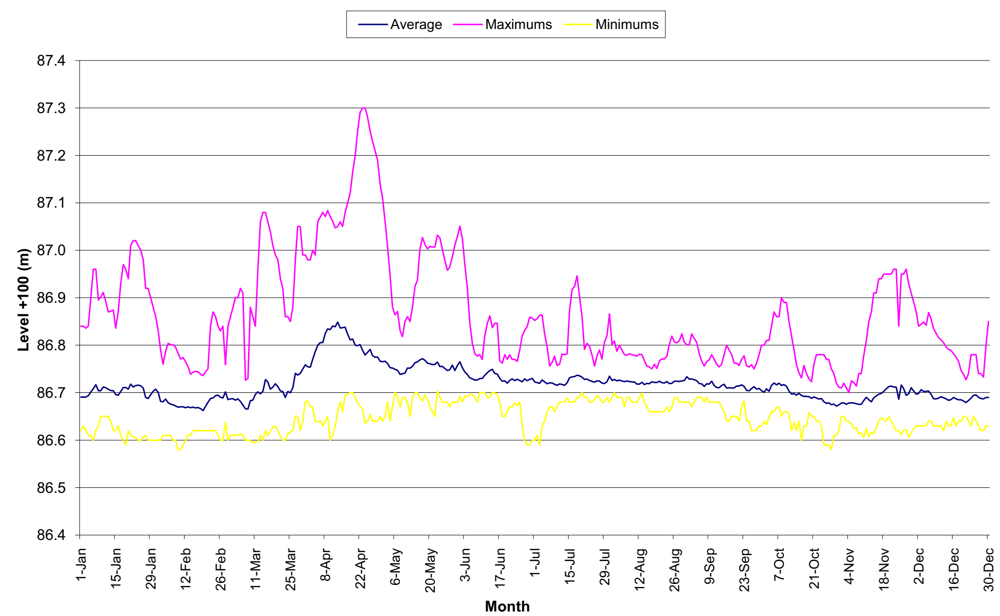

Stony Lake Levels
Average
Maximums
Minimums
Level +200 (m)
Month


Sturgeon Lake Levels
Average
Maximums
Minimums
Level +200 (m)
Month

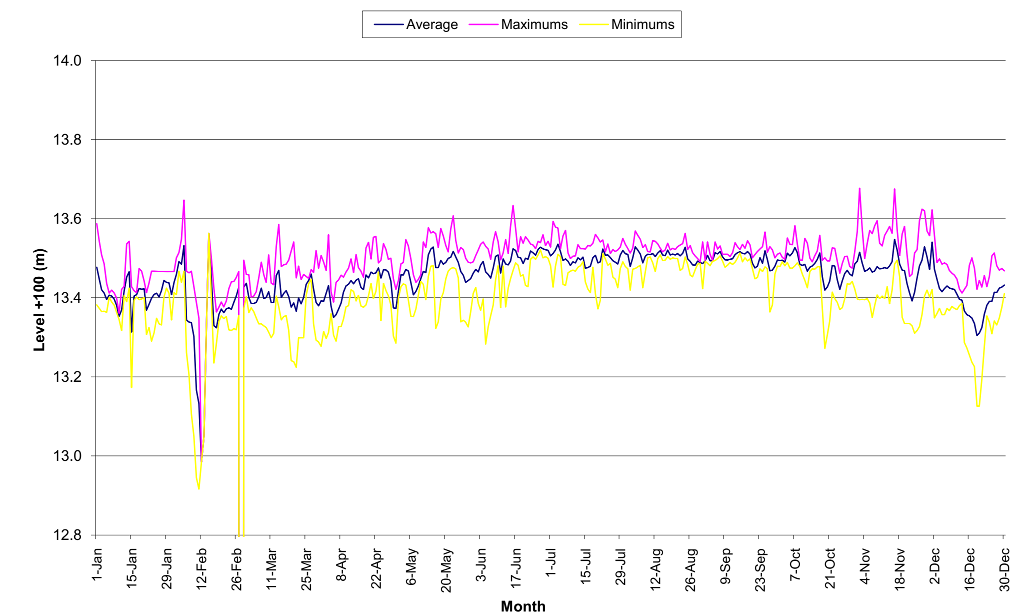
Little Lake Levels



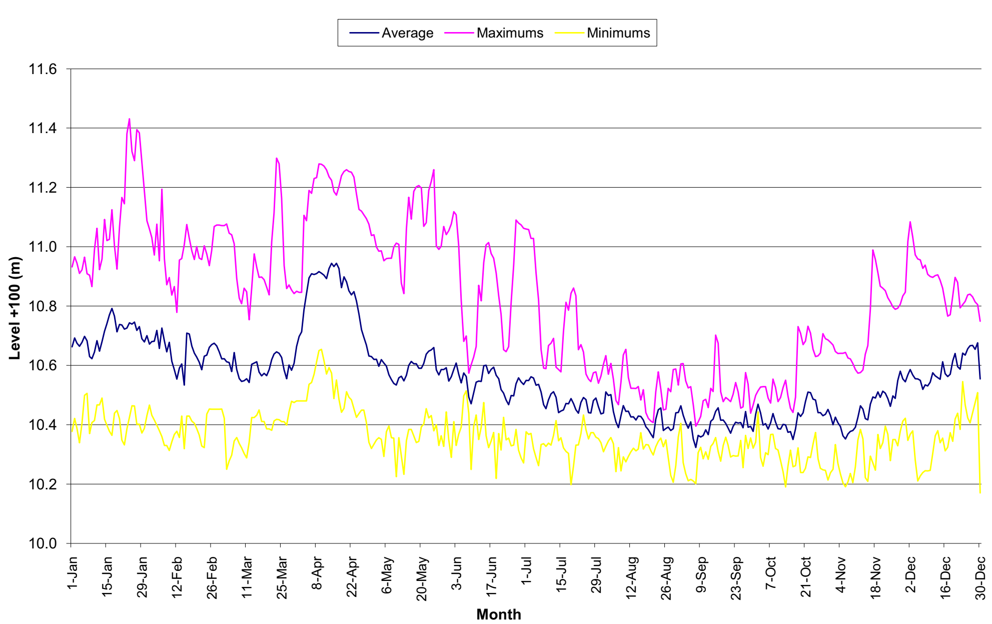
Rice Lake Levels



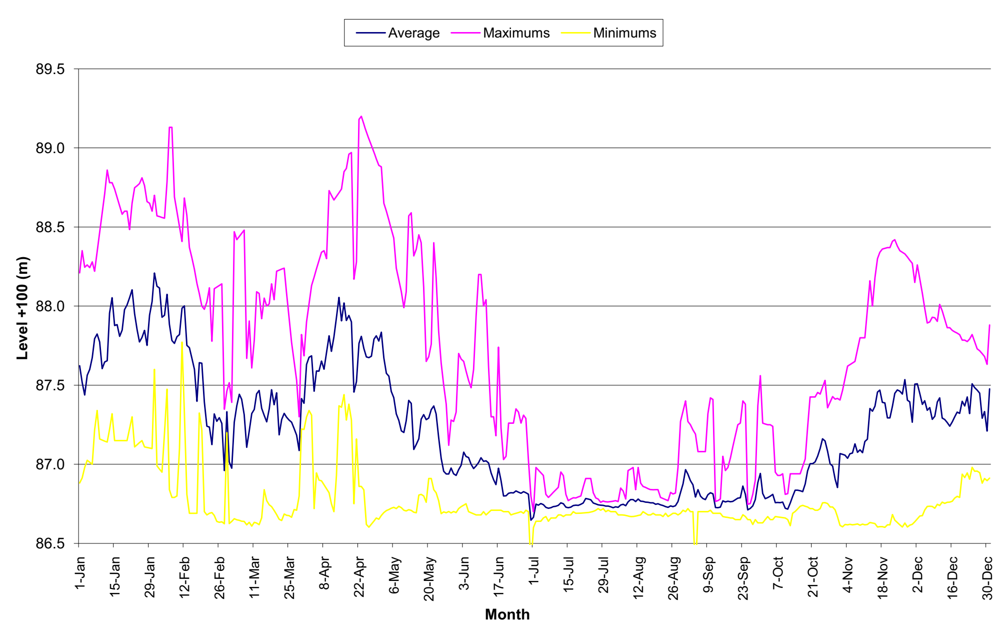
Upper Glen Ross Levels



Lower Glen Ross Levels



Lower Lock 19 Levels



Percy Reach Levels

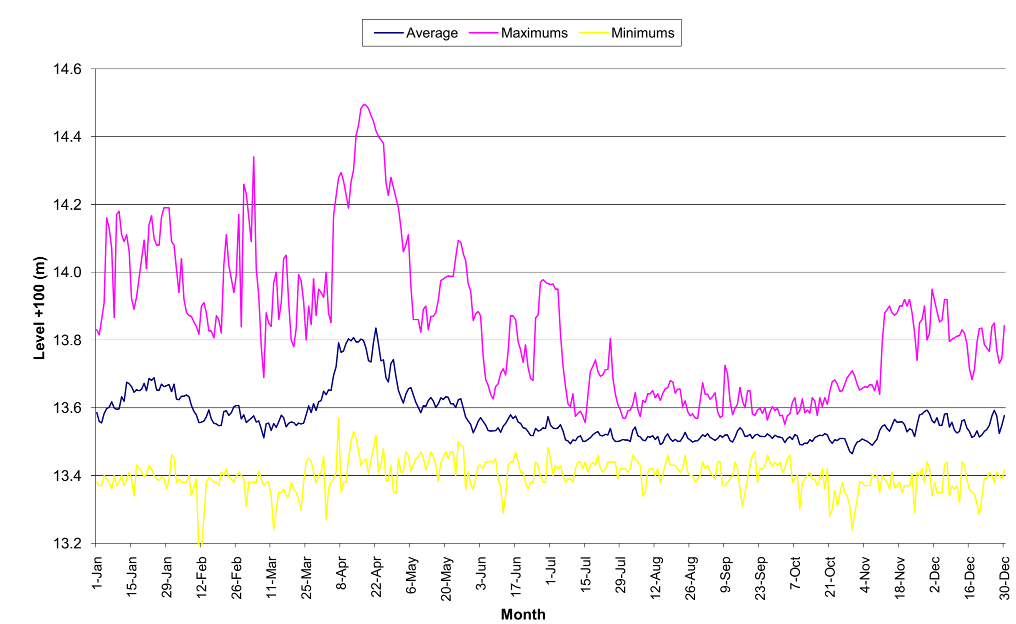


Table C4c - Shadow Lake Gauge Height at Government Dock versus Gull River Flow @ Norland

Notes:
1) maximum observed flow of 95.6 m3/s, without corresponding dock gauge reading
2) maximum observed flow of 70.2 m3/s, with corresponding dock gauge reading
3) table extrapolated beyond recorded maximums

Height(m)	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	1.50	1.70	1.90	2.10	2.30	2.50	2.70	2.90	3.20	3.40
0.1	3.60	3.80	4.00	4.20	4.40	4.70	4.90	5.10	5.30	5.50
0.2	5.80	6.00	6.20	6.40	6.70	6.90	7.10	7.30	7.60	7.80
0.3	8.00	8.30	8.50	8.80	9.00	9.20	9.50	9.70	10.00	10.20
0.4	10.50	10.70	11.00	11.20	11.50	11.70	12.00	12.20	12.50	12.80
0.5	13.00	13.30	13.60	13.80	14.10	14.40	14.70	14.90	15.20	15.50
0.6	15.80	16.10	16.40	16.70	17.00	17.30	17.60	17.90	18.20	18.50
0.7	18.80	19.10	19.40	19.70	20.10	20.40	20.70	21.10	21.40	21.70
0.8	22.10	22.40	22.80	23.20	23.50	23.90	24.30	24.70	25.00	25.40
0.9	25.80	26.20	26.70	27.10	27.50	28.00	28.40	28.80	29.30	29.70
1.0	30.20	30.70	31.10	31.60	32.10	32.60	33.10	33.60	34.10	34.70
1.1	35.20	35.80	36.30	36.90	37.40	38.00	38.60	39.20	39.80	40.40
1.2	41.10	41.70	42.30	43.00	43.70	44.30	45.00	45.70	46.40	47.10
1.3	47.90	48.60	49.30	50.10	50.90	51.70	52.50	53.30	54.10	54.90
1.4	55.80	56.70	57.50	58.40	59.30	60.20	61.20	62.10	63.10	64.00
1.5	65.00	66.00	67.10	68.10	69.20	70.20	71.30	72.40	73.50	74.70
1.6	75.80	77.00	78.20	79.40	80.60	81.90	83.10	84.40	85.70	87.00
1.7	88.40	89.70	91.10	92.50	94.00	95.40	96.90	98.40	99.90	100.00

Table C5a - Dam Spillway Configurations

Trent-Severn Waterway
Reservoir Dam Layouts

Yellow = denotes a generating station; Orange = denotes inoperable/nonoperable spillways

		Sluice Count	1	2	3	4	5	6	7	8	9
1	Kennisis Lake	Total Logs	9.5								
		Spillway width	16.75'								
2	Red Pine	Total Logs	4								
		Spillway width	17'								
3	Nunikani Lake	Total Logs	10								
		Spillway width	12'								
4	Hawk Lake	Total Logs	14.5								
		Spillway width	13'								
5	Halls Lake	Total Logs	8.5								
		Spillway width	17.5'								
6	Trout Lake	Total Logs	5								
		Spillway width	11'								
7	Kushog Lake	Total Logs	10.5								
		Spillway width	12'								
8	Percy Lake	Total Logs	6.5								
		Spillway width	18'								
9	Oblong Lake	Total Logs	10								
		Spillway width	16'								
10	Redstone Lake	Total Logs	12	12							
		Spillway width	12'	6.5'							
11	Redstone Lake East	Total Logs	10								
		Spillway width	14'								
12	Eagle Lake	Total Logs	7.5								
		Spillway width	20'								
13	Twelve Mile	Total Logs	5	6							
		Spillway width	25'	25'							
14	Horseshoe Lake	Total Logs	8 (orange)	8	8	8 (orange)					
		Spillway width	20' (orange)	20'	20'	20' (orange)					
15	Big Bob	Total Logs	9.5								
		Spillway width	9'								
16	Little Bob	Total Logs	5								
		Spillway width	12'								
17	Gull Lake #1	Total Logs	7								
		Spillway width	25'								
18	Gull Lake #2	Total Logs	2	2							
		Spillway width	25'	25'							
19	Moore Lake	Total Logs	(yellow)	(yellow)	(yellow)	6	5	9			
		Spillway width	(yellow)	(yellow)	(yellow)	20	10'	20'			

Trent-Severn Waterway

Reservoir Dam Layouts

(yellow) denotes a generating station

(orange) denotes inoperable/nonoperable spillways

		Sluice Count	1	2	3	4	5	6	7	8	9
20	Norland	Total Logs	11	5							
		Spillway width	20'	20'							
21	Coboconk	Total Logs	6	8	8	9	9	9	8	8	6
		Spillway width	20'	20'	20'	20'	20'	20'	20'	20'	20'
22	Drag Lake (S Chan)	Total Logs	6.75								
		Spillway width	8'								
23	Drag Lake (N Chan)	Total Logs	7.5	5							
		Spillway width	12'	12.5'							
24	Canning Lake	Total Logs	4	4	5						
		Spillway width	17.5'	17.5'	17.5'						
25	Miskwabi Lake	Total Logs	7.5								
		Spillway width	12'								
26	Loon Lake	Total Logs	6.5								
		Spillway width	12'								
27	Koshlong Lake	Total Logs	7.5								
		Spillway width	10'								
28	Farquhar Lake	Total Logs	10								
		Spillway width	9.83'								
29	Grace Lake	Total Logs	7								
		Spillway width	11.5'								
30	Esson Lake	Total Logs	10								
		Spillway width	11'								
31	Little Glamor Lake	Total Logs	6								
		Spillway width	10'								
32	Big Glamor Lake	Total Logs	8								
		Spillway width	10'								
33	Gooderham Lake	Total Logs	6								
		Spillway width	15.75'								
34	Contau Lake	Total Logs	5.5								
		Spillway width	7'								
35	White Lake	Total Logs	6								
		Spillway width	10'								
36	Crystal Lake	Total Logs	9								
		Spillway width	7.33'								
37	Anstruther Lake	Total Logs	7.5								
		Spillway width	12'								
38	Mississagua Lake	Total Logs	11	8	8						
		Spillway width	19'	20'	14'						

Trent-Severn Waterway
Reservoir Dam Layouts

denotes a generating station (yellow)

denotes inoperable/nonoperable spillways (orange)

		Sluice Count	1	2	3	4	5	6	7	8	9
39	Eels Lake East	Total Logs	12								
		Spillway width	8'								
40	Eels Lake West	Total Logs	11	8							
		Spillway width	8'	8'							
41	Jack Lake	Total Logs	6.5								
		Spillway width	10'								
		Total Logs	7								
		Spillway width	16'								

Trent-Severn Waterway

Canal Dam Layouts

denotes a generating station (yellow)

denotes inoperable/nonoperable spillways (orange)

			Sluice Count	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Dam 1	Lock 1 - Trenton	Total Logs	12	12	12	12	9	9	9	9	9	12	12	12	12	9	9	9	9	9
			Spillway width	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'
2	Dam 2	Lock 2 - Sidney	Gate Count / Total Logs	2.40	2.40	2.40	2.40	3.82	3.82	3.82	3.82	12	12								
			Spillway Width	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'								
3	Dam 3	Lock 3 - Glen Miller	Total Logs	9	9	9	9	9	9	9	9	9	9	12	12	12	12				
			Spillway Width	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'				
4	Dam 4	Lock 4 - Batawa	Total Logs/Gate Count	9	9	9	9	9	9	12	12	12	12	4.42 Gate							
			Spillway Width	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'							
5	Dam 5	Lock 5 - Trent	Total Logs/Gate Count	9	2.89	2.89	2.89	2.89	2.89	3.81	3.81	3.81	12								
			Spillway Width	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'								
6	Dam 6	Lock 6 - Frankford	Gate Settings	2.40	2.40	3.82	3.82	3.82	3.82	2.40	2.40	2.40	2.40								
			Spillway Width	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'								
7	Dam 7	Lock 7 - Glen Ross	Gate Settings in Metres	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10						
			Spillway Width	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'						
8	Dam 8	Lock 9 - Meyers	Total Logs/Gate Settings in Metres				12	2.75	2.75	2.75	3.66	3.66	3.66	3.66	9	9	9				
			Spillway Width				25'	25'	25'	25'	25'	25'	25'	25'	25'	25'	25'				
9	Dam 9	Lock 10 - Hagues Reach	Total Logs/Gate Settings in Metres	9	9	9	12	12	9	9	9	9	3.66	3.66							
			Spillway Width	20'	20'	20'	20'	20'	20'	20'	20'	20'	50'	50'							
10	Dam 10	Lock 11/12 - Ranney Falls	Gate Settings in Metres	3.61	3.61	3.61	3.61	3.61	3.61												
			Spillway Width	10 m	10 m	10 m	10 m	10 m	10 m												
11	Dam 11	Lock 13 - Campbellford	Total Logs/Gate Settings in Metres	3.14	3.14	12	12	12	12	12											
			Spillway Width	50'	50'	25'	25'	25'	25'	25'											
12	Dam 12	Lock 14 - Crowe Bay	Gate Settings in Metres	3.65	3.65	3.65	3.65	3.65													
			Spillway Width	10 m	10 m	10 m	10 m	10 m													
13	Dam 13	Lock 15 - Healey Falls	Weir	No Info																	
14	Dam 14	Lock 16/17 - Healey Falls		10	10	10	10	10	2.65	2.65	2.65	2.65	2.65	2.65	2.65	2.65	2.65	2.65			
				20'	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'			
15	Dam 15	Lock 18 - Hastings	Total Logs/Gate Settings in Metres	2.85	2.85	9	9	9	9	7	7	7	7								
			Spillway Width	50'	50'	19'	25'	25'	25'	25'	25'	25'	25'								
16		Lock 19 - Scotts Mills	Total Logs	7	7	8	8	5	8	8	8										
			Spillway Width	25'	25'	25'	25'	10'	25'	25'	25'										
17		Lock 21 - Peterborough Lift Locks	Total Logs/Gate Settings in Metres	9	11	11	11	7	3.28	4.45	3.28	3.28	3.28	3.28	11	11					
			Spillway Width					8'	20'	20'	20'	20'	20'	20'	20'	20'					
			Bay**	7																	
				20'																	
18		Lock 22 - Nassau Mills	Total Logs	10	12	12	12	10	10	6	10	10	10								
			Spillway Width	20'	20'	20'	20'	20'	20'	8'	20'	20'	20'								
19		Lock 23 - Otonabee	Total Logs	10	10	10	10	10	10	8	12	12	12								
			Spillway Width	20'	20'	20'	20'	20'	20'	8'	20'	20'	20'								
20		Lock 24 - Douro	Total Logs	10	10	10	10	10	10	8	12	12	12								
			Spillway Width	20'	20'	20'	20'	20'	20'	8'	20'	20'	20'								
21		Lock 25 - Sawer Creek	Total Logs	10	10	12	12	12	10	6	10	10	10								
			Spillway Width	20'	20'	20'	20'	20'	20'	8'	20'	20'	20'								
22		Lock 26 - Lakefield	Total Logs/Gate Settings in Metres	10	3.1	8	3.1	3.1	3.1	3.1	9	9	9	9							
			Spillway Width	8'	20'	8'	20'	20'	20'	20'	20'	20'	20'	20'							

Trent-Severn Waterway

Canal Dam Layouts

Yellow: denotes a generating station. Orange: denotes inoperable/nonoperable spillways.

		Sluice Count	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
23	Lock 27 - Youngs Point	Total Logs/Gate Settings in Metres					3.42	3.42	3.42	8	3.42	3.42	2.51	8	8					
		Spillway Width	20'	20'	20'	20'	20'	20'	20'	8'	20'	20'	20'	20'	20'					
24	Lock 28 - Burleigh Falls	Total Logs	4	7	7	7	7	7	7	4	4	4	4	4						
		Spillway Width	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'						
		Total Logs	7	7	7															
		Spillway Width	15'	15'	15'															
25	Lock 30 - Lovesick	Total Logs - Sunrise	5	4																
		Spillway Width	25'	25'																
		Total Logs - Sunset	5																	
		Spillway Width	20'																	
		Total Logs - Main	5	5	5	5														
		Spillway Width	20'	20'	20'	20'														
		Total Logs - Black Duck	4	4																
		Spillway Width	20'	20'																
		Total Logs - Grey Duck	5																	
		Spillway Width	20'																	
26	Lock 31 - Buckhorn	Gate Settings in Metres	2.92	2.92	2.92	2.92														
		Spillway Width	50'	50'	50'	50'														
27	Lock 32 - Bobcaygeon	Gate Settings in Inches/ Total Logs	120	120	11	11	9	9	9	9	9									
		Spillway Width	50'	50'	20'	20'	20'	20'	20'	20'	20'									
			9	9	9	9														
			25'	25'	25'	10'														
28	Lock 33 - Lindsay	Total Logs	5.5	5.5																
		Spillway Width	15'	15'																
29	Lock 34 - Fenelon Falls	Total Logs	9	9	9	9	9	9	9	9	9	9	9	8	8	8				
		Spillway Width	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'	20'				
30	Lock 35 - Rosedale	Total Logs	8	8	8	8														
		Spillway Width	25'	25'	25'	25'														
31	Lock 36 - Kirkfield	Total Logs	7																	
		Spillway Width	20'																	
		Total Logs	7	7																
		Spillway Width	16'	16'																
32	Lock 37 - Bolsover	Logs	11	13																
		Spillway Width	25'	25'																
33	Lock 38 - Talbot	Logs	11	11																
		Spillway Width	25'	25'																
34	Lock 39 - Portage	Logs	10	10																
		Spillway Width	25'	25'																
35	Lock 42 - Couchiching	Logs	5	5	5															
		Spillway Width	15'	15'	15'															
		Logs	5																	
		Spillway Width	25'																	
		Logs	3	3																
		Spillway Width	10'	10'																
		Logs	10																	
		Spillway Width	25'																	
		Logs	5	5																
		Spillway Width	8'	8'																
		Logs	6																	
		Spillway Width	25'																	
36	Lock 43 - Swift Rapids	Gate Settings in Metres	4.57	4.57	4.57	4.57	4.57													
		Spillway Width	20'	20'	20'	20'	20'													
37	Lock 44 - Big Chute	Logs	9	9	9	9	9	9	9											
		Spillway Width	20'	20'	20'	20'	20'	20'	20'											

Trent-Severn Waterway
Canal Dam Layouts

denotes a generating station (yellow)

denotes inoperable/nonoperable spillways (orange)

		Sluice Count	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
38	Lock 45 - Port Severn	Logs	10	12	12	10	10	10	10	10	10									
		Spillway Width	20'	20'	20'	20'	20'	20'	20'	20'	20'									
		Logs	9																	
		Spillway Width	20'																	
		Logs	6																	
		Spillway Width	8'																	
		Logs	5																	
		Spillway Width	No Info																	
6Mile	Dam 6Mile - 6 Mile		No Info																	

Table C5c – South Sector Dam Discharge Curves

Table C5b - South Sector Dam Discharge Curves

Flow Chart for 4.6m Sluice - Discharge in cms

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.4	5.2	9.8	15.2	21.3	28.4	36.1	44.1	52.6	61.8	71.4	81.1
2		3.8	8.4	13.8	19.9	27	34.7	42.7	51.2	60.4	70	79.7
3			4.6	10	16.1	23.2	30.9	38.9	47.4	56.6	66.2	75.9
4				5.4	11.5	18.6	26.3	34.3	42.8	52	61.6	71.3
5					6.1	13.2	20.9	28.9	37.4	46.6	56.2	65.9
6						7.1	14.8	22.8	31.3	40.5	50.1	59.8
7							7.7	15.7	24.2	33.4	43	52.7
8								8	16.5	25.7	35.3	45
9									8.5	17.7	27.3	37
10										9.2	18.8	28.5
11											9.6	19.3
12												9.7

Flow Chart for 6.1m Sluice - Discharge in cms

	1	2	3	4	5	6	7	8	9	10	11	12
1	1.2	4.3	8	12.3	17.2	22.7	28.8	35	41.5	48.5	55.8	63.3
2		3.1	6.8	11.1	16	21.5	27.6	33.8	40.3	47.3	54.6	62.1
3			3.7	8	12.9	18.4	24.5	30.7	37.2	44.2	51.5	59
4				4.3	9.2	14.7	20.8	27	33.5	40.5	47.8	55.3
5					4.9	10.4	16.5	22.7	29.2	36.2	43.5	51
6						5.5	11.6	17.8	24.3	31.3	38.6	46.1
7							6.1	12.3	18.8	25.8	33.1	40.6
8								6.2	12.7	19.7	27	34.5
9									6.5	13.5	20.8	28.3
10										7	14.3	21.8
11											7.3	14.8
12												7.5

Table C5c – South Sector Dam Discharge Curves

Flow Charts for 30cm Stoplogs

Log Depth	6.1m	Spillway	7.6m	Spillway
1	1.2		1.4	
		1.2		1.4
2	3.1		3.8	
		4.3		5.2
3	3.7		4.6	
		8		9.8
4	4.3		5.4	
		12.3		15.2
5	4.9		6.1	
		17.2		21.3
6	5.5		7.1	
		22.7		28.4
7	6.1		7.7	
		28.8		36.1
8	6.2		8	
		35		44.1
9	6.5		8.5	
		41.5		52.6
10	7		9.2	
		48.5		61.8
11	7.3		9.6	
		55.8		71.4
12	7.5		9.7	
		63.3		81.1

Table C5c – South Sector Dam Discharge Curves

Hastings: Dam # 15			
15.2 m (50ft.) Radial Gate Rating Table			
Gate Opening (m)	Discharge (cms)	Gate Opening (m)	Discharge (cms)
0.00	0.0	1.30	83.6
0.05	3.2	1.35	86.9
0.10	6.4	1.40	90.0
0.15	9.6	1.45	93.2
0.20	12.9	1.50	96.5
0.25	16.1	1.55	99.7
0.30	19.3	1.60	102.9
0.35	22.5	1.65	106.1
0.40	25.7	1.70	109.3
0.45	28.9	1.75	112.5
0.50	32.2	1.80	115.7
0.55	35.4	1.85	119.0
0.60	38.6	1.90	122.2
0.65	41.8	1.95	125.4
0.70	45.0	2.00	128.6
0.75	48.2	2.05	131.8
0.80	51.4	2.10	135.0
0.85	54.7	2.15	138.2
0.90	57.9	2.20	141.5
0.95	60.1	2.25	144.7
1.00	64.3	2.30	147.9
1.05	67.5	2.35	151.1
1.10	70.7	2.40	154.3
1.15	73.9	2.45	157.5
1.20	77.2	2.50	160.8
1.25	80.4	2.55	164.0

Table to be used only for the gates in the water

Discharges should be reduced for head leavels below full; a reduction of 10% for .30 - .60 m of drawdown

Table developed by transferring discharges derived from a meter measurement program at Buckhorn Dam

Table C5c – South Sector Dam Discharge Curves

Healey Falls: Dam #14			
6.1 m(20ft.) x 3.07 m(10.1ft.) Vertical Lift Gate Rating Table			
Gate Opening (mm)	Discharge (cms)	Gate Opening (mm)	Discharge (cms)
0	0.0	1500	42.0
50	1.4	1550	43.4
100	2.8	1600	44.8
150	4.2	1650	46.2
200	5.6	1700	47.6
250	7.0	1750	49.0
300	8.4	1800	51.4
350	9.8	1850	52.8
400	11.2	1900	54.2
450	12.6	1950	55.6
500	14.0	2000	57.0
550	15.4	2050	58.3
600	16.8	2100	59.6
650	18.2	2150	60.9
700	19.6	2200	62.2
750	21.0	2250	63.5
800	22.4	2300	64.8
850	23.8	2350	65.1
900	25.2	2400	66.4
950	26.6	2450	67.7
1000	28.0	2500	69.0
1050	29.4	2550	70.3
1100	30.8	2600	71.6
1150	32.2	2650	72.9
1200	33.6	2700	74.2
1250	35.0	2750	75.5
1300	36.4	2800	76.8
1350	37.8	2850	78.1
1400	39.2	2900	79.4
1450	40.6	2950	80.7

Table to be used only for the gates in the water

Discharges should be reduced for head levels below full; a reduction of 10% for .20 and 20% for .40 m of drawdown

Discharges derived from relationships with Healey Falls Weir and Lakefield grate rating

Table C5c – South Sector Dam Discharge Curves

Ranney Falls Lock: Dam #10			
10 m(33ft.) x 3.18 m(10.4ft.) Radial Gate Rating Table			
Gate Opening (cm)	Discharge (cms)	Gate Opening (cm)	Discharge (cms)
0	0.0	110	54.4
5	2.5	115	56.9
10	5.0	120	59.4
15	7.4	125	61.9
20	9.9	130	64.4
25	12.4	135	66.8
30	14.8	140	69.3
35	17.3	145	71.8
40	19.8	150	74.3
45	22.3	155	76.7
50	24.8	160	79.2
55	27.2	165	81.7
60	29.7	170	84.2
65	32.2	175	86.6
70	34.7	180	89.1
75	37.1	185	91.6
80	39.6	190	94.1
85	42.1	195	96.5
90	44.6	200	99.0
95	47.0	205	101.5
100	49.5	210	104.0
105	52.0	215	106.4

Table to be used only for the gates in the water

Discharges should be reduced for head levels below full; a reduction of 10% for .20 m and 20% for .40 m of drawdown

Discharges derived from meter measurements at Dam 10; modified by a relationship between the Campbellford Town Power Plan and observed Dam 10 gate changes (assumed a head level of 145.80m)

Table C5c – South Sector Dam Discharge Curves

Campbellford: Dam #11			
15.2 m(50ft.) Radial Gate Rating Table			
Gate Opening (m)	Discharge (cms)	Gate Opening (m)	Discharge (cms)
0.00	0.0	1.30	83.6
0.05	3.2	1.35	86.9
0.10	6.4	1.40	90.0
0.15	9.6	1.45	93.2
0.20	12.9	1.50	96.5
0.25	16.1	1.55	99.7
0.30	19.3	1.60	102.9
0.35	22.5	1.65	106.1
0.40	25.7	1.70	109.3
0.45	28.9	1.75	112.5
0.50	32.2	1.80	115.7
0.55	35.4	1.85	119.0
0.60	38.6	1.90	122.2
0.65	41.8	1.95	125.4
0.70	45.0	2.00	128.6
0.75	48.2	2.05	131.8
0.80	51.4	2.10	135.0
0.85	54.7	2.15	138.2
0.90	57.9	2.20	141.5
0.95	60.1	2.25	144.7
1.00	64.3	2.30	147.9
1.05	67.5	2.35	151.1
1.10	70.7	2.40	154.3
1.15	73.9	2.45	157.5
1.20	77.2	2.50	160.8
1.25	80.4	2.55	164.0

Table to be used only for the gates in the water

Discharges should be reduced for head levels below full; a reduction of 10% for .30 - .60 m of drawdown

Table developed by transferring discharges derived from a meter measurement program at Buckhorn Dam

Table C5c – South Sector Dam Discharge Curves

Hagues Reach: Dam #9			
15.2 m(50 ft.) x 4.75 m(15.6ft.) Radial Gate Rating Table			
Gate Opening (cm)	Discharge (cms)	Gate Opening (cm)	Discharge (cms)
0	0.0	155	99.7
5	3.2	160	102.9
10	6.4	165	106.1
15	9.6	170	109.3
20	12.9	175	112.5
25	16.1	180	115.7
30	19.3	185	119
35	22.5	190	122.2
40	25.7	195	125.4
45	28.9	200	128.6
50	32.2	205	131.8
55	35.4	210	135
60	38.6	215	138.2
65	41.8	220	141.5
70	45.0	225	144.7
75	48.2	230	147.9
80	51.4	235	151.1
85	54.7	240	154.3
90	57.9	245	157.5
95	61.1	250	160.8
100	64.3	255	164
105	67.5	260	167.2
110	70.7	265	170.4
115	73.9	270	173.7
120	77.2	275	176.9
125	80.4	280	180.1
130	83.6	285	183.3
135	86.8	290	186.5
140	90.0	295	189.7
145	93.2	300	193
150	96.4	305	196.2

Table to be used only for the gates in the water

Discharges should be reduced for head levels below full; a reduction of 10% for .30 - .60 m of drawdown

Discharges derived from a meter measurement program at Buckhorn Dam and transferred to Dam 9

Table C5c – South Sector Dam Discharge Curves

Meyers: Dam #8 (Gates1 -3)			
2.74 m(9ft.) x 6.1 m(20ft.) Vertical Lift Gate Rating Table			
Gate Opening (mm)	Discharge (cms)	Gate Opening (mm)	Discharge (cms)
0	0.0	1300	36.4
50	1.4	1350	37.6
100	2.8	1400	39.3
150	4.1	1450	40.7
200	5.6	1500	42.0
250	6.9	1550	43.4
300	8.3	1600	44.9
350	9.8	1650	46.2
400	11.2	1700	47.7
450	12.5	1750	49.1
500	14.0	1800	50.5
550	15.4	1850	51.9
600	16.9	1900	53.3
650	18.2	1950	54.7
700	19.6	2000	56.1
750	21.0	2050	57.5
800	22.4	2100	58.9
850	23.8	2150	60.3
900	25.2	2200	61.7
950	26.6	2250	63.1
1000	28.0	2300	64.5
1050	29.4	2350	65.9
1100	30.9	2400	67.3
1150	32.2	2450	68.7
1200	33.6	2500	70.1
1250	35.0	2550	71.5

Table to be used only for the gates in the water

Discharges should be reduced for head levels below full; a reduction of 10% for .20 m and 20% for .40 m of drawdown

Discharges derived from meter measurements conducted on a 9ft. Gate opening at Dam 8

Table C5c – South Sector Dam Discharge Curves

Meyers: Dam #8 (Gates 4 - 7)			
3.66 m(12ft.) x 6.1 m(20ft.) Vertical Lift Gate Rating Table			
Gate Opening (mm)	Discharge (cms)	Gate Opening (mm)	Discharge (cms)
0	0.0	1550	54.1
50	1.7	1600	56.0
100	3.3	1650	57.7
150	5.1	1700	59.5
200	6.9	1750	61.2
250	8.6	1800	63.0
300	10.3	1850	64.7
350	12.2	1900	66.5
400	14.0	1950	68.3
450	15.7	2000	70.0
500	17.5	2050	71.8
550	19.2	2100	73.5
600	21.0	2150	75.2
650	22.7	2200	77.0
700	24.5	2250	78.7
750	26.2	2300	80.5
800	28.0	2350	82.2
850	29.7	2400	84.0
900	31.5	2450	85.7
950	33.2	2500	87.4
1000	35.0	2550	89.2
1050	36.7	2600	91.0
1100	38.5	2650	92.7
1150	40.2	2700	94.5
1200	42.0	2750	96.3
1250	43.7	2800	98.0
1300	45.5	2850	99.8
1350	47.1	2900	101.5
1400	49.0	2950	103.3
1450	50.6	3000	105.0
1500	52.4	3050	106.8

Table to be used only for the gates in the water

Discharges should be reduced for head levels below full; a reduction of 10% for .20 m and 20% for .40 m of drawdown

Discharges derived from meter measurements conducted on a 12ft. Gate opening at Dam 8

Table C5b – South Sector Water Level Change vs. Discharge

Level Change to Flow Equivalent - Rice Lake to Lock 9														
Level Change (cm)	**Rice Lake (10123 ha)**		**Lock 17 (1335 ha)**		**Lock 14 (194 ha)**		**Lock 13 (37.6 ha)**		**Lock 12 (53.4 ha)**		**Lock 10 (29.1 ha)**		**Lock 9 (48.6ha)**	
	(day)	**(hr)**	**(day)**	**(hr)**	**(day)**	**(hr)**	**(day)**	**(hr)**	**(day)**	**(hr)**	**(day)**	**(hr)**	**(day)**	**(hr)**
1	281	11.7	37	1.5	5	0.2	1	0	1.5	0.1	0.8	0	1.4	0.1
2	562	23.4	74	3.1	11	0.4	2.1	0.1	3	0.1	1.6	0.1	2.7	0.1
3	844	35.1	111	4.6	16	0.7	3.1	0.1	4.5	0.2	2.4	0.1	4.1	0.2
4	1125	46.9	148	6.2	22	0.9	4.2	0.2	5.9	0.2	3.2	0.1	5.4	0.2
5	1406	58.6	185	7.7	27	1.1	5.2	0.2	7.4	0.3	4.0	0.2	6.8	0.3
6	1587	70.3	222	9.3	32	1.3	6.3	0.3	8.9	0.4	4.9	0.2	8.1	0.3
7	1968	82.0	260	10.8	38	1.6	7.3	0.3	10.4	0.4	5.7	0.2	9.5	0.4
8	2250	93.7	297	12.4	43	1.8	8.4	0.3	11.9	0.5	6.5	0.3	10.8	0.5
9	2531	105.4	334	13.9	48	2.0	9.4	0.4	13.3	0.6	7.3	0.3	12.2	0.5
10	2812	117.2	371	15.5	54	2.2	10.4	0.4	14.8	0.6	8.1	0.3	13.5	0.6
11	3093	128.9	408	17	59	2.5	11.5	0.5	16.3	0.7	8.9	0.4	14.9	0.6
12	3374	140.6	445	18.5	65	2.7	12.5	0.5	17.8	0.7	9.7	0.4	16.2	0.7
13	3656	152.3	482	20.1	70	2.9	13.6	0.6	19.3	0.8	10.5	0.4	17.6	0.7
14	3937	164.0	519	21.6	75	3.1	14.6	0.6	20.8	0.9	11.3	0.5	18.9	0.8
15	4218	175.7	556	23.2	81	3.4	15.7	0.7	22.3	0.9	12.1	0.5	20.3	0.8
16	4499	187.5	593	24.7	86	3.6	16.7	0.7	23.7	1	12.9	0.5	21.6	0.9
17	4780	199.2	630	26.3	92	3.8	17.8	0.7	25.2	1.1	13.7	0.6	23	1
18	5062	210.9	667	27.8	97	4.0	18.8	0.8	26.7	1.1	14.6	0.6	24.3	1
19	5343	222.6	705	29.4	102	4.3	19.8	0.8	28.2	1.2	15.4	0.6	25.7	1.1
20	5624	234.3	742	30.9	108	4.5	20.9	0.9	29.7	1.2	16.2	0.7	27	1.1
21	5905	246.0	779	32.4	113	4.7	21.9	0.9	31.2	1.3	17.0	0.7	28.4	1.2
22	6186	257.8	816	34	119	4.9	23	1	32.6	1.4	17.8	0.7	29.7	1.2
23	6467	269.5	853	35.5	124	5.2	24	1	34.1	1.4	18.6	0.8	31.1	1.3
24	6749	281.2	890	37.1	129	5.4	25.1	1	35.6	1.5	19.4	0.8	32.4	1.4
25	7030	292.9	927	38.6	135	5.6	26.1	1.1	37.1	1.5	20.2	0.8	33.8	1.4
26	7311	304.6	964	40.2	140	5.8	27.2	1.1	38.6	1.6	21.0	0.9	35.1	1.5
27	7592	316.3	1001	41.7	146	6.1	28.2	1.2	40.1	1.7	21.8	0.9	36.5	1.5
28	7873	328.1	1038	73.3	151	6.3	29.2	1.2	41.5	1.7	22.6	0.9	37.8	1.6
29	8155	339.8	1075	44.8	156	6.5	30.3	1.3	43	1.8	23.4	1.0	39.2	1.6
30	8436	351.5	1113	46.4	162	6.7	31.3	1.3	44.5	1.9	24.3	1.0	40.5	1.7

1. Enter the table at column 1 with the number of cm change that you have observed
2. Go across to the left column of the two for your site if the change is per hour or to the right column if the change is for a whole day (24hr)
3. The figure shoes is the number of cubic meters per second the observed change is

Table C5c – Log Depth-Discharge Relationships

Summary Table of Log Depth Discharge

Log Depth	Logs Changed	Log Length (ft)														
		7	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**25**
1	1	0.5	0.6	0.7	0.7	0.8	0.9	1	1	1.1	1.2	1.3	1.3	1.4	1.5	1.9
2	2	0.9	1	1.2	1.3	1.5	1.6	1.7	1.9	2	2.2	2.3	2.4	2.6	2.7	3.4
	1-2	1.4	1.6	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.4	3.6	3.8	4	4.2	5.3
3	3	1.2	1.4	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.2	3.4	3.6	4.6
	2-3	2.1	2.4	2.7	3.1	3.4	3.7	4	4.4	4.7	5	5.4	5.7	6	6.3	8
	1-3	2.6	3	3.4	3.8	4.2	4.6	5	5.4	5.8	6.2	6.6	7	7.4	7.8	9.8
4	4	1.3	1.6	1.8	2	2.3	2.5	2.7	3	3.2	3.4	3.7	3.9	4.1	4.3	5.5
	3-4	2.5	2.9	3.4	3.8	4.2	4.6	5	5.4	5.9	6.3	6.7	7.1	7.5	8	10.1
	2-4	3.4	4	4.5	5.1	5.7	6.2	6.8	7.3	7.9	8.4	9	9.6	10.1	10.7	13.5
	1-4	3.9	4.6	5.2	5.8	6.5	7.1	7.7	8.4	9	9.6	10.3	10.9	11.5	12.2	15.3
5	5	1.5	1.7	2	2.3	2.5	2.8	3.1	3.3	3.6	3.9	4.1	4.4	4.7	5	6.3
	4-5	2.8	3.3	3.8	4.3	4.8	5.3	5.8	6.3	6.8	7.3	7.8	8.3	8.8	9.3	11.8
	3-5	4	4.7	5.4	6	6.7	7.4	8.1	8.8	9.5	10.2	10.9	11.5	12.2	12.9	16.3
	2-5	4.9	5.7	6.5	7.4	8.2	9	9.9	10.7	11.5	12.3	13.2	14	14.8	15.6	19.8
	1-5	5.4	6.3	7.2	8.1	9	9.9	10.8	11.7	12.6	13.5	14.4	15.3	16.2	17.1	21.6
6	6	1.6	1.9	2.2	2.5	2.8	3.1	3.4	3.7	4	4.3	4.6	4.9	5.2	5.5	7
	5-6	3	3.6	4.2	4.7	5.3	5.9	6.4	7	7.6	8.1	8.7	9.3	9.8	10.4	13.2
	4-6	4.4	5.2	6	6.8	7.6	8.4	9.2	10	10.8	11.6	12.4	13.2	14	14.7	18.7
	3-6	5.6	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.4	14.4	15.4	16.4	17.4	18.4	23.3
	2-6	6.5	7.6	8.7	9.8	11	12.1	13.2	14.3	15.5	16.6	17.7	18.8	20	21.1	26.7
	1-6	7	8.2	9.4	10.6	11.8	13	14.2	15.4	16.6	17.8	19	20.2	21.4	22.6	28.6
7	7	1.6	1.9	2.3	2.6	2.9	3.3	3.6	3.9	4.3	4.6	4.9	5.3	5.6	5.9	7.6
	6-7	3.2	3.8	4.4	5.1	5.7	6.3	7	7.6	8.2	8.9	9.5	10.1	10.8	11.4	14.5
	5-7	4.7	5.6	6.5	7.4	8.2	9.1	10	10.9	11.8	12.7	13.6	14.5	15.4	16.3	20.8
	4-7	6	7.1	8.3	9.4	10.5	11.6	12.8	13.9	15	16.2	17.3	18.4	19.5	20.7	26.3
	3-7	7.2	8.5	9.8	11.1	12.4	13.8	15.1	16.4	17.7	19	20.3	21.7	23	24.3	30.9
	2-7	8.1	9.5	11	12.4	13.9	15.4	16.8	18.3	19.7	21.2	22.6	24.1	25.6	27	34.3
	1-7	8.6	10.1	11.7	13.2	14.7	16.2	17.8	19.3	20.8	22.4	23.9	25.4	27	28.5	36.2
8	8	1.6	2	2.4	2.7	3.1	3.4	3.8	4.2	4.5	4.9	5.2	5.6	6	6.3	8.1
	7-8	3.3	3.9	4.6	5.3	6	6.7	7.4	8.1	8.8	9.5	10.2	10.9	11.6	12.2	15.7
	6-8	4.8	5.8	6.8	7.8	8.8	9.8	10.8	11.8	12.7	13.7	14.7	15.7	16.7	17.7	22.7
	5-8	6.3	7.6	8.8	10.1	11.3	12.6	13.8	15.1	16.4	17.6	18.9	20.1	21.4	22.7	28.9
	4-8	7.6	9.1	10.6	12.1	13.6	15.1	16.6	18.1	19.6	21	22.5	24	25.5	27	34.4
	3-8	8.8	10.5	12.2	13.8	15.5	17.2	18.9	20.5	22.2	23.9	25.6	27.3	28.9	30.6	39
	2-8	9.7	11.5	13.3	15.2	17	18.8	20.6	22.4	24.2	26.1	27.9	29.7	31.5	33.3	42.4
	1-8	10.2	12.1	14	15.9	17.8	19.7	21.6	23.5	25.4	27.3	29.2	31	32.9	34.8	44.3
9	9	1.6	2	2.4	2.8	3.2	3.6	4	4.3	4.7	5.1	5.5	5.9	6.3	6.7	8.6
	8-9	3.3	4	4.8	5.5	6.3	7	7.8	8.5	9.3	10	10.7	11.5	12.2	13	16.7
	7-9	4.9	6	7.1	8.1	9.2	10.3	11.4	12.4	13.5	14.6	15.7	16.8	17.8	18.9	24.3
	6-9	6.5	7.8	9.2	10.6	12	13.3	14.7	16.1	17.5	18.9	20.2	21.6	23	24.4	31.3
	5-9	7.9	9.6	11.2	12.9	14.5	16.2	17.8	19.4	21.1	22.7	24.4	26	27.7	29.3	37.6
	4-9	9.3	11.2	13	14.9	16.8	18.7	20.5	22.4	24.3	26.2	28	29.9	31.8	33.7	43
	3-9	10.4	12.5	14.6	16.6	18.7	20.8	22.8	24.9	27	29	31.1	33.2	35.2	37.3	47.6
	2-9	11.4	13.6	15.8	18	20.2	22.4	24.6	26.8	29	31.2	33.4	35.6	37.8	40	51
	1-9	11.9	14.1	16.4	18.7	21	23.3	25.5	27.8	30.1	32.4	34.7	36.9	39.2	41.5	52.9
10	10	1.6	2	2.4	2.8	3.3	3.7	4.1	4.5	4.9	5.3	5.7	6.1	6.6	7	9
	9-10	3.2	4	4.8	5.6	6.4	7.2	8	8.8	9.6	10.4	11.2	12	12.8	13.6	17.6
	8-10	4.9	6	7.2	8.4	9.5	10.7	11.8	13	14.2	15.3	16.5	17.6	18.8	20	25.8
	7-10	6.5	8	9.5	11	12.5	14	15.4	16.9	18.4	19.9	21.4	22.9	24.4	25.9	33.3
	6-10	8.1	9.9	11.6	13.4	15.2	17	18.8	20.6	22.4	24.2	26	27.8	29.5	31.3	40.3
	5-10	9.5	11.6	13.7	15.7	17.8	19.8	21.9	23.9	26	28.1	30.1	32.2	34.2	36.3	46.6
	4-10	10.9	13.2	15.5	17.8	20	22.3	24.6	26.9	29.2	31.5	33.8	36.1	38.3	40.6	52.1
	3-10	12.1	14.5	17	19.5	22	24.4	26.9	29.4	31.9	34.3	36.8	39.3	41.8	44.2	56.6
	2-10	13	15.6	18.2	20.8	23.4	26	28.7	31.3	33.9	36.5	39.1	41.7	44.4	47	60
	1-10	13.5	16.2	18.9	21.5	24.2	26.9	29.6	32.3	35	37.7	40.4	43.1	45.8	48.5	61.9
11	11	1.6	2	2.4	2.9	3.3	3.7	4.2	4.6	5	5.5	5.9	6.3	6.8	7.2	9.4
	10-11	3.2	4	4.9	5.7	6.5	7.4	8.2	9.1	9.9	10.8	11.6	12.5	13.3	14.2	18.4
	9-11	4.8	6	7.3	8.5	9.7	11	12.2	13.4	14.7	15.9	17.1	18.4	19.6	20.8	27
	8-11	6.4	8	9.6	11.2	12.8	14.4	16	17.6	19.2	20.8	22.4	24	25.6	27.2	35.1
	7-11	8.1	10	11.9	13.8	15.8	17.7	19.6	21.5	23.5	25.4	27.3	29.2	31.2	33.1	42.7
	6-11	9.6	11.8	14.1	16.3	18.5	20.7	23	25.2	27.4	29.6	31.9	34.1	36.3	38.5	49.7
	5-11	11.1	13.6	16.1	18.6	21.1	23.6	26	28.5	31	33.5	36	38.5	41	43.5	56
	4-11	12.4	15.2	17.9	20.6	23.3	26.1	28.8	31.5	34.2	36.9	39.7	42.4	45.1	47.8	61.5
	3-11	13.6	16.5	19.4	22.3	25.3	28.2	31.1	34	36.9	39.8	42.7	45.6	48.5	51.5	66
	2-11	14.5	17.6	20.6	23.7	26.7	29.8	32.8	35.9	38.9	42	45	48.1	51.1	54.2	69.4
	1-11	15	18.2	21.3	24.4	27.5	30.7	33.8	36.9	40	43.2	46.3	49.4	52.5	55.7	71.3
12	12	1.5	1.9	2.4	2.9	3.3	3.8	4.2	4.7	5.2	5.6	6.1	6.5	7	7.5	9.8
	11-12	3	3.9	4.8	5.7	6.6	7.5	8.4	9.3	10.2	11.1	12	12.9	13.8	14.7	19.1
	10-12	4.6	6	7.3	8.6	9.9	11.2	12.5	13.8	15.1	16.4	17.7	19	20.3	21.6	28.2
	9-12	6.3	8	9.7	11.4	13.1	14.8	16.4	18.1	19.8	21.5	23.2	24.9	26.6	28.3	36.8
	8-12	7.9	10	12	14.1	16.1	18.2	20.2	22.3	24.4	26.4	28.5	30.5	32.6	34.6	44.9
	7-12	9.5	11.9	14.3	16.7	19.1	21.5	23.9	26.2	28.6	31	33.4	35.8	38.2	40.5	52.5
	6-12	11.1	13.8	16.5	19.2	21.8	24.5	27.2	29.9	32.6	35.3	38	40.6	43.3	46	59.4
	5-12	12.6	15.5	18.5	21.4	24.4	27.3	30.3	33.2	36.2	39.1	42.1	45.1	48	51	65.7
	4-12	13.9	17.1	20.3	23.5	26.7	29.8	33	36.2	39.4	42.6	45.8	48.9	52.1	55.3	71.2
	3-12	15.1	18.5	21.8	25.2	28.6	31.9	35.3	38.7	42.1	45.4	48.8	52.2	55.5	58.9	75.8
	2-12	16	19.5	23	26.5	30	33.6	37.1	40.6	44.1	47.6	51.1	54.6	58.1	61.6	79.2
	1-12	16.5	20.1	23.7	27.3	30.9	34.4	38	41.6	45.2	48.8	52.4	56	59.5	63.1	81.1

Table C6 - Snowpack Survey Data Sheet

Trent-Severn Waterway - Snow Survey Data

Snow Course Name:	**Date:**	**Year:**	**Observed By:**

Descriptions	**Observation Point (m)**	**Snow Depth (cm)**	**Length of Core (cm)**	**Weight of Empty Tube (cm)**	**Weight of Tube and Core (cm)**	**Water Content (cm)**	**Crust Cond.**	**Ice Layers**	**Soil Cond.**	**Remarks**
Crust Conditions										
A No Crust	0									
B Light Crust	50									
C Crust Supports Person on Snowshoes	100									
D Crust Supports Person Without Snowshoes Sometimes	150									
E Crust Supports Person Without Snowshoes Most of the Time	200									
	250									
	300									
Ice Layers	350									
0 Nil	400									
1 Layers within Pack	450									
2 Layers at Base of Pack	500									
3 Layers both within & at Base of Pack	550									
	600									
	650									
Soil Conditions	700									
"F" = Frozen	750									
"UD"= Unfrozen dry	800									
"UW"= Unfrozen wet	850									
	900									
	950									
	Total =	0	/ 20		Total =	0	/ 20			
	Average Depth =	0	centimetres		Average Water Content =	0	centimetres			
	Average Depth =	0	millimetres		Average Water Content =	0	millimetres			

Comments:

Table C7 – Kawartha Lakes Winter Drawdown Schedule

Kawartha's Winter Drawdown Schedule							Snow Survey Dates
20 year Average Water Elevation							
Date	Balsam (m)	Scugog (m)	Sturgeon (m)	Buckhorn (m)	Stony (m)		Start Date
December 31, 2010	56.08	49.85	47.67	45.94	34.22		January 4, 2011
January 7, 2011	56.02	49.81	47.63	45.84	34.15		January 18, 2011
January 14, 2011	55.96	49.78	47.59	45.75	34.07		February 1, 2011
January 21, 2011	55.90	49.74	47.55	45.65	34.00		February 8, 2011
January 28, 2011	55.85	49.70	47.51	45.55	33.93		February 15, 2011
February 4, 2011	55.79	49.66	47.47	45.45	33.86		February 22, 2011
February 11, 2011	55.73	49.63	47.42	45.36	33.78		March 1, 2011
February 18, 2011	55.67	49.59	47.38	45.26	33.71		March 8, 2011
February 25, 2011	55.61	49.55	47.34	45.16	33.64		March 15, 2011
March 4, 2011	55.55	49.51	47.30	45.06	33.57		March 22, 2011
March 11, 2011	55.50	49.48	47.26	44.97	33.49		
March 18, 2011	55.44	49.44	47.22	44.87	33.52		

Table C7 – Kawartha Lakes Winter Drawdown Schedule (Management of Fall Lake Levels)

25 Year Average Fall Drawdown Schedule (Lake Levels in m)														
Date	Glouces	Sixmile	Canal	Mitchell	Balsam	Cameron	Scugog	Sturgeon	Buckhorn	Deer Bay	Lovesick	Stony	Katch	Rice
11/1	80.44	86.36	40.75	55.62	56.11	54.94	49.83	47.69	46.02	42.47	41.28	34.27	32.01	86.67
11/2	80.43	86.36	40.70	55.59	56.11	54.94	49.83	47.69	46.02	42.48	41.28	34.27	32.02	86.68
11/3	80.44	86.36	40.66	55.56	56.11	54.94	49.84	47.70	46.02	42.49	41.28	34.28	32.01	86.68
11/4	80.44	86.36	40.61	55.49	56.11	54.94	49.84	47.71	46.02	42.48	41.28	34.28	32.01	86.68
11/5	80.43	86.37	40.57	55.47	56.12	54.94	49.84	47.71	46.02	42.50	41.29	34.28	32.00	86.68
11/6	80.42	86.37	40.46	55.45	56.12	54.94	49.84	47.71	46.02	42.49	41.31	34.27	31.98	86.68
11/7	80.42	86.36	40.41	55.44	56.12	54.93	49.84	47.71	46.02	42.49	41.31	34.28	31.98	86.68
11/8	80.42	86.35	40.44	55.46	56.12	54.93	49.84	47.71	46.02	42.50	41.31	34.28	31.98	86.68
11/9	80.42	86.35	40.47	55.45	56.12	54.93	49.84	47.71	46.02	42.50	41.32	34.29	31.99	86.68
11/10	80.42	86.34	40.56	55.43	56.12	54.92	49.84	47.71	46.02	42.50	41.29	34.29	32.00	86.68
11/11	80.41	86.33	40.51	55.45	56.11	54.92	49.84	47.71	46.02	42.50	41.28	34.29	32.00	86.68
11/12	80.41	86.34	40.52	55.45	56.11	54.93	49.84	47.70	46.02	42.50	41.27	34.30	32.00	86.69
11/13	80.41	86.34	40.54	55.45	56.11	54.93	49.85	47.70	46.02	42.50	41.28	34.30	32.00	86.68
11/14	80.42	86.33	40.54	55.44	56.11	54.92	49.85	47.70	46.03	42.50	41.24	34.30	31.99	86.68
11/15	80.41	86.32	40.54	55.44	56.12	54.92	49.85	47.70	46.03	42.49	41.23	34.30	31.99	86.69
11/16	80.41	86.30	40.52	55.45	56.12	54.91	49.86	47.70	46.03	42.44	41.22	34.30	31.98	86.69
11/17	80.41	86.28	40.56	55.45	56.12	54.90	49.86	47.71	46.03	42.40	41.19	34.30	31.98	86.70
11/18	80.41	86.23	40.53	55.46	56.12	54.88	49.86	47.70	46.03	42.36	41.15	34.30	31.96	86.70
11/19	80.41	86.21	40.50	55.45	56.12	54.86	49.85	47.70	46.03	42.30	41.17	34.31	31.93	86.70
11/20	80.41	86.19	40.49	55.46	56.12	54.84	49.86	47.70	46.03	42.25	41.15	34.31	31.95	86.71
11/21	80.41	86.13	40.46	55.45	56.12	54.83	49.86	47.70	46.03	42.22	41.14	34.30	31.93	86.71
11/22	80.40	86.10	40.43	55.45	56.12	54.81	49.86	47.70	46.03	42.19	41.11	34.30	31.94	86.71
11/23	80.40	86.06	40.41	55.44	56.11	54.80	49.86	47.69	46.03	42.17	41.08	34.30	31.94	86.71
11/24	80.40	86.03	40.41	55.43	56.11	54.78	49.86	47.69	46.03	42.16	41.07	34.30	31.96	86.71
11/25	80.40	85.95	40.39	55.43	56.10	54.77	49.86	47.69	46.02	42.16	41.04	34.29	31.97	86.69
11/26	80.39	85.96	40.37	55.43	56.10	54.76	49.85	47.69	46.02	42.16	41.03	34.29	31.98	86.72
11/27	80.38	85.93	40.36	55.42	56.10	54.74	49.85	47.69	46.02	42.16	41.04	34.29	31.99	86.71
11/28	80.38	85.90	40.35	55.43	56.10	54.74	49.86	47.69	46.01	42.14	41.08	34.28	31.98	86.69
11/29	80.37	85.87	40.35	55.43	56.10	54.74	49.86	47.69	46.01	42.13	41.09	34.28	31.97	86.70
11/30	80.38	85.86	40.38	55.44	56.10	54.74	49.86	47.69	46.01	42.14	41.10	34.28	31.97	86.71
12/1	80.38	85.85	40.47	55.46	56.10	54.74	49.87	47.70	46.01	42.15	41.11	34.28	31.98	86.70
12/2	80.37	85.82	40.50	55.47	56.10	54.72	49.87	47.70	46.01	42.12	41.11	34.28	31.97	86.70
12/3	80.37	85.80	40.51	55.49	56.11	54.72	49.86	47.70	46.01	42.14	41.11	34.28	31.99	86.70
12/4	80.35	85.79	40.50	55.49	56.10	54.71	49.87	47.70	46.01	42.15	41.12	34.28	32.02	86.71
12/5	80.35	85.77	40.49	55.49	56.10	54.70	49.87	47.70	46.00	42.16	41.12	34.28	32.03	86.70
12/6	80.35	85.76	40.50	55.49	56.10	54.70	49.86	47.70	46.00	42.16	41.13	34.28	32.02	86.70
12/7	80.35	85.77	40.49	55.48	56.10	54.69	49.87	47.70	46.00	42.17	41.12	34.28	31.99	86.70
12/8	80.35	85.75	40.48	55.48	56.10	54.68	49.86	47.69	45.99	42.15	41.11	34.27	31.97	86.70
12/9	80.35	85.75	40.47	55.47	56.10	54.68	49.86	47.68	45.99	42.14	41.10	34.26	31.96	86.69
12/10	80.35	85.75	40.47	55.47	56.10	54.67	49.85	47.68	45.99	42.11	41.09	34.26	31.94	86.69
12/11	80.35	85.74	40.42	55.47	56.09	54.66	49.85	47.68	45.99	42.09	41.08	34.26	31.98	86.69
12/12	80.35	85.73	40.43	55.46	56.10	54.66	49.85	47.67	45.99	42.07	41.09	34.26	31.99	86.69
12/13	80.34	85.72	40.42	55.47	56.10	54.66	49.85	47.67	45.98	42.07	41.08	34.26	31.99	86.69
12/14	80.34	85.70	40.43	55.47	56.10	54.66	49.85	47.67	45.98	42.06	41.08	34.25	31.99	86.69
12/15	80.33	85.70	40.43	55.47	56.09	54.66	49.84	47.67	45.98	42.07	41.06	34.25	31.99	86.68
12/16	80.33	85.70	40.44	55.47	56.09	54.66	49.84	47.67	45.97	42.07	41.06	34.24	31.97	86.69
12/17	80.34	85.70	40.43	55.47	56.09	54.66	49.84	47.67	45.97	42.07	41.05	34.24	31.99	86.69
12/18	80.34	85.69	40.40	55.47	56.09	54.67	49.84	47.67	45.97	42.07	41.04	34.24	31.99	86.69
12/19	80.34	85.70	40.40	55.47	56.09	54.67	49.84	47.67	45.96	42.08	41.01	34.24	31.98	86.68
12/20	80.33	85.71	40.39	55.46	56.09	54.67	49.83	47.67	45.96	42.08	41.00	34.23	32.00	86.68
12/21	80.33	85.72	40.39	55.46	56.08	54.67	49.83	47.67	45.95	42.08	41.01	34.23	31.99	86.68
12/22	80.33	85.73	40.40	55.45	56.08	54.66	49.83	47.67	45.95	42.07	41.00	34.23	31.99	86.68
12/23	80.34	85.73	40.40	55.45	56.08	54.66	49.83	47.66	45.95	42.06	40.99	34.22	32.01	86.68
12/24	80.35	85.74	40.43	55.48	56.08	54.67	49.83	47.67	45.95	42.05	40.99	34.23	32.01	86.69
12/25	80.36	85.74	40.51	55.47	56.08	54.68	49.83	47.67	45.95	42.05	41.00	34.22	32.01	86.69
12/26	80.36	85.74	40.55	55.48	56.08	54.69	49.83	47.67	45.95	42.05	41.01	34.22	32.01	86.70
12/27	80.36	85.74	40.48	55.48	56.08	54.70	49.83	47.67	45.94	42.05	41.01	34.22	32.01	86.69
12/28	80.36	85.73	40.51	55.50	56.07	54.69	49.83	47.68	45.94	42.05	41.00	34.22	32.01	86.69
12/29	80.36	85.74	40.45	55.49	56.07	54.68	49.84	47.68	45.94	42.05	41.00	34.22	32.00	86.69
12/30	80.36	85.75	40.43	55.49	56.08	54.68	49.84	47.68	45.94	42.06	41.01	34.22	32.02	86.69
12/31	80.34	85.75	40.48	55.49	56.08	54.69	49.85	47.67	45.94	42.08	41.02	34.22	32.01	86.69
LOW	80.33	85.69	40.35	55.42	56.07	54.66	49.83	47.67	45.94	42.05	40.99	34.22	31.93	86.67
HIGH	80.44	86.37	40.75	55.62	56.12	54.94	49.87	47.71	46.03	42.50	41.29	34.31	32.03	86.71

Table C8 – Sample of Daily Levels/Instructions from Water Control Engineer

Daily Levels				
Date: 11/1/2011				
Norland	4.015	m	-0.1	cm/day
Balsam	56.053	m	-1.8	cm/day
Gelert Level	1.122	m	-1	cm/day
Gelert Rain	0	mm		
Irondale Level		m	-111.9	cm/day
Irondale Rain	-2447.6	mm		
Burnt River	3.665	m	-0.9	cm/day
Cameron	54.682	m	-2.7	cm/day
Scugog Level	49.875	m	-0.5	cm/day
Scugog Rain	0	mm		
Sturgeon	47.641	m	-2.9	cm/day
Deer Bay	42.51	m		
Lovesick	41.335	m	-0.7	cm/day
Stony	34.271	m	-0.1	cm/day
Katchewanooka	32.043	m	-8.8	cm/day
Otonabee	89	cms	-10.4	cms
Nassau	12.584	m		
Little	88.695	m	11.5	cm/day
Lower Lock 19	88.013	m	24.3	cm/day
Lock 19 Rain	0.2	mm		
Rice Level	86.707	m	-0.5	cm/day
Rice Rain	0.2	mm		
Healey Weir	0.48	m		
Crowe River		m		
Crowe Bay	60.671	m		
Percy Reach	13.623	m	4.6	cm/day
Glen Ross Upper	13.256	m		
Glen Ross Lower	11.082	m		
Jacksons	18.719	m	0.1	cm/day
Jacksons Rain	0	mm		
Black 169 S	8.421	m	-1.3	cm/day
Black 169 N	16.929	m	-0.6	cm/day
Black 169 N	65.3	cms	-1.6	cms/day
Dam D	17.132	m	1.2	cm/day
Sparrow	12.818	m	-1.1	cm/day
Severn Flow	62.1	cms	-1.5	cms
Six Mile	85.713	m	-0.9	cm/day
Gloucester	80.454	m	0	cm/day
Mitchell	55.483	m	-0.7	cm/day
Canal	40.632	m	-1.3	cm/day
Kirkfield Rain	0	mm		
Upper Talbot	28.904	m	-1.2	cm/day
Lower Talbot	26.189	m	-0.1	cm/day
Kennisis	1.545	m		
Redpine	1.011	m		
Halls	1.973	m		
Maple Level	6.796	m	-0.7	cm/day
Maple Rain	1	mm		
Twelve Mile	1.45	m		
Horseshoe	1.865	m	-0.9	cm/day
Gull Lake	6	m	0	cm/day
Moore Lake	1.999	m	0	cm/day
Canning	1.193	m		
Gooderham	2.34	m		
Anstruther	1.126	m		
Mississauga Level	12.28	m	-0.8	cm/day
Mississauga Rain	0	mm		
Eels Lake	1.587	m		
Eels Creek	11.177	m	-2	cm/day
Jack	1.234	m		
Black 169 N	16.929	m	1692.9	cm/day
Black 169 N	65.3	cms	65.3	cms/day
Trenton	49	m	-3011.7	cm/day
Trent Flow	0	cms	-85.1	cms

Table C9a - Logbook Sample from 2002

DATES 2002	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
TRENT AREA June	9		10		11		12		13		Nav. Cased #1-#2 14		15	
Weather			10 hazy calm		17 hazy WSW 9		10 o'cast ENE15		14 p cldy NW4		15 o'cast ENE 9		12 o'cast	
Precipitation							44.5mm LF (0.35" Hal.) 33 mm KLL						7.7 mm 24 mm C Place	
Gull-Maple (Q)			0.60	7.06	0.59	6.81	0.61	7.31	0.64	8.17	0.66	8.77		
Gull-Norland (Q)			3.636	11.84 (+2)	3.639	11.96	3.644	12.16	3.720	15.46	3.719 (+)	15.412	3.754	17.1
BALSAM L*(256.16-256.19)		32	56.21 (20)		56.20		56.236 (24)	33	56.22		56.21		56.20	
(Laidlaw Z=250.00)			nc		nc		1X		nc		nc		nc	
Burnt-Gelert (Q)			0.88	4.42	0.87	4.21	0.89	4.64	0.89	4.64	0.88	4.42		
Irondale-Furnace (Q)	1.520	6.30	1.492	5.512	1.472	4.984	1.461	4.696	1.471	4.957	1.518	6.242		
Burnt-Burnt R (Q)			3.300	11.18	3.244	9.908	3.300	11.18	3.292	10.996	3.301	11.204	3.313	11.5
CAMERON LAKE*	55.018		55.026		55.001	(Show Flow not right)	55.033	(Show Flo not right)	55.051		55.081		55.010	
(254.96 - 255.04)			nc/26		-6/20		+6/26		+4/30		+15/45		-12/33	
(Rosedale Z=200.00)														
SCUGOG L(249.78-249.92)		1 5½	50.03	1'2	50.02		50.09	1 5½	50.15	5½ 5½	50.17		50.17	
(Caesarea Z=245.00)			3½ □	(-12)	nc		3½ x	(+12)	4½ x	(+14)	nc		nc	
STURGEON LAKE*			47.77		47.78		47.83 (84)		47.83		47.80		47.81	
(247.73 - 247.76)	12	12	nc/12	nc/12	nc		+9/21	+9/21	+9/30	+9/30	nc		nc	
(Sturg.Pt. Z=240.00)								(+28.2)		(+28.2)				
BUCKHORN LAKE*	46.124		46.104		46.104		46.147		46.174		46.179		46.170	
(245.92 - 246.08)	20	60	-20/0	-10/50	nc		+40/40	nc/50	nc/40	+60/110	+20/60	nc/110	nc	
(Gannon Z=200.00)				(-20)				(+26)		(+39.5)		(+13.1)		
Deer Bay (42.56-42.64)	42.686	41.562	42.677	41.557	42.678	41.481	42.702	41.490	42.687	41.486	42.703	41.401	42.713	41.452
Lovesick (41.42-41.47)			(-20)	(-15)	nc		(+30)	(+30)			(+17)	(+15)	1X	1X
STONY LAKE*	34.334		34.333		34.340		34.384		34.391		34.436		34.448	
234.05 - 234.35			#2 -400/700 #5 -650/600		nc		#2 +650/1350 #5 +600/1200		#4 +1850/1850 4 pm		#4 +1850/1850		#5 +150/1350	
(McCracken Z=230.00)								(+30.2)	#4 -1850 -44.5/0	(+44.5)		(+44.5)		(+3.3)
KATCH. L*(231.92-232.02)			#3 -600/0 PP-10		Sw. to Sum. blade PP(-2)		#3 +1200/12		#2 +1500/1500 #2 +1500/0	(+35.6)	#3 +400/1600 #2 +1500/1500 (+44)		#4 +250/250 (+7)	
LakefieldAffra (Z=230.631)			31.996	72.89	31.961	42.19	31.978	45.77	31.864	85.88	31.958	75E	32.026	
River Rd (<pp>)				RR(-25)				(+30)	#4 -350/0 (-40 pp)					
Nassau (212.48 - 212.58) gates kilowatts									Special flow cut (-40) @ 4pm					
Lock 19 (189.01 - 189.17) (Driscolls)				1.582		1.472		1.755	sewer break at oton. R. 2.105 4pm	1.975		1.887		2.067
RICE LAKE*	86.722		86.718		86.711		86.777		86.846		86.862		86.818	
(186.59 - 186.72)				(-25.7)						(+70)		(+70)		(+30)
(Harwood Z=100.00)														
Healy Falls			83.81		83.86		83.95		83.94		83.72		83.52	
(183.69 - 183.99)							87mm					(+50)		(+10)
Healy @ Weir (Q) <pp>			0.131	9.71	0.048	2.338	0.053	2.72	0.388	57.98	0.615	125.1	0.738	167.68
Crowe @ Marmora (Q)			10.524	26.44	10.379	17.74	10.395	18.7	10.429	20.74	10.479	23.74	10.543	27.58
Crowe Bay (160.70-160.85)			60.821		60.658		60.941		60.746		60.909	(+60)	60.684	nc
Percy Reach (Z=100.0)	13.546		13.578		13.537		13.618		13.715		13.673		13.768	
Glen Ross U = 113.32 - 113.47 L = 110.09 - 110.39	113.447	110.517	113.467	110.549	113.467	110.538	113.511	110.573	113.563	110.876	113.357	110.818	113.271	110.947
Ontario Hydro														

Winter Settings: Balsam: 255.25 Scugog:249.44 Sturgeon:247.22 Buckhorn:244.87 Stony:233.42

SEVERN AREA	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
Weather	18° clr	calm	20° P cld	S 5-10	18 p cld	Calm	11 vag	SE 5-10	16° o'cast	calm	15 cldy	N 5	15° driz	calm
Precipitation	Trace		NP		NP		13.7mm		0.7mm		NP		12.6	
Washago- DAM D	17.10													
Wasdell Aff. (Q)(Z=209.936)	16.70	92.7	16.63	92.8	16.74	99.24	16.739	96.44	16.738	97.44	16.727	98.94	16.649	99.271
Jack Pt.(218.69-219.06) C	19.13		19.13	D 1x16x AM 1x17x PM	19.11 (.14)		19.14 (.15)		19.13		19.14 (.15)		19.15	
Orch. Pt.(218.69-219.06) M	19.13		19.12	(-10)	19.12 (.13)		19.13 (.12)		19.14		19.13 (.14)		19.15	
Washago Q	19.046	79.5	19.048	76.3	19.025	83.972	19.024	81.0	19.020	81.81	19.023	84.042	19.052	84.802
Black River @ Washago (Q)	7.895	18.2	7.823	16.5	7.787	15.268	7.790	15.37	7.798	15.63	7.776	14.898	7.763	14.469
Severn Total -Q														
Sparrow (212.36-212.48)	12.624		12.605		12.604		12.651		12.685		12.700		12.696	
Swift Rap. (212.36-212.48)	12.12	98.26	12.09	98.26	12.12	98.26	12.23	98.24	12.27	98.21	12.26	98.27	12.19	98.32
total kilowatts <pp>Q			V3 -6/54	(-5)	V3 -6/48	(-6)				V3 +6/54	V3 +3/51	(+2.9)		
total Q log Q	7636 61.6+32	= 93.6	7534 61.6+29.2	= 90.8	7555	62.0+23 = 85.0	7650 63+20.4	= 83.4	7693 62.6+24.5	= 87.1	V3+9/66 7140	PM (+6) 67.5+30.5 = 97.8	7568 61.8+36	= 97.8
Pretty Channel DAM	98.07	80.45	98.08	80.45	98.09	80.60	98.06	80.49	98.06	80.49	98.10	80.49	98.10	80.49
Big Chute (198.06-198.21)	64.4 2.7		64.5 1.7	2/3x	64.8 8.9	1 0/3x	59.7 17.8		64.6 5.4	1x 3 4	64.4 8.9		64.5 20.2	
<pp> Q	93.4 26.6		87.0 20.8	(-9)	87.9 14.2	(-4)	89.5 12.0		84.5 14.5		89.4 16.1		102.0 17.3	
Six Mile	86.457		86.446	3 1	86.444		86.444		86.411		86.407		86.431	
(185.67 - 186.43)			2□	(-9)	nc						nc		nc	
Port Severn	80.458	3 6	80.459		80.433	3 5	80.479	3 6	80.467		80.419		80.455	3 7
(180.42 - 180.50)	1X	+4	nc		1□	(-5.5)	1X	(+5.5)	nc		1□		2X	(+11)

<pp>= power plant M= mean level C= curve Q= flow U= upper L= lower Z= zero R= River

Table C9b - Haliburton Reservoir Stoplog Settings from 2007

Date (dd/mm/yyyy)	Kennisis Lake	Kennisis Lake Percentage	Kennisis Lake Logs In	Kennisis Lake Logs Out	Kennisis Lake Outflow	Red Pine Lake	Red Pine Lake Percentage	Red Pine Lake Logs In	Redpine Lake Logs Out	Redpine Lake Outflow	Nunikani Lake	Nunikani Lake Percentage	Nunikani Lake Logs In	Nunikani Lake Logs Out	Nunikani Lake Outflow	Hawk Lake	Hawk Lake Percentage	Hawk Lake Logs In	Hawk Lake Logs Out	Hawk Lake Outflow	Hawk Lake Flow Level	Hawk Lake Flow
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	2.900		3	9.5	16.75	1.220		1	4	17	3.050		2	10	12	4.420		5	14.5	13		
Formules	0.000			0.000	1641	0.000			0.000	385	0.300			0.000	109	0.380			0.000	842		
1/3/2007	1.484	51.2	3	6.5	3.2	1.010	82.8	1	3	4.9	1.275	35.4	2	8	3.0	2.430	50.7	5	9.5	4.9		
1/1/2007			3	6.5				1	3				2	8				5	9.5			
1/2/2007			3	6.5				1	3				2	8		2.430	50.7	5	9.5	4.9	2.254	
1/3/2007	1.484	51.2	3	6.5	3.2	1.010	82.8	1	3	4.9	1.275	35.4	2	8	3.0			5	9.5			
1/4/2007	1.461	50.4	3	6.5	3.0	0.998	81.8	1	3	4.8	1.263	35.0	2	8	2.9			5	9.5			
1/5/2007	1.464	50.5	3	6.5	3.0	1.001	82.0	1	3	4.8	1.266	35.1	2	8	2.9			5	9.5			
1/6/2007	1.474	50.8	3	6.5	3.1	1.010	82.8	1	3	4.9	1.275	35.4	2	8	3.0			5	9.5			
1/7/2007	1.477	50.9	3	6.5	3.2	1.020	83.6	1	3	5.0	1.285	35.8	2	8	3.0			5	9.5			
1/8/2007	1.490	51.4	3	6.5	3.3	1.023	83.8	1	3	5.1	1.288	35.9	2	8	3.1	2.450	51.2	5	9.5	5.0	2.250	
1/9/2007	1.500	51.7	3	6.5	3.4	1.026	84.1	1	3	5.1	1.290	36.0	2	8	3.1			5	9.5			
1/10/2007	1.510	52.1	3	6.5	3.4	1.029	84.3	1	3	5.1	1.293	36.1	2	8	3.1			5	9.5			
1/11/2007	1.520	52.4	3	6.5	3.5	1.031	84.5	1	3	5.2	1.296	36.2	2	8	3.1			5	9.5			
1/12/2007	1.510	52.1	3	6.5	3.4	1.034	84.8	1	3	5.2	1.299	36.3	2	8	3.1			5	9.5			
1/13/2007	1.500	51.7	3	6.5	3.4	1.037	85.0	1	3	5.2	1.302	36.4	2	8	3.2			5	9.5			
1/14/2007	1.500	51.7	3	6.5	3.4	1.035	84.8	1	3	5.2	1.299	36.3	2	8	3.1			5	9.5			
1/15/2007	1.499	51.7	3	6.5	3.3	1.032	84.6	1	3	5.2	1.297	36.2	2	8	3.1	2.430	50.7	5	9.5	4.9	2.223	
1/16/2007	1.494	51.5	3	6.5	3.3	1.034	84.8	1	3	5.2	1.299	36.3	2	8	3.1			5	9.5			
1/17/2007	1.478	51.0	3	6.5	3.2	1.026	84.1	1	3	5.1	1.291	36.0	2	8	3.1			5	9.5			
1/18/2007	1.477	50.9	3	6.5	3.2	1.017	83.4	1	3	5.0	1.282	35.7	2	8	3.0			5	9.5			
1/19/2007	1.478	51.0	3	6.5	3.2	1.009	82.7	1	3	4.9	1.274	35.4	2	8	3.0			5	9.5			
1/20/2007	1.478	51.0	3	6.5	3.2	1.005	82.4	1	3	4.9	1.270	35.3	2	8	2.9			5	9.5			
1/21/2007	1.459	50.3	3	6.5	3.0	0.997	81.7	1	3	4.8	1.262	35.0	2	8	2.9			5	9.5			
1/22/2007	1.457	50.2	3	6.5	3.0	0.984	80.7	1	3	4.6	1.249	34.5	2	8	2.8	2.380	49.5	5	9.5	4.5	2.254	
1/23/2007	1.459	50.3	3	6.5	3.0	0.977	80.1	1	3	4.6	1.242	34.2	2	8	2.8			5	9.5			
1/24/2007	1.444	49.8	3	6.5	2.9	0.966	79.2	1	3	4.5	1.231	33.8	2	8	2.7			5	9.5			
1/25/2007	1.431	49.3	3	6.5	2.8	0.959	78.6	1	3	4.4	1.224	33.6	2	8	2.6			5	9.5			
1/26/2007	1.424	49.1	3	6.5	2.7	0.947	77.6	1	3	4.3	1.212	33.2	2	8	2.6			5	9.5			
1/27/2007	1.416	48.8	3	6.5	2.6	0.935	76.6	1	3	4.1	1.200	32.7	2	8	2.5			5	9.5			
1/28/2007	1.412	48.7	3	6.5	2.6	0.930	76.2	1	3	4.1	1.195	32.5	2	8	2.4			5	9.5			
1/29/2007	1.402	48.3	3	6.5	2.5	0.920	75.4	1	3	4.0	1.185	32.2	2	8	2.4	2.300	47.5	5	9.5	3.9	2.276	
1/30/2007	1.392	48.0	3	6.5	2.5	0.908	74.4	1	3	3.9	1.173	31.7	2	8	2.3			5	9.5			
1/31/2007	1.384	47.7	3	6.5	2.4	0.896	73.4	1	3	3.7	1.161	31.3	2	8	2.2			5	9.5			
2/1/2007	1.378	47.5	3	6.5	2.3	0.885	72.5	1	3	3.6	1.150	30.9	2	8	2.2			5	9.5			
2/2/2007	1.372	47.3	3	6.5	2.3	0.873	71.6	1	3	3.5	1.138	30.5	2	8	2.1			5	9.5			
2/3/2007	1.366	47.1	3	6.5	2.3	0.869	71.2	1	3	3.5	1.134	30.3	2	8	2.1			5	9.5			
2/4/2007	1.361	46.9	3	6.5	2.2	0.859	70.4	1	3	3.4	1.124	30.0	2	8	2.0			5	9.5			
2/5/2007	1.352	46.6	3	6.5	2.2	0.851	69.8	1	3	3.3	1.116	29.7	2	8	2.0	2.290	47.3	5	9.5	3.8	2.296	
2/6/2007	1.346	46.4	3	6.5	2.1	0.842	69.0	1	3	3.2	1.107	29.3	2	8	1.9			5	9.5			
2/7/2007	1.336	46.1	3	6.5	2.0	0.832	68.2	1	3	3.1	1.097	29.0	2	8	1.8			5	9.5			
2/8/2007	1.328	45.8	3	6.5	2.0	0.822	67.4	1	3	3.0	1.087	28.6	2	8	1.8			5	9.5			
2/9/2007	1.327	45.8	3	6.5	2.0	0.819	67.1	1	3	3.0	1.084	28.5	2	8	1.8			5	9.5			
2/10/2007	1.321	45.6	3	6.5	1.9	0.807	66.1	1	3	2.9	1.072	28.1	2	8	1.7			5	9.5			
2/11/2007	1.317	45.4	3	6.5	1.9	0.800	65.6	1	3	2.8	1.065	27.8	2	8	1.7			5	9.5			
2/12/2007	1.310	45.2	3	6.5	1.8	0.793	65.0	1	3	2.8	1.058	27.6	2	8	1.6			5	9.5			
2/13/2007	1.303	44.9	3	6.5	1.8	0.789	64.7	1	3	2.7	1.054	27.4	2	8	1.6	2.250	46.3	5	9.5	3.5	2.275	
2/14/2007	1.305	45.0	3	6.5	1.8	0.780	63.9	1	3	2.7	1.045	27.1	2	8	1.5			5	9.5			
2/15/2007	1.295	44.7	3	6.5	1.7	0.777	63.7	1	3	2.6	1.042	27.0	2	8	1.5			5	9.5			
2/16/2007	1.286	44.3	3	6.5	1.7	0.768	63.0	1	3	2.6	1.033	26.6	2	8	1.5			5	9.5			
2/17/2007	1.276	44.0	3	6.5	1.6	0.760	62.3	1	3	2.5	1.025	26.4	2	8	1.4			5	9.5			
2/18/2007	1.277	44.0	3	6.5	1.6	0.754	61.8	1	3	2.4	1.019	26.1	2	8	1.4			5	9.5			
2/19/2007	1.276	44.0	3	6.5	1.6	0.747	61.2	1	3	2.4	1.012	25.9	2	8	1.4	2.150	43.8	5	9.5	2.8	2.233	
2/20/2007	1.270	43.8	3	6.5	1.6	0.738	60.5	1	3	2.3	1.003	25.6	2	8	1.3			5	9.5			
2/21/2007	1.261	43.5	3	6.5	1.5	0.729	59.8	1	3	2.2	0.994	25.2	2	8	1.3			5	9.5			
2/22/2007	1.241	42.8	3	6.5	1.4	0.720	59.0	1	3	2.2	0.985	24.9	2	8	1.2			5	9.5			
2/23/2007	1.254	43.2	3	6.5	1.5	0.727	59.6	1	3	2.2	0.992	25.2	2	8	1.3			5	9.5			
2/24/2007	1.250	43.1	3	6.5	1.4	0.720	59.0	1	3	2.2	0.985	24.9	2	8	1.3			5	9.5			
2/25/2007	1.246	43.0	3	6.5	1.4	0.711	58.3	1	3	2.1	0.976	24.6	2	8	1.2			5	9.5			
2/26/2007	1.245	42.9	3	6.5	1.4	0.702	57.5	1	3	2.0	0.967	24.2	2	8	1.1	2.050	41.3	5	9.5	2.2	2.195	
2/27/2007	1.235	42.6	3	6.5	1.3	0.696	57.0	1	3	2.0	0.961	24.0	2	8	1.1			5	9.5			
2/28/2007	1.230	42.4	3	6.5	1.3	0.691	56.6	1	3	1.9	0.956	23.8	2	8	1.1			5	9.5			
3/1/2007	1.224	42.2	3	6.5	1.3	0.685	56.1	1	3	1.9	0.950	23.6	2	8	1.1			5	9.5			
3/2/2007	1.239	42.7	3	6.5	1.4	0.691	56.6	1	3	1.9	0.956	23.8	2	8	1.1			5	9.5			
3/3/2007	1.234	42.6	3	6.5	1.3	0.693	56.8	1	3	1.9	0.958	23.9	2	8	1.1			5	9.5			
3/4/2007	1.232	42.5	3	6.5	1.3	0.690	56.6	1	3	1.9	0.955	23.8	2	8	1.1			5	9.5			
3/5/2007	1.233	42.5	3	6.5	1.3	0.688	56.4	1	3	1.9	0.953	23.7	2	8	1.1	2.000	40.1	5	9.5	1.9	2.132	
3/6/2007	1.222	42.1	3	6.5	1.3	0.686	56.2	1	3	1.9	0.951	23.7	2	8	1.1			5	9.5			
3/7/2007	1.219	42.0	3	6.5	1.2	0.680	55.7	1	3	1.8	0.950	23.6	5	5				5	9.5			
3/8/2007	1.215	41.9	3	6.5	1.2	0.671	55.0		3	1.8			5	5				5	9.5			
3/9/2007	1.207	41.6	3	6.5	1.2	0.665	54.5		3	1.7			5	5				5	9.5			
3/10/2007	1.229	42.4	3	6.5	1.3	0.665	54.5		3	1.7			5	5				5	9.5			
3/11/2007	1.213	41.8	3	6.5	1.3	0.667	54.7		3	1.7			5	5				5	9.5			
3/12/2007	1.206	41.6	3	6.5	1.2	0.662	54.3		3	1.7			5	5		1.980	39.6	5	9.5	1.8	2.100	
3/13/2007	1.205	41.6	3	6.5	1.2	0.656	53.8		3	1.7			5	5				5	9.5			
3/14/2007	1.200	41.4	3	6.5	1.1	0.652	53.4		3	1.6			5	5				5	9.5			
3/15/2007	1.202	41.4	3	6.5	1.1	0.649	53.2		3	1.6			5	5				5	9.5			
3/16/2007	1.192	41.1	5	4.5		0.644	52.8		3	1.6			5	5		1.940	38.6	7	7.5			
3/17/2007	1.200	41.4	5	4.5		0.603	49.4		3	1.3			5	5				7	7.5			
3/18/2007	1.198	41.3	5	4.5		0.580	47.5		3	1.1			5	5				7	7.5			
3/19/2007	1.203	41.5	5	4.5		0.556	45.6		3	1.0			5	5		2.010	40.3	7	7.5			
3/20/2007	1.211	41.8	5	4.5		0.544	44.6		3	0.9			5	5				7	7.5			
3/21/2007	1.205	41.6	5	4.5		0.526	43.1		3	0.8			5	5				7	7.5			
3/22/2007	1.236	42.6	5	4.5		0.526	43.1		3	0.8			5	5				7	7.5			
3/23/2007	1.249	43.1	5	4.5		0.527	43.2		3	0.8			5	5		2.090	42.3	8	6.5			
3/24/2007	1.248	43.0	5	4.5		0.519	42.5		3	0.8			5	5				8	6.5			
3/25/2007	1.267	43.7	5	4.5		0.518	42.5		3	0.8			5	5				8	6.5			
3/26/2007	1.272	43.9	5	4.5		0.513	42.0		3	0.7			5	5		2.150	43.8	8	6.5			
3/27/2007	1.298	44.8	5	4.5		0.523	42.9		3	0.8			5	5				8	6.5			
3/28/2007	1.338	46.1	6	3.5		0.539	44.2		3	0.9			5	5				8	6.5			
3/29/2007	1.358	46.8	6	3.5		0.548	44.9		3	0.9			5	5				8	6.5			
3/30/2007	1.387	47.8	6	3.5		0.558	45.7		3	1.0			5	5				8	6.5			
3/31/2007	1.417	48.9	6	3.5		0.566	46.4		3	1.0			5	5				8	6.5			
4/1/2007	1.451	50.0	6	3.5		0.569	46.6		3	1.1			5	5				8	6.5			
4/2/2007	1.486	51.2	6	3.5		0.590	48.4		3	1.2			5	5		2.470	51.7	9	5.5			
4/3/2007	1.511	52.1	6	3.5		0.604	49.5		3	1.3			5	5				9	5.5			
4/4/2007	1.588	54.8	6	3.5		0.635	52.0		3	1.5			5	5				9	5.5			
4/5/2007	1.655	57.1	8	1.5		0.707	58.0		3	2.1			5	5		2.750	58.7	11	3.5			

Date (dd/mm/yyyy)	Halls Lake	Halls Lake Percentage	Halls Lake Logs In	Halls Lake Logs Out	Halls Lake Outflow	Sherborne Lake	Sherborne Lake Percentage	Sherborne Lake Logs In	Sherborne Lake Logs Out	Sherborne Lake Outflow	Kushog Lake	Kushog Lake Percentage	Kushog Lake Logs In	Kushog Lake Logs Out	Kushog Lake Outflow	Percy Lake	Percy Lake Percentage	Percy Lake Logs In	Percy Lake Logs Out	Percy Lake Outflow	Oblong Lake	Oblong Lake Percentage	Oblong Lake Logs In	Oblong Lake Logs Out	Oblong Lake Outflow
1	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
	2.590		4	8.5	17.5	1.520		0	5	11	3.200		4	10.5	12	1.980		1	6.5	18	3.050		4	10	16
Formules	0.910			0.000	529	0.000			0.000	245	1.220			0.000	111	0.000			0.000	563	1.070			0.000	1094
1/3/2007	2.044	67.5	4	4.5	5.8	0.300	19.7	0	5	1.0	1.755	27.0	4	6.5	2.1	0.360	18.2	0	6.5	2.2	1.730	33.3	4	6	2.6
1/1/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/2/2007	2.044	67.5	4	4.5	5.8			0	5		1.755	27.0	4	6.5	2.1	0.360	18.2	0	6.5	2.2	1.730	33.3	4	6	2.6
1/3/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/4/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/5/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/6/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/7/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/8/2007	2.053	68.0	4	4.5	5.9			0	5		1.792	28.9	4	6.5	2.3	0.372	18.8	0	6.5	2.3	1.750	34.3	4	6	2.7
1/9/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/10/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/11/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/12/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/13/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/14/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/15/2007	2.050	67.9	4	4.5	5.9			0	5		1.785	28.5	4	6.5	2.2	0.379	19.1	0	6.5	2.4	1.760	34.8	4	6	2.8
1/16/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/17/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/18/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/19/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/20/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/21/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/22/2007	2.005	65.2	4	4.5	5.4			0	5		1.724	25.5	4	6.5	1.9	0.360	18.2	0	6.5	2.2	1.710	32.3	4	6	2.4
1/23/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/24/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/25/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/26/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/27/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/28/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/29/2007	1.944	61.5	4	4.5	4.8			0	5		1.663	22.4	4	6.5	1.6	0.316	15.9	0	6.5	1.8	1.670	30.3	4	6	2.1
1/30/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
1/31/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/1/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/2/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/3/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/4/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/5/2007	1.886	58.1	4	4.5	4.2			0	5		1.617	20.1	4	6.5	1.3	0.274	13.8	0	6.5	1.5	1.610	27.3	4	6	1.7
2/6/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/7/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/8/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/9/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/10/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/11/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/12/2007			4	4.5				0	5				4	6.5		0.239	12.0	0	6.5	1.2	1.560	24.7	4	6	1.4
2/13/2007	1.817	54.0	4	4.5	3.6			0	5		1.566	17.5	4	6.5	1.1			0	6.5				4	6	
2/14/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/15/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/16/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/17/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/18/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/19/2007	1.761	50.7	4	4.5	3.1			0	5		1.536	16.0	4	6.5	0.9	0.218	11.0	0	6.5	1.0	1.530	23.2	4	6	1.2
2/20/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/21/2007			4	4.5				0	5				4	6.5				0	6.5				4	6	
2/22/2007	1.750	50.0	5	3.5	0.9			0	5		1.324	5.3	5	5.5				0	6.5				4	6	
2/23/2007			5	3.5				0	5				5	5.5				0	6.5				4	6	
2/24/2007			5	3.5				0	5				5	5.5				0	6.5				4	6	
2/25/2007			5	3.5				0	5				5	5.5				0	6.5				4	6	
2/26/2007	1.850	56.0	5	3.5	1.5			0	5		1.559	17.1	5	5.5	0.1	0.176	8.9	0	6.5	0.8	1.470	20.2	4	6	0.9
2/27/2007			5	3.5				0	5				5	5.5				0	6.5		1.460	19.7	6	4	
2/28/2007	1.920	60.1	6	2.5	0.3			0	5		1.564	17.4	6	4.5				0	6.5				6	4	
3/1/2007			6	2.5				0	5				6	4.5				0	6.5				6	4	
3/2/2007			6	2.5				0	5				6	4.5				0	6.5				6	4	
3/3/2007			6	2.5				0	5				6	4.5				0	6.5				6	4	
3/4/2007			6	2.5				0	5				6	4.5				0	6.5				6	4	
3/5/2007	2.064	68.7	6	2.5	0.9			0	5		1.614	19.9	6	4.5				0	6.5		1.570	25.3	6	4	
3/6/2007			6	2.5				0	5				6	4.5				0	6.5				6	4	
3/7/2007			6	2.5		0.070	4.6	5	0				6	4.5		0.100	5.1	3	3.5				6	4	
3/8/2007			6	2.5				5	0				6	4.5				3	3.5				6	4	
3/9/2007			6	2.5				5	0				6	4.5				3	3.5				6	4	
3/10/2007			6	2.5				5	0				6	4.5				3	3.5				6	4	
3/11/2007			6	2.5				5	0				6	4.5				3	3.5				6	4	
3/12/2007	2.160	74.4	6	2.5	1.5			5	0		1.642	21.3	6	4.5				3	3.5		1.580	25.8	6	4	
3/13/2007			6	2.5				5	0				6	4.5				3	3.5				6	4	
3/14/2007			6	2.5				5	0				6	4.5				3	3.5				6	4	
3/15/2007			6	2.5				5	0				6	4.5				3	3.5				6	4	
3/16/2007	2.180	75.6	7	1.5	0.2			5	0				6	4.5				3	3.5				6	4	
3/17/2007			7	1.5				5	0				6	4.5				3	3.5				6	4	
3/18/2007			7	1.5				5	0				6	4.5				3	3.5				6	4	
3/19/2007	2.156	74.2	7	1.5	0.2			5	0		1.686	23.5	6	4.5				3	3.5		1.610	27.3	6	4	
3/20/2007			7	1.5				5	0				6	4.5				3	3.5				6	4	
3/21/2007			7	1.5				5	0				6	4.5				3	3.5				6	4	
3/22/2007			7	1.5				5	0				6	4.5				3	3.5				6	4	
3/23/2007	2.165	74.7	7	1.5	0.2			5	0		1.740	26.3	7	3.5				3	3.5				6	4	
3/24/2007			7	1.5				5	0				7	3.5				3	3.5				6	4	
3/25/2007			7	1.5				5	0				7	3.5				3	3.5				6	4	
3/26/2007	2.177	75.4	7	1.5	0.2			5	0		1.803	29.4	7	3.5		0.410	20.7	3	3.5		1.680	30.8	6	4	
3/27/2007			7	1.5				5	0				7	3.5				3	3.5				6	4	
3/28/2007			7	1.5				5	0				7	3.5				3	3.5		1.740	33.8	8	2	
3/29/2007			7	1.5				5	0				7	3.5				3	3.5				8	2	
3/30/2007			7	1.5				5	0				7	3.5				3	3.5				8	2	
3/31/2007			7	1.5				5	0				7	3.5				3	3.5				8	2	
4/1/2007			7	1.5				5	0				7	3.5				3	3.5				8	2	
4/2/2007	2.255	80.1	7	1.5	0.4			5	0		2.130	46.0	8	2.5		0.780	39.4	3	3.5		1.860	39.9	8	2	
4/3/2007			7	1.5				5	0				8	2.5		0.810	40.9	5	1.5				8	2	
4/4/2007			7	1.5				5	0		2.270	53.0	8	2.5				5	1.5				8	2	
4/5/2007	2.333	84.7	7	1.5	0.8			5	0		2.417	60.5	10	0.5				5	1.5				8	2	

Date (dd/mm/yyyy)	Redstone Lake	Redstone Lake Percentage	East Redstone Lake Logs In	East Redstone Lake Logs Out	East Redstone Lake Outflow	West Redstone Lake Logs In	West Redstone Lake Logs Out	West Redstone Lake Outflow	Eagle Lake	Eagle Lake Percentage	Eagle Lake Logs In	Eagle Lake Logs Out	Eagle Lake Outflow	Maple Lake Flow Level	Gull @ Maple Lake Flow
1	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
	3.660		3	10	14.0	4	12	12	2.290		2	7.5	20		
Formules	0.000			0.509			0.000	1422	0.457			0.000	515		
1/3/2007	1.798	49.1	3	7	1.4	4	8	2.3	1.365	49.5	2	5.5	6.1		
1/1/2007	1.798	49.1	3	7	1.4	4	8	2.3			2	5.5		6.855	15.7
1/2/2007	1.794	49.0	3	7	1.4	4	8	2.3	1.365	49.5	2	5.5	6.1	6.849	15.5
1/3/2007	1.788	48.9	3	7	1.4	4	8	2.3			2	5.5		6.844	15.3
1/4/2007	1.782	48.7	3	7	1.3	4	8	2.2			2	5.5		6.838	15.0
1/5/2007	1.786	48.8	3	7	1.4	4	8	2.2			2	5.5		6.837	15.0
1/6/2007	1.790	48.9	3	7	1.4	4	8	2.3			2	5.5		6.849	15.5
1/7/2007	1.795	49.0	3	7	1.4	4	8	2.3			2	5.5		6.865	16.1
1/8/2007	1.799	49.1	3	7	1.4	4	8	2.3	1.372	49.9	2	5.5	6.2	6.882	16.7
1/9/2007	1.803	49.3	3	7	1.4	4	8	2.3			2	5.5		6.894	17.2
1/10/2007	1.807	49.4	3	7	1.5	4	8	2.4			2	5.5		6.889	17.0
1/11/2007	1.812	49.5	3	7	1.5	4	8	2.4			2	5.5		6.884	16.8
1/12/2007	1.816	49.6	3	7	1.5	4	8	2.4			2	5.5		6.877	16.5
1/13/2007	1.820	49.7	3	7	1.5	4	8	2.4			2	5.5		6.872	16.4
1/14/2007	1.815	49.6	3	7	1.5	4	8	2.4			2	5.5		6.868	16.2
1/15/2007	1.810	49.5	3	7	1.5	4	8	2.4	1.386	50.7	2	5.5	6.4	6.864	16.1
1/16/2007	1.805	49.3	3	7	1.5	4	8	2.4			2	5.5		6.858	15.8
1/17/2007	1.801	49.2	3	7	1.4	4	8	2.3			2	5.5		6.843	15.2
1/18/2007	1.796	49.1	3	7	1.4	4	8	2.3			2	5.5		6.836	14.9
1/19/2007	1.791	48.9	3	7	1.4	4	8	2.3			2	5.5		6.839	15.1
1/20/2007	1.785	48.8	3	7	1.3	4	8	2.2			2	5.5		6.833	14.8
1/21/2007	1.780	48.6	3	7	1.3	4	8	2.2			2	5.5		6.819	14.4
1/22/2007	1.774	48.5	3	7	1.3	4	8	2.2	1.326	47.4	2	5.5	5.6	6.812	14.1
1/23/2007	1.760	48.1	3	7	1.2	4	8	2.1			2	5.5		6.805	13.8
1/24/2007	1.752	47.9	3	7	1.2	4	8	2.0			2	5.5		6.799	13.6
1/25/2007	1.743	47.6	3	7	1.1	4	8	2.0			2	5.5		6.790	13.2
1/26/2007	1.735	47.4	3	7	1.1	4	8	1.9			2	5.5		6.774	12.6
1/27/2007	1.726	47.2	3	7	1.0	4	8	1.9			2	5.5		6.762	12.2
1/28/2007	1.718	46.9	3	7	1.0	4	8	1.8			2	5.5		6.756	12.0
1/29/2007	1.709	46.7	3	7	0.9	4	8	1.8	1.244	42.9	2	5.5	4.7	6.745	11.6
1/30/2007	1.701	46.5	3	7	0.9	4	8	1.8			2	5.5		6.732	11.2
1/31/2007	1.692	46.2	3	7	0.9	4	8	1.7			2	5.5		6.721	10.7
2/1/2007	1.684	46.0	3	7	0.8	4	8	1.7			2	5.5		6.713	10.5
2/2/2007	1.675	45.8	3	7	0.8	4	8	1.6			2	5.5		6.704	10.2
2/3/2007	1.667	45.5	3	7	0.7	4	8	1.6			2	5.5		6.698	10.0
2/4/2007	1.658	45.3	3	7	0.7	4	8	1.5			2	5.5		6.688	9.7
2/5/2007	1.650	45.1	3	7	0.7	4	8	1.5	1.162	38.5	2	5.5	3.8	6.678	9.3
2/6/2007	1.645	44.9	3	7	0.7	4	8	1.5			2	5.5		6.666	9.0
2/7/2007	1.640	44.8	3	7	0.6	4	8	1.4			2	5.5		6.655	8.6
2/8/2007	1.634	44.7	3	7	0.6	4	8	1.4			2	5.5		6.646	8.4
2/9/2007	1.629	44.5	3	7	0.6	4	8	1.4			2	5.5		6.639	8.1
2/10/2007	1.624	44.4	3	7	0.6	4	8	1.4			2	5.5		6.631	7.9
2/11/2007	1.619	44.2	3	7	0.5	4	8	1.3			2	5.5		6.624	7.7
2/12/2007	1.614	44.1	3	7	0.5	4	8	1.3	1.102	35.2	2	5.5	3.2	6.613	7.4
2/13/2007	1.608	43.9	3	7	0.5	4	8	1.3			2	5.5		6.607	7.2
2/14/2007	1.603	43.8	3	7	0.5	4	8	1.3			2	5.5		6.598	7.0
2/15/2007	1.598	43.7	3	7	0.5	4	8	1.2			2	5.5		6.589	6.8
2/16/2007	1.593	43.5	3	7	0.4	4	8	1.2			2	5.5		6.580	6.6
2/17/2007	1.588	43.4	3	7	0.4	4	8	1.2			2	5.5		6.573	6.4
2/18/2007	1.582	43.2	3	7	0.4	4	8	1.2			2	5.5		6.567	6.3
2/19/2007	1.577	43.1	3	7	0.4	4	8	1.1	1.043	32.0	2	5.5	2.6	6.561	6.1
2/20/2007	1.572	43.0	3	7	0.4	4	8	1.1			2	5.5		6.552	5.9
2/21/2007	1.570	42.9	3	7	0.4	4	8	1.1			2	5.5		6.546	5.8
2/22/2007	1.568	42.8	3	7	0.4	4	8	1.1			2	5.5		6.541	5.6
2/23/2007	1.564	42.7	3	7	0.3	4	8	1.1			2	5.5		6.542	5.7
2/24/2007	1.561	42.6	3	7	0.3	4	8	1.1			2	5.5		6.535	5.5
2/25/2007	1.557	42.5	3	7	0.3	4	8	1.0			2	5.5		6.530	5.4
2/26/2007	1.553	42.4	3	7	0.3	4	8	1.0	1.004	29.8	2	5.5	2.2	6.523	5.3
2/27/2007	1.549	42.3	3	7	0.3	4	8	1.0			2	5.5		6.517	5.1
2/28/2007	1.544	42.2	3	7	0.3	4	8	1.0			2	5.5		6.512	5.0
3/1/2007	1.553	42.4	3	7	0.3	4	8	1.0			2	5.5		6.505	4.9
3/2/2007	1.562	42.7	3	7	0.3	4	8	1.1			2	5.5		6.502	4.8
3/3/2007	1.550	42.3	3	7	0.3	4	8	1.0			2	5.5		6.501	4.8
3/4/2007	1.546	42.2	3	7	0.3	4	8	1.0			2	5.5		6.493	4.7
3/5/2007	1.551	42.4	3	7	0.3	4	8	1.0	0.902	24.3	2	5.5	1.4	6.487	4.5
3/6/2007	1.549	42.3	3	7	0.3	4	8	1.0			2	5.5		6.474	4.3
3/7/2007	1.546	42.2	3	7	0.3	4	8	1.0			2	5.5		6.461	4.1
3/8/2007	1.544	42.2	3	7	0.3	4	8	1.0			2	5.5		6.450	3.9
3/9/2007	1.541	42.1	3	7	0.3	4	8	1.0	0.866	22.3	2.5	5	0.3	6.443	3.8
3/10/2007	1.539	42.0	3	7	0.3	4	8	1.0			2.5	5		6.436	3.6
3/11/2007	1.536	42.0	3	7	0.3	4	8	0.9			2.5	5		6.429	3.5
3/12/2007	1.526	41.7	3	7	0.2	4	8	0.9			2.5	5		6.423	3.4
3/13/2007	1.530	41.8	3	7	0.2	4	8	0.9			2.5	5		6.416	3.3
3/14/2007	1.530	41.8	3	7	0.2	4	8	0.9			2.5	5		6.409	3.2
3/15/2007	1.536	42.0	3	7	0.3	4	8	0.9			2.5	5		6.402	3.1
3/16/2007	1.528	41.7	3	7	0.2	6	6				2.5	5		6.395	3.0
3/17/2007	1.532	41.9	3	7	0.2	6	6				2.5	5		6.391	2.9
3/18/2007	1.536	42.0	3	7	0.3	6	6				2.5	5		6.382	2.8
3/19/2007	1.534	41.9	3	7	0.2	6	6		0.922	25.4	2.5	5	0.6	6.369	2.6
3/20/2007	1.546	42.2	3	7	0.3	6	6				2.5	5		6.361	2.5
3/21/2007	1.542	42.1	3	7	0.3	6	6				2.5	5		6.352	2.3
3/22/2007	1.538	42.0	3	7	0.3	6	6				2.5	5		6.357	2.4
3/23/2007	1.554	42.5	4	6		6	6		0.964	27.7	2.5	5	0.8	6.366	2.5
3/24/2007	1.560	42.6	4	6		6	6				2.5	5		6.373	2.6
3/25/2007	1.583	43.3	4	6		6	6				2.5	5		6.392	2.9
3/26/2007	1.602	43.8	4	6		6	6		0.982	28.6	2.5	5	0.9	6.401	3.1
3/27/2007	1.631	44.6	4	6		6	6		0.998	29.5	3	4.5	0.2	6.433	3.6
3/28/2007	1.663	45.4	5	5		6	6		1.040	31.8	3	4.5	0.4	6.487	4.5
3/29/2007	1.701	46.5	5	5		6	6				3	4.5		6.533	5.5
3/30/2007	1.739	47.5	5	5		8	4		1.094	34.8	3.5	4	0.1	6.558	6.0
3/31/2007	1.764	48.2	5	5		8	4				3.5	4		6.567	6.3
4/1/2007	1.827	49.9	5	5		8	4				3.5	4		6.563	6.2
4/2/2007	1.887	51.6	5	5		8	4		1.172	39.0	3.5	4	0.3	6.563	6.2
4/3/2007	1.931	52.8	7	3		8	4		1.199	40.5	3.5	4	0.5	6.566	6.2
4/4/2007	1.996	54.5	7	3		8	4		1.261	43.9	4.5	3		6.597	7.0
4/5/2007	2.101	57.4	7	3		10	2		1.338	48.1	4.5	3		6.692	9.8

Date (dd/mm/yyyy)	Twelve Mile Lake	Twelve Mile Percentage	Twelve Mile Logs In, Sluice 1	Twelve Mile Logs Out, Sluice 1	Twelve Mile Logs In, Sluice 2	Twelve Mile Logs Out, Sluice 2	Twelve Mile Lake Outflow	Horseshoe Lake	Horseshoe Lake Percentage	Horseshoe Lake Logs In, Sluice 2	Horseshoe Lake Logs Out, Sluice	Horseshoe Lake Logs In, Sluice 3	Horseshoe Lake Logs Out, Sluice	Horseshoe Lake Outflow	Horseshoe Lake Flow Level	Horseshoe Lake Flow	Big Bob Lake	Big Bob Lake Percentage	Big Bob Lake Logs In	Big Bob Lake Logs Out
1	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83
	1.980		3	5.5	3	6.5	25.0	2.440		4	8	4	8	20.0			2.900		3	9.5
Formules	0.460			0.305		0.000	1161	0.460			0.000		0.000	556			0.000			0.000
1/3/2007	1.698	81.4	0	5.5	3	3.5	30.6	2.178	86.8	4	4	3	5	21.6			1.180	40.7	3	6.5
1/1/2007	1.698	81.4	0	5.5	3	3.5	30.6	2.178	86.8	4	4	3	5	21.6	5.136				3	6.5
1/2/2007	1.688	80.8	0	5.5	3	3.5	30.2	2.176	86.7	4	4	3	5	21.5	5.129		1.180	40.7	3	6.5
1/3/2007	1.676	80.0	0	5.5	3	3.5	29.7	2.167	86.2	4	4	3	5	21.2	5.131				3	6.5
1/4/2007	1.668	79.5	0	5.5	3	3.5	29.4	2.154	85.6	4	4	3	5	20.9	5.107				3	6.5
1/5/2007	1.673	79.8	0	5.5	3	3.5	29.6	2.145	85.1	4	4	3	5	20.6	5.113				3	6.5
1/6/2007	1.677	80.1	0	5.5	3	3.5	29.7	2.158	85.8	4	4	3	5	21.0	5.111				3	6.5
1/7/2007	1.684	80.5	0	5.5	3	3.5	30.0	2.170	86.4	4	4	3	5	21.3	5.130				3	6.5
1/8/2007	1.691	81.0	0	5.5	3	3.5	30.3	2.171	86.4	4	4	3	5	21.4	5.127		1.260	43.4	3	6.5
1/9/2007	1.706	82.0	0	5.5	3	3.5	30.9	2.180	86.9	4	4	3	5	21.6	5.146				3	6.5
1/10/2007	1.712	82.4	0	5.5	3	3.5	31.1	2.170	86.4	4	4	3	5	21.4					3	6.5
1/11/2007	1.705	81.9	0	5.5	3	3.5	30.8	2.161	85.9	4	4	3	5	21.1					3	6.5
1/12/2007	1.704	81.8	0	5.5	3	3.5	30.8	2.151	85.4	4	4	3	5	20.8					3	6.5
1/13/2007	1.706	82.0	0	5.5	3	3.5	30.9	2.142	84.9	4	4	3	5	20.5					3	6.5
1/14/2007	1.701	81.6	0	5.5	3	3.5	30.7	2.132	84.5	4	4	3	5	20.2					3	6.5
1/15/2007	1.695	81.3	0	5.5	3	3.5	30.5	2.123	84.0	4	4	3	5	20.0			1.210	41.7	3	6.5
1/16/2007	1.685	80.6	0	5.5	3	3.5	30.1	2.113	83.5	4	4	3	5	19.7					3	6.5
1/17/2007	1.675	79.9	0	5.5	3	3.5	29.7	2.104	83.0	4	4	3	5	19.4					3	6.5
1/18/2007	1.670	79.6	0	5.5	3	3.5	29.5	2.094	82.5	4	4	3	5	19.2					3	6.5
1/19/2007	1.663	79.1	0	5.5	3	3.5	29.2	2.085	82.1	4	4	3	5	18.9					3	6.5
1/20/2007	1.657	78.8	0	5.5	3	3.5	29.0	2.075	81.6	4	4	3	5	18.6					3	6.5
1/21/2007	1.645	78.0	0	5.5	3	3.5	28.5	2.066	81.1	4	4	3	5	18.4					3	6.5
1/22/2007	1.637	77.4	0	5.5	3	3.5	28.2	2.056	80.6	4	4	3	5	18.1			1.150	39.7	3	6.5
1/23/2007	1.626	76.7	0	5.5	3	3.5	27.8	2.047	80.1	4	4	3	5	17.8					3	6.5
1/24/2007	1.616	76.1	0	5.5	3	3.5	27.4	2.037	79.7	4	4	3	5	17.6					3	6.5
1/25/2007	1.605	75.3	0	5.5	3	3.5	27.0	2.028	79.2	4	4	3	5	17.3					3	6.5
1/26/2007	1.591	74.4	0	5.5	3	3.5	26.5	2.018	78.7	4	4	3	5	17.1					3	6.5
1/27/2007	1.581	73.8	0	5.5	3	3.5	26.1	2.009	78.2	4	4	3	5	16.8					3	6.5
1/28/2007	1.569	73.0	0	5.5	3	3.5	25.6	1.999	77.7	4	4	3	5	16.5					3	6.5
1/29/2007	1.555	72.0	0	5.5	3	3.5	25.1	1.990	77.3	4	4	3	5	16.3			1.150	39.7	3	6.5
1/30/2007	1.543	71.3	0	5.5	3	3.5	24.7	1.980	76.8	4	4	3	5	16.0					3	6.5
1/31/2007	1.528	70.3	0	5.5	3	3.5	24.1	1.971	76.3	4	4	3	5	15.8					3	6.5
2/1/2007	1.515	69.4	0	5.5	3	3.5	23.7	1.961	75.8	4	4	3	5	15.5					3	6.5
2/2/2007	1.505	68.8	0	5.5	3	3.5	23.3	1.952	75.3	4	4	3	5	15.3					3	6.5
2/3/2007	1.493	68.0	0	5.5	3	3.5	22.9	1.942	74.9	4	4	3	5	15.0					3	6.5
2/4/2007	1.484	67.4	0	5.5	3	3.5	22.6	1.933	74.4	4	4	3	5	14.8					3	6.5
2/5/2007	1.473	66.6	0	5.5	3	3.5	22.2	1.923	73.9	4	4	3	5	14.5			1.100	37.9	3	6.5
2/6/2007	1.463	66.0	0	5.5	3	3.5	21.8	1.912	73.3	4	4	3	5	14.3					3	6.5
2/7/2007	1.444	64.7	0	5.5	3	3.5	21.2	1.900	72.8	4	4	3	5	14.0					3	6.5
2/8/2007	1.436	64.2	0	5.5	3	3.5	20.9	1.889	72.2	4	4	3	5	13.7					3	6.5
2/9/2007	1.431	63.9	0	5.5	3	3.5	20.7	1.878	71.6	4	4	3	5	13.4					3	6.5
2/10/2007	1.419	63.1	0	5.5	3	3.5	20.3	1.867	71.0	4	4	3	5	13.1					3	6.5
2/11/2007	1.405	62.2	0	5.5	3	3.5	19.9	1.855	70.5	4	4	3	5	12.9					3	6.5
2/12/2007	1.397	61.6	0	5.5	3	3.5	19.6	1.844	69.9	4	4	3	5	12.6			1.090	37.6	3	6.5
2/13/2007	1.385	60.9	0	5.5	3	3.5	19.2	1.833	69.3	4	4	3	5	12.3					3	6.5
2/14/2007	1.376	60.3	0	5.5	3	3.5	18.9	1.822	68.8	4	4	3	5	12.0					3	6.5
2/15/2007	1.363	59.4	0	5.5	3	3.5	18.5	1.810	68.2	4	4	3	5	11.8					3	6.5
2/16/2007	1.351	58.6	0	5.5	3	3.5	18.1	1.799	67.6	4	4	3	5	11.5					3	6.5
2/17/2007	1.341	57.9	0	5.5	3	3.5	17.8	1.788	67.1	4	4	3	5	11.2					3	6.5
2/18/2007	1.330	57.2	0	5.5	3	3.5	17.4	1.777	66.5	4	4	3	5	11.0					3	6.5
2/19/2007	1.315	56.3	0	5.5	3	3.5	17.0	1.765	65.9	4	4	3	5	10.7			1.050	36.2	3	6.5
2/20/2007	1.303	55.5	0	5.5	3	3.5	16.6	1.754	65.4	4	4	3	5	10.5					3	6.5
2/21/2007	1.295	54.9	0	5.5	3	3.5	16.3	1.743	64.8	4	4	3	5	10.2					3	6.5
2/22/2007	1.285	54.3	0	5.5	3	3.5	16.0	1.732	64.2	4	4	3	5	10.0					3	6.5
2/23/2007	1.273	53.5	0	5.5	3	3.5	15.7	1.720	63.6	4	4	3	5	9.7					3	6.5
2/24/2007	1.240	51.3	0	5.5	3	3.5	14.7	1.709	63.1	4	4	3	5	9.5					3	6.5
2/25/2007	1.215	49.7	0	5.5	3	3.5	14.0	1.698	62.5	4	4	3	5	9.2					3	6.5
2/26/2007	1.195	48.4	0	5.5	3	3.5	13.4	1.686	61.9	4	4	3	5	9.0			1.000	34.5	3	6.5
2/27/2007	1.180	47.4	0	5.5	3	3.5	13.0	1.675	61.4	4	4	3	5	8.7					3	6.5
2/28/2007	1.166	46.4	0	5.5	3	3.5	12.6	1.664	60.8	4	4	3	5	8.5			1.030	35.5	6	3.5
3/1/2007	1.141	44.8	0	5.5	3	3.5	11.9	1.653	60.2	4	4	3	5	8.3					6	3.5
3/2/2007	1.140	44.7	0	5.5	3	3.5	11.9	1.641	59.7	4	4	3	5	8.0					6	3.5
3/3/2007	1.123	43.6	0	5.5	3	3.5	11.4	1.630	59.1	4	4	3	5	7.8					6	3.5
3/4/2007	1.112	42.9	0	5.5	3	3.5	11.1	1.619	58.5	4	4	3	5	7.6					6	3.5
3/5/2007	1.098	42.0	0	5.5	3	3.5	10.8	1.608	58.0	4	4	3	5	7.4			1.050	36.2	6	3.5
3/6/2007	1.084	41.1	0	5.5	3	3.5	10.4	1.596	57.4	4	4	3	5	7.1					6	3.5
3/7/2007	1.075	40.5	0	5.5	3	3.5	10.2	1.585	56.8	4	4	3	5	6.9					6	3.5
3/8/2007	1.062	39.6	0	5.5	3	3.5	9.9	1.574	56.3	4	4	3	5	6.7					6	3.5
3/9/2007	1.049	38.8	0	5.5	3	3.5	9.6	1.563	55.7	4	4	3	5	6.5					6	3.5
3/10/2007	1.051	38.9	0	5.5	3	3.5	9.6	1.551	55.1	4	4	3	5	6.3					6	3.5
3/11/2007	1.050	38.8	0	5.5	3	3.5	9.6	1.540	54.5	4	4	3	5	6.1					6	3.5
3/12/2007	1.042	38.3	0	5.5	3	3.5	9.4	1.529	54.0	4	4	3	5	5.9			1.120	38.6	6	3.5
3/13/2007	1.036	37.9	0	5.5	3	3.5	9.3	1.518	53.4	4	4	3	5	5.7					6	3.5
3/14/2007	1.031	37.6	0	5.5	3	3.5	9.2	1.506	52.8	4	4	3	5	5.5					6	3.5
3/15/2007	1.028	37.4	0	5.5	3	3.5	9.1	1.495	52.3	4	4	3	5	5.3					6	3.5
3/16/2007	1.021	36.9	0	5.5	3	3.5	8.9	1.486	51.8	4	4	3	5	5.1					6	3.5
3/17/2007	1.008	36.1	0	5.5	3	3.5	8.6	1.476	51.3	4	4	3	5	4.9					6	3.5
3/18/2007	0.989	34.8	0	5.5	3	3.5	8.2	1.467	50.9	4	4	3	5	4.8					6	3.5
3/19/2007	0.971	33.6	3	2.5	3	3.5	0.2	1.456	50.3	4	4	4	4	2.1	4.437		1.170	40.3	6	3.5
3/20/2007	1.001	35.6	3	2.5	3	3.5	0.3	1.491	52.1	4	4	4	4	2.5	4.290				6	3.5
3/21/2007	1.011	36.3	3	2.5	3	3.5	0.4	1.507	52.9	4	4	5	3	1.4					6	3.5
3/22/2007	1.041	38.2	3	2.5	3	3.5	0.5	1.523	53.7	4	4	5	3	1.5					6	3.5
3/23/2007	1.063	39.7	3	2.5	3	3.5	0.7	1.570	56.1	4	4	5	3	2.0					6	3.5
3/24/2007	1.083	41.0	3	2.5	3	3.5	0.8	1.564	55.8	4	4	5	3	2.0					6	3.5
3/25/2007	1.105	42.4	3	2.5	3	3.5	0.9	1.564	55.8	4	4	5	3	2.0					6	3.5
3/26/2007	1.132	44.2	3	2.5	3	3.5	1.1	1.566	55.9	4	4	5	3	2.0			1.390	47.9	6	3.5
3/27/2007	1.156	45.8	3	2.5	4	2.5	0.0	1.598	57.5	5	3	5	3	0.5					6	3.5
3/28/2007	1.214	49.6	4	1.5	5	1.5	0.0	1.640	59.6	5	3	5	3	0.9					6	3.5
3/29/2007	1.275	53.6	4	1.5	5	1.5	0.0	1.664	60.8	5	3	5	3	1.1					6	3.5
3/30/2007	1.337	57.7	4	1.5	5	1.5	0.0	1.678	61.5	6	2	5	3	0.6					6	3.5
3/31/2007	1.396	61.6	4	1.5	5	1.5	0.0	1.689	62.1	6	2	5	3	0.7					6	3.5
4/1/2007	1.459	65.7	4	1.5	5	1.5	0.0	1.714	63.3	6	2	5	3	0.8					6	3.5
4/2/2007	1.525	70.1	4	1.5	5	1.5	0.2	1.733	64.3	6	2	5	3	0.9			1.900	65.5	7	2.5
4/3/2007	1.594	74.6	4	1.5	5	1.5	0.6	1.750	65.2	6	2	5	3	1.0					7	2.5
4/4/2007	1.673	79.8	4	1.5	5	1.5	1.4	1.812	68.3	6	2	5	3	1.4					7	2.5
4/5/2007	1.793	87.7	4	1.5	5	1.5	3.2	1.926	74.0	7	1	6	2	0.4			2.350	81.0	8	1.5

84 Big Bob Lake Outflow	85 Little Bob Lake	86 Little Bob Lake Percentage	87 Little Bob LakeLogs In	88 Little Bob Lake Logs Out	89 Little Bob Lake Outflow	90 Gull Lake	91 Gull Lake Percentage	92 Gull Lake Logs In, Sluice 1	93 Gull Lake Logs Out, Sluice 1	94 Gull Lake Logs In, Sluice 2	95 Gull Lake Logs Out, Sluice 2	96 Gull Lake Logs In, Sluice 3	97 Gull Lake Logs Out, Sluice 3	98 Gull Lake Outflow	99 Moore Lake	100 Moore Lake Percentage	101 Eliotts Dam Level	102 Eliotts Dam Percentage	103 Eliotts Logs In	104 Elliotts Falls Logs Out	105 Elliotts Falls Outflow	106 Gull River @ Norland	107 Gull River @ Norland
9	1.520		0	5	12	2.130		2	7	0	2	0	2	25	1.520		1.520		7	9	20		
226	0.000			0.000	73	1.220								998	1.000		1.000			-1.220	194		
0.5	0.370	24.3	0	5	1.5	2.055	91.8	2	5	0	2	0	2		1.350	67.3	1.100	19.2	4	5			
			0	5		2.055	91.8	2	5	0	2	0	2						4	5		4.062	35.1
0.5	0.370	24.3	0	5	1.5	2.058	92.1	2	5	0	2	0	2		1.350	67.3	1.100	19.2	4	5		4.061	35.1
			0	5		2.055	91.8	2	5	0	2	0	2						4	5		4.056	34.7
			0	5		2.043	90.4	2	5	0	2	0	2						4	5		4.050	34.3
			0	5		2.044	90.5	2	5	0	2	0	2						4	5		4.050	34.3
			0	5		2.057	92.0	2	5	0	2	0	2						4	5		4.060	35.0
			0	5		2.075	93.9	2	5	0	2	0	2						4	5		4.071	35.8
0.8	0.410	27.0	0	5	1.8	2.092	95.8	2	5	0	2	0	2		1.394	75.8	1.130	25.0	4	5		4.081	36.5
			0	5		2.100	96.7	2	5	0	2	0	2						4	5		4.089	37.0
			0	5		2.105	97.3	2	5	0	2	0	2						4	5		4.093	37.3
			0	5		2.087	95.3	2	5	0	2	0	2						4	5		4.089	37.0
			0	5		2.084	94.9	2	5	0	2	0	2						4	5		4.085	36.8
			0	5		2.088	95.4	2	5	0	2	0	2						4	5		4.086	36.8
			0	5		2.084	94.9	2	5	0	2	0	2						4	5		4.079	36.3
0.6	0.410	27.0	0	5	1.8	2.080	94.5	2	5	0	2	0	2		1.377	72.5	1.120	23.1	4	5		4.072	35.8
			0	5		2.073	93.7	2	5	0	2	0	2						4	5		4.072	35.8
			0	5		2.060	92.3	2	5	0	2	0	2						4	5		4.065	35.4
			0	5		2.046	90.8	2	5	0	2	0	2						4	5		4.057	34.8
			0	5		2.037	89.8	2	5	0	2	0	2						4	5		4.050	34.3
			0	5		2.022	88.1	2	5	0	2	0	2						4	5		4.044	33.9
			0	5		2.019	87.8	2	5	0	2	0	2						4	5		4.038	33.5
0.5	0.350	23.0	0	5	1.4	2.001	85.8	2	5	0	2	0	2		1.272	52.3	1.030	5.8	4	5		4.032	33.1
			0	5		1.997	85.3	2	5	0	2	0	2						4	5		4.020	32.3
			0	5		1.992	84.8	2	5	0	2	0	2						4	5		4.013	31.8
			0	5		1.976	83.1	2	5	0	2	0	2						4	5		4.004	31.2
			0	5		1.969	82.3	2	5	0	2	0	2						4	5		3.998	30.8
			0	5		1.952	80.4	2	5	0	2	0	2						4	5		3.994	30.5
			0	5		1.936	78.7	2	5	0	2	0	2						4	5		3.982	29.7
0.5	0.350	23.0	0	5	1.4	1.930	78.0	2	5	0	2	0	2		1.154	29.6			4	5		3.973	29.1
			0	5		1.918	76.7	2	5	0	2	0	2						4	5		3.970	28.9
			0	5		1.900	74.7	2	5	0	2	0	2						4	5		3.967	28.7
			0	5		1.890	73.6	2	5	0	2	0	2						4	5		3.947	27.4
			0	5		1.881	72.6	2	5	0	2	0	2						4	5		3.936	26.8
			0	5		1.860	70.3	2	5	0	2	0	2						4	5		3.922	26.0
			0	5		1.849	69.1	2	5	0	2	0	2						4	5		3.916	25.6
0.3	0.260	17.1	0	5	0.9	1.838	67.9	2	5	0	2	0	2		1.038	7.3			4	5		3.916	25.6
			0	5		1.822	66.2	2	5	0	2	0	2						4	5		3.879	23.5
			0	5		1.809	64.7	2	5	0	2	0	2						4	5		3.867	22.9
			0	5		1.794	63.1	2	5	0	2	0	2						4	5		3.862	22.6
			0	5		1.782	61.8	2	5	0	2	0	2						4	5		3.849	21.8
			0	5		1.776	61.1	2	5	0	2	0	2						4	5		3.842	21.5
			0	5		1.758	59.1	2	5	0	2	0	2						4	5		3.833	21.0
0.3	0.250	16.4	0	5	0.8	1.751	58.4	2	5	0	2	0	2				0.720	-53.8	4	5		3.822	20.4
			0	5		1.746	57.8	2	5	0	2	0	2		0.926	-14.2	0.700	-57.7	4	5		3.813	20.0
			0	5		1.747	57.9	2	5	0	2	0	2						4	5		3.808	19.7
			0	5		1.717	54.6	2	5	0	2	0	2		0.920	-15.4	0.690	-59.6	6	3		3.799	19.3
			0	5		1.697	52.4	2	5	0	2	0	2						6	3		3.739	16.4
			0	5		1.701	52.9	2	5	0	2	0	2						6	3		3.761	17.4
			0	5		1.688	51.4	2	5	0	2	0	2						6	3		3.763	17.5
0.2	0.200	13.2	0	5	0.6	1.675	50.0	2	5	0	2	0	2		0.971	-5.6	0.870	-25.0	6	3		3.759	17.3
			0	5		1.658	48.1	2	5	0	2	0	2				0.850	-28.8	6	3		3.753	17.0
			0	5		1.649	47.1	2	5	0	2	0	2				0.840	-30.8	6	3		3.748	16.8
			0	5		1.636	45.7	2	5	0	2	0	2				0.830	-32.7	6	3		3.743	16.6
			0	5		1.647	46.9	2	5	0	2	0	2						6	3		3.741	16.5
			0	5		1.615	43.4	2	5	0	2	0	2						6	3		3.731	16.0
			0	5		1.621	44.1	2	5	0	2	0	2						6	3		3.725	15.7
0.1			0	5		1.589	40.5	2	5	0	2	0	2		0.915	-16.3	0.762	-45.8	6	3		3.719	15.4
			0	5		1.589	40.5	2	5	0	2	0	2				0.750	-48.1	6	3		3.708	14.9
			0	5		1.565	37.9	2	5	0	2	0	2						6	3		3.697	14.4
			0	5		1.553	36.6	2	5	0	2	0	2						6	3		3.692	14.2
			0	5		1.523	33.3	2	5	0	2	0	2						6	3		3.687	14.0
			0	5		1.552	36.5	2	5	0	2	0	2						6	3		3.682	13.7
			0	5		1.528	33.8	2	5	0	2	0	2						6	3		3.677	13.5
			0	5		1.520	33.0	2	5	0	2	0	2		1.128	24.6	0.990	-1.9	6	3		3.672	13.3
			0	5		1.505	31.3	2	5	0	2	0	2				1.000	0.0	6	3		3.667	13.1
			0	5		1.489	29.6	2	5	0	2	0	2				1.020	3.8	6	3		3.662	12.9
			0	5		1.484	29.0	2	5	0	2	0	2				1.020	3.8	6	3		3.657	12.7
			0	5		1.479	28.5	2	5	0	2	0	2				1.020	3.8	6	3		3.649	12.4
			0	5		1.447	24.9	2	5	0	2	0	2						6	3		3.642	12.0
			0	5		1.449	25.2	2	5	0	2	0	2						6	3		3.634	11.7
			0	5		1.422	22.2	2	5	0	2	0	2		1.066	12.7	1.030	5.8	6	3		3.626	11.4
	0.090	5.9	2	3		1.413	21.2	2	5	0	2	0	2				1.030	5.8	6	3		3.618	11.1
			2	3		1.419	21.9	2	5	0	2	0	2				1.040	7.7	6	3		3.611	10.8
			2	3		1.412	21.1	2	5	0	2	0	2				1.030	5.8	6	3		3.603	10.5
			2	3		1.415	21.4	2	5	0	2	0	2				1.030	5.8	6	3		3.595	10.2
			2	3		1.402	20.0	2	5	0	2	0	2						6	3		3.593	10.1
			2	3		1.390	18.6	2	5	0	2	0	2						6	3		3.589	10.0
	0.160	10.5	2	3		1.377	17.3	2	5	0	2	0	2		1.063	12.1	1.000	0.0	6	3		3.586	9.8
			2	3		1.367	16.2	2	5	0	2	0	2				1.130	25.0	6	3		3.479	6.5
			2	3		1.353	14.6	4	3	0	2	0	2				1.174	33.5	7.5	1.5		3.500	7.1
			2	3		1.396	19.3	4	3	0	2	0	2				1.130	25.0	7.5	1.5		3.371	4.1
			2	3		1.459	26.3	4	3	0	2	0	2				1.110	21.2	7.5	1.5		3.376	4.2
			2	3		1.505	31.3	4	3	0	2	0	2						7.5	1.5		3.360	3.9
			2	3		1.571	38.6	4	3	0	2	0	2						7.5	1.5		3.362	3.9
	0.470	30.9	2	3		1.608	42.6	4	3	0	2	0	2				1.220	42.3	7.5	1.5		3.369	4.0
			2	3		1.668	49.2	5	2	0	2	0	2		1.304	58.5	1.370	71.2	7.5	1.5		3.399	4.6
			2	3		1.758	59.1	5	2	0	2	0	2				1.410	78.8	7.5	1.5		3.439	5.5
			2	3		1.806	64.4	5	2	0	2	0	2				1.470	90.4	7.5	1.5		3.463	6.1
			2	3		1.834	67.5	5.5	1.5	0	2	0	2				1.570	109.6	7	2		3.490	6.8
			2	3		1.847	68.8	5.5	1.5	0	2	0	2						7	2		3.541	8.3
			2	3		1.887	73.3	5.5	1.5	0	2	0	2						7	2		3.626	11.4
	0.770	50.7	3	2		1.888	73.4	5.5	1.5	0	2	0	2		1.387	74.4	1.410	78.8	7	2		3.600	10.4
			3	2		1.893	74.0	5.5	1.5	0	2	0	2				1.370	71.2	7	2		3.590	10.0
			3	2		1.963	81.6	5.5	1.5	0	2	0	2				1.410	78.8	7	2		3.616	11.0
			3	2		2.069	93.3	4	3	0	2	0	2				1.540	103.8	7	2		3.679	13.6

108 Norland Pool Level	109 Norland Pool Logs In, Sluice 1	110 Norland Pool Logs Out, Sluice 1	111 Norland Pool Logs In, Sluice 2	112 Norland Pool Logs Out, Sluice 2	113 Norland Dock Level	114 Coboconk Level	115 Coboconk Sluice 1 Logs In	116 Coboconk Sluice 1 Logs Out	117 Coboconk Sluice 2 Logs In	118 Coboconk Sluice 2 Logs Out	119 Coboconk Sluice 3 Logs In	120 Coboconk Sluice 3 Logs Out	121 Coboconk Sluice 4 Logs In	122 Coboconk Sluice 4 Logs Out	123 Coboconk Sluice 5 Logs In	124 Coboconk Sluice 5 Logs Out	125 Coboconk Sluice 6 Logs In	126 Coboconk Sluice 6 Logs Out	127 Coboconk Sluice 7 Logs In	128 Coboconk Sluice 7 Logs Out	129 Coboconk Sluice 8 Logs In	130 Coboconk Sluice 8 Logs Out	131 Coboconk Sluice 9 Logs In	132 Coboconk Sluice 9 Logs Out
		11		6	20			6		8		8		9		9		9		8		8		6
																								20
1.050	8	3	3	3	1.030	7.841	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
1.050	8	3	3	3	1.030	7.841	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
1.070	8	3	3	3	1.080	7.859	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
1.060	8	3	3	3	1.070	7.854	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
1.020	8	3	3	3	0.990	7.817	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
0.950	8	3	3	3	0.900	7.776	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
0.880	8	3	3	3	0.830	7.731	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
0.820	8	3	3	3	0.780	7.685	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
0.750	8	3	3	3	0.630	7.645	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
0.720	8	3	3	3	0.570	7.624	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
0.650	8	3	3	3	0.430	7.562	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
0.660	8	3	3	3	0.420	7.557	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
0.490	8	3	3	3	0.450	7.549	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3	0.200	7.474	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
0.650	8	3	3	3	0.460	7.599	6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1
	8	3	3	3			6	0	7	1	7	1	8	1	8	1	7	2	7	1	7	1	5	1

133 Drag Lake	134 Drag Lake Percentage	135 Drag Lake South Logs In	136 Drag Lake South Logs Out	137 Drag Lake North Logs In	138 Drag Lake North Logs Out	139 Drag Lake PP Flow	140 Drag Lake Outflow	141 Head Lake Level	142 Head Lake Level Percentage	143 Canning Lake Level	144 Canning Lake Level Percentage	145 Canning Lake Logs In Sluice 1	146 Canning Lake Logs Out Sluice 1	147 Canning Lake Logs In Sluice 2	148 Canning Lake Logs Out Sluice 2	149 Canning Lake Logs In Sluice 3	150 Canning Lake Logs Out Sluice 3	151 Canning Lake Outflow	152 Miskwabi Lake	153 Miskwabi Lake Percentage	154 Miskwabi Lake Logs In	155 Miskwabi Lake Logs Out	156 Miskwabi Lake Outflow	157 Loon Lake	158 Loon Lake Percentage	159 Loon Lake Logs In	160 Loon Lake Logs Out	161 Loon Lake Outflow	162 Koshlong Lake	163 Koshlong Lake Percentage	164 Koshlong Lake Logs In	165 Kosklong Lake Logs Out	166 Koshlong Lake Outflow	167 Burnt River @ Gelert Level	168 Burnt River @ Gelert Flow	169 Farquhar Lake
2.290		4	7.5	7	7.5		12.0	1.520		1.520		2	4	2	4	2	5	17.5	2.290		5	7.5	12	1.980		2	6.5	12	2.290		3	7.5	10			3.050
0.457			0.000		0.000		1102	0.457		0.457								1274	0.300			0.000	335	0.610			0.000	254	0.610			0.000	405			0.610
1.795	73.0	4	4	7	0.5		2.3			1.220	71.8	2	2	2	2	2	3		1.740	72.4	5	2.5	0.6	1.306	50.8	2	4.5	3.2	1.210	35.7	3	4.5	0.7			2.070
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.197	11.1	
1.795	73.0	4	3.5	7	0.5		2.3			1.220	71.8	2	2	2	2	2	3		1.740	72.4	5	2.5	0.6	1.306	50.8	2	4.5	3.2	1.210	35.7	3	4.5	0.7	1.211	11.5	2.070
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.185	10.7	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.170	10.4	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.193	11.0	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.253	12.6	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.316	14.5	
1.834	75.1	4	3.5	7	0.5		2.5			1.260	75.5	2	2	2	2	2	3		1.760	73.4	5	2.5	0.6	1.391	57.0	2	4.5	3.8	1.270	39.3	3	4.5	0.9	1.334	15.1	2.110
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.334	15.1	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.253	12.6	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.309	14.3	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.330	15.0	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.289	13.7	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.265	13.0	
1.837	75.3	4	3.5	7	0.5		2.5			1.260	75.5	2	2	2	2	2	3		1.760	73.4	5	2.5	0.6	1.357	54.5	2	4.5	3.6	1.330	42.9	3	4.5	1.2	1.240	12.3	2.110
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.201	11.2	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.242	12.3	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.174	10.5	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.207	11.3	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.178	10.6	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.254	12.7	
1.774	71.8	4	3.5	7	0.5		2.2			1.210	70.8	2	2	2	2	2	3		1.720	71.4	5	2.5	0.5	1.268	48.0	2	4.5	2.9	1.190	34.5	3	4.5	0.6	1.144	9.7	2.090
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.137	9.5	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.115	9.0	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.238	12.2	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.344	15.4	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.272	13.2	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.115	9.0	
1.707	68.2	4	3.5	7	0.5		1.8			1.150	65.2	2	2	2	2	2	3		1.700	70.4	5	2.5	0.4	1.194	42.6	2	4.5	2.4	1.140	31.5	3	4.5	0.5	1.170	10.4	2.020
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.272	13.2	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.177	10.5	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.036	7.1	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.004	6.5	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.995	6.3	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.999	6.3	
1.652	65.2	4	3.5	7	0.5		1.5			1.125	62.8	2	2	2	2	2	3		1.680	69.3	5	2.5	0.4	1.142	38.8	2	4.5	2.1	1.110	29.8	3	4.5	0.4	0.992	6.2	2.010
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.091	8.4	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.069	7.9	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.043	7.3	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.007	6.5	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.007	6.5	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.987	6.1	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.968	5.7	
1.604	62.6	4	3.5	7	0.5		1.3					2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.967	5.7	
		4	3.5	7	0.5					1.070	57.7	2	2	2	2	2	3		1.670	68.8	5	2.5	0.3	1.128	37.8	2	4.5	2.0			3	4.5		0.976	5.9	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.982	6.0	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.987	6.1	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.983	6.0	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.984	6.0	
1.570	60.7	4	3.5	7	0.5		1.1			1.040	54.8	2	2	2	2	2	3		1.650	67.8	5	2.5	0.3	1.087	34.8	2	4.5	1.8	1.080	28.0	3	4.5	0.3	0.985	6.1	1.990
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.991	6.2	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.983	6.0	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.972	5.8	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.966	5.7	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		1.003	6.4	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.978	5.9	
1.540	59.1	4	3.5	7	0.5		1.0			1.010	52.0	2	2	2	2	2	3		1.630	66.8	5	2.5	0.2	1.068	33.4	2	4.5	1.7	1.060	26.8	3	4.5	0.3	0.947	5.3	1.980
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.905	4.6	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				3	4.5		0.842	3.6	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5		1.060	26.8	6	1.5		0.853	3.7	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				6	1.5		0.833	3.4	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				6	1.5		0.836	3.5	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				6	1.5		0.831	3.4	
		4	3.5	7	0.5							2	2	2	2	2	3		1.640	67.3	5	2.5	0.3	1.071	33.6	2	4.5	1.7			6	1.5		0.828	3.4	1.980
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				6	1.5		0.899	4.5	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				6	1.5		0.882	4.2	
		4	3.5	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				6	1.5		0.852	3.7	
1.516	57.8	4.5	3	7	0.5		0.3					2	2	2	2	2	3				5	2.5				2	4.5				6	1.5		0.851	3.7	
		4.5	3	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				6	1.5		0.829	3.4	
		4.5	3	7	0.5							2	2	2	2	2	3				5	2.5				2	4.5				6	1.5		0.833	3.4	
1.528	58.4	4.5	3	7	0.5		0.4			0.970	48.3	2	2	2	2	2	3		1.680	69.3	5	2.5	0.4	1.062	33.0	2	4.5	1.6	1.110	29.8	6	1.5		0.818	3.2	1.960
		4.5	3	7	0.5							2	2	2	2	2	3		1.650	67.8	6	1.5		1.060	32.8	4	2.5				6	1.5		0.817	3.2	
		4.5	3	7	0.5							2	2	2	2	2	3				6	1.5				4	2.5				6	1.5		0.828	3.4	
		4.5	3	7	0.5							2	2	2	2	2	3				6	1.5				4	2.5				6	1.5		0.851	3.7	
		4.5	3	7	0.5							2	2	2	2	2	3				6	1.5				4	2.5				6	1.5		0.843	3.6	
		4.5	3	7	0.5							2	2	2	2	2	3				6	1.5				4	2.5				6	1.5		0.829	3.4	
		4.5	3	7	0.5							2	2	2	2	2	3				6	1.5				4	2.5				6	1.5		0.817	3.2	
1.549	59.6	4.5	3	7	0.5		0.4			0.950	46.4	2	2	2	2	2	3		1.650	67.8	6	1.5		1.111	36.6	4	2.5				6	1.5		0.809	3.1	1.940
		4.5	3	7	0.5							2	2	2	2	2	3				6	1.5				4	2.5				6	1.5		0.812	3.1	
		4.5	3	7	0.5					0.950	46.4	4	0	4	0	2	3				6	1.5				4	2.5		1.140	31.5	6	1.5		0.790	2.8	
		4.5	3	7	0.5							4	0	4	0	2	3				6	1.5				4	2.5				6	1.5		0.818	3.2	
1.585	61.5	4.5	3	7	0.5		0.5					4	0	4	0	2	3		1.690	69.8	6	1.5		1.190	42.3	5	1.5				6	1.5		0.894	4.4	
		4.5	3	7	0.5							4	0	4	0	2	3				6	1.5				5	1.5				6	1.5		0.930	5.0	
		4.5	3	7	0.5							4	0	4	0	2	3				6	1.5				5	1.5				6	1.5		0.940	5.2	
1.626	63.8	4.5	3	7	0.5		0.7			1.030	53.9	4	0	4	0	2	3		1.730	71.9	6	1.5		1.280	48.9	5	1.5				6	1.5		0.953	5.4	2.050
1.645	64.8	5	2.5	7	0.5		0.3			1.060	56.7	4	0	4	0	3	2				6	1.5				5	1.5		1.290	40.5	6	1.5		1.069	7.9	
1.704	68.0	5.5	2	7	0.5		0.1					4	0	4	0	3	2				6	1.5				5	1.5				6	1.5		1.101	8.6	
		5.5	2	7	0.5							4	0	4	0	3	2				6	1.5				5	1.5				6	1.5		1.087	8.3	
		5.5	2	7	0.5					1.230	72.7	4	0	4	0	3.5	1.5				6	1.5				5	1.5				6	1.5		1.038	7.2	
		5.5	2	7	0.5							4	0	4	0	3.5	1.5				6	1.5				5	1.5				6	1.5		1.013	6.6	
		5.5	2	7	0.5							4	0	4	0	3.5	1.5				6	1.5				5	1.5				6	1.5		0.938	5.2	
1.904	78.9	6	1.5	7	0.5		0.2	1.332	82.3	1.340	83.1	4	0	4	0	3.5	1.5		1.870	78.9	6	1.5	0.1	1.721	81.1	5	1.5	0.5	1.490	52.4	6	1.5		0.948	5.4	2.170
		6	1.5	7	0.5							4	0	4	0	3.5	1.5		1.880	79.4	7	0.5				5	1.5				6	1.5		0.984	6.0	2.190
2.051	87.0	6	1.5	7	0.5		0.6	1.470	95.3	1.470	95.3	4	0	4	0	2	3		1.960	83.4	7	0.5		1.890	93.4	5	1.5	1.2			6	1.5		1.120	9.1	
		6	1.5	7	0.5			1.527	100.7			4	0	4	0	2	3				7	0.5				5	1.5				6	1.5		1.629	25.9	

170	171	172	173	174	175	176	177	178	179	180	181	182	183
Farquhar Lake Percentage	Farquhar Lake Logs In	Farquhar Lake Logs Out	Farquhar Lake Outflow	Pusey Lake	Pusey Lake Percentage	Pusey Lake Logs In	Pusey Lake Logs Out	Pusey Lake Outflow	Esson Lake	Esson Lake Percentage	Esson Lake Logs In	Esson Lake Logs Out	Esson Lake Outflow
	6	10	9.83	2.060		2	7	11.5	3.050		4	10	11
		0.000	345	0.457			0.000	295	0.910			0.000	236
59.8	6	4	0.5	1.020	35.1	2	5	1.4	1.500	27.6	4	6	0.7
	6	4				2	5				4	6	
59.8	6	4	0.5	1.020	35.1	2	5	1.4	1.500	27.6	4	6	0.7
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
61.5	6	4	0.7	1.060	37.6	2	5	1.6	1.520	28.5	4	6	0.8
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
61.5	6	4	0.7	1.060	37.6	2	5	1.6	1.520	28.5	4	6	0.8
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
60.7	6	4	0.6	1.020	35.1	2	5	1.4	1.480	26.6	4	6	0.7
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
57.8	6	4	0.4	0.940	30.1	2	5	1.0	1.470	26.2	4	6	0.6
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
57.4	6	4	0.4	0.880	26.4	2	5	0.7	1.410	23.4	4	6	0.4
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4		0.860	25.1	2	5	0.6	1.390	22.4	4	6	0.4
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
	6	4				2	5				4	6	
56.6	6	4	0.3	0.820	22.6	2	5	0.5	1.380	22.0	4	6	0.3
	6	4				2	5				4	6	
	6	4		0.820	22.6	2.5	4.5	0.1			4	6	
	6	4				2.5	4.5				4	6	
	6	4				2.5	4.5				4	6	
	6	4				2.5	4.5				4	6	
	6	4				2.5	4.5				4	6	
56.1	6	4	0.3	0.950	30.8	2.5	4.5	0.4	1.370	21.5	4	6	0.3
	6	4				2.5	4.5				4	6	
	6	4				2.5	4.5				4	6	
	6	4				2.5	4.5				4	6	
	6	4				2.5	4.5				4	6	
	6	4				2.5	4.5				4	6	
	6	4				2.5	4.5				4	6	
56.1	6	4	0.3	0.980	32.6	2.5	4.5	0.5	1.370	21.5	4	6	0.3
	6	4				2.5	4.5				4	6	
	6	4				2.5	4.5				4	6	
	6	4				2.5	4.5		1.370	21.5	6	4	
	6	4				2.5	4.5				6	4	
	6	4				2.5	4.5				6	4	
	6	4				2.5	4.5				6	4	
55.3	6	4	0.3	0.950	30.8	2.5	4.5	0.4	1.500	27.6	6	4	
	6	4				2.5	4.5				6	4	
	6	4				2.5	4.5				6	4	
	6	4				2.5	4.5				6	4	
	6	4				2.5	4.5				6	4	
	6	4				2.5	4.5				6	4	
	6	4				2.5	4.5				6	4	
54.5	8	2		1.050	37.0	2.5	4.5	0.8	1.520	28.5	6	4	
	8	2				2.5	4.5				6	4	
	8	2				2.5	4.5				6	4	
	8	2				2.5	4.5				6	4	
	8	2		1.090	39.5	2.5	4.5	1.0	1.560	30.4	7	3	
	8	2				2.5	4.5				7	3	
	8	2				2.5	4.5				7	3	
59.0	8	2		1.120	41.4	2.5	4.5	1.1	1.630	33.6	7	3	
	8	2		1.130	42.0	3.5	3.5	0.1			7	3	
	8	2				3.5	3.5				7	3	
	8	2				3.5	3.5				7	3	
	8	2				3.5	3.5				7	3	
	8	2				3.5	3.5				7	3	
	8	2				3.5	3.5				7	3	
63.9	8	2		1.310	53.2	3.5	3.5	0.6	1.870	44.9	7	3	
64.8	9	1		1.330	54.5	5	2		1.900	46.3	8	2	
	9	1				5	2				8	2	
	9	1				5	2				8	2	

184	185	186	187	188	189	190	191	192	193	194	195	196	197	198
Little Glamor Lake	Little Glamor Lake Percentage	Little Glamor Lake Logs In	Little Glamor Lake Logs Out	Little Glamor Lake Outflow	Glamor Lake	Glamor Lake Percentage	Glamor Lake Logs In	Glamor Lake Logs Out	Glamor Lake Outflow	Gooderham Lake	Gooderham Lake Percentage	Gooderham Lake Logs In	Gooderham Lake Logs Out	Gooderham Lake Outflow
1.830		0	6	10	2.440		2	8	10	1.830		3	6	15.75
0.000			0.000	63	0.710			0.000	187	0.610			0.000	85
0.210	11.5	0	6	0.5	1.070	20.8	2	6	1.4	1.240	51.6	3	3	1.3
		0	6				2	6				3	3	
0.210	11.5	0	6	0.5	1.070	20.8	2	6	1.4	1.240	51.6	3	3	1.3
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
0.250	13.7	0	6	0.7	1.090	22.0	2	6	1.5	1.310	57.4	3	3	1.7
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
0.260	14.2	0	6	0.7	1.100	22.5	2	6	1.5	1.260	53.3	3	3	1.4
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
0.200	10.9	0	6	0.5	1.040	19.1	2	6	1.3	1.210	49.2	3	3	1.1
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
0.180	9.8	0	6	0.4	0.960	14.5	2	6	0.9	1.160	45.1	3	3	0.9
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
0.170	9.3	0	6	0.4	0.940	13.3	2	6	0.8	1.140	43.4	3	3	0.8
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
0.150	8.2	0	6	0.3	0.850	8.1	2	6	0.5	1.140	43.4	3	3	0.8
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
0.140	7.7	0	6	0.3	0.820	6.4	2	6	0.4	1.130	42.6	3	3	0.7
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
0.130	7.1	0	6	0.3	0.790	4.6	2	6	0.3	1.110	41.0	3	3	0.6
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6				2	6				3	3	
0.130	7.1	0	6	0.3	0.780	4.0	2	6	0.3	1.100	40.2	3	3	0.6
		0	6				2	6				3	3	
		0	6				2	6				3	3	
		0	6		0.830	6.9	4	4				3	3	
		0	6				4	4				3	3	
		0	6				4	4				3	3	
		0	6				4	4				3	3	
0.110	6.0	0	6	0.2	0.850	8.1	4	4		1.000	32.0	3	3	0.2
0.110	6.0	2	4				4	4				3	3	
		2	4				4	4		1.030	34.4	4	2	
		2	4				4	4				4	2	
		2	4				4	4				4	2	
		2	4				4	4				4	2	
		2	4				4	4				4	2	
0.270	14.8	2	4		0.850	8.1	4	4		1.150	44.3	4	2	
		2	4				4	4				4	2	
		2	4				4	4				4	2	
		2	4				4	4				4	2	
		2	4		0.870	9.2	4	4				4	2	
		2	4				4	4				4	2	
		2	4				4	4				4	2	
0.600	32.8	2	4		0.880	9.8	4	4		1.410	65.6	4	2	0.6
		2	4		0.890	10.4	5	3				4	2	
0.790	43.2	3	3				5	3		1.550	77.0	4	2	1.3
		3	3				5	3				4	2	
		3	3				5	3				4	2	
		3	3				5	3				4	2	
		3	3				5	3				4	2	
1.220	66.7	3	3	0.7	1.050	19.7	5	3		1.520	74.6	4	2	1.2
1.230	67.2	4	2	0.0	1.110	23.1	5	3				4	2	
		4	2				5	3				4	2	
1.610	88.0	4	2	1.1	1.220	29.5	6	2				4	2	

199	200	201	202	203	204	205	206	207	208	209	210	211	212
Contau Lake	Contau Lake Percentage	Contau Lake Logs In	Contau Lake Logs Out	Contau Lake Outflow	White Lake	White Lake Percentage	White Lake Logs In	White Lake Logs Out	White Lake Outflow	Irondale @ Furance Falls Level	Irondale @ Furance Falls Flow	Burnt River @ Burnt River Level	Burnt River @ Burnt River Flow
1.680		2	5.5	7	1.830		1	6	10				
0.457			0.000	119	0.000			0.000	160				
0.770	25.6	2	3.5	0.2	0.650	35.5	1	5	0.9				
		2	3.5				1	5		1.700	12.0	3.820	27.0
0.770	25.6	2	3.5	0.2	0.650	35.5	1	5	0.9	1.723	12.9	3.870	28.9
		2	3.5				1	5		1.722	12.8	3.863	28.6
		2	3.5				1	5		1.697	11.9	3.826	27.2
		2	3.5				1	5		1.694	11.8	3.824	27.1
		2	3.5				1	5		1.758	14.2	3.934	31.5
		2	3.5				1	5		1.844	17.7	4.096	38.9
0.800	28.0	2	3.5	0.3	0.710	38.8	1	5	1.2	1.873	19.1	4.150	41.6
		2	3.5				1	5		1.887	19.7	4.160	42.1
		2	3.5				1	5		1.861	18.5	4.123	40.3
		2	3.5				1	5		1.912	20.9	4.031	35.8
		2	3.5				1	5		1.823	16.8	4.045	36.5
		2	3.5				1	5		1.812	16.3	4.040	36.2
		2	3.5				1	5		1.789	15.3	3.980	33.5
0.780	26.4	2	3.5	0.2	0.720	39.3	1	5	1.3	1.765	14.5	3.919	30.9
		2	3.5				1	5		1.750	13.9	3.905	30.3
		2	3.5				1	5		1.854	18.2	3.940	31.8
		2	3.5				1	5		1.784	15.1	3.880	29.3
		2	3.5				1	5		1.709	12.4	3.905	30.3
		2	3.5				1	5		1.671	11.0	3.861	28.5
		2	3.5				1	5		1.659	10.5	3.775	25.3
0.760	24.8	2	3.5	0.2	0.610	33.3	1	5	0.8	1.646	10.2	3.754	24.5
		2	3.5				1	5		1.633	9.7	3.742	24.1
		2	3.5				1	5		1.612	9.0	3.738	24.0
		2	3.5				1	5		1.590	8.3	3.647	20.8
		2	3.5				1	5		1.583	8.1	3.590	19.0
		2	3.5				1	5		1.584	8.2	3.593	19.1
		2	3.5				1	5		1.589	8.3	3.592	19.1
0.740	23.1	2	3.5	0.1	0.560	30.6	1	5	0.6	1.574	7.9	3.578	18.6
		2	3.5				1	5		1.566	7.6	3.545	17.7
		2	3.5				1	5		1.554	7.3	3.522	17.0
		2	3.5				1	5		1.555	7.3	3.496	16.2
		2	3.5				1	5		1.547	7.1	3.494	16.1
		2	3.5				1	5		1.541	6.9	3.481	15.8
		2	3.5				1	5		1.535	6.7	3.449	14.9
0.700	19.9	2	3.5	0.1	0.520	28.4	1	5	0.5	1.529	6.6	3.420	14.2
		2	3.5				1	5		1.521	6.3	3.399	13.6
		2	3.5				1	5		1.516	6.2	3.378	13.1
		2	3.5				1	5		1.513	6.1	3.374	13.0
		2	3.5				1	5		1.513	6.1	3.357	12.6
		2	3.5				1	5		1.508	6.0	3.352	12.4
		2	3.5				1	5		1.503	5.8	3.340	12.1
		2	3.5				1	5		1.499	5.7	3.326	11.8
0.700	19.9	2	3.5	0.1	0.520	28.4	1	5	0.5	1.494	5.6	3.316	11.6
		2	3.5				1	5		1.494	5.6	3.301	11.2
		2	3.5				1	5		1.491	5.5	3.282	10.8
		2	3.5				1	5		1.492	5.5	3.281	10.7
		2	3.5				1	5		1.488	5.4	3.262	10.3
		2	3.5				1	5		1.481	5.2	3.253	10.1
0.690	19.1	2	3.5	0.1	0.470	25.7	1	5	0.3	1.474	5.0	3.241	9.8
		2	3.5				1	5		1.474	5.0	3.217	9.3
		2	3.5				1	5		1.465	4.8	3.215	9.3
		2	3.5				1	5		1.454	4.5	3.201	9.0
		2	3.5				1	5		1.452	4.4	3.203	9.1
		2	3.5				1	5		1.444	4.3	3.202	9.0
		2	3.5				1	5		1.435	4.0	3.190	8.8
0.680	18.2	2	3.5	0.1	0.460	25.1	1	5	0.3	1.429	3.9	3.169	8.4
		2	3.5				1	5		1.428	3.8	3.166	8.3
		2	3.5				1	5		1.423	3.7	3.165	8.3
		2	3.5				1	5		1.421	3.6	3.150	8.0
		2	3.5				1	5		1.431	3.9	3.144	7.9
		2	3.5				1	5		1.429	3.9	3.137	7.8
		2	3.5				1	5		1.429	3.9	3.148	8.0
0.680	18.2	2	3.5	0.1	0.460	25.1	1	5	0.3	1.427	3.8	3.149	8.0
		2	3.5				1	5		1.424	3.7	3.148	8.0
		2	3.5				1	5		1.431	3.9	3.136	7.8
		2	3.5				1	5		1.428	3.8	3.148	8.0
		2	3.5				1	5		1.429	3.9	3.116	7.4
		2	3.5				1	5		1.425	3.8	3.116	7.4
		2	3.5				1	5		1.428	3.8	3.129	7.7
0.680	18.2	2	3.5	0.1	0.460	25.1	1	5	0.3	1.422	3.6	3.147	8.0
0.680	18.2	4	1.5				1	5		1.418	3.6	3.144	7.9
		4	1.5				1	5		1.421	3.6	3.150	8.0
		4	1.5				1	5		1.431	3.9	3.150	8.0
		4	1.5				1	5		1.426	3.8	3.150	8.0
		4	1.5				1	5		1.429	3.9	3.238	9.8
		4	1.5				1	5		1.417	3.5	3.212	9.2
0.830	30.5	4	1.5		0.480	26.2	3	3		1.406	3.3	3.190	8.8
		4	1.5				3	3		1.407	3.3	3.168	8.4
		4	1.5				3	3		1.380	2.8	3.158	8.2
		4	1.5				3	3		1.417	3.5	3.174	8.5
		4	1.5				3	3		1.505	5.9	3.418	14.1
		4	1.5				3	3		1.564	7.6	3.576	18.6
		4	1.5				3	3		1.594	8.4	3.631	20.3
0.930	38.7	4	1.5		0.770	42.1	3	3		1.609	8.9	3.661	21.3
		4	1.5				3	3		1.718	12.7	3.896	29.9
		4	1.5				3	3		1.834	17.3	4.174	42.8
		4	1.5				3	3		1.873	19.1	4.209	44.6
		4	1.5				3	3		1.874	19.1	4.128	40.5
		4	1.5				3	3		1.833	17.3	4.004	34.6
		4	1.5				3	3		1.779	15.0	3.887	29.6
1.110	53.4	4	1.5		0.920	50.3	3	3	0.0	1.746	13.7	3.810	26.6
1.130	55.0	5	0.5		1.250	68.3	5	1		1.744	13.6	3.824	27.1
		5	0.5				5	1		1.793	15.5	3.970	33.1
1.280	67.3	5	0.5		1.530	83.6	5	1	0.1	2.098	31.1	4.663	69.7

213	214	215	216	217	222	223	224	225	226	227	228	229	230	231	232	233
Crystal Lake	Crystal Lake Percentage	Crystal Lake Logs In	Crystal Lake Logs Out	Crystal Lake Outflow	Anstruther Lake	Anstruther Lake Percentage	Anstruther Lake Logs In	Anstruther Lake Logs Out	Anstruther Lake Outflow	Mississagua Lake	Mississagua Lake Percentage	Mississagua Lake Logs In	Mississagua Lake Logs Out	Mississagua Lake Outflow	Mississagua Lake Flow Level	Mississagua Lake Flow
2.740		3	9	7.33	2.290		2.5	7.5	12	2.440		2	8	14		
0.610			0.000	449	0.000			0.000	621	0.000			0.000	2061		
1.300	32.4	3	6	0.8	1.258	54.9	2.5	5	1.9	1.534	62.9	2	6	5.8		
		3	6		1.258	54.9	2.5	5	1.9	1.534	62.9	2	6	5.8		
1.300	32.4	3	6	0.8	1.295	56.6	2.5	5	2.1	1.526	62.5	2	6	5.7		
		3	6		1.267	55.3	2.5	5	1.9	1.516	62.1	2	6	5.6		
		3	6		1.267	55.3	2.5	5	1.9	1.504	61.6	2	6	5.5		
		3	6		1.257	54.9	2.5	5	1.9	1.512	62.0	2	6	5.6		
		3	6		1.272	55.5	2.5	5	1.9	1.525	62.5	2	6	5.7		
		3	6		1.349	58.9	2.5	5	2.4	1.537	63.0	2	6	5.8		
1.320	33.3	3	6	0.8	1.316	57.5	2.5	5	2.2	1.554	63.7	2	6	6.0		
		3	6		1.386	60.5	2.5	5	2.7	1.576	64.6	2	6	6.2		
		3	6		1.413	61.7	2.5	5	2.8	1.582	64.8	2	6	6.3		
		3	6		1.387	60.6	2.5	5	2.7	1.590	65.2	2	6	6.3		
		3	6		1.378	60.2	2.5	5	2.6	1.594	65.3	2	6	6.4		
		3	6		1.404	61.3	2.5	5	2.8	1.601	65.6	2	6	6.4		
		3	6		1.369	59.8	2.5	5	2.5	1.599	65.5	2	6	6.4		
1.330	33.8	3	6	0.9	1.334	58.3	2.5	5	2.3	1.596	65.4	2	6	6.4		
		3	6		1.385	60.5	2.5	5	2.6	1.597	65.5	2	6	6.4		
		3	6		1.370	59.8	2.5	5	2.6	1.587	65.0	2	6	6.3		
		3	6		1.315	57.4	2.5	5	2.2	1.576	64.6	2	6	6.2		
		3	6		1.304	56.9	2.5	5	2.1	1.567	64.2	2	6	6.1		
		3	6		1.326	57.9	2.5	5	2.3	1.559	63.9	2	6	6.0		
		3	6		1.311	57.2	2.5	5	2.2	1.546	63.4	2	6	5.9		
1.290	31.9	3	6	0.7	1.273	55.6	2.5	5	2.0	1.539	63.1	2	6	5.8		
		3	6		1.263	55.2	2.5	5	1.9	1.524	62.5	2	6	5.7		
		3	6		1.277	55.8	2.5	5	2.0	1.514	62.0	2	6	5.6		
		3	6		1.261	55.1	2.5	5	1.9	1.501	61.5	2	6	5.5		
		3	6		1.237	54.0	2.5	5	1.7	1.486	60.9	2	6	5.3		
		3	6		1.201	52.4	2.5	5	1.6	1.471	60.3	2	6	5.2		
		3	6		1.238	54.1	2.5	5	1.8	1.461	59.9	2	6	5.1		
1.250	30.0	3	6	0.6	1.223	53.4	2.5	5	1.7	1.447	59.3	2	6	5.0		
		3	6		1.204	52.6	2.5	5	1.6	1.432	58.7	2	6	4.8		
		3	6		1.182	51.6	2.5	5	1.4	1.419	58.2	2	6	4.7		
		3	6		1.168	51.0	2.5	5	1.4	1.404	57.5	2	6	4.6		
		3	6		1.148	50.1	2.5	5	1.3	1.389	56.9	2	6	4.5		
		3	6		1.169	51.0	2.5	5	1.4	1.374	56.3	2	6	4.3		
		3	6		1.162	50.7	2.5	5	1.3	1.364	55.9	2	6	4.2		
1.190	27.2	3	6	0.5	1.151	50.3	2.5	5	1.3	1.351	55.4	2	6	4.1		
		3	6		1.136	49.6	2.5	5	1.2	1.336	54.8	2	6	4.0		
		3	6		1.116	48.7	2.5	5	1.1	1.324	54.3	2	6	3.9		
		3	6		1.117	48.8	2.5	5	1.1	1.314	53.9	2	6	3.8		
		3	6		1.119	48.9	2.5	5	1.1	1.301	53.3	2	6	3.7		
		3	6		1.087	47.5	2.5	5	1.0	1.291	52.9	2	6	3.6		
		3	6		1.095	47.8	2.5	5	1.0	1.277	52.3	2	6	3.5		
		3	6		1.094	47.8	2.5	5	1.0	1.265	51.8	2	6	3.4		
1.110	23.5	3	6	0.3	1.092	47.7	2.5	5	1.0	1.252	51.3	2	6	3.3		
		3	6		1.037	45.3	2.5	5	0.8	1.246	51.1	2	6	3.3		
		3	6		1.062	46.4	2.5	5	0.9	1.232	50.5	2	6	3.1		
		3	6		1.056	46.1	2.5	5	0.8	1.219	50.0	2	6	3.0		
		3	6		1.055	46.1	2.5	5	0.8	1.211	49.6	2	6	3.0		
		3	6		1.067	46.6	2.5	5	0.9	1.201	49.2	2	6	2.9		
1.110	23.5	3	6	0.3	1.053	46.0	2.5	5	0.8	1.190	48.8	2	6	2.8		
		3	6		1.026	44.8	2.5	5	0.7	1.176	48.2	2	6	2.7		
		3	6		1.045	45.6	2.5	5	0.8	1.170	48.0	2	6	2.7		
		3	6		1.035	45.2	2.5	5	0.8	1.159	47.5	2	6	2.6		
		3	6		1.025	44.8	2.5	5	0.7	1.160	47.5	2	6	2.6		
		3	6		1.017	44.4	2.5	5	0.7	1.151	47.2	2	6	2.5		
		3	6		0.997	43.5	2.5	5	0.6	1.140	46.7	2	6	2.5		
1.110	23.5	3	6	0.3	0.984	43.0	2.5	5	0.6	1.132	46.4	2	6	2.4		
		3	6		1.000	43.7	2.5	5	0.6	1.122	46.0	2	6	2.3		
		3	6		0.995	43.4	2.5	5	0.6	1.116	45.7	2	6	2.3		
		3	6		0.980	42.8	2.5	5	0.5	1.107	45.4	2	6	2.2		
		3	6		0.943	41.2	2.5	5	0.4	1.114	45.7	2	6	2.3		
		3	6		0.986	43.1	2.5	5	0.6	1.106	45.3	2	6	2.2		
		3	6		1.000	43.7	2.5	5	0.6	1.101	45.1	2	6	2.2		
1.080	22.1	5	4		0.976	42.6	2.5	5	0.5	1.095	44.9	2	6	2.1		
		5	4		0.996	43.5	2.5	5	0.6	1.089	44.6	2	6	2.1		
		5	4		0.958	41.8	2.5	5	0.5	1.081	44.3	2	6	2.1		
		5	4		0.980	42.8	2.5	5	0.5	1.074	44.0	2	6	2.0		
		5	4		0.960	41.9	2.5	5	0.5	1.065	43.6	2	6	1.9		
		5	4		0.912	39.8	2.5	5	0.3	1.061	43.5	2	6	1.9		
		5	4		0.980	42.8	2.5	5	0.5	1.062	43.5	2	6	1.9		
1.210	28.2	5	4		0.951	41.5	2.5	5	0.4	1.055	43.2	2	6	1.9		
		5	4		0.936	40.9	2.5	5	0.4	1.051	43.1	2	6	1.9		
		5	4		0.941	41.1	4.5	3		1.047	42.9	2	6	1.8		
		5	4		0.980	42.8	4.5	3		1.035	42.4	4	4			
		5	4		0.981	42.8	4.5	3		1.047	42.9	4	4			
		5	4		0.948	41.4	4.5	3		1.052	43.1	4	4			
		5	4		1.012	44.2	4.5	3		1.061	43.5	4	4			
1.150	25.4	5	4		1.007	44.0	4.5	3		1.062	43.5	4	4			
		5	4		1.025	44.8	4.5	3		1.071	43.9	4	4			
		5	4		1.011	44.1	4.5	3		1.080	44.3	4	4			
		5	4		1.013	44.2	4.5	3		1.095	44.9	4	4			
		5	4		1.096	47.9	4.5	3		1.110	45.5	4	4			
		5	4		1.101	48.1	4.5	3		1.122	46.0	4	4			
		5	4		1.135	49.6	4.5	3		1.147	47.0	4	4			
1.290	31.9	5	4		1.132	49.4	4.5	3		1.171	48.0	4	4			
		5	4		1.190	52.0	4.5	3		1.200	49.2	4	4			
		5	4		1.266	55.3	4.5	3		1.237	50.7	6	2			
		5	4		1.331	58.1	6.5	1		1.282	52.5	6	2			
		5	4		1.345	58.7	6.5	1		1.326	54.3	6	2			
		5	4		1.424	62.2	6.5	1		1.376	56.4	6	2			
		5	4		1.430	62.4	6.5	1		1.414	58.0	6	2			
1.530	43.2	5	4	0.0	1.489	65.0	6.5	1		1.455	59.6	6	2			
1.570	45.1	7	2		1.556	67.9	6.5	1		1.491	61.1	6	2			
		7	2		1.607	70.2	6.5	1		1.556	63.8	6	2			
		7	2		1.787	78.0	6.5	1		1.627	66.7	6	2			

234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251
Eels Lake	Eels Lake Percentage	Eels Lake West Logs In	Eels Lake West Logs Out	Eels Lake East Logs In, Sluice 1	Eels Lake East Logs Out, Sluice 1	Eels Lake East Logs In, Sluice 2	Eels Lake East Logs Out, Sluice 2	Eels Lake Outflow	Eels CreekLevel Before	Eels Creek Flow	Jack Lake	Jack Lake Percentage	Jack Lake West Logs In	Jack Lake West Logs Out	Jack Lake East Logs In	Jack Lake East Logs Out	Jack Lake Outflow
3.660		4	12	8	8	11	11	8			1.930		2	6.5	6	6	10
0.000			0.000		####		0.305	815			0.380			0.000		0.000	1296
1.586	43.3	12	0	0	8	11	0				1.298	59.2	2	4.5	6	0	2.6
1.586	43.3	12	0	0	8	11	0		11.332	4.9	1.298	59.2	2	4.5	6	0	2.6
1.588	43.4	12	0	0	8	11	0		11.335	4.9	1.296	59.1	2	4.5	6	0	2.6
1.579	43.1	12	0	0	8	11	0		11.324	4.7	1.293	58.9	2	4.5	6	0	2.6
1.571	42.9	12	0	0	8	11	0		11.305	4.4	1.287	58.5	2	4.5	6	0	2.5
1.578	43.1	12	0	0	8	11	0		11.320	4.7	1.298	59.2	2	4.5	6	0	2.6
1.602	43.8	12	0	0	8	11	0		11.384	5.8	1.305	59.7	2	4.5	6	0	2.6
1.638	44.8	12	0	0	8	11	0		11.470	7.5	1.315	60.3	2	4.5	6	0	2.7
1.664	45.5	12	0	0	8	11	0		11.502	8.2	1.322	60.8	2	4.5	6	0	2.7
1.682	46.0	12	0	0	8	11	0		11.492	8.0	1.329	61.2	2	4.5	6	0	2.8
1.685	46.0	12	0	0	8	11	0		11.387	5.8	1.329	61.2	2	4.5	6	0	2.8
1.679	45.9	12	0	0	8	11	0		11.305	4.4	1.326	61.0	2	4.5	6	0	2.8
1.672	45.7	12	0	0	8	11	0		11.430	6.7	1.324	60.9	2	4.5	6	0	2.7
1.670	45.6	12	0	0	8	11	0		11.421	6.5	1.318	60.5	2	4.5	6	0	2.7
1.659	45.3	12	0	0	8	11	0		11.386	5.8	1.319	60.5	2	4.5	6	0	2.7
1.648	45.0	12	0	0	8	11	0		11.351	5.2	1.319	60.6	2	4.5	6	0	2.7
1.642	44.9	12	0	0	8	11	0		11.299	4.3	1.319	60.6	2	4.5	6	0	2.7
1.627	44.5	12	0	0	8	11	0		11.234	3.4	1.315	60.3	2	4.5	6	0	2.7
1.612	44.0	12	0	0	8	11	0		11.267	3.9	1.306	59.7	2	4.5	6	0	2.6
1.600	43.7	12	0	0	8	11	0		11.331	4.8	1.301	59.4	2	4.5	6	0	2.6
1.586	43.3	12	0	0	8	11	0		11.307	4.5	1.297	59.2	2	4.5	6	0	2.6
1.573	43.0	12	0	0	8	11	0		11.246	3.6	1.288	58.6	2	4.5	6	0	2.5
1.560	42.6	12	0	0	8	11	0		11.235	3.4	1.283	58.3	2	4.5	6	0	2.5
1.547	42.3	12	0	0	8	11	0		11.266	3.9	1.277	57.9	2	4.5	6	0	2.5
1.534	41.9	12	0	0	8	11	0		11.249	3.6	1.271	57.5	2	4.5	6	0	2.4
1.520	41.5	12	0	0	8	11	0		11.222	3.3	1.264	57.0	2	4.5	6	0	2.4
1.503	41.1	12	0	0	8	11	0		11.166	2.6	1.256	56.5	2	4.5	6	0	2.4
1.491	40.7	12	0	0	8	11	0		11.207	3.1	1.248	56.0	2	4.5	6	0	2.3
1.480	40.4	12	0	0	8	11	0		11.215	3.2	1.242	55.6	2	4.5	6	0	2.3
1.467	40.1	12	0	0	8	11	0		11.211	3.1	1.234	55.1	2	4.5	6	0	2.2
1.453	39.7	12	0	0	8	11	0		11.215	3.2	1.227	54.6	2	4.5	6	0	2.2
1.437	39.3	12	0	0	8	11	0		11.215	3.2	1.220	54.2	2	4.5	6	0	2.2
1.426	39.0	12	0	0	8	11	0		11.181	2.8	1.211	53.6	2	4.5	6	0	2.1
1.413	38.6	12	0	0	8	11	0		11.154	2.4	1.206	53.3	2	4.5	6	0	2.1
1.402	38.3	12	0	0	8	11	0		11.167	2.6	1.200	52.9	2	4.5	6	0	2.1
1.386	37.9	12	0	0	8	11	0		11.160	2.5	1.195	52.6	2	4.5	6	0	2.0
1.376	37.6	12	0	0	8	11	0		11.146	2.4	1.191	52.3	2	4.5	6	0	2.0
1.366	37.3	12	0	0	8	11	0		11.139	2.3	1.181	51.7	2	4.5	6	0	1.9
1.354	37.0	12	0	0	8	11	0		11.141	2.3	1.175	51.3	2	4.5	6	0	1.9
1.345	36.7	12	0	0	8	11	0		11.117	2.1	1.168	50.8	2	4.5	6	0	1.9
1.335	36.5	12	0	0	8	11	0		11.109	2.0	1.166	50.7	2	4.5	6	0	1.9
1.323	36.1	12	0	0	8	11	0		11.106	1.9	1.157	50.1	2	4.5	6	0	1.8
1.312	35.8	12	0	0	8	11	0		11.099	1.9	1.150	49.7	2	4.5	6	0	1.8
1.302	35.6	12	0	0	8	11	0		11.124	2.1	1.146	49.4	2	4.5	6	0	1.8
1.292	35.3	12	0	0	8	11	0		11.121	2.1	1.142	49.2	2	4.5	6	0	1.7
1.281	35.0	12	0	0	8	11	0		11.121	2.1	1.138	48.9	2	4.5	6	0	1.7
1.270	34.7	12	0	0	8	11	0		11.121	2.1	1.132	48.5	2	4.5	6	0	1.7
1.262	34.5	12	0	0	8	11	0		11.121	2.1	1.127	48.2	2	4.5	6	0	1.7
1.250	34.2	12	0	0	8	11	0		11.119	2.1	1.122	47.9	2	4.5	6	0	1.6
1.241	33.9	12	0	0	8	11	0		11.116	2.0	1.116	47.5	2	4.5	6	0	1.6
1.232	33.7	12	0	0	8	11	0		11.116	2.0	1.111	47.2	2	4.5	6	0	1.6
1.224	33.4	12	0	0	8	11	0		11.115	2.0	1.105	46.8	2	4.5	6	0	1.6
1.216	33.2	12	0	0	8	11	0		11.076	1.7	1.100	46.5	2	4.5	6	0	1.5
1.208	33.0	12	0	0	8	11	0		11.075	1.7	1.094	46.1	2	4.5	6	0	1.5
1.211	33.1	12	0	0	8	11	0		11.071	1.6	1.101	46.5	2	4.5	6	0	1.5
1.209	33.0	12	0	0	8	11	0		11.071	1.6	1.096	46.2	2	4.5	6	0	1.5
1.215	33.2	12	0	0	8	11	0		11.050	1.4	1.093	46.0	2	4.5	6	0	1.5
1.218	33.3	12	0	0	8	11	0		10.964	0.9	1.086	45.5	2	4.5	6	0	1.5
1.222	33.4	12	0	0	8	11	0		10.942	0.8	1.082	45.3	2	4.5	6	0	1.5
1.226	33.5	12	0	0	8	11	0		10.935	0.7	1.078	45.0	2	4.5	6	0	1.4
1.228	33.6	12	0	0	8	11	0		10.926	0.7	1.076	44.9	2	4.5	6	0	1.4
1.248	34.1	12	0	0	8	11	0		10.919	0.6	1.082	45.3	2	4.5	6	0	1.5
1.256	34.3	12	0	0	8	11	0		10.931	0.7	1.082	45.3	2	4.5	6	0	1.5
1.263	34.5	12	0	0	8	11	0		10.943	0.8	1.080	45.2	2	4.5	6	0	1.4
1.265	34.6	12	0	0	8	11	0		10.955	0.8	1.075	44.8	2	4.5	6	0	1.4
1.273	34.8	12	0	0	8	11	0		10.966	0.9	1.073	44.7	2	4.5	6	0	1.4
1.273	34.8	12	0	0	8	11	0		10.978	0.9	1.070	44.5	2	4.5	6	0	1.4
1.276	34.9	12	0	0	8	11	0		10.990	1.0	1.066	44.3	2	4.5	6	0	1.4
1.279	34.9	12	0	0	8	11	0		11.002	1.1	1.062	44.0	2	4.5	6	0	1.4
1.279	34.9	12	0	0	8	11	0		11.014	1.2	1.054	43.5	2	4.5	6	0	1.3
1.290	35.2	12	0	0	8	11	0		11.026	1.2	1.059	43.8	2	4.5	6	0	1.3
1.292	35.3	12	0	0	8	11	0		11.037	1.3	1.057	43.7	2	4.5	6	0	1.3
1.296	35.4	12	0	0	8	11	0		11.049	1.4	1.053	43.4	2	4.5	6	0	1.3
1.304	35.6	12	0	0	8	11	0		11.061	1.5	1.050	43.2	2	4.5	6	0	1.3
1.315	35.9	12	0	6	2	11	0		11.073	1.6	1.053	43.4	2	4.5	6	0	1.3
1.321	36.1	12	0	6	2	11	0		11.085	1.7	1.052	43.4	2	4.5	6	0	1.3
1.328	36.3	12	0	6	2	11	0		11.097	1.8	1.051	43.3	2	4.5	6	0	1.3
1.334	36.4	12	0	6	2	11	0		11.108	2.0	1.050	43.2	2	4.5	6	0	1.3
1.341	36.6	12	0	6	2	11	0		11.120	2.1	1.047	43.0	2	4.5	6	0	1.3
1.351	36.9	12	0	6	2	11	0		11.132	2.2	1.048	43.1	2	4.5	6	0	1.3
1.355	37.0	12	0	6	2	11	0		11.144	2.3	1.045	42.9	3	3.5	6	0	0.2
1.377	37.6	12	0	6	2	11	0		11.156	2.5	1.054	43.5	3	3.5	6	0	0.2
1.411	38.6	12	0	6	2	11	0		11.168	2.6	1.076	44.9	3	3.5	6	0	0.3
1.440	39.3	12	0	6	2	11	0		11.179	2.7	1.083	45.4	3	3.5	6	0	0.3
1.473	40.2	12	0	6	2	11	0		11.191	2.9	1.098	46.3	3	3.5	6	0	0.4
1.503	41.1	12	0	6	2	11	0		11.203	3.0	1.106	46.8	3	3.5	6	0	0.4
1.557	42.5	12	0	6	2	11	0		11.215	3.2	1.124	48.0	3	3.5	6	0	0.4
1.636	44.7	12	0	6	2	11	0		11.227	3.3	1.145	49.4	3	3.5	6	0	0.5
1.709	46.7	12	0	6	2	11	0		11.239	3.5	1.163	50.5	5	1.5	6	0	0.0
1.772	48.4	12	0	6	2	11	0		11.250	3.6	1.178	51.5	5	1.5	6	0	0.0
1.823	49.8	12	0	6	2	11	0		11.262	3.8	1.195	52.6	5	1.5	6	0	0.0
1.867	51.0	12	0	6	2	11	0		11.274	4.0	1.208	53.4	5	1.5	6	0	0.0
1.911	52.2	12	0	6	2	11	0		11.286	4.1	1.231	54.9	5	1.5	6	0	0.0
1.952	53.3	12	0	6	2	11	0		11.287	4.2	1.247	55.9	5	1.5	6	0	0.0
2.033	55.5	12	0	6	2	11	0		11.365	5.4	1.298	59.2	5	1.5	6	0	0.0
2.188	59.8	12	0	6	2	11	0		11.640	11.5	1.360	63.2	5	1.5	6	0	0.0

Table C9c - Haliburton Reservoir Weekly Level Changes Log

Month _______________	Monday _______________					Tuesday _______________					Wednesday _____________					Thursday _______________					Friday _______________					_______________				
Year _________________	Level	%	In	Out	+/-	Level	%	In	Out	+/-	Level	%	In	Out	+/-	Level	%	In	Out	+/-	Level	%	In	Out	+/-	Level	%	In	Out	+/-
Drag (0.46-2.29)																														
Head																														
Canning #3 (0.46-1.52)																														
Canning #1 #2																														
Miskwabi (0.30-2.29)																														
Loon (0.61-1.98)																														
Koshlong (0.61-2.29)																														
Farquhar (0.61-3.05)																														
Pusey (0.46-2.06)																														
Esson (0.91-3.05)																														
Little Glam. (0.00-1.83)																														
Glamour (0.71-2.44)																														
Gooderham (0.61-1.83)																														
Contau (0.46-1.68)																														
White (0.00-1.84)																														
Crystal (0.61-2.74)																														
Salerno																														
Nogies																														
Ansturther (0.00-2.29)																														
Mississagua (0.00-2.44)																														
Mississagua Q																														
Eels (0.00-3.66)																														
Eels Q																														
Jack (0.38-1.93)																														
Gull Maple Q																														
Gull Norland Q																														
Burnt - Gelert Q																														
Irondale - Furnace Q																														
Burnt - Burnt Q																														

Month _______________	Monday _____________					Tuesday _____________					Wednesday __________					Thursday ____________					Friday _______________					_________________________				
Year _________________	Level	%	In	Out	+/-	Level	%	In	Out	+/-	Level	%	In	Out	+/-	Level	%	In	Out	+/-	Level	%	In	Out	+/-	Level	%	In	Out	+/-
Kennisis (0.00-2.90)																														
Red Pine (0.00-1.22)																														
Nunikani (0.30-3.05)																														
Hawk (0.38-4.42)																														
Halls (0.91-2.59)																														
Sherborne (0.00-1.52)																														
Kushog (1.22-3.20)																														
Percy (0.00-1.98)																														
Oblong (1.07-3.05)																														
Redstone E. (0.76-3.66)																														
Redstone W. (0.76-3.66)																														
Eagle (0.46-2.29)																														
Mud (0.00-1.58)																														
12 Mile (0.46-1.98)																														
Horseshoe (0.46-2.44)																														
Horseshoe Q																														
Big Bob (0.00-2.90)																														
Little Bob (0.00-1.52)																														
Gull (1.22-2.13)																														
Moore (1.00-1.52)																														
Elliot Falls																														
Norland Pool																														
Norland Dock																														
Coboconk																														
4 Mile																														

Table C10 – Channel Flow Constraints

Channel Flow Constraints at Coboconk and Peterborough		
	Coboconk (cfs)	Peterborough (cfs)
Summer (Navigation) Period		
Conservation Zone	450-750	800-1000
Flood Zone	Less than 1500	Less than 4500
Spill Zone	Uncontrolled	Uncontrolled
Buffer Zone	200-450	500-800
Inactive Zone	Greater than 50	Greater than 330
Spring Period		
Flood Zone	200-1500	500-8000
Spill Zone	Uncontrolled	Uncontrolled
Fall/Winter Period		
Flood Zone	200-1500	500-6000
Spill Zone	Uncontrolled	Uncontrolled

AECOM

Trent Severn Waterway
Water Management Study

Evaluation of the Current Approach to Water Management

Parks Canada Parcs Canada

Canada

Parks Canada

Trent Severn Waterway: Water Management Study Evaluation of the Current Approach to Water Management

Prepared by:

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Project Number:

60150039

Date:

June, 2011

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June 30, 2011

Roger Stanley
Director of Operations (Acting) – Trent Severn Waterway
Parks Canada
P.O. Box 567
Peterborough, Ontario, K9J 6Z6

Dear Mr. Stanley:

Project No: 60150039

Regarding: Trent Severn Waterway: Water Management Study
Evaluation of the Current Approach to Water Management

We are pleased to submit ten (10) hard copies and a digital copy of the final version of the Evaluation of the Current Approach to Water Management.

If you have any questions regarding this submittal, please contact the undersigned at (519) 650-8696.

Sincerely,
AECOM Canada Ltd.

Jeff Prince, P.Eng.
Senior Project Manager, Water
Jeff.Prince@aecom.com

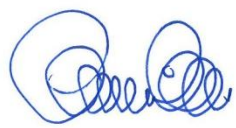
JP:jp
Encl.

Revision Log

Revision #	Revised By	Date	Issue / Revision Description
1	AD, GAW, DCA, JP	13-May-2011	Draft Report
2	GAW, DCA, JP	30-June-2011	Final Report

AECOM Signatures

Report Prepared By:



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Appendices

1. Introduction and Background

1.1 Study Objectives and Rationale

A common theme that resonates throughout most, if not all water management programs is the desire to contribute to and enhance the environmental, social and economic well being of the watershed through sustainable management of the water resource. Through achieving this, the benefits of the resource can be fully enjoyed by present and future generations.

It is to that end, that the objectives of the Trent Severn Waterway - Water Management Improvement Program were developed. The specific objectives include the following:

1. To understand the variables that are critical to effective water management decision making;
2. To ensure that the Agency and its water management partners have access in an accurate and timely way to the appropriate data that allows these variables to be used in making decisions;
3. To describe the current approach to water management in the form of a "Water Management Manual" that describes in considerable detail how water is managed now;
4. To validate and/or suggest improvements in how water is currently managed such that broad water management goals described above are best achieved;
5. To construct a numerical predictive tool that allows the basic operational model(s) to be readily adjusted in response to changes in critical variables; and,
6. To construct a numerical management tool, linked to real time gauging and data collection systems that allows the water manager to:
    a) Understand the current state of water levels and flows throughout the system;
    b) Predict the quantifiable impact of specific water management decisions;
    c) Document when and why specific water management decisions are taken; and,
    d) Provide agencies and individuals with internet-accessible, real time information that contributes to their operations and enjoyment of the Trent Severn Waterway and its associated reservoir lakes.

The Trent Severn Waterway: Water Management Study addresses the first four of these program objectives.

The competition for the water of the Trent Severn Waterway has always been a condition of the system's operation. However, in recent decades, the stakeholders and variables at play as part of that competition have increased and subsequently so to have the demands and complexities of the operating environment. The following examples highlight some of the operational considerations within the Waterway:

- The Haliburton Lakes have become one of the most significant cottage regions in the province; and more recently there has been a shift toward year round residency on these lakes;
- Shoreline properties have increased in value, and with that the demands to maintain the levels of the reservoir lakes have increased;
- Cities and Towns have developed along the shorelines and have infrastructure demands to draw water from the system;
- The shores are home to thousands of businesses that rely on those that live in and visit the area;
- The societal awareness of and desire to protect the natural environment is increasing;
- There are legitimate concerns about global warming and the potential impacts of climate change; and
- Growing environmental concern has led to an interest in the potential for hydro electric power generation as a source of renewable energy.

These issues have been recently documented by the Panel on the Future of the Trent Severn Waterway in, *It's All About the Water,* and a study of the past, present and future of the waterway completed in 2007 by Ecoplans Limited.

This study is intended to build upon this work toward ensuring that water management personnel have the tools necessary to assist them in making water management decisions. These tools must ensure that management decisions are; timely, information and science based, reflect a thorough understanding of the variables, and achieve an optimal and appropriate balance of the overall water management goals.

This study represents the first phase of what could be a multi-phase endeavour towards achieving the vision and objectives of the overall Water Management Improvement Program.

This study has been organized into four components that directly correspond to the specific objectives of the Water Management Improvement Program:

- **Data Collection and Management Guide**
- **Review of Water Management Systems and Models**
- **Water Management Manual – Description of the Current Approach to Water Management**
- **Evaluation of the Current Approach to Water Management**

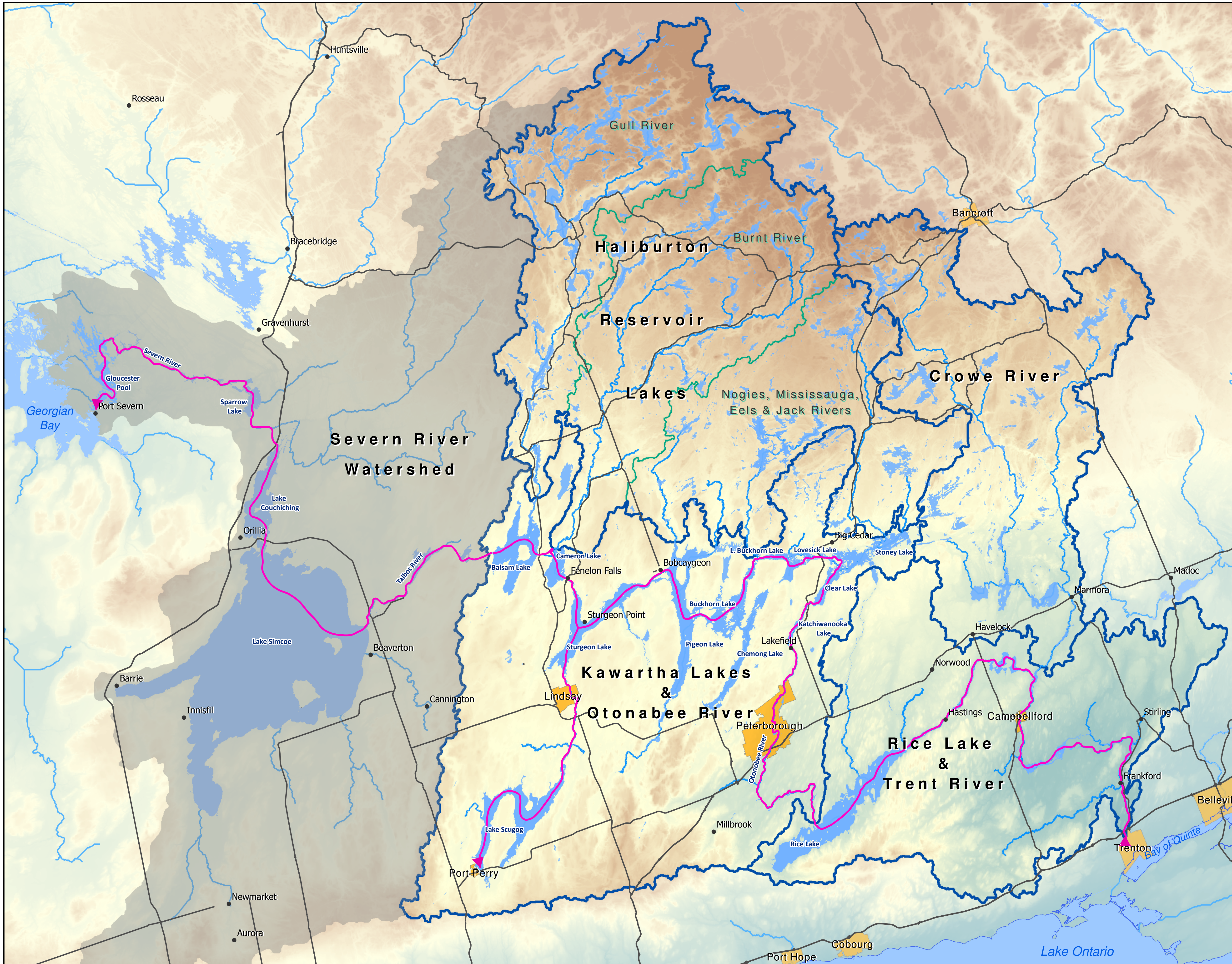
This component of the study, titled "Evaluation of the Current Approach to Water Management" has been developed to evaluate the current approach to water management while considering the potential impacts of climate change on water management and increasing requirements to better balance the water management goals and objectives.

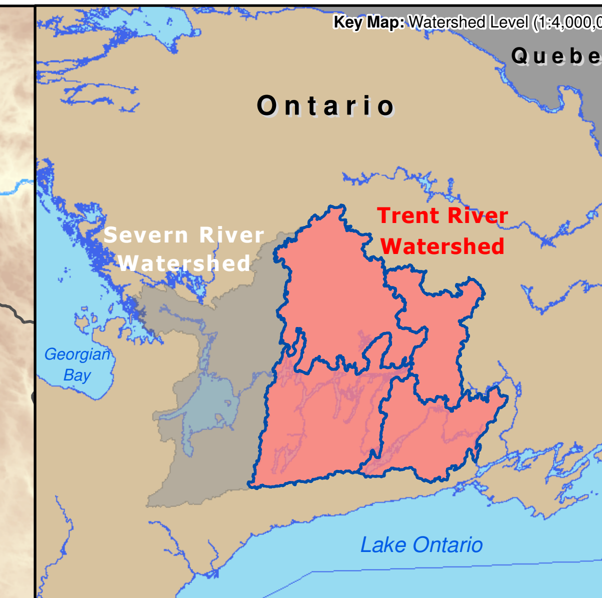
1.2 The Trent Severn Waterway

The Trent Severn Waterway (TSW or Waterway) is a 386km inland navigation route crossing south central Ontario, from Trenton on the Bay of Quinte to Port Severn on Georgian Bay with a total drainage area of 18,690km^2 (**Figure 1-1**). It comprises several navigable lakes and their interconnecting channels as well as many reservoir lakes. There are two watersheds within the Waterway: the Trent River Watershed and the Severn River Watershed. Although this Study concentrates only on the Trent River Watershed, both are characterized below.

The Trent River Watershed is the eastern watershed, with an area of 12,530km^2 draining to Lake Ontario. It lies in the rolling farmlands of southern Ontario. This watershed contains three (3) sub-watersheds:

- **The Haliburton Reservoir Lakes** (3,320km^2) to the north consists of forty-four (44) lakes in the northern shield area that have been dammed to collect Spring runoff. Water from these lakes is released over the summer to supply the Trent component of the Waterway. These lakes are on the tributaries of the Gull, Burnt and Mississauga rivers, as well as Nogies, Eels and Jack creeks.
- The **Kawartha Lakes and the Otonabee River** (4,862km^2) that drain to Rice Lake including: Katchewanooka, Clear, Stony, Lovesick, Lower Buckhorn, Buckhorn, Chemong, Pigeon, Sturgeon, Scugog, Cameron and Balsam Lakes. These lakes are south of the Canadian Shield in rolling countryside, where rainfall runoff is usually slow and evaporation losses in the summer are high.
- **Rice Lake and the Trent River** (4,348km^2) that drain to the Bay of Quinte (Lake Ontario), including the **Crowe River** (1,894km^2) sub-watershed that drains to the Trent River at a confluence downstream of Rice Lake.





Trent-Severn Waterway: Water Management Study

Figure 1-1
General Location Plan - TSW

UTM 17 NAD 83 Datum	April 2011	1:600,000

Parcs Canada Parks Canada

AECOM

The Severn River Watershed lies immediately to the west of the Trent Basin and drains to Georgian Bay. This 6,160km^2 drainage area has three (3) sub-watersheds:

- The **Lake Simcoe and Lake Couchiching** sub-watershed, including the Talbot River. Most of the drainage area for this sub-watershed is in rolling farmland with deeper soils. As a result, water runoff is slow and evaporation losses from both land and lake surfaces are high. Only about 25% of the precipitation falling on this watershed eventually appears as runoff flows.
- The **Black River** sub-watershed feeds into the Severn River downstream of Lake Couchiching. This sub-watershed is characterized by the thin soils and rock of the Precambrian Shield. It is virtually unregulated and produces rapid runoff from precipitation while evaporation losses are lower. Consequently, even though the Black River sub-watershed is less than half of the area of the Simcoe-Couchiching basin, its long-term average flow is comparable. The Black River also has high peak flows during the spring period.
- The **Severn River** below Washago, including Sparrow Lake, Six Mile Lake Tea Lake, and Gloucester Pool. The natural watercourses of the Black and the Severn Rivers are constrained by numerous narrow reaches and constrictions, which are prone to increased water levels in the river and upstream flooding during high flows.

The area influenced by management of the TSW includes more than 120,000 properties as identified in a recent study (Ecoplans 2007):

- Approximately 35,000 shoreline properties in the reservoir lakes;
- More than 400 commercial operations;
- Six Conservation Authorities; and
- Several tiers of government, including: 6 First Nations; 2 regional municipalities; 3 municipalities; 1 district municipality; 5 counties; 5 cities; 4 towns; and, 26 townships.

1.3 Goals and Objectives of the Trent Severn Waterway

Construction of the Trent Severn Waterway began in the late 18th century with the building of small dams and water powered mills at numerous locations throughout south-central Ontario. In the early 19th century, dams and timber slides were added to support a growing logging industry by facilitating transportation of logs from the interior of Upper Canada to the United States and Great Britain.

Key early goals for management of the Waterway were to provide navigation and to protect public safety and property. By the mid-19th century, architects of the Waterway realized that a reservoir system was required to feed water to the system in order to maintain navigation through the summer months. A series of dams in the northern part of the TSW were transferred from the Province to the Federal government in 1905 and 1906. This transfer formally recognized the need for a reservoir system and provided the means to manage and control flow from a number of water bodies that collectively could be used as a reservoir lake system. The Orders-in-Council that transferred these works explicitly acknowledged that the transfers were to benefit operation of the TSW. The Orders-in-Council also designated the water in the listed lakes and rivers as reservoirs for the Waterway.

When the reservoir lakes were conceived, there was very little permanent settlement in the Haliburton region. Since the 1930s, the Haliburton lakes have grown to become one of the most important cottage areas in Ontario. Furthermore, a recent shift from seasonal to permanent, year-round residency in the Haliburton lakes region is occurring. Associated changes in the operating environment of the Waterway include increasing trends in uses other than through navigation, economic development and commercial operations along the Waterway, as well as increasing value placed on natural ecosystems and habitats. Finally, meteorological changes have also been observed (as discussed in the "**Evaluation of the Current Approach to Water Management**"), including: increased number of heavy rainfall events of shorter duration, increasing annual precipitation in some regions and decreasing

annual precipitation in others, regional warming in some areas resulting in increased water temperatures, life cycle impacts to aquatic and wetland species and habitat changes.

These changes in the operating environment of the Trent Severn Waterway are reflected in a recent study (Ecoplans, 2007) which indicates that the present-day array of expectations and obligations are unprecedented in the history of the Waterway operations. Six Water Management Goals and associated Objectives were developed in this study to capture these expectations and enhance operations. These goals and objectives are listed in **Table 1-1**.

Table 1-1 - Water Management Goals and Objectives of the Trent Severn Waterway

Water Management Goals	Objectives
Reducing threats to public safety and negative impacts to public and private infrastructure from over-bank flooding, ice damage, extreme water level fluctuations, and high volume flows	• Mitigate Flooding • Protect Infrastructure • Provide for Public Safety
Contributing to the health of Canadians through the availability of drinking water for residents, cities and towns throughout the watershed	• Manage for Water Supply (agricultural and municipal) • Manage for Water Quality (human health and aquatic life)
Providing safe boating and navigation along the marked navigation channels of the Trent Severn Waterway	• Provide Navigation
Protecting significant aquatic habitats and species	• Protect Natural Environment (wetlands, fish, wildlife, invasive species, species at risk)
Optimizing the enjoyment of the water throughout the watershed by shoreline residents and visitors	• Enhance Aesthetics • Optimize Recreation • Optimize Cultural Resources • Provide Public Access (physical access, access to information)
Allowing hydroelectric generation plants to operate at plant capacity and meet demand for renewable energy insofar as possible	• Optimize Water Power Generation

1.4 Introduction to the Water Management Process

The management of the Trent Severn Waterway to achieve these goals and objectives requires consideration of a variety of different factors, including the Waterway's mandated requirements, scientific objectives, regulatory impacts, environmental impacts, political and public concerns, as well as the day-to-day and long-term operation of the Waterway. A Water Management Process was developed through this study as a way to address this complexity and to consider the interests of the many different stakeholders. The Water Management Process is displayed in **Figure 1-2**, and describes the steps required to implement decisions with respect to the operation of the Waterway.

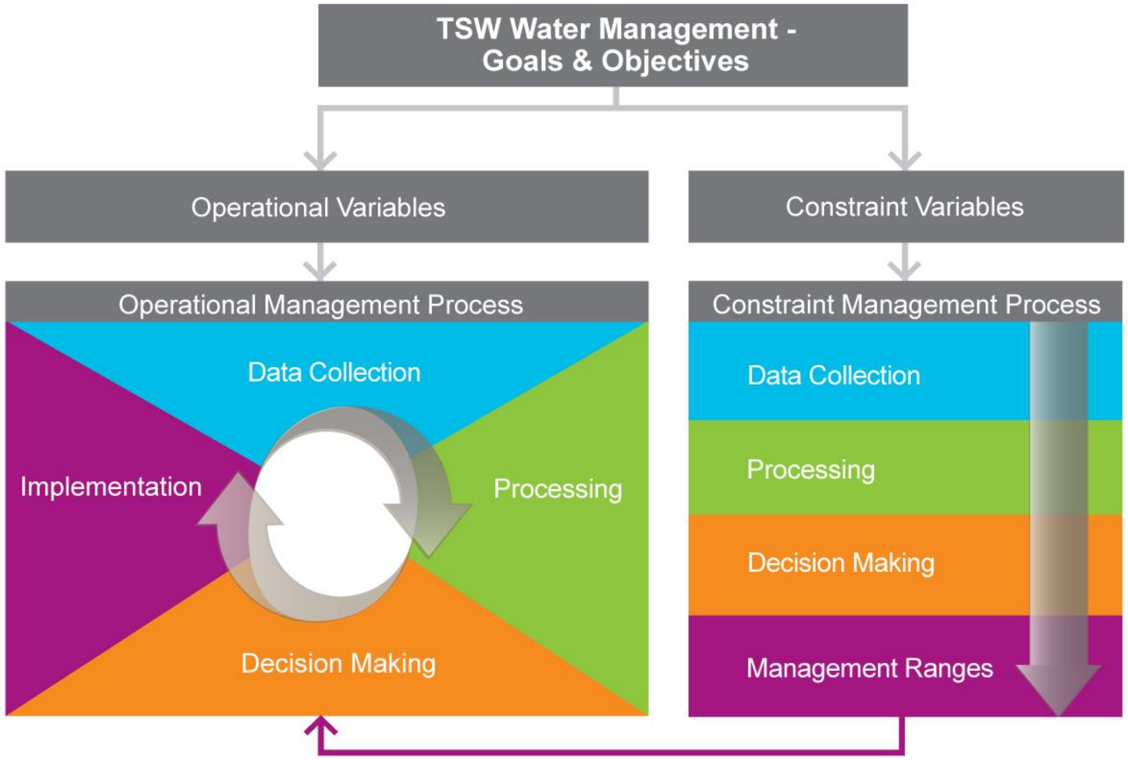


Figure 1-2 - Water Management Process for the Trent Severn Waterway

The Operational Management Process shown on the left side of **Figure 1-2** describes the core activities of Parks Canada staff in the operations of the TSW. These activities are implemented on a continual basis and consist of the day-to-day operations of the locks, dams and other water control structures to manage the flows and water levels in the Waterway through regular monitoring, the balancing of water between the different components of the Waterway (i.e., the Haliburton Reservoir Lakes and the Kawartha Lakes/Trent River), and the communications with staff to implement management decisions.

The Constraint Management Process shown on the right side of **Figure 1-2** describes the activities undertaken to establish the constraints, or “Management Ranges”, that define the range of water levels and flows on all lakes with the aim of satisfying the goals and objectives of the Waterway in a comprehensive and balanced manner. This process includes the evaluation of a diverse array of variables that impact the goals and management of the Waterway. The frequency that the Constraint Management Process is undertaken depends on the data being evaluated; for example, the review of historic flood events and levels need only be completed once to establish the historical record, and then updated only when new events occur.

In both the Operational and Constraint Management Processes, there are three primary activities:

- **Data Collection**. The gathering of information that is applicable to either the operations (i.e., **operational variables**) or management ranges (i.e., **constraint variables**) of the Waterway.
- **Processing**. The use of processing and optimization tools to interpret the collected data and produce results appropriate for effecting operational or management/constraint changes.
- **Decision Making**. The evaluation of processing results to make operational decisions or to establish new management ranges throughout the Waterway.

These activities result in an **Implementation** decision with respect to the operation of the Waterway (i.e., increase or decrease water levels or flows at certain locations), or the establishment of a **Management Range** to consider in the processing of operational data (i.e., minimum water levels or flows for navigation in summer or fish spawning in fall).

Through the continual application of this management process, the Waterway can be effectively managed to achieve the goals and objectives of the TSW, giving due consideration to the wide range of stakeholders and users that make the Waterway the dynamic entity it is today.

1.5 Document Map

The Water Management Process introduced in **Section 1.4** provides a context upon which each of the four reports in the Water Management Study is presented. **Figure 1-3** overlays a Document Map on the management process (**Figure 1-2**), highlighting the different components of the Waterway Management Process that are described in this component of the study.

The **Evaluation of the Current Approach to Water Management** encompasses all aspects of the Water Management Process, as illustrated in the Document Map. Through the evaluation of current operations, recommendations are developed to enhance operational procedures and to better represent each of the Water Management Goals through the day-to-day activities of Parks Canada staff. There is a particular focus on the impacts of climate change (**Section 2** to **Section 4**) and the goal to protect significant aquatic habitats and species (i.e., natural environment, **Section 5**).

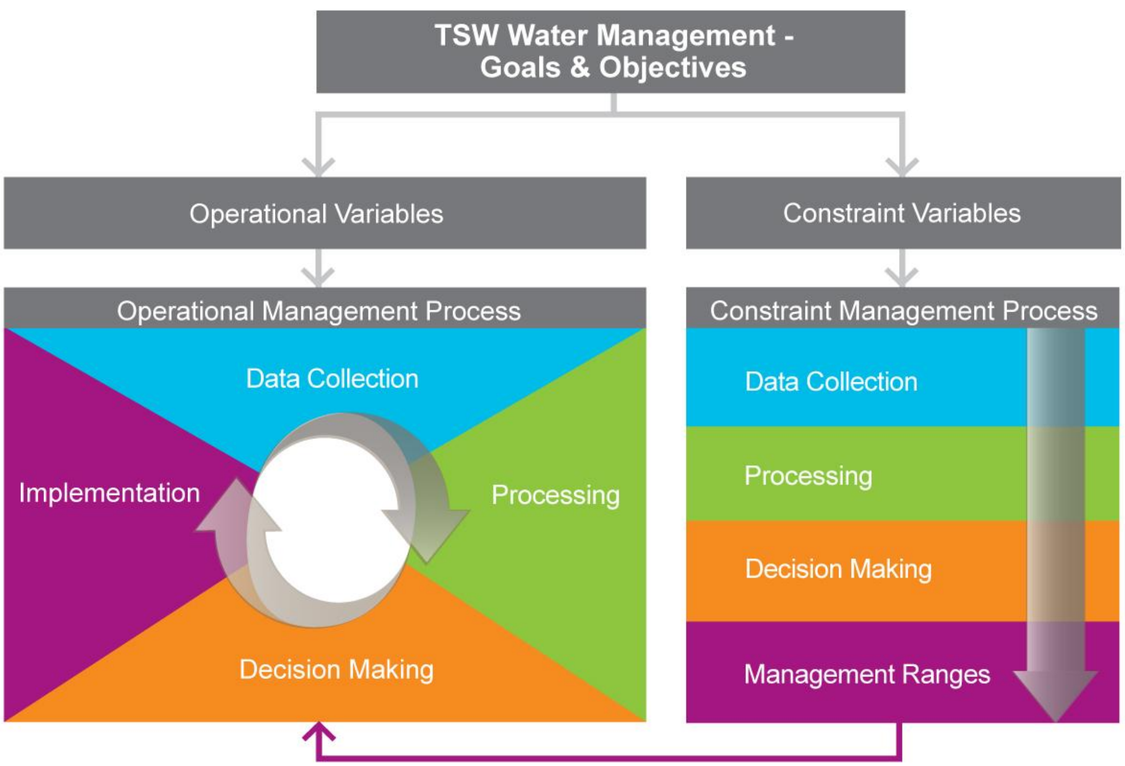


Figure 1-3 - Trent Severn Waterway: Water Management Study - Document Map

2. Assessment of Current Climate

The goal of this project component is to understand if there have been significant changes in regional weather patterns along the waterway that might suggest changes in water management decision making would be appropriate.

Climate stations needed to be selected to conduct the Assessment of the Impacts of Climate Change, outlined in **Section 4**. These climate stations were chosen to be representative of the climate in the three main regions of the watershed. For each region, the temperature and precipitation data sets for the past eighty years from weather stations were analyzed.

The relevant regions in the Trent River Watershed for the Trent Severn Waterway Water Management Study are the following:

- the Haliburton Reservoir region (i.e., Haliburton Sector),
- the Kawartha Lakes / Otonabee River sub-watershed region (i.e., North/Central Sector); and
- the Rice Lake / Lower Trent River sub-watershed region (i.e., South Sector).

2.1 Climatological Data

2.1.1 Selection of Representative Climate Stations

The climate stations selected to be representative of these regions are presented in Table A-1, in **Appendix A** and summarized in **Table 2-1**. Figure A-1 (**Appendix A**) shows the Trent River Watershed and the selected stations location.

For a specific location, climate data often needs to be from several different climate stations in order to produce a complete set of data. All climate stations available from Environment Canada in the vicinity of this specific location and installed to a similar elevation may be selected to complete the data set. The aggregated data set of these stations is called a “combo” station; the combo stations used in this study are shown in **Table 2-1**.

In each sub-watershed region, two “combo” climate stations are proposed. They are selected based on their period of record and completeness of the data set (no or few missing data).

The selected stations are the following:

- In the Haliburton Reservoir Lakes Region: Haliburton and Minden combo stations,
- Kawartha Lakes and Otonabee River Region: Lindsay and Peterborough,
- Rice Lake and Lower Trent River Region: Trenton (Belleville, outside the watershed, is used for temperature) and Peterborough.

The first “combo” station in each region/sector (designated as the Rank 1 station) covers more than 80 years of historical records and has one station which is still active. An active station provides the opportunity to be used, for example, in real-time flood forecasting or any other future use. An active station also allows future update of the Assessment of the Impacts of Climate Change.

The second station in each region/sector (designated as the Rank 2 station) is also considered representative of each of the three regions but can only be used to assess past climate trends. They are also used to confirm the representativeness of the first station and may be used to complete some missing data in the first “combo” data set. If the second station shows some different climate normals over the last 80 years, each of the two stations are considered representative of a portion of the sub-watershed region, as discussed in **Section 2.1.3**.

Table 2-1 - Representative Climate Stations (Environment Canada, reference 0)

	Climate Station ID	Climate Station Name	Record Period	Record Length (years)	Comment on Data Set
Haliburton Reservoir Lakes Region					
1st Station	6163170	Haliburton 2	1949-1955	7	to complete the 2 other stations
	6163171	Haliburton 3	1987-2010	22	2007, 2010 are incomplete
	6163156	Haliburton A	1889-1992	104	lot of missing data before 1950
	Combo	**HALIBURTON**	**Total**	**121**	
2nd Station	6165195	Minden	1956-2006	51	good
	6165197	Minden Forestry	1948-1955	8	many missing data
	Combo	**MINDEN**	**Total**	**60**	
Kawartha lakes / Otonabee River Sub-Watershed Region					
1st Station	6166416	Peterborough	1867-1970	104	good
	6166418	Peterborough A	1969-2005	34	good
	6166420	Peterborough AWOS	2004-2010	6	good
	Combo	**PETERBOROUGH**	**Total**	**144**	
2nd Station	6164430	Lindsay	1881-1971	91	good
	6164432	Lindsay Filtration Plant	1964-1990	27	good
	6164433	Lindsay Frost	1974-2006	33	good
	Combo	**LINDSAY**	**Total**	**126**	
Rice Lake / Lower Trent River Sub-Watershed Region					
1st Station	6158875	Trenton A	1953-2010	57	good
	6158885	Trenton Ont Hydro	1915-1992	77	no temperature data
	6150689	Belleville (1)	1866-2006	140	temperature data to complete Trenton
	6150717	Belleville Par Lab (1)	1929-1959	31	temperature data to complete Trenton
	Combo	**TRENTON**	**Total**	**95**	
2nd Sta.	**Combo**	**PETERBOROUGH** (same as above)	**Total**	**144**	Representative for Rice Lake Region

(1) Belleville stations are outside the watershed (east of Trenton), but temperature dataset is complete and used to assess climate trends over the last 80 years for the Lower Trent area.

Station still in operation (at the end of 2010) (highlighted: 6163171 Haliburton 3, 6166420 Peterborough AWOS, 6158875 Trenton A)

2.1.2 Climate Normals for the Three Regions

The climate normals (annual mean precipitation and temperature) obtained from Environment Canada for the selected stations are presented in Table A-2 (**Appendix A**) and summarized in **Table 2-2**.

Table 2-2 - Climate Normals – Mean Annual Precipitation and Temperature for the period 1971-2000 (Env. Canada, reference 0)

Region	Station Rank	Station Name	Mean Annual Temperature (°C)	Mean Annual Precipitation (mm)
Haliburton Reservoir Lakes Region	1	Haliburton	4.90	1009
	2	Minden	5.17	1045
Kawartha Lakes and Otonabee River Region	1	Peterborough	5.93	840
	2	Lindsay	6.31	882
Rice Lake and Lower Trent River Region	1	Trenton	6.93	894
		Belleville (1)	7.72	892
	2	Peterborough	(same as above)	

(1) Belleville station is outside the watershed (east of Trenton), but temperature data set is complete and used to assess climate trends over the last 80 years for the Lower Trent area.

2.1.3 Summary of Climate Data

2.1.3.1 Haliburton Reservoir Lakes Region

There are only two “combo” stations having a long set of climate data in this region for temperature and precipitation: Haliburton and Minden. The climate normals (**Table 2-2**) for the two stations are similar for temperature as well as for precipitation, and are considered equally representative of the Haliburton Reservoirs Region.

Since the two stations are close to each other and since the Minden station only covers 60 years (with many missing data) and is not active anymore, the “combo” station Haliburton, which covers 120 years has been selected to represent the Haliburton reservoir lakes region.

However, the Haliburton “combo” has too many missing data from 1921 to 1950, (only 13 complete years having 30 missing daily values or less) and therefore past climate trends cannot be assessed in the Haliburton Reservoir Lakes region. The Minden station has been used to complete some of the missing data in the Haliburton data set.

2.1.3.2 Kawartha Lakes / Otonabee River Sub-Watershed Region

In this region, two stations have a long set of climate (data for more than 100 years) for temperature and precipitation: Peterborough and Lindsay. The climate normals (**Table 2-2**) for the two stations show similar temperatures, but mean annual precipitation for Peterborough is 5% less than for Lindsay.

Since the Peterborough station is still active and is located closer to most of the Kawartha Lakes, it is considered to be more representative of the Kawartha Lakes / Otonabee River Sub-watershed Region and has been chosen to be the first station. The second station, Lindsay, is used to complete some missing data in the Peterborough dataset.

2.1.3.3 Rice Lake / Lower Trent River Sub-Watershed Region

In the Lower Trent River, the Trenton station is the only station having a long and complete data set in addition to still being active. The Trenton station has been chosen to be the first (i.e., Rank 1) “combo” station. However, before 1950 there are no temperature data; the Belleville station, located outside the watershed approximately 13km East of Trenton, has been also selected for past climate trends assessment.

Development of the second “combo” station (i.e., Rank 2) faced several challenges. The only other station having a relatively long data set is Stirling (6158050-51-52), but this station only has a complete set of data from 1941 to 1968. After 1968, there is no temperature data and much of the precipitation data is missing. Moreover, this station is located approximately 20 km north of Trenton near Glen Ross and this region is already represented by the Trenton “combo” station. The west part of the region (i.e., Rice Lake area), would benefit from better climate representation.

In the Rice Lake area, no station having a long and complete data set is available. The stations at Campbellcroft (6151135-36) and Gores Landing (6152950-51) were considered but there are no data available after 1997 and there is a significant amount of missing data. The other stations are sparse, do not cover a long observation period or do not have temperature data. The closest station that meets the criteria is the Peterborough station, already selected to represent the Otanabee River region. This station is located approximately 20 km North-West of Rice Lake.

However, the climate normals for Peterborough show that temperature and precipitation are lower than those for Lindsay or Trenton, which suggest that Peterborough may be a microclimate. This appears to be confirmed by the the mean annual precipitation at Hastings (6168525-616C3P9), located at the downstream end of Rice Lake (30 km east of Peterborough), which is about 900 mm based on 12 complete years of data between 1989 and 2009. This is approximately equivalent to the precipitation normals at Trenton.

Therefore, the Trenton station is considered representative of a large portion of the Rice Lake / Lower Trent region, while the Peterborough station can only be considered representative of the west end of Rice Lake and is not selected as representative of the entire Rice Lake / Lower Trent region.

2.2 Analysis of Climate Data and Past Climate Trends

An analysis was carried out on historic climate data at the three “combo” stations representing the three main regions in the Trent River Watershed. The analysis was conducted for two periods of 30 years, set 50 years apart: the past period 1921-1950 and the reference period 1971-2000. The analysis results are presented in **Appendix A**.

For the Haliburton region, there are significant amounts of missing precipitation data for the past period (only 13 years have 30 missing daily values or less). Therefore, because missing precipitation data induce a bias, no analysis was carried out on precipitation for this region.

Monthly mean precipitation and temperatures were calculated for the past period and the reference period for the three regions, allowing the changes in mean temperatures and precipitations to be determined. The results for the past climate change analysis are summarized in **Table 2-3** and plotted in **Figure 2-1**.

Table 2-3 - Past Climate Change by Month for Temperature and Precipitation between the Past Period (1921-1950) and the Reference Period (1971–2000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Δ Surface temperature (°C)													**-0.1**
Haliburton	-0.6	0.5	0.2	0.6	0.5	-0.2	0.0	0.0	-0.3	-0.4	0.1	0.3	0.1
Peterborough	-1.1	-0.2	0.0	0.2	-0.2	-1.0	-1.0	-1.7	-2.0	-1.5	-0.3	-0.2	-0.8
Trenton (Belleville)	0.0	1.2	0.5	0.8	1.1	0.3	0.3	0.2	0.0	0.1	0.5	1.2	0.5
Δ Precipitation (%)													**6 %**
Peterborough	-15%	-19%	-2%	10%	18%	20%	-7%	27%	2%	14%	16%	13%	6%
Trenton	-21%	-21%	-6%	20%	0%	30%	-15%	28%	28%	12%	17%	10%	6%

Temperature

The change in mean annual temperature is small for the 3 stations (less than ± 1°C) but shows different changes seasonally:

- During winter months, Haliburton and Belleville show a small increase while Peterborough does not show any significant temperature change; and
- During the summer months, Haliburton and Belleville do not show any significant change while Peterborough show a clear temperature decrease of 1 to 2°C.

Therefore, there is no significant clear temperature change between the past period (1921-1950) and the reference period (1971-2000).

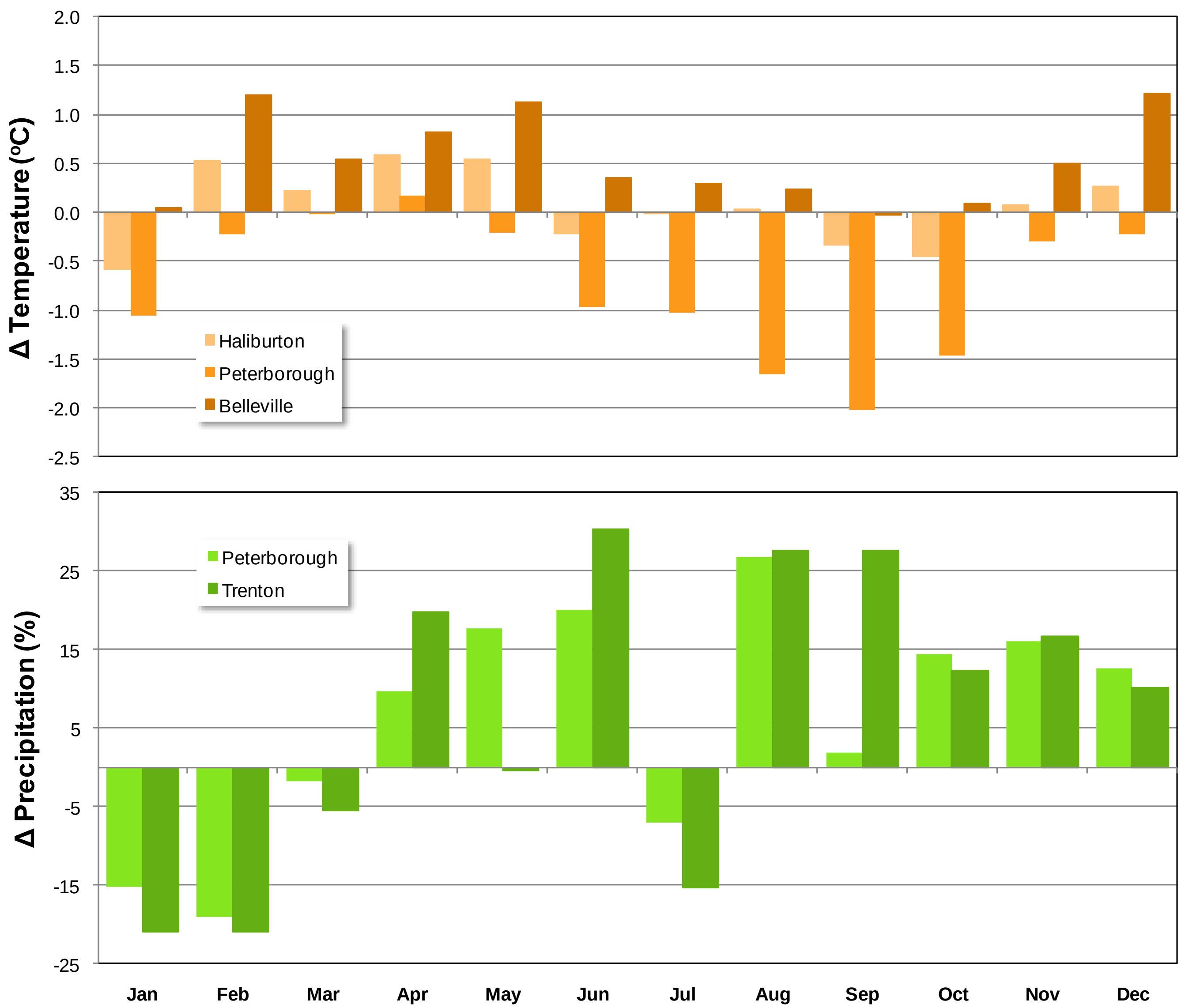
For the temperature analysis, as outlined previously, there is no temperature data for the Trenton station for the past period. To facilitate the comparison between the past and reference period, it is necessary to use the same climate station and therefore the Belleville station is used for Trenton, even though it is located outside the watershed.

Precipitation

For precipitation, the results show an increase in average annual precipitations of about 6% for both Peterborough and Trenton between the two periods, and monthly changes for the two “combo” stations are comparable. The following observations were shown in the results:

- An average decrease of 19% was noted for January and February; and
- An average increase of 26% was noted for June and August, but July shows a decrease of 11 %.

Figure 2-1 - Past Climate Change by Month for Temperature and Precipitation between the Past Period (1921–1950) and the Reference Period (1971–2000)



In order to extract the past climate trends for the Trent River Watershed from the previous results, it is important to understand that climate differences from season to season or from a station to another can be explained by all or part of the following for Canadian climate stations (Atmospheric Environment Services, AES):

1. Rainfall measurement errors: these errors may be due to the instrument shape or type, that can vary from an instrument to another, which may be the case from a climate station composing the “combo” station to another, and which certainly occurred during the last 90 years; as an example, the MSC rain gage used since about 1920 by the AES was changed in the early 1970’s by the Type-B rain gauge;
2. Snowfall measurement errors: prior to 1960, all AES stations relied on snow ruler measurements to estimate fresh snowfall precipitation and the snowfall water equivalent is then estimated assuming the density of fresh snow to be 100kg/m³, while Goodison and Metcalfe (1981) estimated that fresh snowfall densities ranged from 70 to 165kg/m³ with average densities of 71 to 84kg/m³ across Canada; this can lead to substantial errors, resulting in a 20% overestimation of winter precipitation for the past period (1921-1950) and may explain the decrease of about 20% for January and February in the results.

Also, the past climate monthly changes can be fluctuations due to natural climatic variability within each period rather than clear climate trends between the past period and the reference period.

2.3 Summary of Past Climate Trends

For all the reasons outlined above, climate trends between the past period (1921-1950) and the reference period (1971-2000) in the Trent River Watershed are summarized as follows:

- There is no clear changing trend in temperature; and
- The average annual precipitation shows an increase of about 6% at both Peterborough and Trenton.

Since climate trends are similar for Peterborough and Trenton, both stations can be used to assess future climate changes and their impacts on the water management of the Watershed. For the purposes of this study, the Peterborough station is selected to represent the climate for the Trent River Watershed because it is located in the centre of the Watershed.

The past climate trends along with future climate trends, outlined in **Section 3**, are assessed to understand if future climate changes might suggest changes in water management decision making (**Section 4**).

3. Future Climate Trends

3.1 Climate Variability and Climate Change in Canada

3.1.1 Climate Change in Guidelines and Literature

The CDA Dam Safety Guidelines contains the following observation about climate trends in its Hydrotechnical Considerations section:

> *"A gradual increase in the temperature of the planet has been observed over the past century, and is expected to continue into the future, at least for some decades; however, the pattern is far from being uniform. The consequences of this temperature change on river runoff patterns and quantities are not yet clearly determined. Rainfall and evaporation patterns (spatial and temporal) will be modified and it is expected that the variability of extreme events (floods and droughts) will increase, but it is not possible to quantify this change.*
>
> *All these changes are quite recent and intense research is active in that domain but thus far, no generally accepted methodology exists to evaluate the effect of climate change on flood frequencies. Until the scientific community defines safe practices, high and extreme floods should be evaluated with a (realistic) degree of conservatism and flood frequency estimates should be updated as frequently as possible, when new information becomes available, for example after the occurrence of a very large flood or when new advances on climate modeling become available."*

In the Guidelines on Extreme Flood Analysis (Alberta Transportation), the following is found in the Climate Variability and Climate Change section: *"global warming over the 20th century was apparently greater than expected on the basis of long-term natural variability, and accelerated in the final decades of the century. Some scientific forecasts of future warming and sea-level change are alarming, while others are more cautious."*

It is often speculated that higher mean temperatures will be accompanied by a greater range of extremes in climatic parameters, and it is sometimes claimed that a wider range has in fact been observed. Such claims are difficult to prove on the basis of climatic and hydrologic records usually lasting only a few decades. With respect to storm precipitation in Canada, Zhang et al. (2001) state: "*For the country as a whole, there appear to be no discernible trends in extreme precipitation (either frequency or intensity) during the last century*". Referring to the Prairie Provinces as a whole, Hopkinson (1999) states: "*For the period 1953 to 1998, there is no evidence of a significant trend in maximum persisting dew point or in precipitable water derived from upper air soundings of the atmosphere."*

3.1.2 Climate Change in the Engineering Community

The need to consider climate change is becoming a more widespread recommendation among the engineering community. References that support this position are presented below.

3.1.2.1 Public Infrastructure Engineering Vulnerability Committee (PIEVC)

The Vulnerability Committee was created to conduct an engineering assessment of the vulnerability of Canada's public infrastructure to the impacts of climate change. It is co-funded by Natural Resources Canada (NRCan) and Engineers Canada. In the Vulnerability Committee Overview on the PIEVC website, the following was reported:

> *"Regardless of the causes, our climate is changing and it will increasingly affect infrastructure over time, exposing Canada's infrastructure to conditions it was not originally designed to withstand. This can reduce its useable lifespan and may result in economic loss, disruptions to the lives and daily routines of Canadians, and increased risks to public health and safety. Engineers have a responsibility to prevent*

and/or minimize such disruptions and reduce risks by designing, building and maintaining resilient infrastructure that can adapt to the impacts of a changing climate.

(…)

Engineers have traditionally relied upon historical data to design long-lasting, safe and reliable infrastructure, but now they must develop new design and operational practices to withstand new weather conditions - both extremes and gradual changes."

3.1.2.2 PIEVC Engineering Protocol for Climate Change

From the Infrastructure Canada website and drawn from the report "Adapting Infrastructure to Climate Change in Canada's Cities and Communities: A Literature Review":

"In order to ensure that public infrastructure such as roads, bridges, communications structures, water and wastewater infrastructure, border crossings, energy transmission networks, and public buildings can safely provide essential services and support economic activities, they must continually be adapted to the impacts of climate change."

3.1.2.3 Environment Canada

From the Environment Canada website and drawn from the report "Climate Information to Inform New Codes and Standards":

"Since almost all of today's infrastructure has been designed using climatic design values derived from historical climate data, any changes in future climates will require modifications to how structures are engineered, maintained and operated. As infrastructure built in current times is intended to survive for decades to come, it is important that adaptation options for the changing climate be developed today and that future climate changes be incorporated into infrastructure design whenever possible.

(…)

In support of these interim approaches, Environment Canada and the Canadian Commission on Building and Fire Codes are updating and improving more than 6000 specific climatic design values used in the National Building Code of Canada and by many Canadian Standards Association (CSA) national standards."

3.2 Analysis of Climate Change for the Trent Severn Waterway

An analysis was carried out by OURANOS as part of the Trent Severn Waterway Water Management Study. OURANOS is a research consortium focusing on regional climatology and adaptation to climate change. It is a joint initiative from the Québec Government, Hydro-Québec and the Meteorological Service of Canada, with the participation of UQAM, INRS, Laval and McGill universities.

The study report from OURANOS presents an analysis of climate change projections for the Trent Severn Waterway region. The complete report from OURANOS is presented in **Appendix B**.

This section presents a summary of the methodology and the study results of the climate change analysis.

3.2.1 Methodology

The emission of atmospheric greenhouse gases (GHG) is inducing a series of climatic changes, most notably an increase in global mean temperatures and an intensification of the global hydrological cycle (Meehl et al., 2007a). To assess the magnitude of those changes and understand their impact on climate, modelling teams around the world have created coupled numerical models of atmospheric circulation, the ocean and surface processes. Given an initial climatic state and the evolution of GHG concentrations, these Global Climate Models (GCM) simulate the Earth's climate over hundreds, if not thousands of years.

Typically, models contributing to the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report have a horizontal resolution of about 250 km. It is clear that local weather specificities, for example related to proximity to the Great Lakes, cannot be adequately reproduced by GCMs. Rather, GCMs strive to reproduce accurately climate statistics, e.g. the large scale mean state and seasonal cycle of climatic variables (Randall et al., 2007).

Climate change studies typically use a large number of simulations to ensure clear climate change signals are extracted rather than random fluctuations due to natural climatic variability. For example, an exceptionally warm year is a manifestation of this natural climatic variability, while a gradual increase in mean temperatures over 30 years is a signal of underlying climate changes. To simulate the climate over the next century, modellers need to specify GHG emission scenarios for the future. Three scenarios are generally used in most simulations: SRESA2 (called A2 hereafter), SRESA1B (A1B) and SRESB1 (B1). For the reference period, models use a scenario called 20C3M, which represents observed GHG concentrations.

For the purpose of this study, all GCM simulations with data available for precipitation and temperatures during the control (1961–1999) and future (2041–2070) periods were selected. An ensemble of 23 global climate models and 136 global climate model simulations, driven by three future greenhouse gas emission scenarios A2, A1B and B1, and 55 simulations driven by the 20th century scenario 20C3M, is used to estimate changes in temperatures and precipitations.

For more details on the analysis carried out by OURANOS, see **Appendix B**.

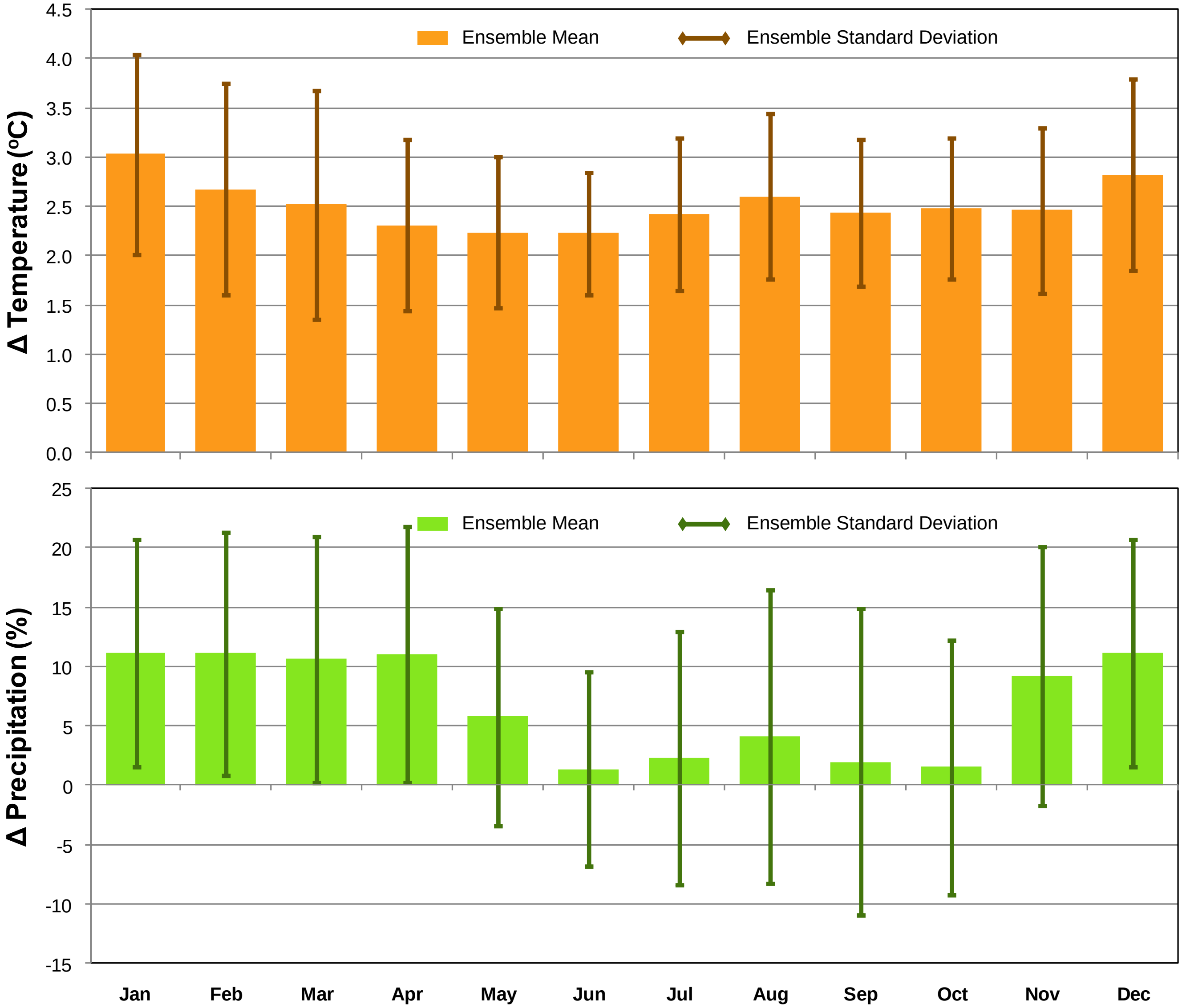
3.2.2 Results

The results of the climate change analysis carried out by OURANOS are summarized in **Table 3-1** and plotted in **Figure 3-1**. All climate change results by month for the 136 simulations are presented in **Appendix C**.

Table 3-1 - Ensemble Averaged Climate Change by Month for Temperature and Precipitation between the Future Period (2041–2070) and the Reference Period (1961–1999)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Δ Surface temperature (°C)													
Mean	3.03	2.68	2.52	2.31	2.24	2.23	2.42	2.60	2.44	2.48	2.46	2.82	2.52
Standard Deviation	1.02	1.07	1.16	0.87	0.76	0.62	0.77	0.84	0.75	0.71	0.84	0.97	0.67
Δ Precipitation (%)													
Mean	11.2	11.1	10.6	11.0	5.8	1.3	2.3	4.1	2.0	1.5	9.2	11.1	6.1
Standard Deviation	9.6	10.2	10.3	10.8	9.1	8.2	10.6	12.3	12.9	10.7	10.9	9.5	3.6

Figure 3-1 - Ensemble Averaged Climate Change by Month for Temperature and Precipitation between the Future Period (2041–2070) and the Reference Period (1961–1999)



Temperatures

The results show a clear increase in average annual temperatures of about 2.5 ± 0.7°C in 2041–2070 with respect to 20th century conditions.

The past climate analysis showed no clear temperature change signal between the past period (1921-1950) and the reference period (1971-2000), as outlined in **Section 2.3**.

Precipitation

The results are less clear for annual precipitations, with an increase of just 6 ± 4% of the mean reference value. Projections for winter (Dec., Jan., Feb.) precipitations are more conclusive with an increase of 11 ± 6%.

The lack of a clear climate change trend for summer precipitation is consistent with IPCC results.

The past climate analysis also showed an increase of annual precipitations of about 6% between the past period (1921-1950) and the reference period (1971-2000), as outlined in **Section 2.3**.

3.3 Conclusions on the Climate Change Analysis

As outlined in the OURANOS climate change report (**Appendix B**), an important caveat to consider is that the resolution of GCMs is very coarse compared with the area under study. Local climatic features therefore cannot be adequately represented by GCMs. This is especially relevant the case of the Trent River Watershed, as it is surrounded by the Great Lakes whose influence on weather is significant. Regional Climate Models (RCMs) are expected to perform better in this respect, since they resolve features at a scale of about 50 km (Laprise, 2008).

4. Assessment of the Impacts of Climate Change

As outlined in the OURANOS report (**Appendix B**), climate change impacts on the hydrological regime are generally made using downscaled precipitations (Maraun et al., 2010). Downscaling refers to methods that adjust coarse scale model output to point or local scales using observed time series. Downscaled precipitations can then be used as inputs in hydrological models to assess modifications in the hydrological cycle, such as changes in the occurrence of floods and low-flows. The biases typically found in climate model precipitation make this downscaling correction critically important for hydrological studies.

4.1 Methodology

To assess the impacts of climate change on the monthly flows along the Waterway, downscaled datasets of precipitation and temperature were developed for the Trent River Watershed for the future period (2041–2070) and for the reference period (1971–1999). The downscaled datasets of precipitation and temperature are then used as input data in a hydrological model developed and calibrated based on the Watershed physical characteristics to generate runoff for the future period and the reference period.

The hydrological model used is the SSARR watershed model (Streamflow Synthesis and Reservoir Routing). The model was developed and calibrated for the Trent River Watershed Hydro-Technical Study in 2010 (AECOM).

The SSARR model is comprised of a generalized watershed model and a streamflow and reservoir regulation model:

- **The watershed model**: simulates rainfall-runoff, snow accumulation and snowmelt-runoff. Algorithms are included for modeling of snowpack cold content, liquid water content and seasonal conditioning for melt. Interception, evapotranspiration, soil moisture, baseflow infiltration and routing of runoff into the stream system are accounted for.
- **The river system and reservoir regulation model**: routes streamflows from upstream to downstream points through channel and lake storage and reservoirs under free flow or controlled-flow modes of operation. Flows may be routed as a function of multivariable relationships involving backwater effects from reservoirs. Diversions and overbank flows may be simulated.

For the present study, in order to estimate runoff only (inflows to the system without considering routing effect of the reservoirs), all reservoirs were removed from the river system and reservoir regulation model.

For more details on the model development and calibration, see the Trent River Watershed Hydro-Technical Study and Dam 1 Dam Safety Review – Phase II, Hydro-Technical Study – Flood Flows Estimation Study Report (AECOM, 2010).

4.2 Development of Downscaled Sets of Precipitations and Temperatures

First, a dataset of daily precipitation and temperature representing the study area for the reference period (1970–1999) was selected. The Peterborough station was chosen because it is located in the centre of the Trent River Watershed.

For each simulation for the future period (2041–2070), the averaged climate change by month for temperature and precipitation between the future period and the reference period, as estimated by OURANOS and presented in **Appendix C**, are applied to the daily temperature and precipitation values over the entire reference period (30 years of daily data) to generate a set of downscaled future climate data for that specific scenario.

Results from 136 simulations for the future period were provided by OURANOS. Running the hydrological model using 136 sets of daily temperatures and precipitations over 30 years would require a tremendous amount of data. It is therefore desirable to reduce the number of climate change simulations to use in order to reduce the number of hydrological model runs and results. From the 136 global climate model (GCM) simulations, a single simulation was randomly selected for each of the 23 GCMs to represent the future period. Table C-1 in **Appendix C** highlights the 23 selected simulations.

Figure 4-1 shows the mean annual climate change for the 136 simulations between the future period and the reference period and **Figure 4-2** shows the mean annual climate change for the selected 23 simulations.

Figure 4-1 - Mean Annual Climate Change for the 136 Simulations for Temperature and Precipitation between the Future Period (2041–2070) and the Reference Period (1961–1999)

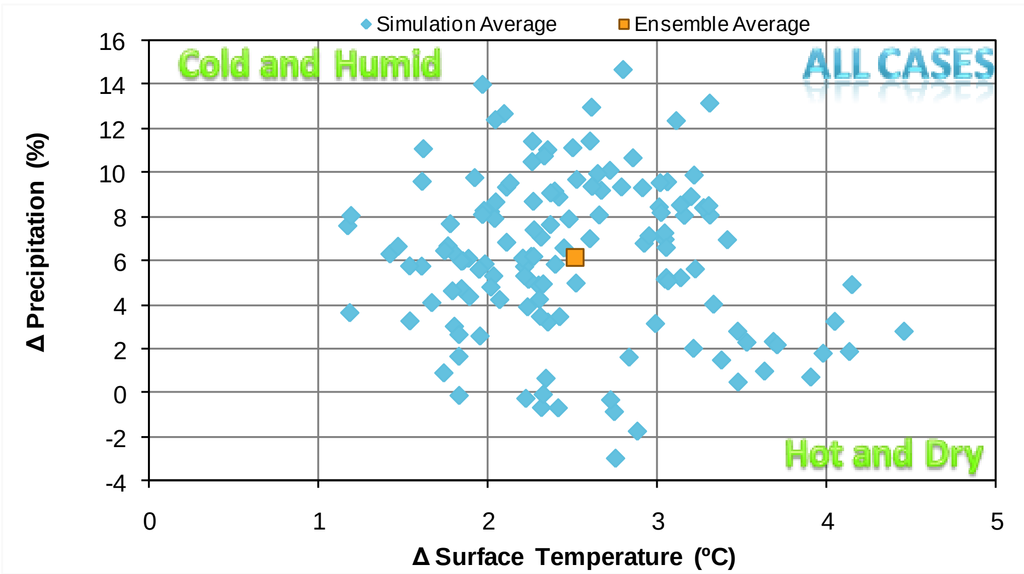
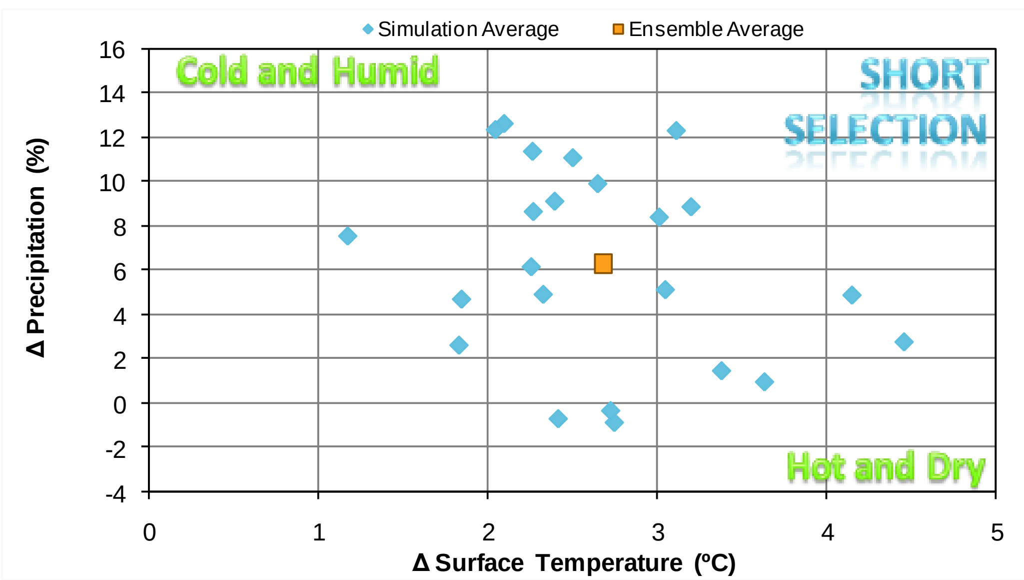


Figure 4-2 - Mean Annual Climate Change for the Short Selection of 23 Simulations for Temperature and Precipitation between the Future Period (2041–2070) and the Reference Period (1961–1999)



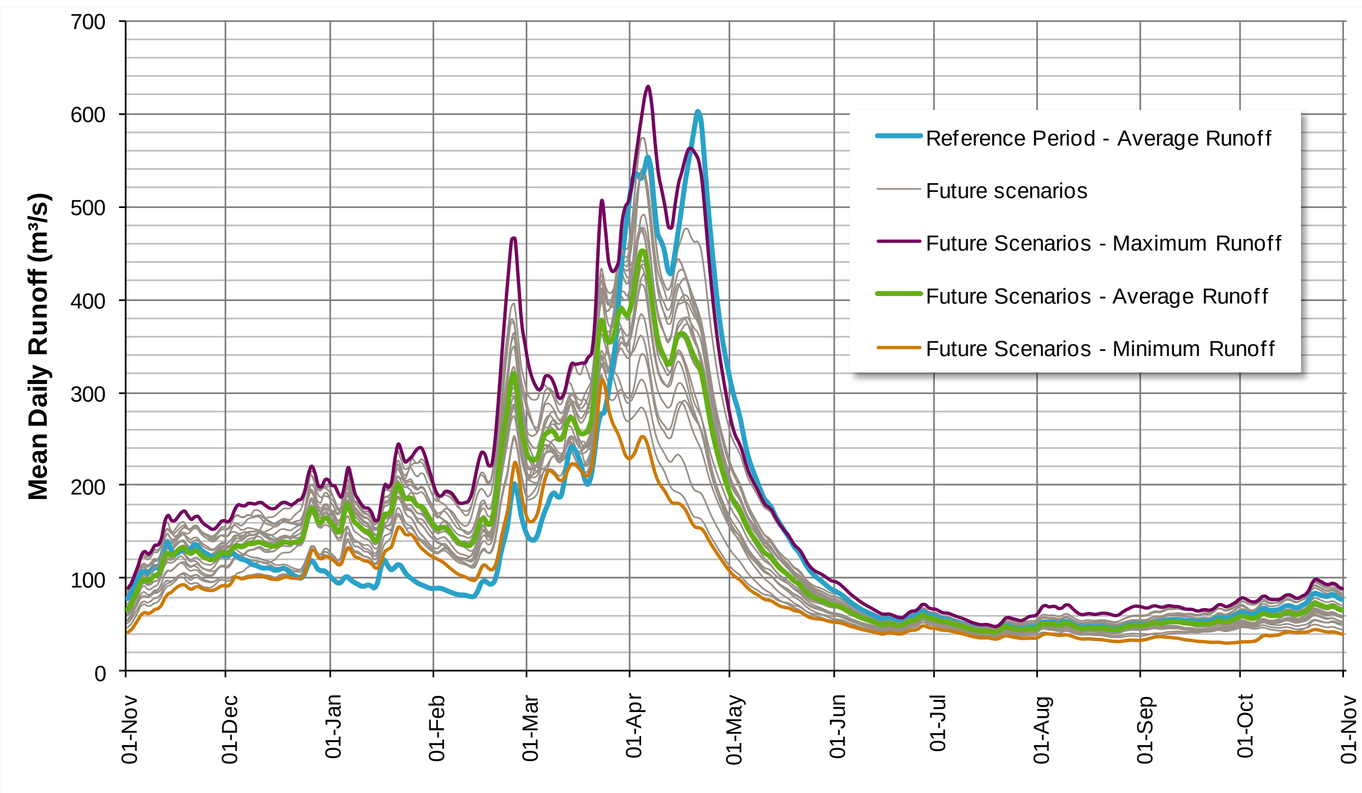
From **Figure 4-1** and **Figure 4-2**, it appears that the ensemble average and dispersion for the “short selection” of 23 simulations are comparable to those for the complete set of simulations. The short selection is therefore considered representative of the complete set of 136 GCM simulations.

4.3 Estimation of Future Runoff

Runoff for the reference period and for the 23 GCM simulations for the future period is estimated with the SSARR model of the Watershed. As outlined in **Section 4.1**, reservoir routing is not considered in the hydrological model because it requires water management decisions on a day-to-day basis over the 30 years of simulations and may vary from one scenario to another. Therefore, outputs from the hydrological simulations are runoff flows, representing inflows to the system, and do not correspond to historic flows, allowing the different time periods of simulation to be compared equally without impact from Waterway operations.

Figure 4-3 shows the mean daily runoff flows for the reference period and for the 23 future scenarios for the Dam 1 at Lock 1 location, the most downstream dam in the Trent River Watershed.

Figure 4-3 - Mean Daily Runoff for the 23 Future Scenarios (2041–2070) and for the Reference Period (1970–1999)



However, because the future GCMs are used to extract the climate change trends, the 23 future scenarios used to assess the climate change impacts on flows cannot be interpreted separately but as an ensemble. Therefore, in order to extract the future trends of the impacts of climate change, all scenarios results are averaged to obtain daily runoff flows for the future period.

Figure 4-4 shows the daily runoff for the reference period (1970–1999) and **Figure 4-5** shows the projected runoff for the 2050 horizon based on estimated climate changes.

Figure 4-4 - Daily Runoff for the Reference Period (1970–1999)

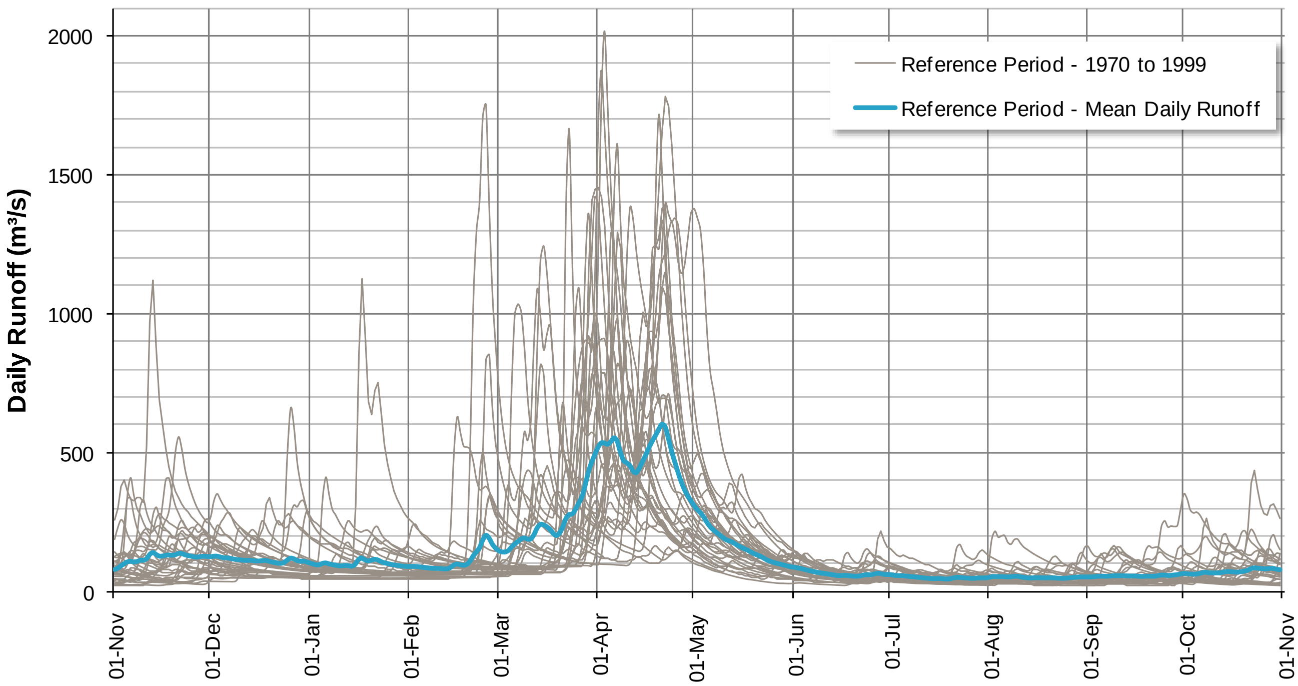
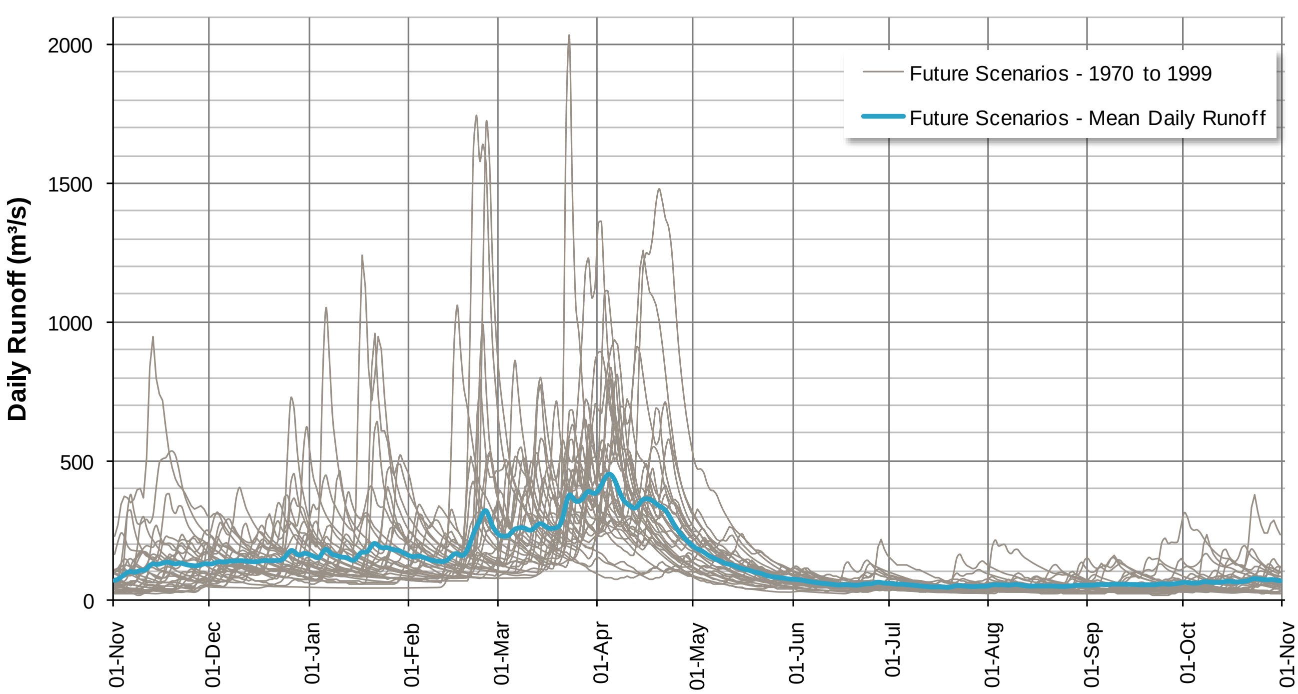


Figure 4-5 - Daily Runoff for the Future Period (2041–2070)



The comparison of daily runoff flows for the reference period (**Figure 4-4**) and for the future period (**Figure 4-5**) shows that:

- A larger variability of future runoff flows is noted during winter months, i.e., more winter floods (December to February); this is due to snow melt or more frequent rainfalls, thus reducing the snow cover and therefore water input to spring freshet;
- The variability of future runoff flows is reduced during the spring freshet (March to May);
- The future summer-fall runoff flows (June to November) are similar for both average flow and variability;
- The spring freshet covers a longer period and shows, in general, smaller peak runoff flows; and
- The 3 largest maximum annual runoff flows are similar, leading to the conclusion that climate change impacts may not affect floods having a return period of 10 years or more.

4.4 Climate Change Impacts of Future Runoff

Figure 4-6 shows the ensemble average mean daily runoff of the 23 simulations for the future period (2041-2070) along with the mean daily runoff for the reference period (1970-1999). Comparison of the two curves shows that, for the 2050 horizon:

- The magnitude of the spring freshet is reduced;
- Winter flows increase;
- Summer-fall flows remain the same; and
- The mean annual peak runoff flow occurs 17 days sooner than for the reference period.

An analysis was carried out on the dates of the annual peak runoff flow. The average number of days of difference per scenario (over 30 years of estimated runoff flows) is estimated at an average is 17 ± 11 days sooner for the future scenarios than for the reference period. The Gaussian distribution of the number of days separating the peak runoff flows for the future period and for the reference period is shown on **Figure 4-6**.

Figure 4-6 - Ensemble Average Mean Daily Runoff for the Future scenarios (2041–2070) and Mean Daily Runoff for the Reference Period (1970–1999)

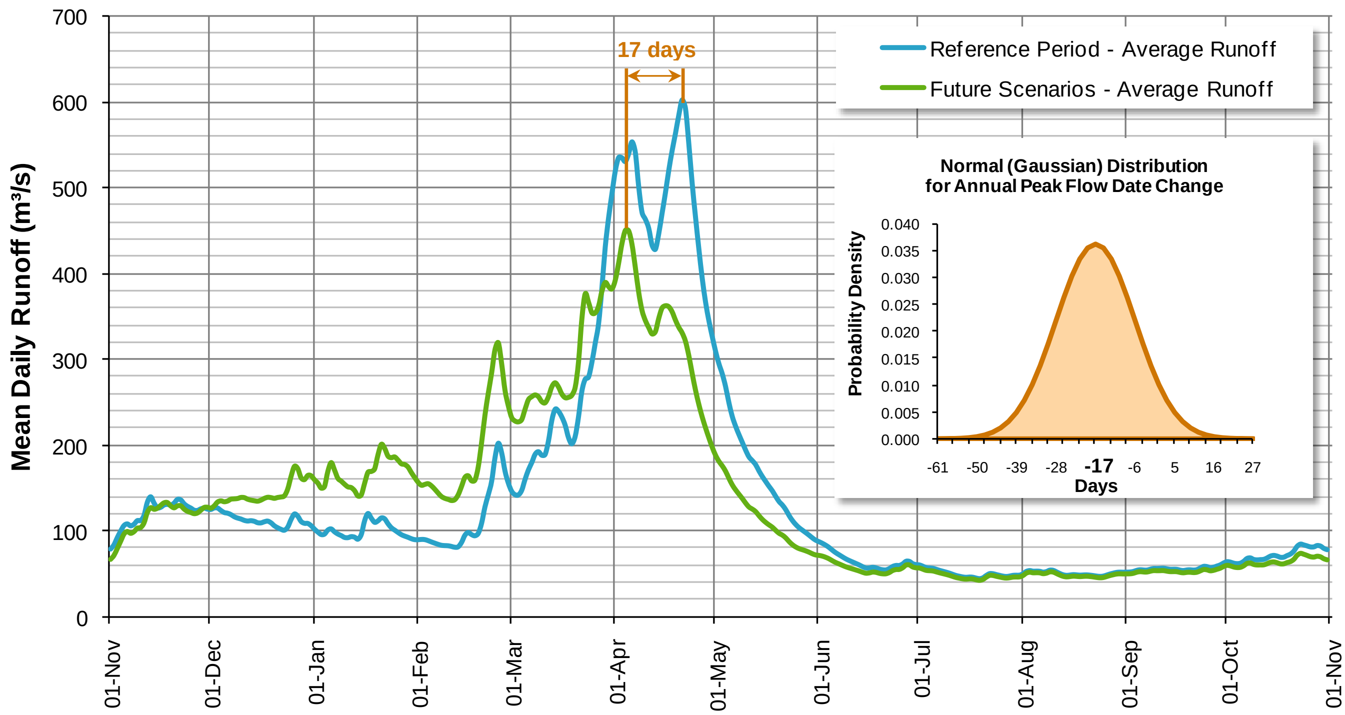
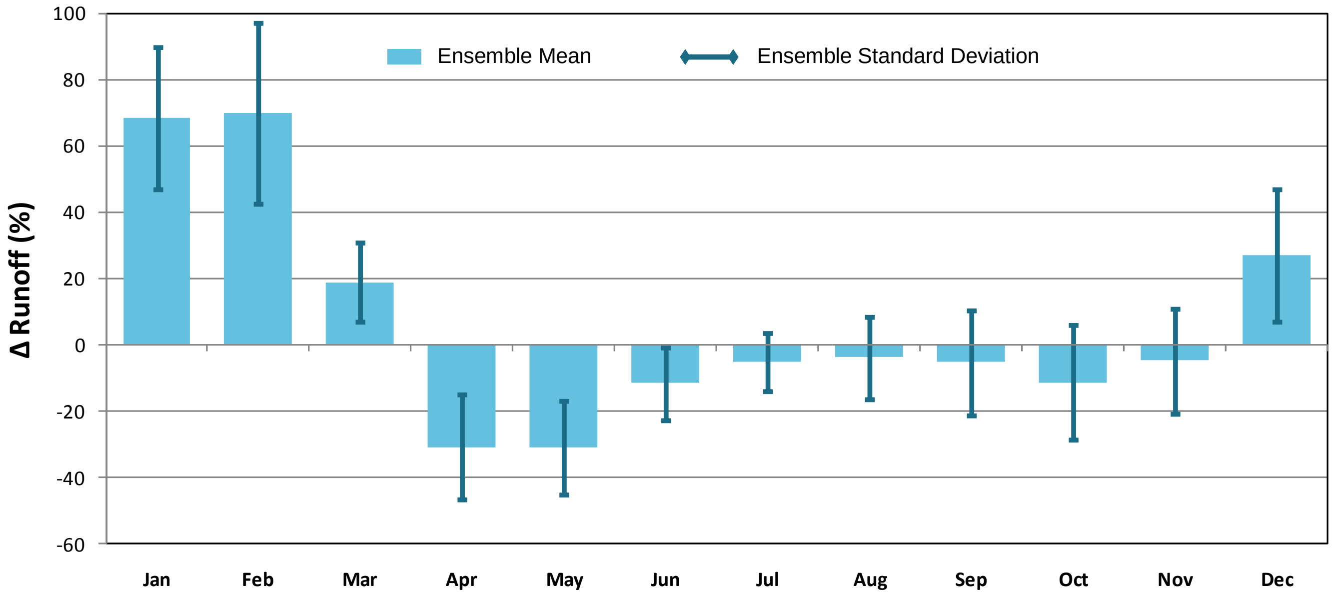


Table 4-1 and **Figure 4-7** present a summary of the ensemble averaged runoff change by month between the future period and the reference period.

Table 4-1 - Ensemble Averaged Runoff Change by Month between the Future Period (2041–2070) and the Reference Period (1970–1999)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Runoff (m³/s)													
Reference Period	100	111	245	490	169	65	50	50	56	72	120	113	137
Future Period	168	189	292	338	116	57	47	48	53	64	114	143	135
∆ Runoff	67	78	46	-151	-53	-8	-3	-2	-3	-8	-6	30	-1
Δ Runoff (%)													
Mean	67.0	69.8	18.9	-30.9	-31.2	-11.8	-5.1	-3.9	-5.4	-11.3	-4.9	26.9	-0.8
Standard Deviation	21.4	27.2	12.0	16.0	14.2	11.1	8.7	12.4	15.8	17.5	16.1	19.8	10.1

Figure 4-7 - Ensemble Averaged Runoff Change by Month between the Future Period (2041–2070) and the Reference Period (1970–1999)



The results show a clear increase in runoff flows of 38 ± 14% during the winter months (December to March) and a clear reduction in runoff flows of 31 ± 15% during the spring freshet (April and May) in 2041–2070 with respect to 20th century conditions[1].

The results are less clear for annual runoff, with a reduction of just 1 ± 10% of the mean reference value.

The impact of climate change on the mean annual runoff of -1% is consistent with the trends estimated for the province of Québec as outlined in *Savoir s'adapter aux changements climatiques*, where the evolution of flow regime varies from about +15% in the north of the province to +1% in the south-east of the province, close to the Trent River Watershed, as shown on **Figure 4-8**.

[1] *The uncertainty given here corresponds to the standard deviation of climate change signals among models, and not the inter-annual variability within models.*

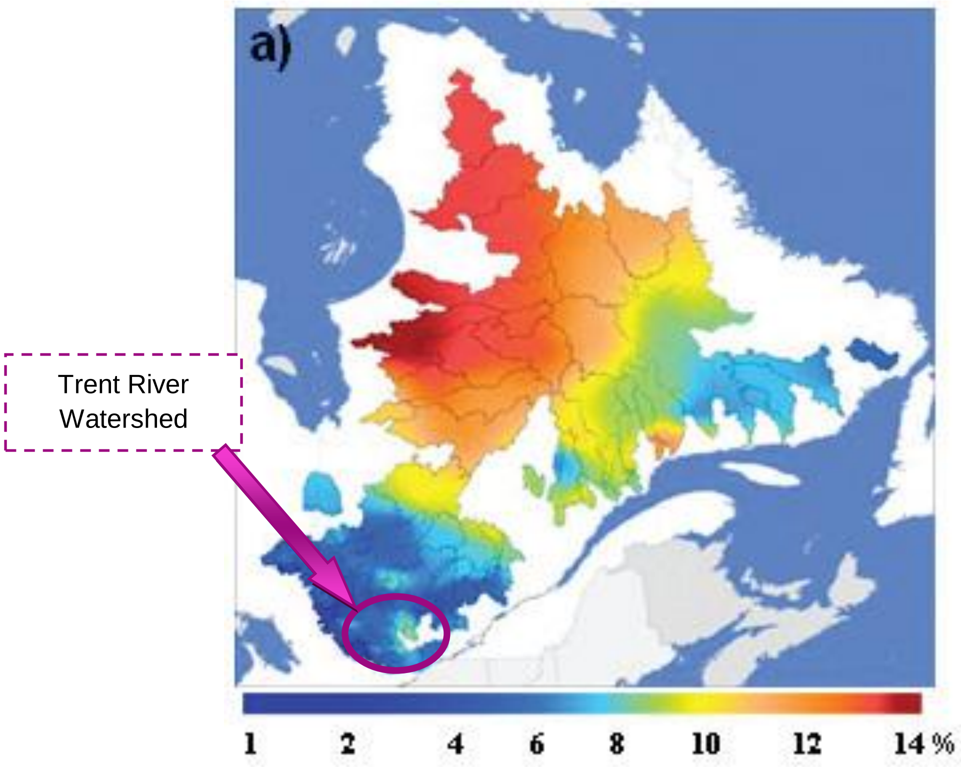


Figure 4-8 - Evolution of Flow Regime for the 2050 Horizon – Increase of Mean Annual Flow

4.5 Summary of Future Runoff Flows Trends

Results of the analysis of climate change impacts on runoff flows for the 2050 horizon can be summarized as follows:

- The increase of the mean winter temperatures causes partial melting of the snow cover between snowfalls and/or more precipitation in the form of rainfall; this would lead to runoff flows increase of 20 to 70% from December to March;
- The spring peak runoff flow would occur 17 days sooner than for the reference period, from end of April for the reference period (1970-1999) to the beginning of April for the 2050 horizon;
- The magnitude of the spring freshet runoff flows (April and May) would be reduced by 31%, due to smaller snow cover at the beginning of the snowmelt;
- The increase of the summer-fall temperatures would also increase the evapotranspiration on the watershed, leading to a flow reduction of 7% (June to November), in spite of the increasing precipitations; and
- The overall impact of climate change would be a reduction of 1% of the mean annual runoff.

Therefore, the impacts of climate change on the runoff flow distribution throughout the year would be more significant than impacts on mean annual runoff flows or on peak runoff flows during large floods.

It is important to mention that impacts of climate change on runoff flows only took into account the mean monthly climate change trends. It did not take into account possible impacts of climate change on synoptic systems generating heavy precipitations, therefore the change in occurrence, magnitude or duration of heavy rainfall leading to large floods cannot be assessed.

4.6 Possible Impacts of Climate Changes on Water Management

Since mean annual runoff volume in the Trent River Watershed would remain almost the same for the 2050 horizon, the possible impacts of climate change on water management are mainly due to the availability of the water resource throughout the year. Therefore, large spring floods should be managed in the same manner. However, general impacts on water management may be the following:

- Summer-fall runoff volume reduction of about 7% may lead to difficulties in feeding the waterway for the navigation period with current reservoir lakes storage capacities or management rules; and
- The smaller snow cover during winter months would lead to a spring freshet having a smaller volume, requiring addition of stoplogs sooner during winter months, or would require eventually to reduce the storage capacity (by adopting higher winter stoplogs settings) to assure complete filling of the reservoirs.

5. Characterization of the Natural Environment

5.1 Introduction

The Trent Severn watershed accommodates vast ecosystems with diverse aquatic and terrestrial species. The Waterway passes through the large transition zone of biota and ecosystems of southern/central Ontario with elements of Northern Ontario, referred to as “The Land Between”. Overlapping ecodistricts include 6E and 5E: 6E-6, 6E-9, 6E-8, 5E-8, and 5E-11, representing a wide range of habitats and community associations from remnants of Carolinian species in the southern portions of the system to more northern species on the Precambrian Shield. The Trent Severn Watershed has one of the highest levels of biodiversity in the province and contains 35 species at risk under Committee On the Status of Endangered Wildlife in Canada (COSEWIC) and similar numbers of provincially endangered and threatened species. The centre of distribution for several Species At Risk (SAR) is focussed on this transitional zone, such as Golden-winged Warbler. In addition, the Waterway includes a significant assemblage of wetland habitats (over 230 Provincially Significant Wetlands) and supports a number of rare community types including prairies, savannahs, alvars and sand barrens.

The portion of the Trent Severn Waterway evaluated in this project has been divided into three general regions: the Haliburton Reservoirs (Haliburton Sector of the TSW), the Kawartha Lakes (North and Central TSW sectors), and Rice Lake and the Trent River (South Sector of the TSW). Geology and landscape features vary across these regions. Lakes in the TSW can be characterized generally into a few types that support characteristic fish wildlife and vegetation species.

This chapter describes the natural environment of the TSW within the study area, shows the distribution of key indicator species, and identifies their key life history requirements and sensitivities with respect to water level management within the Waterway.

5.1.1 Haliburton Reservoirs

The Precambrian rock of the northern part of the study area consists of predominantly felsic igneous intrusives and derived metamorphic rock and metasediments and is often associated with till-covered uplands and ice contact deposits*, e.g*. esker kame complexes. Sand is the most prevalent material class occurring as a shallow mantle of sandy or silty sand over bedrock.

The Haliburton Reservoirs in the north part of the TSW serve the downstream parts of the Waterway. They are located predominantly on the Precambrian Shield and exhibit relatively low surface area to volume ratios. Productivity in these relatively deep lakes is comparatively low and many of these lakes are populated with Lake Trout, a slow growing, late maturing fish that prefers cold, deep waters. A glacial waterway connected Georgian Bay to the Champlain Sea near Ottawa, and remnant populations of Atlantic Coastal Plain species, often associated with the modern lakes and watercourses, persist. The Haliburton Reservoir area is shown in **Figure 5-1**.

5.1.2 North and Central Sectors

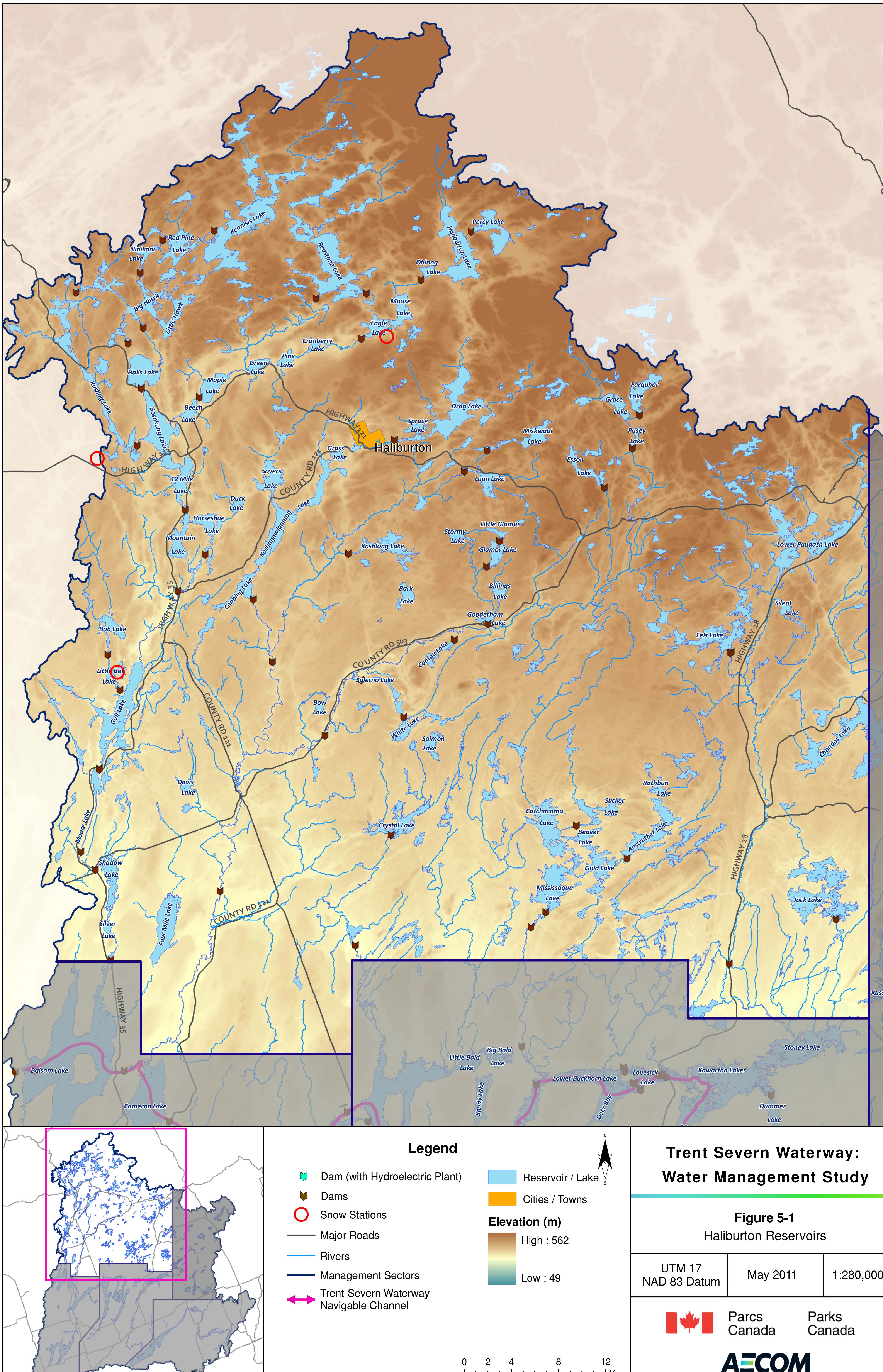
The south portion of the Haliburton region and the northern portions of the Kawartha region characterize a transition from Precambrian Shield geology of thin acidic soils, forest and wetlands to Quaternary geology of thin tills which overlie sedimentary rocks: The Land Between. These areas support forests, wetlands and some agricultural land use. Balsam Lake receives drainage from areas comprising thin till plains and from Gull River which carries Precambrian Shield runoff by way of Moore Lake.

The Kawartha Lakes are relatively shallow and productive, located in a landscape characterized by rolling terrain and numerous wetlands and large lakes. The glacial soils vary from thin to thick where they support a substantial base of mixed agricultural use. Some of the larger lakes include Balsam, Pigeon, Buckhorn and Chemong, and Stoney Lakes. Balsam and Cameron Lakes receive approximately 25% of their flow as local drainage from mixed agricultural, wetland and forested areas and substantial (75%) drainage from the Precambrian Shield to the north by way of the Gull and Burnt Rivers. Walleye are found in the deeper parts of these lakes and some of the connecting channels support Muskellunge, Smallmouth and Largemouth Bass in the warmer, shallower areas. The North and Central Sectors are shown in **Figure 5-2**.

5.1.3 South Sector

In the southern portion of the Waterway, softer, sedimentary limestones, shales and sandstones overlying the more ancient Precambrian bedrock originated as marine sediments of marl, clay and sand. Overall, the diverse geological formations throughout the watershed create a heterogeneous physical environment in which many ecological communities have developed. Lake Scugog and Rice Lake are shallow, marshy lakes in the system, both elevated by dams. Typical fish in these lakes include Muskellunge, Smallmouth and Largemouth Bass.

This interconnected system passes through numerous jurisdictions including five cities, three towns, five counties and five regional municipalities. Along the watercourse there are also six First Nations, six Conservation Authorities, five Ontario Ministry of Natural Resources Districts and hundreds of conservation and landowner associations. Actions taken for development, review and approval can include all levels of government and involve numerous agencies and organizations. The South Sector is shown in **Figure 5-3**.



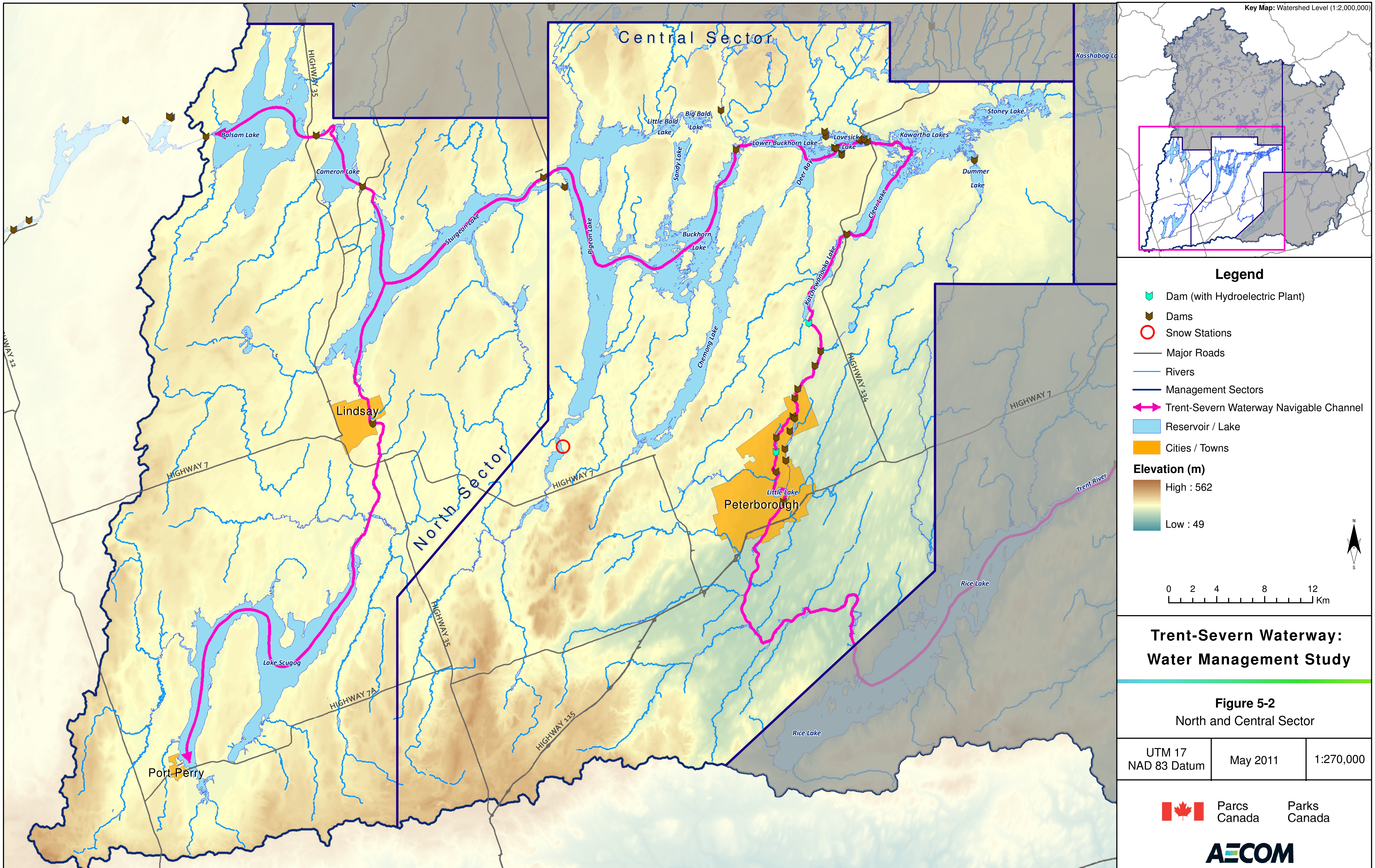
Trent Severn Waterway: Water Management Study

Figure 5-1
Haliburton Reservoirs

UTM 17 NAD 83 Datum	May 2011	1:280,000

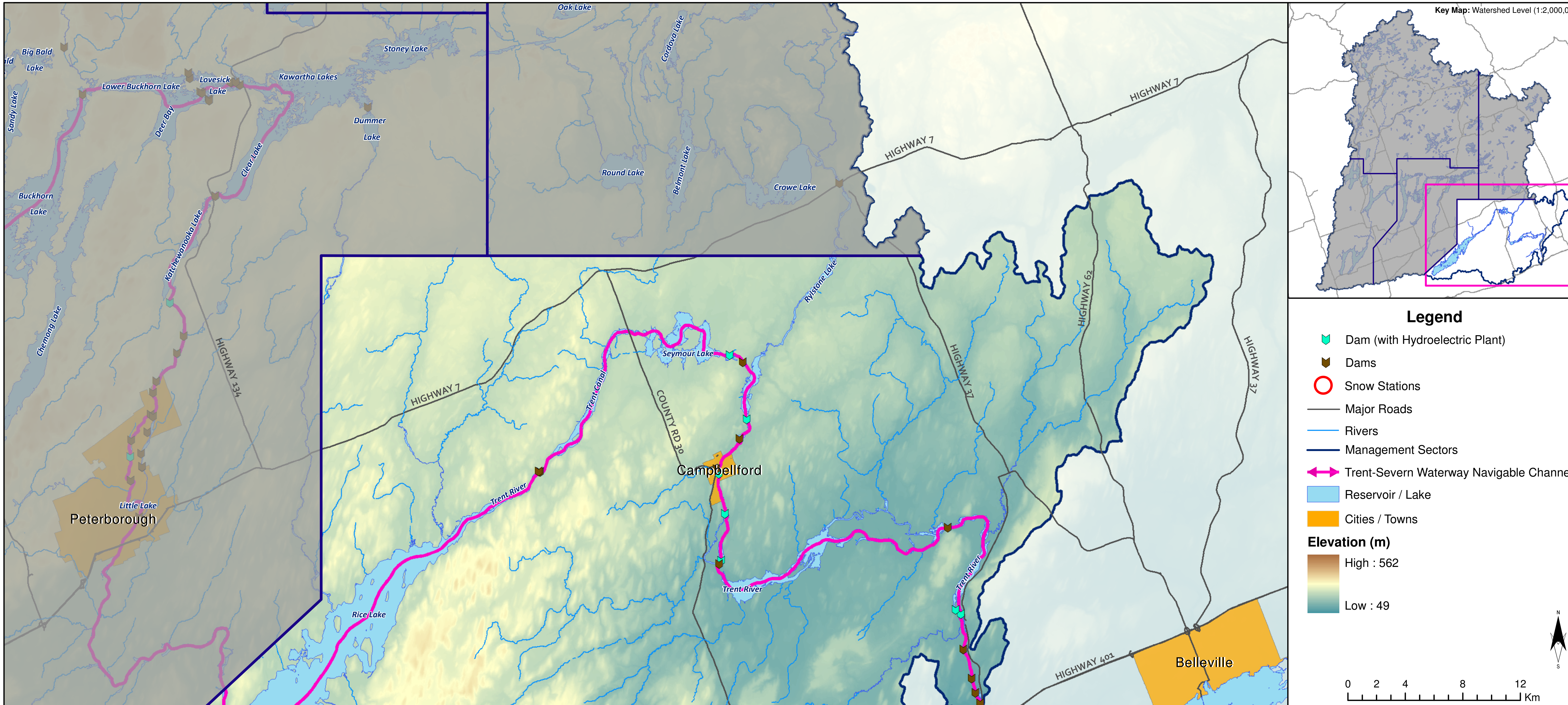
Parcs Canada Parks Canada

AECOM



Trent-Severn Waterway: Water Management Study

Figure 5-2
North and Central Sector



Trent Severn Waterway: Water Management Study

Figure 5-3
South Sector

UTM 17 NAD 83 Datum	May 2011	1:260,000

Parcs Canada Parks Canada

AECOM

5.1.4 General Ecosystem Types

Aquatic habitat characteristics can be linked to suitability of support functions required for key species, and are also associated with water level management in the Waterway. Although aquatic species utilize flowing water and lakes throughout the system, this study focuses primarily on the lakes because they seem most sensitive to changes in water levels for fish species.

The shallow and intermittent littoral zone refers to the area defined by the <2m depth at low water. Frequency, duration and depth of inundation maintain the structure and composition of riparian plant communities. Most fish species spawn in the littoral zone and this zone also serves as a nursery area for growth and refuge for young fish. Some species of turtles, frogs and benthic invertebrates either hibernate or find over-winter refuge in shallow areas. Some Lake Trout spawn in water depths as shallow as 0.3m. Groundwater inputs in the shallow littoral areas can prevent localized freezing thus supporting over-wintering populations. Habitat functions in the littoral zone that support over-wintering activities are sensitive to water level changes after early October.

Deep water habitat refers to the area deeper than the 2m contour at low water. Although they spawn in the littoral zone, fish such as Walleye, Smallmouth and Largemouth Bass, Muskellunge, and Lake Trout spend most of their adult life in deep water habitat. Spawning and nursery functions provide a link between the shallow and deep parts of lakes. In the temperate climate of the TSW, Lake Trout spend summer months at depths below the thermocline where water temperatures are cooler, thus they require lakes deep enough for stratification to occur. Maintaining stratification in Lake Trout lakes is an example of a water level management objective supporting natural environment goals for the Waterway. Eastern Musk Turtles and Northern Map Turtles hibernate in deep, well oxygenated water (COSEWIC, 2002), thus these species can be sensitive to water fluctuations occurring during the winter months.

5.2 Aquatic Habitat and Indicator Species

Due to the unique location of the Trent Severn Waterway through "The Land Between", there is greater biodiversity and a corresponding greater concentration of Species at Risk (SAR). SAR are designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) based on reviews of the health of the population in Ontario and across Canada. Species listed by COSEWIC are subject to the requirements of the federal Species at Risk Act. Many of them are also subject to the Ontario Endangered Species Act as designated by the Committee on the Status of Species At Risk in Ontario (COSSARO). In order to evaluate the potential water management effects that may create an impact to aquatic species, a number of species were selected with critical portions of their life cycle determined by water depths, and for which data were available.

5.2.1 Data Sources

Fish were used as indicators to identify potential aquatic ecosystem and hydrologic conditions within the TSW and potential effects of present water management within the waterway on biota and habitat. Indicator species show sensitivity to littoral zone fluctuations; plant community and nutrition; and thermoclines.

Information on species distributions and life history requirements were obtained from:

Fish Atlases – used to develop species distribution maps for indicator species:

- MNR. 2006. Inland Lakes Designated for Lake Trout Management. Ministry of Natural Resources.
- MNR. 2002. Atlas of Lake Sturgeon Waters in Ontario. Ministry of Natural Resources,
- MNR. 1990. Atlas of Largemouth Bass Lakes in Ontario. Ministry of Natural Resources.
- MNR. 1987. Atlas of Muskellunge Lakes in Ontario. Ministry of Natural Resources.

- MNR. 2001. Atlas of Muskellunge Streams and Rivers in Ontario. Ministry of Natural Resources.
- MNR. 1987. Atlas of Smallmouth Bass Lakes in Ontario. Ministry of Natural Resources.
- MNR. 1987. Atlas of Walleye Lakes in Ontario. Ministry of Natural Resources.
- MNR. 2004. Atlas of Walleye Streams and Rivers in Ontario. Ministry of Natural Resources.
- NHIC. 2011. Element Occurrences for Species at Risk.

Life History Requirements – used to develop spawning and key habitat requirements for indicator species:

- Cook, M.F. and R.C. Solomon. 1987. Habitat Suitability Index Models: Muskellunge. U.S. Fish and Wildlife Service Biology Report 82(10.148). 33 pp.
- Edwards, E.A., G. Gebhart, and O.E. Maughan. Habitat Suitability Information: Smallmouth Bass. U.S. Department of the Interior, Fish and Wildlife Service FWS/OBS-82/10.36. 47 pp.
- Marcus, M.D., W.A. Hubert, and S.H. Anderson. 1984. Habitat Suitability Index Models: Lake Trout (exclusive of the Great Lakes). U.S. Fish and Wildlife Service. FWS/OBS-8210.84). 12 pp.
- Scott, W.B., and E.J. Crossman. 1973. Freshwater Fishes of Canada. Bulletin 184. Fisheries Research Board of Canada, Ottawa, 1973.
- Stuber, R.J., G. Gebhart,and O.E. Maughan, Habitat Suitability Index Models: Largemouth Bass. FWS/OBS-82/10.16 July 1982.

Agreements:

- Ecoplans. 2007a. A Study of Past, Present and Future of Water Management on the Trent Severn Waterway National Historic Site of Canada: Obligations and Expectations. Ecoplans Limited. May 31, 2007.
- Ecoplans. 2007b. A Study of Past, Present and Future of Water Management on the Trent Severn Waterway National Historic Site of Canada: Consultation Report. Ecoplans Limited. May 31, 2007.
- TSW and MNR. 1987. Guidelines for the Trent Severn Waterway: Water Level Management to Assist the Sport Fishery in Lindsay District of the Ministry of Natural Resources. Trent Severn Waterway, Environment Canada – Parks, and Ministry of Natural Resources, Lindsay District. May 1987.

5.2.2 Fish Indicator Species and Life History Requirements

The Trent Severn Waterway traverses diverse landscape. The lakes and connecting channels of the TSW support a rich variety of aquatic species. Historically TSW management has focused on navigation and safety throughout the waterway, and some natural environment objectives in a few localities. More recently canal operators have been challenged with meeting natural environment and additional goals throughout the waterway. In this section fish species have been identified that serve as indicators of key life cycle and habitat requirements in various parts of the TSW. These indicator species are selected because their life cycle and habitat requirements are influenced directly by water management in the TSW and increasing the environmental suitability for these species will increase the environmental suitability for suites of other species as well. The distribution of fish species within the Waterway is displayed on **Figure 5-4**. Relevant life history information for indicator species is recorded below and summarized in **Table 5-2** at the end of this section.

Lake Trout (*Salvelinus namaycush*) prefer cold water temperatures, 11-12°C for optimum growth, and typically are found in relatively deep lakes with small surface area to volume ratios. This species spawns in the fall and occurs most often over large boulder or rubble at depths shallower than 12m and as shallow as 0.3m in some inland lakes. Shallow-spawning individuals are susceptible to desiccation of incubating eggs if water level decreases from late September to April when eggs typically hatch.

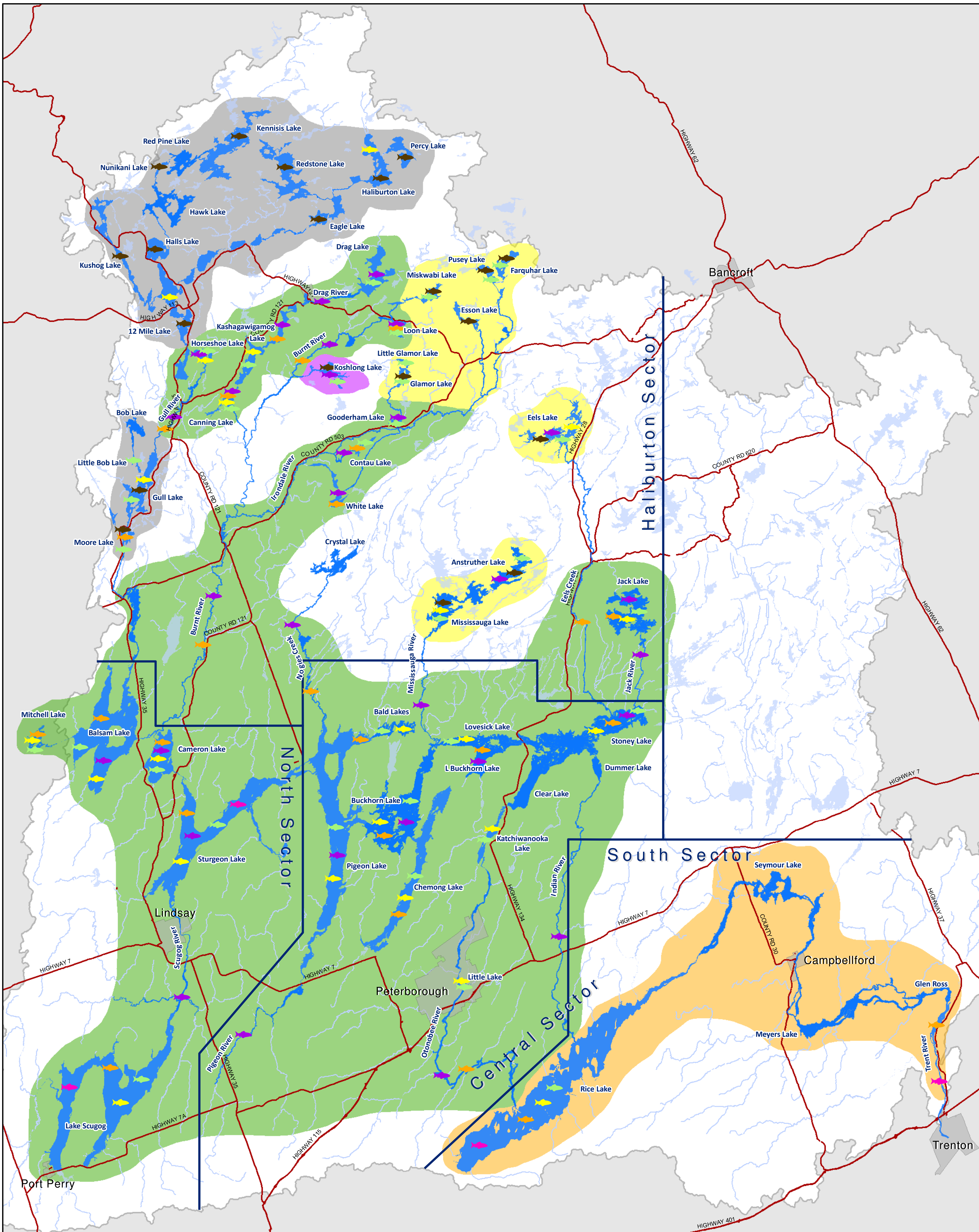
Walleye *(Sander vitreus*) prefer cool water, approximately 22°C for optimum growth, in the 3 to 10m depth range and are most abundant in water bodies greater than 100ha. Spawning habitat includes clean wind-swept shoals in lakes, rocky white-water streams and flooded marshes. Spawning occurs in the spring and walleye are susceptible to water level reductions below the April 1st water level when spawning begins and mid to late May when fry emerge.

Muskellunge (*Esox masquinongy*) prefer water temperatures from 24-25°C for optimum growth. Lakes most suitable for Muskellunge are typically larger than 100ha, with 25-50% area coverage with emergent or submergent vegetation. Spawning typically occurs in shallow, vegetated areas 1-2m deep and are known to spawn in water as deep as 9m. Muskellunge are susceptible to drops in water level from spawning in late April through the embryo and larval stages in mid to late May.

Smallmouth Bass (*Micropterus dolomieu*) prefer relatively warm water, approximately 28°C, and are well distributed throughout the lakes and connecting channels of the TSW. Males of this species construct and guard the nests. Typically spawning occurs over gravel in flowing water or over rocky areas of lakes at depths of 5-7m when water temperatures reach 20-25°C.

Largemouth Bass (*Micropterus salmoides*) prefer water temperatures of approximately 30°C, slightly warmer than the Smallmouth Bass and is found over soft bottoms and in marshes of shallow parts of lakes and small to large rivers. Like the Smallmouth Bass, male Largemouth Bass construct and guard nests. Spawning occurs from May to June at water temperatures of 16-23°C.

Smallmouth and Largemouth Bass are not particularly vulnerable to present TSW canal operations, however they represent suitable indicator species owing to their wide distribution throughout the Waterway and their position in the food web.



Lakes	Fish Species	Watershed
Kennisis Lake	Lake Trout	Gull River
Red Pine Lake		
Nunikani Lake	Lake Trout	
Hawk Lake		
Halls Lake	Lake Trout	
Kushog Lake	Lake Trout	
Twelve Mile Lake	Lake Trout	
	Largemouth Bass	
Horseshoe Lake	Walleye	
	Largemouth Bass	
	Smallmouth Bass	
Gull River	Muskellunge	
	Walleye	
Gull Lake	Lake Trout	
	Largemouth Bass	
	Smallmouth Bass	
Little Bob Lake	Smallmouth Bass	
Bob Lake		
Moor Lake	Lake Trout	
	Muskellunge	
	Smallmouth Bass	
Eagle Lake	Lake Trout	
Redstone Lake	Lake Trout	
Haliburton Lake	Lake Trout	
	Largemouth Bass	
Percy Lake	Lake Trout	

Lakes	Fish Species	Watershed
Mitchell Lake	Muskellunge	Kawartha Lakes
	Largemouth Bass	
	Smallmouth Bass	
Balsam Lake	Muskellunge	
	Walleye	
	Largemouth Bass	
	Smallmouth Bass	
Cameron Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Sturgeon Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
	Lake Sturgeon	
Lake Scugog	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
	Lake Sturgeon	
Bald Lakes	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Pigeon Lake	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	

Lakes	Fish Species	Watershed
Pigeon River	Walleye	Kawartha Lakes
Buckhorn Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Chemong Lake	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Lower Buckhorn Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Lovesick Lake		
Clear Lake		
Stoney Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Dummer Lake		
Katchiwanooka Lake	Largemouth Bass	
	Smallmouth Bass	
Little Lake	Largemouth Bass	
	Smallmouth Bass	
Ontonobee River	Walleye	
	Muskellunge	

Lakes	Fish Species	Watershed
Burnt River	Walleye	Burnt River
	Muskellunge	
Canning Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Drag River	Walleye	
Drag Lake	Lake Trout	
	Smallmouth Bass	
Koshlong Lake	Lake Trout	
	Walleye	
	Smallmouth Bass	
Loon Lake	Walleye	
	Largemouth Bass	
	Smallmouth Bass	
Miskwabi Lake	Lake Trout	
	Smallmouth Bass	
White Lake	Walleye	
	Muskellunge	
Contaue Lake	Walleye	
	Muskellunge	
	Smallmouth Bass	
Gooderham Lake	Walleye	
	Smallmouth Bass	
Glamor Lake	Lake Trout	
	Smallmouth Bass	
Little Glamour Lake	Smallmouth Bass	
Esson Lake	Lake Trout	
Pusey Lake	Lake Trout	
	Smallmouth Bass	
Farquhar Lake	Lake Trout	
	Smallmouth Bass	

Lakes	Fish Species	Watershed
Nogies Creek	Walleye	Nogies Creek
	Muskellunge	
Crystal Lake		
Mississauga River	Walleye	Mississauga River
Mississauga Lake	Lake Trout	
	Largemouth Bass	
	Smallmouth Bass	
Mississauga Creek		
Anstruther Lake	Lake Trout	
	Walleye	
	Smallmouth Bass	
Eels Creek	Muskellunge	Eels Creek
Eels Lake	Lake Trout	
	Walleye	
	Largemouth Bass	
	Smallmouth Bass	
Jack River	Walleye	Jacks Creek
Jack Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Indian River	Walleye	Rice Lake
Rice Lake	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
	Lake Sturgeon	
Seymour Lake		Trent River
Myers		
Glen Ross		
Trent		
Trent River	Muskellunge	
	Lake Sturgeon	

Note: Fish symbol only identifies the particular species within a lake or river, not an exact location.

Trent-Severn Waterway: Water Management Study

Fish Distribution Patterns for the Water Management Study Area

UTM 17 NAD 83 Datum	May 2011	1:450,000
0 4 8 16 Kilometers		FIGURE 5 - 4

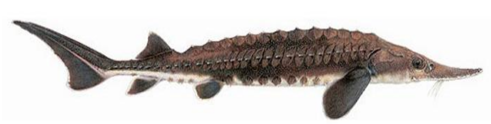
Lake Trout Only
Lake Trout & Walleye
Muskellunge & Bass
Walleye, Bass & Muskellunge
Lake Trout & Bass
Lake Sturgeon
Muskellunge
Smallmouth Bass
Lake Trout
Largemouth Bass
Walleye
Management Sector
Major Roads
Storage Reservoirs

Parcs Canada Parks Canada AECOM

5.2.3 Species at Risk

Key habitat and life history characteristics are presented for several SAR that occur in parts of the TSW. The use of these species as integrative indicators of general ecosystem conditions or to inform general water management practice is limited because of their limited distribution in the Waterway. Nevertheless, knowledge of their locations, life cycle and habitat characteristics is useful for local water management decision making. In addition, the Waterway operators may be obligated under the Endangered Species Act of Ontario and/or the Species at Risk Act (SARA, Federal) to ensure that SAR are not "harmed, harassed or killed" as a result of TSW operations. Their occurrence has been noted here, but further investigation would be required to satisfy the Acts.

Lake Sturgeon (*Acipenser fulvescens*), listed Special Concern in Ontario under SARA, have been identified in the Trent River, Rice Lake, and Sturgeon Lake (MNR 2002). This species is typically found in large rivers and lakes over mud, clay, sand or gravel in waters 5-10m deep. Lake Sturgeon typically spawn in shallow, flowing water, less than 1m deep in some locations, from May to June when water temperatures range from 13-18°C. Given the shallow spawning areas used by Lake Sturgeon, this species is susceptible to decreasing water levels during spawning and egg incubation periods.



River Redhorse (*Moxostoma carinatum*), listed Special Concern under SARA, has been identified at Lock 3 (Glenn Miller), Lock 4 (Batawa), and Lock 7 (Glenn Ross). Pools and swift runs in medium to large rivers are suitable for this species where it is found over gravel, cobble, and rubble or bedrock substrate. The River Redhorse typically spawns in riverine locales in late May-June over rocky substrates at water temperatures ranging from 16-20°C. River Redhorse in the Trent River spawn at water depths ranging from 0.2 to 1.2m and are susceptible to reductions in water depth over this period.

Channel Darters (*Percina copelandi*), listed Threatened under SARA, occur at Lock 1 (Trenton), Lock 3 (Glenn Miller), and Lock 7 (Glenn Ross). This species typically occurs in warm waters of pools and margins of riffles over sand and gravel substrate in small to medium size rivers, and over sand and gravel beaches in lakes. Spawning occurs in June and July when water temperatures reach 19-22°C over rock and gravel substrates in riverine locations at depths typically less than 1m. Given the shallow spawning areas used by Channel Darter, this species is susceptible to decreasing water levels during spawning and egg incubation periods.

5.3 Wildlife

Due to the unique location of the Trent Severn Waterway through "The Land Between", there is greater biodiversity than elsewhere in Ontario and a corresponding greater concentration of Species at Risk (SAR). SAR are designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) based on reviews of the health of the population in Ontario and across Canada. Species listed by COSEWIC are subject to the requirements of the federal Species at Risk Act. Many of them are also subject to the Ontario Endangered Species Act as designated by the Committee on the Status of Species At Risk in Ontario (COSSARO). In order to evaluate the potential water management effects that may create an impact to wildlife, a number of species were selected with critical portions of their life cycle determined by water depths, and for which data were available. Due to the rarity of SAR in the watershed, it was important to also choose representative species more commonly found.

5.3.1 Data Sources

The Natural Heritage Information Centre (NHIC) provided baseline data to map Species at Risk within the Trent Severn Waterway. Joan Chamberlain, TSW, provided additional mapping, and passed on comments from Doug Williams, First Nation Elder (Chemong, Pigeon and Buckhorn Lake areas). Jeff Beaver provided valuable insight into conditions in the Rice Lake and Trent River region.

Data were also derived from:

- Ecoplans, Inc. 2007b. A Study of the Past, Present and Future of Water Management on the Trent- Severn Waterway National Historic Site of Canada Consultation Report. Parks Canada Agency
- Gartner Lee Limited *In Association With* French Planning Services Inc., 2002. Shoreline Environmental Studies in Support of Official Plan Policies. The Corporation of the City of Kawartha Lakes
- Ontario Nest Record Study housed at the Royal Ontario Museum, and we thank Mark Peck for making these records available to the study.

5.3.2 Mammals, Birds and Herptile Indicator Species and Life History Requirements

The following species were chosen because they are valuable components of the Trent Severn ecosystem and represent the biodiversity of the system and have a portion of their life cycle dependent on water level management. Many are also listed species by COSEWIC and/or OSSARO.

Table 5-1 - Non-fish Indicator Species for TSW Water Management

Plants	Birds	Herptiles (Turtles and Amphibians)*	Mammals
• Wild Rice • Atlantic Coastal Plain Species	• Common Loon • Marsh Wren (colonial nester) • Virginia Rail • Sora • Least Bittern (Threatened) • Pied-billed Grebe • Black Tern (colonial nester)	• Northern Map Turtle (Threatened) • Eastern Musk Turtle (Threatened) • Blanding's Turtle (Threatened) • Spotted Turtle (Endangered) • Frogs: Northern Leopard, Bullfrog, Green Frog	• Beaver • Muskrat

**many of these species hibernate communally (several to many individuals over-wintering in one area = hibernaculum) and are therefore disproportionately vulnerable to water management impacts*

5.3.3 Species Descriptions

Each species or species group is described below with respect to the critical portion of the life cycle that is susceptible to water level fluctuation. The rationale for water level management is provided. Guidance is based on capturing the majority of reproductive effort and/or hibernation, but is not inclusive of the full range of dates over which the activity occurs. **Table 5-3** provides a summary of the sensitivity, guidance and the relative level of concern for three indicator lakes within the three representative regions in the study area.

5.3.3.1 Plants

Wild Rice

This native, aquatic grass sprouts annually from seed. It grows best in quiet bays or slow moving streams on organic soil with a mixture of silt or clay where there is some water movement. The seeds require light to germinate, so shallow water is important in the spring. An ideal depth is 0.3m; however it will grow in depths ranging from 0.15m to 1.5m. By June the leaves are floating on the surface of the water making that a stage sensitive to water level fluctuation. It is well distributed throughout the TSW and occurs in large virtual monocultures in Pigeon, Mitchell, Sturgeon and Bald Lakes. Ironically it is quite restricted in Rice Lake due to historical changes in water depth.

Sensitivity:
Wild Rice is susceptible to water level fluctuations at the germination stage and at the floating leaf stage in June.

Guidance:
Maintain water levels within 0.2m of spring maxima until mid-July.

Atlantic Coastal Plain Species

During the retreat of the last glaciation, there was a period approximately 11,000 years ago when the Champlain Sea extended up the valley of the St. Lawrence as far as Ottawa. Plants typical of the Atlantic Coast were able to colonize far inland, and even extended west along the ancient watercourse that connected the inland sea to the glacial lake engulfing what would become Georgian Bay. Remnants of this community of plants that favour the saturated sandy soils of the coast remain and occur on some of the Reservoir Lakes. Meadow Beauty is an example of one of these eastern relicts.

Sensitivity:
The community depends on moderate water level fluctuation to provide the disturbance to maintain this community. Extreme fluctuations would result in flooding or alternatively, desiccation of the community. A Recovery Plan is in place as many of these species are rare in Ontario. Their distribution is restricted to only a few Reservoir Lakes.

Guidance:
Drawdown up to 0.3m starting in mid-May.

5.3.3.2 Birds

Common Loon (Gavia immer)

Breeding evidence is found throughout the Trent Severn Watershed and the population within Ontario are generally considered stable (Atlas of Breeding Birds of Ontario 'ABBO' 2001-2005). This species was listed (Blue List 1981 82; Local Concern 1986) on the basis of vulnerable nesting habitat. Overall, flooding of the nests due to mortorboat wash is likely a bigger concern than drawdowns (M.Peck, *Pers. Comm*.). However, from a water management perspective, allowing water levels to rise during nesting could be fatal to the eggs. Loons cannot walk on land due to the location of the legs well back on the body. Therefore, a drawdown that made nest access more difficult not only makes the birds more vulnerable to predation, but increases the chances that the eggs will be knocked from the nest during struggles to reach it. Nest building occurs in May and June with chicks hatching in late June or early July (McIntyre 1988, Breeding Bird Atlas of Ontario, 2008). If the nest is lost early enough in the season, re-nesting can occur (McIntyre 1988, Campbell *et al.* 1990). Breeding pairs rear only one brood each year of one or two chicks. Nests are formed of simple vegetative mats located at the water's edge on marshy shorelines or islands. Nest data

(ONRS) indicate eggs as close as 3cm to the lake, but also note the use of muskrat houses and low scrapes at the water's edge. Nesting occurs from late May through early July (incubation from 26 to 31 days), and the chicks, while immediately active, remain at the nest after hatching.

Sensitivity:
Naturally nesting loons on shorelines/islands are significantly susceptible to fluctuating water levels, affecting nesting success that may contribute to the decline of populations. Lakes with fluctuating water levels may constitute an ecological trap for this species.

Guidance:
Stable water levels should be maintained in May through early July during nesting (6 weeks).

Marsh Wren (Cistothorus palustris)

Breeding evidence is found throughout the Trent Severn Watershed with higher concentrations focused along Lake Ontario (around Kingston). Breeding occurs predominantly in shallow to deep water cattail marshes. Large shallow water emergent marshes with good interspersion tend to support larger populations (ABBO 2001-2005). Nests are domed structures using woven vegetation and are either spherical or elliptical in shape, conspicuous early in the season. Ontario records (ONRS) indicate that the nests occur as close as 10 cm above the water and are active from late May to early July. Incubation requires 12 to 16 days and the young fledge 13 to 16 days later.

Sensitivity:
Nesting above water typically in cattails, water level increases could inundate nests while drawdown may expose the supporting plants to damage and desiccation.

Guidance:
Water level as of late May should be maintained throughout to the end of June (3½ to 4½ weeks).

Black Tern (Chlidonias niger)

Breeding colonies are most frequently encountered in The Land Between, along the Waterway, but not in the Reservoir Lakes. Significant declines in probability of observations were noted throughout its range as compared to the previous atlas. Egg laying occurs typically between May 31 and June 21 although the ONRS records eggs as early as May 18 and as late as June 28. Its preferred nesting habitat is a wetland with a ratio of 50:50 of emergent vegetation and open water. Black Tern nests are relatively small and flimsy, found to be nearly flush with the water surface. They are typically built on upturned cattail root, floating vegetation mat or a patch of mud. Eggs require incubation for 19 to 21 days and up to 21 days for the young to leave the nest. Several Royal Ontario Museum records show that nests were located between 5cm and 20cm above the water surface.

Sensitivity:
Due to their proximity to the water, nests are highly susceptible to water fluctuations during egg laying and incubation.

Guidance:
No increase to water levels from May 25 to July 25 to avoid flooding the nest and downy young. Drawdown may increase exposure of eggs and young to predators.

Least Bittern (Ixobrychus exilis)

The breeding range is concentrated in The Land Between but records are scattered throughout southern Ontario, but largely absent from the Reservoir lakes. It is most commonly found in marshes of at least 5 ha in size (James 1999, in the ABBO). Breeding sites typically are found in cattail (Gibbs *et al*. 1992b), but other vegetation including bulrushes, grasses, horsetail and willow have been used. Nests are usually found close to the edge of vegetation or near muskrat trails. They can be up to 45m away from the water's edge (Peck and James 1983). The nests are constructed on a platform of vegetation 0.2-0.7m above the water surface and water as deep as 1m. An ONRS record found a Least Bittern nest 0.2m above the water surface over 0.6 m water depth and dates range from June 7 to July 4. Incubation occurs over 19 to 20 days followed by care at the nest for another 25 days.

Sensitivity:
Nests occur on vegetation platforms typically in cattails, 0.2-0.7m above the water surface making them susceptible to flooding.

Guidance:
No increase in water levels from June 15 to July 31 to avoid flooding nest and young. Drawdown may increase exposure to predation.

Pied-billed Grebe (Podilymbus podiceps)

Breeding evidence is found throughout central and southern Ontario including the Reservoir lakes and the TSW. Nesting occurs primarily in marshes dominated by cattails or bulrushes and less frequently among burreeds, spike-rushes, and arrowheads (ABBO, 2001-2005). The nesting locations are predominantly associated with larger marshes and open water, though they do occur on small ponds and beaver ponds, where shrubs instead of herbaceous emergent plants are found around the edges (Chabot and Francis, 1996). ONRS records indicate that nesting occurs mid May (one record in April) to mid-June. Nests are typically a floating platform of decaying vegetation among emergent vegetation in 0.3m to 1.0m of water (Glover ,1953; Peck and James, 1983) and confirmed by ONRS data noting that some nests failed due to flooding. Incubation occurs for 23 days and the young immediately leave the nest. Least Bittern are visual feeders, therefore maintenance of clear water is important.

Sensitivity:
The nests occur at water level therefore susceptible to flooding. This species also selects for habitat that includes shrubs requiring that water level fluctuation is limited to 0.2m.

Guidance:
To maintain shrub cover, limit water level fluctuation to 0.2m above and below spring maximum. No increase in water levels from mid May to late June.

Sora (Porzana carolina)

Although distributed throughout Ontario, breeding more typically occurs in southern Ontario but they do occur in the Reservoir lakes in emergent marshes of almost any type. They require enough exposed damp substrate for gathering invertebrate food for their young. They will breed in wetlands as small as 0.5ha and prefer water depth somewhat greater than Virginia Rail. Nests are built about 0.15m above the water from mid-May to late June (Meyer 2006) and eggs are incubated for 18 to 20 days. The young leave the nest soon after hatching and fledge in about 25 days.

Sensitivity:
Nests in marshes and needs enough exposed damp substrate to gather invertebrate food for their young therefore flooding or desiccation would make feeding the young more difficult and could reduce productivity.

Guidance:
Maintain stable water levels from May 1 through July 25.

Virginia Rail (Rallus limicola)

Atlas data indicates that this species is most common in The Land Between and the TSW, however it occurs throughout southern Ontario and frequent in the Reservoir lakes, They breed primarily in marshes with dense emergent vegetation interspersed with shallow-water pools and mudflats. The species occurs in wetlands less than 0.2 ha, however are frequently found in wetlands greater than 1 ha. Nest sites are generally drier than those of Sora, but incubation and fledging follows as similar pattern, although adults may move broods from brood-rearing habitat as soon as the young are independant.

Sensitivity:
Nests tend to be located in high marsh areas with drier substrates and therefore more tolerant of flooding and/or drawdown.

Guidance:
Some tolerance to water level fluctuations (± 0.2m) from May 1 through July 6.

5.3.3.3 Herptiles (Turtles and Amphibians)

Aquatic frogs that hibernate under water

These species include: American Bullfrog (*Lithobates catesbeianus*), Northern Leopard Frog (*Lithobates pipiens*), Green Frog (*Lithobates clamitans*), and Mink Frog (*Lithobates septentrionalis*).

Aquatic hibernating frogs are susceptible to anoxic conditions and freezing. Typical water quality requirements include relatively high levels of dissolved oxygen (7-10ppm), low water temperatures (<4° C) and a bottom substrate that remains ice free (Survey Protocol for the Northern Leopard Frog, Alberta Species at Risk Report No.43, 2002). Frogs often move from ponds to fast flowing streams and seeps to remain unfrozen and provide adequate oxygen for survival (Lamoureux, 1999) occurring during October and November in southern Ontario. The key factors for winter survival include avoidance of freezing solid (unlike terrestrial species the aquatic species are not physiologically adapted to freezing), access to dissolved oxygen to allow for gas exchange across their skin, and avoidance of predation. These conditions are found in small, permanent streams, seeps and deep water (Helferty, 2002).

Sensitivity:
Drawdown after aquatic frogs have hibernated in the late fall and winter months may result in freezing down to the substrate that may also freeze the frogs, resulting in death, or reduced oxygen levels with lethal consequences. Exposure also increases predation.

Guidance:
Avoid drawdown after mid October through April.

Shallow water hibernating turtles

These species include: Snapping Turtle (*Chelydra serpentina*), Midland Painted Turtle (*Chrysemys picta marginata*), Blanding's Turtle (*Emydoidea blandingi*) and Spotted Turtle (*Clemmys guttata*).

Turtles in general have a significant ability to tolerate anoxic environments. Incorporating metabolic and buffering mechanisms one study found that the turtles in the lab were able to survive for 3 to 4 months at 3°C with no oxygen (Jackson, 2002). While embedding themselves in mud overwinter provides protection from predators, it is also an anoxic environment (Ultsch, 2006). They appear to return to favourable hibernation sites annually (Carroll, 1991). They appear to select sites that are deep enough for survival, but shallow enough to trigger early emergence in the spring, therefore winter flooding may create a negative impact.

Midland Painted Turtles are the most tolerant of low to zero oxygen levels. They occur throughout the study area and have also been reported to use muskrat burrows and in water up to a metre deep and embedded in mud up to 0.45m (Carroll, 1991). The mud provides insulation which may maintain a critical temperature for successful overwintering. Some evidence suggests that between November and late December they move about under the ice in their lake/pond presumably searching out an optimal hibernation spot dictated by site characteristics, as was found for two lakes in Algonquin Park (Hollinson *et al.* 2008).

Snapping Turtles, occurring throughout the study area, are vulnerable to below freezing temperature (ice reaching down to the substrate) and predation if exposed, as they hibernate in shallow waters (Brown and Brooks, 1994). A case was reported from Iowa where low water levels resulted in the death of 186 turtles of 5 species due to anoxia or freezing; a similar study from Missouri documented the deaths of 144 turtles as a result of drawdown. Some of the turtles tried to find refuge but died from exposure. In Ontario, Snapping Turtle typically hibernate in shallow water (<0.5m) and remained sedentary (Pettit *et al.,* 1995 in Ultsch, 2006) however they have been observed moving below the ice. Hibernation sites were often associated with downed woody debris, and muskrat and beaver runs and lodges. Well oxygenated water increases the potential for survival.

Spotted Turtles hibernate beneath hummocks in swamps as well as shallow water (0.3m to 0.4m) and muskrat burrows, often in groups up to 34 individuals (Ultsch, 2006). The depth may be critical to avoid freezing to the substrate (Carroll, 1991). This species emerges earlier than others in late April and has been reported from the Tri-Lakes (Trent Severn Waterway Wildlife Fact Sheet).

Blanding's Turtles make use of pools and streams, sometimes buried in mud but sometimes exposed on the bottom. They may aggregate in hibernacula to which they migrate. They appear to be less tolerant of anoxia and some may overwinter on land. They are less common but well distributed across the TSW including the Reservoir lakes (TSW data).

Sensitivity:
Drawdown could allow the water to freeze down to the substrate, killing turtles that are unable to move in response to this change. Increasing anoxic conditions might be a greater concern for Blanding's Turtles. Flooding may also create a secondary impact by delaying emergence. This may push the individuals past their tolerance for low oxygen resulting in death, or delay breeding and result in a nesting failure for that year.

Guidance:
Avoid drawdown from minimum after October 1st through to mid-May. Avoid flooding in the same time period, although this is likely a less significant issue.

Deep water hibernating turtles

These species include: Northern Map Turtle *(Graptemys geographica*) and Eastern Musk Turtle (*Sternotherus odoratus*).

Northern Map Turtle is a species of big water, preferring shallow water in large lakes and big rivers. It occurs in Rice Lake and the Trent and Otonabee Rivers with some records in Tri-lakes (TSW data). They overwinter on the bottom, often in hibernacula, in 4 to 8m of water. In spite of the near zero water temperature, hibernating Northern Map Turtles are capable of response when disturbed (Ultsch, 2006).

Eastern Musk Turtle, also known as Stinkpot Turtle, has been recorded from the Tri-Lakes through the Otonobee to Rice Lake (TSW data). It is the least anoxia tolerant of the turtles. They hibernate in mink and muskrat burrows, under over-hanging banks and under rocks, or buried in shallow mud where it can extend its neck out of the mud and in to the water column to allow for oxygen exchange.

Sensitivity:
Hibernacula in the shallow end of the range of water depths could be affected by severe winter drawdown.

Guidance:
Avoid drawdown from minimum after October 1st through to mid-May.

Turtle Nesting

Turtle nests are excavated at sites that receive a half day direct sun (Carroll, 1991), often on southwest facing slopes (Leadbeater, D. Pers. Obs., Bishop, C., Pers. Comm.). Snapping Turtles usually nest in pure sand in the open without vegetation and field edges. Heat is critical for egg development and determination of gender. Although females often range far and wide to nest, Musk Turtles tend to nest right at the shoreline (Carroll, 1991) or on muskrat houses (MacCullough, 2002) making them particularly susceptible to flooding. Painted Turtle nests have been found just above the water line on beaver lodges and they may nest in colonies. A good example of this exists at Serpent Mounds National Historic Site on the north shore of Rice Lake. Nesting occurs throughout June, with incubation typically last approximately 76 days. In a cool year the eggs may not hatch until the following spring.

Northern Map Turtle hatchlings overwinter in the nest (Ultsch, 2006) as do Midland Painted Turtles (Carroll, 1991). They appear to have the capability to withstand partial freezing that they lose as adults. Snapping Turtles must avoid freezing therefore will leave the nest unless the hatchlings can dig below the frost line.

Sensitivity:
There is a risk that flooding will destroy nests. This is not only significant for the incubation period, but through the first winter for species that overwinter as hatchlings or embryos in the nest, emerging in the spring.

Guidance:
Avoid flooding June 1 through to May 20.

5.3.3.4 Mammals

Muskrat (*Ondatra zibethicus*) construct underwater entrances to their houses in the banks of lakes and rivers. These mammals spend much of the winter either in their homes or swimming under the ice after freeze-up. The depth of the entrance to muskrat houses typically are not modified after early October, thus they are susceptible to flooded houses or frozen entrances if water levels fluctuate more than 0.2m from early October until the spring freshet (Beaver, J. Pers.Comm.).

Beaver (*Castor canadensis*) construct lodges in sufficiently deep water that will not freeze to the bottom. When building in a pond, the beavers first make a pile of sticks and then eat out one or more underwater entrances and two platforms above the water surface inside the pile. Beaver lodges and entrances are susceptible to freezing if water levels in the fall rise or fall after beaver have finalized lodge elevation and entrance holes.

Smith and Peterson (1991) observed that beaver behaviour in reservoirs with fluctuating water levels differed from that in stable conditions, and that the impact to the health of the animals was negative. They recommend that the total annual water fluctuation should not exceed 1.5m, and winter drawdown should not exceed 0.7 m. This is consistent with observations (Beaver, J., Pers. Comm.) that winter drawdown should be limited to 0.5 m for beaver, and even less for muskrat. Jeff Beaver also noted that when drawdowns occur that freeze muskrat and/or beaver into their lodges, that they will chew through the roof and wander about until they die of exposure. The muskrat population on Rice Lake was reduced by an order of magnitude following a severe drawdown in 2009 (Beaver, J., Pers. Comm.). These animals are of particular interest to aboriginal communities.

Sensitivity:
Both species build lodges for overwintering and cache food that is accessible from the underwater burrows below the ice. Water level fluctuations up until October can be accommodated, but as the lakes and waterways begin to freeze their ability to adapt is compromised.

Guidance:
Do not drawdown from October 1 to April 30.

5.4 Summary of Geographic Distributions, Habitat and Life Cycle Requirements for Aquatic Species

Based on natural environment information available for the Trent Severn Waterway, indicator species sensitive to water level management were identified. **Table 5-2** shows habitat suitability requirements and general geographic distributional abundance for fish species. Similar information for birds, herptiles and mammals appear in **Table 5-3**.

Wild Rice, found in greatest abundance in the southern sector, and predominantly in Rice Lake, is sensitive to fluctuating water levels from early April when seeds germinate until mid-July (**Table 5-4**).

The North and Central sectors of the Waterway support relatively high abundances of Black Tern, Marsh Wren, Least Bittern, frogs and turtles that hibernate in deep water. The birds listed above are sensitive to water level fluctuations that occur between May and June. The frogs and turtles are sensitive to freezing as a result of water level reductions that occur from when they begin hibernation in October to when the emerge the spring – typically April and May (**Table 5-4**).

All sectors of the TSW (Reservoir Lakes, North, Central and South) support high abundances of the following species: Common Loon, Pied-Billed Grebe, turtles hibernating in shallow water, nesting turtles and incubation of eggs, Beaver and Muskrat. The Common Loon and Pied-Billed Grebe, found in all sectors of the TSW, are sensitive to water level fluctuations from mid-May to late June; Muskrats and Beaver are sensitive to reductions in water levels from when they establish winter entrances to their lodges in early October until late April or early May after ice on the Waterway has thawed. In warm summers turtle eggs deposited in June will hatch in September and are sensitive to flooding only while incubating during the summer months. In cool summers incubating eggs hatch the following summer because temperatures are too low for eggs to complete the incubation cycle within a single summer season. These eggs can be sensitive to flooding from June when eggs are laid to the following May when they emerge (**Table 5-4**). Northern Map Turtle eggs typically do not hatch the same summer they are deposited and over-winter in the nest.

As a taxonomic group, indicator fish species in the TSW exhibit more regional distribution patterns than the aquatic indicator birds, amphibians, reptiles and mammals in the TSW. Lake Trout are found almost exclusively in the Reservoir Lakes. Incubating Lake Trout eggs are sensitive to reductions in water levels that occur after early October when they spawn until after fry emerge the following March (**Table 5-4**).

Although they occur in low abundance in all sectors, Walleye and Muskellunge are found in highest abundance in the North and Central Sectors (Kawartha Lakes) of the TSW. These species typically begin to spawn in May when water temperatures reach 4°C (Walleye) or 9°C (Muskellunge) and incubating eggs are sensitive to stranding and desiccation if water levels reduce after spawning occurs and before fry emerge from the eggs (**Table 5-4**).

Largemouth and Smallmouth Bass occur in greatest abundance in the North, Central and South Sectors of the Waterway. These species typically spawn in May and June when relatively stable water levels are maintained for navigation, thus these species are not particularly sensitive to TSW canal operations. Nevertheless attention should be paid to these species if future changes in Waterway operations are considered due to their economic interest associated with recreational fisheries.

Lake Sturgeon, River Redhorse, and Channel Darter are listed under federal or provincial Species at Risk legislation. These species are found predominantly in the South Sector of the Waterway and are sensitive to water level reductions that occur after the onset of spawning in mid-May until after fry emerge in early to mid-July (**Table 5-4**).

This information on species geographic distribution and life cycle sensitivities provides the basis to identify potential natural environment impacts from present water level management and canal operations assessed in **Section 6**, and information used to develop new water management ranges and operational constraints in **Section 7**.

Table 5-2 - Typical Habitat and Spawning Requirements

Adult Habitat	Spawning habitat and conditions	General Suitability		
		Haliburton Reservoirs	North/Central Sectors	South Sector
Lake Trout				
• Cold, deep waters of lakes, typically 12 to 18 m deep • Below the thermocline in summer time • Preferred water temperature 9-13°C	• Substrate: cobble, rubble • Season: September to November • Water Temperature: 9-14°C • Incubation: until fry emerge by March 31st	High	Low	Low
Walleye				
• Lacustrine, at depth up 20 m • Backwaters and runs of medium to large rivers • Preferred water temperature: 19-23°C	• Lacustrine, riverine • Substrate: rocky, boulder to coarse gravel shoals • Season: April to May • Fry emerge in mid to late May • Water Temperature: 4-11°C	Moderate	High	Low
Muskellunge				
• Lacustrine: medium to large lakes • Marshy areas • Preferred Water Temperature: 22-26°C	• Lacustrine, riverine • Season: late April to May • Fry emerge in mid to late May • Water Temperature: 9-16°C	Low	High	Low-moderate
Smallmouth Bass				
• Clear, gravel-bottom streams • Small to large rivers • Shallow (5-7m depth) sandy and rocky areas of lakes • Water temperature: 20-25°C	• Lacustrine, riverine • Gravel areas • Nest-guarders • Season: May to June • Water temperature: 13-20°C	Low-moderate	High	High
Largemouth Bass				
• Shallow lakes, small to large rivers • Marshes often with soft bottom substrate • Water temperature: 26-30°C	• Lacustrine, riverine • Nest-guarders • Season: May-June • Water temperature: 16-23°C		High	High
Lake Sturgeon				
• Large lakes and rivers • Usually 5-10m deep over mud, clay, sand, gravel • Water temperature: 15-17°C	• Riverine, lacustrine • Season: May-June • Water temperature: 13-18°C	Low	Low-moderate	High
River Redhorse				
• Pools and swift runs of medium to large rivers • Gravel, cobble, boulder, bedrock substrate • Water temperature: cool	• Riverine • Rocky substrate • Season: May-June • Water temperature: 15-24°C	Low	Low	High
Channel Darter				
• Pools and margins of riffles over sand and gravel substrate in small to medium size rivers • sand and gravel beaches in lakes • Water temperature: warm	• riverine • rocks and gravel substrate • season: June-July • Water temperature: 19-22°C	Low	Low	High

Table 5-3 - Habitat Sensitivities for Shoreline Plants, Wildlife and Fish

Indicator	Sensitivity to Water Level Fluctuation	Haliburton Reservoirs	North/Central Sectors	South Sector
Wild Rice	Needs mud substrate and 30 cm min. depth; tolerates fluctuations similar to hydrograph of Mitchell Lake Wild Rice is susceptible to water level fluctuations at the germination stage in May and at the floating leaf stage in June.	Low	Medium	High
Atlantic Coastal Plain Species	The community depends on moderate water level fluctuation to provide the disturbance to maintain this community. Extreme fluctuations would result in flooding or alternatively, desiccation of the community. Recovery Plan is in place as many of these species are rare in Ontario. Restricted to only a few reservoir lakes.	Medium	n/a	n/a
Common Loon	Naturally nesting loons on shorelines/islands are significantly susceptible to fluctuating water levels that affect nesting success may contribute to the decline of populations. Lakes with fluctuating water levels may constitute an ecological trap for this species.	High	High	High
Black Tern	Due to their proximity to the water, nests are highly susceptible to water fluctuations during egg laying and incubation	n/a	High	High
Marsh Wren	Nesting above water typically in cattails, water level increases could inundate nests while drawdown may expose the supporting plants to damage and desiccation.	Low	High	High
Sora	Nests in marshes and needs enough exposed damp substrate to gather invertebrate food for their young therefore flooding or desiccation would make feeding the young more difficult and could reduce productivity.	Low	High	High
Virginia Rail	Nests tend to be located in high marsh areas with drier substrates and therefore more tolerant of flooding and/or drawdown.	Medium	High	High
Least Bittern	Nests occur on vegetation platforms typically in cattails, 0.2-0.7 m above the water surface making them susceptible to flooding.	Medium	High	High
Pied-billed Grebe	The nests occur at water level therefore susceptible to flooding. This species also selects for habitat that includes shrubs requiring that water level fluctuation is limited to 20 cm.	High	High	High
Frogs – hibernation	Drawdown after aquatic frogs have hibernated in the late fall and winter months may result in freezing down to the substrate that may also freeze the frogs, resulting in death, or reduced oxygen levels with lethal consequences. Exposure also increases predation.	Moderate	High	High
Turtles – shallow water hibernating	Sensitive to drawdown after hibernation mid to late October on shorelines; Drawdown could allow the water to freeze down to the substrate, killing turtles that are unable to move in response to this change. Increasing anoxic conditions might be a greater concern for Blanding's Turtles. Flooding may also create a secondary impact by delaying emergence. This may push the individuals past their tolerance for low oxygen resulting in death, or delay breeding and result in a nesting failure for that year.	High	High	High
Turtles – deep water hibernating	Sensitive to drawdown after hibernation mid to late October if depths reduced to <2 m; oxygen depletion issues. Hibernacula in the shallow end of the range of water depths could be affected by severe winter drawdown.	Do not occur	High SAR species	High SAR species
Turtle nesting and Hatchling overwintering	There is a risk that flooding will destroy nests. This is not only significant for the incubation period, but through the first winter for species that overwinter as hatchlings or embryos in the nest, emerging in the spring.	High	High	High
Beaver and Muskrat	Both species build lodges for overwintering and cache food that is accessible from the underwater burrows below the ice. Water level fluctuations up until October can be accommodated, but as the lakes and waterways begin to freeze their ability to adapt is compromised.	High	High	High

Indicator	Sensitivity to Water Level Fluctuation	Haliburton Reservoirs	North/Central Sectors	South Sector
Lake Trout	Lake Trout spawn in cobble and rubble substrates at depths as shallow as 1 m. The spawning season extends from late September to November when water temperatures achieve 9-14°C. Eggs incubate through the winter during which period they are susceptible to reductions in water levels. Fry emerge by March 31st after which time they are no longer sensitive to water level reductions, unless reductions are sufficient to reduce cold, well-oxygenated deep-water habitat substantially.	High	Low	Low
Walleye	Walleye spawn in lacustrine and riverine environments on suitably located substrates ranging from rocky, boulder to coarse gravel shoals. Spawning occurs from April to May at water temperatures of 4-11°C and fry emerge in mid to late May. Walleye are sensitive to water level reductions from April when spawning begins until mid to late May when fry emerge.	Moderate	High	Low
Muskellunge	Muskellunge spawn in water depths or 1-2 m and often less than 1 m over muck and sand and matted vegetation. Spawning occurs in late April to May shortly after ice-out when water temperatures range from 10-15°C and typically leave the spawning areas when water temperatures reach 16°C. Because they frequently spawn in water depths of less than 1 m, Muskellunge are highly sensitive to water level reductions that occur after spawning until fry emerge in May.	Low	High	Low-moderate
Smallmouth Bass	Smallmouth Bass typically spawn in lacustrine and riverine environments over gravel substrates at depth greater than 1.5 m. Spawning season occurs in water temperatures ranging from 13-20°C and extends from May to June when fry emerge. Smallmouth Bass are sensitive to reductions in water levels after spawning begins in May; however water levels typically fall below spring time highs before Smallmouth Bass begin spawning.	Low-moderate	High	High
Largemouth Bass	Largemouth Bass typically spawn in lacustrine and riverine environments over soft substrates at depth greater than 1.5 m. Spawning season occurs in water temperatures ranging from 16-23°C and extends from May to June when fry emerge. Largemouth Bass are sensitive to reductions in water levels after spawning begins in May; however water levels typically fall below spring time highs before Largemouth Bass begin spawning.	Low	High	High
Lake Sturgeon	Lake Sturgeon typically spawn in riverine, lacustrine and lacustrine environments from early May to late June when water temperatures reach13-18°C. Lake sturgeon spawn at depths between 0.6 and 4.5 m in fast flowing water typically over clean, coarse substrates such as gravel, rubble and broken angular rock. Sturgeon are sensitive to water level reductions after spawning begins in May until larvae drift downstream in June; however water levels typically fall below spring time highs before Sturgeon begin spawning.	Low	Low-moderate	High
River Redhorse	River Redhorse typically spawn in lacustrine habitat at depths of 0.5 to 1 m over rocky substrate in May and June when water temperatures reach 15-24°C. River Redhorse are sensitive to water level reductions after spawning begins in May until larvae drift downstream in June; however water levels typically fall below spring time highs before this Redhorse species begins spawning.	Low	Low	High
Channel Darter	Channel Darter spawn in riverine habitat in water depths of approximately 0.5 m over rocks and gravel substrate. Spawning occurs in June-July when water temperatures range from 19-22°C. Channel Darters are sensitive to water level reductions after spawning begins in May until larvae drift downstream in June; however water levels typically fall below spring time highs before Channel Darters begin spawning.	Low	Low	High

Table 5-4 - Timing for Life Cycle Requirements Sensitive to Water Level Fluctuations by Sector

Species	Jan		Feb		Mar		April		May		June		July		Aug		Sept		Oct		Nov		Dec	
Haliburton Reservoirs																								
Common Loon										■	■	■												
Pied-Billed Grebe										■	■	■												
Turtle hibernation (shallow)	■	■	■	■	■	■	■	■	■										■	■	■	■	■	■
Turtle nesting	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■
Muskrat	■	■	■	■	■	■	■	■											■	■	■	■	■	■
Beaver	■	■	■	■	■	■	■	■	■										■	■	■	■	■	■
Lake Trout	■	■	■	■	■	■												■	■	■	■	■	■	■
North and Central Sectors																								
Common Loon										■	■	■												
Marsh Wren											■	■	■											
Black Tern										■	■	■												
Least Bittern											■	■	■											
Pied-Billed Grebe										■	■	■												
Frog Hibernation	■	■	■	■	■	■														■	■	■	■	■
Turtle hibernation (shallow)	■	■	■	■	■	■	■	■	■										■	■	■	■	■	■
Turtle nesting	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■
Muskrat	■	■	■	■	■	■	■	■											■	■	■	■	■	■
Beaver	■	■	■	■	■	■	■	■	■										■	■	■	■	■	■
Walleye							■	■	■	■														
Muskellunge								■	■	■														
Smallmouth Bass									■	■	■	■												
Largemouth Bass									■	■	■	■												
South Sector																								
Wild Rice							■	■	■	■	■	■	■											
Common Loon										■	■	■												
Marsh Wren											■	■	■											
Black Tern										■	■	■												
Least Bittern											■	■	■											
Pied-Billed Grebe										■	■	■												
Frog Hibernation	■	■	■	■	■	■														■	■	■	■	■
Turtle hibernation (shallow)	■	■	■	■	■	■	■	■	■										■	■	■	■	■	■
Turtle nesting	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■
Muskrat	■	■	■	■	■	■	■	■											■	■	■	■	■	■
Beaver	■	■	■	■	■	■	■	■	■										■	■	■	■	■	■
Smallmouth Bass									■	■	■	■												
Largemouth Bass									■	■	■	■												
Lake Sturgeon										■	■	■	■											
River Redhorse										■	■	■	■											
Channel Darter										■	■	■	■											
Non-Specific																								
Sora										■	■	■	■	■										
Virginia Rail									■	■	■	■	■											

Note: Species within each Sector reflect those with high sensitivity to water level fluctuations, as described in Table 5-3.

5.5 Conclusions

In this chapter key habitat functions sensitive to water level management in the Trent Severn Waterway were identified. Key management sectors in the TSW and species distributions and SAR that occur within these sectors were also identified. Indicator species were identified and described in terms of habitat suitability and sensitivity to water level management in the Waterway and we described an approach to use the life cycle requirements of these species as an approach to water level management to support the natural environment goal and objectives. In **Section 6** and **Section 7** a combination of expert judgement and information found in the scientific literature is employed to identify and assess potential impacts of Waterway operations on the life cycle needs and habitat requirements of the indicator species identified in this section.

The findings from **Section 5** revealed some data gaps and the need for additional investigation described below. Some of the additional data and information requirements include:

- Updated and more detailed species distributions to refine lake specific water level management;
- Flood lines and topographic surveys to delineate potential habitat;
- Groundwater contributions;
- Wetted areas in fish spawning locations – especially at control structures;
- Detailed natural features mapping; and
- Specific habitat details at locations.

Additional natural environment investigations could focus on opportunities to mitigate the impacts of the current water management practices (e.g., water levels, timing, locations) on the key species and habitats that are most vulnerable to these practices.

6. Impacts of Current Approach to Water Management

This section evaluates the current water control operations of the Waterway, characterized in the report "**Water Management Manual – Description of the Current Approach to Water Management**", in terms of how well the Water Management Process and the Water Management Goals are addressed.

6.1 Impacts of Current Approach to the Water Management Process

The Water Management Process describes the steps required to make decisions with respect to the management of the Waterway. The Water Management Process is made up of two separate but related processes:

- The Operational Management Process; and
- The Constraint Management Process.

These two processes are illustrated again in **Figure 6-1**. The Operational Management Process describes the core activities of Parks Canada staff in the water control operations of the TSW, while the Constraint Management Process describes the activities undertaken to establish the constraints, or "Management Ranges", which describe the desired upper and lower limits for the water levels or flows in a specific lake or river. The Water Management Process was developed as a representative framework under which the activities of the TSW water control activities could be organized and enhanced; this process does not necessarily represent the current methodology in the TSW. As such, this section attempts to evaluate how the current approach is similar to the proposed Water Management Process in order to identify potential areas for enhancement.

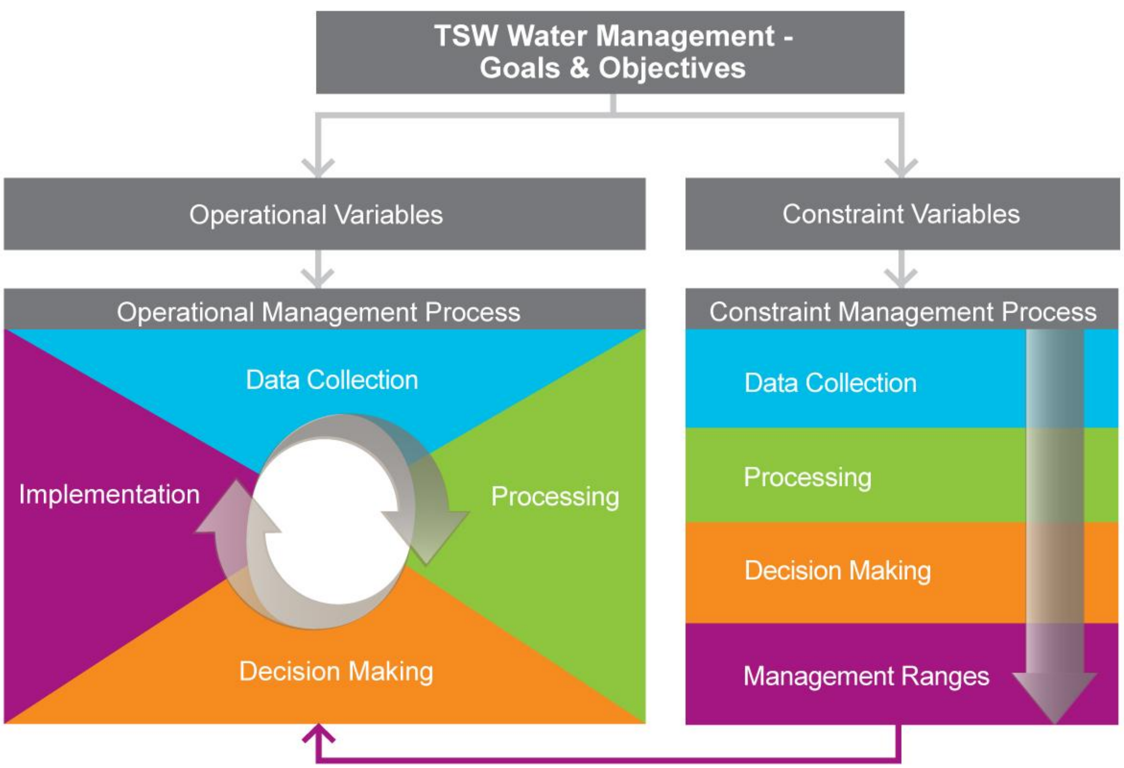


Figure 6-1 - The Water Management Process

Each of these processes include steps of Data Collection, Processing and Decision Making, resulting in an Implementation decision with respect to the water control operations of the Waterway (i.e., increase or decrease water levels or flows at certain locations), or the establishment of a Management Range to consider in the processing of operational data (i.e., minimum water levels or flows for navigation in summer or fish spawning in fall). The extent to which the current system operations address the Operational and Constraint Management Processes is described in the following sections.

6.1.1 The Current Approach to the Operational Management Process

The Operational Management Process represents the core activities of the water control operations in the Waterway: the day-to-day operations of the locks, dams and other water control structures to manage the flows and water levels in the Waterway through regular monitoring, the balancing of water between the different components of the Waterway (i.e., the Haliburton Reservoir Lakes and the Kawartha Lakes), and the communications with staff to implement management decisions. The current approach is discussed below in the context of the components of the Operational Management Process:

Data Collection

The first component of the Process is data collection of operational variables (i.e., flow and water level). The collection of water levels and flows throughout the Waterway is a well-established procedure for TSW operators. Most lakes in the North, Central and South sectors have automated water level gauges installed, allowing data to be automatically downloaded for management purposes. Most lakes in the Haliburton sector do not have automated gauges and require the water level to be recorded from manual gauges at each reservoir which can be time consuming and labour intensive. Meteorological data is not used in a significant way for operations, other than the monitoring of snowpack to gain insight into the spring freshet; however, the snowpack monitoring has also decreased in recent years, and may be contributing to difficulties with filling the Reservoirs.

The freshet assessment also forms part of the data collection component, and is currently performed by measuring the water equivalency in the snowpack at five sites throughout the Waterway. If the snowpack is found to be smaller than anticipated, some of the stoplogs may be placed in the Haliburton Reservoirs to ensure that the lakes are completely filled. However, if the snowpack is larger than anticipated, additional stoplogs will not be removed from the reservoirs, since the goal is to fill the lakes, not to mitigate high flows from the freshet. The freshet assessment includes a qualitative assessment of the ground conditions to estimate the proportion of the snow that will runoff into the lakes; however, the assessment observes only whether the ground is frozen or unfrozen, and does not assess water content or saturation levels, limiting its usefulness in estimating freshet runoff.

Processing and Decision Making

The second component of the Process is the processing of operational data. Until recently, a hydraulic model was used to determine the required stop log settings in the Haliburton Reservoirs to provide the desired flows in the Waterway. The model was developed in 1973 by Acres, and has been periodically updated as available technology has changed. The hydraulic model calculates the required stop log settings to achieve an equal percentage withdrawal of water from the Reservoirs, based on the total available reservoir storage. The model does not include a hydrologic element to predict inflows into the system, which may provide benefit to the optimization of operations. In addition, the available modelling does not provide information or strategies on how to accommodate high and low flow situations.

Use of the current processing tools (e.g., water levels, model outputs) results in the third component of the Operational Management Process: decision making. The water control engineer evaluates various strategies and issues operational instructions to satisfy the Water Management Goals. However, other than the established navigational ranges, much of the consideration of Water Management Goals occurs integrally with the operational decisions, resulting in the potential for inconsistency. Decisions about optimum water levels or flows to satisfy the Water Management Goals should instead be isolated to the Constraint Management Process.

Implementation

The final component of the Process is the implementation of operational decisions issued by the water control engineer. There are many dams that are controlled with hydraulic gates, allowing a great deal of control over water levels, but also many dams, particularly in the Haliburton Sector, that are operated by stoplogs. Stoplogs require are labour intensive to operate and do not permit the same level of control over the water levels in the reservoir; however, water control operations could still be optimized given these restrictions.

6.1.2 The Current Approach to the Constraint Management Process

The Constraint Management Process describes the activities undertaken to establish the constraints for water control operations in the Waterway, including the evaluation of a diverse array of variables that impact the goals and objectives of the Waterway. The frequency that this process is undertaken depends on the variable, and specifically the data being evaluated; for example, the review of historic flood events and levels need only be completed once to establish the historical record, and then updated only when new events occur.

Similar to the Operational Management Process, data collection is the first component of this Process. There are many different variables that can be considered in the Constraint Management Process (detailed in the **Data Collection and Management Guide**), describing data related to hydrology, climate, natural environment and social considerations. Currently, much of these data are not collected or evaluated in a manner that would impact the operational water levels (i.e., Management Ranges).

The processing and decision making components of this Process are not completed in a significant way under the current operations. There is no formal process to evaluate new data as it arises and incorporate the results into the management ranges.

Several management ranges currently inform water level management in the Waterway, including:

- Navigation ranges on the navigable portions of the Waterway, including maximum navigational flows in key areas;
- Drawdown schedules for the Kawartha Lakes and Haliburton Reservoirs to provide storage for the freshet;
- Minimum flows for water intakes, wastewater discharges and sustaining lake levels; and,
- Isolated environmental flow requirements for fish spawning, established through existing MOU’s with the Ministry of Natural Resources.

The most prominent example of a management range for the current operations is the 25-year minimum and maximum water levels. These water levels are used to assess the lakes and reservoirs, which are generally determined to be in an acceptable range if the water levels are within the 25-year minimum and maximum level. However, since this range is a moving average, the levels will vary over time as old years are excluded from the average and new ones are included, or as years of extreme operations (i.e., droughts or floods) skew the average readings. This drift can be difficult to account for when attempting to audit the performance of Waterway operations. However, a benefit of using the 25-year average as a management range is that long-term changes in operational conditions, such as climate change, are implicitly accommodated: over time as the climate changes, water control operations will adjust to new levels of precipitation and evaporation.

Management ranges are more prominent in the navigable portion of the Waterway (i.e., North, Central and South Sector), due to the emphasis on maintaining navigational water levels. There are few water level range requirements in the Haliburton Reservoirs, other than the winter settings to accommodate the freshet. There are isolated environmental requirements in the fall to manage water levels in the Reservoirs for fish spawning, but these do not form part of the established management range to govern operations.

Many of the considerations that should be integrated into a management range are instead evaluated on a day-by-day basis during water control operations, resulting in potentially inconsistent operational procedures. Formalized management ranges, established through the Constraint Management Process, would provide operators with water level and flow ranges that must be maintained throughout the year. The ranges implicitly account for the Water Management Goals, and thus the Goals do not need to be considered during operations, allowing potential for a greater level of optimization to be achieved.

6.2 Impacts of Current Approach to the Water Management Goals

The Water Management Goals, first described in **Section 1.3**, were developed to better represent the increased expectations that are faced by the current managers and operators and address the complete range of stakeholder interests in the Waterway. These goals are:

1. Reducing threats to public safety and negative impacts to public and private infrastructure from over-bank flooding, ice damage, extreme water level fluctuations, and high volume flows.
2. Contributing to the health of Canadian through the availability of drinking water for residents, cities and towns throughout the watershed.
3. Providing safe boating and navigation along the marked navigation channels of the Trent Severn Waterway
4. Protecting significant aquatic habitats and species.
5. Optimizing the enjoyment of the water throughout the watershed by shoreline residents and visitors.
6. Allowing hydroelectric generation plants to operate at plant capacity and meet demand for renewable energy insofar as possible.

The current water control operations in the Waterway include consideration of each of these goals, either formally or informally. The following sections describe how the current operations address these goals, and identify potential impacts of the current approach to the goals.

The current approach is not clear regarding the prioritization of the Water Management Goals. In the case of a conflict between one goal and another, there is no protocol for resolution except for reducing threats to public safety, which is always of highest priority.

6.2.1 Goal 1 - Reducing Threats to Public Safety and Infrastructure

Protecting public safety is currently one of the foremost goals of water management. However, there are several limitations to operations that can impact the satisfaction of this goal, including:

- Limited available storage to manage flash floods when lakes are full;
- No absolute maximum water level for dam safety, typically defined by a Dam Safety Review (DSR);
- No clear procedures for high water levels;
- Limited capability to implement water management decisions in some situations (remoteness of lakes, safety of management staff, man power, frozen logs, etc.);
- Limited ability to control flows in some areas; and
- Limited warning of flows from the Crowe River in the South Sector.

When lakes and reservoirs are filled following the spring freshet, there is little additional capacity to accommodate event-based floods. Instead, extensive operations are required throughout the Waterway to adjust dam settings and increase flows to mitigate flooding. There are also no established maximum flows at the Waterway dams for dam safety or established procedures to accommodate high flows beyond the extensive operations to pass the flows.

The spring freshet is currently managed only to fill the Haliburton Reservoirs to supplement the navigable portion of the Waterway during the navigation season. The assessment of the freshet is conducted using five snow course surveys, estimating a snow pack water equivalency which is then extrapolated to the representative area for that site. The water equivalency is converted to a total runoff volume, assuming that the entire volume will enter the Reservoirs. With improved freshet forecasting methods, it may be possible to manage the Reservoir winter settings to not only fill up the Reservoirs each year, but also improve flood mitigation and therefore reduce threats to public safety.

There are, however, certain limitations in the Waterway that reduce the ability of water managers to respond to high flow events. These are hydraulic bottlenecks where increases in flows cause potentially large increases in water level, and therefore water must be controlled upstream to mitigate flooding, including the Gull River between Norland and Coboconk, Cameron Lake and Katchewanooka Lake.

6.2.2 Goal 2 - Contributing to Health of Canadians

This goal includes managing water to address water supply and water quality (i.e., assimilative capacity for wastewater discharge) requirements. The locations of water intakes and wastewater discharges in the Waterway are established and well known to operators. The requirements specific to these locations, such as water levels and flows, form part of the current water control strategy, allowing them to be easily incorporated into new management ranges. Examples of minimum flow requirements in the Waterway due to water supply or quality needs include:

- Coboconk - $12.7m^3/s$;
- Peterborough - $22.6m^3/s$;
- Otonabee River at Peterborough - $17m^3/s$; and
- Buckhorn Lake (i.e., downstream of Lock #31) - $3m^3/s$.

6.2.3 Goal 3 - Safe Boating and Navigation

Maintaining appropriate water levels and flows for navigation has long been one of the primary functions of the Waterway. Navigational ranges for water levels and flows are well established throughout the navigable portion of the Waterway. The Haliburton Reservoirs are filled each spring to provide supplementary water to maintain navigation in downstream areas, releasing water gradually through the summer to offset evaporation in the large Kawartha Lakes. However, as the lakes and Reservoirs have evolved into one of Ontario's foremost cottage destinations, and also supporting many permanent residents, there has been increased pressure to balance navigation against maintaining higher water levels in the Haliburton Reservoirs. Although there is a legislated mandate to maintain navigation, there may be opportunity to improve the management of the Reservoir storage volume.

6.2.4 Goal 4 - Protect Significant Habitat and Species

6.2.4.1 Existing Water Level Management

The timing for key life history requirements such as germination, reproduction, over-wintering, and nest-building for resident species along the Trent Severn Waterway coincide with some general predictabilities in the timing, magnitude, frequency, rate of change and duration of the natural hydrologic flow regime. The natural flow regime is modified from natural conditions owing to normal Waterway operations, thus the Waterway influences habitat suitability for resident species in negative ways.

Owing to natural environmental concerns and observed impacts created to fish habitat resulting from water management in the TSW, Parks Canada canal operations and natural resource management agencies have sought agreement on the following water management protocols:

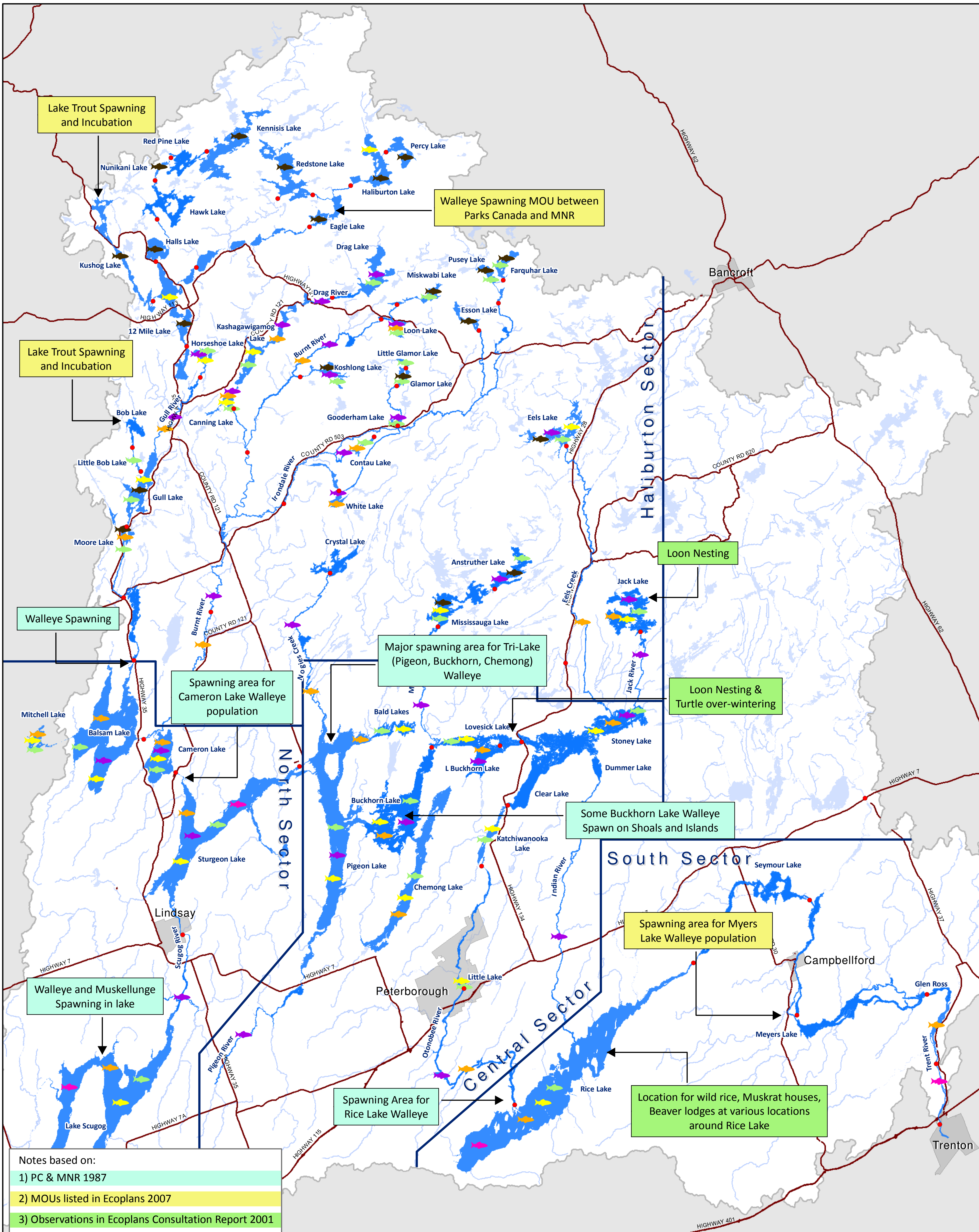
- Prevent drawdown from stranding fish in shallow waters when oxygen levels may decline;
- Provide sufficient flow downstream of dams to support migration and spawning of adult fish and maturing young-of-the-year fishes;
- Delay drawdown of lakes where fish are highly vulnerable to harvest and over-exploitation;
- Coordinate major repairs or renovations of waterway structures to avoid sensitive life cycle phases and to improve spawning habitat near these structures; and
- Balance impacts created to users of the system and to plant and animal habitats.

6.2.4.2 Lake-Specific Water Management Procedures and Agreements

Cooperation in the form of discussions and informal agreements between Parks Canada and Natural Resources Management Agencies, Department of Fisheries and Oceans and Ontario Ministry of Natural Resources, have modified some water management procedures to benefit fisheries. These primarily focus on timing of water level draw downs on particular lakes. For example:

- Draw down on Mitchell Lake occurs over a three-week period in November so that fish have sufficient opportunity to seek deeper waters in this shallow lake. In addition, some of the valves in the guard gate near Balsam Lake are left partially open over the entire winter to allow oxygenated water to flow into Mitchell Lake.
- Prior to mid-November draw down in Lower Buckhorn and Lovesick Lake is delayed and water levels kept high to decrease angling catchability below the control dam at Buckhorn and reduce risk of over-exploitation. After mid-November, drawdown is completed by early December so fish have the opportunity to move to deeper waters.
- Rubble generated from dam repairs was placed immediately downstream from the dam at Young’s Point to enhance Walleye spawning habitat.

Some of these agreements are displayed in **Figure 6-2**.



Lakes	Fish Species	Watershed
Kennisis Lake	Lake Trout	Gull River
Red Pine Lake		
Nunikani Lake	Lake Trout	
Hawk Lake		
Halls Lake	Lake Trout	
Kushog Lake	Lake Trout	
Twelve Mile Lake	Lake Trout	
	Largemouth Bass	
Horseshoe Lake	Walleye	
	Largemouth Bass	
	Smallmouth Bass	
Gull River	Muskellunge	
	Walleye	
Gull Lake	Lake Trout	
	Largemouth Bass	
	Smallmouth Bass	
Little Bob Lake	Smallmouth Bass	
Bob Lake		
Moor Lake	Lake Trout	
	Muskellunge	
	Smallmouth Bass	
Eagle Lake	Lake Trout	
Redstone Lake	Lake Trout	
Haliburton Lake	Lake Trout	
	Largemouth Bass	
Percy Lake	Lake Trout	

Lakes	Fish Species	Watershed
Mitchell Lake	Muskellunge	Kawartha Lakes
	Largemouth Bass	
	Smallmouth Bass	
Balsam Lake	Muskellunge	
	Walleye	
	Largemouth Bass	
	Smallmouth Bass	
Cameron Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Sturgeon Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
	Lake Sturgeon	
Lake Scugog	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
	Lake Sturgeon	
Bald Lakes	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Pigeon Lake	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	

Lakes	Fish Species	Watershed
Pigeon River	Walleye	Kawartha Lakes
Buckhorn Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Chemong Lake	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Lower Buckhorn Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Lovesick Lake		
Clear Lake		
Stoney Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Dummer Lake		
Katchiwanooka Lake	Largemouth Bass	
	Smallmouth Bass	
Little Lake	Largemouth Bass	
	Smallmouth Bass	
Ontonobee River	Walleye	
	Muskellunge	

Lakes	Fish Species	Watershed
Burnt River	Walleye	Burnt River
	Muskellunge	
Canning Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Drag River	Walleye	
Drag Lake	Lake Trout	
	Smallmouth Bass	
Koshlong Lake	Lake Trout	
	Walleye	
	Smallmouth Bass	
Loon Lake	Walleye	
	Largemouth Bass	
	Smallmouth Bass	
Miskwabi Lake	Lake Trout	
	Smallmouth Bass	
White Lake	Walleye	
	Muskellunge	
Contaue Lake	Walleye	
	Muskellunge	
	Smallmouth Bass	
Gooderham Lake	Walleye	
	Smallmouth Bass	
Glamor Lake	Lake Trout	
	Smallmouth Bass	
Little Glamour Lake	Smallmouth Bass	
Esson Lake	Lake Trout	
Pusey Lake	Lake Trout	
	Smallmouth Bass	
Farquhar Lake	Lake Trout	
	Smallmouth Bass	

Lakes	Fish Species	Watershed
Nogies Creek	Walleye	Nogies Creek
	Muskellunge	
Crystal Lake		
Mississauga River	Walleye	Mississauga River
Mississauga Lake	Lake Trout	
	Largemouth Bass	
	Smallmouth Bass	
Mississauga Creek		
Anstruther Lake	Lake Trout	
	Walleye	
	Smallmouth Bass	
Eels Creek	Muskellunge	Eels Creek
Eels Lake	Lake Trout	
	Walleye	
	Largemouth Bass	
	Smallmouth Bass	
Jack River	Walleye	Jacks Creek
Jack Lake	Walleye	
	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
Indian River	Walleye	Rice Lake
Rice Lake	Muskellunge	
	Largemouth Bass	
	Smallmouth Bass	
	Lake Sturgeon	
Seymour Lake		Trent River
Myers		
Glen Ross		
Trent		
Trent River	Muskellunge	
	Lake Sturgeon	

Note: Fish symbol only identifies the particular species within a lake or river, not an exact location.

Trent-Severn Waterway: Water Management Study

Multi-party Agreements in the Water Management Study Area

UTM 17 NAD 83 Datum | May 2011 | 1:450,000

0 4 8 16 Kilometers

FIGURE 6 - 2

Lake Sturgeon
Lake Trout
Largemouth Bass
Muskellunge
Smallmouth Bass
Walleye
Sub Basin Node
Storage Reservoirs
Major Roads
Cities

Parcs Canada Parks Canada AECOM

Mitchell and Balsam Lakes

The major river site for Walleye spawning is at Coboconk immediately downstream of the Gull River control dam (MNR – PC 1987). The usual spring flow appears adequate to support the upstream migration of Walleye from Balsam Lake and sufficient water coverage over incubating eggs and emerging fry.

Walleye spawn in numerous locations on rubble deposits in Balsam Lake. Gradual filling of the lake to normal summer level during spring, and then maintaining this level through the incubation and emergence of fry, supports spawning activity and success. Spring filling of the lake also floods the riparian wetlands and contributes to the success of Muskellunge reproduction.

Mitchell and Balsam Lakes – Operational Constraints

	Spring (Mar 1 – May 31)
Walleye (River)	Sufficient flow to support migration, incubation and emergent fry. No major change from Apr 1 to mid-May
Walleye (Lake)	Fill gradually to summer level and maintain until fry emerge
Muskellunge (Lake)	Spring fill supports spawning success

Cameron Lake

The main Walleye spawning grounds are upstream of Cameron Lake, immediately downstream from Rosedale dam and also approximately 300 m further downstream (MNR – PC 1987). Aeration of the incubating eggs requires steady flow from April 1 to mid-May. If flows are low during the spawning period, minimal flow requirements can be met by spilling water through the northern-most sluiceway of the dam. Spring filling also supports Muskellunge spawning and fry survival.

Cameron Lake – Operational Constraints

	Spring (Mar 1 – May 31)
Walleye (River)	Steady flow from Apr 1 to mid-May. Use north sluiceway to achieve minimum flow if spring flow is low
Walleye (Lake)	Maintain stable water levels until fry emerge
Muskellunge (Lake)	Spring fill and subsequent water level stabilization supports spawning success

Sturgeon Lake

Walleye spawn at two sites upstream from Sturgeon Lake: one downstream from the falls at Fenelon Falls, and the other downstream from the locks and dam in Lindsay. Water flow through Fenelon falls typically is sufficient to support Walleye reproductive requirements. While flow from Lake Scugog typically is sufficient to support Walleye migration and spawning, flows often decrease significantly or terminate during the incubation and hatching period and thus do not support the latter part of the reproductive cycle (MNR – PC 1987).

Shore and shoal Walleye spawning areas typically receive adequate water cover and aeration as long as water levels do not drastically after fish have spawned. Stable water levels also provide reproductive requirements for Muskellunge migrating to and spawning in marshes fringing the lake.

Sturgeon Lake – Operational Constraints

	Spring (Mar 1 – May 31)
Walleye (River)	Steady flow from Apr 1 to mid-May. Use north sluiceway to achieve minimum flow if spring flow is low
Walleye (Lake)	Maintain stable water levels until fry emerge

	Spring (Mar 1 – May 31)
Muskellunge (Lake)	Maintain stable water levels until fry emerge

Lake Scugog and Scugog River (upstream from Lindsay)

Lake Scugog does not have any known immigration from river Walleye spawning population. The Lake Scugog Walleye population seems dependent on in-lake, shore and shoal spawning Walleye sites for reproduction (MNR – PC 1987). Reproductive success depends on the spring fill and stable lake levels during the reproductive period. A major drop in water levels before fry are mobile could significantly reduce the reproductive success of the species.

Lake Scugog and Scugog River – Operational Constraints

	Spring (Mar 1 – May 31)
Walleye (River)	No river spawning population
Walleye (Lake)	Maintain stable water levels until fry emerge
Muskellunge (Lake)	No reproductive activity

Pigeon, Buckhorn, Chemong and the Bald Lakes

Major River spawning site for Pigeon and Buckhorn Lakes is on rubble in the Bobcaygeon River downstream of the dam (MNR – PC 1987). Other spawning locations include:

- Squaw River mouth in Bald Lakes
- Sandy Point area of Pigeon Lake
- Stone along the high span bridge and causeway at Gannon Narrows
- Island and shore locations in Buckhorn Lake

Walleye move between Pigeon and Buckhorn Lakes during the spawning period. Walleye in Chemong Lake appear to be a separate population that spawns entirely within the lake, mainly along the easterly shore, shoals and rock along the causeway at Bridgenorth.

Water level management appears adequate for the reproductive requirements of Walleye in the Pigeon, Buckhorn, Chemong, Bald Lake complex (MNR – PC 1987). General filling of these lakes during the crucial March 15 to May 15 has not caused observable adverse impact to Walleye reproductive success. As with other Walleye spawning areas, sudden decreases in water levels should be avoided during the spawning and incubation period to protect the spawn. This practice will also provide water depth and water level stability to support the reproductive success of Muskellunge spawning in the marshy areas.

Pigeon, Buckhorn, Chemong and the Bald Lakes – Operational Constraints

	Spring (Mar 1 – May 31)
Walleye (River)	Maintain stable water levels until fry emerge
Walleye (Lake)	Maintain stable water levels until fry emerge
Muskellunge (Lake)	Maintain stable water levels until fry emerge

Lower Buckhorn Lake

Walleye in Lower Buckhorn Lake typically spawn in rubble immediately downstream from the Buckhorn Dam and the highway bridge. Muskellunge utilize the northern shore inlets, and marshes and vegetated sites and marshes in the southern portion of Deer Bay (MNR – PC 1987).

Spring flows through the Buckhorn dam usually are adequate to support fish migration, incubation and hatching of Walleye spawn. Optimal success of Walleye and Muskellunge occurs when water levels inundate Muskellunge spawning areas and are maintained at or above levels observed when Walleye and Muskellunge spawn.

Lower Buckhorn Lake – Operational Constraints

	Spring (Mar 1 – May 31)
Walleye (River)	Maintain stable water levels until fry emerge
Walleye (Lake)	Maintain stable water levels until fry emerge
Muskellunge (Lake)	Maintain stable water levels until fry emerge

Lovesick Lake

Walleye spawn on rocky material immediately downstream from the main dam, beside the locks, and below some of the smaller dams. Muskellunge spawn in marshy areas near Black Duck dam, inlets around the perimeter, and in the bay on the easterly side of Wolfe Island (MNR – PC 1987).

Flows should be maintained through the main dam between April1 and May 15 to support Walleye spawn and incubation. As water flow, side dams should be stopped first and flow through main dam should be maintained to optimize Walleye spawning success. Lake levels should be stabilized after the Muskellunge spawn to support reproductive success for this species.

Lovesick Lake – Operational Constraints

	Spring (Mar 1 – May 31)
Walleye (River)	Maintain stable water levels until fry emerge
Walleye (Lake)	Spawning assumed, details unknown
Muskellunge (Lake)	Maintain stable water levels until fry emerge

Stony and Clear Lakes

Walleye spawn below Burleigh Falls is exposed when the spring freshet has a large run-off followed by a period of low precipitation (MNR – PC 1987). Options to optimize reproductive success include:

- Release more water from upstream lakes than normally occurs
- Sacrifice flow at one of the two dams at Burleigh Falls to support the spawn
- Lower the spawning rubble to reduce the risk of exposure of incubating eggs

Stony and Clear Lakes – Operational Constraints

	Spring (Mar 1 – May 31)
Walleye (River)	Maintain stable water levels until fry emerge. Consider lowering spawning rubble
Walleye (Lake)	Not applicable
Muskellunge (Lake)	Not applicable

Katchewanooka Lake

Walleye from Lake Katchewanooka spawn primarily in the river between Young's Point dam and the Highway 28 overpass, although some shore and shoal spawning may also occur. Muskellunge spawn in several in-lake marsh sites. Spring flows through Young's Point typically is more than adequate to support incubation and hatching of Walleye eggs deposited at this location (MNR – PC 1987). Operational constraints suggest the middle sluices are fully opened prior to fully opening the side sluices to reduce the risk of producing strong flows that may prevent spawning or wash away deposited eggs. As the freshet reduces, the side sluices should be closed prior to closing the middle sluices. Lake level stabilization from April 1 to May 30 provides optimum conditions for the hatch of fry from the in-lake areas.

Lake Katchewanooka – Operational Constraints

	Spring (Mar 1 – May 31)
Walleye (River)	Open side sluices after middle sluices are fully opened
Walleye (Lake)	Maintain stable levels April 1 to May 30
Muskellunge (Lake)	Maintain stable levels April 1 to May 30

Otonabee River (Upper) and Little Lake

A relatively small fishery, primarily Bass and Muskellunge, located in the River upstream from Little Lake and in the lake appears sustainable (MNR – PC 1987). No specific operational constraints to enhance the fishery are recommended.

Otonabee River (Lower), Rice Lake and the Trent River to Hastings

The area downstream from Lock 19 and its dam (immediately downstream from Lansdowne Street in Peterborough) may support the largest and most important Walleye spawning run in the Kawartha Lakes. Many Walleye migrate upstream from Rice Lake to spawn at this location.

Fry production at this site is maximized by maintaining river elevation and flow over the spawn. Large portions of spawning rubble exposed, resulting in the loss of many eggs in some years. Recognizing TSW cannot prevent changes in water volume at this site and the importance of successful reproduction to support high demands and fishing pressure on Rice Lake, MNR examined feasibility of altering the water levels over the spawning areas downstream from Lock 19 (MNR – PC 1987).

Walleye appear to utilize shoals, shoreline and areas around islands for spawning. Muskellunge reproduce in flooded marshy areas. These spawning areas further downstream from Lock 19 do not appear adversely affected by usual water level and flow fluctuations (MNR – PC 1987). Optimum reproduction occurs in these downstream areas for both species, provided reasonable lake and river levels are maintained from April 1 to May 30.

Otonabee River (Lower), Rice Lake and the Trent River to Hastings – Operational Constraints

	Spring (Mar 1 – May 31)
Walleye (River)	Little opportunity to control changes in availability of water to control levels
Walleye (Lake)	Reproduction not adversely affected by normal water level fluctuations
Muskellunge (Lake)	Reproduction not adversely affected by normal water level fluctuations

Memoranda of Understanding (MOUs)

A purpose of this investigation was to identify general constraints to provide guidance for establishing water management ranges and operational constraints to facilitate the development of an operational water management process. Although the purpose was to describe general constraint guidelines and water management ranges for the principle management sectors of the TSW, some relatively detailed operational processes in the form of Memoranda of Understanding (MOUs) have been in place for particular locations along the Waterway (**Table 6-1**). Details including currency of the agreements, and species use of the area should be updated and documented as required in future investigations.

Table 6-1 - Summary of MOUs between Parks Canada and MNR for locations along the TSW (Ecoplans 2007a)

Haliburton Reservoirs	
Location	**Eagle Lake, below dam**
Parties	MNR
Purpose	Provide water for Walleye spawning
Operational Guideline	Provide as much water as possible for the spring Walleye spawn
Duration	Walleye spawning season – inferred
Performance Criteria	Not specified
Status of Agreement	unknown
Location	**Big Bob and Kushog Lakes**
Parties	MNR
Purpose	Manage water levels to minimize risk of exposing Lake Trout eggs during incubation
Operational Guideline	Begin drawdown of Big Bob and Kushog Lakes on September 1st and continue until September 30th. No additional draw down after September 30th.
Duration	Perform draw down from September 1st to 30th.
Performance Criteria	Achieve minimum drawdown by September 30th to minimize risk of exposing Lake Trout spawn.
Status of Agreement	unknown
South Sector	
Location	**Lower Lock 19, below dam**
Parties	OFAH, MNR
Purpose	Support Walleye spawning
Operational Guideline	Provide flow from Otonabee to cover Walleye spawn downstream from Lock 19
Duration	Throughout spawning period from April 1st to May 31st
Performance Criteria	Minimum flow required to avoid exposure of Walleye spawn
Status of Agreement	Unknown

Conclusions – Lake-specific Management Agreements

While the current operations focus on public safety and navigation, agreements with the Department of Fisheries and Oceans and the Ministry of Natural Resources to manage water in the Waterway for environmental purposes have been noted and summarized in the previous sections. These agreements represent good management practices to protect sensitive life history requirements for fish based on an understanding of TSW water management and physical habitat constraints at the time of writing the agreements.

6.2.4.3 Analysis of Impacts

The existing water management guidelines for the TSW prioritize reducing threats to public safety and infrastructure and providing for safe boating and navigation. As a result, there are potential impacts to the natural environment associated with the current approach to water management in each sector of the TSW; these are described in the following sections.

Haliburton Reservoirs

The hydrograph for Kennisis Lake was used as a reference to assess potential impacts to the natural environment from existing water management ranges and operations of the TSW in the Reservoirs (**Figure 6-3**). The 25-year moving average showing water levels in Kennisis Lake indicates that levels in the fall typically are lowest after October 1st when minimum winter levels for the year are observed. In some individual years the lowest winter levels appear up to 0.3m to 0.5m less that levels observed in early October. In a few years the lowest levels are observed around October 1st, and it is these few cases that represent ideal conditions for the natural environment.

As indicated in **Table 5-4**, several species initiate key activities sensitive to water levels in early October. Lake Trout select nests and spawn; their eggs incubate typically from October until the following March. Beaver and Muskrat finalize opening to their lodges based on water levels observed in early October. Turtles and frogs select hibernation locations in early October as well.

Reductions in water levels after these activities have begun may lead to exposure of Lake Trout eggs to air, freezing of beaver and muskrat entrances and freezing of hibernating frogs and turtles if water freezes to the bottom as a result of reduced water levels. Increases in water levels after early October risk flooding beaver and muskrat lodges.

Common Loon and Pied-billed Grebe are observed in high abundance in the Reservoir Lakes. Water level fluctuations during the 6-8-week period from mid-May to late June may impact the nesting sites of aquatic birds, which have a limited mobility on land and require nesting sites constructed in the shore-fringe area. These fluctuations come at a time when the Reservoirs are still being filled from the freshet and then subsequently drained to augment downstream water levels.

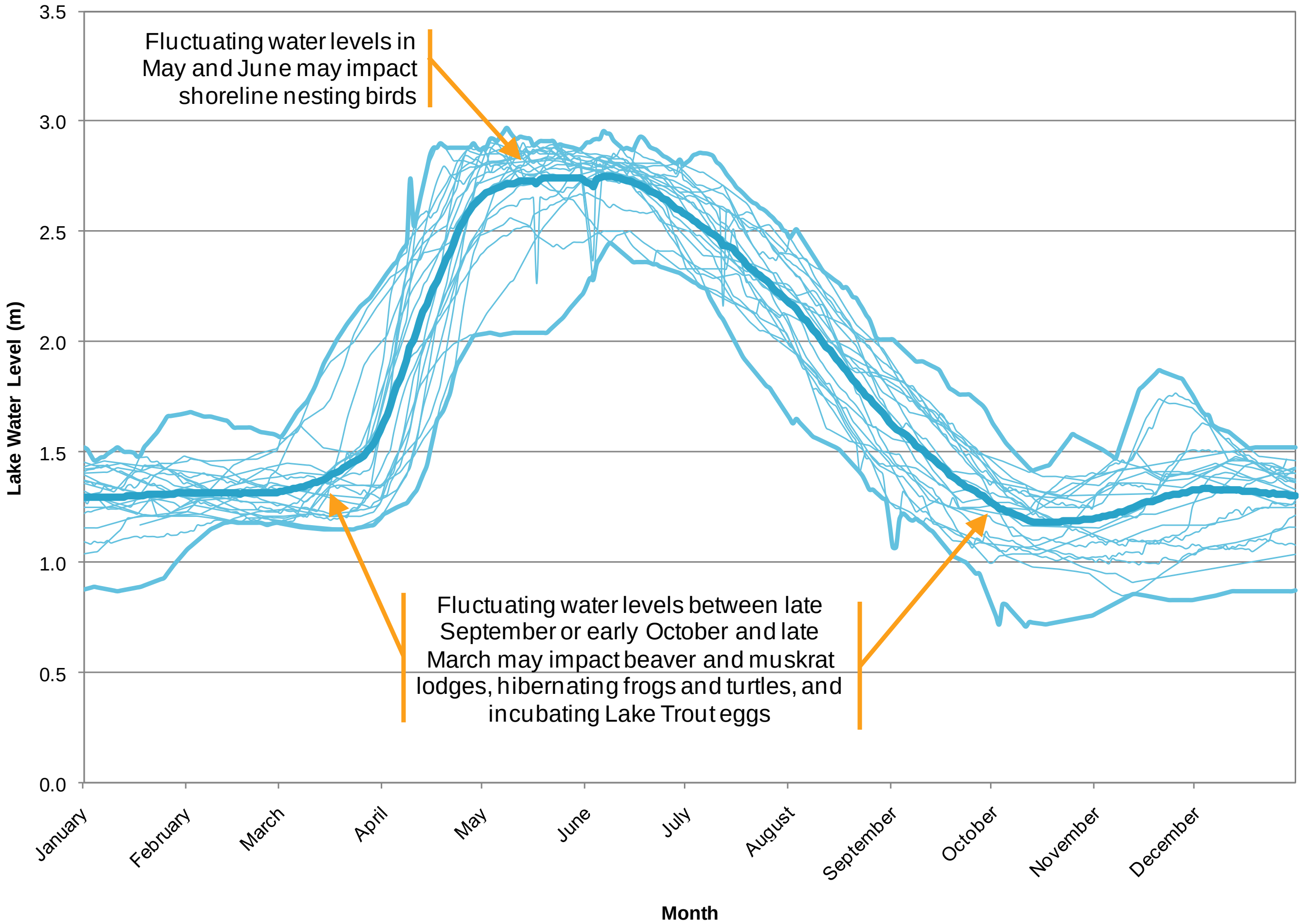


Figure 6-3 - Potential Natural Environment Impacts at Kennisis Lake

North and Central Sector

The hydrograph for Buckhorn Lake was used as a reference to assess potential impacts to the natural environment from water management ranges and operations in the North and Central sectors of the TSW (**Figure 6-4**). The 25-year moving average shows a pronounced reduction in water levels from January to late February each year followed by an increase in levels from early March to mid- to late April and then relatively stable levels through the rest of the year. Some year-to-year variability in the extent of the early spring reduction in water levels is observed, however the same pattern is observed each year.

As indicated in **Table 5-4**, life history requirements for several indicator species in the North and Central Sectors of the TSW are sensitive to water levels during the spring and summer period. Common Loon, Black Tern, Marsh Wren, Least Bittern, Sora and Virginia Rail are found in high abundance in the North and Central sector of the TSW. These species nest in spring and are sensitive to water fluctuations greater than ±0.1m from early or mid-May to late June or early July. Fish indicator species found in high abundance in the North and Central Sectors include Walleye and Muskellunge. These species spawn in the spring and are sensitive to reductions in water levels occurring after initiation of spawning in early to mid-April until fry emerge from eggs in late May. The existing hydrograph for Buckhorn Lake shows increasing water levels through this sensitive period.

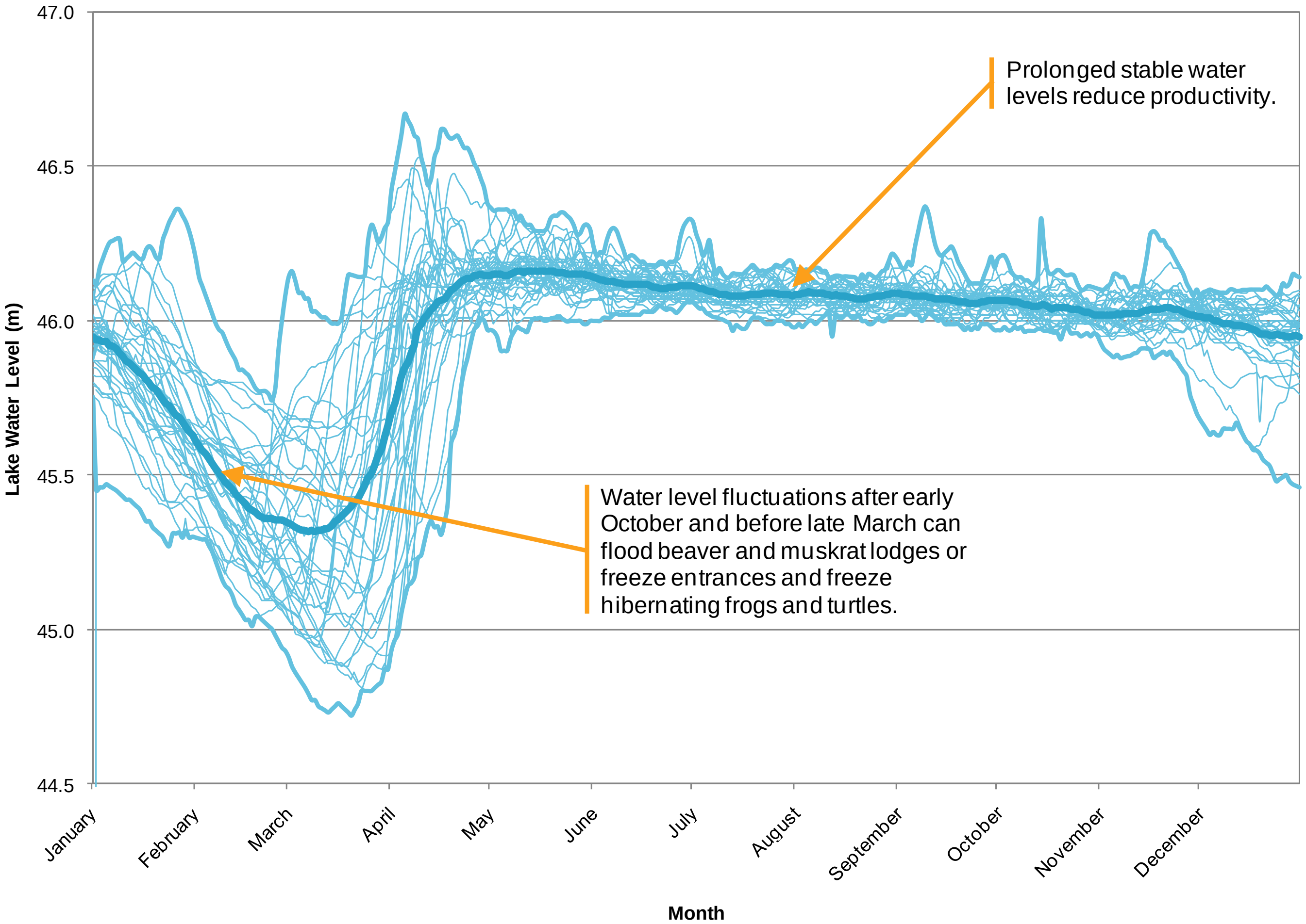


Figure 6-4 - Potential Natural Environment Impacts at Buckhorn Lake

Frogs and turtles that hibernate in shallow and deep water are found in high abundance in lakes and connecting channels of the North and Central sector of the TSW, as are beaver and muskrat. Frogs and turtles select hibernation sites and beavers and muskrats finalize entrances to their lodges in early October. Reductions in water levels after these activities have begun may lead to exposure of Lake Trout eggs to air, freezing of beaver and muskrat entrances and freezing of hibernating frogs and turtles if water freezes to the bottom as a result of reduced water levels. Increases in water levels after early October risk flooding beaver and muskrat lodges.

South Sector

The hydrograph for Rice Lake was used as a reference to assess potential impacts to the natural environment from water management ranges and operations in the South sector of the TSW (**Figure 6-5**). The 25-year moving average shows an increase in water levels from late March peaking in mid-April followed by steady decline to mid-May and then variable decline to mid-June. On average water levels are maintained with relatively low variability from mid-June until mid- September after which water levels decline to a seasonal minimum in early November. Water levels typically begin to rise in early November to levels observed during the summer months in late November and then vary between the November minimum to summer levels from December to late march when they rise again to annual maximum observed levels. Annual variation in water levels shows that frequent events 0.3m to 0.5m above the 25-year average occur throughout the year.

Wild Rice is found in high abundance in water bodies of the South Sector. This species requires mud substrates with a minimum 0.3m water depth and is susceptible to water fluctuations greater than ±0.1m during germination and floating leaf stages. Water level sensitivities for Wild Rice extend from early April until mid-July.

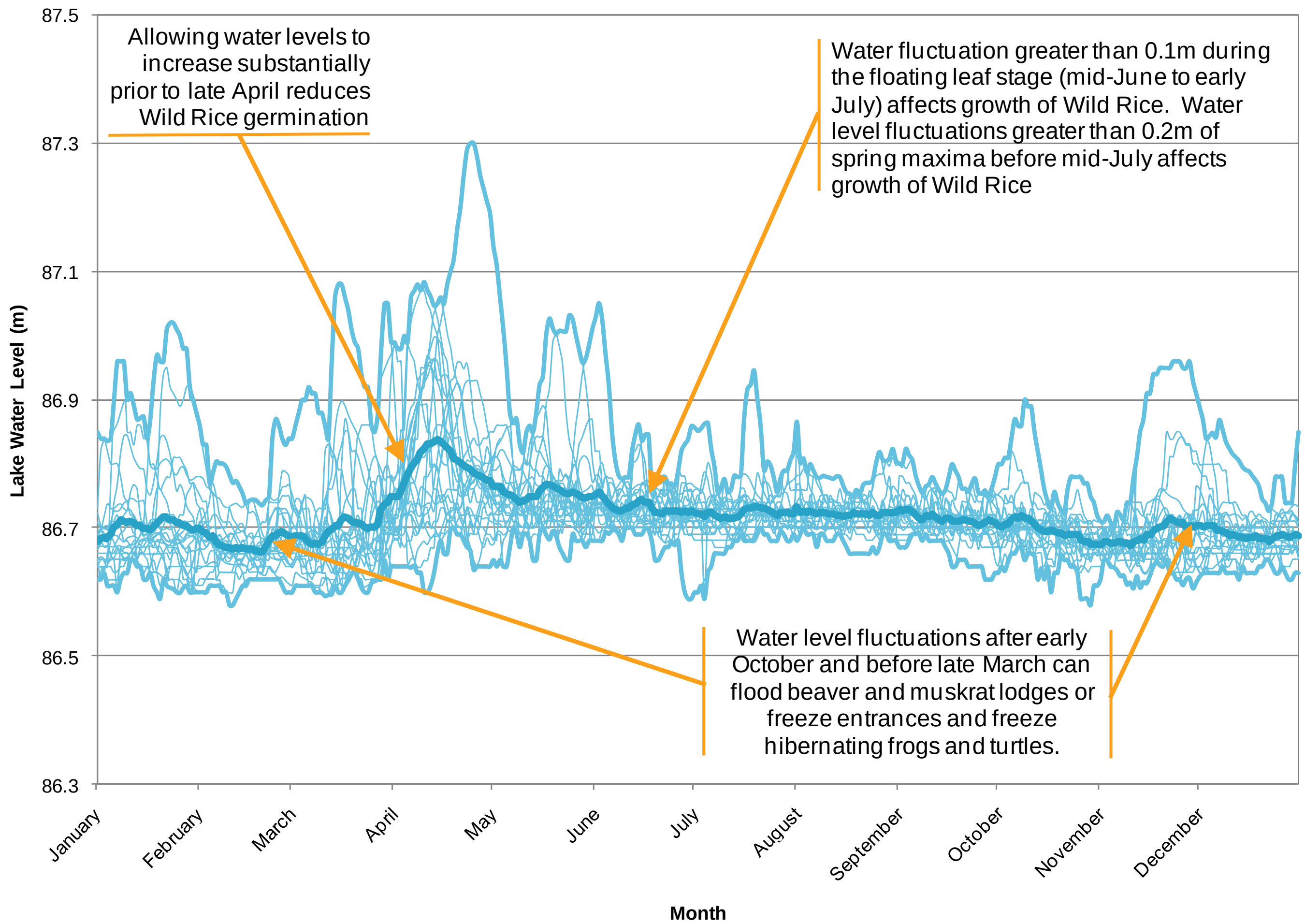


Figure 6-5 - Potential Natural Environment Impacts at Rice Lake

As with the North and Central sector of the TSW, Common Loon, Black Tern, Marsh Wren, Least Bittern, Sora, Virginia Rail, Beaver and Muskrat are found in high abundance in the South sector of the TSW. These species are sensitive to the same spring water level fluctuations in the South sector as they are in the North and Central sector of the TSW.

Fish species including Walleye and Muskellunge, and species at risk Lake Sturgeon, River Redhorse and Channel Darter, are found in the South sector of the TSW. Walleye and Muskellunge spawn in the spring and are sensitive to reductions in water levels occurring after initiation of spawning in early to mid-April until fry emerge from eggs in late May. Lake Sturgeon, River Redhorse, and Channel Darter begin spawning in early May and are sensitive to water level reductions until mid-July when fry emerge. Water levels typically increase through this sensitive period; however care should be taken to ensure that plans to maintain or increase water levels during this period are included in future water management protocols for the South sector.

6.2.5 Goal 5 - Optimize Enjoyment of the Water

This goal encompasses a number of objectives, including aesthetics, recreation, cultural resources, and public access to both the Waterway and information regarding the Waterway. Current operations focus primarily on enjoyment as it relates to navigation, but there is consideration of the residents on the Haliburton Reservoirs through the equal-percentage drawdown during the summer, ensuring that the impact is shared equally across all Reservoirs. However, there is no maximum acceptable rate of drawdown defined. In a typical year this is not an issue, but in particularly dry years the Reservoirs may be drawn down very quickly, resulting in an adverse impact to shoreline residents and cottagers.

During the summer, there are no threshold minimum water levels established for the Reservoirs other than the established winter setting. In addition, even the winter setting may be breached if more water is required to augment navigable flows (if the winter setting is not already at the sill of the Reservoir dam). This means that there is no minimum water level that must be maintained in the Reservoirs through the summer for the purpose of recreation and enjoyment of the water.

There are also concerns with the timing of the drawdown in the Reservoirs (winter settings by October) as more people become year-round residents of the Haliburton Reservoirs. Some properties are accessible only by water, and drawing down too early can impact access to these properties. Access is also an issue on the Kawartha Lakes during the fall, when navigable water levels are maintained until the winter drawdown in January to allow continued access on the Lakes, particularly for residents where road access is not available.

6.2.6 Goal 6 - Optimize Hydroelectric Power Generation

Hydroelectric generation facilities are present in every sector of the Waterway, although the largest impacts of hydro operations are felt in the South Sector where the majority of the generation facilities are located and limited storage is available. 24-hour response availability is required in order to adjust to hydro plant operations, which can turn off turbines at any time, causing water to rise in upstream areas. In the South Sector, this may cause localized flooding if the TSW dams are not adjusted promptly. The requirement to maintain this ability to respond causes a strain on manpower and scheduling, although on-call staff are required regardless of hydro power operations to attend to other emergencies on the Waterway (e.g., over-night precipitation events).

The current approach to water management does not attempt to optimize operations to increase hydro power generation. The hydro power facilities are not owned by Parks Canada, although a portion of the revenue is received by Parks Canada. Optimizing operations to increase power production, while not adversely impacting other goals, can potentially increase revenues and provide additional resources to enhance other goals.

6.2.7 Summary of Current Approach to the Water Management Goals

The potential impacts of the current approach of operations on the Water Management Goals, as described in the preceding sections, are provided in **Table 6-2**. The impacts identify ways in which the current operations could potentially be enhanced.

Table 6-2 Potential Impacts of Current Approach to Water Management Goals

Water Management Goal	Haliburton Reservoirs	North and Central Sector	South Sector
Reducing threats to public safety and negative impacts to public and private infrastructure from over-bank flooding, ice damage, extreme water level fluctuations, and high volume flows	• Limited available storage to manage flash floods when Reservoirs are full • No absolute maximum water level for dam safety, typically defined by DSR • No clear procedures for high water levels • Freshet forecast only based on snow cover • Limited capability to implement water management decisions (remoteness, man power, frozen logs, etc.)	• Limited available storage to manage flash floods when Lakes are full • No absolute maximum water level for dam safety, typically defined by DSR • No clear procedures for high water levels • Freshet forecast only based on snow cover • Bottlenecks in the system limit high water response (i.e., Cameron Lake, Katchewanooka Lake)	• No absolute maximum water level for dam safety, typically defined by DSR • No clear procedures for high water levels • Freshet forecast only based on snow cover • Limited capability to implement water management decisions (manpower, etc.) • Limited warning of flows from Crowe River
Contributing to the health of Canadian through the availability of drinking water for residents, cities and towns throughout the watershed	• The known sites are well established and water levels and flows are already identified	• The known sites are well established and water levels and flows are already identified	• The known sites are well established and water levels and flows are already identified
Providing safe boating and navigation along the marked navigation channels of the Trent-Severn Waterway	• Assess volume required to augment navigation on the Waterway	• Better assess tolerance to navigational ranges for summer and fall	• Better assess tolerance to navigational ranges for summer and fall
Protecting significant aquatic habitats and species	• Allowing water levels to drop to winter settings after October impacts fall spawning species and in-water refuge habitat • Lake water level fluctuations during the 8-week period from mid May to early July impacts nesting sites	• Allowing water levels to drop between early April and mid-May impacts spring spawning species • Allowing water levels to drop from late May to early July impacts riparian and shallow water flora and fauna • Allowing water levels to drop between late September and late March impacts in-water over-winter habitat • Fluctuations exceeding 0.1m (from mid June level) from mid June to mid July impacts aquatic vegetation	• Allowing water levels to drop between early April and late May impacts spring spawning species • Prolonged high water levels (above HWL) in April impacts aquatic vegetation (i.e., germination, etc.) • Fluctuations exceeding 10cm (from mid June level) from mid June to mid July impacts aquatic vegetation
Optimizing the enjoyment of the water throughout the watershed by shoreline residents and visitors	• Rate of Summer drawdown can impact resident enjoyment of Reservoirs • No maximum acceptable drawdown rate defined • No threshold minimum water level established • Equal drawdown does not reflect active storage volume	• Extension of navigation water levels past the navigation season not included in formal management plan	• Water levels typically maintained close to navigation range year-round due to low storage available in reservoirs
Allowing hydroelectric generation plants to operate at plant capacity and meet demand for renewable energy insofar as possible	• Operations are not optimized for power production	• Operations are not optimized for power production	• Operations are not optimized for power production • 24-hour response to hydro power activities (strain to manpower and scheduling, etc.)

7. Development of the Constraint Management Process

7.1 Overview of the Constraint Management Process

The Constraint Management Process is part of the larger Water Management Process proposed for the Trent Severn Waterway, and is shown in **Figure 7-1**. The Constraint Management Process involves the processing of data relating to the Water Management Goals, defined by constraint variables, for the purpose of establishing Management Ranges for the water control operations on the lakes and rivers of the TSW. This process is intended to be undertaken as required to address the evolving conditions in the Waterway, as opposed to the Operational Management Process which recurs on a daily basis.

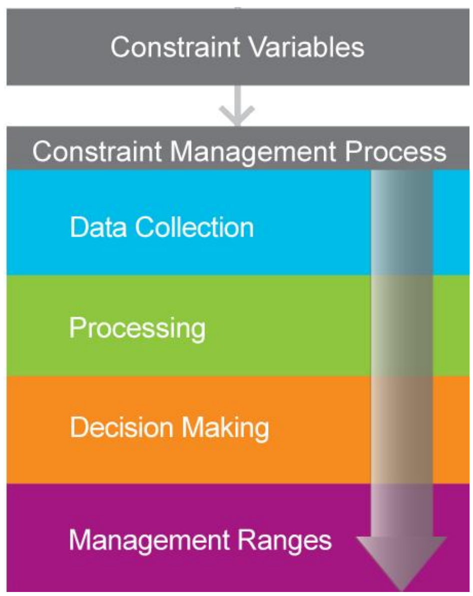


Figure 7-1 - The Constraint Management Process

The Constraint Management Process begins with the Data Collection phase, involving the characterization of the Constraint Variables. Information regarding the Constraint Variables, including available datasets and how to obtain the data, is included in the **Data Collection and Management Guide**. Cultivating an understanding of the Constraint Variables applicable to each of the Water Management Goals in each sector and season, through the Processing phase, will reveal that for each of the goals, there will be an optimal range of water levels or flows for each lake and river that will best satisfy that goal, i.e., resulting in the greatest level of utility for the users and stakeholders relating to that goal. Establishing these Goal-Specific Management Ranges is the first step towards developing a comprehensive and balanced integrated Management Range that incorporates the considerations of each of the goals and objectives. Goal-Specific Management Ranges are described in **Section 7.2**, and the range is developed for three representative lakes for the goal of protecting significant habitats and species in **Section 7.3**. The representative lakes were selected to illustrate the different management regimes that are inherent with the three sector groups, although each lake will have specific concerns that would be included in a Management Range. The representative lakes are: Kennisis Lake (for the Haliburton Reservoirs), Buckhorn Lake (for the North and Central Sectors) and Rice Lake (for the South Sector).

The Goal-Specific Management Ranges are combined into one range, the integrated Management Range, in the final phase of the Process: Decision Making. The integration incorporates the considerations of each of the Water

Management Goals, as well as the seasonal and geographical variations in optimal ranges that are inherent with the management of the Waterway. In some situations, there may be conflicts between the optimal ranges of different Goals, wherein no one integrated Management Range can best satisfy all goals. In these situations, this conflict should be resolved through a process of negotiation and conflict resolution to ensure that the concerns of all Stakeholders are recognized. The impact of these discrepancies between different ranges, or residuals, can be an important consideration when conducting these negotiations, and can help to prioritize certain Goals depending on the season or area of the Waterway. When certain conflicts are unable to be resolved to the mutual benefit of two or more Goals, or when one Goal must be favoured over another given the limitations of the system, mitigation measures can be evaluated for the potential to reduce impacts due to the conflict. These considerations are described in **Section 7.4**. Integrated Management Ranges for several representative lakes are developed in **Section 7.5**.

The methodology for developing the Management Ranges is anticipated to include the establishment of a Goals & Objectives Committee (GOC), responsible for establishing the Goal-Specific Management Ranges and for conducting the required conflict resolution and negotiation processes to arrive at the integrated Management Range for each lake and river. The use of the GOC in this process also helps to promote transparency in the development of the Management Ranges. The proposed methodology for developing the Management Ranges, including the use of the GOC and other considerations, is described in **Section 7.6**.

7.2 Goal-Specific Management Ranges

The process of developing Management Ranges is oriented around the Water Management Goals for the TSW. Each goal will have an optimal range of water levels for which it is best satisfied. For some goals, establishing this optimal Management Range is straightforward: for example, in order to satisfy the goal to provide navigation, water levels and flows must be kept at established navigational values. Other goals are not so straightforward to quantify, and will require a greater level of evaluation and consultation with stakeholders and experts to establish. This section describes the various considerations and observations that have been developed through this study relating to the anticipated optimal water levels for each goal. In addition, Goal-Specific Management Ranges are developed for the goal of protecting significant aquatic habitats and species.

7.2.1 Goal 1 - Reducing Threats to Public Safety and Infrastructure

The Goal-Specific Management Range to reduce threats to public safety and infrastructure would be oriented around the three objectives of the goal: to mitigate flooding, protect infrastructure and provide for public safety. An optimal management range for this goal would consider, at the least:

- Installed infrastructure vulnerable to fluctuating water levels in all lakes and rivers;
- Impacts to public safety due to rate of change in water levels and flows;
- Seasonal impacts of operations on public and infrastructure (i.e., impacts due to ice);
- Impacts of flooding using established assessment procedures; and
- Potential for and impacts of dam failure at each reservoir, typically as part of a Dam Safety Review (DSR).

Of particular importance for this goal is the completion of DSR’s at all of the water control structures that contribute to the water management of the TSW. A dam failure typically incurs the highest risk to public safety downstream of the dam, due to the potentially large quantities of water released in a short time.

The resulting Goal-Specific Management Range is anticipated to consist primarily of threshold high water levels or flows representing different levels of risk to infrastructure and public safety, for example:

- Optimal range – water levels and flows present a negligible risk to public safety and infrastructure, operations should strive to maintain water levels within this range.
- Warning range – high water levels or flows begin to incur a risk to public safety and infrastructure, risk is low to medium.
- Critical range – high water levels or flows present a high risk to public safety or infrastructure.

Each range would be associated with operational protocols in order to reduce risk due to water levels or flows, such as high and low water management plans, which are described further in **Section 8**.

7.2.2 Goal 2 - Contributing to Health of Canadians

The goal of contributing to the health of Canadians is comprised of two objectives: to manage for water supply (agricultural and municipal) and to manage for water quality (human health and aquatic life).

The first objective to manage for water supply is potentially more straightforward than to manage for water quality, since established water demands are typically better characterized than water quality requirements, particularly those related to the natural environment. Some of the considerations that are anticipated to be required to develop an optimal management range for water supply include:

- The locations and types (i.e., municipal, agricultural) of water demands throughout the TSW; the Permit To Take Water database of the Ministry of Environment may have information on many of these water demands;
- The intake elevation for each water demand, to establish threshold low water levels; and
- The criticality of each water demand, to establish threshold low water levels and flows; a greater margin of safety in the Management Range would be established for a critical water demand (i.e., municipal drinking water supply).

To establish a Goal-Specific Management Range to manage for water quality, both for human and aquatic health, the following considerations are anticipated to be required:

- Locations of water demands where water quality may be critical to the function of the demand (i.e., municipal drinking water) and their respective water quality requirements;
- Areas of sensitive environmental habitat where water quality may impact aquatic species; and
- Locations and requirements of wastewater discharges (i.e., minimum flow to maintain assimilative capacity).

Establishing a Management Range for water supply and water quality would consist of ensuring that the supply can be maintained, particularly at critical demands, and that sufficient flow is present for water quality concerns. Therefore, the range would primarily consist of threshold low water levels and flows, arranged into tiers representing varying levels of risk, such as the following examples:

- Optimal range – water levels and flows sufficient to maintain water supply and water quality requirements, operations should strive to maintain water levels within this range.
- Warning range – low water levels or flows begin to impair the function of some non-critical water demands, or to create water quality concerns in non-critical areas.
- Critical range – low water levels or flows significantly impair the function of critical water demand or create water quality concerns in sensitive areas.

Each range would be associated with operational protocols in order to reduce risk due to water levels or flows, such as high and low water management plans, which are described further in **Section 8**.

There have been historical concerns, identified through the research associated with this study, with high water levels and flows related to this Goal, particularly with respect to increased levels of suspended solids due to high flows and the impact on water intakes (i.e., the performance of water treatment systems). These concerns should also be incorporated into the optimal Management Range for this goal.

7.2.3 Goal 3 - Safe Boating and Navigation

Meeting the requirements for navigation is an established practice in the TSW. Water levels and flows required for navigation have been set for those lakes and rivers that are part of the navigable portion of the Waterway, and form part of the published navigational charts for the Waterway. However, if the Goal-Specific Management Range for navigation were to be reevaluated, the following considerations are expected to be required:

- Characteristics of the vessels that navigate along the Waterway;
- Reassessment of the types of vessels that would be permitted to access the Waterway; and
- Restrictions to navigation along the navigable portion of the Waterway (i.e., lock sizes, bridges, shallow areas).

It is anticipated that the existing navigational ranges would be suitable for use as the optimal Management Range for the goal of providing navigation, and that no modifications would be required for short-term use. However, additional flexibility in this Management Range may be obtained through an evaluation of boating use trends and vessel characteristics with a subsequent revision to the navigational depth that must be provided.

7.2.4 Goal 4 - Protect Significant Habitat and Species

Numerous species depend on water bodies and watercourses along the Waterway to provide suitable habitat conditions and support life cycle requirements. Activities of fish spawning, nesting birds, turtle and frog hibernation, construction of muskrat and beaver lodges are governed by the advance of the seasons and sensitive to water levels. Significant habitat and species in controlled systems are protected when unnatural water level changes are minimized during sensitive periods for species along the TSW. Sector-specific management guidance is provided in **Section 7.3**. In general aquatic species and habitat are most sensitive to water levels from early spring to early summer and in the fall until winter water levels are achieved in the TSW.

7.2.5 Goal 5 - Optimize Enjoyment of the Water

The goal to optimize enjoyment of the water consists of four objectives: to enhance aesthetics; optimize recreation; optimize cultural resources; and to provide public access, both physical access on the Waterway and access to information. The requirements that satisfy these objectives may vary from lake to lake; however, an understanding of each lake's needs is anticipated to include the following considerations:

- Locations and characteristics of properties that rely on water-based access (i.e., minimum water level required for access);
- Characteristics of lake-based recreation (i.e., seasonal timing, nature of activities, water requirements);
- Incremental impact to goal satisfaction from changes in water level (e.g., certain lakes may be affected by small changes in water level more than others, particularly those with a wide, shallow shoreline that can be easily exposed by low water levels); and
- Presence of significant cultural and tourism resources.

The resultant Management Range is expected to reflect the optimal water requirements for the various users of the Waterway for recreational, cultural and access purposes. Stakeholder surveys could potentially be used to determine the level of utility that users receive for certain water levels or flows, the results of which can be translated into a Management Range based on user satisfaction.

In addition to these considerations, public access to information is also an objective of this goal. This objective is not isolated to specific lakes, but in order to be satisfied should address the information needs of all users of the Waterway. Public access to information does not suggest or require a Management Range; however, the Constraint Management Process can help to define the communication requirements to be maintained by water management staff, including:

- Frequency of communication updates;
- Types of information communicated (i.e., water levels, flows, operational logs, forecasts);
- Staff responsibilities for communication;
- Protocols for addressing and communicating unusual conditions on the Waterway; and
- Requirements for public open-houses, stakeholder meetings, educational campaigns, etc.

7.2.6 Goal 6 - Optimize Hydroelectric Power Generation

The current operations of the Waterway provide for hydroelectric power generation only in as much that the generation facilities can use the flow of the Waterway for generation. However, under the current operations flows will not be intentionally increased or decreased for the purpose of generation (i.e., water will not be released from the Haliburton Reservoirs for the purpose of hydro generation). The Goal-Specific Management Range to optimize hydroelectric power generation would consider:

- Flow schedule to optimize production, including an economic analysis (i.e., to account for variable pricing of electricity);
- Characteristics of individual generating facilities (i.e., maximum and minimum flows, intake elevation); and
- Coordination required by Parks Canada staff for hydro operations (i.e., additional adjustment of dam settings, maintenance of hydro facilities).

7.3 Goal-Specific Management Ranges for Natural Environment (Representative Lakes)

7.3.1 Reservoir Lakes

Maintaining relatively stable water levels from early May until late June in the Haliburton Lakes will support shoreline nesting birds such as the Common Loon and Pied-billed Grebe. By achieving winter water levels in late September or early October, to simulate natural conditions, and maintaining these levels until the ice breaks up the following spring, entrances to muskrat and beaver lodges will remain at appropriate positions relative to water levels and the lodges will not be at risk of freezing. This achievement of water levels will also protect hibernating turtles and frogs from freezing and incubating Lake Trout eggs from freezing or from exposure to air. Finally, reducing the overall amplitude of the overall hydrograph in the Haliburton Lakes will more closely reflect natural conditions and will generally benefit aquatic species in the area. The natural environment Goal-Specific Management Range for Kennisis Lake, as representative of the Haliburton Reservoirs, is shown in **Figure 7-2**.

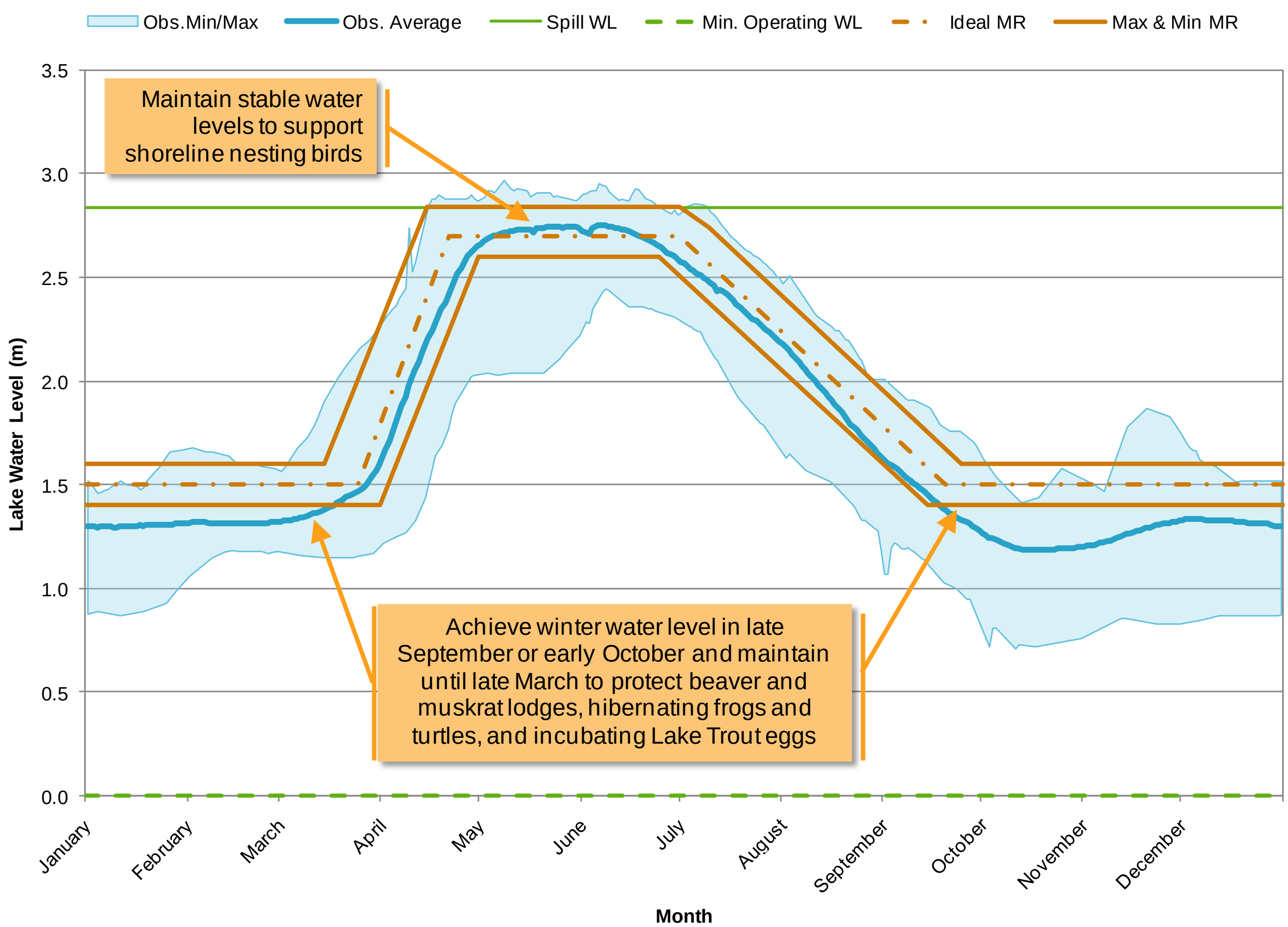


Figure 7-2 - Natural Environment Goal-Specific Management Range for Kennisis Lake

7.3.2 North/Central Sector

Achieving the winter water levels in late September or early October and maintaining these levels will protect muskrat and beaver lodges, and hibernating turtles and frogs. Allowing water level increases in lakes of the North and Central sector beginning in early April through mid-May will protect spawning areas for spring spawning species such as Walleye and Muskellunge. By holding water levels steady from mid-May until late June, nesting areas for shoreline birds should be protected. Note that this range accounts only for the optimal natural environment conditions, and does not consider the needs of other goals (i.e., to fill the lake for navigation). The natural environment Goal-Specific Management Range for Buckhorn Lake, as representative of the North and Central Sectors, is shown in **Figure 7-3**.

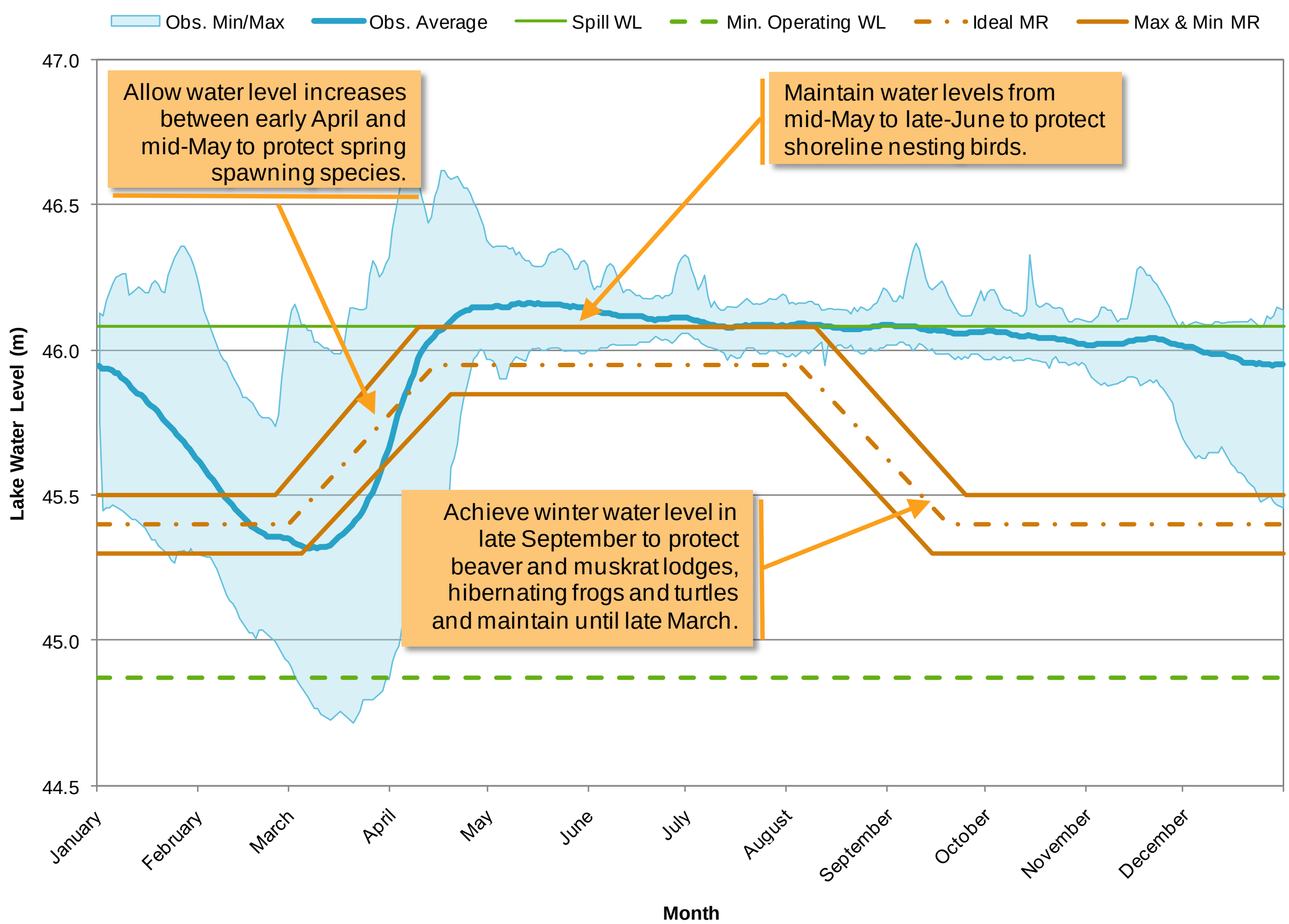


Figure 7-3 - Natural Environment Goal-Specific Management Range for Buckhorn Lake

7.3.3 South Sector

Achieve winter water levels in late September or early October and minimize water level fluctuations until late March to protect beaver and muskrat lodges. This procedure will also keep lodge entrances ice free and prevent freezing hibernating frogs and turtles. Water levels should rise in late March to mid-April, but maintain peak spring water levels within 0.2m of summer levels to promote germination of Wild Rice. Between early April and late May hold minimum water levels to those observed in early April to protect spring spawning species. Allow water fluctuations of less than ± 0.1m from late April to mid-July to promote growth of Wild Rice during the floating leaf stage. Finally, water levels should be maintained within 0.2m of spring maximum until mid-July. The natural environment Goal-

Specific Management Range for Rice Lake, as representative of the reservoirs in the South Sector, is shown in **Figure 7-4**.

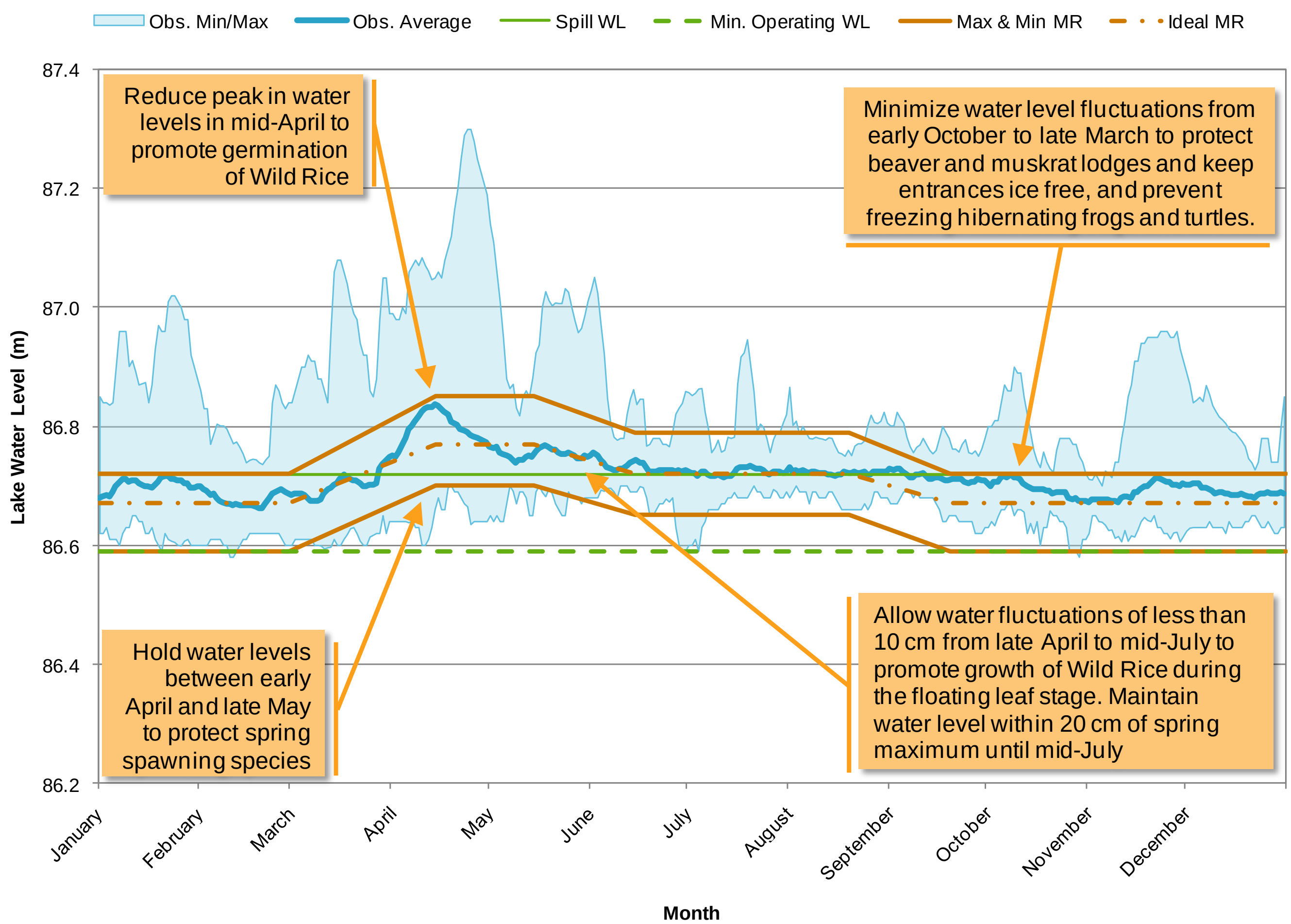


Figure 7-4 - Natural Environment Goal-Specific Management Range for Rice Lake

7.4 Integration of Goal-Specific Management Ranges

The Goal-Specific optimal Management Ranges describe how the individual goals are best satisfied through water management activities. However, to be of use in a comprehensive water management strategy, the Goal-Specific ranges must be integrated to produce one inclusive Management Range that reflects the considerations of all goals. Given the different requirements for the satisfaction of each goal, it is clear that this integration can be challenging. The requirements of each goal can vary from season to season, and from area to area, meaning that the optimal water level for one lake may not be the same as another lake, or even for the same lake at a different time of year. Additionally, the requirements of one goal may conflict with the requirements for another goal, producing a conflict that must be resolved in a way that results in the overall optimal satisfaction of both goals. This may produce a range that satisfies one goal more than another, creating a residual, or difference between that goal's optimal water level and the overall optimal water level that is produced in the Management Range. The impact of these residuals and their potential mitigation should be an important consideration with resolving the conflicts between goal requirements. The following sections describe these challenges in further detail.

7.4.1 Seasonal and Geographic Variations

When considering the requirements for each Water Management Goal (i.e., when developing the Goal-Specific optimal management ranges), it becomes clear that the requirements for each goal change from season to season and from sector to sector (and from lake to lake within a sector). In addition, some goals are more prominent than others in certain seasons or areas, and may require greater consideration when developing the Management Ranges.

The most apparent example of the seasonal variation in the prominence of goals is when considering the goal of providing navigation in the Waterway. Navigation is provided exclusively during the summer season (defined as mid-May to mid-October to reflect the navigation season) in the North, Central and South sectors, with the Haliburton Reservoirs supplying water to augment the other sectors. Conversely, in the fall, winter and spring there is no requirement to provide for navigation, and therefore the range for navigation would not be considered in an integrated Management Range. Related to this example is the difference in satisfying the goal of providing navigation among the different sectors. Satisfying this goal in the North, Central and South sector requires that optimal navigational ranges be maintained during the season. However, satisfying this goal in the Haliburton Reservoirs requires that water be released from the Reservoirs to augment flows in the other sectors as required; the navigable portion of the Waterway does not extend into the Haliburton Reservoirs, and therefore the satisfaction of this goal can only be measured by the success of maintaining navigational ranges in the North, Central and South sectors.

Another important example involves managing the water for the goal of protecting significant habitats and species (i.e., natural environment). The requirements of the different species that inhabit the Waterway vary significantly from season to season, and the distinct areas of the Waterway each support a different ecological community with their own unique requirements. An example of the varying requirements for natural environment considerations is the management for Lake Trout in the Haliburton Reservoirs. Lake Trout spawn in the fall, choosing relatively shallow portions of cold-water lakes in which to deposit their eggs, which will remain in those spawning beds until the following spring before hatching. Since the eggs are placed in shallow waters, decreases in water level can potentially expose the eggs, causing them to be lost. Therefore, the optimal Management Range for Lake Trout in the Haliburton Reservoirs that support them would require that the minimum water level for the winter be attained prior to Lake Trout spawning (i.e., approximately mid- to end-September). During the summer months, when the Lake Trout are not spawning, there are no specific water level or flow requirements to manage for their habitat and thus the integrated Management Range will not need to consider potential impacts. Similar seasonally variable natural environment considerations can be found in the other sectors, as well. This topic was discussed in detail in **Section 5**, and was summarized in **Table 5-4**.

Table 7-1 and **Table 7-2** describe some of the seasonal variations in goal requirements for the Haliburton Reservoirs and North/Central/South Sectors, respectively (i.e., navigable and non-navigable portions of the Waterway), providing a general indication of the water management needs of each season. Note that the tables describe Goal-Specific requirements that are optimal to their satisfaction, i.e., they do not necessarily reflect current practice. The development of integrated Management Ranges should consider the seasonal variations in Goal-Specific requirements for individual lakes, in order to reflect each lake's unique needs as accurately as possible.

Table 7-1 - Haliburton Reservoirs - Goal-Specific Seasonal Requirements

Goals	Winter	Spring	Summer	Fall
Reducing threats to public safety and infrastructure	• Establish threshold high water levels that impact public safety • Provide storage for the spring freshet to mitigate flooding	• Establish threshold high water levels that impact public safety • Provide storage for the spring freshet to mitigate flooding	• Establish threshold high water levels that impact public safety • Adjust flows as required to respond to public safety threats	• Establish threshold high water levels that impact public safety • Adjust flows as required to respond to public safety threats
Contributing to health of Canadians	• Establish threshold low water levels that impact water supply and quality • Provide flow to maintain water quantity and quality needs	• Establish threshold low water levels that impact water supply and quality • Provide flow to maintain water quantity and quality needs	• Establish threshold low water levels that impact water supply and quality • Provide flow to maintain water quantity and quality needs	• Establish threshold low water levels that impact water supply and quality • Provide flow to maintain water quantity and quality needs
Safe boating and navigation	• No requirement to provide for navigation	• Fill Reservoirs to provide water supply for navigation	• Provide flow when required to maintain navigation	• No requirement to provide for navigation
Protect significant habitats and species	• Maintain relatively stable water levels	• Allow water levels to rise during the freshet	• Hold lake water levels for 8 weeks from early May to late July	• Achieve winter water levels by October 1 and hold as minimum levels until April
Optimize enjoyment of the water	• Minimize water level fluctuations to mitigate impact on winter activities	• Fill Reservoirs to provide for recreational needs	• Maintain water levels for recreation and lake access	• Maintain water levels for recreation and lake access
Optimize hydroelectric power generation	• Provide flows to optimize hydroelectric generation	• Provide flows to optimize hydroelectric generation	• Provide flows to optimize hydroelectric generation	• Provide flows to optimize hydroelectric generation

Table 7-2 - North/Central/South Sector - Goal-Specific Seasonal Requirements

Goals	Winter	Spring	Summer	Fall
Reducing threats to public safety and infrastructure	• Establish threshold high water levels that impact public safety • Provide storage for the spring freshet to mitigate flooding	• Establish threshold high water levels that impact public safety • Adjust flows as required to respond to public safety threats	• Establish threshold high water levels that impact public safety • Adjust flows as required to respond to public safety threats	• Establish threshold high water levels that impact public safety • Adjust flows as required to respond to public safety threats

Goals	Winter	Spring	Summer	Fall
Contributing to health of Canadians	• Establish threshold low water levels that impact water supply and quality • Provide flow to maintain water quantity and quality needs	• Establish threshold low water levels that impact water supply and quality • Provide flow to maintain water quantity and quality needs	• Establish threshold low water levels that impact water supply and quality • Provide flow to maintain water quantity and quality needs	• Establish threshold low water levels that impact water supply and quality • Provide flow to maintain water quantity and quality needs
Safe boating and navigation	• No requirement to provide for navigation	• No requirement to provide for navigation	• Adjust water levels as required to maintain navigational depths	• No requirement to provide for navigation
Protect significant habitats and species	• Hold water levels between late September and late March to protect in-water over-winter habitat • Allow low winter water levels to increase after late April to promote Wild Rice germination and growth	• Hold water levels between early April and mid-May to protect spring spawning species • Reduce peak in water levels in mid-April to promote germination of Wild Rice	• Hold water levels from late May to early July to protect riparian and shallow water flora and fauna • Hold water levels with + 10 cm from late April to mid-July • Maintain summer water levels within 20 cm of spring peak	• Achieve winter water levels by late September or early October
Optimize enjoyment of the water	• Minimize water level fluctuations to mitigate impact on winter activities	• Maintain water levels for recreation and lake access	• Maintain water levels for recreation and lake access	• Maintain water levels for recreation and lake access
Optimize hydroelectric power generation	• Manage water levels and flows to optimize hydroelectric generation	• Manage water levels and flows to optimize hydroelectric generation	• Manage water levels and flows to optimize hydroelectric generation	• Manage water levels and flows to optimize hydroelectric generation

As demonstrated in the tables, most of the goals are applicable to all seasons of operations, except for the goal of providing navigation, which is generally only applicable during the summer. However, the specific requirements of each goal may vary from season to season, particularly when considering the protection of significant habitats and species (see **Section 5**).

7.4.2 Conflicts between Goal-Specific Management Ranges

The integration of Goal-Specific Management Ranges may yield conflicts wherein the optimal ranges for two goals for a specific lake and time of the year inherently conflict, i.e., there is no single Management Range that can optimally satisfy both goals. Through this study it has become apparent that the management of water in the Waterway cannot optimally satisfy all of the goals at all times. In these situations the requirements of one goal must be selected over the other in order to produce the integrated Management Range. This requires the different goals to be prioritized depending on location and season, and for a conflict resolution process to be implemented to assist with the compromise between goals.

The prioritization of the six Water Management Goals is a challenging undertaking; however, there are several considerations that can assist in this process:

- The goal of reducing threats to public safety and infrastructure would be the highest priority when resolving conflicts between optimal Management Ranges; there are no situations in which an increase in threat to public safety would be acceptable in order to better satisfy one of the other goals.
- The goal of contributing to the health of Canadians would also be a high priority goal when resolving optimal range conflicts, since many people rely on the Waterway for drinking water, and to safely assimilate wastewater discharges.
- Under the current water control operations, the goal of optimizing hydroelectric generation is of a relatively low priority, since the facilities only have access to the water that is available in the Waterway (i.e., run of the river) and additional water will not be released from the Haliburton Reservoirs to augment flows for hydro generation. In addition, most of the hydroelectric stations are located in the South Sector where there is less potential to store volume upstream of the stations to increase generation, due to the general lack of reservoirs.

The satisfaction of the first two goals – reducing threats to public safety and infrastructure, and contributing to the health of Canadians – will tend not to elicit many conflicts. This is due to the nature of their anticipated optimal Management Ranges. Threats to public safety are typically associated with high water levels (i.e., flooding) and the damage that can accompany the high water levels, whereas the requirements of water supply and water quality are typically associated with maintaining a minimum flow, with low water levels having an adverse impact on the goal. Therefore, the goals naturally complement each other, and will likely determine the upper and lower critical water levels for the Management Range in many areas throughout the year.

After considering that these three goals will typically be prioritized in this manner, there are the remaining three Water Management Goals which may yield conflicts in optimal ranges:

- Providing for navigation; this goal has traditionally been a high priority for the TSW, due to the history of legislation that establishes the operational mandate of the TSW as providing for navigation.
- Protecting significant habitats and species; this goal has become more prominent through the development of MOU's (as described in **Section 6**) and other agreements to manage the Waterway to benefit fish spawning.
- Optimizing enjoyment of the water; this goal has become more prominent as development throughout the Waterway has increased, particularly in the Haliburton Reservoirs.

The Waterway is open for navigation during the summer months, between the Victoria Day and Thanksgiving holiday weekends. As such, there is no required navigation-specific Management Range outside of this period, and thus no potential for a direct conflict with other Goal-Specific Management Ranges (with the exception of the need to fill the Haliburton Reservoirs during the spring to provide for navigation, discussed below). In addition, during the navigation period, maintaining water levels at a range suitable for navigation will tend to satisfy the requirements of aquatic habitat protection and enjoyment of the water in the navigable portion of the Waterway (i.e., North, Central and South Sector).

To maintain water levels at the navigational range requires water to be withdrawn from the Haliburton Reservoirs in most years, since the natural inflows into the Kawartha Lakes and Trent River are typically insufficient to offset evaporation and the natural outflow into Lake Ontario. These withdrawals cause water levels in the Haliburton Reservoirs to decline during the summer when the majority of cottagers and other residents of the Reservoirs make use of their properties. The goal of optimizing enjoyment of the water, which is the primary goal to reflect the satisfaction of residents in the Haliburton Reservoirs, is typically best satisfied through maintaining consistently high water levels; fluctuations and declines in water levels over the summer impact the enjoyment of the water by the residents. This creates a conflict between the need to provide for navigation in the North, Central and South sectors, and the need to optimize enjoyment of the water in the Haliburton Reservoirs. The protection of aquatic habitat can also incur conflicts in the Management Ranges outside of the navigation period when considering the need to optimize enjoyment of the water, evidenced from the discussion in **Section 7.3**.

The resolution of these conflicts is anticipated to be a significant phase in developing the integrated Management Ranges, following the creation of the Goal-Specific Management Ranges. A potential methodology to effectively manage these conflicts and produce integrated ranges is described in **Section 7.6**, including the use of the dedicated Goals & Objectives Committee to steer the Constraint Management Process.

7.4.3 Impact and Mitigation of Management Range Residuals

The conflicts between the Goal-Specific Management Ranges, described in the previous section, occur when there are differences in the optimal water levels required to satisfy each goal. The resolution of these conflicts when they occur will invariably satisfy one or more of the goals in a less than optimal manner. In these situations, and when considering how to implement a compromise between the goals, the impact of less than optimally satisfying each goal must be evaluated. The difference between the optimal range for a goal and the actual integrated Management Range is called the residual; this section discusses the potential impact of these residuals and opportunities to mitigate the impacts.

There are several situations in which a residual is anticipated to occur when developing the integrated Management Ranges, including the following as examples for discussion:

- Winter drawdown in the Kawartha Lakes to provide storage for the spring freshet;
- Summer drawdown in the Haliburton Reservoirs to provide for navigation in North, Central and South Sector; and
- Optimizing hydro power generation, which typically requires daily water level fluctuations.

Winter Drawdown in the Kawartha Lakes

Each winter the Kawartha Lakes in North and Central Sector are drawn down to provide storage to accommodate the spring freshet, related to the satisfaction of the goal to reduce threats to public safety and infrastructure. As discussed in **Section 6.2.4**, water level fluctuations in the Kawartha Lakes between October and March can adversely impact wildlife, including beavers, muskrats and hibernating frogs and turtles. To satisfy the goal of protecting aquatic habitat, the Kawartha Lakes would be drawn down in the late summer or early fall, similar to the Haliburton Reservoirs, and the water levels would be maintained at this low level until the freshet filled the lakes again in the following spring. Drawing down the water levels in early fall (following the end of the summer navigation season) would adversely impact the goal to optimize enjoyment of the water, since the Kawartha Lakes still receive regular use well into the fall season. When integrating these Goal-Specific Management Range requirements, one of these goals will as a result be less than optimally satisfied: less storage would be available to accommodate the freshet; over-wintering wildlife would be impacted; or enjoyment and use of the Kawartha Lakes in the fall would be affected.

To effectively integrate these ranges, the residuals related to less than optimally satisfying each goal must be determined and evaluated. The residuals could be defined by factors such as:

- Benefit to over-wintering wildlife of a drawdown in early fall as opposed to during the winter;
- Amount of water use during the fall by local residents, cottagers, businesses and other users; and
- Benefit of additional storage in accommodating the spring freshet (i.e., if the additional volume provides a small or negligible benefit, drawdown may be mitigated).

During the evaluation of these factors, it may be found that few people actually make use of the Waterway after the navigation season, and these users may be able to be accommodated with the lower water levels after the drawdown. In this case, drawing down the water levels in early fall may be an acceptable solution to the conflict and there would be only minor impacts from the residuals. On the other hand, it may be found that the residuals associated with each of the three goals incur a significant impact: the additional storage may be critical to freshet management; the winter drawdown of water levels may be disastrous to native over-wintering species; and significant use of the water may be important in the fall season. In this case, the residuals would be evaluated by a comprehensive Goals & Objectives Committee and ultimately the integrated Management Range would be developed in a way that minimizes the overall impact or risk. This ability to mitigate the residuals that may occur may mean that one goal is less optimally satisfied because it can be mitigated.

Summer Drawdown in the Haliburton Reservoirs

Water is withdrawn from the Haliburton Reservoirs in the summer to provide for navigation in the North, Central and South Sectors, as discussed in **Section 7.4.2**. In addition, drawing down the Reservoirs provides storage to capture the spring freshet and mitigate flooding. However, residents of the Reservoirs typically desire a continually high water level during the summer, or at least a mitigation of rapid water level drawdown, to optimize their enjoyment of the water. Similar to the winter drawdown in the Kawartha Lakes, several factors would be evaluated to determine the impact of less than optimally satisfying each of these goals:

- Benefit of additional storage in accommodating the spring freshet (i.e., if the additional volume provides a small or negligible benefit, drawdown may be mitigated), and actual volume requirement to effectively manage the freshet;
- Benefit of higher or more stable water levels to residents and cottagers in their enjoyment of the water; and
- Actual water requirement in North, Central and South Sector to maintain navigation in a typical year.

The potential difference between the volume required to manage the freshet and the volume required to provide for navigation is illustrated in **Figure 7-5**, reflecting current practices. This preliminary evaluation demonstrates that there may be distinctly different volumes required to satisfy each goal.

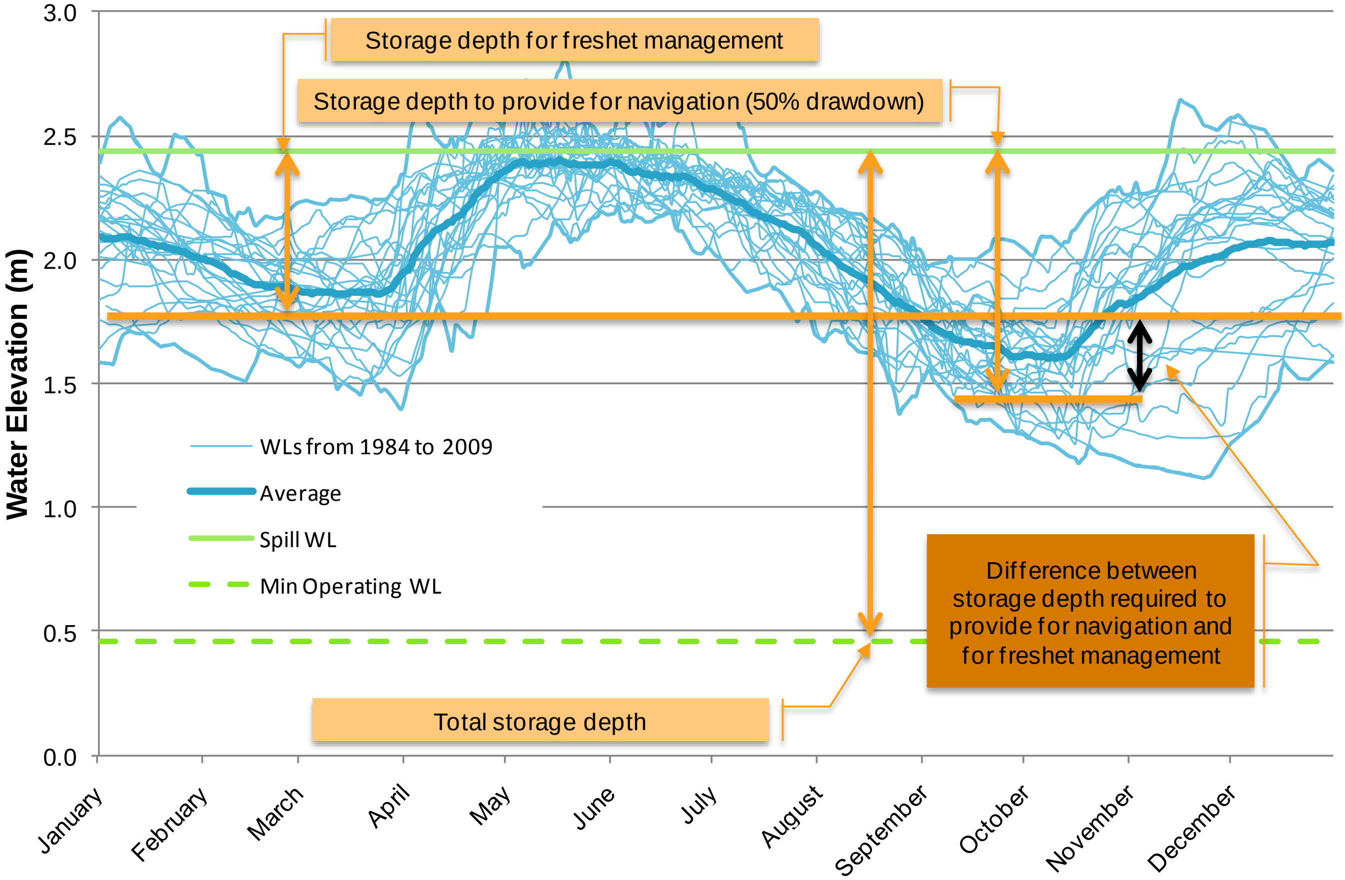


Figure 7-5 - Storage Depth Requirements in the Haliburton Reservoirs - Horseshoe Lake Example

If the volume required to manage the freshet and to provide for navigation are mismatched, the risk of being unable to satisfy either goal increases:

- If the volume to manage the freshet is larger than the volume required to provide for navigation, water is released from the Reservoirs at the end of the summer even though it is not required in downstream areas; and
- If the volume to manage the freshet is smaller than the volume required to provide for navigation, there is a possibility that the Reservoir will not be completely filled in the spring if the freshet is unusually small.

Once these factors are determined, a Management Range that satisfies these requirements may be developed in a context that supports the enjoyment of local residents and cottagers, for example through minimizing or regulating the rate of drawdown.

Optimization for Hydro Power

The optimization of water levels for hydro power would depend on the specific operations of each generation facility, but would typically include daily fluctuations in water levels to produce more generating potential at certain times to take advantage of variable electricity pricing. Water level fluctuations generally impact the other Water Management Goals adversely and incur a higher level of operational effort to manage: gradual changes and stable water levels are typically preferred for other Goals. However, maintaining high water levels would typically provide more generating potential than the alternative of low water levels, and may be considered to optimize hydro power generation. Hydro requirements remain relatively consistent from season to season, unlike most of the other goals, which may also incur conflicts and residuals as the seasons change.

Mitigation of Residuals

In many situations where Goal-Specific Management Ranges are integrated into a single Management Range, there will be residuals wherein some goals are not optimally satisfied. The impact of these residuals may be small, but in extreme situations could be significant. In all cases where there is an impact that cannot be accommodated within the integrated Management Range, opportunities to mitigate this impact should be explored. Mitigation can include:

- Monitoring of the impact;
- Development of special management zones to accommodate the impact; and
- Physical changes to the Waterway (i.e., creation of aquatic habitat in new locations).

Mitigation in these forms is most commonly associated with natural environment impacts, and is typically referred to as Adaptive Environmental Management (AEM). These principles can be adapted to respond to mitigation requirements for any of the Water Management Goals.

The ability to mitigate the residuals of each Goal is an important consideration during the integration of Goal-Specific Management Ranges. If the residual of one Goal can be easily and effectively mitigated, the integrated Management Range should more readily accommodate those Goals that cannot be easily mitigated.

7.5 Integrated Management Ranges for Representative Lakes

Management Ranges for several representative lakes were developed using the considerations described in the previous sections. The representative lakes are:

- Kennisis Lake (as representative of the Haliburton Reservoirs);
- Buckhorn Lake (as representative of the Kawartha Lakes and the North/Central Sectors); and
- Rice Lake (as representative of the South Sector).

The development of Management Ranges for these lakes is described in the following sections.

7.5.1 Kennisis Lake – Haliburton Reservoirs

The Management Range developed in this study for Kennisis Lake, as representative of the considerations of the Haliburton Reservoirs, is shown in **Figure 7-6**. Several key dates are shown on the figure, and described in **Table 7-3**, as they indicate times when the Management Range changes due to the changing Goal-Specific ranges from season to season.

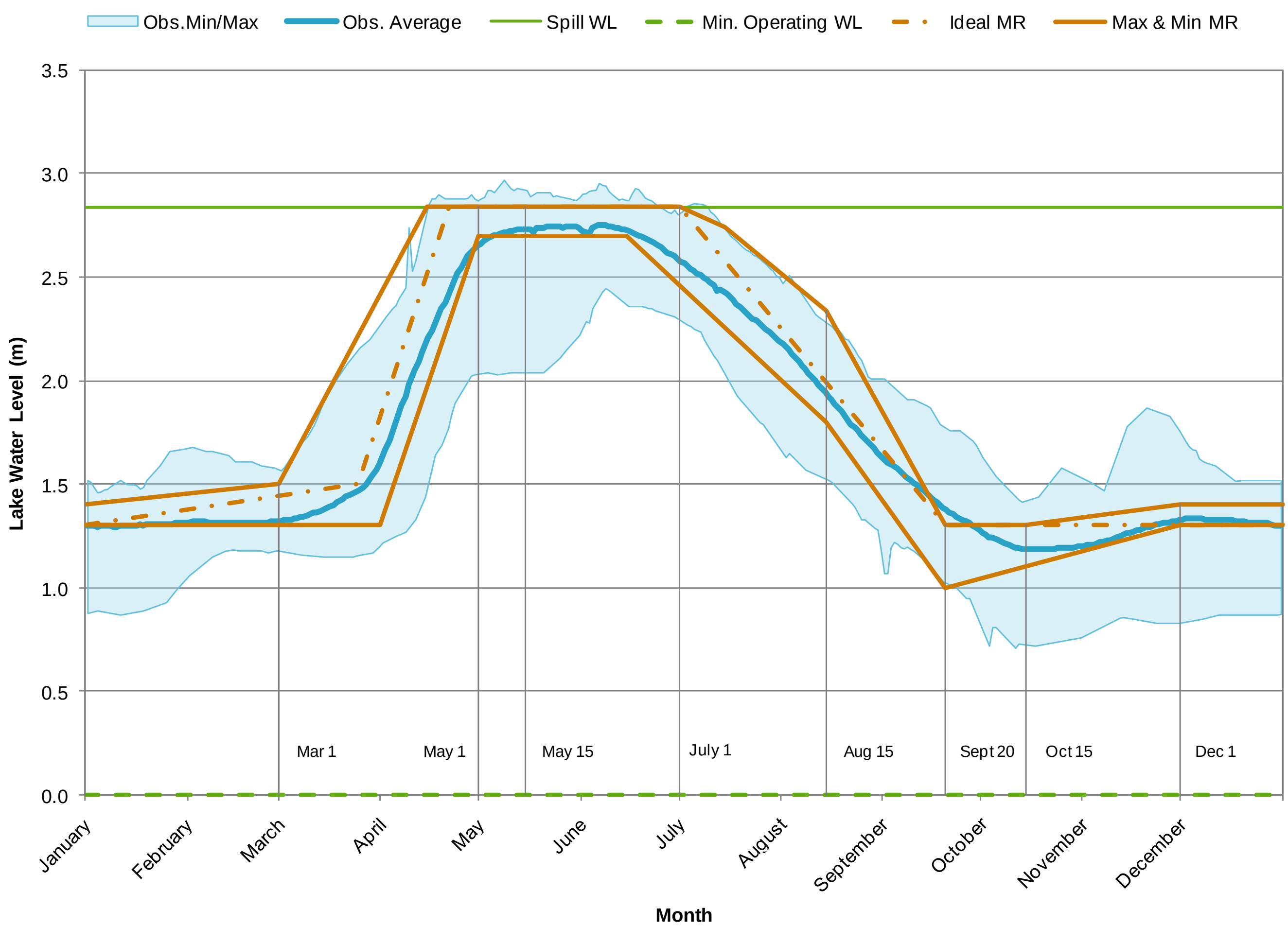


Figure 7-6 - Integrated Management Range for Kennisis Lake

Table 7-3 - Description of Integrated Management Range for Kennisis Lake

Date	Description of Management Range
March 1 to May 1	• March 1 represents the time in a typical year when stoplogs are replaced in the dam to catch the spring freshet. • May 1 is the target date for the lake to be completely filled, as shown by the Management Range becoming equal to the spill level of the dam.
May 1 to May 15	• During this period the lake is targeted to be completely full. • Navigation in the Waterway has not yet started and therefore there is typically no demand to augment flows in downstream areas.
May 15 to July 1	• During this period the optimal Management Range is to maintain the lake near the full level, since demands for flow from other sectors is typically low and recreational use is high.

Date	Description of Management Range
July 1 to August 15	• July 1 is the date that is optimal to begin the drawdown towards winter lake settings, in order to address natural environment concerns regarding Lake Trout spawning. The drawdown is executed at 0.5% of maximum lake levels per day, as per current operations. • The upper limit of the Management Range decreases at a slower rate during this period, since if downstream flow demands are low (such as in a wet year), flow releases from Kennisis Lake may be mitigated to provide higher water levels to optimize enjoyment of the water for recreation. However, this requires a quicker drawdown of water levels later in the summer, since the same winter water level must be attained.
August 15 to September 20	• September 20 is the target date to achieve the winter lake water level. This is done to mitigate impacts on Lake Trout spawning, which are vulnerable to water levels dropping after spawning. Muskrat and beaver finalize entrances to their lodges at this time. Water fluctuations after entrance elevations are set risk freezing or flooding the lodges and their entrances. • The upper limit of the Management Range on September 20 is equal to the minimum winter lake level, so that no further decreases in water level are planned. • Water levels can be drawn down lower than winter settings, if flow requirements from other sectors is high (such as in a dry year), but typically precipitation during the fall will slightly fill the lake back to winter settings.
September 20 to October 15	• The target for this period is to maintain lake levels as stable as possible. • Flow demands from downstream areas may continue during this period, since the Waterway is still open for navigation, but it is anticipated that the demands may be reduced due to lower evaporation from the Kawartha Lakes. Water demands from Kennisis Lake during this time should be carefully considered to mitigate impact on Lake Trout spawning and muskrat and beaver lodges.
October 15 to December 1	• October 15 (i.e., when navigation closes in the Waterway) is the target date to achieve winter settings at the Kennisis Lake dam. • Water levels may rise slightly during this period due to fall precipitation, as well as the reduction of downstream flow demands, and the Management Range drifts upwards to account for this.
December 1 to March 1	• Water levels are maintained at winter settings. • The upper limit of the Management Range drifts upwards over this period to account for the possibility of replacing stoplogs prior to March 1 if the freshet forecast indicates a small runoff volume.

This integrated Management Range reflects the existing long-term average water levels relatively closely, since the current water control operations satisfy many of the goals in a typical year. However, there are some potential residuals that may require additional consideration, including:

- The summer drawdown has not been significantly altered, due to the requirement to provide storage for the spring freshet, impacting the enjoyment of the water by residents and cottagers. An evaluation of the volume required to manage the freshet and to provide for navigation could mitigate this drawdown; however, this evaluation was not completed as part of this study.
- Similarly, since the volumes required for freshet management and navigation have not been established, there may be additional residuals for these goals wherein there is a risk that either insufficient storage will be available to manage the freshet (thus increasing flooding), or there will be insufficient water to provide for navigation.

7.5.2 Buckhorn Lake – North/Central Sector

The Management Range developed in this study for Buckhorn Lake, as representative of the considerations of the North and Central Sectors (i.e., the Kawartha Lakes), is shown in **Figure 7-7**. Several key dates are shown on the figure, and described in **Table 7-4**, as they indicate times when the Management Range changes due to the changing Goal-Specific ranges from season to season.

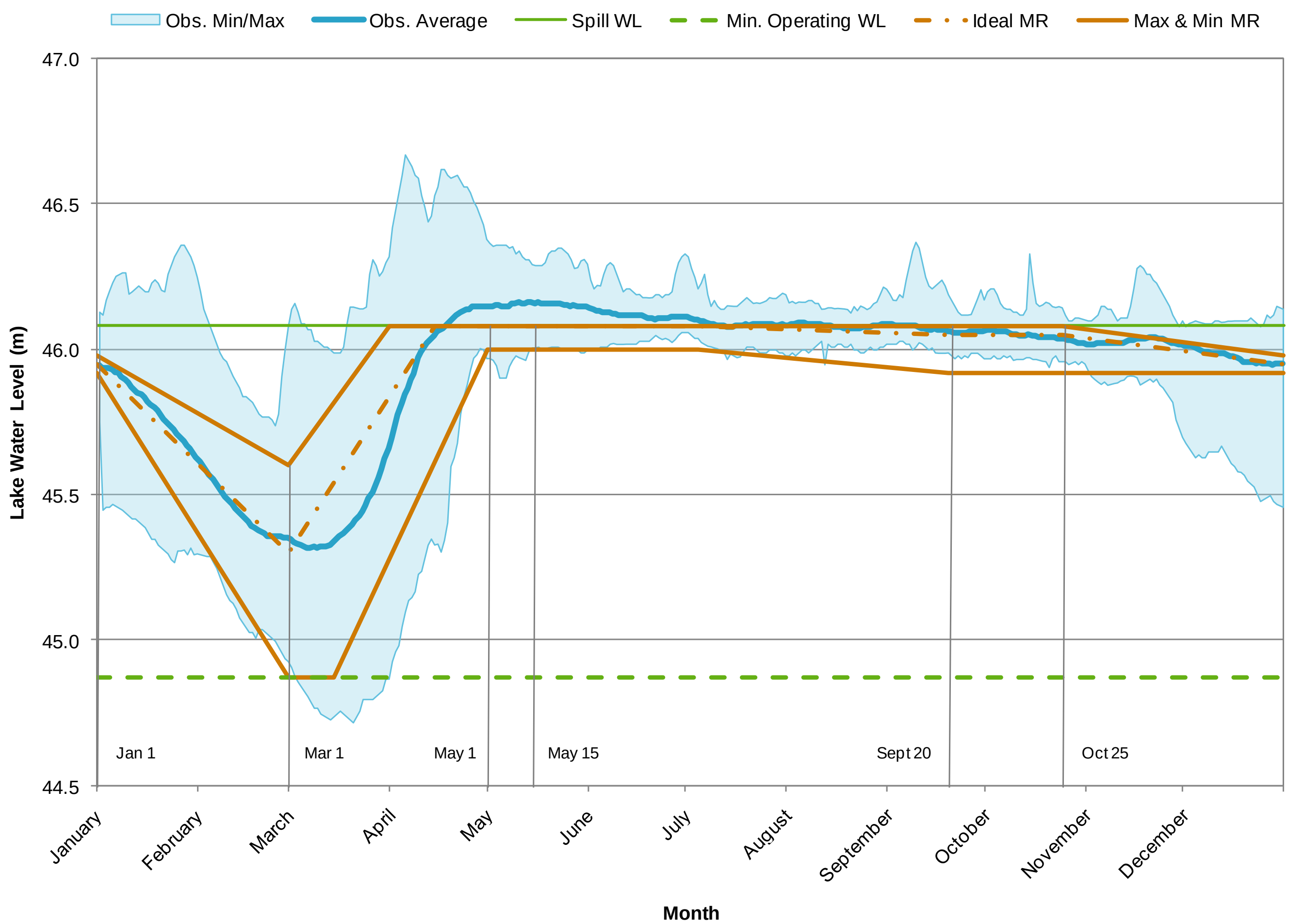


Figure 7-7 - Integrated Management Range for Buckhorn Lake

Table 7-4 - Description of Integrated Management Range for Buckhorn Lake

Date	Description of Management Range
January 1 to March 1	• Starting January 1 the Kawartha Lakes are drawn down to provide storage for the spring freshet and mitigate flooding in the system.
March 1 to May 1	• The Lakes are refilled with runoff from the spring freshet. • May 1 is the target date for the lake to be completely filled, as shown by the Management Range becoming equal to the spill level of the dam.
May 1 to May 15	• Lakes are full during this period. There are few flow demands from downstream areas. Navigation has not yet begun on the Waterway.

Date	Description of Management Range
May 15 to September 20	• Navigation is the primary activity in the North and Central Sectors during this period. Lakes are kept at the required navigational depths, with flow augmentations from the Haliburton Reservoirs if required.
September 20 to October 25	• During this period, the Management Range expands slightly to accommodate the reduced flows from the Haliburton Reservoirs due to protection of Lake Trout spawning; however, water levels should not be reduced below the minimum navigational depth.
October 25 to January 1	• Water levels are kept close to navigational range to accommodate property access considerations; however, water levels could be allowed to decrease slightly to accommodate reduced flow from Haliburton Reservoirs.

Similar to the integrated Management Range developed for Kennisis Lake, the range for Buckhorn Lake reflects the existing long-term average water levels relatively closely. Providing water levels in the navigation range for the summer and fall seasons satisfy many of the Water Management Goals, and the winter drawdown provides storage for the freshet to mitigate flooding. The primary residual that arises from this Management Range is with the goal of protecting aquatic habitat. As shown in **Section 7.3.2**, the Goal-Specific Management Range for the natural environment at Buckhorn Lake would require the drawdown of the Lake to pre-freshet levels in late summer or early fall, so that over-wintering wildlife would be protected. However, in this preliminary analysis, it was anticipated that such a change in the drawdown timing would not be feasible in the short-term, and would incur an unacceptable impact on the remaining goals during the fall season. Other alternatives not considered in this study may provide a Management Range that better mitigates this residual, or the implementation of adaptive management procedures could likewise be used.

7.5.3 Rice Lake – South Sector

The Management Range developed in this study for Rice Lake, as representative of the considerations of the reservoirs in the South Sector, is shown in **Figure 7-8**. Several key dates are shown on the figure, and described in **Table 7-5**, as they indicate times when the Management Range changes due to the changing Goal-Specific ranges from season to season.

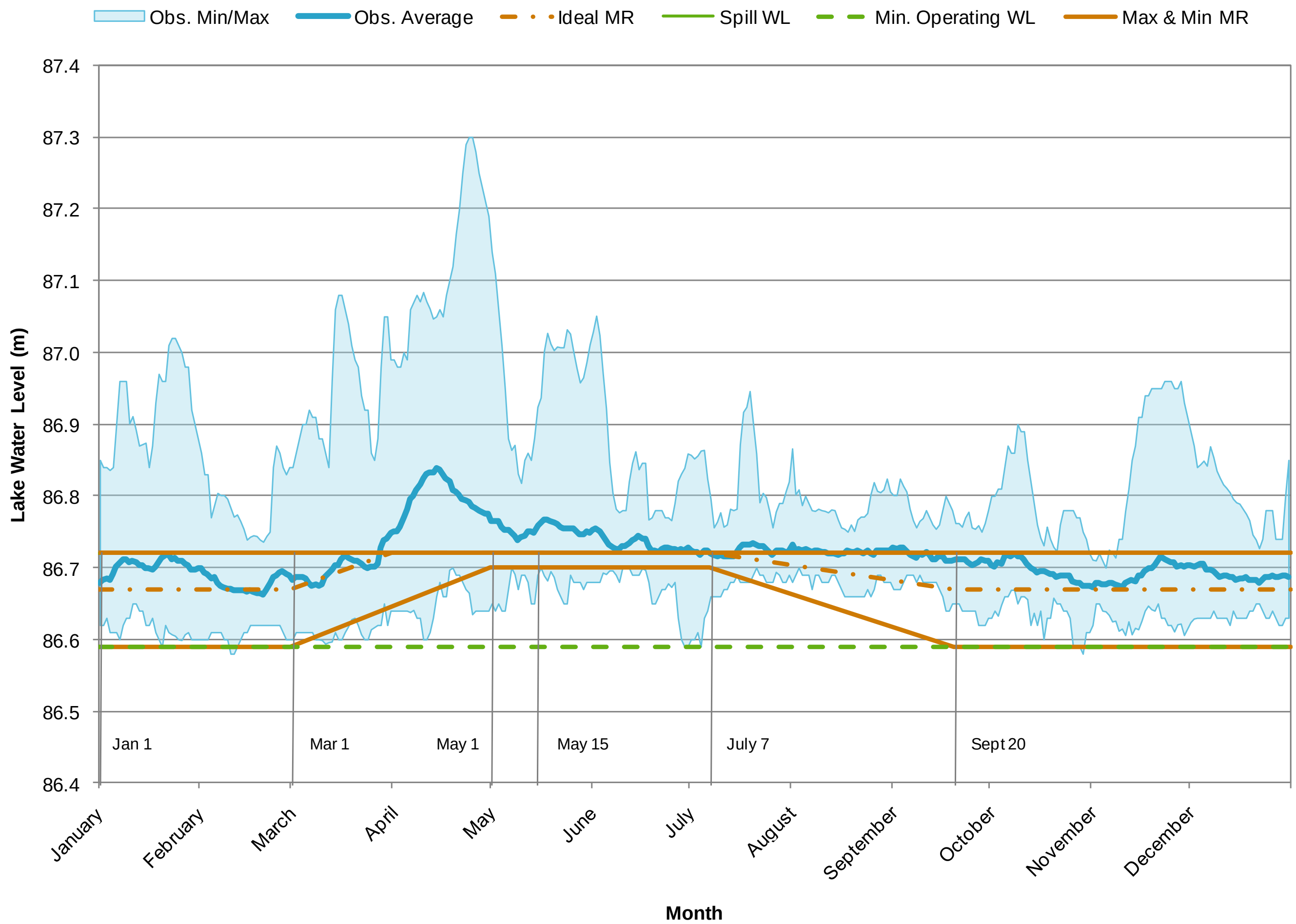


Figure 7-8 - Integrated Management Range for Rice Lake

Table 7-5 - Description of Integrated Management Range for Rice Lake

Date	Description of Management Range
March 1 to May 1	• Spring freshet runoff from upstream areas is accommodated during this period. Limited storage capacity in Rice Lake.
May 1 to May 15	• Lakes are completely filled during this period to prepare for the start of navigation.
May 15 to July 7	• Water levels maintained at navigational depths. • Water level fluctuations are mitigated to promote growth of wild rice.
July 7 to September 20	• Management Range expands to accommodate greater flexibility in operations, following establishment of wild rice.
September 20 to March 1	• Water levels are maintained near navigational levels, but permitted to fluctuate to a greater degree to accommodate upstream flows. • Fluctuations are mitigated during this period to protect muskrat and beaver lodges.

The integrated Management Range for Rice Lake is developed primarily around the constraints of the Lake itself. There is little storage capacity to accommodate changes in flows, and only a narrow range in water levels between the minimum (i.e., sill) and maximum (i.e., spill) levels. Therefore, water levels are maintained close to the navigation range year-round, satisfying the majority of the goals and creating few residuals. The primary concern at this Lake is the management of high flows, particularly during the freshet, that result in water levels well above the spill level. TSW staff have a limited capability to manage these flows, relying on upstream areas to throttle high flows appropriately, and the appropriateness of a Management Range that requires flows at or below the spill level should be evaluated.

7.6 Proposed Methodology for the Development of Management Ranges

The development of Management Ranges is the ultimate product of the Constraint Management Process, illustrated at the beginning of this Chapter in **Figure 7-1**. Although this process is shown to be linear, the results are intended to be reviewed on an ongoing basis, and the entire process repeated as necessary to revise the Management Ranges and respond to changing conditions (i.e., operational methods, climate change). Through this Chapter, the individual stages in the development of the Management Ranges have been described; this section details how these stages can be coordinated to effectively complete the process. The proposed methodology consists of the following stages:

1. Formation of the Goals & Objectives Committee (GOC) and Study Team
2. Background Review and Data Collection
3. Development of the Goal-Specific Management Ranges
4. Integration of Goal-Specific Management Ranges
5. Public Communication and Engagement

These stages are described in the following sections.

7.6.1 Formation of the Goals & Objectives Committee and Study Team

The Constraint Management Process has the task of considering each of the six Water Management Goals and integrating the various requirements into a single Management Range to guide the water control operations of the Waterway. Because of the diverse nature of the Water Management Goals, as has been demonstrated extensively through this study, a similarly diverse and comprehensive study team is anticipated to be required to appropriately represent each of the Goals. The study team is divided into two components: the GOC, responsible for representation of the Water Management Goals; and the study facilitator, responsible for guiding the Constraint Management Process and ultimately producing integrated Management Ranges.

The following representatives/stakeholders are anticipated to form the GOC:

- Waterway operations and water management expertise, likely represented by the TSW water control engineer, operations supervisors and other staff;
- Representatives from hydro power utilities;
- Natural environment scientists (fisheries, terrestrial ecology, wildlife ecology);
- Agency representatives: Department of Fisheries and Oceans, Environment Canada, Ministry of Environment, Ministry of Natural Resources, Conservation Authorities;
- Municipal representatives; and
- Citizen group representatives (i.e., local cottage-owners associations).

In relation to the existing Water Management Advisory Committee (WMAC), it is recommended that the GOC be an independent technical body, and that the WMAC serve as an oversight committee to the Constraint Management Process. The GOC would be expected to present the results of the Process to the WMAC as they progress, such as the Goal-Specific and integrated Management Ranges. The WMAC in turn would review the study results and provide recommendations to Parks Canada for implementation.

The study facilitator is anticipated to consist of an external party with capabilities appropriate to this process, including:

- Understanding of the technical components of the Trent Severn Waterway;
- Coordination of public processes; and
- Stakeholder group facilitation, including consensus building and conflict resolution.

The study facilitator is required to have an understanding of the technical components of the Waterway since they will be ultimately responsible for the production of the integrated Management Ranges, albeit with the input and consensus of the GOC. However, this technical knowledge must accompany skill in facilitating groups as comprehensive and diverse as the GOC, so that the collaboration required to produce the Management Ranges can be effective.

7.6.2 Background Review and Data Collection

The members of the study team (i.e., GOC and study facilitator) will be required to develop an understanding of the water control operations and needs (as detailed in the **Water Management Manual** developed as part of this study), as well as an appreciation for the previous studies that have been completed regarding Waterway management.

All information and data required to develop the Goal-Specific Management Ranges is also collected at this stage. The **Data Collection and Management Guide** developed as part of this study contains information on the available data that could be used for this process.

7.6.3 Development of the Goal-Specific Management Ranges

The study team analyses and evaluates the data collected during the background review stage, and proceeds to develop the Goal-Specific Management Ranges, the water levels from season-to-season and Sector-to-Sector that best satisfies each of the Water Management Goals. The development of these ranges is described in **Section 7.2**.

At this stage in the process, the representatives of the GOC function relatively independently, albeit in cooperation with the study facilitator who oversees the process. The members of the GOC responsible for each Water Management Goal (there may be several assigned to each Goal) develop their respective Goal-Specific Management Range and provide them to the rest of the study team to prepare for the next stage.

It may be necessary to augment the GOC with increased technical capabilities or increased local representation, depending on the nature of the Goal being evaluated. In these situations, it is anticipated that the study facilitator (e.g., a consulting firm) would possess the necessary capabilities, whether a technical understanding of the Waterway or the ability to effectively solicit public input, to enhance the GOC.

7.6.4 Integration of Goal-Specific Management Ranges

The integration of the Goal-Specific Management Ranges, described in **Section 7.4**, involves the consideration of geographic and seasonal differences in operational priorities, the resolution of conflicts between the different Water Management Goals, and the mitigation of residuals that may occur when a Goal is less than optimally satisfied by the resulting integrated Management Range.

The importance of the multi-stakeholder GOC and study facilitator becomes apparent at this stage of the process, where the potentially divergent Goal-Specific Management Ranges must be integrated. Representation of all the Goals at this stage is crucial to achieve the transparency necessary for public approval of the integrated Management Ranges.

7.6.5 Public Communication and Engagement

The final stage of the Constraint Management Process involves the communication of the results to the public. Public interests should be represented through the GOC (i.e., through cottage-owners associations, etc.), and thus the resultant integrated Management Ranges should reflect the considerations of the public. This stage will begin the process of ongoing transparency in operations and engaging the public in Waterway matters.

Note that it is anticipated that it would also be beneficial to present the study methodology to the public prior to the study commencing. Public input into the process may reveal certain key considerations that are potentially overlooked in the process. In addition, public understanding and buy-in of the process can help to improve acceptance and approval of the final product, the Management Ranges.

8. Development of the Operational Management Process

The Operational Management Process is part of the larger Water Management Process proposed for the Trent Severn Waterway, shown in **Figure 8-1**. The Operational Management Process involves the day-to-day activities of the operational staff to manage the water levels and flows in the Waterway. This process is undertaken on an on-going basis with the goal of maintaining water levels and flows within the defined Management Ranges. This process is also intended to respond to situations when the water levels or flows are outside the Management Ranges.

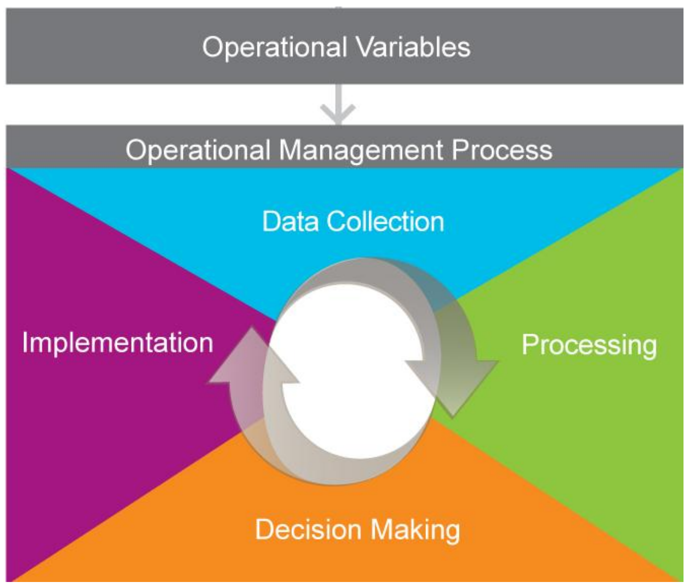


Figure 8-1 - The Operational Management Process

A benefit of the Water Management Process is the ability to effectively audit the performance of the system, since there are established water level ranges for each season and sector that is optimal to be within. It is anticipated that an annual review and report of operational performance (i.e., level of service) would be beneficial to the TSW to demonstrate transparency and accountability in water management decisions, and to develop public support and engagement in the Waterway operations.

The components of the Operational Management Process illustrated in the figure are described in the following sections.

8.1 Data Collection

As described in detail in the **Water Management Manual – Description of the Current Approach to Water Management**, flow and water levels are collected throughout the waterway on a daily basis. This information is processed and used in the decision making toward the implementation of the necessary operational strategy. In the spring, snow pack data and the winter stoplog settings in the Haliburton Sector also contribute to the information that is available for decision making.

The strength of the Operational Management Process relies on the accuracy and reliability of the data collected in this stage of the process. As shown in the **Evaluation of Water Management Systems and Models**, contemporary water management systems obtain this level of data integrity through extensive and comprehensive data collection efforts, taking advantage of many different existing sources of data and supplementing it with internal data collected and managed with appropriate technology. With respect to the TSW, an operational data collection strategy would include the following components, each of which is described further below:

- Internal Data - Consistent, accurate and reliable recording of water levels and flows at all lakes, reservoirs and rivers, as well as freshet runoff volumes, including field staff with expertise in data collection;
- External Data - Collection of applicable data from external agencies, particularly meteorological data (Environment Canada);
- Data Management - Management of all data in an appropriate database that allows backups, automatic linkages, and efficient manipulation and analysis of all data; and
- Staff Capabilities - Sufficient expertise to support such a data collection and management system.

Internal Data

Consistent, accurate and reliable recording of water levels and flows can be achieved through implementation of effective monitoring technologies at required locations or key indicator sites. Many locations in the TSW, particularly in the North, Central and South Sectors, currently use extensive automated water level gauges; however, the Haliburton Reservoirs are still largely monitored using manual staff gauges. While staff gauges are not necessarily less accurate than automated gauges, and while automated gauges require ongoing maintenance and calibration to ensure reliability, the collection of data from manual gauges is resource-intensive and difficult to integrate with an automated data management system.

In addition to water levels and flows, accurate assessment of the freshet volume is critical to mitigate flooding impacts and to ensure that Reservoirs are filled prior to the summer. An effective operational data collection strategy for the freshet volume would include the following:

- Evaluate freshet volume and estimated peak flow using proven techniques and modelling tools;
- Estimates should include both an optimistic (i.e., for flood management) and conservative (i.e., to fill the Reservoirs) freshet forecast;
- The use of a hydrological model to include spring rainfall, water content of snow cover and antecedent and future temperatures in order to estimate freshet volume, peak flow, time to beginning of runoff and time to peak flow.

With respect to freshet volume estimation in the TSW, there are several items that may improve the current process, including:

- Additional snow course observation stations in the headwater areas that have significant storage capabilities to better identify potential runoff volumes;
- Automated/remote snow sensors can be a solution for stations located in difficult to reach areas; and
- The use of a hydrologic model is required for flood management (snow course observation can only estimate the freshet volume, not anticipate flood impacts).

External Data

There are several external agencies that collect data that would be useful to TSW operations, most notably Environment Canada which distributes meteorological forecasts that are of interest to water managers interested in mitigating weather-related risks. Developing data sharing agreements with these external agencies has the potential to greatly expand the data resources available for TSW staff to make effective operational decisions. For example, meteorological forecast data supplied by Environment Canada could be input into a hydrologic model of the TSW to determine the potential impact of precipitation events on the water levels and flows in the system. Using a risk-based approach, operations could then be adjusted to mitigate impacts from flooding or low water (i.e., if forecast is for drought). This use of external data is currently implemented by the Rio Tinto Alcan hydro electric system in the Lac St-Jean region of Quebec, to great effect.

Data Management

The power and usability of consistent, reliable and accurate data, both internal and external, is greatly diminished without the proper management tools, such as a database. An effective data management tool would automatically process and store data as it is collected, perform some general quality assurance checks (e.g., identifying data gaps for later review by TSW staff), and allow easy manipulation of stored data for decision making. The database could be used to develop inputs into a hydrotechnical decision making model/tool, or to provide data for public communication purposes (i.e., water level graphs that update automatically on the internet).

Staff Capabilities

With the increasingly technical and specialized nature of data collection and management, as well as the use of that data for decision making, it is important for the TSW to have access to staff with capabilities to support the data system. Although the current TSW operations staff have extensive experience with the management of the Waterway, it is anticipated that additional staff would be required to effectively manage the data system to the extents described in this study.

8.2 Processing and Decision Making

Data processing and decision making are done on a daily basis during the navigational season and as required throughout the rest of the year. Currently, the collected data is recorded and compared to the previously recorded data, and decisions are made for the implementation of the operational strategy throughout the system based on lake-by-lake comparisons to the 25-year average water levels (rule curves). When data collection and management improvements as described in the previous section are adopted, there will be a greater availability and usability of data, permitting the use of more advanced processing and decision making tools for water management decisions, including:

- Hydrologic modelling for runoff forecasting;
- Hydraulic modelling to enhance system operations; and
- Decision making modelling to assist with the optimization of operations.

Hydrologic Modelling

Hydrologic modelling provides TSW staff the ability to forecast runoff flows given meteorological inputs (i.e., from Environment Canada data sharing agreements) and existing hydrotechnical conditions, allowing information on the potential impacts of precipitation and freshet events to be obtained. This information offers the potential to conduct water control operations on a proactive basis if required, although the long lag time for operational changes to affect the system conditions would remain a barrier to proactive operations.

Several potential hydrologic models have been evaluated in the **Evaluation of Water Management Systems and Models** report developed in this study, ranging in levels of complexity, cost and level of effort required to maintain and use. It is anticipated that a hydrologic model developed for the TSW would not require a high level of complexity, and thus would likely not be high in cost or level of effort, although the appropriate staff capabilities would be required to effectively implement the model. At a minimum, the model would be required to contain reservoir storage relationships and travel times through the system, while incorporating hydrologic routines to estimate runoff from meteorological conditions.

Hydraulic Modelling

Hydraulic modelling would provide the capability for TSW staff to identify stoplog/gate settings at dams to achieve the desired water levels and flows throughout the system. This model would be best integrated with a hydrologic model in an integrated hydrotechnical model, allowing runoff flow predictions to guide potential operational alternatives to achieve Management Ranges. The hydraulic component of this model would be similar in function to the current model developed by Acres (1973) that determines stoplog settings in the Haliburton Reservoirs to achieve desired flows at the Lakefield dam, and can potentially be developed from this legacy model.

Decision Making Modelling

Decision making modelling could be used to assist with the optimization of operational activities, for example, to determine dam settings that best meet Management Ranges throughout the system, or that meet Management Ranges while minimizing required operations, or other similar measure of efficiency and effectiveness. This model could be used to evaluate different operational scenarios or alternatives and determine the implications and performance of each scenario, potentially using forecasted meteorological and hydrological conditions to evaluate decisions before implementation. Simulations could also be run to evaluate impacts of climate change to the watershed hydrology and water levels during operations.

The decision making model is anticipated to be best integrated with the hydrotechnical model, so that the model results can be directly evaluated, but could also incorporate real-time monitoring data from the system to assist with daily decision making.

8.3 Implementation

Within the current management process, operational decisions are implemented when changes to the stoplog or dam settings are required. This implementation process can be completed within hours in the North, Central and South Sectors, but can take up to several days to complete dam setting adjustments in the Haliburton Sector. The current implementation methods generally meet the requirements of the Operational Management Process, since there are established roles, staff and communications that implement water management decisions. However, there are two items that are recommended to enhance the effectiveness of the operations group:

- The role of the water control group should be expanded and revised within the context of the Water Management Process; and
- Functional controls in the Haliburton Reservoirs should be enhanced.

In addition, increased communication of water control activities and decisions will increase transparency and help to develop public support for the system management.

Role of the Water Control Group

To effectively implement water management decisions and in the context of the Water Management Process (i.e., related to activities of managing the water), the water control group should be focused solely on water control, which consist largely of maintaining water levels and flows within the determined Management Ranges. There are a number of other roles that the current water control group is required to fulfill, such as maintenance of Waterway structures and equipment; however, these tasks have not been evaluated in this study.

The benefit of this role clarification is the separation of the development of Management Ranges from the actual Waterway operations, leading to a more consistent performance and measurable level of service. While representatives from the water control group are recommended to be part of the Goals & Objectives Committee during the Constraint Management Process, the day-to-day water control activities would not be concerned with issues related to the Water Management Goals. Instead, the Management Ranges establish water levels and flows for each season and lake wherein the Goals are satisfied, and through maintaining these water levels the water control group implicitly satisfy these Goals.

The current water control group is integrated within a larger operations group, which is also responsible for a large number of tasks on the Waterway, including the maintenance of dams and other structures, operation of navigation locks, upkeep of equipment, etc. Within the context of this larger group, the effective implementation of water control activities may benefit from additional staff capabilities, including:

- Data collection and management staff;
- Hydrotechnical (i.e., modelling) staff; and
- Media/public relations staff.

These capabilities would be required to implement the recommendations contained in this study, and are anticipated to be of great benefit to the effectiveness, transparency and accountability of future TSW operations.

Functional Control in the Haliburton Reservoirs

The ability to exercise a greater level of control over water levels in the Haliburton Reservoirs would provide benefit in the management and distribution of water throughout the system, as it relates to satisfying Management Ranges. Currently, the dams in the Reservoirs are controlled with 12-inch stoplogs, meaning that water level adjustments can only be implemented in increments allowed by a 12-inch stoplog. Increasing the functional control of the Reservoir dams may be as straightforward as including a 6-inch stoplog at each dam to allow water level changes in smaller increments, and recognizing these smaller stoplog increments in the hydrotechnical model.

Winter operations in the Haliburton Reservoirs has traditionally been a challenge for the operations group, given the difficulty of access to some of the lakes and the risk associated with stoplog changes compared to summer operations. However, greater adaptability and capability to implement stoplog changes in winter months will increase the likelihood that all Reservoirs are filled during the freshet more often. The methods to improve this adaptability may include specialized training and equipment for winter operations or modified dam control structures. Potential implications to manpower requirements and operational costs would have to be considered.

The need for this adaptability becomes apparent particularly when considering the potential impacts of climate change, discussed in **Section 2** to **Section 4** in this report. Although the overall volume of the freshet is not anticipated to significantly change, the snowpack will melt earlier, and more precipitation will fall as rain during the winter. If the ability to implement winter stoplog changes and provide operational control is not enhanced, there will be an increased probability of not capturing enough of the freshet runoff to fill the Reservoirs in a typical year.

Public Communication

In its role as a heritage site and significant recreational destination, public support and engagement in the TSW is critical. To enhance this support, it is important that water control operations be transparent to the greatest extent possible, so that operational decisions are understood and no “black-box” elements of the system exist that may be confusing or misunderstood. Regular operational communications would include updates on navigation and storage levels, warnings of impending water level drawdowns or increases, and notification of stoplog manipulations for

Reservoirs with significant population or concerns. The Management Ranges for each lake would also be publically available.

It may be beneficial to develop dedicated staff capabilities in public communication, whether through cross-training or new hires, that are specific to communication of technical material to non-technical audiences, as well as on effective strategies to ensure transparency of water control operations is achieved.

The TSW currently displays water levels at each lake on its website, but these levels must be manually updated by the Water Control Engineer, and there are no Management Ranges displayed to provide context to the water level, other than the 25-year minimum and maximum levels which do not necessarily provide an accurate representation of future operations. The navigation ranges are also displayed for the navigable lakes, which again do not necessarily represent the true operating range.

Operational communications would also include an annual public forum to foster stakeholder relationships and provide results on the past year's performance.

8.4 Operations outside of Management Ranges

The Management Ranges are developed to reflect the water levels and flows at which the Water Management Goals are optimally satisfied (as much as possible); however, there is an understanding that there will be circumstances that cause water levels to move out of the Management Range, such as drought, flood, or operational requirements (i.e., to allow for maintenance of a dam). Protocols for these critical situations, both high and low water level, should be developed to mitigate the potential impacts of being outside of the Management Ranges. These management plans do not approve or condone these critical situations, merely acknowledge the inevitability of their occurrence and provide a means to return water levels to the Management Range with the least possible impact.

8.4.1 High Water Level Management Plan

The High Water Level Management Plan should be developed and implemented to mitigate the impact of floods, high water levels and high flows, typically associated with the goal of reducing threats to public safety and infrastructure.

This may lead, for example, to having winter water levels in the Haliburton Reservoirs decrease below winter settings (by removal of stoplogs) after a freshet forecast indicates a potential large flood. This may negatively impact the natural environment (i.e., fish spawning), but may be a less severe impact than the results of more significant flooding during the freshet. The impacts to each of the goals would be evaluated when considering the need to implement this plan; however, a high water level management plan would typically involve the goal of reducing threats to public safety, which is the highest priority goal for Waterway operations regardless of the season or Sector.

In this critical situation management plan, the maximum number of stoplogs to be removed per day to lower the Reservoirs should be determined in order to not create high flows in downstream areas which can also lead to increasing flood risk. It may be that the most effective way to mitigate risk due to high water is to instead place logs in the lakes to retain more water. It is recommended to better define this critical situation management plan, which could be conducted in parallel to the development of Management Ranges and/or hydrotechnical model.

8.4.2 Low Water Level Management Plan

The Low Water Level Management Plan should be developed and implemented to mitigate the impact of drought, low water levels and low flows, typically associated with the goals of contributing to the health of Canadians (i.e., water quantity and quality), navigation and recreation.

This may lead, for example, to having water levels in the Kawartha Lakes during the navigation season to the lower limit of the Management Ranges, but since it is still within the Management Range the Water Management Goals are being satisfied. This will help to avoid being below the lower limit of Management Ranges in the Haliburton Reservoirs. The plan would explicitly balance the impact of being low within the Kawartha Lakes Management Range with dropping below the Haliburton Reservoirs Management Range.

9. Operational Case Studies

The review of the Operational and Constraint Management Processes has suggested several modifications or new elements that might be considered in future operations, including:

1. Management Ranges for all lakes, reservoirs and waterways in the system;
2. Enhanced collection, management and utilization of data from a variety of internal and external sources;
3. Hydrotechnical modelling tools for runoff forecasting and optimal hydraulic management of water levels and flows, including enhanced snowpack, water equivalent and runoff assessment during the spring freshet; and
4. Increased communications with watershed residents.

As part of the **Water Management Manual**, two operational case studies were evaluated for potential causes of high flows and water shortages in the system (1991 and 1999, respectively). To complement this evaluation, the case studies are presented again with consideration of the potential impacts of implementing the recommendations in this report, particularly the points listed above.

9.1 Case Study #1 – 1991 – High Flows

The spring of 1991 saw very high flows through the Burnt River system, causing record-high water levels in some downstream lakes (e.g., Buckhorn Lake, Rice Lake). The excess water came from a large precipitation event in early April.

With regards to high flows, there are two factors that have a significant influence on the impact that TSW operations can have on flood levels:

1. The magnitude of storage that is available within the system can impact operational control during flood events since the outlet controls were never developed for flood control but rather as a means to regulate for low flow augmentation for log-drives and navigation; and
2. Typical practice for reservoir operations states that discharges should not be conducted to create storage in the face of forecasted rainfall due to the following potential impacts:
    a) the rainfall may never come and the future low flow augmentation capability may be compromised; and
    b) the discharge may increase risk of downstream flooding.

It was apparent, as stated in the *1991 Burnt River Flood Investigation (MacLaren)*, that the storage capacity of the reservoirs was quickly exceeded due to the magnitude of the rainfall event and that operations at the time appeared to maximise any flow reduction that could be achieved with the minimal storage available.

When evaluated in the context of the integrated Management Ranges developed in **Section 7** of this report, the Reservoirs appeared to fill appropriately along the ideal Management Range during April, after a slightly low start in February and March. However, the water level graph representing the Reservoirs, shown in **Figure 9-1**, displays Kennisis Lake, which is on the Gull River system whereas the major flooding occurred on the Burnt River system. Although, unless the precipitation was extremely localized to the Burnt River watershed, it is likely that the Gull River Reservoirs also experience high flows. Regardless, Kennisis Lake filled up to its maximum storage level and experienced no abnormally high water levels that may have caused impacts to shoreline property or infrastructure.

Areas of the TSW downstream of the Reservoirs, represented through Buckhorn Lake (**Figure 9-2**) and Rice Lake (**Figure 9-3**), did experience abnormally high water levels due to the precipitation, and potentially exacerbated by stoplog removals in the Reservoirs.

After a typical winter drawdown in Buckhorn Lake (and the rest of the Kawartha Lakes), water levels began to rise in March as the snowpack melted. The extreme precipitation at the beginning of April quickly caused water levels to rise to a new 25-year high, approximately 50cm above the spill elevation of the dam. Although the water levels returned close to the long-term average by the beginning of May, there is the potential that the high water levels in April incurred impacts to adjacent property and infrastructure. A similar situation was found in Rice Lake, with water levels almost 55cm above the spill elevation of the dam, all the more significant considering the very small range of water level control available at the Rice Lake dam (13cm).

This uneven exceedance of the Management Ranges between the different sectors of the TSW would have been cause for concern. Ideally, as lakes in the system begin to exceed their Management Ranges, measures would be taken in the other areas of the system to mitigate this impact. Small exceedances in more lakes is generally anticipated to be desirable to large exceedances in only one or two lakes, since a small exceedance would likely have a negligible impact to public safety. Considerations such as this would also form part of the development of Management Ranges, as well as the High and Low Water Management Plans (described in **Section 8**).

The use of hydrotechnical modelling tools could have allowed a more comprehensive understanding of the impacts of the extreme precipitation, including more effective management scenarios to accommodate the flooding, such as attempting to retain more water in the Reservoirs. In addition, the implementation of enhanced data collection and management systems could have improved the ability of TSW staff to respond to the event, providing the most accurate information for the hydrotechnical model in a timely manner. Although responding to extreme precipitation events is a difficult task in a system as large and complex as the TSW, these tools would have provided the resources necessary to mitigate risk due to the high flows, within the capabilities of the system.

An established public communication medium regarding water control operations would have provided a means of informing shoreline residents of the potential impacts of the precipitation, for example by presenting summary results from the hydrotechnical model, further reducing the potential for impacts to public safety.

The April 1991 high flows create a useful case study to develop Management Ranges and hydrotechnical tools for improved water management on the TSW, and should be considered during future studies.

Figure 9-1 - Kennisis Lake Levels - 1991

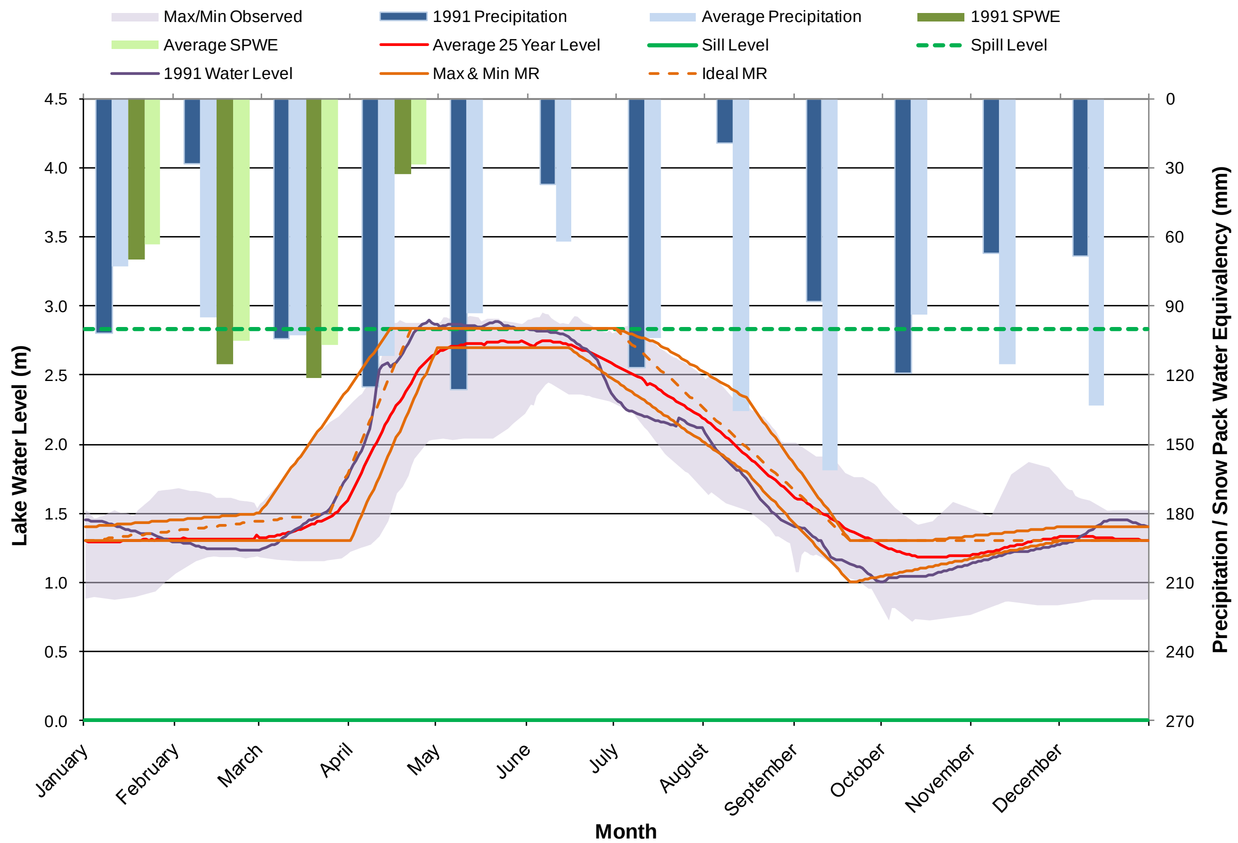


Figure 9-2 - Buckhorn Lake Levels - 1991

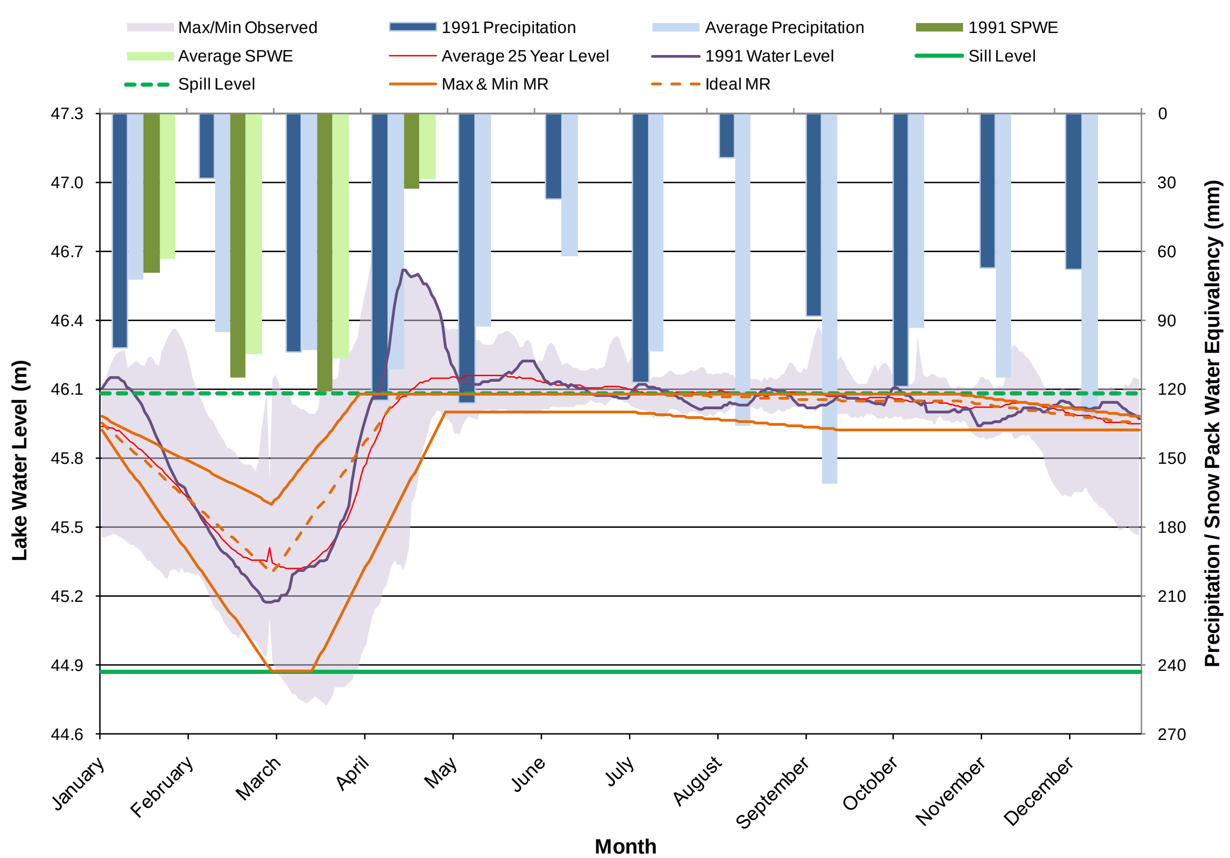
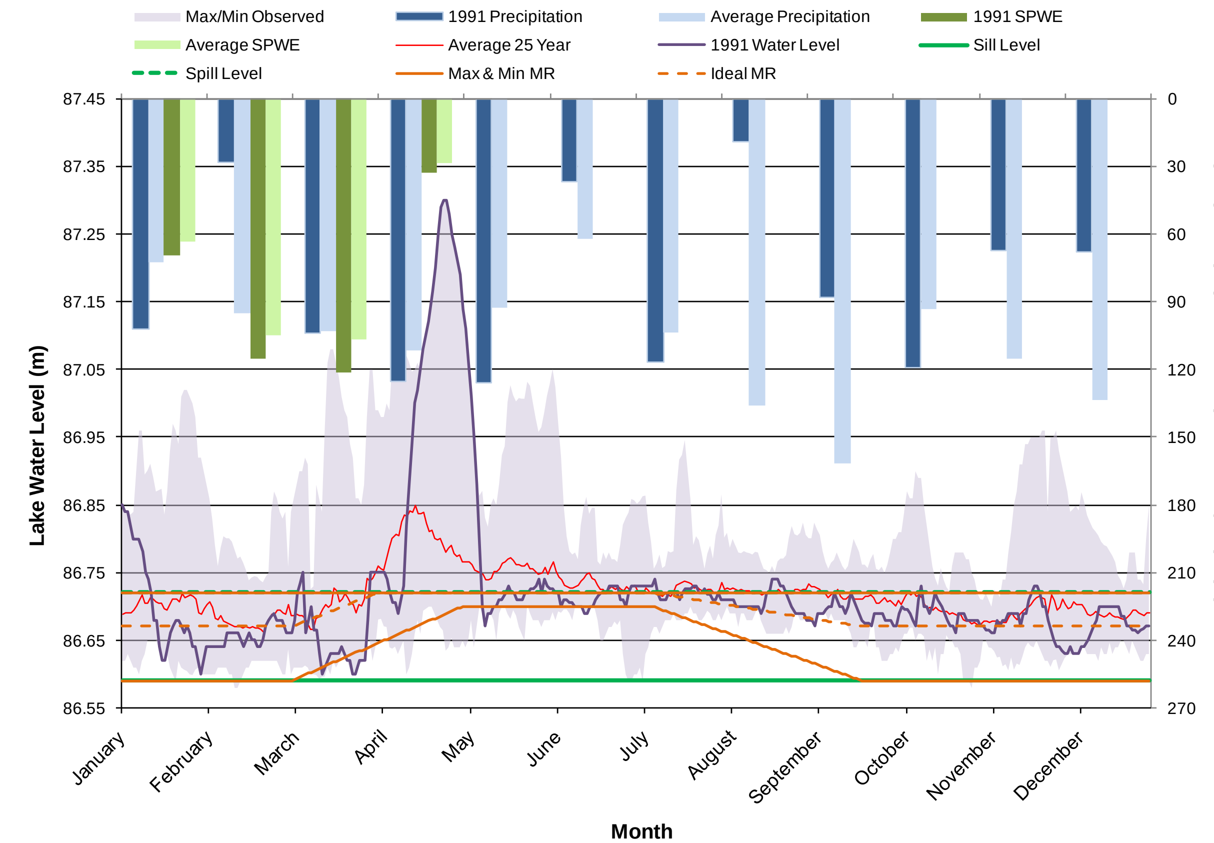


Figure 9-3 - Rice Lake Levels - 1991



9.2 Case Study #2 – 1999 – Low Flows

An average snowpack and well-below average precipitation during February, March and April of 1999 created a water shortage and caused record-low water levels in some Reservoirs. However, these conditions are only partially responsible for the water shortages in the Reservoirs; many also had record-low water levels during the fall months of 1998 which were never corrected prior to the 1999 freshet. The water levels in Kennisis Lake (**Figure 9-4**) were between 0.3m and 0.4m lower than the long-term average over the winter of 1998-99.

The rest of the TSW did not experience low water levels, as shown in **Figure 9-5** and **Figure 9-6** for Buckhorn Lake and Rice Lake, respectively. Buckhorn Lake, and the remaining Kawartha Lakes, were drawn down over the winter and filled during March and April, staying close to the long-term average water levels. Through the end of April and into May, water levels were at the spill level of the Buckhorn Lake dam. There was no impact due to low water levels when the navigation season opened.

Similar to the 1991 case study, this difference in Management Range divergences would have been a cause for concern. Developing hydrotechnical tools and enhanced data collection and management would have provided water managers with a more comprehensive understanding of the system and allowed the water to be potentially better balanced between the different sectors. The balance of low water levels throughout the system is also the primary consideration for a Low Water Management Plan, recommended to be developed as part of the Operational Management Process.

The most significant impact that the recommendations of this study would have had on this scenario is the management of water levels in the fall of 1998, when levels fell well below the minimum Management Range. The potential for these water levels to create water shortages the following spring would have been recognized and corrected over the winter months, if possible, or the water levels would never have been drawn so low, especially so late in the season when flow augmentation in the Kawartha Lakes is no longer required for navigation. Although there was the potential for the snowpack and regular winter/spring precipitation to fill the Reservoirs as per usual, the drawdown of the Reservoirs below the Management Range (or long-term average) created an unacceptable level of risk that the Reservoirs would not be filled, a risk that was only mitigated by above-average precipitation in June of 1999.

Figure 9-4 - Kennisis Lake Levels - 1999

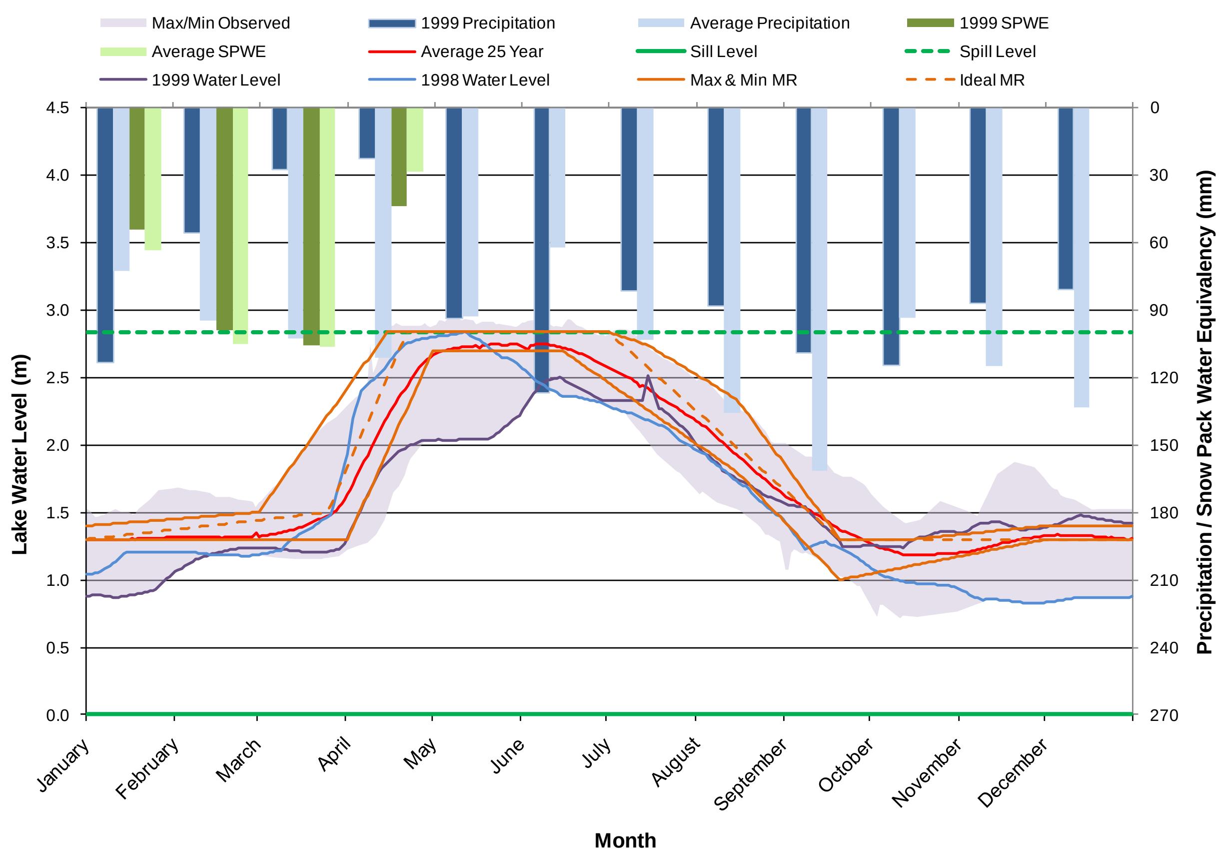


Figure 9-6 - Rice Lake Levels - 1999

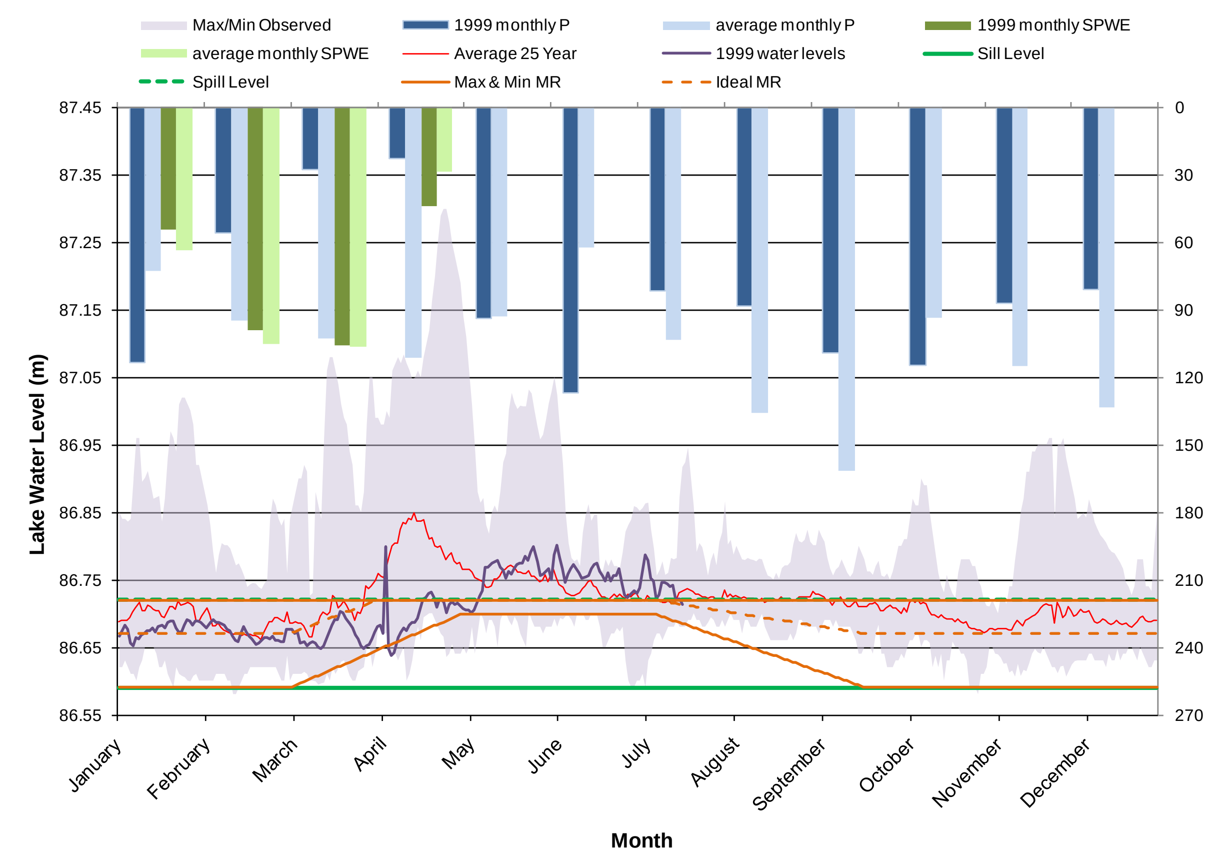
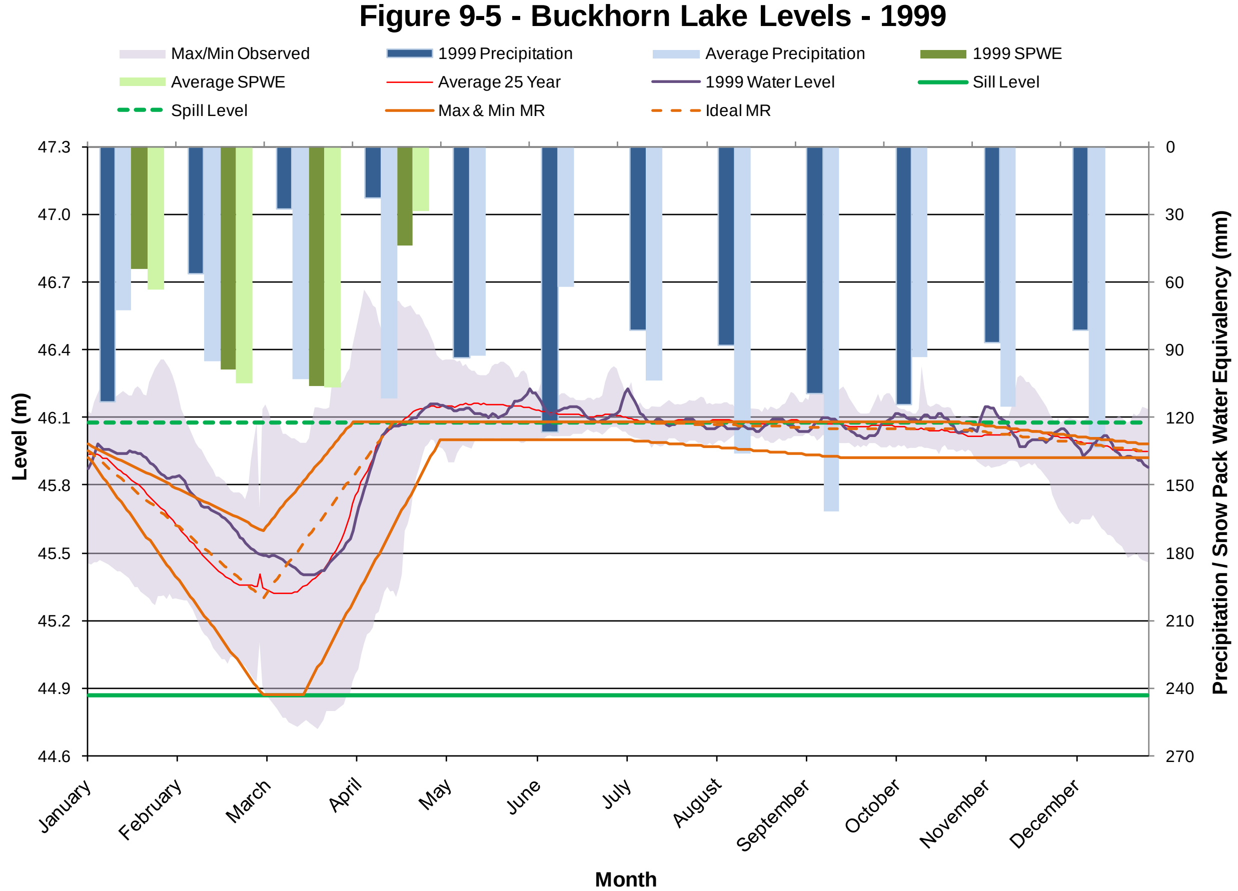


Figure 9-5 - Buckhorn Lake Levels - 1999



10. Recommendations for an Improved Water Management Strategy

The primary recommendation of this study is to incorporate the proposed Water Management Process, described in each of the study reports and shown in Figure 10-1, into the water control operations of the Trent Severn Waterway. In particular, it is recommended that the following concepts be identified and developed:

- An **Operational Management Process** that involves data collection, processing, decision making and implementation for the optimization of the TSW resources for the benefit of all users in the TSW system; and
- A **Constraint Management Process** that results in "Management Ranges" for all of the lakes, reservoirs and rivers of the TSW.

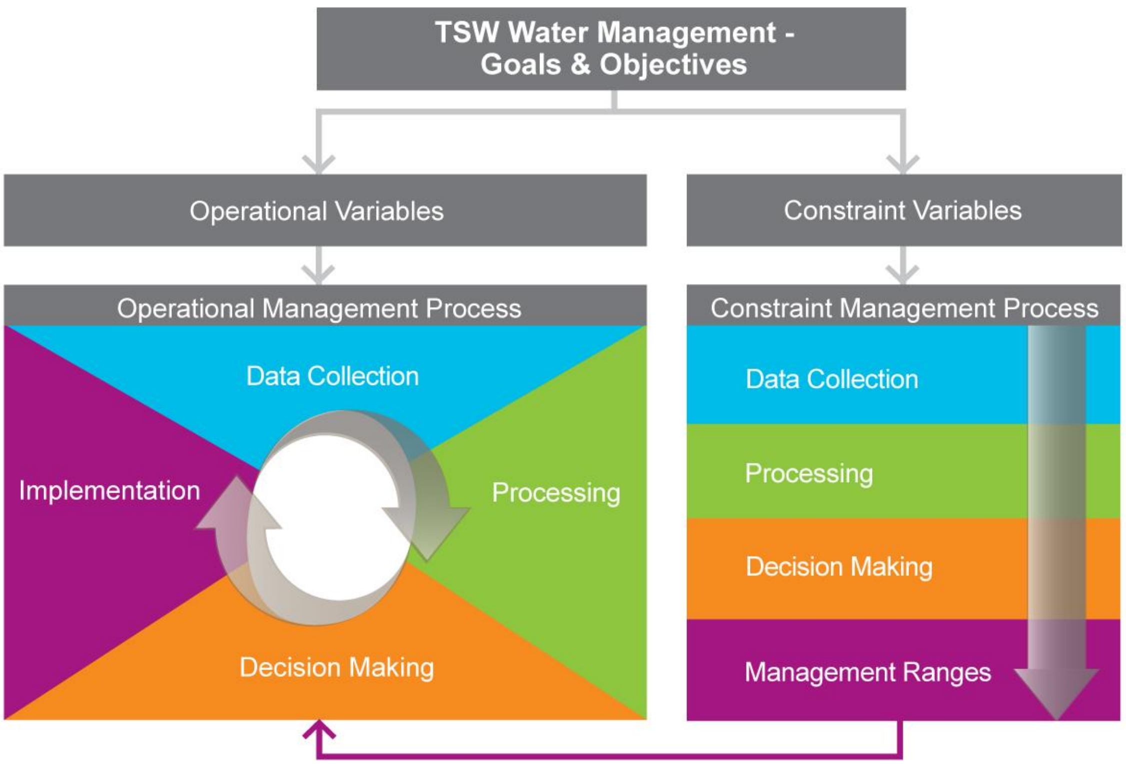


Figure 10-1 - Water Management Process for the Trent Severn Waterway

The protocols and terms of reference required to successfully implement each process are also to be developed to establish the roles and responsibilities for those involved in each process, for example:

- The Constraint Management Process establishes Management Ranges through the systematic evaluation of all considerations related to the six Water Management Goals for all lakes, reservoirs and rivers of the TSW.
- The Operational Management Process executes water control activities that maintain water levels and flows within the Management Ranges and accommodates high and low flow conditions in the TSW.

The remaining study recommendations relate to either the Operational or Constraint Management Processes, as described in **Table 10-1**.

Table 10-1 - Recommendations Related to the Proposed Water Management Processes

Operational Management Process Recommendations	Constraint Management Process Recommendations
• Expand and revise the role of the current water control group • Enhance freshet forecasting procedures • Increase functional control in the Haliburton Reservoirs • Enhance the collection of operational data • Develop a hydrologic model for runoff forecasting • Develop a hydraulic model to improve system operations • Develop operational protocols for high- and low-water conditions • Increase communication of operational activities	• Establish a Goals & Objectives Committee and study team • Identify Goal-Specific requirements • Establish Management Ranges for all Lakes and Reservoirs • Establish adaptive management protocols to revise Management Ranges as conditions evolve

These recommendations are described in greater detail in the following sections.

10.1 Recommendations to Develop the Constraint Management Process

The Constraint Management Process involves the task of developing Management Ranges on all lakes and rivers of the Waterway that reflect the consideration of the six Water Management Goals. An evaluation of the current approach to the tasks associated with the proposed Constraint Management Process is described in **Section 6**, and the considerations and methodology for incorporating this process into the TSW management is described in **Section 7**. The recommendations in this section are focused around incorporating the Constraint Management Process into the current water control strategy, following the proposed methodology presented in **Section 7.6**.

Establish a Goals & Objectives Committee and Study Team

It is recommended to establish a Goals & Objectives Committee (GOC) to guide the implementation of the Constraint Management Process. The GOC would contain representation for each of the six Water Management Goals, for a total of six to eight members, including but not limited to the following expertise:

- Waterway operations and water management expertise, likely represented by the TSW water control engineer, operations supervisors and other staff;
- Hydro power;
- Natural environment science (fisheries, terrestrial ecology, wildlife ecology);
- Agency expertise and representation: Department of Fisheries and Oceans, Environment Canada, Ministry of Environment, Ministry of Natural Resources, Conservation Authorities, etc.;
- Municipal representation; and
- Citizen group representation (i.e., local cottage-owners associations).

The specific composition of the GOC may vary within the Waterway, as Management Ranges are developed for the different sectors and areas. Given the diverse array of representation recommended for the GOC, and the recommended size of six to eight people to maintain effective working relationships, it is anticipated that GOC members may have to fulfill more than one representation role.

In relation to the existing Water Management Advisory Committee (WMAC), it is recommended that the GOC be an independent technical body, and that the WMAC serve as an oversight committee to the Constraint Management Process. The GOC would be expected to present the results of the Process to the WMAC as they progress, such as the Goal-Specific and integrated Management Ranges. The WMAC in turn would review the study results and provide recommendations to Parks Canada for implementation.

The GOC is recommended to form part of a larger study team to include a facilitator, who is anticipated to consist of an external party with capabilities appropriate to this process, including:

- Understanding of the technical components of the Trent Severn Waterway;
- Coordination of public processes; and
- Stakeholder group facilitation, including consensus building and conflict resolution.

The study facilitator is required to have an extensive understanding of the technical components of the Waterway since they will be ultimately responsible for the production of the integrated Management Ranges and will be required to contribute technical expertise to the GOC to augment the development of Management Ranges. However, this technical knowledge must accompany skill in facilitating groups as comprehensive and diverse as the GOC, so that the collaboration required to produce the Management Ranges can be effective.

Identify Goal-Specific Requirements

It is recommended to identify water level and flow requirements, as well as acceptable/unacceptable rates of change in water level or flow, to optimally satisfy the requirements for each Water Management Goal in the different seasons and geographies of the Waterway (i.e., Goal-Specific Management Ranges). This is considered one of the primary tasks of the GOC and study team, and as such, this recommendation relies on the formation of the GOC and study team prior to implementation.

At this stage in the process, the representatives of the GOC function relatively independently, albeit in cooperation with the study facilitator who oversees the process. The members of the GOC responsible for each Water Management Goal (there may be several assigned to each Goal) develop their respective Goal-Specific Management Range and provide them to the rest of the study team to prepare for the next stage.

It may be necessary to augment the GOC with increased technical capabilities or increased local representation, depending on the nature of the Goal being evaluated. In these situations, it is anticipated that the study facilitator (e.g., a consulting firm) would possess the necessary capabilities, whether a technical understanding of the Waterway or the ability to effectively solicit public input, to enhance the GOC.

Establish Management Ranges for all Lakes and Reservoirs

It is recommended to develop integrated Management Ranges for all lakes, reservoirs and rivers in the TSW using the Goal-Specific Management Ranges developed by the GOC and study team. The integration of the Goal-Specific Management Ranges involves the consideration of geographic and seasonal differences in operational priorities, the resolution of conflicts between the different Water Management Goals, and the mitigation of residuals that may occur when a Goal is less than optimally satisfied by the resulting integrated Management Range. Representation of all the Goals at this stage is crucial to achieve the transparency necessary for public approval of the integrated Management Ranges.

As part of this recommendation is the communication of the results to the public. Public interests should be represented through the GOC (i.e., through cottage-owners associations, etc.), and thus the resultant integrated Management Ranges should reflect the considerations of the public. Note that it is anticipated that some level of public communication would have occurred throughout the process, and that this stage consists primarily of the communication of results, not the solicitation of feedback.

Establish Adaptive Management Protocols to Revise Management Ranges as Conditions Evolve

It is recommended to develop an adaptive management process by which the Management Ranges can be revised within the context of TSW management, and particularly through operation of the Waterway. This process will help to ensure that the needs of the various users and stakeholders of the Waterway, as represented through the six Water Management Goals, will continue to be satisfied as operational conditions change and as an improved understanding of the system requirements is achieved. This will include facilitate the ability to take climate change into consideration. An additional benefit of an adaptive management protocol is the ability to re-evaluate and re-develop the Management Ranges based on the results of audits regarding the level of service provided by Waterway operations, which is an important component of ongoing transparency and effectiveness of operations.

10.2 Recommendations to Develop the Operational Management Process

The Operational Management Process concerns the activities of the water control group and the efforts to maintain water levels and flows within the Management Ranges established by the Constraint Management Process. The evaluation of the current approach to water control operations is described in **Section 6**, and potential enhancements to this approach, consistent with the adoption of the formalized Operational Management Process, is described in **Section 8**. This portion of the Water Management Process is currently better established in the day-to-day activities of the TSW staff when compared to the Constraint Management Process, and therefore the recommendations in this section are primarily enhancements to current water control operations, with the goal of increasing the effectiveness, efficiency and accuracy of water control decisions.

Expand and Revise the Role of the Current Water Control Group

To effectively implement water management decisions, the water control group should be focused solely on water control activities, which consist of maintaining water levels and flows within the determined Management Ranges and accommodating high and low flow conditions. The anticipated benefit of this role clarification is more consistent performance and measurable level of service in water control activities. The effective implementation of water control activities may benefit from additional staff capabilities, including:

- Data collection and management staff;
- Hydrotechnical (i.e., modelling) staff; and
- Media/public relations staff.

These capabilities would be required to implement the recommendations contained in this study, and are anticipated to be of great benefit to the effectiveness, transparency and accountability of future TSW operations.

Enhance Freshet Forecasting Procedures

Accurate assessment of the freshet volume is critical to mitigate flooding impacts and to ensure that Reservoirs are filled prior to the summer. An effective data collection strategy for the freshet volume is recommended to include the following:

- Enhanced data collection of freshet-related information, including:
  - Additional snow course observation stations in the headwater areas, and other areas as found necessary, that have significant storage capabilities; and
  - Automated/remote snow sensors for stations located in difficult to reach areas.
- Evaluate freshet volume and estimated peak flow using proven techniques and modelling tools;
- Both optimistic (i.e., for flood management) and conservative (i.e., to fill the Reservoirs) freshet forecasts;

- The use of a hydrological model to include spring rainfall, water content of snow cover and antecedent and future temperatures in order to estimate freshet volume, peak flow, time to beginning of runoff and time to peak flow. The use of a hydrologic model is required for mitigation of high water levels, since snow course observation can only estimate the freshet volume, not anticipate flood impacts.

Also recommended to be developed are protocols for water control changes based on the results of the freshet forecast, particularly in the Haliburton Reservoirs, to ensure that the greatest chance of filling the Reservoirs with the freshet flows is maintained throughout the winter. This may require a greater level of water control operations in the winter months, which would require enhancements in the Haliburton Reservoirs, as discussed in the following section.

Increase Functional Control in the Haliburton Reservoirs

The ability to exercise a greater level of control over water levels in the Haliburton Reservoirs would provide benefit in the management and distribution of water throughout the system, as it relates to satisfying Management Ranges. Currently, the dams in the Reservoirs are controlled with 12-inch stoplogs, meaning that water level adjustments can only be implemented in increments allowed by a 12-inch stoplog. Increasing the functional control of the Reservoir dams may be as straightforward as including a 6-inch stoplog at each dam to allow water level changes in smaller increments, and recognizing these smaller stoplog increments in the hydrotechnical model.

Winter water control operations in the Haliburton Reservoirs has traditionally been a challenge for the operations group, given the difficulty of access to some of the lakes and the risk associated with stoplog changes compared to summer operations. However, greater adaptability and capability to implement stoplog changes in winter months will increase the likelihood that all Reservoirs are filled during the freshet in more years, particularly as the impacts of climate change begin to occur. The methods to improve this adaptability may include specialized training and equipment for winter operations or modified dam control structures to reduce the amount of manual labour required to implement stoplog changes. Potential implications to manpower requirements and operational costs will have to be considered. Note that winter operations typically carry a higher level of risk to operations staff, compared to summer operations, and increased activities in the winter months should consider these risks.

Enhance the Collection of Operational Data

The collection and management of data required for water control operations is recommended to be enhanced in four different categories:

- Internal Data - Consistent, accurate and reliable recording of water levels and flows at all lakes, reservoirs and rivers, as well as freshet runoff volumes;
- External Data - Collection of applicable data from external agencies, particularly meteorological data (Environment Canada);
- Data Management - Management of all data in an appropriate database that allows backups, automatic linkages, and efficient manipulation and analysis of all data; and
- Staff Capabilities - Sufficient expertise to support such a data collection and management system.

Consistent, accurate and reliable recording of water levels and flows, and therefore more consistent, accurate and reliable water control decisions, can be achieved through implementation of effective monitoring technologies at required locations. Many locations in the TSW, particularly in the North, Central and South Sectors, currently use extensive automated water level gauges; however, the Haliburton Reservoirs are still largely monitored using manual staff gauges, which is resource-intensive and difficult to integrate with an automated data management system. It is important that data be representative of the unique conditions in the Trent Watershed, which is particularly important given the size and potential climatic variability throughout the Watershed.

There are several external agencies that collect data that may be of use to TSW operations, most notably Environment Canada which distributes meteorological forecasts that are of interest to water managers interested in mitigating weather-related risks. Developing data sharing agreements with these external agencies has the potential to greatly expand the data resources available for TSW staff to make effective operational decisions. Additional sources of external data are described in the **Data Collection and Management Guide** developed under this study.

The power and usability of consistent, reliable and accurate data, both internal and external, is greatly diminished without the proper management tools, such as a database. An effective data management tool would automatically process and store data as it is collected, perform quality assurance checks, and allow easy manipulation of stored data for decision making.

With the increasingly technical and specialized nature of data collection and management, as well as the use of that data for decision making, it is recommended that the TSW have access to staff with capabilities to support the data system. Although the current TSW operations staff have extensive experience with the management of the Waterway, it is anticipated that additional staff or staff capabilities would be required to effectively manage the data system to the extents recommended in this study.

Develop a Hydrologic Model for Runoff Forecasting

It is recommended that a forecast tool for runoff flow prediction be developed. Hydrologic modelling provides TSW staff the ability to forecast runoff flows given meteorological inputs (i.e., from Environment Canada data sharing agreements) and existing hydrotechnical conditions, allowing information on the potential impacts of precipitation and freshet events to be obtained.

Several potential hydrologic models have been evaluated in the **Evaluation of Water Management Systems and Models** report developed in this study, ranging in levels of complexity, cost and level of effort required to maintain and use. It is anticipated that a hydrologic model developed for the TSW would not require a high level of complexity, although the appropriate staff capabilities would be required to effectively implement the model. At a minimum, the model would be required to contain hydrologic routines to estimate runoff into the system from meteorological conditions.

Develop a Hydraulic Model to Improve System Operations

It is recommended to develop a hydraulic model that at a minimum identifies stoplog/gate settings at lakes and reservoirs that meet downstream flow requirements (i.e., Management Ranges). The hydraulic model would be integrated with the hydrological model to allow forecasting of flows and water levels within the system. It is anticipated that this model can be based at least in part on the work completed by Acres (1973).

The integrated hydrotechnical model could be used as a decision making tool to assist with the optimization of operational activities, for example, to determine dam settings that best meet Management Ranges throughout the system, or that meet Management Ranges while minimizing required operations, or other similar measure of efficiency and effectiveness. This model could be used to evaluate different operational scenarios or alternatives and determine the implications and performance of each scenario.

Develop Operational Protocols for High- and Low-Water Conditions

The Management Ranges are developed to reflect the water levels and flows at which the Water Management Goals are optimally satisfied; however, there will be circumstances that cause water levels to move out of the Management Range, such as drought, flood, or operational requirements (i.e., to allow for maintenance of a dam). Protocols for these critical situations, both high- and low-water level, are recommended to be developed to mitigate the potential impacts of being outside of the Management Ranges. The protocols would identify risk thresholds outside of the Management Ranges, criticality of exceedances, and clear water control strategies in the event of the exceedances. These management plans do not approve or condone these critical situations, merely acknowledge the inevitability of their occurrence and provide a means to return water levels to the Management Range with the least possible impact.

Increase Communication of Operational Activities

It is recommended to increase communication of operational water control activities through varied media coverage. As a heritage site and significant recreational destination, public support and engagement in the TSW is critical. To enhance this support, it is important that operations be transparent to the greatest extent possible, so that water control decisions are understood and no “black-box” elements of the system exist that may be confusing or misunderstood. Communications would include updates on navigation and storage levels, warnings of impending water level drawdowns or increases, notification of stoplog manipulations for reservoirs with significant population or concerns and explanations for significant water control changes. The Management Ranges for each lake would also be publicly available.

The Water Control Engineer currently performs much of the public communication activities, but it may be beneficial to develop staff capabilities, whether through cross-training or new hires, that are specific to communication of technical material to non-technical audiences, as well as on effective strategies to ensure transparency of operations is achieved.

Operational communications are also recommended to include an annual public forum to foster stakeholder relationships and provide results on the past year’s performance.

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Appendix A

Climate Data

- **Table A-1 – Climate Stations (Environment Canada)**
- **Table A-2 – Climate Normals (Environment Canada)**
- **Table A-3 - Results of Analysis on Climate Data**
- **Figure A-1 – Climate Stations Location Map**

Table A-1 - Climate Stations (Environment Canada)

	CLIMATE STATION		LOCATION				ELEVATION	RECORD		TYPE OF DATA	COMMENT ON DATA SET
			Latitude N		Longitude W			PERIOD	LENGTH		
	ID	NAME	°	'	°	'	m		years		
HALIBURTON RESERVOIR LAKES REGION											
1st Station	6163170	HALIBURTON 2	45	0.3	78	29	320	1949-1955	7	daily	to complete the 2 others.
	6163171	HALIBURTON 3	45	1.8	78	31.8	330	1987-2010	22	daily	2007, 2010 are incomplete
	6163156	HALIBURTON A	45	0	78	34.8	320	1889-1992	104	daily	missing data before 1950
	Combo	**HALIBURTON**						**Total Record Length**	**121**		
2nd Station	6165195	MINDEN	44	55.8	78	43.2	274.3	1956-2006	51	daily	good
	6165197	MINDEN FORESTRY	44	45	78	42	304.8	1948-1955	8	daily	many missing data
	Combo	**MINDEN**						**Total Record Length**	**60**		
KAWARTHA LAKES AND OTONABEE RIVER SUB-WATERSHED REGION											
1st Station	6166416	PETERBOROUGH	44	16.8	78	19.2	193.5	1867-1970	104	daily	good
	6166418	PETERBOROUGH A	44	14	78	22	191	1969-2005	34	daily	good
	6166420	PETERBOROUGH AWOS	44	14	78	22	191	2004-2010	6	daily	good
	Combo	**PETERBOROUGH**						**Total Record Length**	**144**		
2nd Station	6164430	LINDSAY	44	21	78	45	266.7	1881-1971	91	daily	good
	6164432	LINDSAY FILTRATION PLANT	44	21	78	43.8	254.5	1964-1990	27	daily	good
	6164433	LINDSAY FROST	44	20	78	44	262.1	1974-2006	33	daily	good
	Combo	**LINDSAY**						**Total Record Length**	**126**		
RICE LAKE AND LOWER TRENT RIVER SUB-WATERSHED REGION											
1st Station	6158875	TRENTON A	44	7	77	32	86.0	1953-2010	57	daily	good
	6158885	TRENTON ONT HYDRO	44	8	77	36	88.4	1915-1992	77	daily	no temperature data
	6150689	BELLEVILLE [1]	44	9	77	23	76.2	1866-2006	140	daily	temperature data to
	6150717	BELLEVILLE PAR LAB [1]	44	10	77	21	88.4	1929-1959	31	daily	complete Trenton
	Combo	**TRENTON**						**Total Record Length**	**95**		
2nd Station	**Combo**	**PETERBOROUGH** (described above)						**Total Record Length**	**144**		considered representative for Rice Lake Region

(1) Belleville stations are outside the watershed (east of Trenton), but temperature dataset is complete and used to assess climate trends over the last 80 years for the Lower Trent area.

Table A-2 - Climate Normals (Env. Canada) – Monthly Mean Precipitation and Temperature (1971-2000)

Month	HALIBURTON RESERVOIR LAKES REGION		KAWARTHA LAKES AND OTONABEE RIVER REGION		RICE LAKE AND LOWER TRENT RIVER REGION		
	Haliburton	Minden	Lindsay	Peterborough	Trent	Belleville	Smithfied
Daily Average Temperature (°C)							
Jan	-10.9	-10.2	-8.9	-8.9	-7.5	-7.10	-7.40
Feb	-9.2	-8.7	-7.3	-7.7	-6.3	-5.90	-6.00
Mar	-3.6	-2.9	-1.9	-2.0	-1.0	-0.60	-0.70
Apr	4.4	4.6	5.8	5.7	6.1	6.70	6.50
May	11.7	11.7	12.8	12.4	12.7	13.70	12.70
Jun	16.0	16.3	17.4	16.8	17.6	18.70	17.20
Jul	18.9	18.8	20.1	19.4	20.5	21.60	20.60
Aug	17.8	17.8	18.9	18.2	19.4	20.6	19.70
Sep	13.2	13.2	14.2	13.5	14.8	15.9	15.20
Oct	6.9	7.1	7.9	7.3	8.3	9.3	8.80
Nov	0.6	0.7	1.8	1.7	2.6	3.2	3.10
Dec	-7.0	-6.4	-5.1	-5.3	-4.0	-3.5	-3.60
Year	**4.90**	**5.17**	**6.31**	**5.93**	**6.93**	**7.72**	**7.18**
Precipitation (mm)							
Jan	85.3	94.0	67.6	58.5	70.1	74.0	87.3
Feb	66.4	63.1	47.5	50.6	54.0	56.4	74.7
Mar	76.8	74.2	58.4	65.0	72.4	73.3	94.4
Apr	70.2	74.3	62.5	68.8	77.1	74.6	83.1
May	92.8	92.7	81.9	73.2	71.6	74.3	75.4
Jun	86.8	90.3	83.9	76.7	79.5	70.9	62.0
Jul	78.0	82.7	73.4	66.7	56.1	52.7	53.9
Aug	85.5	87.8	89.7	83.2	77.1	80.7	74.4
Sep	86.6	96.0	91.7	78.4	87.6	86.4	90.7
Oct	89.4	91.5	72.9	70.0	76.0	76.0	79.8
Nov	98.1	102.1	84.1	79.0	91.8	87.3	89.2
Dec	92.9	96.0	67.9	70.3	80.4	85.2	117.4
Year	**1009**	**1045**	**882**	**840**	**894**	**892**	**982**

Table A-3 - Results of Analysis on Climate Data – Monthly Mean Precipitation and Temperature (1921-1950 and 1971-2000)

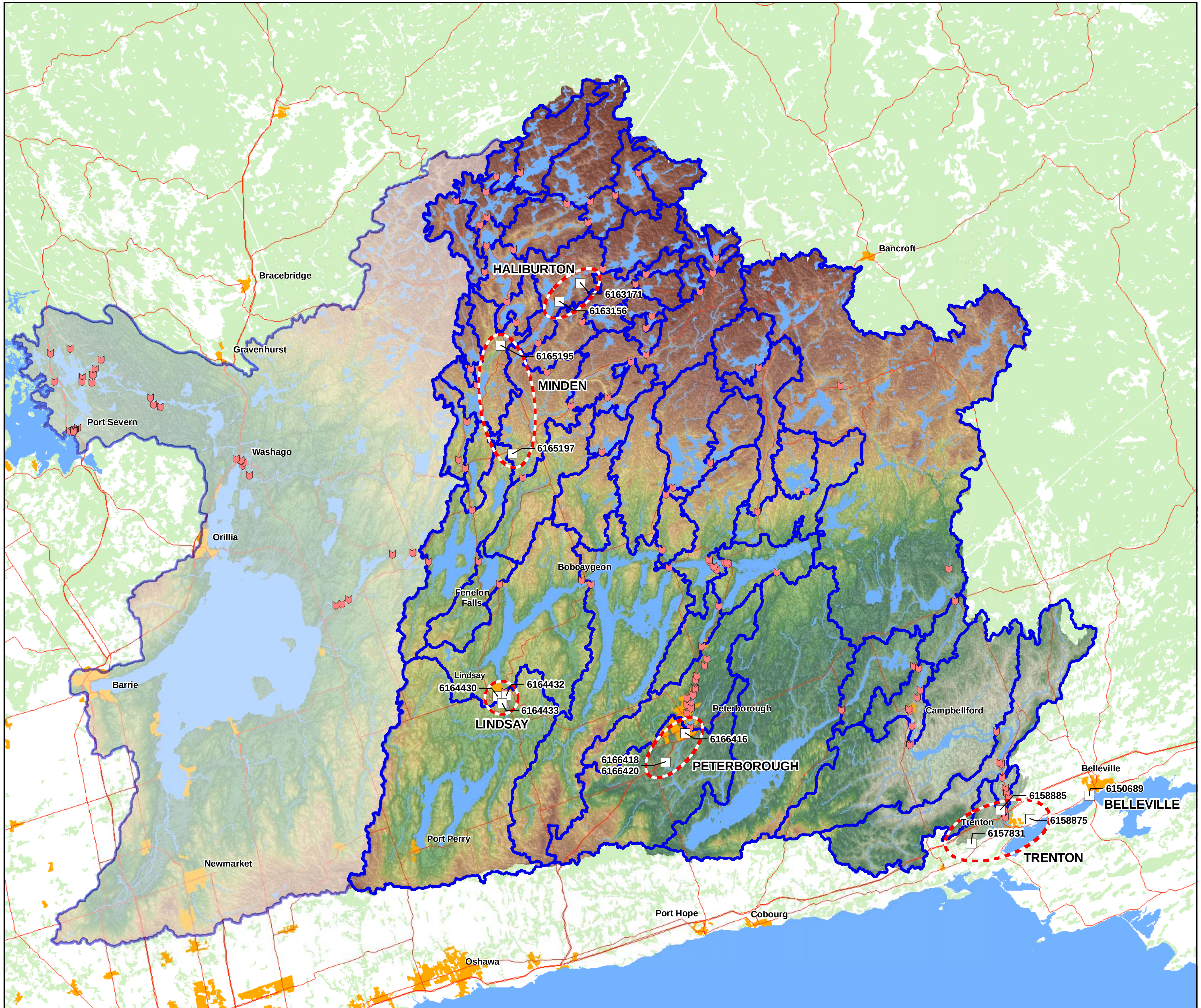
Climate Station	Period	Number of Valid Years [(1)]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Monthly Average Temperature (°C)															
Haliburton	**1921-1950**	**21**	-10.1	-9.7	-3.7	3.7	10.9	16.4	18.8	17.7	13.5	7.4	0.4	-7.1	4.9
	1971-2000	**30**	-10.7	-9.2	-3.4	4.3	11.5	16.1	18.8	17.7	13.2	7.0	0.5	-6.8	5.0
	Δ Temperature (°C)		-0.6	0.5	0.2	0.6	0.5	-0.2	0.0	0.0	-0.3	-0.4	0.1	0.3	0.1
Peterborough	**1921-1950**	**25**	-7.8	-7.5	-1.9	5.5	12.6	17.8	20.4	19.8	15.6	8.8	2.0	-5.0	6.8
	1971-2000	**30**	-8.9	-7.7	-1.9	5.7	12.4	16.8	19.4	18.2	13.5	7.3	1.7	-5.3	6.0
	Δ Temperature (°C)		-1.1	-0.2	0.0	0.2	-0.2	-1.0	-1.0	-1.7	-2.0	-1.5	-0.3	-0.2	-0.8
Trenton (Belleville)	**1921-1950**	**29**	-7.1	-7.1	-1.1	5.9	12.6	18.3	21.3	20.3	15.9	9.2	2.7	-4.7	7.3
	1971-2000	**30**	-7.1	-5.9	-0.6	6.7	13.7	18.7	21.6	20.6	15.9	9.3	3.2	-3.5	7.8
	Δ Temperature (°C)		0.0	1.2	0.5	0.8	1.1	0.3	0.3	0.2	0.0	0.1	0.5	1.2	0.5
Monthly Average Precipitation (mm)															
Haliburton			Too many missing data (only 13 years have 30 missing daily values or less)												
Peterborough	**1921-1950**	**26**	69.2	62.2	66.3	62.8	62.2	63.9	71.8	65.6	77.3	59.8	68.1	62.5	792
	1971-2000	**30**	58.7	50.3	65.0	68.8	73.2	76.7	66.7	83.2	78.7	68.4	79.0	70.3	839
	Δ Precipitation (%)		-15%	-19%	-2%	10%	18%	20%	-7%	27%	2%	14%	16%	13%	6%
Trenton	**1921-1950**	**29**	89.4	68.3	77.1	64.4	71.7	61.2	66.2	60.4	68.7	68.2	78.4	73.3	847
	1971-2000	**30**	70.6	54.0	72.9	77.1	71.4	79.7	56.1	77.2	87.6	76.5	91.5	80.7	895
	Δ Precipitation (%)		-21%	-21%	-6%	20%	0%	30%	-15%	28%	28%	12%	17%	10%	6%

[(1)] A valid year is a year having 15 missing daily values or less. The valid years for precipitation data for the combo stations Peterborough and Trenton have no missing data.

Parcs Canada Parks Canada

TRENT-SEVERN WATERWAY HISTORIC SITE OF CANADA, PARKS CANADA AGENCY

TRENT SEVERN WATERWAY WATER MANAGEMENT STUDY



Climatological Station
Dam
Watershed limits

Value
High : 562
Low : 49

0 10 20 30 km

1 : 720 000

UTM 17
NAD 83 Datum

CLIMATE STATIONS LOCATION MAP

May 2010

AECOM

Appendix B

Report on climate change in the Trent Severn Waterway Region

By:

OURANOS

CONSORTIUM ON REGIONAL CLIMATOLOGY
AND ADAPTATION TO CLIMATE CHANGE

www.ouranos.ca

Report on climate change in the Trent Severn Waterway Region

OURANOS is a research consortium focusing on regional climatology and adaptation to climate change. It is a joint initiative from the Québec Governement, Hydro-Québec and the Meteorological Service of Canada, with the participation of UQAM, INRS, Laval and McGill universities.

SCEN-No. 2010–03

Report on climate change in the Trent Severn Waterway Region

Authors : David Huard
Contributors : Diane Chaumont, Anne Frigon

Summary

This document presents an analysis of climate change projections for the Trent Severn Waterway region. An ensemble of 136 global climate model simulations, driven by three future greenhouse gas emission scenarios, is used to estimate changes in temperatures and precipitations. Results suggest an increase of mean annual temperatures by 2.5 ± 0.7 ℃and an increase in mean annual precipitations of 6 ± 4% for the 2041–2070 horizon.

January 5, 2011

Contents

1 Background on climate change analysis

The emission of atmospheric greenhouse gases (GHG) concentration is inducing a series of climatic changes, most notably an increase in global mean temperatures and an intensification of the global hydrological cycle (*Meehl et al.*, 2007a). To assess the magnitude of those changes and understand their impact on climate, modeling teams around the world have created coupled numerical models of the atmospheric circulation, the ocean and surface processes. Given an initial climatic state and the evolution of GHG concentrations, these Global Climate Models (GCM) simulate the Earth's climate over hundreds, if not thousands of years.

This requirement of producing long term simulations imposes severe constraints on the model, most notably on the model resolution. Each GCM defines a three dimensional grid over the Earth and computes climatic variables (temperature, pressure, wind speed, humidity, etc) at each grid point, based on the values stored at the last time step and the physical equations describing their evolution through time. The higher the resolution, the more equations to solve, the longer the model takes to reach a solution. Typically, models participating in the Intergovernmental Panel on Climate Change (IPCC) 4th assessment report have an horizontal resolution of about 250 km. To illustrate the limitations imposed by the coarse resolution, Figure 1.1 shows the horizontal grid of the CCCma climate model (*CCCma*, 2010). It is clear that local weather specificities, for example related to proximity to the Great Lakes, cannot be adequately reproduced by GCMs. Rather, GCMs strive to reproduce accurately climate statistics, eg. the large scale mean state and seasonal cycle of climatic variables (*Randall et al.*, 2007).

Coarse grid resolution is not the only source of uncertainty affecting GCMs. Due to the sheer complexity of the climate system, a number of processes are left unaccounted for, such as ice sheet dynamics, or are known to be poorly represented, eg. aerosols effect on cloud properties (*Solomon et al.*, 2007a). These modeling uncertainties are unavoidable, but they tend to decrease as research provides new insight about these processes, and novel ways to simulate them.

Another source of uncertainty is, however, irreducible: natural climatic variability. Natural climatic variability can be understood as large scale variations of the climate that arise due to its chaotic nature. For example, an exceptionally warm year is a manifestation of this natural climatic variability, while a gradual increase in mean temperatures over 30 years is a signal of underlying climate changes. Due to this intrinsic variability, two simulations, started with nearly identical initial conditions, will diverge and eventually become completely independent. While these simulations end up projecting different sequences of weather events, their long term climatic averages are similar (*Murphy et al.*, 2009). This is one of the reasons why climate change studies typically use large number of simulations: to make sure we extract climate change signals rather than random fluctuations due to natural variability.

The current trend observed in global air and sea temperatures cannot be explained by this natural climate variability. According to *Solomon et al.* (2007a), *greenhouse gases forcing has very likely caused most of the observed global warming over the last 50 years.* To simulate the climate over the next century, modelers hence need to specify GHG emission scenarios for the future. These emission scenarios are based on different economic, social and technological projections. These scenarios and the rationale behind each one are described in the *Special Report on Emission Scenarios* (SRES) (*Nakicenovic and Swart*, 2000). While the document defines six main future scenarios, three are generally used in most simulations: SRESA2, SRESA1B and SRESB1. The outcome in terms of global temperature change of each one of these scenarios is presented in Figure 1.2. While scenarios A2 and A1B induce the highest temperatures at the end of the 21^{th} century, the differences until the 2050s are not that sig-

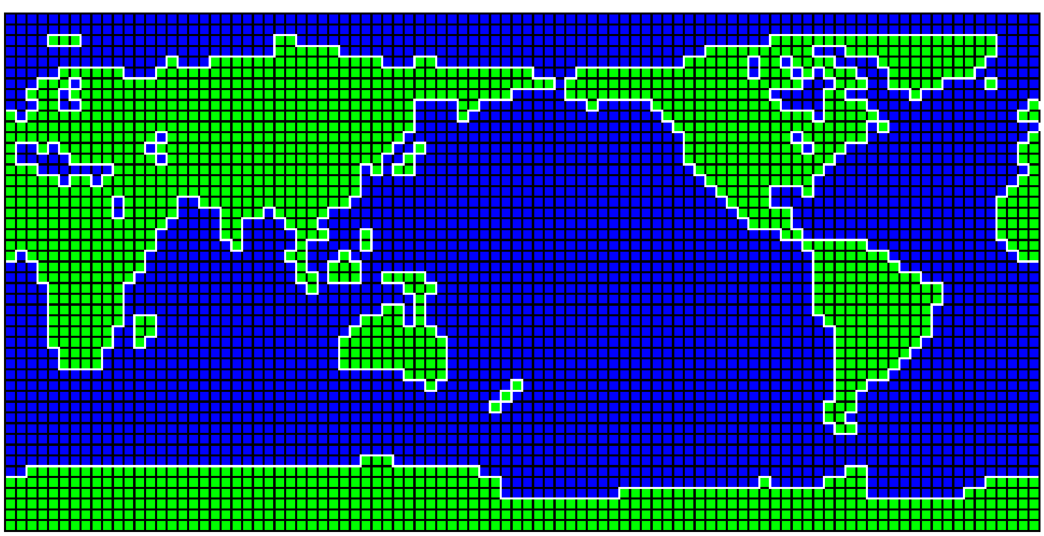


Figure 1.1: Model grid of the Canadian Center for Climate Modeling and Analysis (CCCma) global climate model (*CCCma*, 2010). Notice that the Great Lakes are represented by only two grid cells.

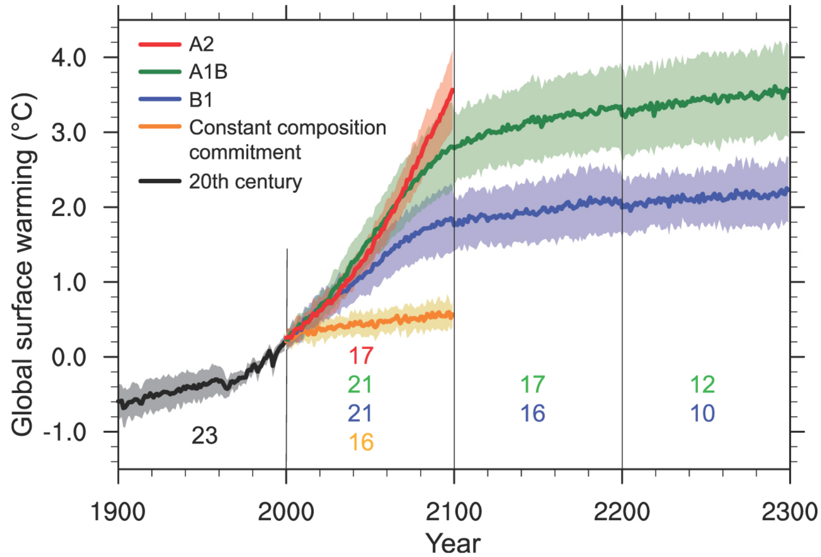


Figure 1.2: From (*Meehl et al.*, 2007a, Fig. 10.4): Multi-model means of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulation. Values beyond 2100 are for the stabilization scenarios (see *Meehl et al.* (2007a) Section 10.7). Linear trends from the corresponding control runs have been removed from these time series. Lines show the multi-model means, shading denotes the ±1 standard deviation range of individual model annual means. Discontinuities between different periods have no physical meaning and are caused by the fact that the number of models that have run a given scenario is different for each period and scenario, as indicated by the colored numbers given for each period and scenario at the bottom of the panel. For the same reason, uncertainty across scenarios should not be interpreted from this figure (see Section 10.5.4.6 for uncertainty estimates).

nificant. For the reference period, models use a *scenario* called 20C3M, which represents observed GHG concentrations.

To account, at least partially, for the various sources of uncertainties (natural variability, modeling uncertainties, GHG emission scenarios), climate change scenarios typically use *ensembles*. Ensembles are made of multiple simulations called *members* which differ either by the model they use, the model parameters, the initial conditions or the GHG emission scenario. Averages over ensemble members are typically more accurate than results from any individual member, since they average out the different sources of uncertainties.

2 Methodology

2.1 Region definition

The area under study includes the seven watersheds of the Trent Severn Waterway (TSW) surrounded by a 20km buffer area (Fig. 2.1). For each GCM, all grid cells lying in totality or in part over the region are included in the areal mean. The number of values averaged over thus depends on the resolution of each GCM, and varies from one to six grid cells (see Table 2.1).

Figure 2.1: Map of the study area.

2.2 Model selection

The World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multi-model dataset hosts model simulations from over twenty teams around the world (*Meehl et al.*, 2007b). For the purpose of this study, all GCM simulations with data available for precipitation and tem-

Table 2.1: Specifications on selected model simulations

Model name	Number of selected members				Grid cells
	20C3M	A2	A1B	B1	
BCCR BCM 2.0	1	1	1	1	2
CCCMA CGCM 3.1	5	5	5	5	2
CCCMA CGCM 3.1 T63	1	0	1	1	2
CNRM CM 3	1	1	1	1	2
CSIRO MK 3.0	1	1	1	1	2
CSIRO MK 3.5	1	1	1	1	2
GFDL CM 2.0	1	1	1	1	2
GFDL CM 2.1	1	1	1	1	2
GISS AOM	2	0	2	2	2
GISS MODEL E H	3	0	3	0	2
GISS MODEL E R	3	1	2	1	2
IAP FGOALS 1.0 G	3	0	3	3	2
INGV ECHAM 4	1	1	1	0	6
INMCM 3.0	1	1	1	1	2
MIROC 3.2 HIRES	1	0	1	1	5
MIROC 3.2 MEDRES	3	3	3	3	2
MIUB ECHO G	3	3	3	3	2
MPI ECHAM 5	4	3	4	3	2
MRI CGCM 2.3.2A	5	5	5	5	2
NCAR CCSM 3.0	8	4	7	8	2
NCAR PCM 1	4	4	4	2	2
UKMO HADCM 3	1	1	1	1	1
UKMO HADGEM 1	1	1	1	0	2

peratures during the control (1961–1999) and future (2041–2070) periods were selected. Table 2.1 presents the models, the number of simulations available for each GHG future emission scenario and the number of grid cells intersecting the study region. In total, there are 55 simulations for the 20th century (20C3M), 38 simulations for the A2 scenario, 53 for the A1B scenario and 45 for B1.

2.3 Data analysis

For each simulation and variable (temperature T and precipitation P), values over grid cells intersecting the study region were averaged spatially. The temporal average $\langle T_m \rangle, \langle P_m \rangle$ for each month m over all years in the reference period (ref) and the future period (fut) are then compared to assess changes in temperatures and precipitations. For temperatures, the difference between the mean monthly temperatures is computed, while a ratio is used for mean monthly precipitations:

$$\Delta\langle T_m \rangle = \langle T_m \rangle_{fut} - \langle T_m \rangle_{ref}, \quad \Delta\langle P_m \rangle = 100 \left(\frac{\langle P_m \rangle_{fut}}{\langle P_m \rangle_{ref}} - 1 \right). \tag{2.1}$$

The deltas (Δ) between the future and reference means for all models are presented in the spreadsheets `CC pr` and `CC tas` of the Excel file named `results.xls`.

The `Climate Change` spreadsheet provides the statistics (mean and standard deviation) on the projected climate change combining all three future GHG emission scenarios. It summarizes the results of spreadsheets `CC pr` and `CC tas`. Results, plotted in Figure 2.2, show a clear increase in average annual temperatures of about 2.5 ± .7 ℃ in 2041–2070 with respect to 20th century conditions[1]. The results are less clear for annual precipitations, with an increase of just 0.16 ± 0.09 mm/d, or about 6 ± 4% of the mean reference value. Projections for winter (Dec., Jan., Feb.) precipitations are more conclusive with an increase of 0.24 ± 0.14 mm/d (11 ± 6%).

The lack of a clear climate change signal for summer precipitation is consistent with IPCC results. IPCC Figure 2.3 shows the Great Lakes region lying right in the transition zone between lower and higher summer precipitation projections. This line of zero change is projected to lie further north under scenarios with larger GHG concentrations (*Christensen et al.*, 2007). However, the GHG emission uncertainty alone does not explain the low summer signal to noise ratio of Figure 2.2. Indeed, deltas computed from simulation driven by any given GHG emission scenario (figure not included) show the same large uncertainty for summer precipitation. This means that irrespective of the GHG future emission scenario, climate models do not agree on expected changes to future summer rainfall in the Great Lakes region. This underlines the importance of using the full spectrum of probable changes for impact and adaptation studies, and not relying uniquely on the mean or median change.

The mean and standard deviation were also computed over the values for each individual GHG scenario. These results are presented in the spreadsheets named after the scenarios `20C3M`, `SRESA2`, `SRESA1B` and `SRESB1`. Again, the standard deviation of the ensemble of GCMs represents the uncertainty related

[1] The uncertainty given here corresponds to the standard deviation of climate change signals (Eq. 2.1) among models, and not the inter-annual variability within models.

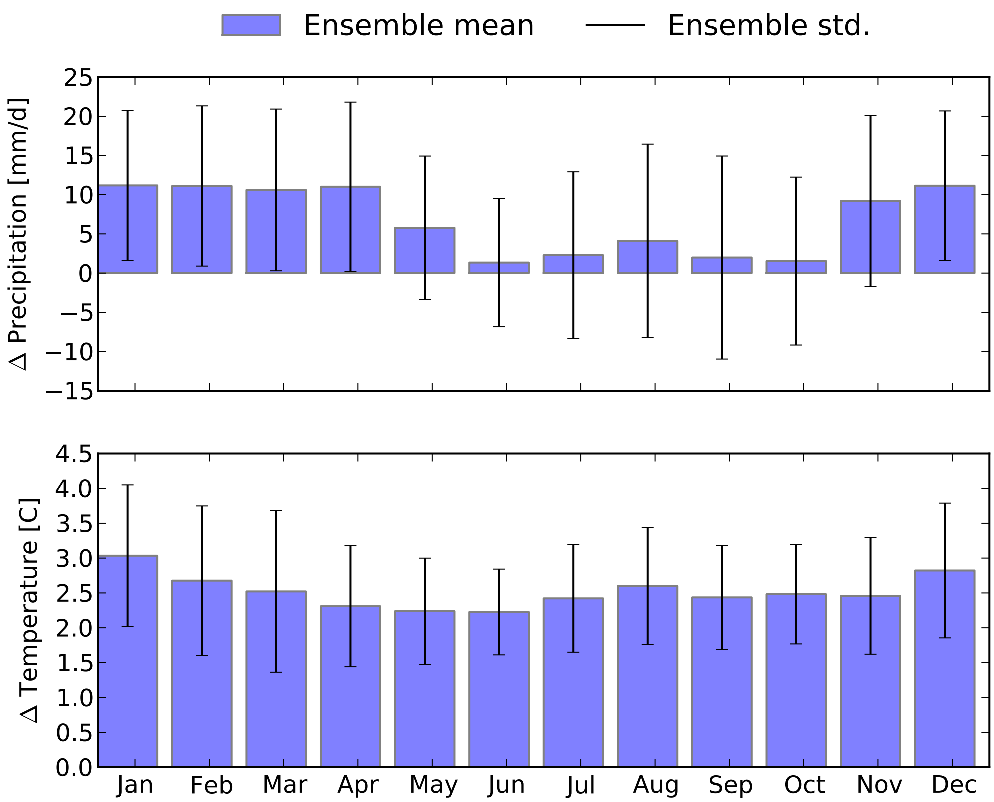


Figure 2.2: Ensemble averaged climate change by month for temperature and precipitation between the future period (2041–2070) and the reference period (1961–1999).

to modeling and the inherent multi-decadal natural variability (*Murphy et al.*, 2009), not the inter-annual variability within models.

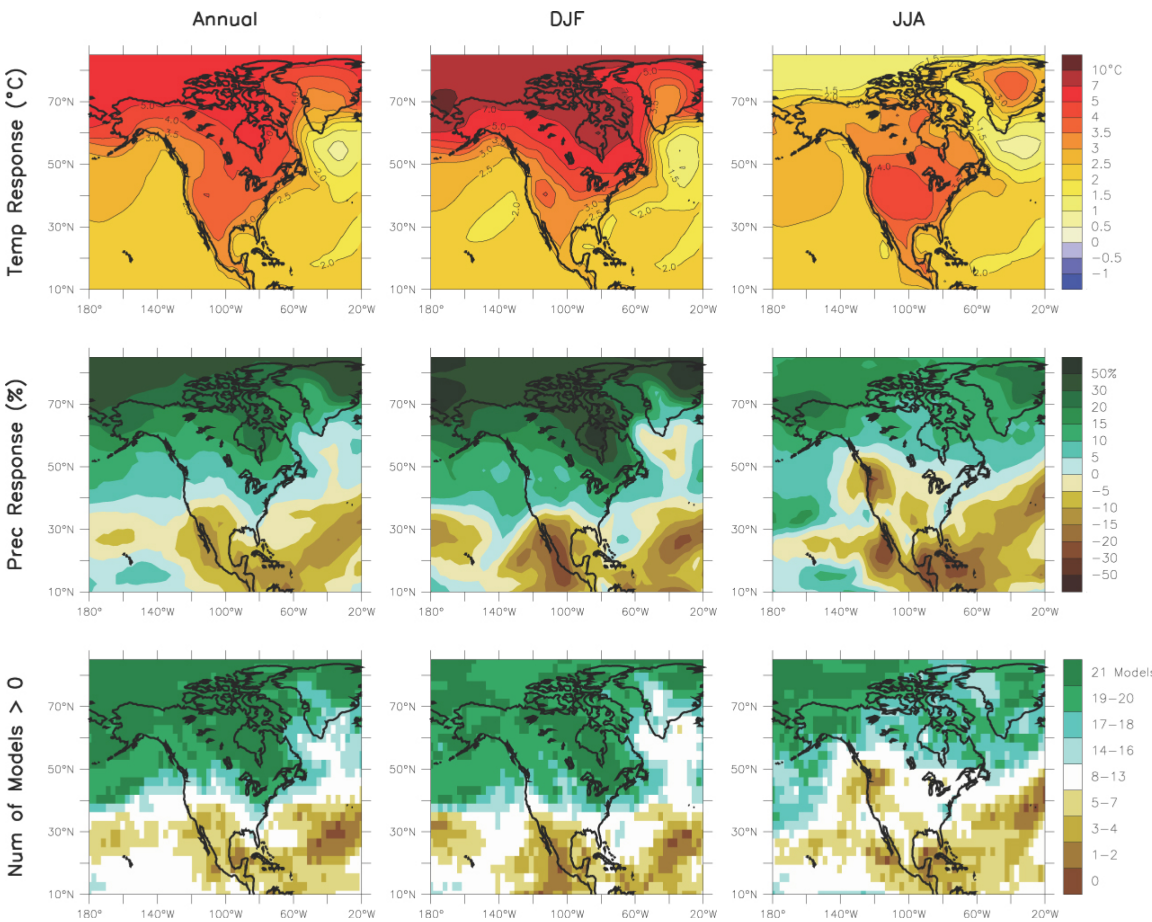


Figure 2.3: From *Christensen et al.* (2007, Fig. 11.12): Temperature and precipitation changes over North America from the multi-model dataset A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation.

3 Conclusion and recommendations

Climate changes in the TSW region were assessed for temperature and precipitation using an ensemble of 23 different GCMs and a total of 136 distinct future simulations driven by three different GHG emission scenarios. Results indicate an increase of 2.5 ± .7 ℃ in surface temperatures by 2041–2070. Changes for annual precipitation are not as conclusive, but results suggest a possible increase in winter precipitations of 11 ± 6 % from the current winter conditions.

An important *caveat* to keep in mind is that the resolution of GCMs is very coarse compared with the area under study. Local climatic features therefore cannot be adequately represented by GCMs. This is specially relevant in this case since the TSW region is completely surrounded by the Great Lakes, whose influence on weather is important. As illustrated by Figure 1.1, Lake Ontario and the Georgian Bay are not resolved by the CCCma model, and thus their impact on local temperatures and precipitations is absent in the model. Regional Climate Models (RCMs) are expected to perform better in this respect, since they resolve features at a scale of about 50 km (*Laprise*, 2008).

Finally, climate change impacts on the hydrological regime are generally made using downscaled precipitations (*Maraun et al.*, 2010). Downscaling refers to methods that adjust coarse scale model output to point or local scale using observed time series. Downscaled precipitations can then be used as inputs in hydrological models to assess modifications in the hydrological cycle, such as changes in the occurrence of floods and low-flows. The biases typically found in climate models precipitation fields make this downscaling correction critically important for hydrological studies.

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We acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison and the WCRP's Working Group on Coupled Modelling for their roles in making available the WCRP CMIP3 multi-model dataset. Support of this dataset is provided by the Office of Science, U.S. Department of Energy.

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Appendix C

Results of Climate Change Analysis in the Trent Severn Waterway Region

By:

OURANOS

Table C-1 - Mean Annual Climate Change by Simulation – Summary of Tables C-1 and C-2

ID	Model	Scenario	Run	Δ Precipitation (%)	Δ Surface Temperature (°C)
1	BCCR BCM2.0	A1B	1	8.66	2.27
2	BCCR BCM2.0	A2	1	11.00	2.36
3	CCCMA CGCM3.1	A1B	1	8.03	3.16
4	CCCMA CGCM3.1	A2	1	9.55	3.06
5	CCCMA CGCM3.1	A1B	2	9.32	2.79
6	CCCMA CGCM3.1	A2	2	9.85	3.22
7	CCCMA CGCM3.1	A1B	3	10.07	2.72
8	CCCMA CGCM3.1	A2	3	12.32	3.12
9	CCCMA CGCM3.1	A1B	4	6.76	2.93
10	CCCMA CGCM3.1	A2	4	9.51	3.02
11	CCCMA CGCM3.1	A1B	5	8.04	3.32
12	CCCMA CGCM3.1	A2	5	8.38	3.28
13	CCCMA CGCM3.1.T63	A1B	1	8.88	3.20
14	CNRM CM3	A1B	1	11.40	2.61
15	CNRM CM3	A2	1	11.09	2.50
16	CSIRO MK3.0	A1B	1	4.71	1.85
17	CSIRO MK3.0	A2	1	7.61	2.37
18	CSIRO MK3.5	A1B	1	8.05	2.66
19	CSIRO MK3.5	A2	1	9.92	2.65
20	GFDL CM2.0	A1B	1	1.47	3.38
21	GFDL CM2.0	A2	1	5.20	3.14
22	GFDL CM2.1	A1B	1	7.87	2.48
23	GFDL CM2.1	A2	1	6.17	2.26
24	GISS AOM	A1B	1	7.04	2.32
25	GISS AOM	A1B	2	12.64	2.10
26	GISS MODEL E H	A1B	1	6.65	1.77
27	GISS MODEL E H	A1B	2	8.20	2.02
28	GISS MODEL E H	A1B	3	7.56	1.18
29	GISS MODEL E R	A2	1	12.36	2.05
30	GISS MODEL E R	A1B	2	9.57	1.62
31	GISS MODEL E R	A1B	4	11.05	1.62
32	IAP FGOALS1.0.G	A1B	1	3.19	2.36
33	IAP FGOALS1.0.G	A1B	2	-0.86	2.75
34	IAP FGOALS1.0.G	A1B	3	-0.13	1.83
35	INGV ECHAM4	A1B	1	0.65	2.35
36	INGV ECHAM4	A2	1	-0.69	2.42
37	INMCM3.0	A1B	1	-0.33	2.73
38	INMCM3.0	A2	1	-2.97	2.76
39	MIROC3.2.HIRES	A1B	1	4.89	4.15
40	MIROC3.2.MEDRES	A1B	1	1.78	3.98
41	MIROC3.2.MEDRES	A2	1	2.32	3.69
42	MIROC3.2.MEDRES	A1B	2	1.86	4.14
43	MIROC3.2.MEDRES	A2	2	0.97	3.64
44	MIROC3.2.MEDRES	A1B	3	0.70	3.91
45	MIROC3.2.MEDRES	A2	3	2.00	3.22
46	MIUB ECHO G	A1B	1	2.78	3.48
47	MIUB ECHO G	A2	1	2.16	3.71
48	MIUB ECHO G	A1B	2	6.94	3.05
49	MIUB ECHO G	A2	2	8.50	3.14
50	MIUB ECHO G	A1B	3	5.14	3.05

Table C-1 - Mean Annual Climate Change by Simulation – Summary of Tables C-1 and C-2 (suite)

ID	Model	Scenario	Run	Δ Precipitation (%)	Δ Surface Temperature (°C)
51	MIUB ECHO G	A2	3	5.21	3.06
52	MPI ECHAM5	A1B	1	7.10	2.96
53	MPI ECHAM5	A2	1	11.38	2.27
54	MPI ECHAM5	A1B	2	10.64	2.86
55	MPI ECHAM5	A2	2	7.37	2.28
56	MPI ECHAM5	A1B	3	9.16	2.67
57	MPI ECHAM5	A2	3	8.86	2.42
58	MPI ECHAM5	A1B	4	9.34	2.62
59	MRI CGCM2.3.2A	A1B	1	4.87	2.30
60	MRI CGCM2.3.2A	A2	1	4.21	2.07
61	MRI CGCM2.3.2A	A1B	2	9.65	2.53
62	MRI CGCM2.3.2A	A2	2	10.72	2.34
63	MRI CGCM2.3.2A	A1B	3	2.56	1.96
64	MRI CGCM2.3.2A	A2	3	7.89	2.04
65	MRI CGCM2.3.2A	A1B	4	5.71	2.22
66	MRI CGCM2.3.2A	A2	4	6.81	2.11
67	MRI CGCM2.3.2A	A1B	5	9.13	2.40
68	MRI CGCM2.3.2A	A2	5	5.13	2.24
69	NCAR CCSM3.0	A1B	1	5.60	3.23
70	NCAR CCSM3.0	A2	1	4.00	3.34
71	NCAR CCSM3.0	A1B	2	8.47	3.31
72	NCAR CCSM3.0	A2	2	13.11	3.31
73	NCAR CCSM3.0	A1B	3	12.93	2.62
74	NCAR CCSM3.0	A2	3	9.28	2.92
75	NCAR CCSM3.0	A2	4	8.41	3.02
76	NCAR CCSM3.0	A1B	5	14.63	2.80
77	NCAR CCSM3.0	A1B	6	2.28	3.53
78	NCAR CCSM3.0	A1B	7	8.16	3.03
79	NCAR CCSM3.0	A1B	9	7.23	3.05
80	NCAR PCM1	A1B	1	3.00	1.81
81	NCAR PCM1	A2	1	6.26	1.81
82	NCAR PCM1	A1B	2	5.83	1.99
83	NCAR PCM1	A2	2	6.08	1.89
84	NCAR PCM1	A1B	3	5.29	2.22
85	NCAR PCM1	A2	3	4.61	1.79
86	NCAR PCM1	A1B	4	2.63	1.83
87	NCAR PCM1	A2	4	0.89	1.74
88	UKMO HADCM3	A1B	1	6.92	3.42
89	UKMO HADCM3	A2	1	4.92	2.33
90	UKMO HADGEM1	A1B	1	2.78	4.46
91	UKMO HADGEM1	A2	1	3.22	4.05
92	BCCR BCM2.0	B1	1	6.43	1.75
93	CCCMA CGCM3.1	B1	1	6.55	2.45
94	CCCMA CGCM3.1	B1	2	6.09	2.21
95	CCCMA CGCM3.1	B1	3	8.25	1.98
96	CCCMA CGCM3.1	B1	4	3.44	2.43
97	CCCMA CGCM3.1	B1	5	6.97	2.61
98	CCCMA CGCM3.1.T63	B1	1	9.04	2.37
99	CNRM CM3	B1	1	9.74	1.93
100	CSIRO MK3.0	B1	1	8.02	1.20

Table C-1 - Mean Annual Climate Change by Simulation – Summary of Tables C-1 and C-2 (suite)

ID	Model	Scenario	Run	Δ Precipitation (%)	Δ Surface Temperature (°C)
101	CSIRO MK3.5	B1	1	13.96	1.97
102	GFDL CM2.0	B1	1	4.23	2.31
103	GFDL CM2.1	B1	1	5.29	2.04
104	GISS AOM	B1	1	5.97	1.86
105	GISS AOM	B1	2	5.73	1.61
106	GISS MODEL E R	B1	1	6.28	1.43
107	IAP FGOALS1.0.G	B1	1	3.25	1.54
108	IAP FGOALS1.0.G	B1	2	-0.68	2.32
109	IAP FGOALS1.0.G	B1	3	5.95	1.85
110	INMCM3.0	B1	1	-0.26	2.23
111	MIROC3.2.HIRES	B1	1	0.48	3.48
112	MIROC3.2.MEDRES	B1	1	6.57	3.06
113	MIROC3.2.MEDRES	B1	2	5.06	3.07
114	MIROC3.2.MEDRES	B1	3	3.13	2.99
115	MIUB ECHO G	B1	1	-1.75	2.89
116	MIUB ECHO G	B1	2	5.81	2.40
117	MIUB ECHO G	B1	3	1.61	2.84
118	MPI ECHAM5	B1	1	8.07	1.97
119	MPI ECHAM5	B1	2	8.64	2.05
120	MPI ECHAM5	B1	3	6.17	2.27
121	MRI CGCM2.3.2A	B1	1	4.08	1.67
122	MRI CGCM2.3.2A	B1	2	4.35	1.90
123	MRI CGCM2.3.2A	B1	3	6.62	1.47
124	MRI CGCM2.3.2A	B1	4	5.59	1.95
125	MRI CGCM2.3.2A	B1	5	9.31	2.11
126	NCAR CCSM3.0	B1	1	4.96	2.52
127	NCAR CCSM3.0	B1	2	3.45	2.31
128	NCAR CCSM3.0	B1	3	10.46	2.27
129	NCAR CCSM3.0	B1	4	7.65	1.78
130	NCAR CCSM3.0	B1	5	9.50	2.13
131	NCAR CCSM3.0	B1	6	3.88	2.24
132	NCAR CCSM3.0	B1	7	4.78	2.02
133	NCAR CCSM3.0	B1	9	1.64	1.83
134	NCAR PCM1	B1	2	5.74	1.54
135	NCAR PCM1	B1	3	3.62	1.19
136	UKMO HADCM3	B1	1	-0.08	2.33
Average - complete set - 136 simulations				**6.13**	**2.52**
Average - short set - 23 simulations				**6.27**	**2.68**

8	Simulation selected for hydrological modeling.

Table C-2 - Monthly Climate Change by Simulation - Δ Precipitation [%]

ID	Model	Scenario	Run	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1	BCCR BCM2.0	A1B	1	5.43	31.26	27.74	21.75	8.27	-1.24	6.86	4.66	-8.50	-6.65	24.74	7.27	8.66
2	BCCR BCM2.0	A2	1	6.86	29.26	15.94	11.08	28.05	-2.00	14.96	7.06	-1.01	-6.01	27.07	11.81	11.00
3	CCCMA CGCM3.1	A1B	1	22.66	21.14	19.48	22.52	4.31	-4.22	-7.17	-6.53	-18.93	-4.09	26.35	32.99	8.03
4	CCCMA CGCM3.1	A2	1	5.22	12.89	32.70	13.93	8.44	-4.72	-11.61	-4.25	-5.36	12.84	30.56	32.61	9.55
5	CCCMA CGCM3.1	A1B	2	29.60	17.15	24.24	18.61	12.11	-0.71	0.55	-9.46	1.30	-8.58	22.69	13.96	9.32
6	CCCMA CGCM3.1	A2	2	34.80	37.37	13.89	21.04	12.31	-9.94	-8.68	-1.71	4.74	-1.14	28.60	6.60	9.85
7	CCCMA CGCM3.1	A1B	3	25.16	15.47	16.07	21.99	14.53	4.55	-8.89	-2.19	-7.89	17.11	16.19	15.32	10.07
8	CCCMA CGCM3.1	A2	3	18.40	35.26	29.09	15.07	17.93	-2.00	-8.93	-7.43	-10.37	16.67	33.45	21.51	12.32
9	CCCMA CGCM3.1	A1B	4	22.44	4.46	26.57	9.53	2.55	-8.62	1.78	-2.87	0.22	0.63	18.86	14.75	6.76
10	CCCMA CGCM3.1	A2	4	33.42	0.38	24.88	17.56	14.45	-9.48	0.81	-9.06	1.66	-2.57	14.00	35.99	9.51
11	CCCMA CGCM3.1	A1B	5	29.09	5.30	28.46	22.46	6.40	-1.94	-7.33	1.64	-5.67	-2.03	13.37	17.71	8.04
12	CCCMA CGCM3.1	A2	5	21.87	10.31	38.92	22.99	11.75	-13.79	-5.18	5.53	-3.07	5.06	6.48	16.02	8.38
13	CCCMA CGCM3.1.T63	A1B	1	29.60	8.79	51.52	19.36	8.34	-8.23	-12.24	2.41	-12.85	5.33	26.70	7.34	8.88
14	CNRM CM3	A1B	1	4.61	15.78	17.54	13.95	2.05	4.26	6.76	7.18	26.19	19.42	10.88	19.89	11.40
15	CNRM CM3	A2	1	-4.25	24.47	17.90	18.56	-3.57	8.30	-0.38	15.96	19.78	11.20	23.62	16.08	11.09
16	CSIRO MK3.0	A1B	1	9.31	11.83	8.62	2.22	-5.74	5.30	0.45	2.34	2.64	5.83	3.45	15.61	4.71
17	CSIRO MK3.0	A2	1	9.32	12.50	10.07	10.12	6.36	-0.10	6.69	4.71	6.00	0.83	8.91	18.16	7.61
18	CSIRO MK3.5	A1B	1	8.18	16.00	5.61	14.61	21.89	10.45	14.20	21.51	-2.36	-5.65	-14.67	6.57	8.05
19	CSIRO MK3.5	A2	1	24.08	25.07	15.07	15.29	12.23	12.52	3.19	-2.86	15.54	-7.80	-6.86	3.95	9.92
20	GFDL CM2.0	A1B	1	18.33	0.47	11.72	2.08	-0.58	-5.14	-6.61	-19.06	-1.45	-3.67	17.21	13.07	1.47
21	GFDL CM2.0	A2	1	7.32	12.10	23.31	13.74	-0.04	9.74	-12.39	-30.87	-3.41	10.44	10.00	35.67	5.20
22	GFDL CM2.1	A1B	1	10.84	-7.42	14.11	21.84	14.93	7.02	-0.46	3.22	13.00	13.55	2.55	4.90	7.87
23	GFDL CM2.1	A2	1	13.83	3.57	3.49	25.81	12.47	3.33	-14.51	7.74	0.51	6.01	10.45	9.57	6.17
24	GISS AOM	A1B	1	20.44	13.57	6.03	9.62	9.33	6.38	1.87	4.26	5.71	10.56	2.13	-0.93	7.04
25	GISS AOM	A1B	2	15.31	22.00	24.17	-6.28	19.02	11.98	10.90	11.16	16.17	6.38	8.65	19.48	12.64
26	GISS MODEL E H	A1B	1	-3.69	15.99	23.72	20.63	10.17	6.76	-3.75	-6.94	-8.14	4.79	23.00	19.91	6.65
27	GISS MODEL E H	A1B	2	-5.14	-6.35	10.75	21.97	11.95	12.43	10.96	2.01	8.72	-2.11	16.42	7.72	8.20
28	GISS MODEL E H	A1B	3	0.15	2.72	14.63	7.65	23.03	0.34	-5.29	4.44	11.84	10.01	12.48	26.05	7.56
29	GISS MODEL E R	A2	1	31.84	8.88	6.68	34.24	25.53	-4.36	4.66	3.48	5.17	16.77	11.40	41.71	12.36
30	GISS MODEL E R	A1B	2	0.60	-11.93	13.46	48.57	18.26	11.28	3.98	-6.96	-7.73	20.21	25.15	12.17	9.57
31	GISS MODEL E R	A1B	4	10.35	-5.51	15.20	25.53	15.81	7.87	9.55	0.83	-2.71	27.09	27.16	7.41	11.05
32	IAP FGOALS1.0.G	A1B	1	0.11	3.37	-7.99	8.32	-3.39	4.12	4.89	17.19	-7.91	8.47	4.22	11.23	3.19
33	IAP FGOALS1.0.G	A1B	2	-0.74	9.60	0.18	11.59	-10.06	6.26	5.40	-1.41	-4.15	-16.67	-1.15	-10.66	-0.86
34	IAP FGOALS1.0.G	A1B	3	-2.97	-5.12	15.12	-2.57	4.23	-6.49	-11.84	0.67	-1.12	-4.91	2.71	8.43	-0.13
35	INGV ECHAM4	A1B	1	3.65	5.37	-6.36	-1.10	8.55	-0.42	6.06	7.45	-6.92	-6.89	12.46	-12.52	0.65
36	INGV ECHAM4	A2	1	1.00	-3.83	6.88	-5.03	1.45	-1.85	-2.22	10.83	-6.59	-12.32	-2.68	3.92	-0.69
37	INMCM3.0	A1B	1	10.02	13.69	9.19	2.00	-13.63	-10.58	-3.47	0.69	-6.96	-23.36	-3.96	11.66	-0.33
38	INMCM3.0	A2	1	5.58	16.75	-1.79	-12.69	-19.23	-1.48	-3.42	6.21	-6.75	-11.09	-4.70	-1.12	-2.97
39	MIROC3.2.HIRES	A1B	1	22.06	21.19	18.77	8.34	-5.48	-9.12	-19.36	2.48	-8.86	15.01	4.83	21.33	4.89
40	MIROC3.2.MEDRES	A1B	1	7.74	7.51	10.71	13.73	12.67	-8.21	-9.74	-13.45	-17.87	12.36	-2.04	21.77	1.78
41	MIROC3.2.MEDRES	A2	1	9.76	-0.97	22.80	13.09	12.45	-7.86	-3.36	-8.44	-10.94	-10.44	4.35	16.55	2.32
42	MIROC3.2.MEDRES	A1B	2	-2.13	13.80	30.74	12.48	3.37	0.75	-9.51	-16.76	-13.77	11.03	-2.79	7.06	1.86
43	MIROC3.2.MEDRES	A2	2	-0.91	23.09	26.79	1.68	10.66	-6.79	-1.16	-10.39	-32.96	-1.23	5.35	9.43	0.97
44	MIROC3.2.MEDRES	A1B	3	6.66	17.19	1.20	10.97	5.49	-12.51	-17.51	-17.52	-11.28	6.46	17.10	16.72	0.70
45	MIROC3.2.MEDRES	A2	3	13.38	4.97	2.81	14.77	4.40	-2.44	-4.77	-5.86	-22.48	8.78	8.78	7.66	2.00
46	MIUB ECHO G	A1B	1	9.91	20.58	11.21	13.85	-2.39	5.05	-10.95	-2.94	1.18	-12.30	-0.57	17.60	2.78
47	MIUB ECHO G	A2	1	19.11	16.75	13.56	14.85	-17.86	-6.55	-6.70	-5.83	3.06	-5.79	5.01	22.66	2.16
48	MIUB ECHO G	A1B	2	14.18	28.71	21.05	27.33	1.99	-4.75	2.49	-6.31	-8.61	1.42	7.57	18.75	6.94
49	MIUB ECHO G	A2	2	20.14	21.88	11.71	21.32	6.45	3.86	15.69	-8.22	4.64	0.39	3.11	12.19	8.50
50	MIUB ECHO G	A1B	3	12.72	9.48	7.36	10.93	8.31	5.52	-0.55	-8.15	-9.12	1.71	10.82	22.56	5.14

ID	Model	Scenario	Run	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
51	MIUB ECHO G	A2	3	14.74	6.33	8.32	13.74	11.96	1.55	0.36	-4.70	-13.54	7.04	15.35	9.43	5.21
52	MPI ECHAM5	A1B	1	12.78	15.42	-4.77	-2.47	2.54	1.48	20.89	-1.66	17.23	0.67	21.99	9.39	7.10
53	MPI ECHAM5	A2	1	25.19	13.47	18.90	12.95	17.25	-6.54	9.94	4.21	7.07	18.04	7.78	16.07	11.38
54	MPI ECHAM5	A1B	2	24.66	23.07	-10.56	11.38	13.46	26.82	4.54	-2.46	16.61	-5.67	17.38	13.99	10.64
55	MPI ECHAM5	A2	2	6.42	22.98	-3.46	7.12	6.58	16.76	8.43	2.19	9.42	-3.95	17.39	1.85	7.37
56	MPI ECHAM5	A1B	3	28.04	13.77	3.44	32.27	13.89	8.37	10.23	6.12	-7.73	-4.25	4.35	7.70	9.16
57	MPI ECHAM5	A2	3	15.56	5.82	3.26	31.50	5.16	12.79	15.92	0.04	-5.50	5.30	11.30	9.33	8.86
58	MPI ECHAM5	A1B	4	8.81	32.34	-0.58	-1.17	0.94	13.77	1.76	3.68	3.77	28.12	7.91	23.52	9.34
59	MRI CGCM2.3.2A	A1B	1	13.71	17.64	9.25	-14.91	6.97	-2.21	0.22	4.36	27.74	1.52	7.93	3.25	4.87
60	MRI CGCM2.3.2A	A2	1	12.59	17.54	5.61	-8.51	-4.14	-7.02	-3.34	16.47	18.82	4.58	-1.72	21.05	4.21
61	MRI CGCM2.3.2A	A1B	2	-1.83	14.80	19.71	23.66	-2.29	3.91	8.34	7.05	11.31	8.95	17.54	9.70	9.65
62	MRI CGCM2.3.2A	A2	2	-9.85	31.71	18.26	10.95	7.68	10.42	-1.37	17.13	17.20	-1.34	26.74	12.21	10.72
63	MRI CGCM2.3.2A	A1B	3	12.82	0.47	5.60	19.53	9.16	-6.91	-18.70	13.10	5.38	-4.41	-1.93	6.63	2.56
64	MRI CGCM2.3.2A	A2	3	14.75	13.64	10.81	19.35	8.12	-3.70	-4.55	16.08	-0.98	-1.07	23.85	9.31	7.89
65	MRI CGCM2.3.2A	A1B	4	23.07	-6.14	-4.72	13.62	15.07	-0.98	-8.14	15.08	8.84	2.17	11.85	2.05	5.71
66	MRI CGCM2.3.2A	A2	4	14.15	4.26	-0.78	-6.00	15.97	0.10	-5.72	9.12	22.83	19.62	9.86	4.53	6.81
67	MRI CGCM2.3.2A	A1B	5	8.25	12.84	-2.18	18.22	11.57	0.02	5.36	2.13	18.44	8.87	7.70	20.38	9.13
68	MRI CGCM2.3.2A	A2	5	15.61	2.36	-3.23	9.58	3.42	-5.43	5.19	8.67	11.50	-1.22	14.92	1.93	5.13
69	NCAR CCSM3.0	A1B	1	11.45	4.11	9.50	2.55	-9.98	4.52	11.75	13.02	6.00	1.91	18.63	-3.85	5.60
70	NCAR CCSM3.0	A2	1	10.31	11.92	13.82	4.78	-16.77	5.16	6.60	23.13	2.84	-20.92	6.54	3.43	4.00
71	NCAR CCSM3.0	A1B	2	26.52	2.04	16.60	3.62	-1.96	-16.45	32.70	10.66	34.62	-12.19	10.25	12.93	8.47
72	NCAR CCSM3.0	A2	2	20.59	0.84	17.84	10.81	-3.46	-1.08	40.61	20.17	25.94	24.37	-0.39	20.92	13.11
73	NCAR CCSM3.0	A1B	3	13.49	24.49	19.65	10.43	-10.40	11.54	19.61	38.75	-3.74	2.28	19.11	10.30	12.93
74	NCAR CCSM3.0	A2	3	13.98	21.85	9.91	5.68	3.91	16.28	11.62	36.74	9.09	-18.76	-1.43	13.97	9.28
75	NCAR CCSM3.0	A2	4	6.14	6.22	3.13	-0.41	13.44	-0.85	32.05	28.77	11.48	-14.87	5.02	23.20	8.41
76	NCAR CCSM3.0	A1B	5	3.58	0.52	9.57	8.72	9.58	7.67	34.94	45.20	51.25	-11.48	30.56	9.34	14.63
77	NCAR CCSM3.0	A1B	6	8.87	14.75	14.54	-5.22	-11.56	-3.83	11.01	11.61	-4.85	-14.61	-5.13	13.49	2.28
78	NCAR CCSM3.0	A1B	7	16.20	11.69	7.16	9.56	1.75	-1.51	20.94	14.69	2.29	-10.27	10.04	12.61	8.16
79	NCAR CCSM3.0	A1B	9	12.89	0.62	13.21	-6.37	-1.57	5.09	5.49	15.53	21.39	2.13	10.81	17.02	7.23
80	NCAR PCM1	A1B	1	-10.29	12.95	0.69	5.40	5.02	12.22	6.23	5.58	4.03	-13.54	-9.41	8.95	3.00
81	NCAR PCM1	A2	1	1.65	11.68	3.95	10.40	10.76	3.63	11.37	6.91	-4.34	3.15	5.24	3.86	6.26
82	NCAR PCM1	A1B	2	9.96	5.70	5.52	11.24	8.16	-11.53	0.74	6.18	14.94	16.07	17.02	-0.50	5.83
83	NCAR PCM1	A2	2	-0.23	0.76	2.21	19.93	6.25	6.09	9.67	-0.10	0.38	-6.78	10.10	13.10	6.08
84	NCAR PCM1	A1B	3	-4.30	10.89	-2.80	4.20	1.28	10.40	2.75	6.99	15.44	14.74	-2.19	13.42	5.29
85	NCAR PCM1	A2	3	3.11	9.61	13.18	1.75	2.18	-1.22	9.46	1.90	7.49	7.09	-6.76	15.01	4.61
86	NCAR PCM1	A1B	4	8.95	6.06	19.03	7.10	4.24	-2.30	-9.74	7.41	-4.58	-8.65	10.66	-7.41	2.63
87	NCAR PCM1	A2	4	9.14	22.94	-3.68	3.74	0.51	-2.61	1.13	-5.30	-20.70	-2.36	6.51	3.96	0.89
88	UKMO HADCM3	A1B	1	12.69	14.34	24.44	13.31	26.78	7.34	7.98	-5.86	-8.06	-1.42	4.91	-5.73	6.92
89	UKMO HADCM3	A2	1	26.31	-3.50	8.22	6.61	-4.65	1.71	0.41	-5.75	11.15	15.74	10.32	-4.78	4.92
90	UKMO HADGEM1	A1B	1	27.75	6.25	-2.29	-4.54	6.58	-2.21	-8.32	-21.58	1.88	-3.68	16.47	24.94	2.78
91	UKMO HADGEM1	A2	1	14.70	13.18	14.85	10.28	1.61	-16.24	-19.71	-11.23	-15.76	7.21	22.88	22.83	3.22
92	BCCR BCM2.0	B1	1	9.74	15.97	9.20	4.16	13.60	0.39	6.82	2.69	2.36	7.05	7.75	3.21	6.43
93	CCCMA CGCM3.1	B1	1	0.86	1.22	13.67	19.27	15.18	-2.42	-5.96	-2.04	-4.21	-4.07	10.62	38.36	6.55
94	CCCMA CGCM3.1	B1	2	17.58	21.72	-1.52	38.97	5.65	-9.06	-8.46	-7.12	-6.36	8.84	21.55	3.17	6.09
95	CCCMA CGCM3.1	B1	3	13.43	34.87	12.30	6.03	7.04	8.66	-12.27	-8.01	5.34	11.98	7.55	24.47	8.25
96	CCCMA CGCM3.1	B1	4	12.14	3.26	16.83	8.88	-5.45	-4.73	6.37	-2.54	8.94	-11.24	0.98	17.89	3.44
97	CCCMA CGCM3.1	B1	5	20.86	10.51	29.73	19.69	12.12	-12.20	-3.26	8.90	-3.08	-9.02	13.10	9.59	6.97
98	CCCMA CGCM3.1.T63	B1	1	19.44	3.15	8.41	10.38	-0.75	5.00	-8.06	4.05	3.14	5.89	48.81	16.59	9.04
99	CNRM CM3	B1	1	8.54	27.19	9.19	20.42	3.49	-1.73	-2.04	7.08	16.30	22.20	12.46	12.65	9.74
100	CSIRO MK3.0	B1	1	12.90	14.47	22.49	10.82	2.58	8.54	5.31	2.20	7.96	0.42	2.53	7.16	8.02

ID	Model	Scenario	Run	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
101	CSIRO MK3.5	B1	1	8.20	25.49	15.50	8.74	10.22	30.86	14.85	42.05	18.31	12.08	-9.53	1.41	13.96
102	GFDL CM2.0	B1	1	7.59	6.88	15.57	10.49	-0.29	12.73	6.53	-6.30	-11.26	-11.88	8.76	15.80	4.23
103	GFDL CM2.1	B1	1	8.70	-12.48	11.29	21.50	14.32	-3.19	2.07	-3.64	-1.13	9.42	15.97	4.05	5.29
104	GISS AOM	B1	1	25.67	4.85	13.38	5.38	3.54	8.41	-1.29	2.70	8.73	2.57	0.90	2.29	5.97
105	GISS AOM	B1	2	13.71	19.81	-2.56	0.80	2.32	2.18	7.26	-0.01	12.28	6.28	4.69	6.09	5.73
106	GISS MODEL E R	B1	1	8.97	-9.41	1.79	42.18	10.62	-1.64	0.98	-0.83	5.22	27.28	0.82	5.67	6.28
107	IAP FGOALS1.0.G	B1	1	10.24	-5.09	8.47	14.53	-1.65	3.05	2.61	10.37	-11.29	3.53	-2.54	6.01	3.25
108	IAP FGOALS1.0.G	B1	2	-6.06	4.07	3.90	0.84	4.95	-2.03	1.13	-7.52	1.09	-5.47	-6.31	1.71	-0.68
109	IAP FGOALS1.0.G	B1	3	0.45	8.49	18.34	17.08	8.08	-7.58	-5.56	13.63	8.65	8.58	5.10	-1.01	5.95
110	INMCM3.0	B1	1	10.32	5.77	5.49	4.69	-19.40	-4.66	3.93	18.31	-0.36	-17.58	-2.54	-5.22	-0.26
111	MIROC3.2.HIRES	B1	1	9.96	12.69	21.80	3.97	1.86	-2.27	-14.85	-7.18	-18.79	-9.17	5.73	12.28	0.48
112	MIROC3.2.MEDRES	B1	1	8.60	3.17	11.67	21.60	18.19	-0.96	-0.09	7.41	-2.77	3.01	6.45	7.04	6.57
113	MIROC3.2.MEDRES	B1	2	8.92	16.50	17.14	3.56	31.36	12.01	-2.03	-3.40	-11.94	0.98	-13.16	6.84	5.06
114	MIROC3.2.MEDRES	B1	3	10.87	12.79	0.24	17.78	-2.66	-9.13	3.52	3.29	-5.66	-4.19	4.98	11.57	3.13
115	MIUB ECHO G	B1	1	-1.58	12.06	9.00	5.02	-1.55	-4.83	-8.56	-9.86	4.85	-13.99	-13.27	14.52	-1.75
116	MIUB ECHO G	B1	2	9.38	13.46	13.99	9.18	2.89	3.96	6.99	-1.78	6.77	-5.74	10.97	7.02	5.81
117	MIUB ECHO G	B1	3	23.40	-3.90	1.56	26.01	-2.26	-7.50	-1.05	-5.06	-0.38	-9.08	-4.28	9.73	1.61
118	MPI ECHAM5	B1	1	19.82	19.40	1.21	-5.60	9.75	-2.71	21.32	0.82	-11.06	19.05	34.08	3.33	8.07
119	MPI ECHAM5	B1	2	2.69	10.17	-2.57	6.05	11.40	16.08	5.42	2.86	20.32	4.51	26.07	5.25	8.64
120	MPI ECHAM5	B1	3	18.75	7.87	-12.23	34.89	12.72	16.90	11.79	0.86	-20.65	-8.49	6.24	10.90	6.17
121	MRI CGCM2.3.2A	B1	1	27.00	27.31	12.27	0.94	7.26	7.19	-7.73	-4.95	16.44	-11.37	1.72	-2.92	4.08
122	MRI CGCM2.3.2A	B1	2	-12.92	25.39	3.35	10.24	0.28	0.19	-5.46	9.40	4.55	-4.40	28.57	1.96	4.35
123	MRI CGCM2.3.2A	B1	3	0.27	-1.05	12.42	8.89	13.23	-0.01	-5.84	18.80	9.15	14.19	1.79	6.38	6.62
124	MRI CGCM2.3.2A	B1	4	11.18	3.91	-5.20	18.42	7.54	5.69	0.97	4.06	5.31	0.71	4.52	9.12	5.59
125	MRI CGCM2.3.2A	B1	5	7.04	5.56	11.13	14.67	4.42	1.44	6.23	7.27	17.22	3.57	13.08	24.33	9.31
126	NCAR CCSM3.0	B1	1	18.29	21.03	10.45	-1.66	-6.70	8.95	4.80	8.55	-0.89	-15.32	13.56	-1.22	4.96
127	NCAR CCSM3.0	B1	2	12.09	-4.07	4.09	4.95	-7.36	-9.66	14.41	18.21	15.04	-15.46	6.96	11.68	3.45
128	NCAR CCSM3.0	B1	3	8.52	17.18	16.91	-0.25	5.41	11.36	9.32	26.75	-7.51	15.07	8.88	15.15	10.46
129	NCAR CCSM3.0	B1	4	-1.85	10.29	6.22	15.30	10.78	-4.33	19.37	40.44	0.12	-9.58	3.79	10.07	7.65
130	NCAR CCSM3.0	B1	5	7.71	8.61	4.78	4.12	-2.33	9.44	22.20	37.37	43.71	5.54	1.58	2.74	9.50
131	NCAR CCSM3.0	B1	6	4.27	18.53	7.10	-14.20	4.07	10.91	19.55	18.20	-10.89	7.51	-2.96	-5.79	3.88
132	NCAR CCSM3.0	B1	7	9.76	-3.10	-0.31	0.83	9.04	2.58	2.89	2.49	-3.80	6.45	6.18	22.16	4.78
133	NCAR CCSM3.0	B1	9	10.15	11.34	-4.78	1.91	-2.17	2.84	-3.28	6.02	-6.10	-1.73	-4.03	9.57	1.64
134	NCAR PCM1	B1	2	16.85	13.35	10.52	8.19	11.69	-2.56	0.52	1.02	8.57	6.75	-3.82	5.68	5.74
135	NCAR PCM1	B1	3	-1.66	3.52	8.44	0.03	7.22	10.28	2.91	12.94	-17.81	-0.34	-8.10	21.45	3.62
136	UKMO HADCM3	B1	1	1.41	8.83	-5.39	12.47	20.80	-11.51	-7.62	-8.44	-23.33	-5.77	14.49	7.60	-0.08
			Average	11.18	11.11	10.60	11.02	5.78	1.34	2.28	4.12	1.99	1.53	9.19	11.15	6.13
			Standard Deviation	9.59	10.25	10.35	10.82	9.18	8.21	10.67	12.37	12.99	10.74	10.96	9.57	3.58

Table C-3 - Monthly Climate Change by Simulation - Δ Surface Temperature [°C]

ID	Model	Scenario	Run	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1	BCCR BCM2.0	A1B	1	3.33	1.57	2.22	2.09	3.51	1.77	1.73	2.04	2.23	1.81	1.46	3.49	2.27
2	BCCR BCM2.0	A2	1	2.77	1.93	2.35	2.56	3.76	1.24	2.33	1.96	1.80	1.91	1.83	3.84	2.36
3	CCCMA CGCM3.1	A1B	1	4.53	4.35	3.35	3.12	3.30	3.13	3.15	2.60	2.77	2.53	2.20	2.94	3.16
4	CCCMA CGCM3.1	A2	1	3.55	3.39	3.58	3.19	3.52	2.89	3.16	2.97	2.62	2.95	2.57	2.39	3.06
5	CCCMA CGCM3.1	A1B	2	3.12	3.51	2.76	2.34	2.85	2.24	2.00	3.32	3.43	2.93	2.60	2.41	2.79
6	CCCMA CGCM3.1	A2	2	3.87	4.74	3.05	2.90	3.16	2.76	2.56	3.08	2.94	3.45	2.53	3.62	3.22
7	CCCMA CGCM3.1	A1B	3	3.27	3.41	2.69	2.86	2.33	2.72	2.63	2.93	2.31	2.66	2.21	2.67	2.72
8	CCCMA CGCM3.1	A2	3	3.79	4.40	2.94	2.54	2.95	2.92	3.09	3.12	2.93	3.25	2.75	2.72	3.12
9	CCCMA CGCM3.1	A1B	4	3.87	3.91	2.16	3.18	2.72	2.57	2.95	3.06	2.35	2.23	2.92	3.20	2.93
10	CCCMA CGCM3.1	A2	4	3.64	4.23	3.57	3.26	2.60	2.76	3.12	3.05	2.38	2.65	2.18	2.83	3.02
11	CCCMA CGCM3.1	A1B	5	5.18	3.26	3.69	3.42	3.38	2.49	3.19	2.51	3.25	3.86	2.05	3.51	3.32
12	CCCMA CGCM3.1	A2	5	4.78	4.69	3.25	2.78	3.21	2.59	3.00	2.85	3.22	2.97	2.40	3.59	3.28
13	CCCMA CGCM3.1.T63	A1B	1	4.13	4.50	3.70	3.56	3.02	2.69	2.97	3.09	3.21	2.85	2.21	2.51	3.20
14	CNRM CM3	A1B	1	3.47	1.65	1.19	2.27	2.10	2.74	2.89	3.22	3.35	2.33	2.21	3.87	2.61
15	CNRM CM3	A2	1	3.05	2.68	1.29	1.94	2.06	2.46	2.71	3.03	2.99	2.03	1.90	3.91	2.50
16	CSIRO MK3.0	A1B	1	3.09	3.30	1.70	0.75	1.14	1.24	1.32	2.10	1.29	1.72	1.40	3.12	1.85
17	CSIRO MK3.0	A2	1	3.73	5.56	1.93	1.17	1.40	1.06	1.62	2.58	1.21	1.80	2.48	3.94	2.37
18	CSIRO MK3.5	A1B	1	2.40	2.11	2.36	3.45	3.66	2.61	3.22	2.57	2.68	2.67	1.90	2.30	2.66
19	CSIRO MK3.5	A2	1	2.08	1.72	1.91	3.11	4.33	2.53	2.97	3.09	3.08	2.37	2.38	2.24	2.65
20	GFDL CM2.0	A1B	1	3.80	2.19	4.07	2.19	2.31	2.68	4.34	5.60	4.63	2.28	2.95	3.56	3.38
21	GFDL CM2.0	A2	1	2.63	2.13	4.73	2.82	1.81	2.46	3.77	4.89	4.16	2.08	2.55	3.67	3.14
22	GFDL CM2.1	A1B	1	1.98	1.65	2.37	2.84	2.03	1.63	3.16	4.35	2.87	2.54	2.04	2.32	2.48
23	GFDL CM2.1	A2	1	2.18	1.23	1.52	2.60	1.37	1.57	2.16	3.76	2.76	2.34	2.31	3.31	2.26
24	GISS AOM	A1B	1	3.97	3.26	2.33	2.23	2.00	2.15	1.93	1.89	1.70	1.61	1.70	3.03	2.32
25	GISS AOM	A1B	2	3.55	2.73	1.47	1.65	2.16	1.89	2.11	1.91	1.56	1.73	1.83	2.60	2.10
26	GISS MODEL E H	A1B	1	1.85	0.71	1.10	1.95	2.15	2.06	1.50	1.95	1.76	2.03	1.47	2.67	1.77
27	GISS MODEL E H	A1B	2	2.64	1.51	1.70	2.15	2.17	2.18	1.83	1.66	2.34	2.08	1.96	2.00	2.02
28	GISS MODEL E H	A1B	3	1.42	0.14	0.45	1.47	1.67	1.48	1.33	1.65	1.24	1.29	0.42	1.53	1.18
29	GISS MODEL E R	A2	1	2.12	2.56	2.39	1.77	1.97	2.05	1.63	1.99	2.23	1.73	1.75	2.38	2.05
30	GISS MODEL E R	A1B	2	1.69	0.81	1.23	2.15	2.22	2.00	1.58	1.28	1.49	1.86	1.40	1.65	1.62
31	GISS MODEL E R	A1B	4	2.22	1.16	1.07	1.73	2.36	1.71	1.55	1.42	1.86	2.29	1.71	0.40	1.62
32	IAP FGOALS1.0.G	A1B	1	3.77	2.12	2.15	2.40	2.54	1.93	2.05	1.83	2.22	2.71	1.60	2.98	2.36
33	IAP FGOALS1.0.G	A1B	2	3.06	3.56	2.95	1.81	1.69	1.94	2.57	2.61	3.03	2.82	3.56	3.41	2.75
34	IAP FGOALS1.0.G	A1B	3	0.23	1.82	1.75	2.57	2.06	2.12	1.81	2.37	2.02	2.62	1.55	1.06	1.83
35	INGV ECHAM4	A1B	1	2.56	1.37	2.22	2.75	1.81	2.38	2.30	2.47	2.38	2.05	3.10	2.78	2.35
36	INGV ECHAM4	A2	1	2.59	2.77	2.01	2.61	2.02	2.36	2.39	2.90	2.15	2.62	2.53	2.08	2.42
37	INMCM3.0	A1B	1	3.09	2.22	2.55	3.38	1.47	1.89	3.13	3.25	2.63	2.78	2.64	3.71	2.73
38	INMCM3.0	A2	1	3.94	3.11	3.42	2.70	1.32	2.31	2.64	2.93	2.20	1.72	3.05	3.75	2.76
39	MIROC3.2.HIRES	A1B	1	4.86	4.82	5.08	3.81	4.08	3.55	3.69	3.60	3.81	4.30	4.37	3.87	4.15
40	MIROC3.2.MEDRES	A1B	1	4.41	4.41	5.95	4.74	3.17	2.97	3.44	3.83	4.14	3.44	3.56	3.72	3.98
41	MIROC3.2.MEDRES	A2	1	3.67	4.00	5.73	4.53	3.12	2.58	3.18	3.21	3.06	3.67	3.65	3.88	3.69
42	MIROC3.2.MEDRES	A1B	2	4.75	5.10	6.56	4.75	3.77	3.02	4.08	3.54	3.28	3.29	3.84	3.69	4.14
43	MIROC3.2.MEDRES	A2	2	4.62	4.69	6.27	4.22	2.66	2.29	3.25	3.67	3.32	3.01	2.25	3.40	3.64
44	MIROC3.2.MEDRES	A1B	3	5.19	4.22	4.43	4.26	3.43	3.44	3.69	3.76	4.04	3.71	3.32	3.45	3.91
45	MIROC3.2.MEDRES	A2	3	3.97	3.28	3.47	3.26	2.64	3.15	3.16	2.89	3.14	3.49	3.22	2.95	3.22
46	MIUB ECHO G	A1B	1	4.44	3.42	2.90	2.92	3.05	2.85	3.14	3.48	3.26	3.82	3.84	4.63	3.48
47	MIUB ECHO G	A2	1	4.56	3.85	3.55	3.04	3.21	3.47	3.33	3.86	3.69	3.53	3.89	4.57	3.71
48	MIUB ECHO G	A1B	2	4.27	3.21	1.19	2.20	2.41	3.10	3.28	3.27	3.46	3.46	3.51	3.23	3.05
49	MIUB ECHO G	A2	2	4.30	3.81	2.31	2.42	2.63	2.63	2.26	3.11	3.03	2.97	3.91	4.31	3.14
50	MIUB ECHO G	A1B	3	3.99	2.07	1.61	1.40	2.46	3.03	3.80	3.79	3.23	3.53	3.34	4.38	3.05

ID	Model	Scenario	Run	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
51	MIUB ECHO G	A2	3	3.64	2.50	2.47	2.75	2.66	2.79	3.03	3.33	2.66	3.04	3.59	4.22	3.06
52	MPI ECHAM5	A1B	1	3.47	3.66	1.89	3.35	3.30	2.14	3.10	3.00	2.68	2.85	3.17	2.85	2.96
53	MPI ECHAM5	A2	1	3.14	1.92	1.58	1.21	2.48	1.95	2.59	2.77	2.41	2.07	2.61	2.46	2.27
54	MPI ECHAM5	A1B	2	3.54	3.95	2.23	2.27	2.03	2.20	2.59	3.05	3.18	3.04	3.05	3.17	2.86
55	MPI ECHAM5	A2	2	1.73	2.72	1.49	2.10	1.75	2.01	2.75	2.03	2.23	3.05	3.09	2.38	2.28
56	MPI ECHAM5	A1B	3	2.78	2.68	1.74	2.24	2.26	2.48	2.46	3.34	3.31	3.81	2.75	2.22	2.67
57	MPI ECHAM5	A2	3	2.45	2.94	2.86	1.96	2.59	2.45	2.19	2.94	2.45	2.83	1.77	1.62	2.42
58	MPI ECHAM5	A1B	4	3.07	3.78	2.91	2.66	2.61	2.23	2.64	2.82	2.46	1.85	1.77	2.63	2.62
59	MRI CGCM2.3.2A	A1B	1	4.22	3.04	1.85	1.96	1.84	2.19	1.95	2.00	1.60	2.42	1.93	2.63	2.30
60	MRI CGCM2.3.2A	A2	1	3.14	2.23	2.28	1.78	1.18	2.25	1.51	2.29	1.71	2.07	2.04	2.40	2.07
61	MRI CGCM2.3.2A	A1B	2	2.33	2.64	2.66	2.38	2.20	2.14	2.18	2.80	2.39	3.04	3.01	2.57	2.53
62	MRI CGCM2.3.2A	A2	2	2.09	2.99	2.31	2.52	1.98	1.99	1.83	2.48	2.04	3.10	2.51	2.19	2.34
63	MRI CGCM2.3.2A	A1B	3	1.48	1.78	2.21	1.42	1.62	1.95	2.12	2.74	1.98	2.23	2.20	1.75	1.96
64	MRI CGCM2.3.2A	A2	3	1.58	2.33	2.59	1.58	1.77	2.14	1.92	2.52	2.23	2.26	2.14	1.47	2.04
65	MRI CGCM2.3.2A	A1B	4	2.68	2.27	1.29	2.32	0.75	2.18	2.22	2.21	1.97	2.95	3.02	2.77	2.22
66	MRI CGCM2.3.2A	A2	4	3.39	2.45	0.87	1.50	1.54	2.11	1.99	1.45	1.70	2.75	2.62	2.99	2.11
67	MRI CGCM2.3.2A	A1B	5	3.05	2.56	2.34	2.13	1.49	2.39	1.78	2.58	2.77	2.33	2.61	2.76	2.40
68	MRI CGCM2.3.2A	A2	5	2.90	2.95	1.50	1.57	1.61	2.28	1.83	1.95	1.69	2.35	2.75	3.54	2.24
69	NCAR CCSM3.0	A1B	1	3.75	3.01	3.39	3.05	3.38	3.10	2.71	3.10	3.23	3.47	3.18	3.36	3.23
70	NCAR CCSM3.0	A2	1	3.61	2.80	3.63	2.91	2.45	3.02	3.18	2.87	4.00	3.99	3.31	4.27	3.34
71	NCAR CCSM3.0	A1B	2	4.77	2.25	3.93	2.86	3.29	3.12	2.99	3.72	2.05	2.86	3.54	4.32	3.31
72	NCAR CCSM3.0	A2	2	4.40	3.07	3.74	2.29	2.48	3.08	3.12	3.34	2.78	3.49	3.08	4.90	3.31
73	NCAR CCSM3.0	A1B	3	3.16	2.31	2.73	1.97	1.29	1.63	3.25	3.01	2.96	3.17	3.19	2.74	2.62
74	NCAR CCSM3.0	A2	3	3.81	2.49	2.18	2.43	1.85	2.47	3.91	3.27	2.68	3.43	3.63	2.85	2.92
75	NCAR CCSM3.0	A2	4	3.17	3.11	2.95	2.53	2.83	3.09	2.95	3.38	2.71	2.50	3.78	3.19	3.02
76	NCAR CCSM3.0	A1B	5	3.37	3.03	1.55	1.79	2.37	2.56	2.65	2.11	2.46	2.74	4.77	4.24	2.80
77	NCAR CCSM3.0	A1B	6	4.01	3.01	3.40	2.73	3.83	3.49	3.70	3.28	3.79	3.22	3.61	4.33	3.53
78	NCAR CCSM3.0	A1B	7	3.03	3.29	2.46	2.65	2.50	3.44	3.51	2.98	2.98	2.60	3.19	3.69	3.03
79	NCAR CCSM3.0	A1B	9	3.48	2.88	3.61	2.48	2.88	3.08	3.35	2.88	1.97	2.73	3.85	3.37	3.05
80	NCAR PCM1	A1B	1	2.18	3.16	1.71	0.73	1.76	1.74	1.53	1.67	1.62	2.35	1.31	1.90	1.81
81	NCAR PCM1	A2	1	3.49	3.00	1.90	0.74	1.48	1.49	1.22	1.41	1.64	1.57	1.23	2.59	1.81
82	NCAR PCM1	A1B	2	3.14	0.77	2.82	1.25	1.49	1.98	1.90	1.74	2.19	1.58	1.55	3.42	1.99
83	NCAR PCM1	A2	2	2.75	1.29	2.28	1.13	1.56	2.17	1.71	1.65	2.14	2.00	1.26	2.74	1.89
84	NCAR PCM1	A1B	3	2.90	3.77	3.12	1.40	1.25	1.97	1.41	2.24	2.39	1.80	2.09	2.30	2.22
85	NCAR PCM1	A2	3	2.87	2.76	2.60	1.13	1.04	1.55	1.15	1.47	2.18	2.58	0.60	1.60	1.79
86	NCAR PCM1	A1B	4	2.02	1.76	2.73	1.05	1.97	1.46	1.80	2.19	2.17	1.06	1.98	1.79	1.83
87	NCAR PCM1	A2	4	1.65	3.02	1.74	0.63	1.40	1.19	1.30	1.54	2.60	1.52	2.38	1.97	1.74
88	UKMO HADCM3	A1B	1	4.06	4.00	4.41	2.71	3.09	2.89	3.59	3.95	3.55	2.91	3.17	2.68	3.42
89	UKMO HADCM3	A2	1	2.20	1.27	1.94	2.88	2.82	2.22	2.22	2.73	2.99	2.54	2.35	1.78	2.33
90	UKMO HADGEM1	A1B	1	5.71	3.91	5.10	3.76	3.68	3.69	4.39	5.10	2.73	4.06	4.84	6.59	4.46
91	UKMO HADGEM1	A2	1	5.04	4.61	4.99	3.05	2.91	3.70	4.23	4.63	3.35	3.20	2.98	5.93	4.05
92	BCCR BCM2.0	B1	1	2.41	0.64	1.56	1.64	2.85	1.43	0.88	1.45	1.34	1.44	1.51	3.83	1.75
93	CCCMA CGCM3.1	B1	1	3.07	3.19	3.48	3.30	2.59	2.04	2.27	2.86	1.37	1.70	1.75	1.81	2.45
94	CCCMA CGCM3.1	B1	2	1.85	2.53	2.67	2.05	2.25	1.87	1.76	2.45	2.50	2.71	2.11	1.77	2.21
95	CCCMA CGCM3.1	B1	3	2.35	2.84	0.83	1.72	1.73	1.94	1.89	2.76	1.58	2.15	2.37	1.61	1.98
96	CCCMA CGCM3.1	B1	4	2.37	3.45	3.17	2.46	2.30	2.09	2.20	2.61	1.68	2.13	1.68	2.99	2.43
97	CCCMA CGCM3.1	B1	5	4.18	3.79	2.60	2.83	2.30	1.76	2.59	2.10	2.41	2.41	1.82	2.48	2.61
98	CCCMA CGCM3.1.T63	B1	1	2.56	2.82	2.06	2.37	2.88	2.52	2.54	2.26	2.01	2.10	2.26	2.12	2.37
99	CNRM CM3	B1	1	3.18	0.93	1.01	1.78	1.81	1.34	2.20	2.18	2.42	1.92	1.62	2.72	1.93
100	CSIRO MK3.0	B1	1	1.89	3.03	1.34	0.74	0.88	0.56	0.60	1.17	0.04	0.79	1.38	1.92	1.20

ID	Model	Scenario	Run	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
101	CSIRO MK3.5	B1	1	1.46	1.93	1.48	2.06	3.11	2.09	2.02	1.51	2.25	2.06	1.71	1.97	1.97
102	GFDL CM2.0	B1	1	2.18	1.16	2.49	1.85	1.83	1.94	2.91	3.89	2.87	1.98	1.94	2.66	2.31
103	GFDL CM2.1	B1	1	2.19	0.58	1.00	2.55	1.26	1.21	2.81	2.90	2.35	2.54	2.57	2.50	2.04
104	GISS AOM	B1	1	2.75	1.46	2.01	2.10	1.94	1.54	1.54	1.52	1.80	1.66	1.60	2.37	1.86
105	GISS AOM	B1	2	2.58	2.01	1.50	1.91	1.68	1.39	1.49	1.32	1.47	1.05	1.19	1.76	1.61
106	GISS MODEL E R	B1	1	1.37	1.12	1.76	1.54	2.09	1.38	1.39	1.51	1.04	1.30	1.00	1.58	1.43
107	IAP FGOALS1.0.G	B1	1	1.57	0.69	1.72	2.26	2.05	1.66	1.66	1.38	1.68	1.74	0.99	1.12	1.54
108	IAP FGOALS1.0.G	B1	2	3.97	2.57	2.40	1.44	1.41	1.55	1.57	1.94	2.21	2.62	3.34	2.81	2.32
109	IAP FGOALS1.0.G	B1	3	1.45	3.21	2.82	2.15	1.59	1.57	1.29	1.31	1.54	1.96	1.32	1.97	1.85
110	INMCM3.0	B1	1	3.31	2.12	2.41	2.64	1.02	1.45	2.51	2.17	2.20	1.84	2.30	2.77	2.23
111	MIROC3.2.HIRES	B1	1	3.98	4.02	4.99	3.55	2.55	2.74	2.94	3.00	3.13	3.82	3.60	3.45	3.48
112	MIROC3.2.MEDRES	B1	1	3.17	3.73	3.35	4.02	2.55	2.14	2.36	2.69	3.03	3.37	3.41	2.84	3.06
113	MIROC3.2.MEDRES	B1	2	4.16	3.25	4.80	3.46	2.62	1.82	2.67	3.12	2.69	2.78	2.46	2.98	3.07
114	MIROC3.2.MEDRES	B1	3	4.28	3.55	3.34	3.30	2.22	2.66	2.59	2.60	2.99	2.61	2.97	2.80	2.99
115	MIUB ECHO G	B1	1	3.30	3.34	1.99	2.55	2.70	2.72	2.89	3.02	2.94	2.93	2.73	3.52	2.89
116	MIUB ECHO G	B1	2	3.35	2.14	1.38	1.72	2.33	2.30	2.56	2.84	2.74	2.43	2.76	2.27	2.40
117	MIUB ECHO G	B1	3	3.54	1.97	2.51	3.06	1.92	2.99	2.63	2.98	2.56	3.27	2.60	4.02	2.84
118	MPI ECHAM5	B1	1	2.56	2.41	1.58	1.57	2.40	1.64	1.76	1.84	2.25	1.74	2.16	1.77	1.97
119	MPI ECHAM5	B1	2	1.87	1.81	1.11	2.13	1.70	2.15	1.80	2.07	1.61	2.30	3.14	2.91	2.05
120	MPI ECHAM5	B1	3	2.32	2.18	1.79	1.71	2.15	2.33	2.12	2.91	2.46	2.62	2.28	2.42	2.27
121	MRI CGCM2.3.2A	B1	1	3.01	1.44	1.17	1.49	1.18	1.38	1.74	1.75	1.67	1.96	1.38	1.91	1.67
122	MRI CGCM2.3.2A	B1	2	1.96	2.52	2.48	1.94	1.46	1.61	1.51	1.78	1.71	2.03	2.14	1.61	1.90
123	MRI CGCM2.3.2A	B1	3	1.01	2.01	1.52	1.01	1.33	1.90	1.55	2.07	1.13	1.20	1.80	1.15	1.47
124	MRI CGCM2.3.2A	B1	4	2.89	1.61	1.40	1.69	1.26	2.16	2.03	1.09	1.73	2.16	2.38	3.02	1.95
125	MRI CGCM2.3.2A	B1	5	2.36	1.74	1.39	1.92	1.29	2.07	1.90	2.11	2.16	2.73	2.81	2.89	2.11
126	NCAR CCSM3.0	B1	1	3.28	2.99	2.29	2.79	1.86	2.32	2.33	1.78	2.51	2.58	2.41	3.16	2.52
127	NCAR CCSM3.0	B1	2	1.81	1.44	3.42	1.46	1.70	2.47	2.59	2.68	2.04	2.26	2.95	2.93	2.31
128	NCAR CCSM3.0	B1	3	2.24	2.82	2.72	1.66	1.17	1.86	2.51	2.51	2.30	2.73	2.31	2.35	2.27
129	NCAR CCSM3.0	B1	4	1.21	1.29	1.81	1.81	1.83	2.30	2.10	2.23	1.39	1.51	2.18	1.71	1.78
130	NCAR CCSM3.0	B1	5	2.53	2.65	1.61	1.52	2.48	1.97	1.48	1.11	2.08	1.44	3.76	2.98	2.13
131	NCAR CCSM3.0	B1	6	2.32	2.66	2.36	2.40	2.40	1.65	2.30	1.87	1.95	2.38	2.69	1.86	2.24
132	NCAR CCSM3.0	B1	7	2.20	2.05	1.45	1.19	1.24	1.94	2.60	2.07	2.62	1.81	1.94	3.15	2.02
133	NCAR CCSM3.0	B1	9	1.28	2.71	2.42	1.47	1.90	1.79	2.57	1.80	1.34	1.52	2.28	0.91	1.83
134	NCAR PCM1	B1	2	2.30	1.29	2.62	0.50	1.41	1.23	1.36	1.60	1.31	1.53	1.02	2.33	1.54
135	NCAR PCM1	B1	3	1.61	2.26	0.97	0.16	0.33	0.86	1.04	1.73	1.85	1.37	1.06	1.02	1.19
136	UKMO HADCM3	B1	1	2.20	1.27	1.94	2.88	2.82	2.22	2.22	2.73	2.99	2.54	2.35	1.78	2.33
		Average		3.03	2.68	2.52	2.31	2.24	2.23	2.42	2.60	2.44	2.48	2.46	2.82	2.52
		Standard Deviation		1.02	1.08	1.16	0.87	0.76	0.62	0.77	0.84	0.75	0.72	0.84	0.97	0.67