District Municipality of Muskoka
Operational Adjustments and Scoping Study for the Muskoka River Water Management Plan

Phase 1 Report

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Executive Summary

The Muskoka River Watershed is very complex, borne from the many lakes and interconnecting river stretches, and the numerous and often conflicting interests in the use of the watershed. While in most years, the waters in the watershed are enjoyed year-round, there have also been a number of years during which spring flooding has negatively impacted people, infrastructure and the natural environment.

In reviewing the Muskoka River Water Management Plan and operations for select, recent flood years, it can be seen that there may be small changes that could help to mitigate local flooding in some areas in specific cases. However, it is impossible to eliminate flooding in all areas in all years, and any of the identified changes have the potential to simply pass the flood issue to another area or negatively impact another interest in the watershed (often fisheries).

The following actions are recommended, and are explained, along with their potential consequences in this report:

- Review Muskoka River Water Management Plan provisions for lake drawdown decisions based on experience from recent flood years to determine if new or revised provisions should be included in the Muskoka River Water Management Plan.
- Test fuller use of the lower range of the Normal Operating Zone, which may allow for greater retention of water in some of the lakes and reduce flooding downstream. Preliminary analysis conducted herein revealed that increased drawdown for only Lake Muskoka for the conditions in 2013 and 2019 resulted in nominal reductions of 0.05 m and 0.01 m for 2013 and 2019, respectively.
- Review the discharge capability of Lake Rosseau to better understand the drawdown limitations, and to determine changes that might allow for greater drawdown of the lake.
- Consider implementing a stepped refill process for Kawagama Lake, Lakes of Bays and its downstream river reach. Additional study may be required to the quantify the step values, as this information was not available for this report.
- Improve understanding of the flows and levels that impact specific locations or infrastructure to better understand how to “share the pain” of flooding. Stage-damage curves for lakes could be developed to understand the effects of flooding on each lake, as a means of optimizing mitigations between lakes.
- Review of the current communication/data sharing processes under high flow conditions may help determine if more information is needed or if development of an early warning system should be considered.

1. Introduction

1.1 Project Background

The Muskoka River Watershed (MRW) has experienced periods of significant springtime flooding throughout history. Most recently, during the spring of 2019, the District Municipality of Muskoka (the District) encountered some of the most severe flooding on record across the MRW which, in turn, resulted in damage to both personal property and municipal infrastructure. This event had been preceded by other significant flooding events in 2008, 2013 and 2016. Concern regarding the impacts of flooding in the watershed has resulted in a number of studies over the years.

Most recently, in August 2018, the Ministry of the Environment, Conservation and Parks (MECP) established the Muskoka Watershed Conservation and Management Initiative (Muskoka Watershed Initiative). This initiative was intended to identify the risks and issues impacting the Muskoka Region so that the community and the Province of Ontario (Province) could work together to establish a path forward to better protect local water resources, infrastructure and the environment.

As a first step, the MECP established the Muskoka Watershed Advisory Group (MWAG) to provide advice and recommendations regarding the Muskoka Watershed Initiative. This group was formed following the most recent flooding in 2019. The primary focus of its work was to provide a strategic assessment of the priority issues in the watershed, and the types of projects that could be undertaken to resolve these issues. Following significant outreach and consultation with representatives of local governments, cottage and tourism organizations, waterpower producers, agriculture, the general public, etc, the MWAG issued their report entitled "*Interim Advice and Recommendations to Address Priority Environmental Issues in the Muskoka River Watershed*" in June 2020. It contained several recommendations covering a wide range of topics.

On April 20, 2021, the Province announced an initial investment of $4.25 million to fund projects aimed at helping to reduce the impacts of flooding, and to address the overall health of the MRW based on the recommendations from the MWAG. Based on this funding, and at the direction of the Province, the District undertook advancement of a number of technical projects focused on the MRW to address some of the areas identified in the MWAG's report.

Project 2, under a Request for Proposal (RFP) issued by the District in September 2021, was entitled "*Operational Adjustments and Scoping Study for the Muskoka River Water Management Plan*". To provide additional review and support for its projects, the District established a Technical Working Group (TWG), consisting of individuals with extensive knowledge of the watershed.

1.2 Project Objective

The District commissioned Hatch to execute Project 2. The intent of Phase 1 of this project was to complete a review of the Muskoka River Water Management Plan (MRWMP) to identify potential operational adjustments. Phase 2 of this project will focus on providing a comprehensive scope of work required to complete an update to the Muskoka River Water Management Plan, with a focus on increasing the ability to attenuate flooding within the watershed. This report addresses Phase 1 of Project 2.

2. Review of Related Documents

A list of reviewed documents (including those of a more general nature covering the Province of Ontario) is included below.

- Hackner-Holden Agreement – between the Province of Ontario and the Hydroelectric Power Commission of Ontario (later Ontario Hydro/OPG) (1940, Addendum 1 – 1969)
- Water Management Improvement Study of the Muskoka River System – MacLaren Plansearch (MacLaren) (May 1985)
- Dam Operations Manual for Muskoka River Dams – Ontario Ministry of Natural Resources (1997, updated 2007)
- Muskoka River Water Management Plan – Ontario Power Generation, Bracebridge Hydro, Orillia Power, Algonquin Power and Ontario Ministry of Natural Resources and Forestry (2006, amended 2016, 2018 and 2019)
- An Independent Review of the 2019 Flood Events in Ontario – report by Douglas McNeil, Ontario's Special Advisor on Flooding (Oct 2019)
- The Case for integrated Watershed Management in Muskoka – report by the Muskoka Watershed Council (January 2020)
- Ontario Flood Strategy – Province of Ontario (March 2020)
- Interim Advice and Recommendations to Address Priority Environmental Issues in the Muskoka River Watershed – report from the Muskoka Watershed Advisory Group (June 2020)
- The Evolution of Water Management in the Muskoka River Watershed – report by Chris Cragg (November 2020)

Many studies and reviews of Muskoka watershed conditions have been carried out over the years. All of them recognize that flooding can be an issue during years of high spring runoff. While an early study (the MacLaren study noted above) offered a "water management plan" to reduce flood losses while still accommodating many of the other demands on the river, it is not clear if any of their recommendations were adopted. Other studies do not appear to have offered any solutions beyond generalizations such as changing operations or making structural modifications to the existing layout.

3. Muskoka River Watershed

3.1 Geography

The District Municipality of Muskoka is often referred to as DMM, the District, or simply as Muskoka. It is a regional municipality in Central Ontario, with its primary population centres being Gravenhurst, Bracebridge and Huntsville. The MRW is a very complex watershed, and while most of it lies within the District, it also overlaps parts of neighbouring municipalities. The watershed itself originates on the western slopes of Algonquin Provincial Park and extends southwesterly for approximately 210 km with two outlets into Georgian Bay. It covers 62 km at its widest point. The watershed encompasses an area of approximately 5100 km^2 and includes about 78,000 ha of lakes.[1]

The watershed can be broken into three distinct sections

- North Branch
- South Branch
- “Muskoka Lakes”/Lower Watershed.

The north and south branches represent approximately two-thirds of the total watershed and originate near the southwest border of Algonquin Park. They both flow in a southwest direction until they meet in the town of Bracebridge, and then outlet as a single river channel into Lake Muskoka. Most of the remaining one-third of the total watershed includes the three largest lakes – Lake Joseph, Lake Rosseau and Lake Muskoka (the ‘Muskoka Lakes’). Lakes Joseph and Rosseau flow into Lake Muskoka. A short distance downstream from the outlet from Lake Muskoka, the river splits into the Moon and Musquash Rivers, which flow into Georgian Bay.

3.2 History of Use and Development of Facilities

The waterways of Muskoka have been critical in providing watershed access and facilitating development of the area over time. As early as the late 1880s, dams were constructed to help transport logs to sawmills in the area. Water was also diverted to power mills for electricity production. The Town of Bracebridge became the first municipality in Canada to own and operate a hydroelectric station through purchase of Bird’s Mill in 1894.[2] In addition, the waterways provided a means for moving people, freight, and mail into the area.

As the area developed, interests in the watershed also changed. Less focus was given to commerce and transportation, while recreation and support for fisheries grew in importance. However, the production of hydroelectric generation has remained a constant. While waterways have always been a popular site for development, the expansion of the tourist

[1] Muskoka River Water Management Plan, Final Plan Report, January 2006, Amended February 2018, Amended December 2019
[2] Bracebridge Generation – Our Facilities (website)

industry led to increased demand for shoreline properties for seasonal and year-round cottages.

Currently, there are 13 generating stations (GS) in the MRW. The most recent station to go into service is Bala GS, which started operation in January 2020. It was built on the site of an earlier power plant that operated between 1924 and 1972.[3] The generating stations are listed in Table 3-1.

Table 3-1 – Generating Stations

Generating Station	Owner/Operator	Watershed Location
High Falls	Bracebridge Generation	North Branch Muskoka River
Wilson's Falls	Bracebridge Generation	North Branch Muskoka River
Bird's Mill	Bracebridge Generation	North Branch Muskoka River
Bracebridge Falls	Bracebridge Generation	North Branch Muskoka River
Matthias	Orillia Power Generation	South Branch Muskoka River
Tretheway Falls	Ontario Power Generation	South Branch Muskoka River
Hanna Chute	Ontario Power Generation	South Branch Muskoka River
South Falls	Ontario Power Generation	South Branch Muskoka River
Burgess	Township of Muskoka Lakes/ private operator	Lake Muskoka
Bala	Swift River Energy Limited	Lake Muskoka
Ragged Rapids	Ontario Power Generation	Lower Watershed/Musquash River
Big Eddy	Ontario Power Generation	Lower Watershed/Musquash River

All of the generating stations, except Burgess GS, also have spill facilities. In addition to the generating stations and their associated spill facilities, there are 29 additional flow control structures owned by the Ministry of Natural Resources and Forestry (MNRF). MNRF operates 27 of these flow control structures, with the remaining two control dams being operated by Swift River Energy Ltd (SREL) (in conjunction with Bala GS). There is also one privately owned dam (Devine Lake Dam).

3.3 Watershed Data

A number of sources of information were considered in the assessment of operations during recent flood years. While 2013 and 2019 were the main focus years of this project, 2008 and 2016 were also years where flooding was experienced, and they were included in the data collection process to expand the available data for comparison. The data considered included

[3] Bala Generating Station – Powering Muskoka (website)

water level gauges, flow gauges, snow survey courses and meteorological stations. These monitoring locations are shown in Figure 3-1 and they are also listed in subsequent sections.

3.3.1 Hydrometric Gauging

Water Survey of Canada maintains several flow and/or level gauging stations within the watershed as listed below in Table 3-2. These gauges provide daily data estimates over the full year. Historical data recorded at these gauges were used to assess the actual annual rise/fall pattern of the water levels at several sites within the watershed, and to compare these patterns with the limits given in the current MRWMP.

Table 3-2 – Hydrometric Gauges

Gauge Identification Number	Hydrometric Gauges	Years of Data Availability	Data Parameter
02EB017	Kawagama Lake at Russell Landing	2002-2021	Level
02EB019	Lake of Bays at Baysville	2002-2021	Level
02EB008	South Branch Muskoka River at Baysville	1941-2020	Level/Flow
02EB013	Big East River Near Huntsville	1973-2021	Level/Flow
02EB016	Fairy Lake at Huntsville	2002-2021	Level
02EB021	Mary Lake at Port Sydney	2002-2021	Level
02EB004	North Branch Muskoka River at Port Sydney	1915-2020	Level/Flow
02EB018	Lake Muskoka at Beaumaris	2002-2021	Level
02EB015	Bala Bay at Bala	2003-2021	Level
02EB006	Muskoka River Below Bala	1937-2020	Flow

3.3.2 Snow Survey Courses

The MNRF maintains and operates a number of snow survey courses within the MRW. They are listed in Table 3-3. Surveys are conducted at these courses twice per month (around the 1st and 15th of each month), from December to May (if there is snow). One of the measurements determined from the survey data is snow water equivalent (SWE), which is the liquid water equivalent of the snowpack expressed in terms of depth (mm). It is an important parameter for understanding how much water may be released from the snowpack when it melts.

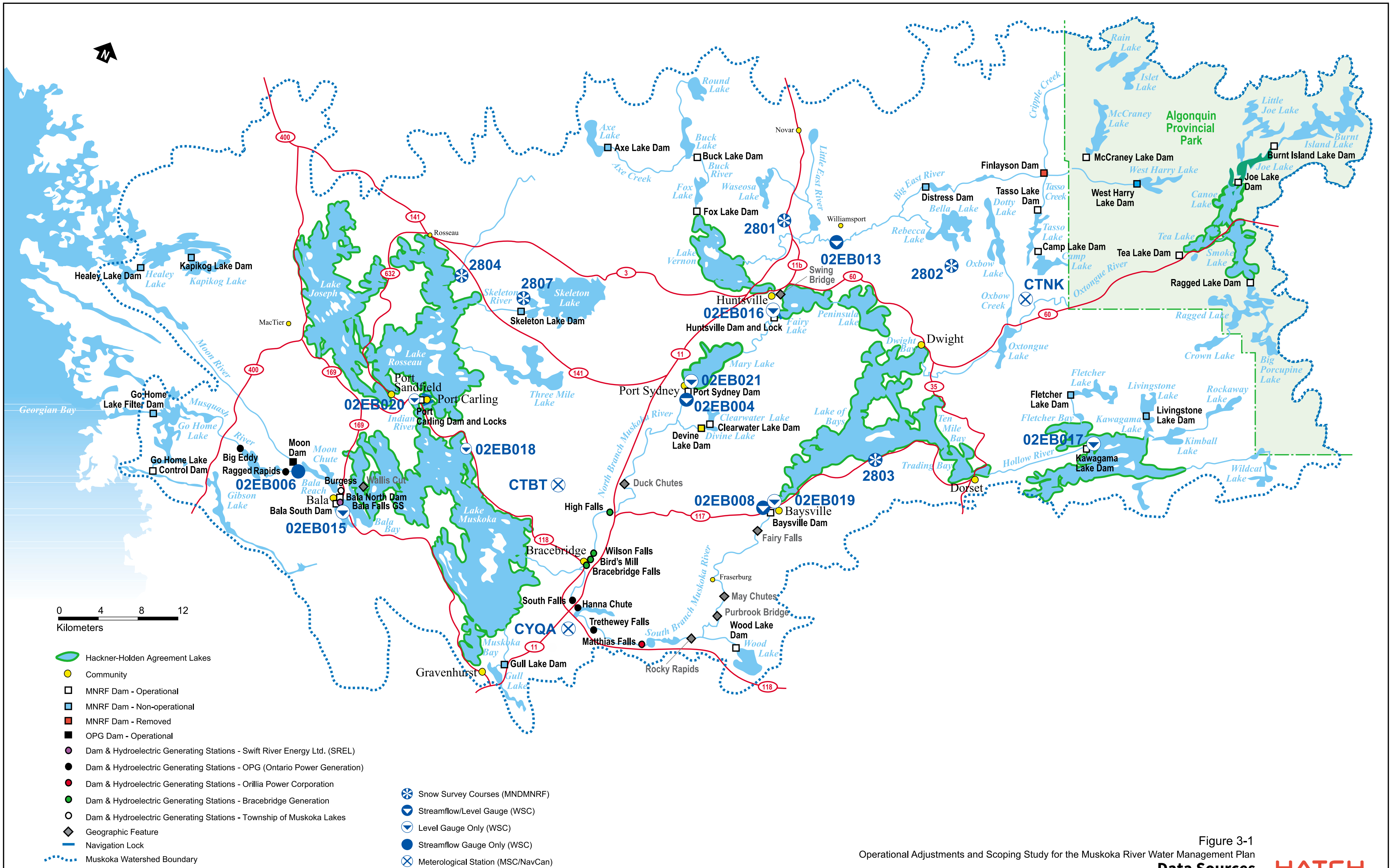


Figure 3-1
Operational Adjustments and Scoping Study for the Muskoka River Water Management Plan
Data Sources

Table 3-3 – Snow Survey Courses

Course Number	Name	Years of Data Availability	Location Description
2801	Big East River	1965 - 2022	Located on Hwy 11, approximately 4.5 km north of Hwy 60, starting 0.2 km north of the entrance to Arrowhead Provincial Park on a ridge beside Hwy 11 on the west side of the highway between the highway and the CNR railway tracks.
2802	Kiwanis Camp	1965 – 2022	On Muskoka District Road 8 at Interlaken,17 km from Hwy 60, 0.65 km west of the culverts at the outlet at Dotty Lake, just east of Interlaken Fire Hall, following a snowmobile trail north, starting about 50 m past the fire hall.
2803	Norway Point	1965 – 2022	On the south side of Lake of Bays, west of Norway Point. Off of the west side of the road beside a snowmobile/cross-country ski trail, north of a gravel pit, starting 20 m in from the road in a young pine grove opposite a house on the east side of the road.
2804	Rosseau Falls	1965-2020	Off Hwy 141, 0.1 km west of Rosseau River bridge crossing, snow course follows a hydro line, starting 15 m south of the highway across a ravine. Discontinued in the fall of 2020.
2807	Skeleton Lake	2020 - 2022	Replaced the Rosseau Falls course in November 2020. Located along Fish Hatchery Road (off of Hwy 141), near the western end of High Lake.

3.3.3 *Meteorological Stations*

The meteorological stations used for this project automatically collect data for a number of weather parameters. The sites used for analysis in this project are listed in Table 3-4. For the purpose of this project, only the temperature and precipitation data from these sites were used.

Table 3-4 – Meteorological Stations

Station ID	Years of Data Availability	Name	Operator
CTBT	2005-2022	Beatrice Climate	MSC
CYQA	2009-2022	Muskoka	Nav Canada
CTNK	2004-2022	Algonquin Park East Gate	MSC

3.4 Project Areas of Concern

Under high flow conditions, such as those experienced in spring of 2013 and 2019, flooding has occurred in a number of areas within the MRW. To provide direction for Projects 2 and 3[4], District staff, in conjunction with the TWG and Hatch, identified five areas of concern for flooding. They are identified as follows:

1. Big East River
2. Huntsville
3. Springdale
4. Baysville/Fraserburg/Purbrook
5. Bala/Lake Muskoka.

These locations are shown in Figure 3-2. While they are distinct areas within the watershed, Project 2 considered flooding in the overall watershed while using these locations as key reference points.

[4] Project 3: Structural and Watershed-scale Flood Mitigation. One of five Muskoka River Watershed Projects summarized in RFP 21-810070-02. Project 3 was executed by Hatch as Project Number H367619. A summary of the work is provided under another report cover.

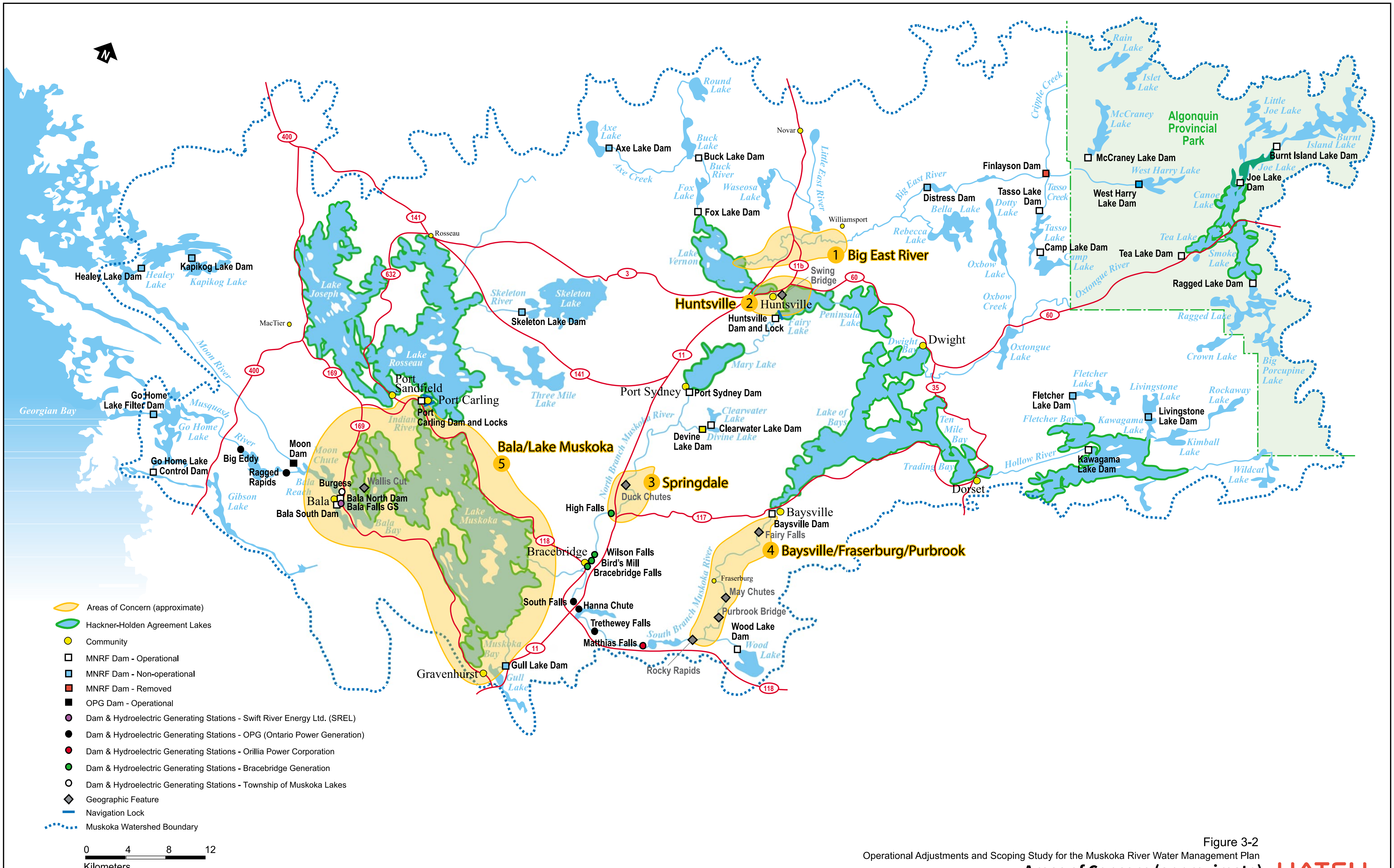


Figure 3-2

Operational Adjustments and Scoping Study for the Muskoka River Water Management Plan

Areas of Concern (approximate)

HATCH

4. History and Current State of Water Management in the Muskoka River Watershed

4.1 Hackner-Holden Agreement

In 1940, the Ontario Government and the Hydroelectric Power Commission of Ontario (now Ontario Power Generation [OPG]) signed the Hackner-Holden Agreement. It provided direction for the control of levels and outflows at select lakes to maximize benefits for all interests – in particular, summer levels were established for navigation, and water use by the power producers was optimized at other times. Several factors were investigated in order to establish a plan for coordination of the use of the water while maintaining necessary water levels. These factors included

- run-off and storage capacity of existing lakes
- variations in streamflow
- the advisability and feasibility of creating further storage
- requirements for navigation and power purposes
- procedures to facilitate any agreed upon operations.

While consideration was given to expanding storage on Porcupine Lake (headwaters of the Oxtongue River in Algonquin Park) or in some of the smaller lakes above Kawagama Lake (formerly Hollow Lake), creation of additional storage was deferred at the time because it was felt that there was sufficient storage considering the range of levels that had been established and pending further studies and observations. Review of several other documents failed to find any evidence that these studies were ever undertaken.

An Addendum to the Hackner-Holden Agreement was written in 1969. It was recognized that the requirements of some of the interests had changed, and that new interests should also be considered. While power production had remained constant, the tourism industry expanded significantly, and consideration was now also directed towards fish and wildlife. It reduced the summer water level fluctuations experienced by cottagers, while also limiting fall, winter and spring drawdown amounts to protect fish spawning. Also at this time, ownership of the Kawagama Lake Dam changed from Ontario Hydro to the Province. Over the period to the mid-1970s, the Province also assumed responsibility of the majority of the control structures (excluding those associated with the generating stations) and continued the operation of these facilities to support the many uses of the watershed.

While none of the water control structures in the MRW were built intentionally for flood control, it was recognized that operations could help with spring flood mitigation through the winter drawdown of various lakes. Operating instructions and supporting documentation for these Provincial assets are contained in the Muskoka River Dam Operations Manual, prepared by the South-Central Region of the Ministry of Natural Resources (MNR) in 1997 (updated in 2007). The generating stations have their own operating instructions. Except for Burgess GS and Bala GS on Lake Muskoka, all of the generating stations are located on river stretches. They have very limited storage capacity in their head ponds, and are considered to be run-of-river plants (limited ability to impact flows). Operation of these facilities is integrated with operation of the Provincial dams to ensure that appropriate flow conditions are maintained. In addition, because Burgess GS has very limited capacity, its operation does not significantly impact the level of Lake Muskoka. Similarly, it should be noted that due to its size, and downstream flow requirements, Bala GS also largely acts as a run-of-river station.

4.2 Muskoka River Water Management Plan

Formal water management planning was introduced in Ontario in 2002. While most hydroelectric generating stations already had operating plans in place to address multiple interests, and to reflect the elevation limits within which they operated, with the opening of the electricity market in 2001, the Province wanted to ensure that operations did not become driven by market forces only. To ensure that all interests would be considered, a formal water management planning process was introduced. This process was governed by a technical bulletin entitled *Water Management Planning Guidelines for Waterpower*, approved by the Minister of Natural Resources on May 14, 2002. To further support the process, public consultation took place during the development of the plan to both include input from the public, and to ensure transparency of the process.

While water management planning was directed towards the power producers, it should be noted that almost all of the dams (one is privately owned) controlling lake outflow in the MRW are owned by the MNRF. A guiding principle of water management planning is to provide a net benefit to society. This objective can be achieved by striving to "*maximize the net environmental, social and economic benefits derived from the management of water levels and flows by waterpower facilities and other water control structures on a river*."[5] Water management planning also supports the concept of adaptive management such that the plan can be changed as interests/values change over time.

The Hackner-Holden Agreement and the MNR Dam Operations Manual, plus existing operating plans at the generating stations tied to legal tenure, structural limitations, and water retention limitations, were the starting points for the MRWMP. Minor changes were made to reflect the changing interests and values within the watershed. Important timelines for the MRWMP are shown in the following table.

[5] Muskoka River Water Management Plan, MNR/OPG/OP/BG/AP, January 2006, p.2-4

Table 4-1– Muskoka River Water Management Plan Timeline

Event	Date	Reason
Issue Water Management Plan	Jan 2006	Issue Plan
Amendment 1	Feb 2016	Administrative – Extension of Term
Amendment 2	Feb 2018	Administrative – To align plan with the approved Maintaining Water Management Plans Technical Bulletin
Amendment 3	Dec 2019	Minor – Inclusion of SREL Bala GS

4.3 Comparison of Hackner-Holden Agreement and the Current Water Management Plan

As referenced earlier in this report, the original Hackner-Holden Agreement put a number of flow and elevation constraints in place to support the main interests at the time. In addition, as the interests evolved, an addendum to the original agreement was written in order to better support the newer interests (e.g., tourism and fish).

While the MRWMP was written with the intent to further support the various interests by aiming for the net benefit to society, there were limited changes to the operating plans for most of the sites. This section summarizes the main changes for the primary lakes within the watershed, and some concerns that may make further changes to the operating plans difficult.

4.3.1 Huntsville Lakes (Fairy, Vernon and Peninsula)

It is recognized that the Huntsville Lakes dam has limited flow capacity and, therefore, has a limited ability to help respond to high water levels or high flow events. While the Normal Operating Zone (NOZ) for these lakes remained unchanged in the MRWMP, the average maximum high water level was increased slightly (4 cm). The Target Operating Level (TOL) in the operating plan provides for a gradual, but continual water level reduction through the spring and summer, and eliminated the stepped approach that had been followed. The TOL for the fall and early winter remained unchanged, but in order to improve lake trout spawning habitat, the difference between fall and winter water levels was reduced from 0.3 m to 0.2 m. Similarly, a consistent outflow from Fairy Lake was implemented to improve fish habitat in the river area below the dam. These minor flow and level changes were expected to more closely follow a natural flow regime. While the maximum spring outflow level remained the same, it was predicted that downstream flood damage zone flows would be exceeded more frequently. Also, it was expected that the summer range of water levels (at the 80th percentile level) would result in an increase of up to 12 cm.

4.3.2 Mary Lake

While the winter drawdown is limited (0.37 m, from 283.75 m to 283.3 m), it is recognized that a number of lake trout spawning shoals are located in the late winter/early spring part of this zone. By reducing the difference between the fall and winter drawdown levels, lake trout spawning habitat was expected to be improved. A slightly higher spring water level also helped to improve conditions for spring spawning fish and wetlands. The summer range is also very limited, and the water level is allowed to decline gradually over the summer. This pattern can be a balance between simulating a more natural flow regime to support ecological conditions and providing conditions that support the many water-based activities that can continue into late fall. Although there may not be any structures within the summer range, it is known that some structures have been built within the upper part of the NOZ.

4.3.3 Kawagama Lake

Kawagama Lake has several potentially conflicting interests that the MRWMP tried to balance. Some of these concerns are as follows:

- significant lake trout spawning shoals are dewatered during winter drawdown
- ice damage and shoreline erosion can result from high spring water levels
- because navigation may continue later into fall, drawdown during this period can impact it
- dug wells and shallow waterlines may be impacted by low winter water levels
- Kawagama Lake can be hard to fill during springs with lower-than-normal snowmelt or rain
- low summer lake levels.

In order to try to manage some of these concerns, the MRWMP established a reduced NOZ and TOL for this lake, and a reduced winter drawdown was established to improve lake trout spawning habitat (i.e., less difference between fall and winter levels). The reduced winter drawdown was also intended to increase available winter aquatic habitat. However, these changes to winter operations also can reduce the flow available for power production. It was expected that increased flow from other lakes in the watershed during the summer would make up for the winter losses. Shoreline erosion at the east end of the lake (windward side) was addressed by lowering the spring peak. A best management practice (BMP) was introduced to address concerns about low summer levels. While the regular TOL is maintained, during years with sufficient rainfall/runoff, initiation of fall drawdown can be delayed until September 15 in order to limit impacts to fall navigation. Finally, to provide a more natural flow regime out of the lake, a baseflow into the Hollow River was set (3 m^3/s).

4.3.4 Lake of Bays

As with Kawagama Lake, Lake of Bays is highly developed. While there does not appear to be any infrastructure within the NOZ, there is some infrastructure within the absolute operating zone (AOZ). In addition to potential impacts from springtime high water, ice damage can occur in the winter if high winds are experienced while the lake level is high. While no changes were made to the upper limit of the NOZ, it was expanded slightly on the lower side in the fall to obtain a lower October 15 TOL. No changes were made to the typical summer range, but a more gradual seasonal drawdown was implemented, resulting is less static summer levels and a change to the median summer value. To improve habitat for lake trout spawning, a lower October 15 TOL was established. Similarly, an earlier and slightly higher spring peak is targeted by the operating plan. Coupled with a more gradual seasonal drawdown, this change can improve conditions for wetlands and spring spawning species. While decreasing the summer levels and lowering the fall level can negatively impact shoreline residents, this action does allow for improved downstream conditions, with higher and more consistent base flows in the summer.

Flooding at Fraserburg and Purbrook (located downstream of Lake of Bays) has historically been recognized as an issue. However, the MRWMP includes a slightly higher maximum outflow (approximately 11%) from Lake of Bays that may result in small, but more frequent exceedances of the downstream flow limit (85.9 m^3/s). In addition, the plan's strategy is to pass high flow events quickly through the system to return the lake levels to the NOZ.

4.3.5 Lakes Rosseau and Joseph

These lakes can also be difficult to fill in the spring if there is below average snowmelt and rainfall. In addition, because of limited inflow and potentially high losses due to evaporation, the lake level can be difficult to maintain in the summer. Considering that the lake has extensive shoreline development and is highly utilized for summer recreational and tourism activities, knowledge of these points may influence spring drawdown. However, in contrast, it is known that high spring levels have the potential to result in ice damage to shoreline infrastructure. Also, to improve downstream flow conditions to support summer ecological health, a slightly higher baseflow out of the lake was included in the plan.

As with some of the other lakes in the watershed, changes that were incorporated into the MRWMP aimed primarily at improving ecological conditions for wetlands, fish spawning and shoreline habitat. For example, in recognition that lake trout spawning shoals may exist within the winter drawdown zone, the differential between the fall and winter drawdown levels was reduced slightly to increase the amount of habitat available. With a slightly higher spring peak and more gradual seasonal drawdown, wetland and spring spawning habitat were expected to be improved.

4.3.6 Lake Muskoka

Like all of the major lakes in the Muskoka watershed, there has been extensive development of high-value properties on Lake Muskoka. It is recognized that some of the infrastructure has been built within the NOZ. However, only minor changes were made with respect to water levels in the MRWMP. A slightly higher spring peak level, coupled with a gradual seasonal drawdown was introduced to provide better ecological conditions for wetland species, spring spawning fish and shoreline zone habitat. A reduced differential between the fall and winter drawdown levels was also included to improve lake trout spawning habitat. While there was public input regarding flooding or the potential for ice damage, no changes were made with respect to these issues.

4.3.7 Bala Reach

No changes were made to the operational levels for the Bala Reach. However, the upper and lower levels which OPG has historically maintained through operation of Ragged Rapids GS became the legally enforceable limits under normal operating conditions. High and low flow triggers were added to address both naturally occurring flow extreme conditions and those that are the result of upstream dam operations. While efforts are made by OPG and SREL to manage the water level in the Bala Reach, it is understood that high levels may still occur during high flow periods in the watershed.

5. Watershed Storage

The MRW is very complex, with many lakes and interconnecting river stretches. The MRWMP suggests that "*although the number of lakes in the watershed is great and storage volumes are considerable relative to the total drainage area of the basin, the amount of available storage is moderate*".[6] Because much of this storage is spread over many small lakes, its value for flood mitigation is limited.

Table 5-1 – Changes in Lake Storage

Region	Lakes	Added/Reduced Storage (cms-Days)			
		+/- 0.15m	+/- 0.30m	+/- 0.45m	+/- 0.60m
North Branch	Vernon, Fairy, Peninsula	54	109	163	217
	Mary	18	36	54	72
South Branch	Kawagama	56	112	169	225
	Lake of Bays	121	241	362	483
Muskoka Lakes	Rosseau and Joseph	214	428	642	857
	Muskoka	207	414	621	828

Table 5-1 shows the main lakes in each of the three distinct watershed sections identified previously. It can be seen that the storage available for moderate changes in elevation in the main lakes of the South Branch and the Muskoka Lakes sections is much greater than in the main lakes of the North Branch. Subsequently, while there may be some opportunity for delay or advancement of the use of storage in the main lakes on the North Branch, the use of additional storage in this section of the watershed is not expected to make much difference in the amount of water flowing downstream (e.g., through the Springdale area) without resulting in significant impacts along the shores of the lakes themselves. However, there does appear to be an opportunity to potentially use additional storage on the South Branch and/or the Muskoka Lakes section.

If Kawagama Lake, Lake of Bays, and the stretch of river downstream from Baysville (including Fraserburg, Purbrook, etc) are considered together, there may be an opportunity to manage some of the high-water impacts by staging releases from the two lakes based on the rise in lake levels and the establishment of trigger elevations. The staging concept would allow the level of the lower river stretch to rise to a set level before an additional rise in the Lake of Bays level was accepted. Similarly, when Lake of Bays reached its first trigger level, Kawagama Lake would then be allowed to rise to its first trigger level before the next set of steps was applied from downstream to upstream. A review of the operational capabilities of

[6] Muskoka River Water Management Plan, MNR/OPG/OP/BG/AP, January 2006, p.3-5

the structures would also be needed to ensure that they would be able to make the changes necessary to meet the steps.

It is recognized that the river section will rise faster than the lakes for the a given amount of water released or stored. While this process would not eliminate flooding in any of the areas, it might provide a better opportunity to share the impacts of flooding between upstream and downstream areas, and it may the delay the arrival of additional water into Lake Muskoka. Further assessment would be required to establish the trigger elevations for each of the lakes and the river section.

Based on the data available regarding storage in the larger Muskoka Lakes, it appears that the storage of Lakes Joseph and Rosseau is approximately the same as in Lake Muskoka and that storing or releasing water from the upper lakes will have the opposite affect on the lower lake. For example, for every extra centimetre of storage used in the upper lakes, a similar decrease in storage would be seen in Lake Muskoka.

It should be noted that the storage tables for these lakes assume that they have a constant area-depth relationship, so that storage increases or decreases in a linear manner. Given the irregular shape of the shorelines and variations in topography, it is unlikely that this assumption is completely true. However, there may be any opportunity to change the timing of the use of storage so that the peak flow to Lake Muskoka can be reduced slightly. This option will be discussed further later in this report, in conjunction with a comparison of actual levels with the MRWMP operating limits.

6. Examination of Operations During Recent High Flow Years

An examination of historical operation in previous flood years was executed to determine if alternate operations could have been undertaken. This examination considered three specific factors:

- Meteorological conditions (rainfall, snowpack, temperature)
- Historical elevations
- Actual dam operations.

These factors are discussed in more detail in the following three sections, with a final section (Section 6.4) outlining the results of the modelling work using the conditions in 2013 and 2019.

6.1 Review of Snow/Precipitation/Temperature Conditions

The largest floods experienced in the Muskoka Watershed occurred during the spring freshet and were characterized by snowpack deletion and significant rainfall leading to large runoff volumes. Data from snow survey courses are an important component of assessing potential spring runoff. These datasets include both snow depth and snow water equivalent (SWE), which provide an idea of how much water the snow could contribute to the runoff. In an average year, snow may melt gradually, leading to moderate and steady runoff supply to the watershed. It is also possible for weather conditions to result in significant snow sublimation, which reduces SWE contributions to the spring freshet.

In addition to SWE volumes, there are a number of factors that contribute to both the timing and magnitude of spring runoff events, including temperature and rainfall patterns. In the event that snowpack is present, heavy rainfall in the spring has the potential to accelerate snow melt and the result can be a significant contribution to waterways already at high flow levels because of increased rainfall. The focus of the analysis outlined in this section is on four particular flood years (2019, 2013, 2016, and 2008).

Graphs presented in the following sub-sections provide a holistic look at the snow, temperature and precipitation conditions that preceded select historical flood events. These graphs include SWE datasets from the Norway Point snow survey course (located near the south shore of Lake of Bays), a combination of the Rosseau Falls (located southeast of Lake Rosseau) and the Skeleton Lake (also referred to as *Skeleton*; located southeast of Lake Rosseau) snow survey courses or the Big East River snow survey course (located on Hwy 11, near Arrowhead Provincial Park). Using all years of data from each of the three snow survey courses, time-series of minimum (Min), median (Median), and maximum (Max) derived from SWE data were plotted for January through May. Norway Point, Rosseau Falls/Skeleton Lake, and Big East River SWE data were paired with temperature and precipitation from the *Beatrice Climate* (ID: 6110607) weather station, the *Muskoka* (ID: 6115529) weather station, and the *Algonquin Park East Gate* (ID: 6080192) weather station, respectively. The locations of both the snow survey courses and the meteorological stations are shown on Figure 3-1, and defined in Table 3-3 and Table 3-4, respectively.

The MRWMP includes provision to drawdown lakes below their March TOL when snow conditions suggest that they may contribute to a higher-than-normal risk of spring flooding (e.g., above average SWE). These provisions, taken from the MRWMP[7], are as follows:

- If snowpack water content is >25% above normal on March 15 on the North Branch of the Muskoka River, lakes controlled by MNR will be lowered to the bottom of the NOZ.
- If snowpack water content is >50% above normal on March 15 on the South Branch of the Muskoka River, lakes controlled by MNR will be lowered to the bottom of the NOZ.
- If snowpack water content is >100% above normal on April 1 on both branches of the Muskoka River, lakes controlled by MNR will be lowered to the bottom of the LOZ.

The Ministry is also expected to start taking snow course measurements on a weekly basis after March 15, if the above conditions exist. The additional data is for monitoring and evaluation purposes and will also help inform additional operating decisions if there is increased potential for the development of more extreme runoff conditions.

Frequent precipitation, and/or rising temperatures, and/or frozen ground are also recognized as potential contributors to higher-than-normal runoff events. They are addressed through additional provisions within the MRWMP.[8]

- On unfrozen ground, with 25 mm of rain in 1 day or 50 mm rainfall over several days and/or >10°C during the day for more than 2 days or above 0°C overnight for more than 2 days lakes controlled by MNR will be lowered to the bottom of the NOZ.
- On frozen ground, with 25 mm of rain in 1 day or 25 mm rainfall over several days and/or >10°C during the day for more than 2 days or above 0°C overnight for more than 2 days, lakes controlled by MNR will be lowered to the bottom of the NOZ.

While rain-on-snow events are difficult to predict, they can be highly impactful. For example, this type of event was the primary flood driver in 2019. However, the MRWMP does not include any criteria for action under these conditions.

6.1.1 2019 Event

Historical datasets for the 2019 flood event for the Norway Point, Rosseau Falls/Skeleton Lake and Big East River Snow Survey Courses are provided in Figure 6-1, Figure 6-2 and Figure 6-3, respectively.

[7] Muskoka River Water Management Plan, MNR/OPG/OP/BG/AP, January 2006, p.12-2
[8] Muskoka River Water Management Plan, MNR/OPG/OP/BG/AP, January 2006, p.12-3

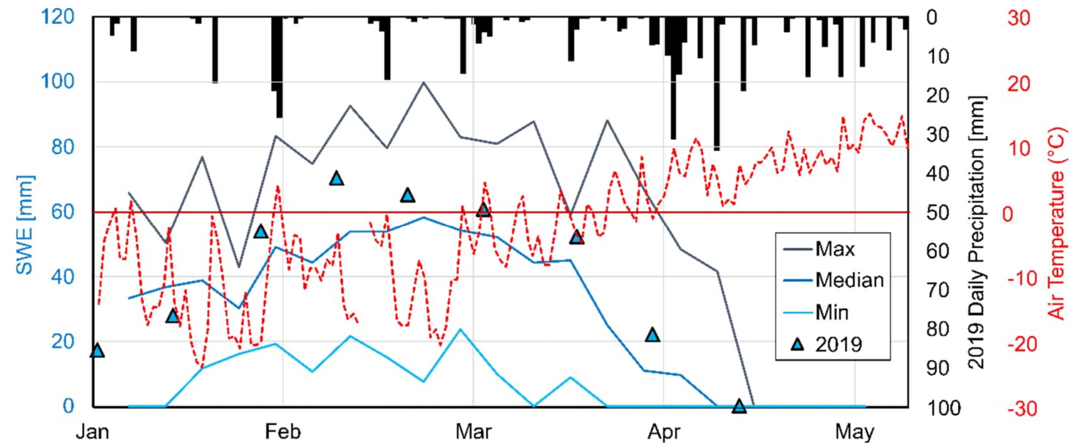


Figure 6-1 – 2019 Precipitation and Temperature Conditions for Norway Point

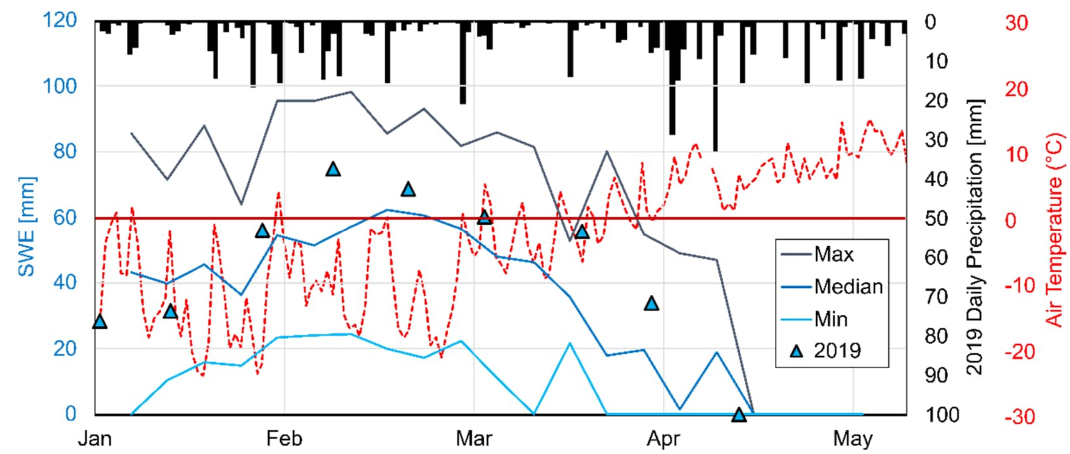


Figure 6-2 – 2019 Precipitation and Temperature Conditions for Rosseau Falls/Skeleton Lake

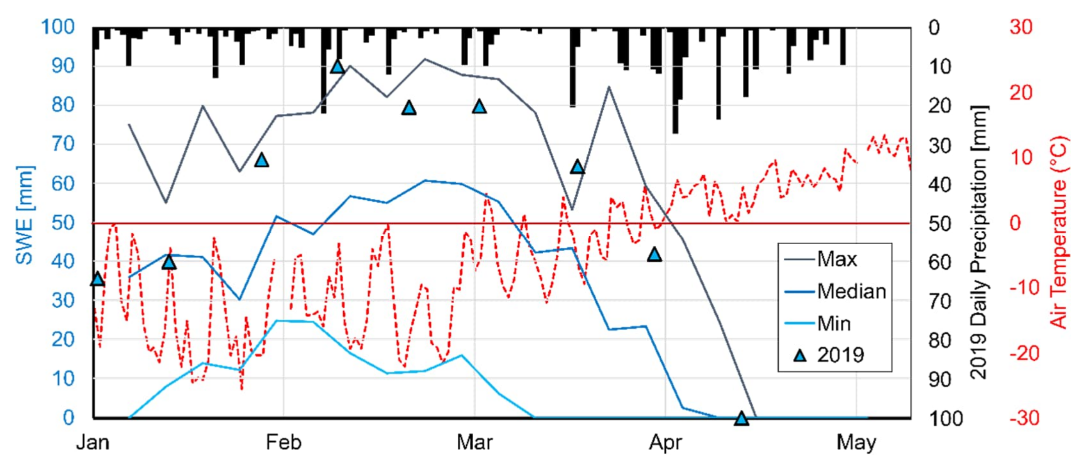


Figure 6-3 – 2019 Precipitation and Temperature Conditions for Big East

As shown in Figure 6-1, the SWE record for Norway Point trended slightly above average, but not close to the maximum values that had been previously experienced for the later part of the 2018 - 2019 snow season. It can also be seen that as the temperature started to rise above zero, a period of significant rainfall was experienced, with one day amounts exceeding 30 mm. It is likely that this significant rainfall event accelerated the snowmelt rate, although based on the frequency of SWE observations (approximately 2 weeks apart), this change in melt rate cannot be quantified. It is highly likely that an increase in snowmelt rate contributed to rapid increases in runoff volumes leading to the 2019 regulatory event.

As shown in Figure 6-2 and Figure 6-3, the SWE record for Rosseau Falls/Skeleton Lake and Big East River also trended slightly above normal for the months preceding freshet. Heavy precipitation was received at the time that temperatures started to rise above zero, during a time when the snowpack was still present. Observations at Rosseau Falls/Skeleton Lake and Big East River are consistent with those from Norway Point. All sites indicate that rain-on-snow events were a significant contributor to flooding during 2019.

6.1.2 2013 Event

Historical datasets for the 2013 flood event for Norway Point, Rosseau Falls/Skeleton Lake and Big East Snow Survey Courses are provided in Figure 6-4, Figure 6-5 and Figure 6-6, respectively.

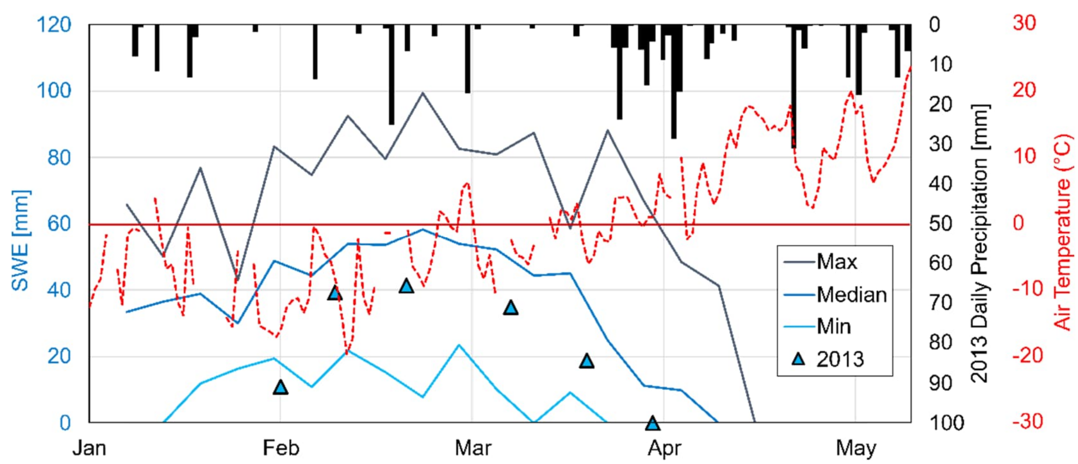


Figure 6-4 – 2013 Precipitation and Temperature Conditions for Norway Point

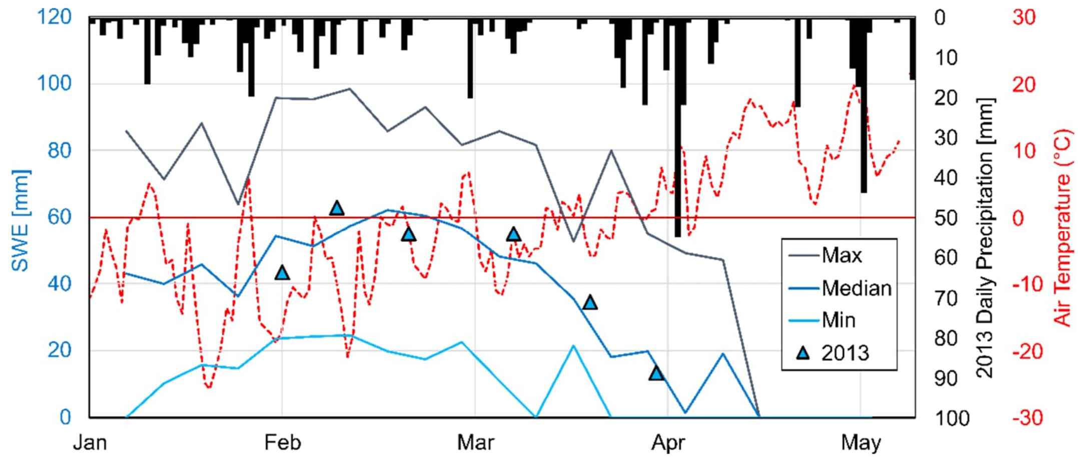


Figure 6-5 – 2013 Precipitation and Temperature Conditions for Rosseau Falls/Skeleton Lake

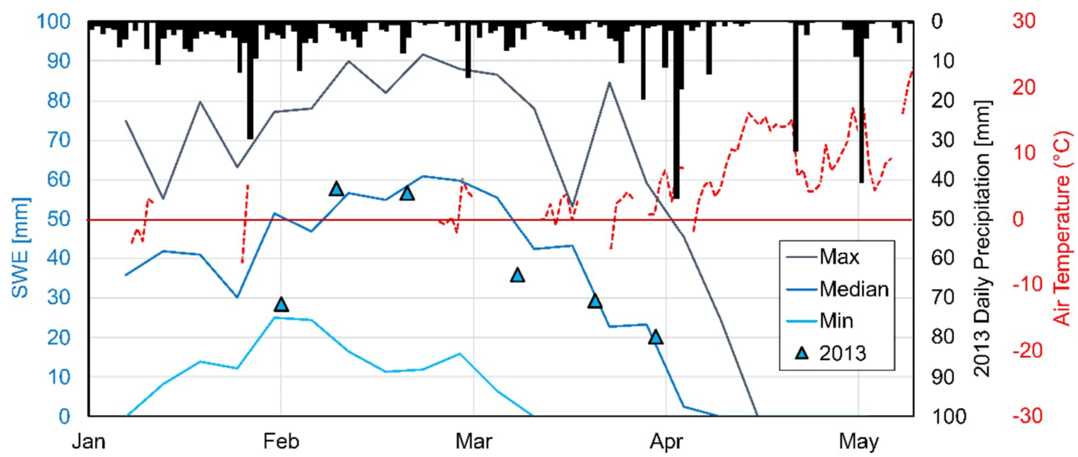


Figure 6-6 – 2013 Precipitation and Temperature Conditions for Big East

As shown in Figure 6-4, the SWE record for Norway Point remained below average for the entire period preceding the freshet, but the snowpack appears to have largely melted before the temperature stayed above zero continuously and heavy spring rainfall was received. These conditions are different from those observed in 2019, where rain-on-snow was a primary driver of flood conditions. The large volumes of water resulting from several large rainfall events, at time when all water content in the snowpack has already been mobilized, resulted in very large runoff volumes.

As shown in Figure 6-5 and Figure 6-6, the SWE record for Rosseau Falls/Skeleton Lake and Big East River followed the median line very closely throughout the season, giving little indication that any excessive input from it to the spring runoff would be expected. Consistent with observations at Norway Point, high rainfall volumes (in one instance, exceeding 50 mm/day) were the primary driver behind the 2013 regulatory event.

6.1.3 2016 Event

Historical datasets for the 2016 flood event for the Norway Point, Rosseau Falls/Skeleton Lake and Big East River Snow Survey Courses are provided in Figure 6-7, Figure 6-8 and Figure 6-9, respectively.

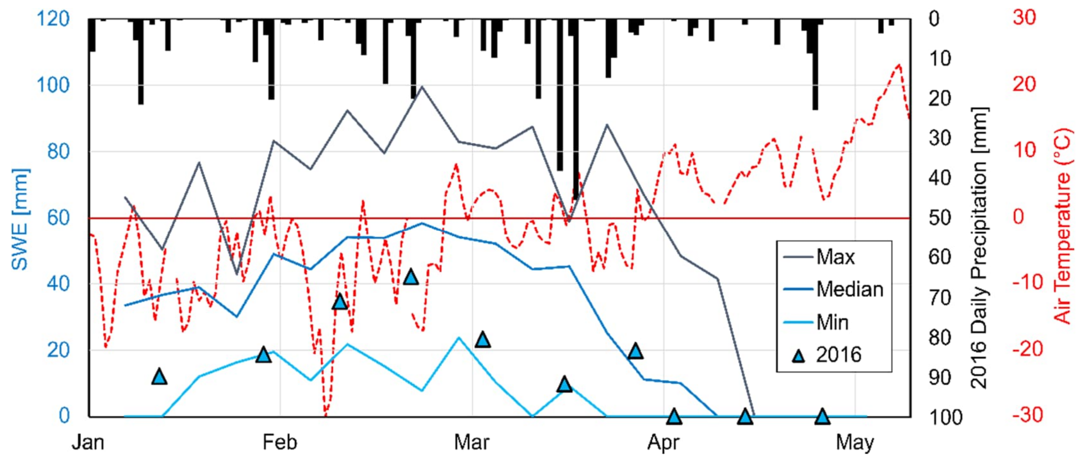


Figure 6-7 – 2016 Precipitation and Temperature Conditions for Norway Point

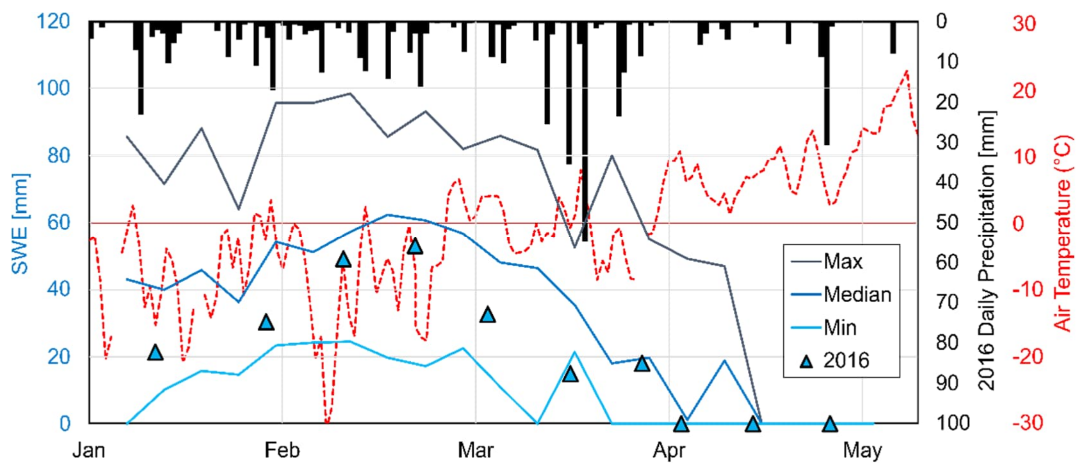


Figure 6-8 – 2016 Precipitation and Temperature Conditions for Rosseau Falls/Skeleton Lake

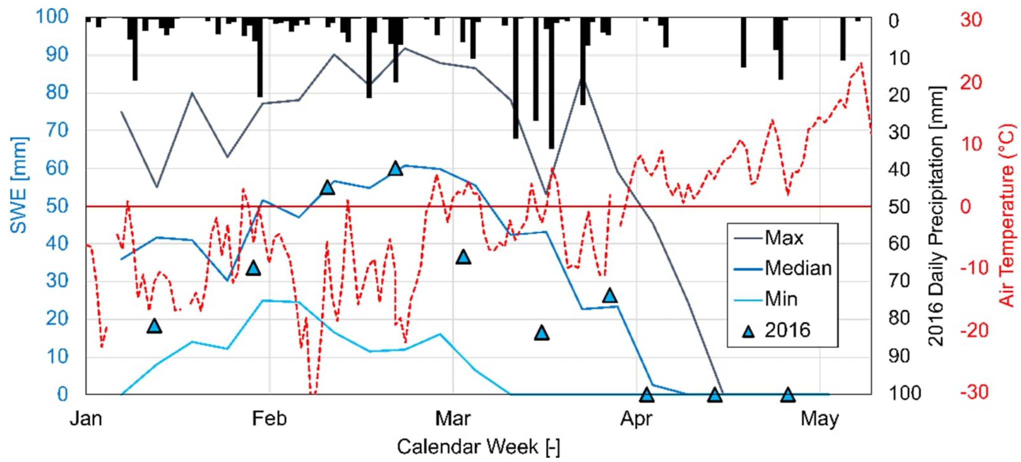


Figure 6-9 – 2016 Precipitation and Temperature Conditions for Big East

As shown in Figure 6-7, the SWE record for Norway Point shows below average values for the entire season, with some of the surveys representing either minimum or near-zero values. While heavy precipitation during a mild period in mid-March may have temporarily accelerated the snow melt, it appears that further precipitation during a below-zero period in the later part of March built the snowpack up again. With a return to above zero temperatures, the snowpack melted quickly in early April, likely contributing to high runoff rates.

Figure 6-8 and Figure 6-9 show the SWE record for Rosseau Falls/Skeleton Lake and Big East River, respectively. They also trended below median conditions for most of the period of record in early 2016, with a slight increase towards the end of March due to precipitation during a period of below zero temperatures. A return to above zero temperatures, and additional spring rain, helped to eliminate the snowpack in early April.

6.1.4 *2008 Event*

Historical datasets for the 2008 flood event for Norway Point, Rosseau Falls/Skeleton Lake and Big East River Snow Survey Courses are provided in Figure 6-10, Figure 6-11 and Figure 6-12, respectively.

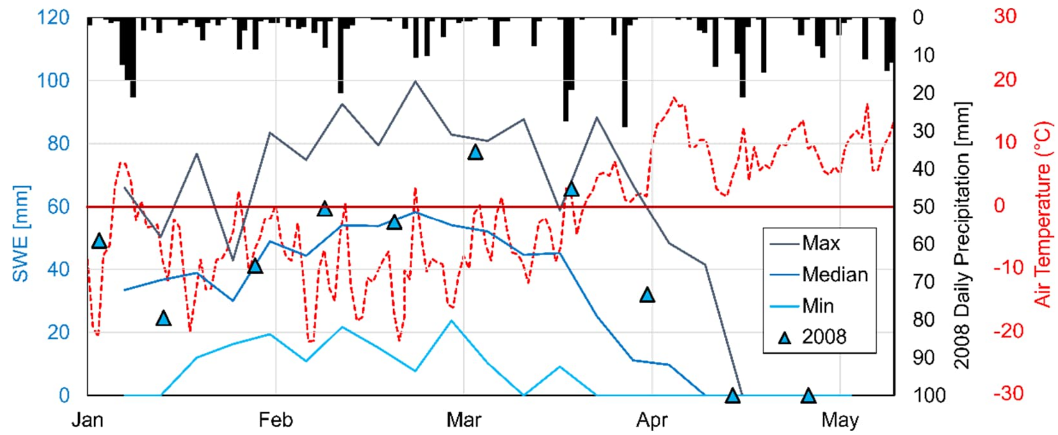


Figure 6-10 – 2008 Precipitation and Temperature Conditions for Norway Point

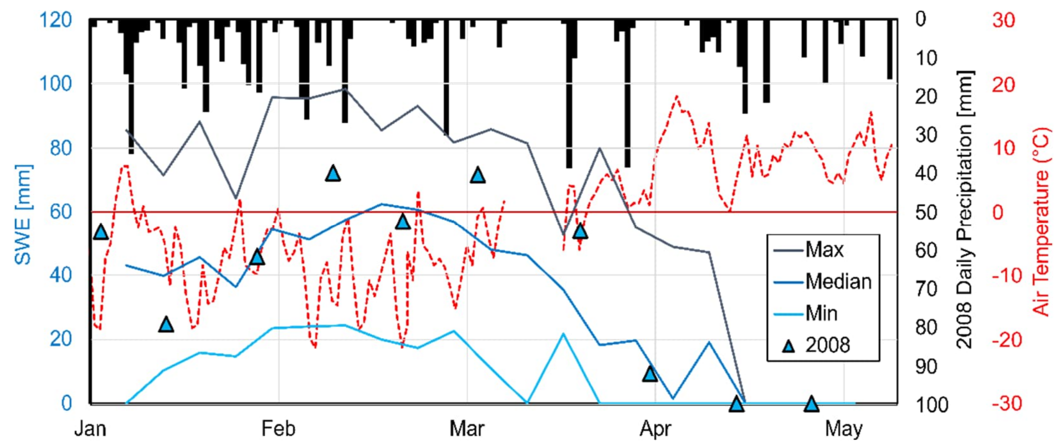


Figure 6-11 – Precipitation and Temperature Conditions for Rosseau Falls/Skeleton Lake

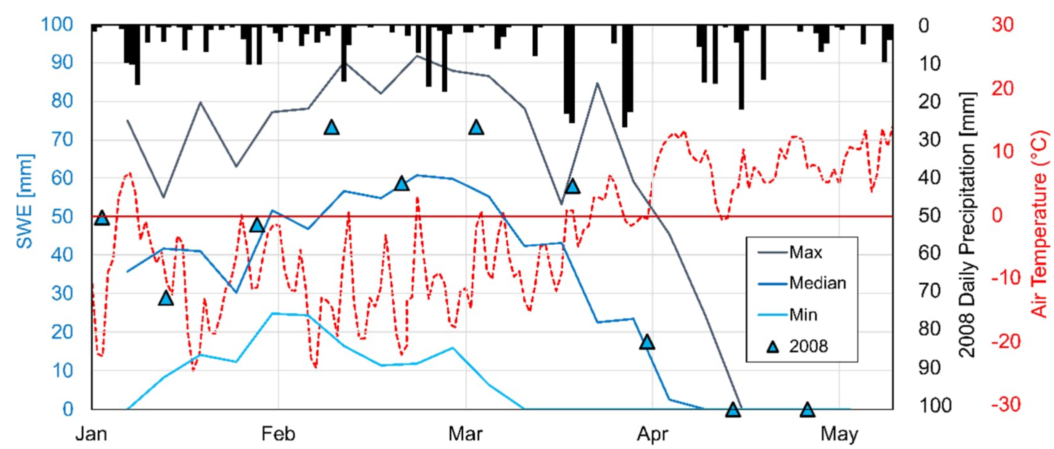


Figure 6-12– 2008 Precipitation and Temperature Conditions for Big East

As shown in Figure 6-10, the SWE record for Norway Point varied from below median to above median over the period of surveys. Similar trends were observed at Rosseau Falls/Skeleton (Figure 6-11) and Big East River (Figure 6-12). Near maximum values declined quickly with warming weather and frequent heavy rainfall in the latter half of March, likely contributing more than average to the runoff.

A comparison of 2008 and 2019 flood events show many similarities, and several distinct differences. Rainfall volumes in April 2019 (129.5 mm) were much higher than in April 2008 (78 mm). Further, the rain-on-snow events in 2019 were coincident with warm air temperatures, while the rain-on-snow events in 2008 (see late March) occurred during colder temperatures. These cold temperatures slowed the snowmelt and runoff formation, which ultimately led to lower peak runoff rates relative to 2019.

6.2 Comparison of Historical Water Levels with the MRWMP

As mentioned previously, the operating plans for dams in the MRW were formalized in the MRWMP to ensure that the maximum net benefit to society would continue. The MRWMP does not prescribe a rule curve with specific elevations for every day of the year. Instead, it provides ranges (*zones*) that govern regulation of water levels at different times of the year, with a TOL prescribed within the normal operating zone. In the case of Kawagama Lake, a BMP operating level is also specified for summer months. To better understand how these zones have been utilized historically, observed water surface elevations for Water Survey of Canada stations on a number of lakes were plotted against MRWMP operating zones and actual levels. The lakes have been paired, with two lakes used for each of the sections of the watershed in order to look at actual, or potential, interactions between the use of storage in each lake. A water year, starting at the beginning of September, has been used in the graphs to show the fall/winter drawdown period as well as the spring refill period.

It should be noted that the operating plans of the MRWMP generally only apply under normal conditions. However, the plans also identify a “flood allowance” zone between the maximum normal operating level and the start of the High-Water Zone (HWZ). Similarly, for river reaches below discharge structures, where similar level information is not available, High Flow Trigger (HFT) values are identified in the plans. Damage (to people, property or infrastructure) is known to occur when these upper level or flow limits are reached. However, as upstream levels rise, if the increased flow is not passed downstream, the upstream water levels (e.g., lakes, forebays or river stretches) will continue to rise, causing further flooding and potentially threatening the discharge structures themselves. Subsequently, when waterpower facility operators must release flows greater than the HFT value, it is recognized that a High-Water Indicator (HWI) has been met, and they are not considered to be out of compliance with their operating plan. While similar zones and triggers also exist for low water/drought conditions, they are not part of this project.

Figure 6-13 through Figure 6-18 show the historical elevations for 2019, 2016, 2013 and 2008 plotted against the MRWMP operating plan zones for the two main lakes in each section of the watershed. These figures are included at the end of Section 6-2. Note, Fairy Lake is considered to represent all three of the Huntsville Lakes.

The Huntsville Lakes dam and the Port Sydney dam on Mary Lake are generally operated together to ensure the water from the upstream section of river and the lakes is passed through to the lower section of the North Branch of the river. This pattern can be seen in Figure 6-13 and Figure 6-14 for the four flood years shown. These figures also show that neither lake was fully drawn down to the bottom of the NOZ in 2013 or 2016. While the level did not exceed the absolute maximum level in 2016, greater use of potential storage available may have helped to reduce the impact of high flows downstream. Similarly, greater use of the available storage may have limited how much the lake level exceeded the absolute maximum elevation in 2013.

In looking at Figure 6-3, Figure 6-6, Figure 6-9 and Figure 6-9, it can be seen that only in 2019 (Figure 6-3) was there a clear picture suggesting that an above average SWE might contribute to an above average spring runoff, while Figure 6-12 (2008) shows that the SWE varied considerably over the winter from average to above average. However, despite being drawn down to their minimum elevations, the lake levels significantly exceeded both the normal maximum, and the absolute maximum, levels in 2019. This result suggests that there may be years where there is too much water to pass through the system without experiencing some flooding (i.e., inflow exceeding available storage capacity).

While 25th percentile line for Kawagama Lake suggests that the lake level is frequently drawn down to its minimum level by mid-winter, it appears that it reached this level much later in the season in the four flood years (Figure 6-15). While the snowpack appeared to be slightly below normal in 2016 (Figure 6-7) and 2013 (Figure 6-4), and mostly normal over the 2008 winter (except for a late storm) (Figure 6-10), it was consistently above normal in 2019 (Figure 6-1), suggesting that the lake level could have been drawn down earlier, and to a greater extent. However, it should also be noted that the lake level did not exceed the maximum normal level in 2019. While a greater drawdown may have allowed for more runoff to be retained in the lake, there was only a very limited exceedance of the absolute maximum in Lake of Bays, suggesting that excess flow may have been passed downstream, and possibly contributed to flooding along the river or to flooding on Lake Muskoka.

In general, operations appear to have kept the level of Kawagama Lake within it NOZ; 2013 is the only year in which it exceeded the absolute maximum level. While water at levels between the normal maximum and the absolute maximum may cause problems, operation in this range is permitted under the MRWMP.

Figure 6-17 shows that Lake Rosseau is often not drawn down to its normal minimum level. Similarly, the full range of Lake Muskoka (Figure 6-18) is not always used. In addition, while the operating plans for both lakes show an extended period over which the normal minimum is allowed, they seem to be consistently operated in a manner where they are drawn down slowly, and then refilled quickly. If the minimum level was reached earlier in the late winter/early spring, it might be possible to allow more water to pass through the lakes before refilling them. However, it is also recognized that lower levels mean a lower head at the dams, making it more difficult to pass water out of the lake. In addition, current over-winter constraints for fisheries must also be considered. The MRWMP identifies a winter drawdown range of 0.35 m for Lake Rosseau, and 0.62 m for Lake Muskoka. To respect these drawdown limits and provide a lower elevation at the start of freshet, a lower fall/start of winter elevation would be required. However, lowering the fall lake levels could negatively impact fall recreational activities and end-of-season boat haul outs, and lower winter levels have the potential to impact some water lines.

As with the graphs for the lake pairings on the other branches of the watershed, 2019 appears to be the only year in which there was greater than average snow (Figure 6-2). It appears that the local inflow to Lake Rosseau was managed in a manner that kept the lake from exceeding its maximum normal level, but Lake Muskoka experienced levels significantly above its absolute maximum. While efforts are made to try to balance the impacts of flooding throughout the watershed, as the last lake in the system, it likely sees an accumulation of impacts from the actions taken to minimize flooding on other lakes.

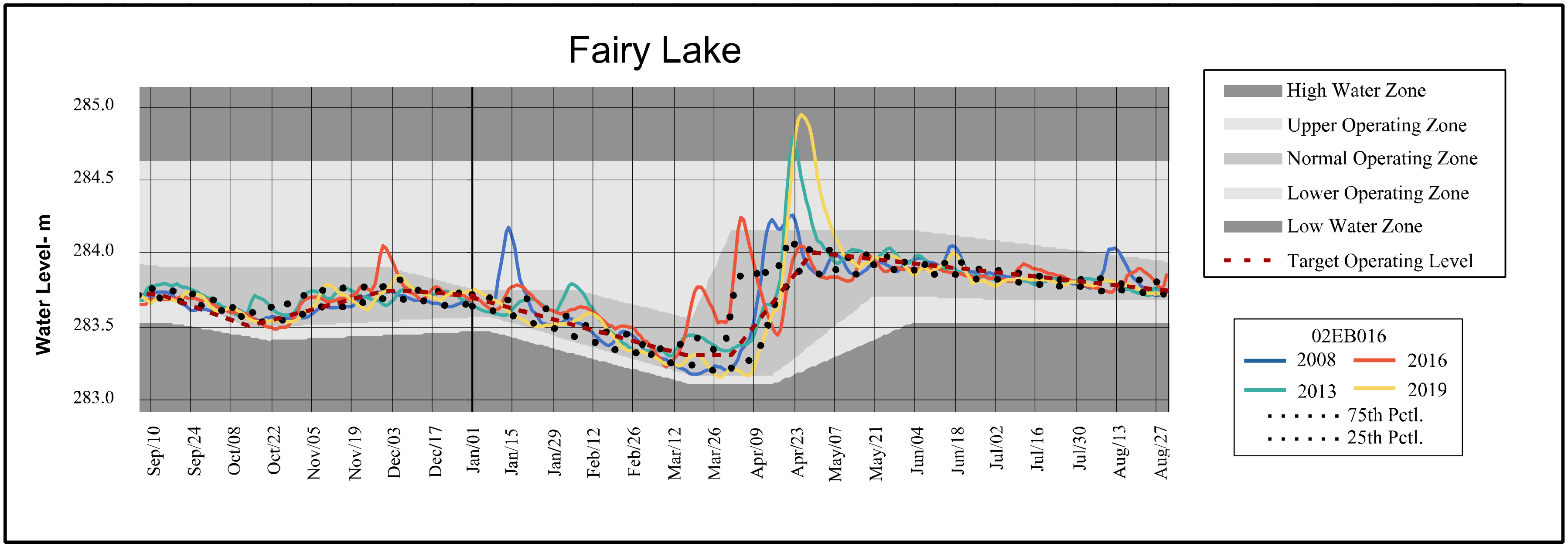


Figure 6-13 – WSC records at 02EB016 vs MRWMP zones and TOL for Fairy Lake

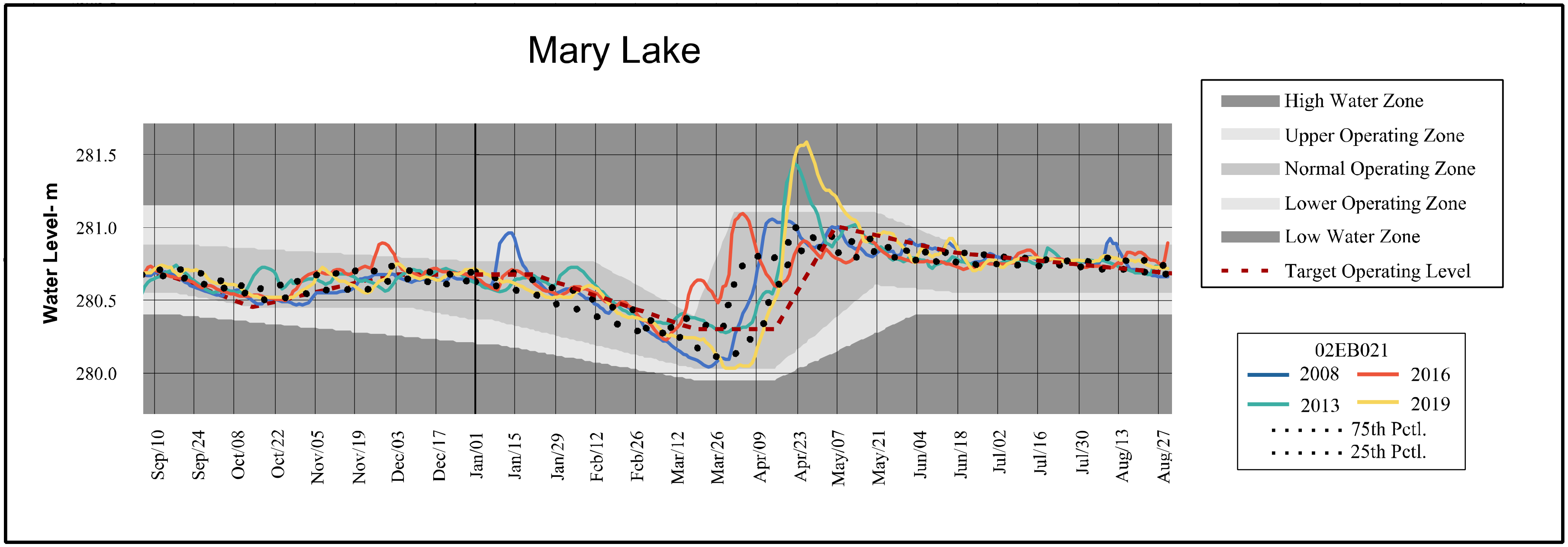


Figure 6-14 – WSC records at 02EB021 vs MRWMP zones and TOL for Mary Lake

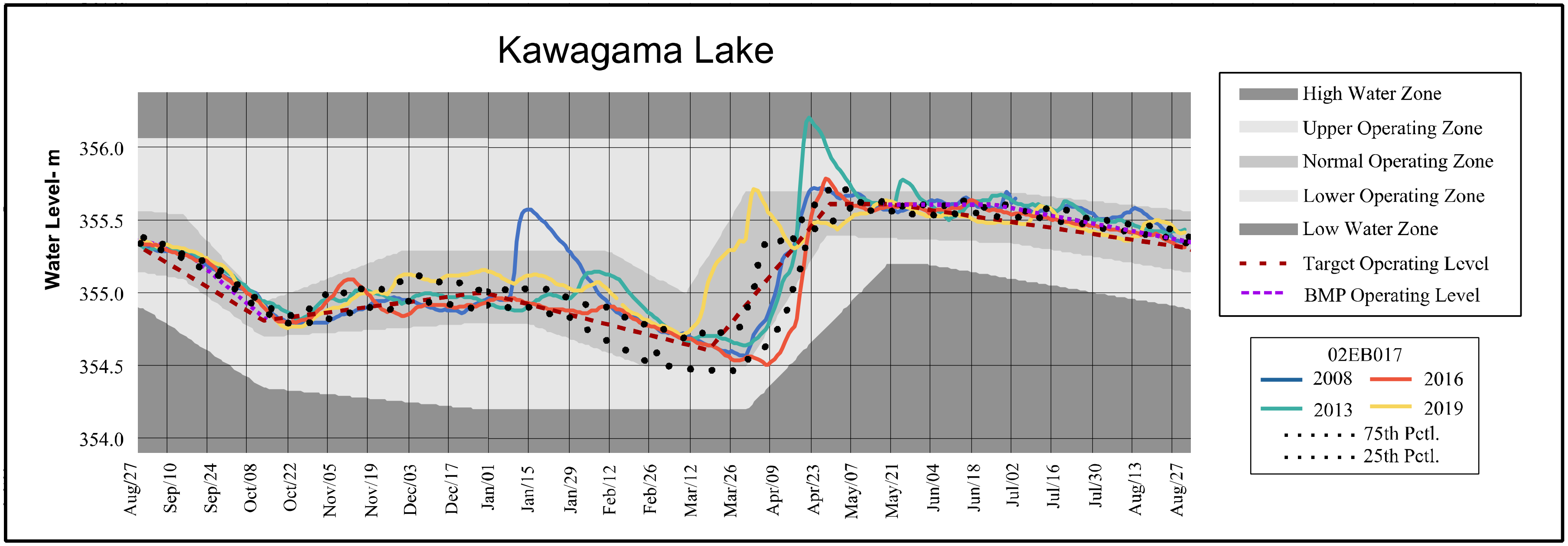


Figure 6-15 – WSC records at 02EB017 vs MRWMP zones, TOL and BMP operating level for Kawagama Lake

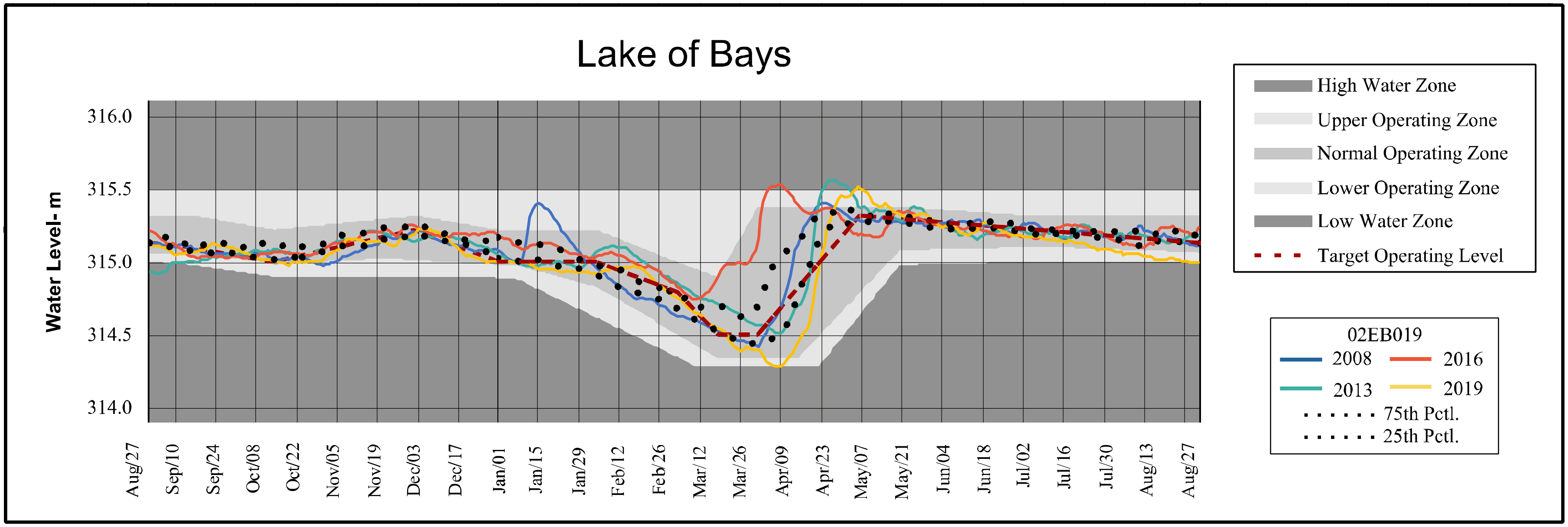


Figure 6-16 – WSC records at 02EB019 vs MRWMP zones and TOL for Lake of Bays

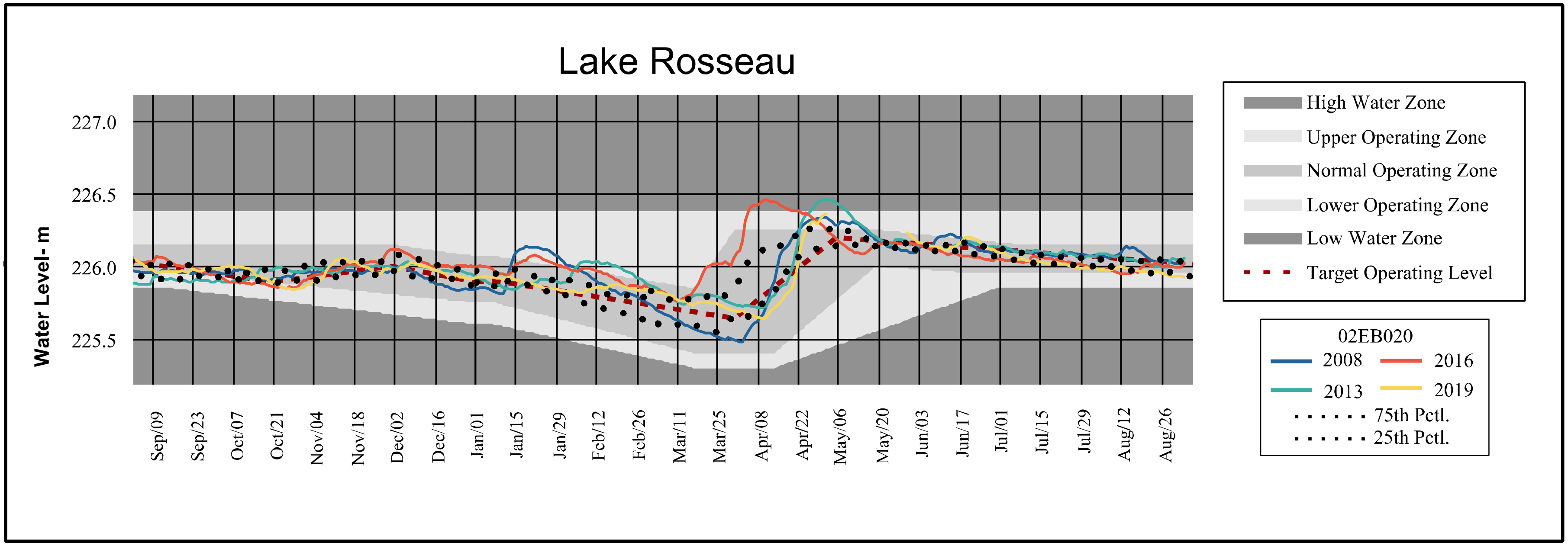


Figure 6-17 - WSC records at 02EB020 vs MRWMP zones and TOL for Lake Rosseau

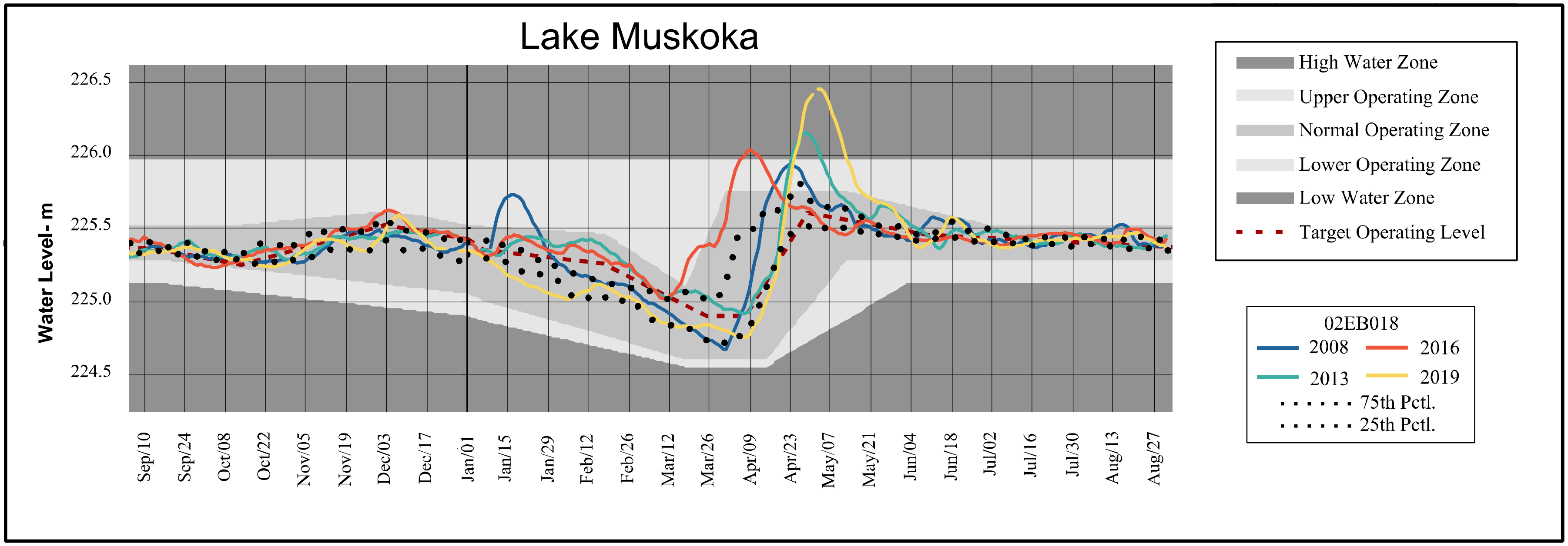


Figure 6-18 - WSC records at 02EB018 vs MRWMP zones and TOL for Lake Muskoka

6.3 Review of Dam Operations

All of the control works not associated with generating stations are currently operated by the MNRF, with the exception of the Bala Dams and the privately owned dam. The Bala dams have been operated by SREL staff, under direction from MNRF, since Bala GS started operations.

While no formal flow forecasting is done, the MNRF has a daily planning cycle that utilizes the existing hydrometric network in the watershed, along with weather forecasts, the Antecedent Precipitation Index, the Canadian Precipitation Analysis (CaPA), and staff/operator experience. These tools are used to identify trends and to determine/confirm the dam operations to be undertaken over the next few days.

It was intended that the actual operations of some of the major dams in the watershed would be reviewed in order to better understand the sequence of lake drawdown/refill and how water was managed through the watershed during the high flow events of 2013 and 2019. Unfortunately, the log operations records were not received at the time of writing of this report.

6.4 Numerical Operational Model

In order to assess the likely impact of potential operational changes in the Muskoka watershed, Hatch used its proprietary Acres Reservoir Simulation Program (ARSP) model to do the evaluation. ARSP is a multi-reservoir, multi-use simulation model that has been used to model the MRW. In particular, it was applied in 2003 to evaluate the watershed as part of the development of the original MRWMP.

For the two major flood years (2019 and 2013), the modelled water levels and flows provided a reasonable representation of the actual operations even though the model is a bit more rigid in adhering to the TOL curves (as well as other zonal boundaries) than was done in practice. Initial model results are provided in Appendix B.

7. Potential Options – Summary

While there are a few potential operational options for consideration, it should be noted that revision of the MRWMP is not part of this project.

7.1 Operations Decision Process

Operational decisions for the dams in the MRW are made based on the best information available at the time of the decision. However, it should also be noted that the dams are spread throughout a very large area with many requiring manual operation. The limited staffing resources of MNRF to execute dam operations (in addition to a completing a number of other duties) prohibits the multiple adjustments to dam outflows on a daily basis necessary to ensure optimal water releases that reduce flood risk.

Operation of these dams follows a seasonal pattern that is influenced by expected/predicted inflow conditions (e.g., snowfall/melt and rainfall), while trying to meet the requirements of multiple, sometimes conflicting, interests (e.g., fisheries, recreation, power production, etc). As shown earlier in the graphs of meteorological conditions, it is very difficult to know in advance how runoff conditions will develop. Spring runoff conditions in south-central Ontario are largely driven by rainfall, and heavy snowfall through the winter alone may not result in heavy spring runoff. Timing, of the snowmelt and rainfall, is the key factor in flood severity. Heavy rainfall on a higher-than-normal snowpack will result in above average inflows. In addition, it has been recognized that in high flow events, there is often not enough storage in the system to absorb the excess inflow. Subsequently, lakes may refill quickly under high inflows, resulting in flooding downstream, or on the lake itself, as there is no where else for the water to go.

The MNRF uses a variety of information sources such as data from the existing hydrometric network, snow survey data, weather forecasts, trends, an Antecedent Precipitation Index and CaPA to inform of expected flow conditions. However, operator experience remains an important tool in dam operation decision making. With knowledge of the conditions in different areas within the watershed, and the potential impacts of retaining or releasing flow, the operators try to balance dam operations to “share the pain” of high flows/flooding over all of the potentially impacted areas. Triggers referenced in the MRWMP related to rainfall (see above in Section 6.1) are also used to support operational decision making. However, these triggers can sometimes come too late to make impactful changes in operations, acknowledging that focus is mainly placed on mid-to-late winter conditions, and not on those very short-term end-of-winter rain events that can really drive flooding.

Previous studies, and the MRWMP, have provided suggestions that development of a detailed flow forecasting model should be considered, but it is not clear if such a model would provide any better information for making operational decisions. Current meteorological forecasts (primarily rainfall) do not exist for a sufficiently long period to allow flow forecasts to be made in a timely manner. It may also not be possible to provide detailed forecasts for every lake or stretch of river.

7.2 Increasing Drawdown

Water level drawdown starts in the fall, without any indication of what spring conditions will be experienced. If the fall level is high (to support late season recreational use), the limited winter drawdown to support fish habitat may reduce the availability of storage in the spring for retaining high spring runoff, potentially resulting in either flooding on a lake (if the water is retained) or flooding on the river reach downstream if the water is passed through the dam.

As seen in graphs comparing the actual water levels with the MRWMP operating plans, the lower limit of the NOZ was not always reached for some of the lakes in the flood years that were plotted. Utilizing the full available drawdown may help in providing additional storage to help reduce peak spring freshet flows but is unlikely to have eliminated all of the flooding that was experienced. In addition, to regularly reach the minimum value in the NOZ would require either a lower fall starting level, or relaxation of the winter drawdown range that is included to support fish spawning. It has also been noted that some of the lakes have a small drainage area, but a large surface area, and can be hard to fill if they start too low, and there is limited spring runoff.

With consideration of these constraints, and recognizing that they would not all be met, one option for reducing the flood impact on Lake Muskoka may be to more fully utilize the available drawdown range in Lake Rosseau/Joseph and Lake Muskoka. As described in Section 5 and shown in Table 5-1, further lowering of Lake Rosseau/Joseph would allow for a similar reduction in level on Lake Muskoka, and potentially a positive impact in the Bala Reach. However, there are concerns based on past experience about the physical capability of removing water from Lake Rosseau at low elevations, and further modelling of this option cannot be done without better understanding of the discharge limitations. Subsequently, additional drawdown was assessed for Lake Muskoka only. Analysis of lowering the level of Lake Muskoka to a point halfway between the current TOL and the lower limit of the NOZ, using the ARSP model, showed that only a nominal reduction in the maximum water surface elevation of 0.05 m and 0.01 m would have been experienced on Lake Muskoka for the 2013 and 2019 events, respectively. The model runs and results are discussed in greater detail in the modelling report included in Appendix B.

In parallel, a similar exchange of storage use could occur between Kawagama Lake and Lake of Bays. However, as Kawagama Lake is about half the size of Lake of Bays, there would be a lesser benefit.

7.3 Volume Transfer Between Lakes

One potential option to alleviate flood impacts on a particular lake is to transfer the water elsewhere. In this section, a ‘target’ lake refers to a water body where flood volumes are being transferred *from*, and a ‘hydrologically-connected’ lake refers to a water body that flood volumes are being transferred *to*. Water can be transferred either by increasing lake outflows prior to a flood event, or by increasing the conveyance capacity at any outlet control structures to allow higher lake outflows during a flood event.

To illustrate the effect of flood volume transfer, focus is placed on reducing target lake levels from the HWZ to the Upper Operating Zone (UOZ; as outlined in the MRWMP) for either 2013 or 2019 regulatory flood levels. Using the water management plan and WSC hydrometric records, the elevation difference between upper limit of the UOZ and the maximum observed level was calculated for the greater of the 2019 or 2013 regulatory events. Elevation differences were converted to an excess volume using the stage-storage relationship for the target lake. Excess volumes varied between target lakes, due to both variation in stage-storage relationships and regulation practices during the 2013 and 2019 regulatory events.

Using target lake excess volumes, an analysis was performed to assess the effect of volume transfer from target lakes to hydrologically connected lakes. Three groups of lakes were identified for this analysis – North-Branch, South-Branch and Muskoka Lakes. Using the stage-volume relationships, excess volumes from target lakes were converted to an equivalent depth for hydrologically connected lakes. This equivalent depth effectively represents an increase in hydrologically connected lake level resulting from volume transfer. These equivalent depths are summarized in Figure 7-1, Figure 7-2, and Figure 7-3, for North-Branch, South-Branch and Lower Watershed lakes, respectively.

		***Target* Lake (lowered WSE)**		
		Hunstville Lakes	Mary Lake	Lake Muskoka
***Hydrologically-Connected* Lake (increased WSE)**	Hunstville Lakes		**0.145**	**1.872**
	Mary Lake	**0.992**		**5.630**
	Lake Muskoka	**0.085**	**0.0371**	

Figure 7-1 - North-branch volume-transfer matrix. Value indicates an equivalent water depth for each *hydrologically connected* lake, resulting from volume transfer from each *target* lake to lower water level from the HWZ to the UOZ (units are in metres).

		Target Lake (lowered WSE)		
		Kawagama Lake	Lake of Bays	Lake Muskoka
***Hydrologically-Connected* Lake (increased WSE)**	Kawagama Lake		1.569	18.125
	Lake of Bays	0.006		0.843
	Lake Muskoka	0.004	0.042	

Figure 7-2 - South-branch volume-transfer matrix. Value indicates an equivalent water depth for each *hydrologically connected* lake, resulting from volume transfer from each *target* lake to lower water level from the HWZ to the UOZ (units are in metres).

		Target Lake (lowered WSE)	
		Lake Rosseau	Lake Muskoka
Hydrologically-Connected Lake (increased WSE)	Lake Rosseau		0.496
	Lake Muskoka	0.097	

Figure 7-3 - Lower Watershed volume-transfer matrix. Value indicates an equivalent water depth for each *hydrologically connected* lake, resulting from volume transfer from each *target* lake to lower water level from the HWZ to the UOZ (units are in metres).

Water levels in small lakes such as Huntsville Lakes, Mary Lake and Kawagama Lake are highly sensitive to storage changes, meaning they have limited potential to mitigate flooding in large downstream lakes. For instance, to lower 2019 regulatory event levels in Lake Muskoka to the ‘Upper Operating Zone’ through increasing Huntsville Lakes storage, a water level rise in these upstream lakes of 1.872 m would be required. While such a mitigation would help to alleviate flooding around Lake Muskoka, the upstream infrastructure requirements and impacts within inundated areas could be significant.

By transferring flood volumes from small upstream lakes to larger downstream lakes (e.g., Lake Muskoka), flood alleviation on small lakes can be achieved with modest increases in large lake levels. For instance, flood volume transfer from Lake of Bays during the 2019 regulatory event would increase Lake Muskoka levels by 0.042 m, a small increase relative to values reported for smaller lakes. While these stage increases are small, larger lakes have long shoreline with many properties and near-shore structures, meaning that even small stage changes can have significant flood impacts. Larger lakes are also more susceptible to wind-induced wave and ice run-up events, both of which can exacerbate flood risks.

The analysis presented above assumes complete transfer of large flood volumes between lakes. The option for staged or partial flood volume transfer also exists, which would provide a more balanced flood mitigation approach between lakes. Regardless of the approach taken, assessments of flood volume transfer approaches should be assessed by looking at net benefit across all hydrologically connected lakes experiencing changes in stage. In addition to assessing relative water levels, incorporating stage-damage curves contributes to a more comprehensive assessment.

7.4 Implement a Stepped Approach to Volume Transfer

Where there is a series of lakes and/or river stretches that may experience flooding, it may be possible to change the refill pattern of the lakes to refill them in “steps” or “stages”. While this pattern would not eliminate flooding, it may lessen the flooding in some of the areas and result in a more equitable sharing of the negative impacts (i.e., “sharing of the pain”). Section 5, Watershed Storage, describes how this process could be applied for the Kawagama Lake/Lake of Bays/downstream river reach area. In order to apply a stepped refill strategy, it would be necessary to determine the appropriate trigger elevations for each step on each lake and for the downstream river reach. Executing this stepped plan would require relatively precise changes to water releases, which may not be currently achievable.

Significant work would be required to determine the criteria for establishing the steps (e.g., flooding tolerances at specific elevations and stage-damage curves), and also to determine the actual steps to use for Kawagama Lake, Lake of Bays, and the downstream river reach. In addition, the existing model would require further work to incorporate these steps in order to test them for the 2013 and 2019 flow conditions. Formal completion of this work would be outside the scope of Project 2. However, as part of Phase 2 of this project, criteria for establishing the steps will be determined, information needs identified, and an outline of the process to be followed to in determining actual step levels will be provided.

7.5 Improved Communications/Information Sharing

A pre-freshet meeting is held every year by the MNRF for all partners in the watershed to share winter observations, to update all participants on recent flows, and to discuss expectations going forward (e.g., developing trends). Updates are provided on a regular basis after this meeting. When conditions require it, MNRF's Surface Water Management Centre (SWMC) issues "provincial" messages about developing high water events, and local District Offices issue "local" messages. The flood message definitions shown on the SWMC website are as follows:

- **Watershed conditions statement – flood outlook** gives early notice of flooding based on weather forecasts calling for heavy rain, snow melt, high winds or other conditions.
- **Watershed conditions statement – water safety** indicates that high flows, melting ice or other factors could be dangerous for boaters, anglers and swimmers. However, flooding is not expected.
- **Flood watch** indicates there is the potential for flooding.
- **Flood warning** indicates flooding is imminent or occurring.

While a lot of information/data is available about MRW conditions, discussions with various partners in the watershed suggest that there are differing opinions on how well this technical information is shared or understood. Similarly, concerns were expressed regarding the knowledge of the some of the partners with respect to what certain flows and levels may mean for existing infrastructure. While many lake levels are well defined and monitored, there is less information available for a number of river reaches that experience flooding.

Further review of the information sharing processes will be carried out in Phase 2 of this project. While further consideration will be given to additional data/information sharing options and whether or not development of a formal early warning system would be of value, determination of specific flow/level triggers for any areas of concern, or the actual development of an early warning system will not be undertaken as they are beyond the scope of this project.

8. Meetings with the District Municipality of Muskoka

During the course of this project, monthly meetings were held to discuss project progress and potential issues. In addition, a presentation was made to the District and the TWG on June 24, 2022, to outline the work completed to date on Phase 1 of this Project, and potential options for operational adjustments. A recording of the meeting was provided to the District for their records. In addition, the slides for Project 2 are included in Appendix C. A follow-up meeting was held between District staff and the TWG to further review the information provided in the presentation and to determine next steps in project execution. During the monthly meeting held on July 7, the District advised that the two options presented in the June 24 meeting:

- fuller use of the available drawdown range for Lake Rosseau and Lake Muskoka, and
- stepped operation for Kawagama Lake/Lake of Bays/downstream river reach should be tested under the conditions for 2019 and 2013.

However, as noted in Section 7.2, improved understanding of the discharge capability of Lake Rosseau is required before further drawdown of it can be fully assessed. Similarly, Section 7.4 notes that analysis and derivation of a stepped operating plan for the Kawagama Lake/Lake of Bays/downstream river reach is beyond the scope of this assignment, but details of the work required to establish criteria for setting the steps, and the process for determining the actual step levels will be outlined in Phase 2.

9. Recommendations

From the work completed for Phase 1 of Project 2 – Operational Adjustments and Scoping Study for the Muskoka River Water Management Plan, the following recommendations can be made:

- Review MRWMP provisions (e.g., different thresholds for snow accumulation and temperature trends) for lake drawdown decisions based on experience in 2008, 2013, 2016 and 2019. These flood years may serve as a basis for adjusting or adding new thresholds (e.g., for snow accumulation and temperature trends) to be adopted into the MRWMP.
- Consider more fully utilizing the lower range of the NOZ, even when snow conditions are not extremely high, for Lake Muskoka. This action may require further review of the impacts of increased drawdown on fisheries, or lower fall drawdown start levels. It may also require reduced flow downstream in the spring to ensure that lakes are filled if high flow events do not occur.
- Review the discharge capability of Lake Rosseau to better understand the drawdown limitations, and to determine changes that might allow for greater drawdown of the lake.
- Develop stage-damage curves for major storage lakes to understand the effects of flooding these lakes, as a means of optimizing mitigations between lakes.
- Determination of the work required to establish criteria for the implementation of a "stepped" refill process for Lake Kawagama/Lake of Bays/downstream river reach should be included in Phase 2.
- Further review the current communication/data sharing processes under high flow conditions to determine if more information is needed, or if implementation of an early warning system for specific areas would be useful. This review will be included in Phase 2.

10. Contacts

The following individuals provided support to this project through discussion, response to questions, and the provision of data.

Table 10-1 – Stakeholder Contacts

Stakeholder	Contact	Title
Ministry of Natural Resources	Adam Wakefield	District Manager, Parry Sound District
	Jason Lorbetskie	District Supervisor, Parry Sound District
	Amanda Vincent	Resource Management Coordinator, Parry Sound District
	Amber Langmuir	Surface Water Monitoring Centre Engineer
Environment and Climate Change Canada	Lindsay Armstrong	Geospatial Applications Officer, National Hydrological Services
District Municipality of Muskoka	Glenn Cunnington	Manager, Watershed Programs
	Kevin Boyle	Climate Change Coordinator
	Steve Taylor	Technical Working Group member; formerly with MNRF
Bracebridge Generation	Bryan Ingram	Operations Manager
Orillia Power Generation Corporation	Grant Hipgrave	President and CEO
Ontario Power Generation	Kurt Kornelsen	Senior Manager - Water Resources
	Justin Bremner	Engineer – Water Management, Operations, Niagara Operations

Appendix A:
List of Acronyms

Appendix A – List of Acronyms

AOZ	Absolute Operating Zone
AP	Algonquin Power
ARSP	Acres Reservoir Simulation Program
BG	Bracebridge Generation
BMP	Best Management Practice
CaPA	Canadian Precipitation Analysis
CMS	Cubic Meters Per Second
CNR	Canadian National Railway
District	District Municipality of Muskoka
GS	Generating Station
HFT	High Flow Trigger
HWI	High-Water Indicator
HWZ	High Water Zone
HWY	Highway
IWM	Integrated Watershed Management
LOZ	Lower Operating Zone
MECP	Ministry of Environment, Conservation and Parks
MNR	Ministry of Natural Resources
MNRF	Ministry of Natural Resources and Forestry
MRW	Muskoka River Watershed
MRWMP	Muskoka River Water Management Plan
MSC	Meteorological Service Canada
Muskoka Lakes	Lake Joseph, Lake Rosseau and Lake Muskoka
MWAG	Muskoka Watershed Advisory Group
NOZ	Normal Operating Zone
OP	Orillia Power Generation Corporation
OPG	Ontario Power Generation
Province	Province of Ontario
RFP	Request for Proposal
SREL	Swift River Energy Limited
SWE	Snow Water Equivalent
SWMC	Surface Water Monitoring Centre
TOL	Target Operating Level
TWG	Technical Working Group
UOZ	Upper Operating Zone
WSC	Water Survey of Canada

Appendix B:
Operational Model Report (ARSP)

District Municipality of Mukoka
Project 2: Operational Adjustments and Scoping Stdudy,
Muskoka River Water Management Plan
H367618

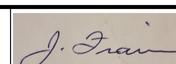
Engineering Report
Civil Engineering

Operational Model Report (ARSP)

Report

Operational Model Report (ARSP)

H367618-0000-2B1-249-0001

					
2022-08-22	**0**	**Final**	**H. J. Cook**	**J. Frain**	**J. Shaw**
DATE	**REV.**	**STATUS**	**PREPARED BY**	**CHECKED BY**	**APPROVED BY**
				Discipline Lead	**Project Manager**

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1. Overview

A numerical model was used to assess the likely impact to the Muskoka River Watershed (MRW) resulting from potential operational adjustments to water management. The model was originally developed in 2003 using Acres Reservoir Simulation Package (ARSP) to evaluate the watershed as part of the development of the original Muskoka River Water Management Plan (MRWMP). This model was resurrected for Project 2 to, specifically, facilitate examination of greater drawdown at Lake Muskoka during two historical flood events - 2013 and 2019. A summary of the analysis is presented herein.

2. Numerical Model

ARSP is a multi-purpose, multi-reservoir simulation/optimization tool that was specifically designed to evaluate water resource systems that are used for many different purposes. ARSP is capable of simulating a wide-range of operating policies to solve water resource allocation problems involving flood control, low-flow augmentation, flow diversions, navigation, environmental enhancement, water supply, hydroelectric energy production, irrigation and many other water uses.

ARSP was first developed in the 1970s and was continually expanded and refined until the early 2000s. Although there has been little additional development since that time, as it has largely been superseded by more recent models (including Hatch's Vista™ Decision Support System suite), ARSP is still a powerful and useful tool for some applications, including the current study.

2.1 Inputs and Outputs

The model takes time-series of natural inflows as a primary input, along with reservoir and channel characteristics and operating policies, system connectivity information, physical flow constraints, hydropower plant characteristics and system hydropower criteria, and flow demand data (including power, irrigation, water supply, and environmental demands).

Primary output parameters include reservoir states (water levels), channel flows, and power and energy production for each time step. Other parameters can also be reported, depending on the application.

2.2 Flexibility

A major advantage of ARSP is its flexibility in allowing the user to make operating policy changes by modifying the input data rather than by changing the computer program itself. Furthermore, the operating policies are modeled separately from the physical system. This approach allows alternative water resource policies to be investigated by superimposing new penalty structures on the existing network. The penalty structure defines the relative priorities of conflicting water uses under various hydrologic conditions, and at various times of year. The priorities are specified by the user and are not dependent on the system configuration.

2.3 Operational Features

Operational features that can be represented include storage and release of water by reservoirs, physical discharge controls at reservoir outlets, water flow in channels (e.g., streams, power channels, diversion or irrigation canals), consumptive demands (e.g., agricultural, industrial or municipal), hydropower releases, head losses in channels, water losses in channels, hydraulic routing through channels and reservoirs, and inflow forecasts. Flow and water level constraints may be absolute, or they may be relative to the flow or level in a previous time step.

2.4 Solution Technique

ARSP is based on the premise that a water resource system can be represented by a flow network and that an optimal operating decision for the upcoming time-period can be made given the initial state of the system and estimates of net inflows during the period. It is a steady-state model since the system configuration and the penalty structure do not change with time.

Although ARSP does not optimize operational decisions over all time steps, it does use optimization principles to obtain the desired water allocation solution within each time step. Since system operators do not have perfect foreknowledge of future inflows, this often provides a more realistic representation of the operational limitations experienced when making real-life decisions.

2.5 System Representation

In the model, a physical water resource system is described as a network consisting of discrete components, each of which is defined separately. Junctions and control points, such as reservoirs, are represented as nodes, while natural or artificial flow paths that connect junctions are referred to as channels. The network solution technique allocates water in such a way that the total benefits for meeting flow requirements, reservoir storage and generation are maximized for each time step. For example, the model might determine if it is preferable to draw down a reservoir to maintain a desired minimum flow in a channel or to keep the water in storage and allow the channel flow to fall below the desired value.

3. Model Setup and Analysis

For Project 2, the 2003 ARSP model was reviewed and reapplied to the MRW. The steps involved in this process are described in the following subsections.

3.1 Model Check

As an initial check on the model, the current version of ARSP was run using the same data set that was created for the Base Case run during the 2003 analysis. There were negligible differences between these results and those obtained in 2003, thus confirming there have been no changes to the model that affect this application.

3.2 Model Update and Extension

The previous analysis was conducted in 2003, but the final version of the MRWMP was not issued until 2006. As a result, some differences were noted between the target water levels and reservoir operating zone boundaries specified in the model data and those eventually published in the MRWMP. Therefore, the data set was modified to reflect the final values reported in the MRWMP.

Although the subsequent modelled results reflect these changes to the “rule curves” (a term used to collectively refer to the target water levels and operating zone boundaries) and are thus “different” than results from the 2003 Base Case, there are no fundamental changes to the “character” of the results. In other words, it is still a suitable (though “new”) Base Case for the current analysis.

To conduct the evaluation defined in the work scope, hydrologic data were required for the two years of particular interest – 2013 and 2019. Consistent with the hydrology used in the 2003 analysis, streamflow data were retrieved from the Environment Canada database for the following two Water Survey of Canada (WSC) gauging stations:

- 02EB013, Big East River near Huntsville
- 02EC002, Black River near Washago.

One or the other of these two-flow series was used at all inflow locations defined in the model, using suitable proration factors (as derived in 2003) to ensure the total inflow volume was appropriate for each location.

For comparison with modelled results, streamflow data for the following gauge was also retrieved:

- 02BE006, Muskoka River below Bala.

Finally, the data set was also modified to include the Bala Generating Station (GS), since it did not exist when the model was set up in 2003. Although an assessment of hydropower was not part of this work scope, the stations was nevertheless included in the model, with appropriate characteristics to capture the effect they have on the overall operation of the system. The key parameters defined for Bala GS are as follows:

- Installed capacity: 4.5 MW
- Design head: 6.2 m
- Maximum discharge: 96 m^3/s

- Nominal efficiency: 85%
- Normal tailwater level: 219.55 m.

3.3 Model Results and Verification

Verification of the model proficiency was initially examined using the 2019 flood event under Base Case conditions. The model parameters were then slightly modified to improve the correspondence between the modelled results and the actual operation in that year. The inclusion of this step reflected the fact that the original calibration of the model in 2003 was done without data from any of the recent large floods.

The results of this run are presented in Figure 3-1 through Figure 3-6. These include water level plots for the following six key reservoirs in the basin:

- Fairy (Huntsville) Lake (Figure 3-1)
- Mary Lake (Figure 3-2)
- Kawagama Lake (Figure 3-3)
- Lake of Bays (Figure 3-4)
- Lake Rosseau/Joseph (Figure 3-5)
- Lake Muskoka (Figure 3-6).

Flow in the Muskoka River reach below Bala is shown in Figure 3-7. The simulated results are designated by the run code 22B5-19J.

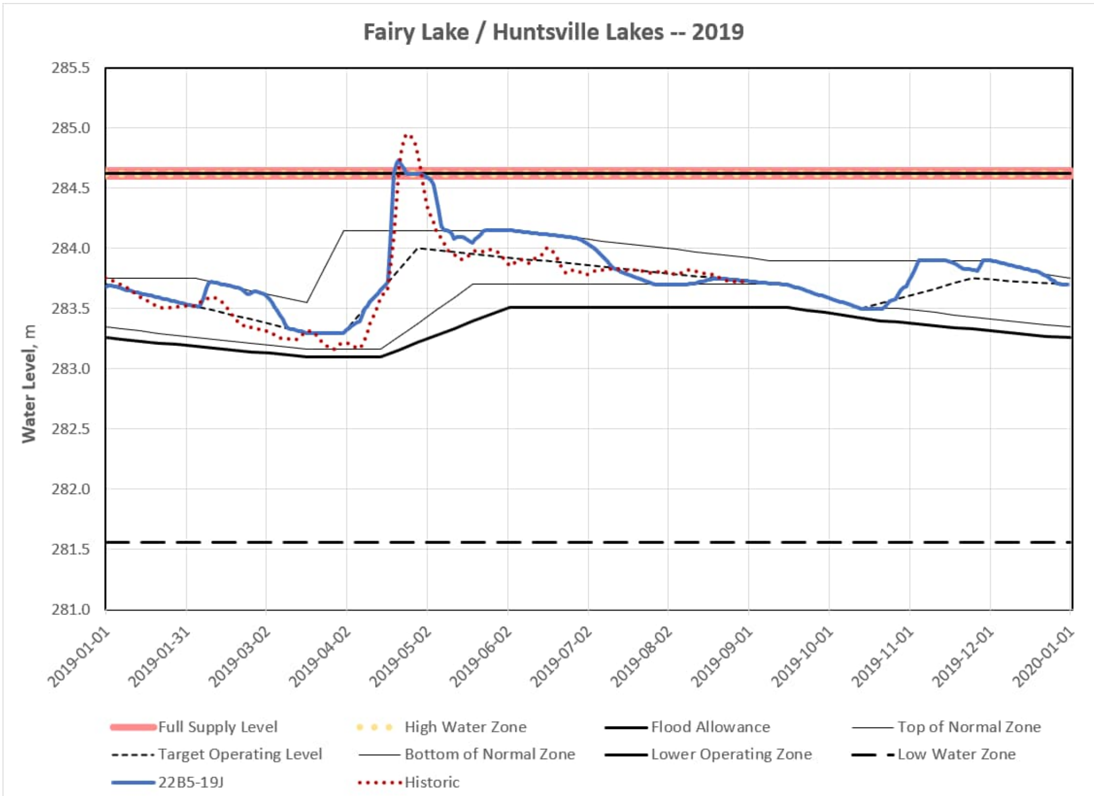


Figure 3-1: ARSP Water Level Results for Fairy Lake, 2019

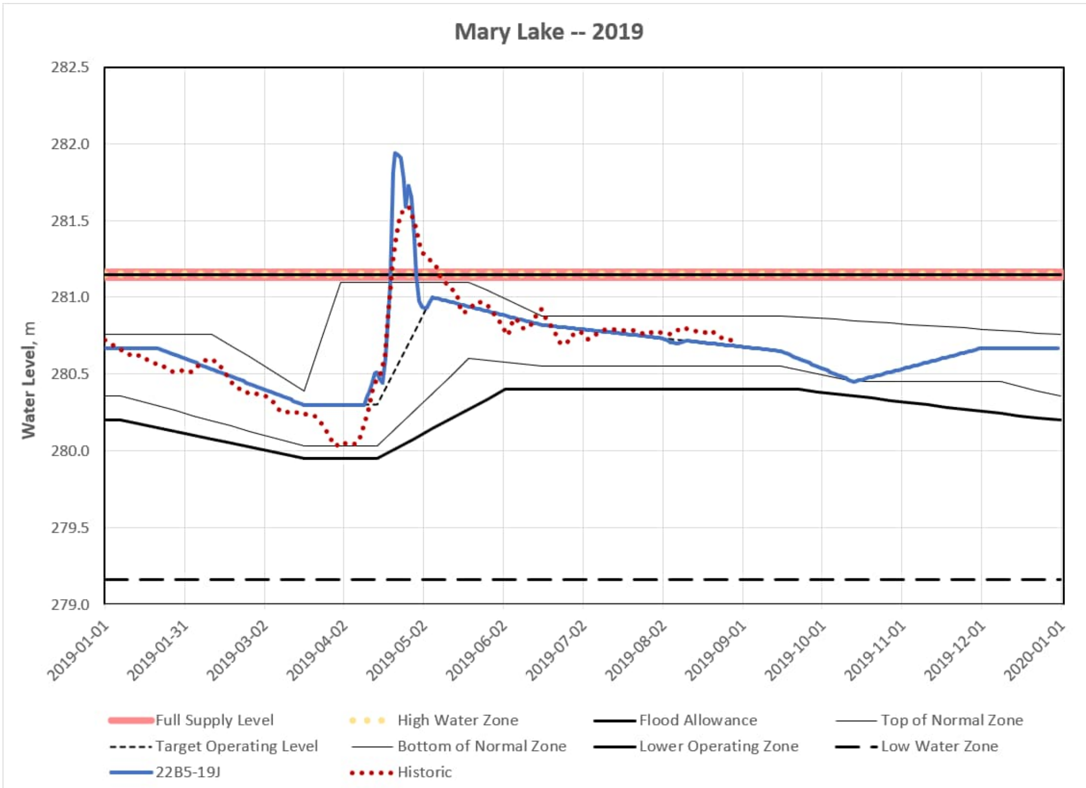


Figure 3-2: ARSP Water Level Results for Mary Lake, 2019

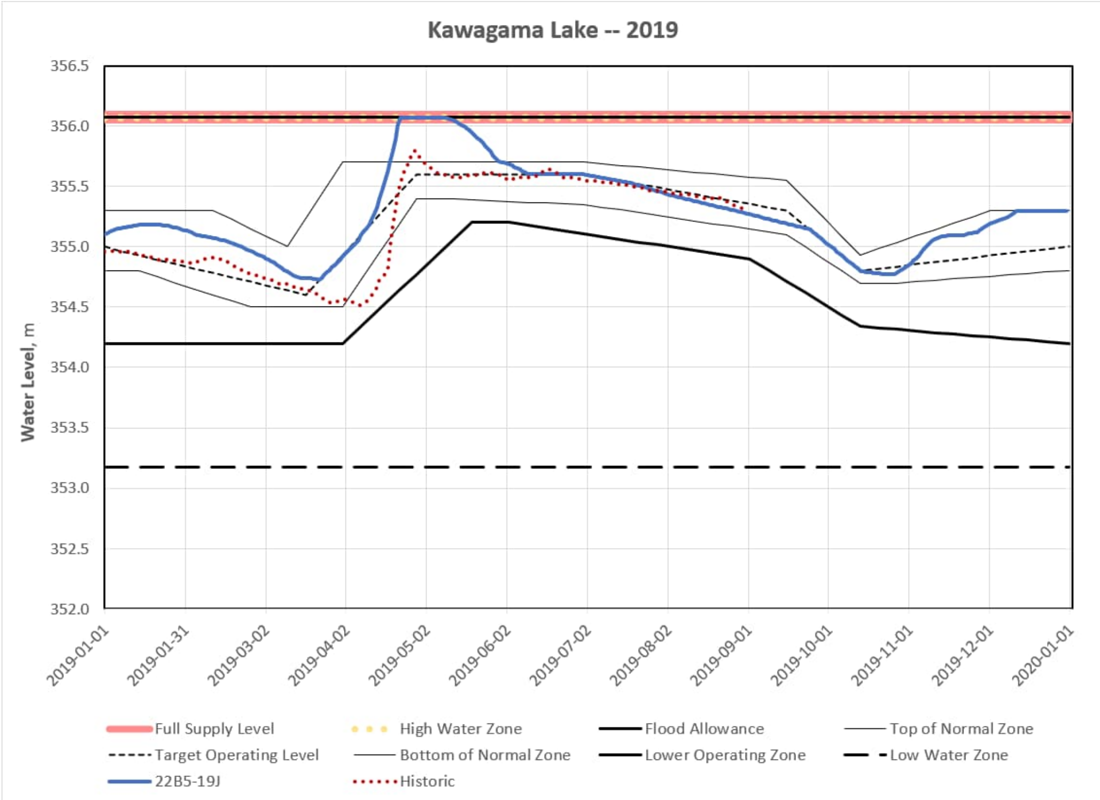


Figure 3-3: ARSP Water Level Results for Kawagama Lake, 2019

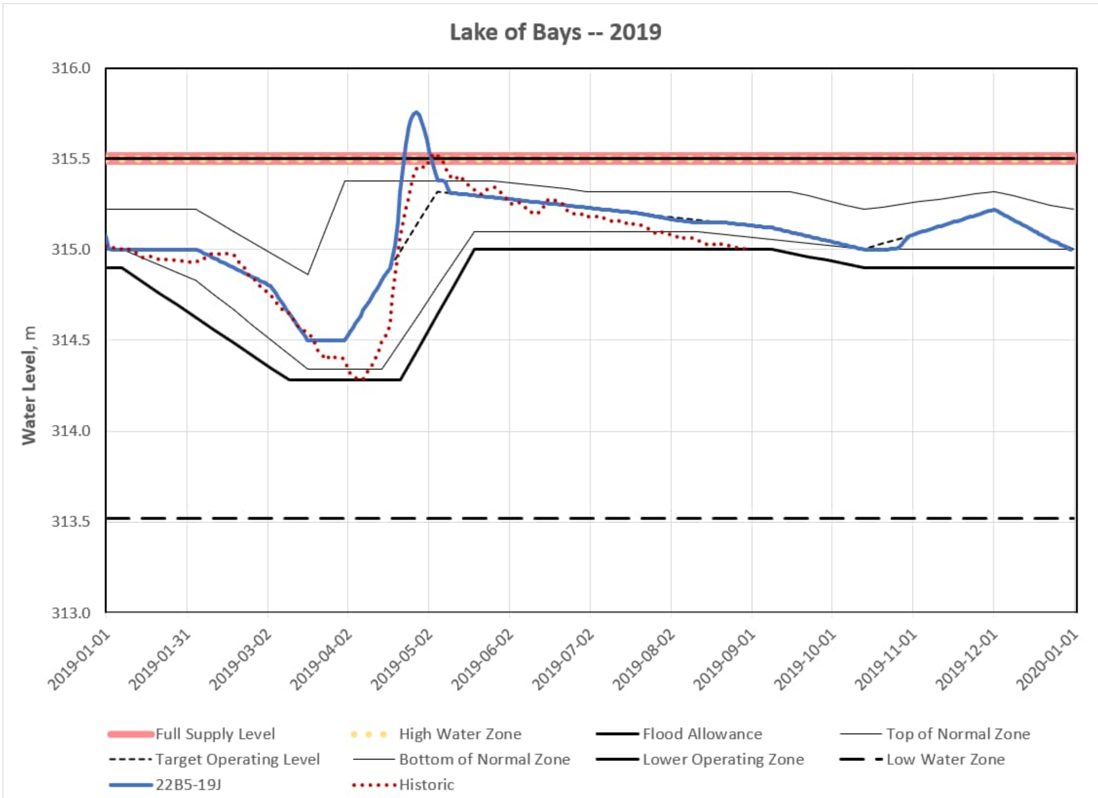


Figure 3-4: ARSP Water Level Results for Lake of Bays, 2019

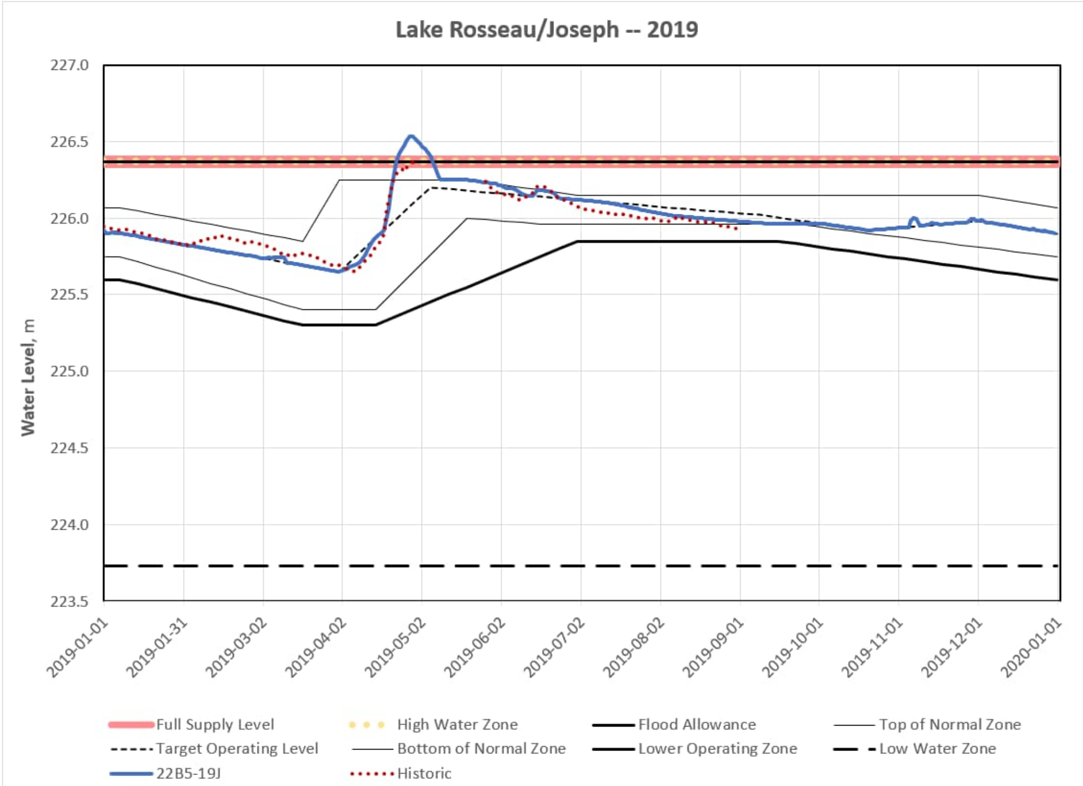


Figure 3-5: ARSP Water Level Results for Lake Rosseau/Joseph, 2019

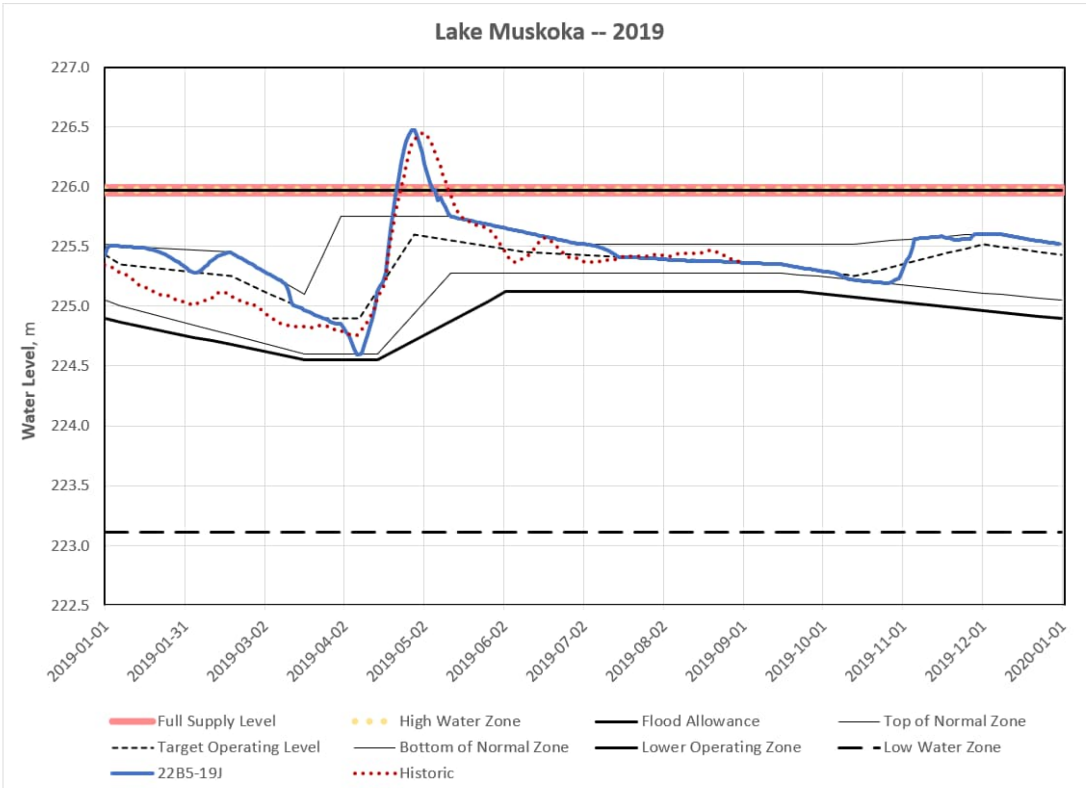


Figure 3-6: ARSP Water Level Results for Lake Muskoka, 2019

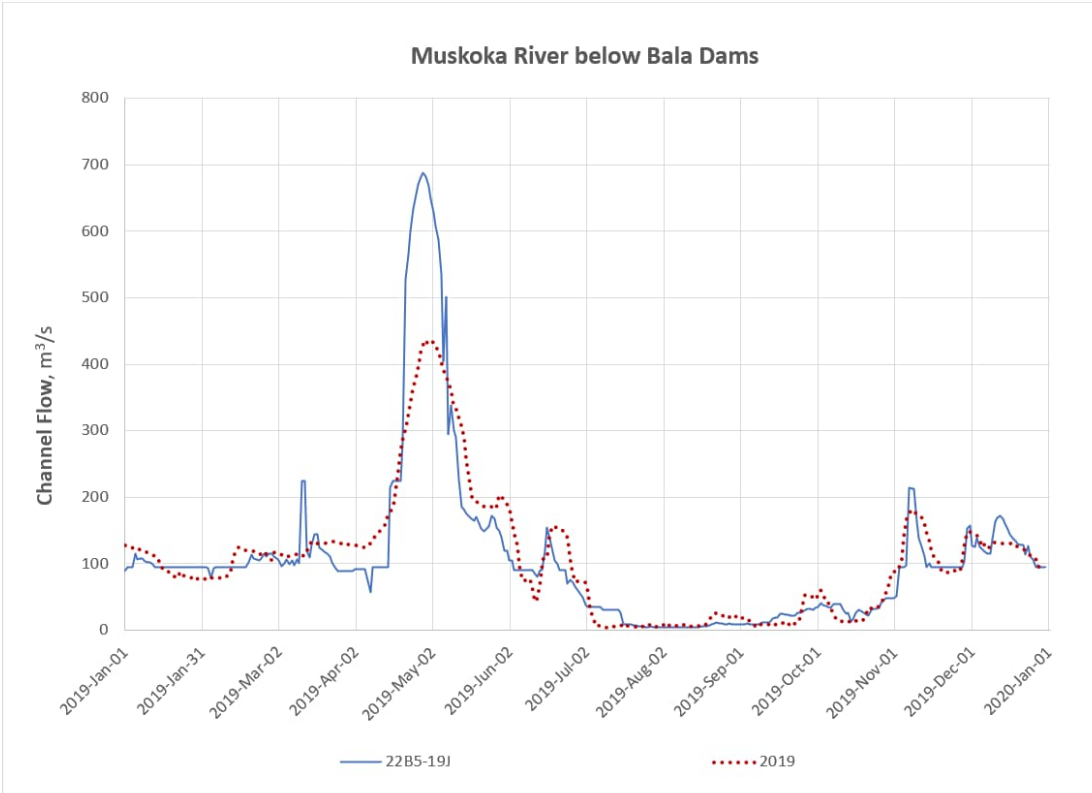


Figure 3-7: ARSP Flow Results for Muskoka River below Bala, 2019

After completing the simulation of 2019, the model was run again (with no additional adjustments) for the year 2013, and the results were compared against the historical operations for that year. Modelled results for the same locations as the 2019 run are shown in Figure 3-8 through Figure 3-14. The simulated results for 2013 are designated by the run Code 22B5-13J.

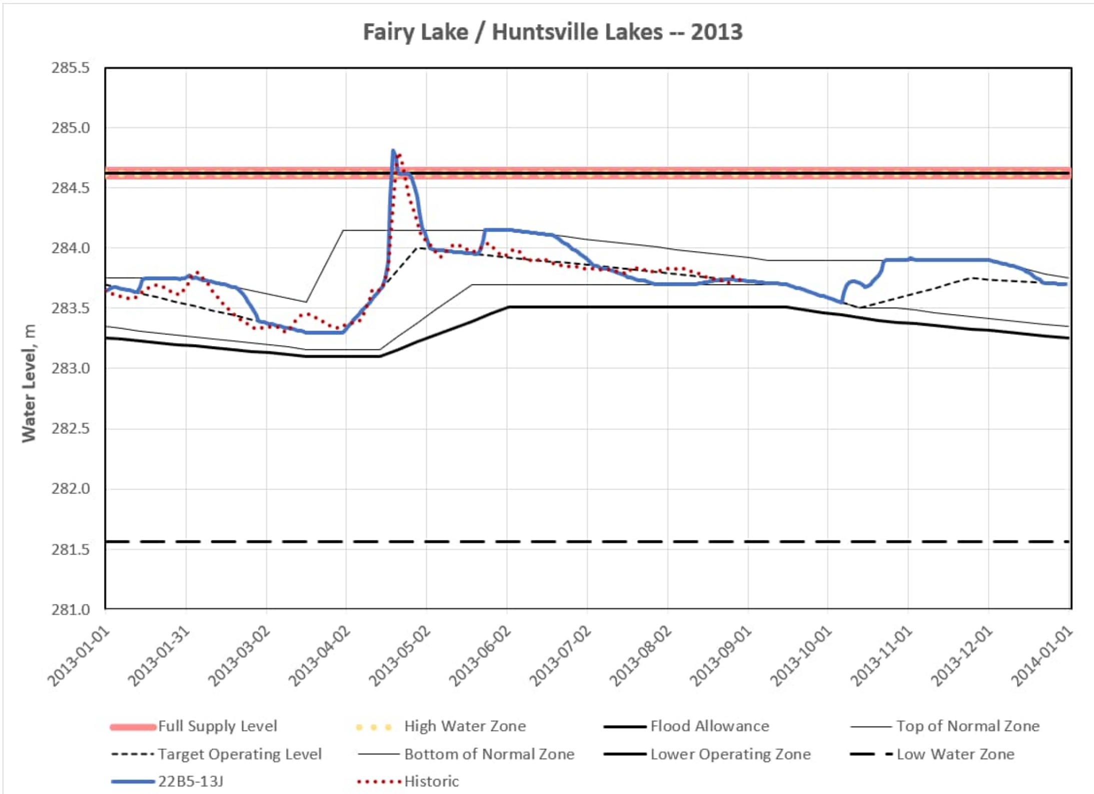


Figure 3-8: ARSP Water Level Results for Fairy Lake, 2013

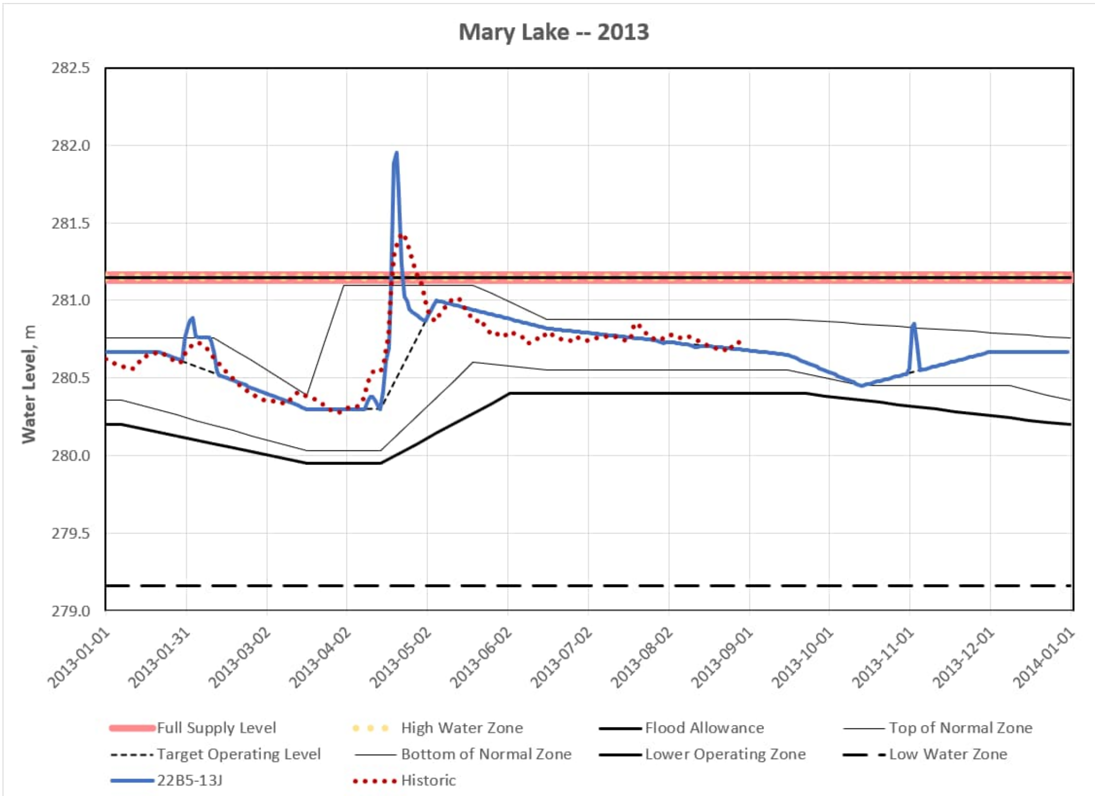


Figure 3-9: ARSP Water Level Results for Mary Lake, 2013

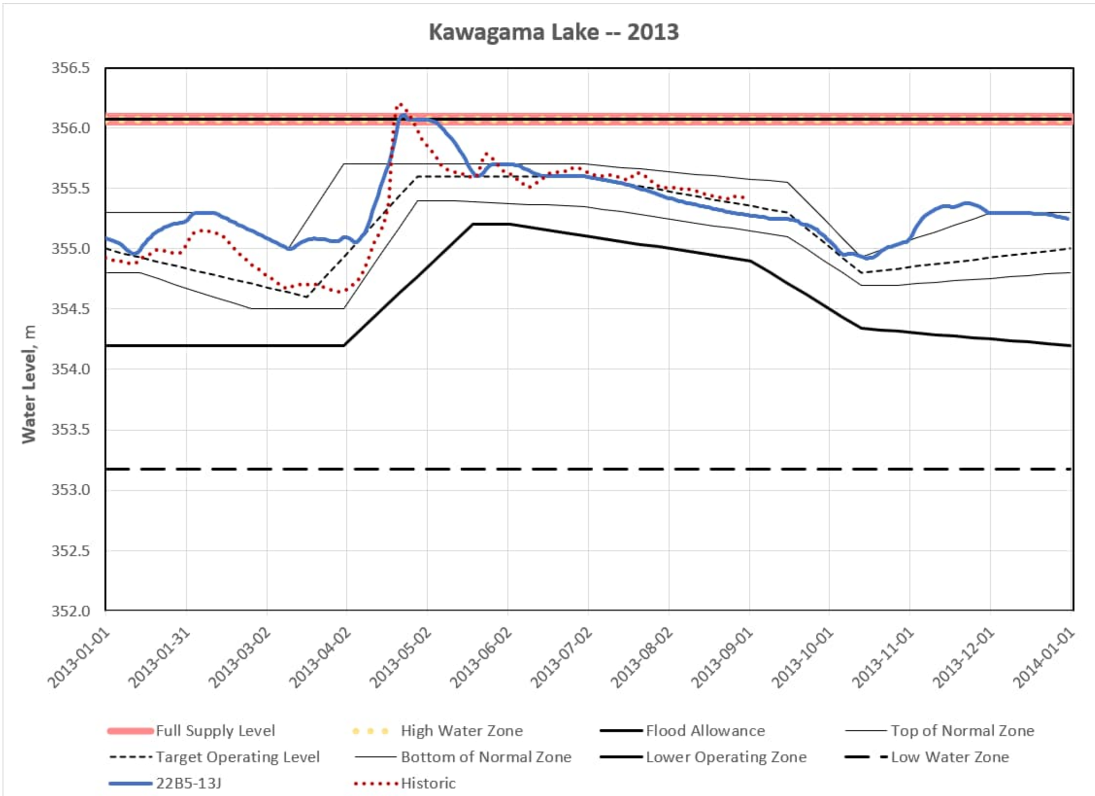


Figure 3-10: ARSP Water Level Results for Kawagama Lake, 2013

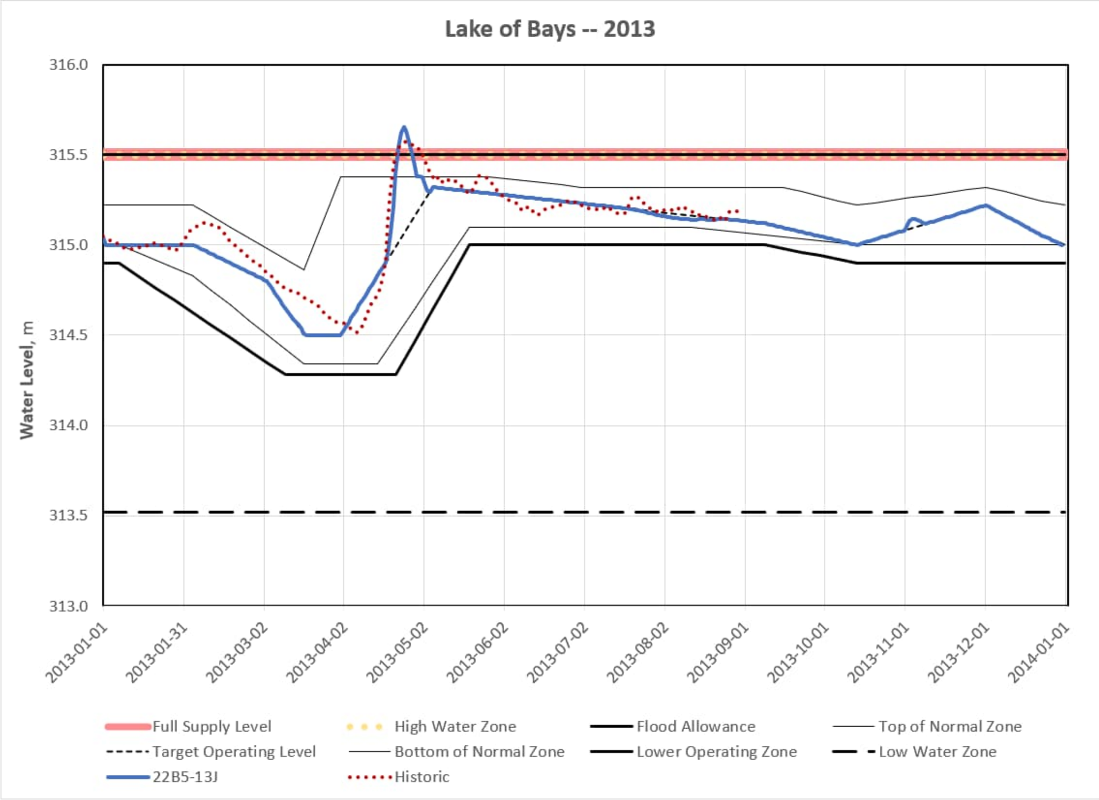


Figure 3-11: ARSP Water Level Results for Lake of Bays, 2013

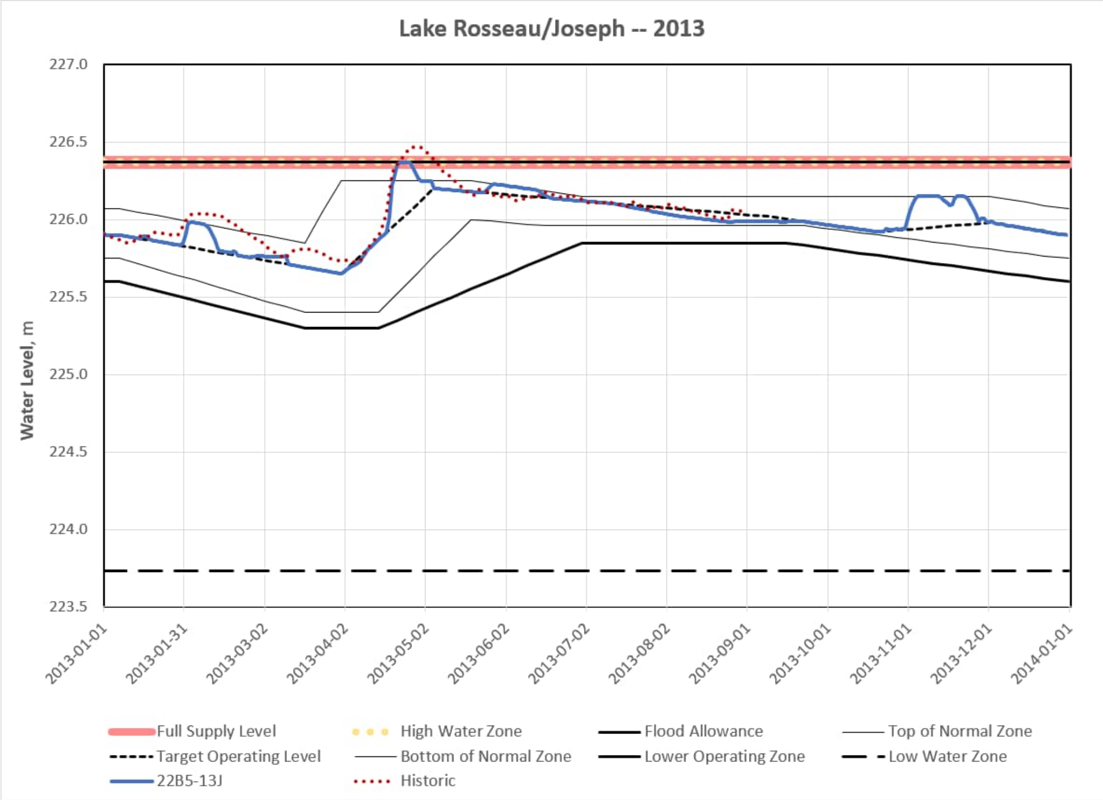


Figure 3-12: ARSP Water Level Results for Lake Rosseau/Joseph, 2013

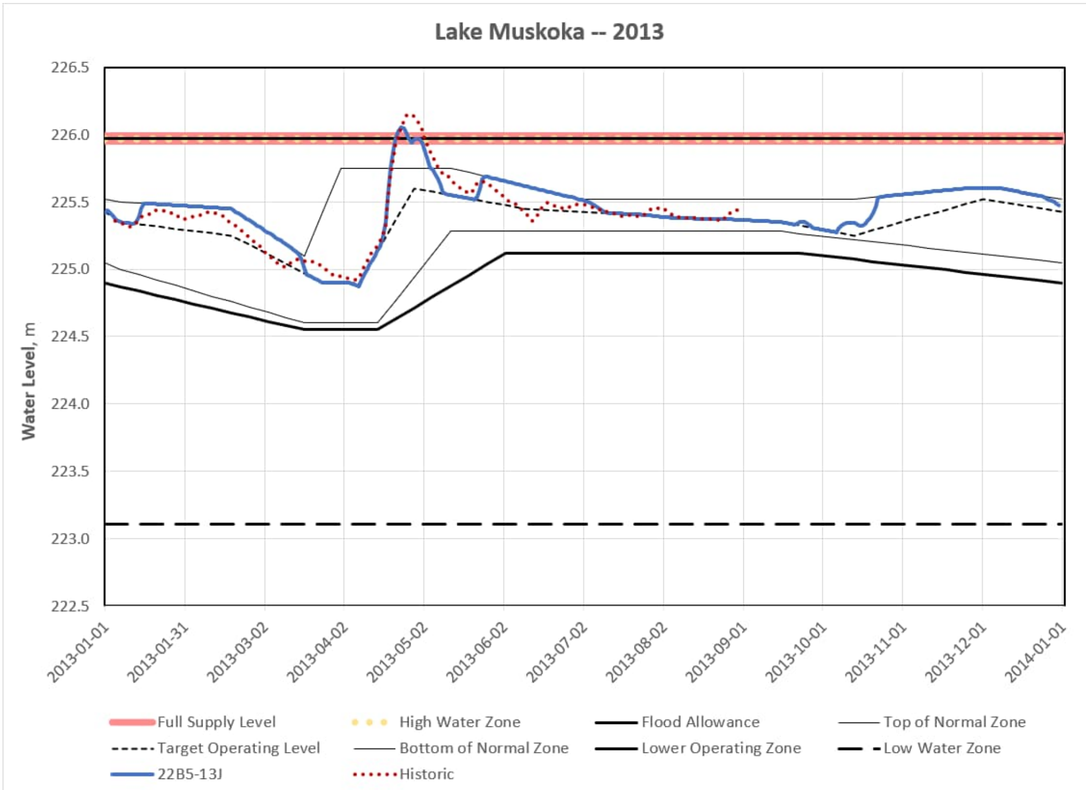


Figure 3-13: ARSP Water Level Results for Lake Muskoka, 2013

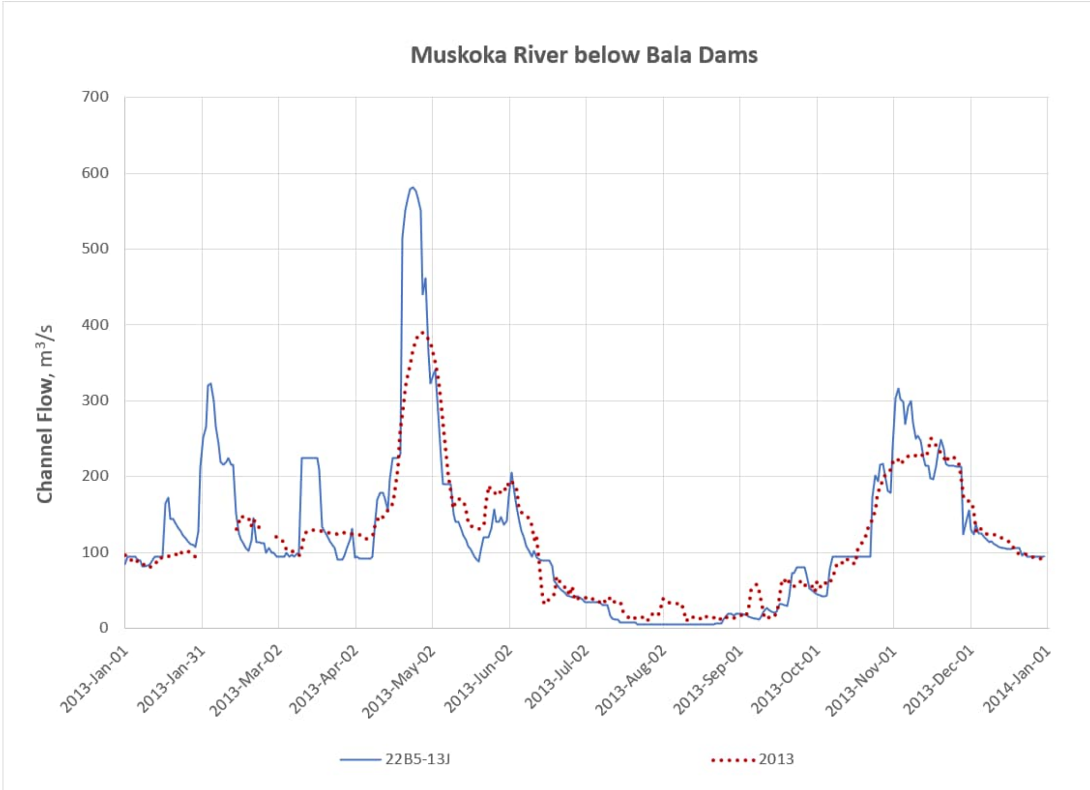


Figure 3-14: ARSP Flow Results for Muskoka River below Bala, 2013

4. Discussion

4.1 Model Validation

For both simulated years, it can be seen that the modelled water levels and flows provide a reasonable representation of the actual operations. The model is more rigid in adhering to the Target Operating Level (TOL) curves (as well as other zonal boundaries) than was done in practice. In particular, it is not clear why the water levels in Kawagama Lake and Lake of Bays were drawn down as much as they were prior to the 2019 freshet, which allowed the (observed) maximum water levels to be kept lower in those lakes than the modelled levels.

As can be seen in Figure 3-7 and Figure 3-14, total channel flows downstream from Bala do not compare as favorably as the water levels at the key reservoir lakes. As some historical streamflow data are missing from the record in the early part of 2013, it is more difficult to do a comparison for that year. Thus, the following discussion is based on the results for 2019, as shown in Figure 3-7.

Although the peak flow during the freshet is much higher in the model than the maximum observed flow, the total volume is similar. In fact, the total volume released over the entire year, as simulated, was less than 2% higher than historically recorded.

While this small difference seems to confirm that the method of estimating inflows for use in the model is reasonable, such a conclusion might or might not be warranted, since the comparison implicitly assumes that the aggregate change in storage over the entire watershed (i.e., at all reservoirs) between the beginning and end of the year is similar between the model and the actual case. In fact, there is not enough data to confirm this change acknowledging that no water level records are kept at many of the reservoirs.

One of the reasons that the simulated peak flow is higher than the historical value is likely due to the decisions made during the lead-up to the freshet. As can be seen in Figure 3-7, the modelled flows downstream from Bala were at or below the nominal maximum power flow through the Bala GS (95 m^3/s) during the period from late March to about mid-April. By comparison, the observed flows were considerably higher, implying that water was being spilled at the Bala dams during that time, which may have been facilitated by the drawdown in most of the key reservoir lakes below their respective targets.

There is currently insufficient information available to explain why these decisions were made, but if the reasons were known and were deemed to be in accordance with the MRWMP, it is likely the model could be revised to operate in a similar fashion.

The simulation results for 2019 and 2013 indicate that the model is capable of representing the Muskoka River system during flood events. Notwithstanding the differences noted above, the model is deemed to be a suitable tool for evaluating some of the recommendations coming out of Phase 1 and determining whether any overall benefits might be obtainable by making operational changes to reduce flood water levels. A scenario modelling an operational change is described in Section 4.1.

4.2 Increased Pre-Freshet Drawdown

An operational change was evaluated to determine the potential value of drawing down Lake Muskoka further than in the Base Case, prior to the freshet. The scenario considered entails lowering the TOL in Lake Muskoka to halfway between the current level and the bottom of the Normal Operating Zone (NOZ) during the period from mid-March to mid-May. The modified operating policy was modelled for both 2013 and 2019.

Although the model uses a daily time step, it does so within a weekly framework. Thus, the selected start (March 18) and end (May 13) dates represent the last day of the respective weeks in which they fall.

Not surprisingly, since the operating constraint change was applied only at Lake Muskoka, the differences between the Pre-Freshet Drawdown case (denoted by ARSP run code LRC2-19J) and the Base Case were limited almost exclusively to the water levels on Lake

Muskoka and the flows in the reach downstream. Therefore, only these results are presented below. Lake Muskoka water level results for 2013 are shown in Figure 4-1, while Muskoka River flows downstream from Bala for the same year are shown in Figure 4-2. Lake Muskoka water levels and Muskoka River flows below Bala for 2019 are shown in Figure 4-3 and Figure 4-4, respectively. The Pre-Freshet Drawdown case results are shown in these figures as Code LRC2-13J.

As the two water level figures clearly show, the water levels in Lake Muskoka are indeed drawn below the Base Case levels in the period from mid-March until the onset of the freshet. In each case, the flows below Bala are generally higher than in the Base Case in order to achieve these water level reductions. [The exception to this occurs in the first week of April in 2019 because inflows are small during that period, and Lake Muskoka is being drawn down even further than the new target in order to support flows at the Bala GS. This support is withdrawn once Lake Muskoka reaches the bottom of the NOZ and, since that happens sooner in the Pre-Freshet Drawdown scenario than in the Base Case, due to the lower water level going into this period, the Bala flows continue to be temporarily higher in the Base Case.]

In both of the years modelled, as a result of the increased drawdown in Lake Muskoka in the Pre-Freshet Drawdown scenario, there is a reduction in both the peak water level reached in Lake Muskoka and the peak flow in the downstream reach. These differences are quantified in Table 4-1.

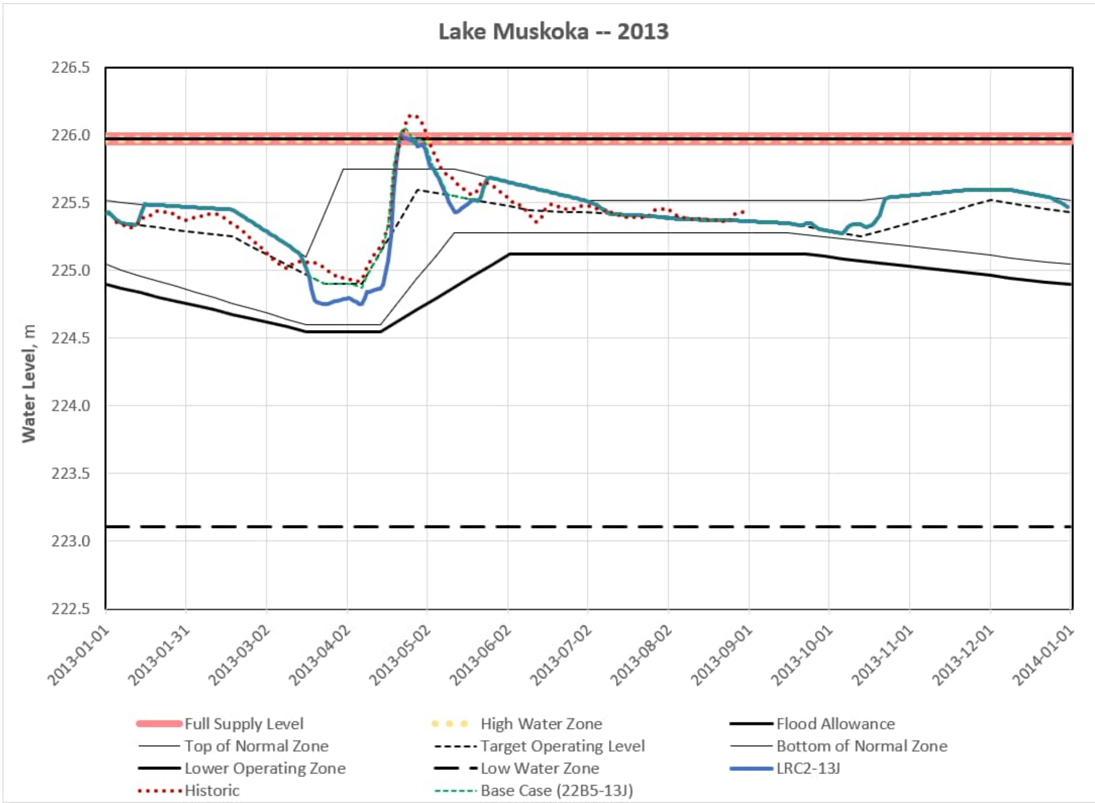


Figure 4-1: Lake Muskoka Water Levels, Pre-Freshet Drawdown Case (2013)

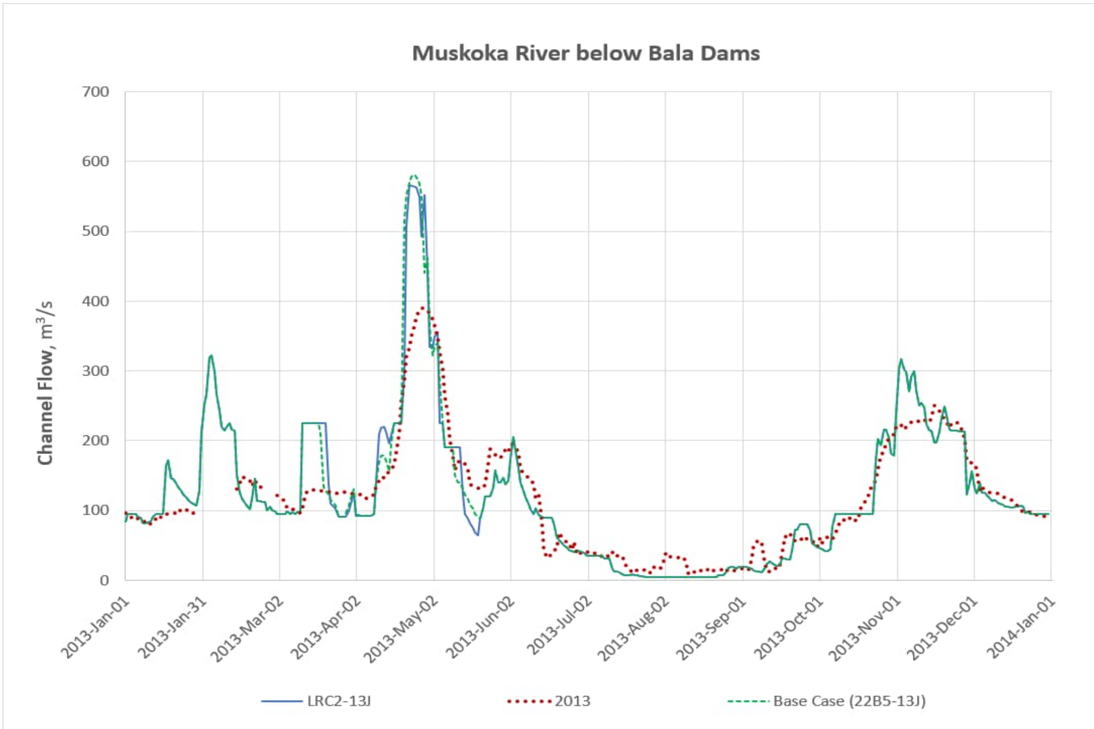


Figure 4-2: Muskoka River Flows below Bala, Pre-Freshet Drawdown Case (2013)

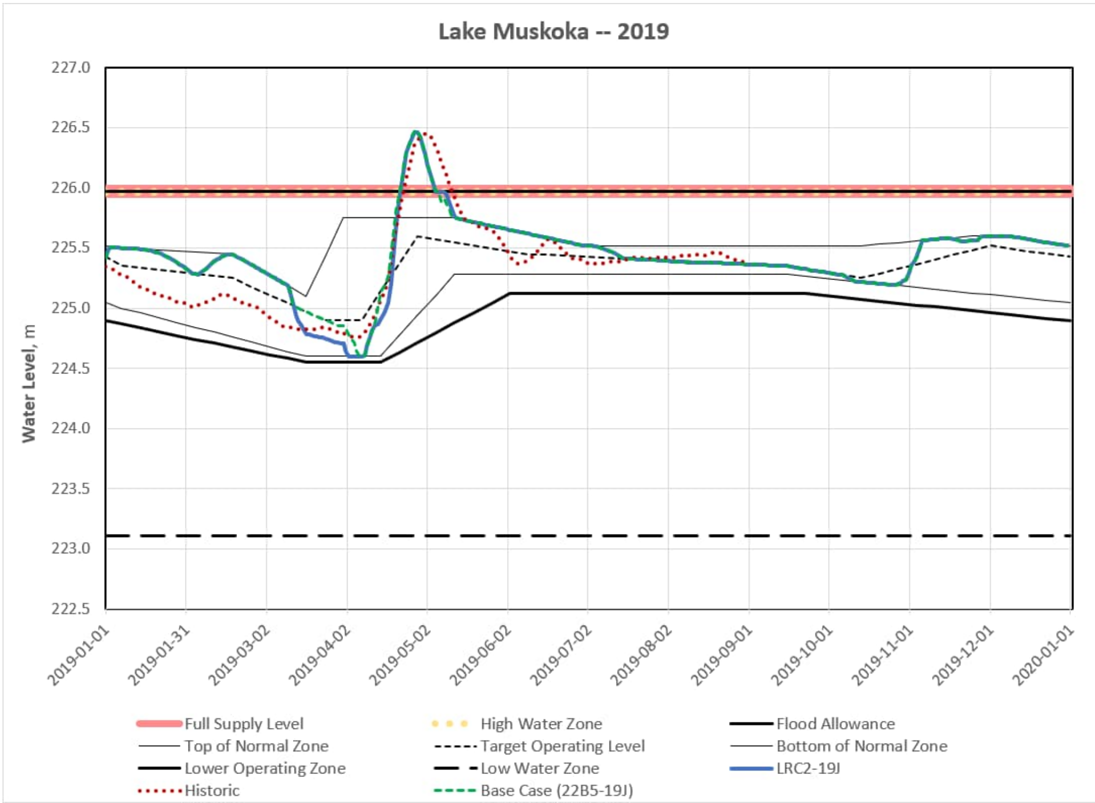


Figure 4-3: Lake Muskoka Water Levels, Pre-Freshet Drawdown Case (2019)

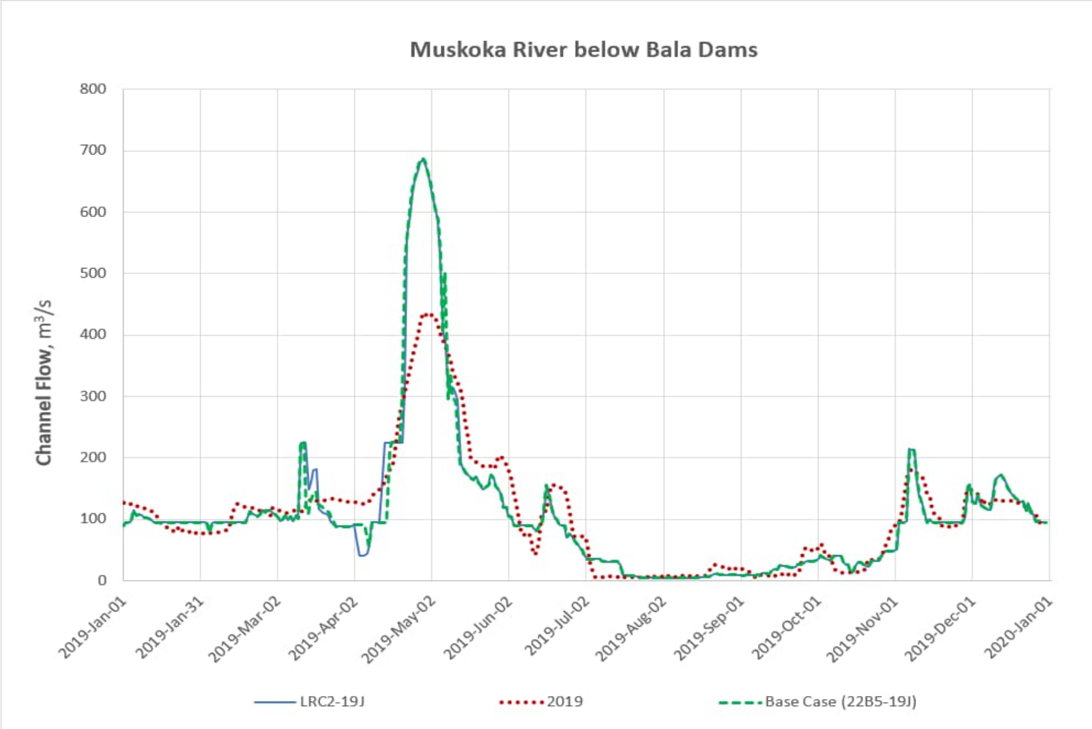


Figure 4-4: Muskoka River Flows below Bala, Pre-Freshet Drawdown Case (2019)

Table 4-1: Comparison of Peak Water Levels and Flows, Pre-Freshet Drawdown vs. Base Case

Hydrologic Year	Location	Base Case	Pre-Freshet Drawdown Case	Difference
2013	Lake Muskoka WL, m	226.05	220.00	-0.05
	Flows below Bala, m^3/s	581.1	565.7	-15.4
2019	Lake Muskoka WL, m	226.48	226.47	-0.01
	Flows below Bala, m^3/s	687.7	685.2	-2.5

As the table shows, while there are benefits of the increased drawdown in Lake Muskoka in both 2013 and 2019, they are nominal in magnitude (5 cm and 1 cm, respectively). Also, as already noted, the benefit is shared between reduced peak water levels in Lake Muskoka and reduced peak flows downstream of Bala, which is exactly what one would hope to see for any proposed changes to the operational policy.

It should not be a surprise that lowering the water level in Lake Muskoka prior to the arrival of the freshet would result in lower peak water levels and flows in years with large floods. It must be remembered, however, that following the same policy in other years could result in unwanted socio-economic impacts on the environment, recreation or other areas of concern, without providing any flood benefit in those years. Therefore, a more thorough investigation, covering many more years of hydrology, is recommended before adopting a change such as the one evaluated here.

It is also worth noting that the “Target Operating Level” in each reservoir is really only a guideline, not a hard constraint, and the flexibility to deviate from it (anywhere within the NOZ) already exists in the MRWMP. In particular (and by way of example), the MRWMP dictates that water levels are to be drawn down to the bottom of the NOZ if defined snowpack water content thresholds are exceeded on specific dates.

Appendix C: Presentation to District of Muskoka Staff and Technical Working Group June 24, 2022 Slides for Project 2

Introductions and Objectives

- Introduction
  - TWG/DMM
  - Hatch
- Objectives
  - Project 2
    - Present and discuss operational adjustments that may reduce flood risk.
  - Project 3
    - Present and discuss structural options conceived.
    - Refine/develop ranking matrix attributes.
    - Collectively determine options to carry forward to Phase 2.

Project Scope

Project 2 – Operational Adjustments and Scoping Study for the Muskoka River Water Management Plan

- Phase 1 - Determining operational adjustments that may reduce flood risk and enhance ecological resiliency in the Watershed
- Phase 2 – Provide a comprehensive work scope necessary to initiate an amendment of the MRWMP

Project 3 – Structural and Watershed-Scale Flood Mitigation

- Phase 1 - Identify structural options within the five high priority areas that will promote flood risk reduction. The characteristics and constraints associated with these options will be defined within a localized context. i.e., within the priority area.
- Phase 2 – Analyze the flood mitigation options conceived in Phase 1 from a holistic or system-based perspective to determine cumulative change (within the watershed) associated with adopting one or more of these options. Recommend flood risk reduction scheme based on decision matrix that includes cost, engineering effort, and perceived environmental impacts.

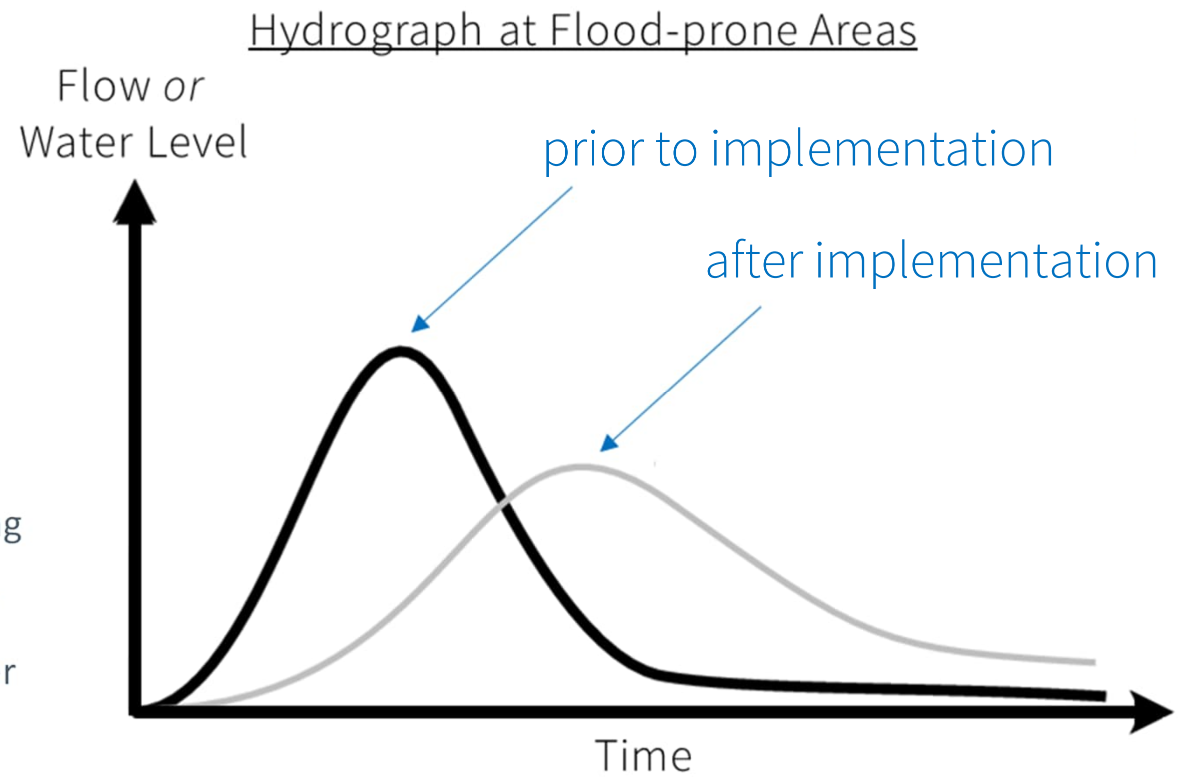
Flood Mitigation Strategies

Strategy 1: Flood Protection or Diversion

- embankments
- bypass channel
- channel modification

Strategy 2: Flood Attenuation

- adapting hydraulic controls
- create temporary storage
- greater/earlier lake drawdown before spring
- phased approach to managing water levels
- increase maximum permitted existing water levels
- staggered arrival of peak inflows

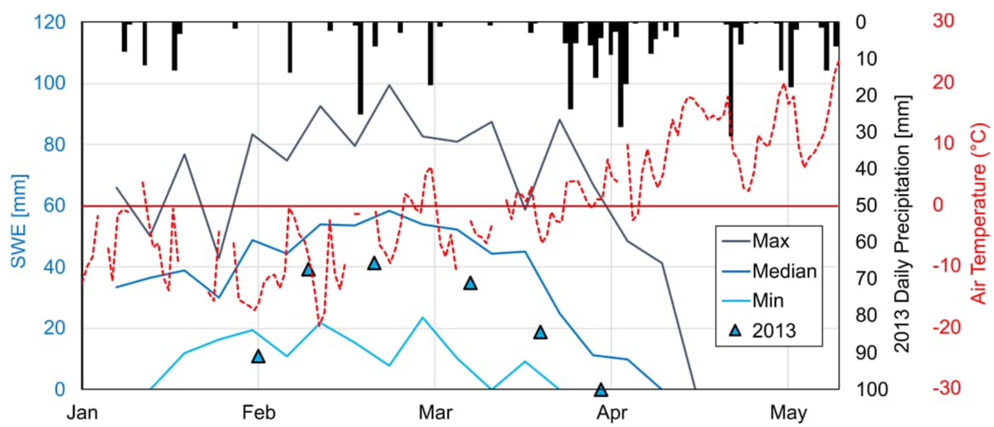


Project 2: Operational Management

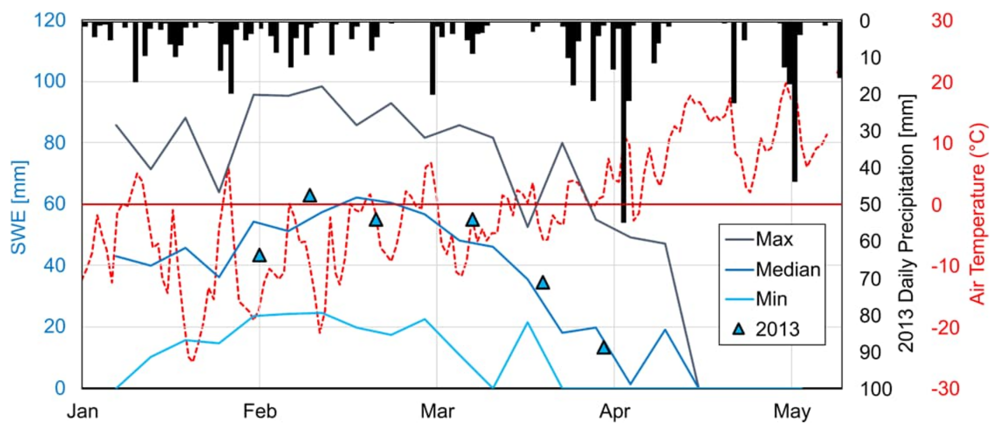
Background on Muskoka River Water Management

- Many interests/drivers/constraints behind water management in the Muskoka River watershed
  - Navigation
  - Hydropower production
  - Recreation
  - Fishery support
- Evolution of Water Management
  - Hackner-Holden Agreement (1940/1969)
  - Water Management Plan (MRWMP) (2006)
- Study focus areas
  - North Branch
  - South Branch
  - Muskoka Lakes (Rosseau, Joseph, Muskoka)

Hydrological Conditions – 2013 Event

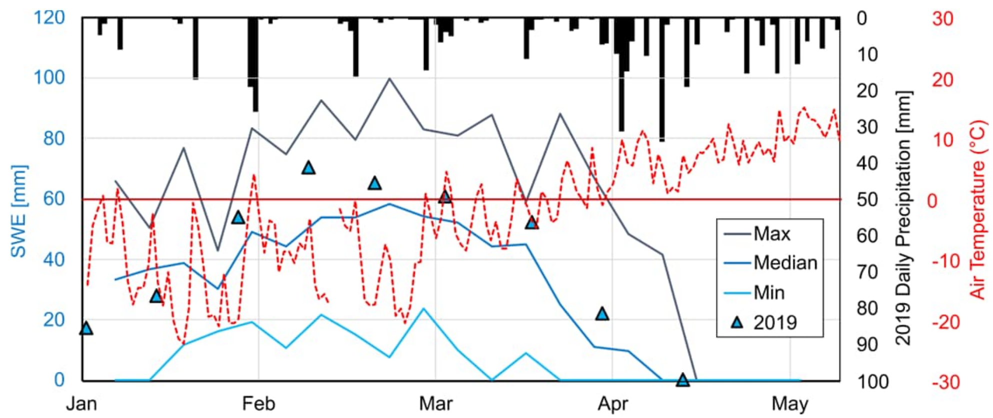


Norway Point
Snow Survey Course

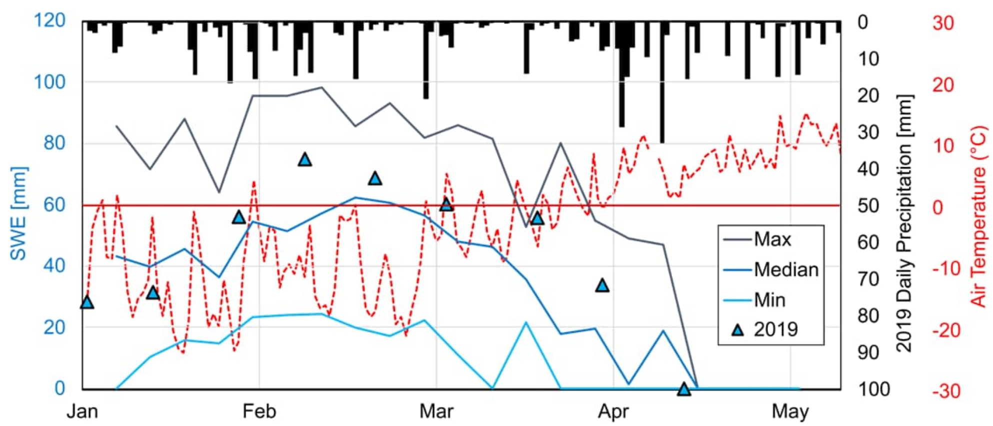


Rosseau Falls/Skeleton Lake
Snow Survey Course

Hydrological Conditions – 2019 Event

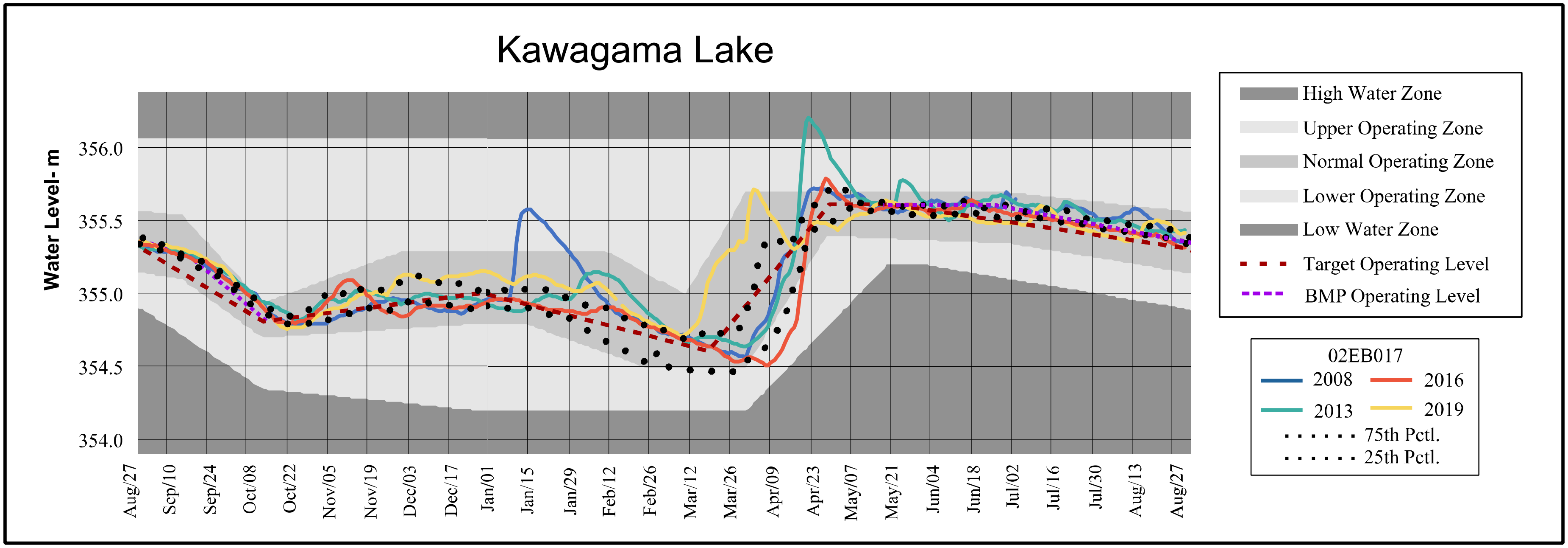


Norway Point
Snow Survey Course



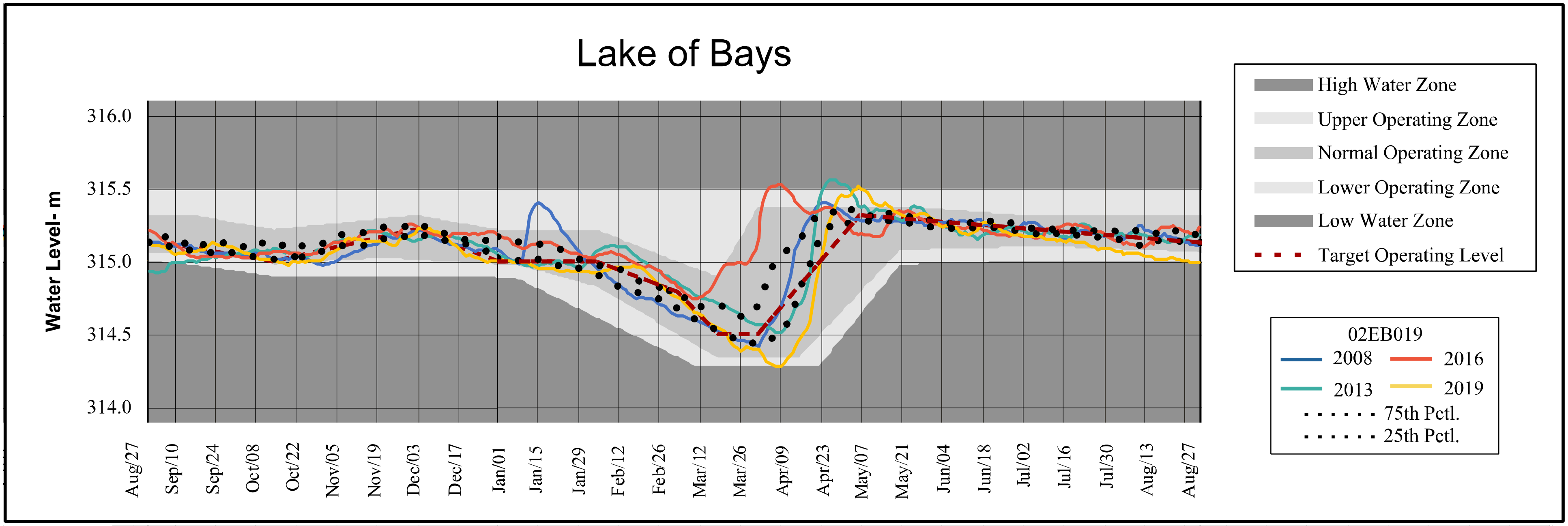
Rosseau Falls/Skeleton Lake
Snow Survey Course

Kawagama Lake



HATCH

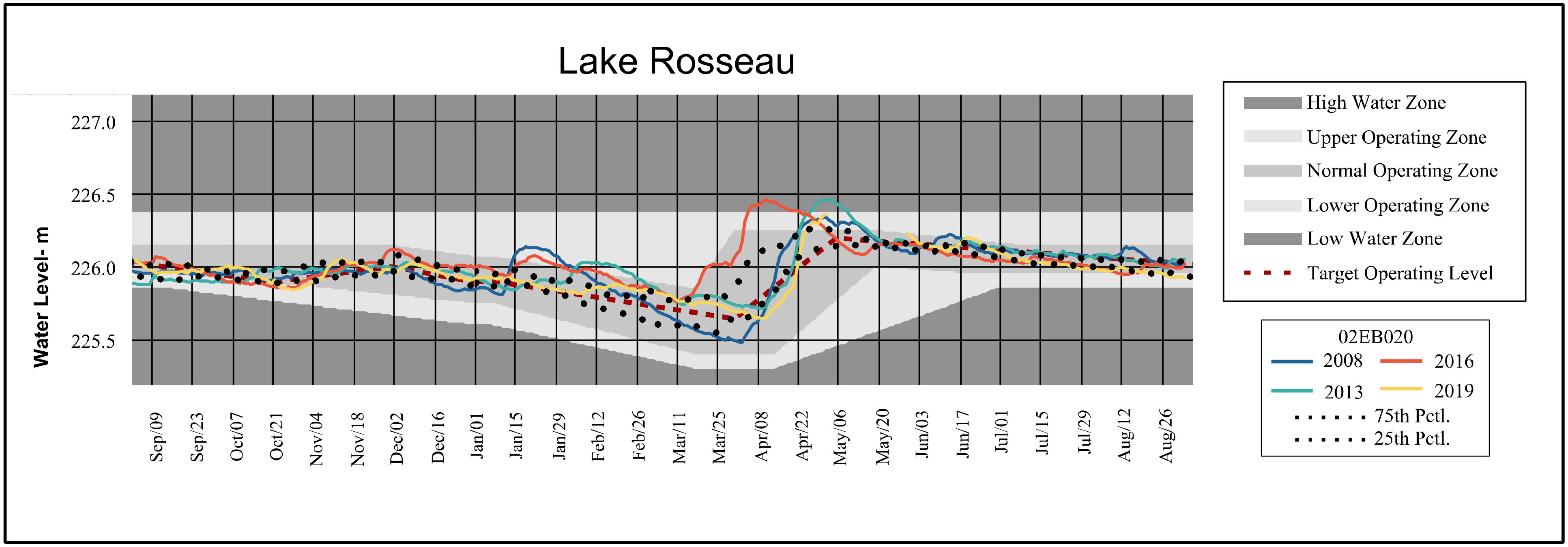
Increasing Lake of Bays Storage



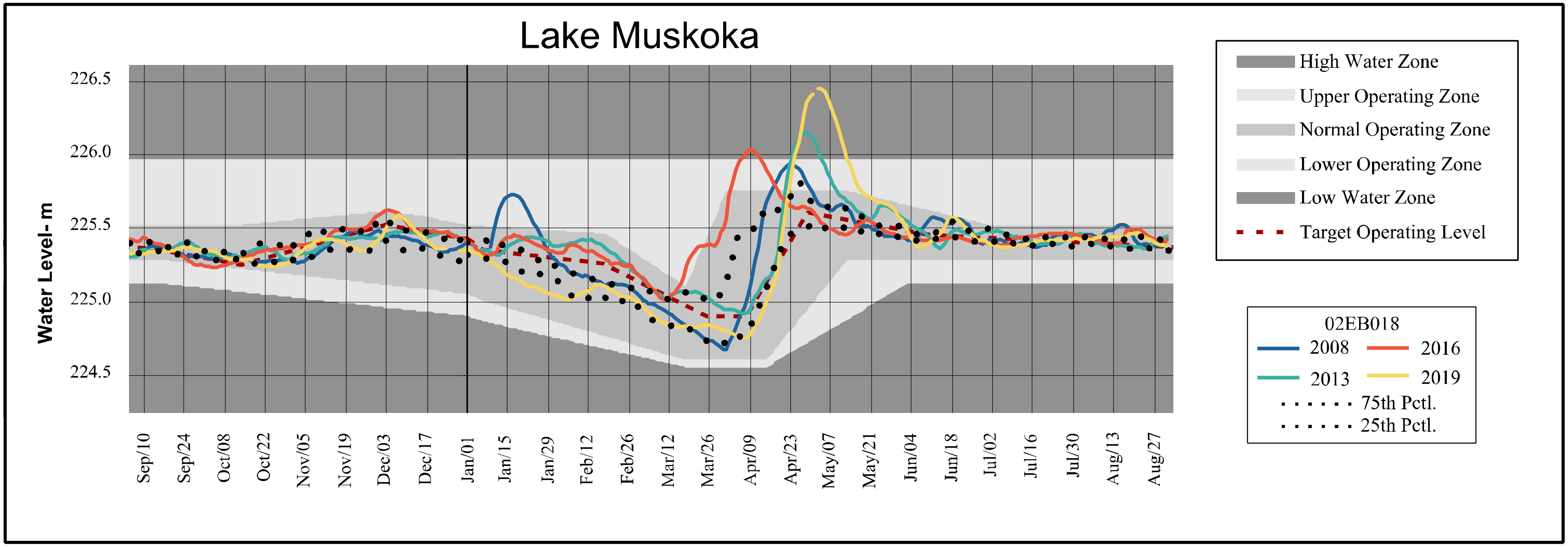
Increasing Lake of Bays Storage

Scenario	Peak Flow at Baysville (m³/s)	Estimated Peak Water Level Lake of Bays (m)	# of Impacted Structures at Lake of Bays (-)	# of Impacted Structures (-)			
				Total	Baysville	Fraserburg	Purbrook
Regulatory Event	165	315.51	1925	206	12	49	145
10% Peak Reduction	149	315.67	1977 (+52)	183 (-23)	10	30	143
20% Peak Reduction	132	315.79	2017 (+92)	163 (-43)	8	14	141
30% Peak Reduction	116	315.92	2059 (+134)	145 (-61)	4	5	136
40% Peak Reduction	99	316.29	2180 (+255)	129 (-77)	1	2	126
50% Peak Reduction	83	316.72	2321 (+396)	126 (-80)	1	2	123

Timing of Lake Releases



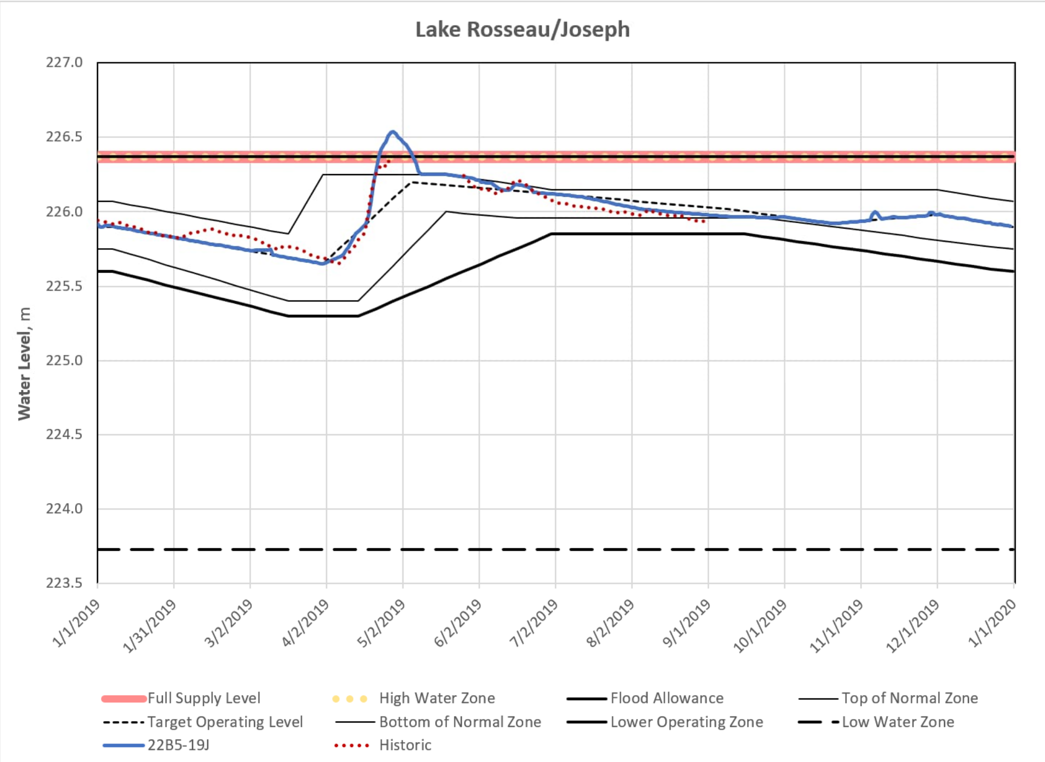
Lake Muskoka

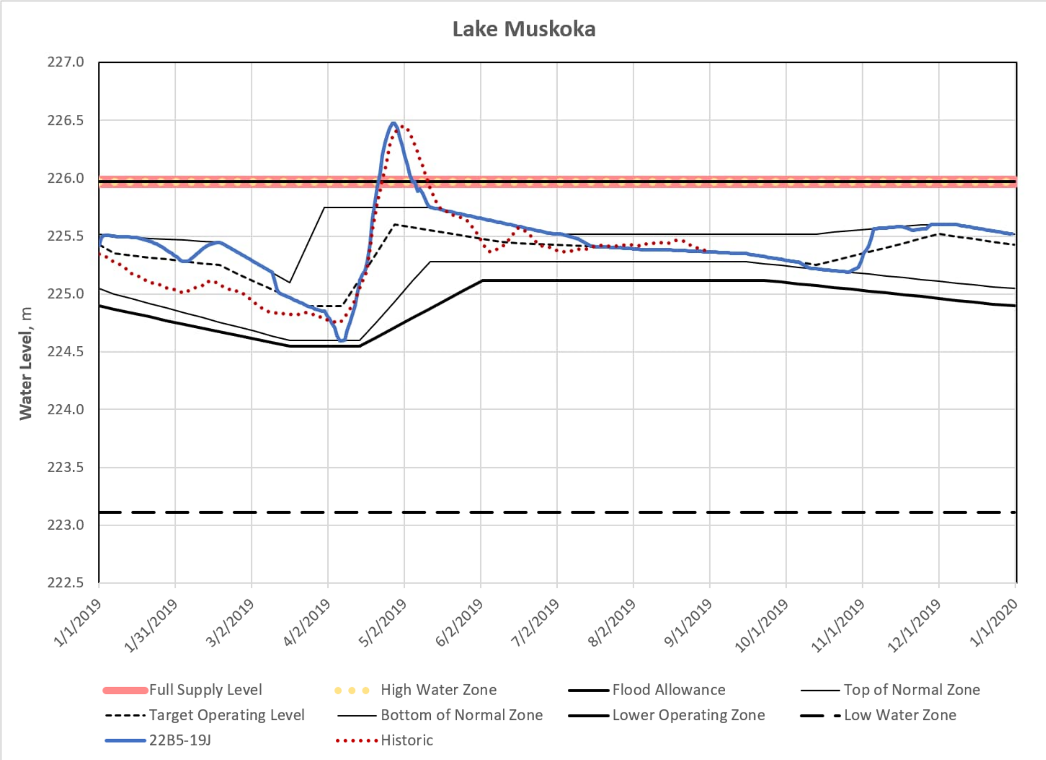


Storage Change Impacts

Region	Lake(s)	Added Storage Based on Lake Level Increase (cms-days)			
		+0.15 m	+0.30 m	+0.45 m	+0.60 m
North Branch	Vernon, Fairy, Peninsula	54	109	163	217
North Branch	Mary	18	36	54	72
South Branch	Kawagama	56	112	168	225
South Branch	Lake of Bays	121	241	362	483
Muskoka Lakes	Rosseau and Joseph	214	428	642	857
Muskoka Lakes	Muskoka	207	414	621	828

Operational Model Update





Summary

- Many conflicting interests in water management
- Changes in water management must balance the impacts on all interests
- Water Management Plans apply only under normal conditions
- Many lakes, but limited storage available to shave flow peak
- Difficult to foresee or manage heavy spring rainfall on ripe snowpack
- Fuller utilization of operating zones could help management of high flow
  - e.g. Lakes Joseph/Rosseau and Lake Muskoka
- May be able to "stage" level increases to mitigate/share flooding impacts
  - e.g. Kawagama Lake/Lake of Bays/downstream river

Next Steps – Project 2

- Complete Phase 1 draft report based on input from this meeting
- Continue to engage with water management plan proponents, MNDNNRF and others regarding options for:
  - Improved forecasting/availability of forecasts
  - Data sharing options
  - Communications (internal/public)
  - Early warning systems
  - Dam operations
- Use operations model from previous MRWMP work to assess any operational changes accepted for further consideration
- If changes to the MRWMP are required, complete scoping study to establish work required to amend the Plan